1. **Management Summary**

Reference: NIP 102 | EM Radiation: Concerns over interference effects on sensitive equipment

**If one doesn't know about or believe in gravity, one has no concerns about falling down.**

**The process**

This objection is based on a report that includes simulation software calculations that have been independently validated with real-life measurements on existing electric railway systems.

The NTA did not provide data relative to the design of M2. Data used for the calculations came from: (i) incomplete figures in the Environmental Impact Assessment; (ii) incomplete information about M1; and (iii) sources on metro systems in general.

Elements such as the number of carriages in a train, electrical power supply characteristics, the use of overhead wires or a third rail, rail return or a fourth rail, power consumption of a train’s drive systems, system power voltage, etc. have not been made available to the University by the NTA. If that information was available at the time of the request and has not been provided, that is a serious omission by the NTA. If that information is still not available then the NTA's conclusion of “no problems” is, at the very least, premature.

Many remarks made by the NTA clearly indicate that it did not carefully read the technical information provided with the objection, if at all. The NTA has not proven that the University was incorrect. It has not supplied any facts based on the laws of physics, but has simply repeated platitudes. Indeed, the NTA's calculations and measurements are presented as if facts, but are not proven. Substantiated criticism of the way those activities were carried out is simply ignored.

**The Contents**

NTA shows an astonishing lack of knowledge and understanding of:

* The fundamental laws of physics as they relate to electromagnetism – The NTA completely disregards the very important consideration of frequency, both in their theoretical calculations and during actual measurements at the University;
* The electromagnetic effects of motion – The NTA disregards the fact that a constant current that is moving in space also causes changes in magnetic fields;
* The technology of electrical rail power supply to moving vehicles and the difference between voltage and current – The NTA confuses rectifier ripple voltage with current;
* The electrical and electromagnetic behavior of vehicles – The NTA simply assumes that power supply at a constant voltage implies constant current consumption by trains. The NTA even uses so-called constant currents from a long-term averaging calculation;
* The way sensitive equipment, as used by the University, functions and will malfunction as a result of ambient interference – Frequency influences in particular are totally misunderstood. Rather than examining the sensitivity of instruments, the NTA refers to guidelines related to the impact of electromagnetic fields on humans.

**The Real World**

The Tel Aviv metro is not the first system to face railway electromagnetic compatibility (EMC) issues and it will not be the last. For many years, quite a few cities around the world have faced problems arising from railway electromagnetic interference. These include, but are not limited to: Antwerp (BE), Bergen (NO), Bielefeld (DE), Copenhagen (DK), Delft (NL), Durham (US), Groningen (NL), Hamilton (CA), Heidelberg (DE), Helsinki (FI), Lund (SE), Jerusalem (IL), Melbourne (AU), Nottingham (UK), Odense (DK), Sidney (AU), Stockholm (SE), Ulm (DE), and Utrecht (NL).

Scientific institutions, universities and hospitals recognize the problems associated with railway EMC. These problems are solved either with adequate physical measures, or by maintaining a significant spatial separation (for example, moving the railway line further away from buildings containing sensitive instruments) or, in some cases, even abandoning the rail project. Regardless of all these cases, The NTA claims to have had no problems at all with EMC, notwithstanding the high currents and strong magnetic fields associated with electric railways, especially in very close proximity.

**Conclusion**

The University's objection should be sustained because The NTA’s lack of knowledge and understanding will result in a situation where either the University can no longer conduct certain research activities, or the operations of M2 will have to be suspended for considerable periods of time.

1. **NTA's Response to Objections and University's Rejoinder**

This section addresses the NTA's response to the objection paragraph by paragraph, in order to specifically point out where the NTA's response “derails.” For ease of understanding, we have marked the material as follows:

* The NTA's summaries of objections have been marked in **black;**
* The NTA's responses to objections have been marked in **red;**
* BIU rejoinders to the NTA's responses have been marked in **blue.**
1. **Rejoinder**

**1. Objection:**

The proposed Southern alternative (Ramat Gan) rail line passes under a large number of research buildings containing EM-sensitive equipment. No appropriate consideration was made concerning these, especially those with sensitive installations.

**Response:**

* All the aforesaid concerns regarding tremors, stray currents and electromagnetic fields are concerns and hypotheses only, without any scientific evidence presented by the University. The NTA treats the University's arguments as mere concerns lacking a scientific basis, while presenting its response without any scientific evidence. The root problem may be the fact that the NTA makes a number of incorrect assumptions concerning traction power supply and the current and magnetic field properties related to traction. Furthermore, the NTA does not appear to have even a basic understanding of the electromagnetic impacts of railways and the relevant properties of scientific instruments. If the NTA cannot refute the University's arguments on a technical and scientific basis, third party experts can judge the validity of the statements from both parties. It is clear that the University brings decades of experience and knowledge of both railway EMC and instrumentation. Knowledge of EMC in general is not sufficient in this case, and the NTA does not appear to have the necessary expertise in railway EMC.
* The topic of radiation was discussed extensively in Section 4.4 of the survey. The fact that the NTA discussed the subject does not necessarily mean that any conclusions drawn are valid.
* EM radiation levels from the Metro tracks were calculated at surface level along the planned route. Those calculations are absolutely wrong.
* Calculations were conducted using dedicated MMI software, according to the equipment characteristics and SYSTRA’s specifications. Such calculations are meaningless in the absence of substantiated information as to what these characteristics are and how the equipment was used; rather, they are hypotheses without any scientific foundation.
* Additionally, the NTA conducted measurements of background EM radiation and found that calculated values from the metro were significantly lower than background values. Since radiation is measured on a logarithmic scale, the radiation effect from the Metro is expected to be much lower. These measurements were totally inadequate; the wrong items and locations were measured with the wrong equipment. Frequencies that are generated by an electric railway could not be measured with the equipment deployed and were not.

Note –The University’s objection does not address EMC effects on human beings. According to the project’s acoustic survey report, no impacts are expected. However, there is concern over the potential effects upon sensitive equipment.

This observation is correct, so any remarks regarding ICNIRP and Environmental Protection Ministry guidelines and related effects on humans must be disregarded as irrelevant in relation to the University's objection.

**Coordination with the University**

On December 3, 2020, the University submitted its objection, attaching a report drawn up on its behalf (the van Bekkum report from September 5, 2020), presenting the laboratories and installations where there are concerns regarding EMC disturbances, as well as the sensitivity thresholds of relevant instrumentation.(1)

On December 6, 2020, an initial expert’s opinion on behalf of the NTA (by Engineer Moshe Netzer) was prepared, which included a reference to the potential for disturbances based on calculations carried out as part of the survey of EM levels at ground level above the route and the instructions for operating permits by the Environmental Protection Ministry. Again, the wrong items and locations were measured with the wrong type of equipment. Guidelines from the Environmental Protection Ministry do not refer to potential impacts on instruments.

On March 17, 2021, the NTA conducted EM measurements at the University’s sensitive buildings. The measurements were coordinated and approved by the University – at all the points where the University sought to measure EM fields, including those far from the route. The measurements were carried out in the presence of University representatives. The measurements were not approved by the University, but proceeded nonetheless. The University witnessed the measurements but had no influence whatsoever on the method and the adequacy of this measurement activity. Northe University have prior knowledge of, of, the NTA ology.

In addition, the NTA’s expert specifically conducted calculation of EM field levels at those locations where the University’s sensitive installations are located, comparing these results with measured background levels. Furthermore, the claims made in the van Bekkum report were examined in depth and significant flaws were found. The NTA's expert calculations were inadequate relative to the problems presented in the objection. The NTA's lack of knowledge concerning both electric railway systems and the properties of relevant instrumentation resulted in significant errors. Information from traction power supply engineers, train manufacturers, and instrument manufacturers can certainly clarify and confirm this position.

**Objection:**

The proposed Southern alternative (Ramat Gan) rail line passes under a large number of research buildings containing EM-sensitive equipment. No consideration was made concerning these especially sensitive installations.

**Response:**

* The topic of radiation was discussed extensively in Section 4.4 of the survey. Extensive discussions do not mean the correct conclusions are reached.
* A calculation of EM fields was conducted along the track route. These results were compared with the Environmental Protection Ministry’s recommended thresholds. The computations were based on incorrect assumptions relative to currents and magnetic fields. Subsequently, these incorrect outputs were compared with irrelevant guidelines for humans, not instruments.
* The calculations show that:
	+ A threshold of 4 mG (the Environmental Protection Ministry’s strict criteria for exposure to humans is obtained inside the tunnels at about 7 meters above the track). The calculated radiation levels at ground level above the Metro are significantly lower than this threshold.
	+ Above surface level, a flux density of about **0.1 mG** was obtained, lower than the characteristic background radiation.
	+ Calculations made with the wrong data result in incorrect conclusions.
* No limits to development above the track [route].
* No expected disturbances to electromagnetic systems, medical equipment, etc.
	+ No expected negative effects from stray currents.
	+ Again, calculations made with the wrong data result in incorrect output figures.

Measuring background values at Bar-Ilan – Moshe Netzer

EM measurements of background radiation levels were conducted at 21 points at Bar-Ilan University in the presence of a University representative. The measurements were performed at locations requested by the University.

* At all the points examined, the existing magnetic field flux level was between 0.25-1 mG, with the exception of Point 4 (structure) at which a level of about 20 mG was measured because the measurement was carried out below the existing shield, a concealed electricity cable ladder. These measurements were recorded for frequencies above 30 Hz. However, metro systems generate powerful low-frequency magnetic fields and instruments are very sensitive to frequencies far below 30 Hz. This characteristic was not measured.
* Background radiation at all measured locations is significantly higher than the predicted magnetic field flux from the Metro at ground level (0.1 mG). Again, this is the wrong conclusion and is based on incorrect calculations.
* Each addition to the background radiation is calculated by a mean vector (not a conventional arithmetic increment). According to the data, the Metro's effect is expected to be significantly weaker than the existing ones, and is accordinglyexpected to be absorbed by background radiation. This conclusion is incorrect and is based on the wrong calculations.
* No significant change in the EM flux at the University’s sensitive installations is expected because of the Metro. This the wrong conclusion and is based on incorrect calculations.
* Furthermore, after receiving the University's objections, another inspection was conducted by the consultant on non-ionizing radiation for this project, Engineer Moshe Netzer, consultant on non-ionizing radiation for this project, to examine the equipment’s sensitivity. As the consultant did not consider , his knowledge of the metro system power supplies and vehicle electronics is questionable.
* Inspections were conducted at nearby buildings and facilities according to the expert opinion submitted with the University’s objection (“Summary of Damage to Research Laboratories and Sensitivity Levels of University Instrumentation, document by The Office of the Deputy Director of Operations in the Faculty of Life Sciences and Exact Sciences, 2020-13319 from September 16, 2020”). Even when looking and measuring at the correct locations, the measurements and any subsequent conclusions may be wrong.
* The sensitivity levels of “resistance-sensitive equipment” are lower than the external background without the Metro, and accordingly, it is likely that the equipment is currently shielded in order to enable it to function correctly. What is meant by “resistance sensitive equipment”? This is not a recognized term in the context of EMC sensitivity.
* The impact on sensitive buildings is expected to be lower than the background [radiation] – the Metro’s additional radiation will therefore be "absorbed" by existing background radiation. Accordingly, there is no expected impact from the Metro on the equipment.This is wrong. It is a conclusion which is based on incorrect calculations.
* It should be clarified that in the detailed planning, the EMC impact will be carefully examined and, if necessary, shielding will be installed. It is very doubtful whether effective shielding can achieved in the range of frequencies that causes these instrumentation problems. Shielding magnetic fields of 0.1 Hz requires the construction of walls many meters thick from an expensive metal alloy. Using active shielding with Maxwell cages also causes new emissions and thus additional associated problems.

**Criticism:**

According to his calculations, Dick van Bekkum predicts an impact on sensitive instrumentation at the University.

**Response:**

Van Bekkum’s report (hereafter: The Report) contains fundamental errors:

* The calculations in the report were conducted according to a higher feed current than the one used by the Metro. The NTA did not provide specific feed current data. A metro train that absorbs 3,500 Amps is not uncommon. The figure used by the NTA is 1,500 Amps but even in this figure is correct, it is still sufficient to cause a huge change in the magnetic field.
* The report incorrectly compares a static magnetic field from the Metro to the sensitivity of University’s instruments, but a static magnetic field does not have an impact on electronic equipment. The NTA clearly did not read the report carefully and is making an error in its consideration of the variation in the traction current. The report also mentions that current variation.
* The report does not take into account that the background radiation is significantly higher than the Metro’s radiation. Therefore, the additional radiation from the Metro will be “absorbed” by the existing background. This conclusion is based on an error in the NTA’s calculations. The changes in the background radiation are far lower than the changes in the radiation from the Metro.
* The report does not consider that the background radiation is higher than the sensitivity threshold of the sensitive instruments. Accordingly, for proper operation, the University’s equipment already requires shielding. The NTA overlooks the frequency of the background radiation and the sensitivity of instruments relative to frequency. Shielding is effective only for higher frequencies. Furthermore, entirely static fields cannot be shielded passively.
* The report uses incorrect data and does not take into account important parameters. The NTA did not deliver the necessary data. Nonetheless, the figures used in the report are representative of a comparable metro system.
* Accordingly, its findings and conclusions are without foundation:
* It uses current and voltage values (including feed voltage) different from those designed for the Metro. The NTA did not provide data on the system, making the use of representative figures necessary.
* Lack of consideration of alternating current ripples upon direct current. The NTA states that the AC rectifier ripple current is 13.6 Amps. That contention is wrong. Rectification causes a voltage ripple even if this ripple current is minor compared to the current change caused by the trains, which ranges from many hundreds to some thousands of Amps.
* Lack of reference to momentary loading current. This is incorrect; the report calculates the current changes associated with the trains.
* Wrong tunnel depth. The tunnel depth figures used in the report are from the NTA information as far as such data was available.

**Conclusion:** Contrary to the claims in the van Bekkum report, there are no concerns expressed over the impact on sensitive scientific instrumentation in nearby University buildings.

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**Summary**: The reasons for which the objection should be rejected because of the EM effect from the Metro on University equipment:

* The objection and the expert report attached to it ignore the fact that the background EM levels are significantly higher than the Metro's predicted contribution. Therefore, (since this contribution is attached to the background as a vector average), its effect is expected to be very low. This is incorrect. The report concludes that the emission levels associated with M2 operations are much higher than the background EM level. The report does, however, contradict calculations and any subsequent conclusions that are in error.
* The objection and the expert report ignore the fact that the background EM levels measured in the actual University buildings are higher than instrumentation sensitivity levels specified in the objection. These already require the equipment to be shielded for its proper functioning and this shielding is probably already installed in sensitive buildings/facilities at the University. This is incorrect. In reaching this conclusion, the NTA ignores the frequency-dependent nature of these EMC phenomena.
* The conclusions of the expert report on Metro effects are fundamentally wrong – they are based on a static field flux from the Metro, which does not affect electronic equipment. Therefore, the comparison made by the report to the sensitivity of the University's equipment is irrelevant. This is incorrect. The report clearly states the emissions from the metro are not static. It is, in fact, the NTA which reaches its conclusions using static field figures.
* The expert's report is based on incorrect data, including placing a higher operating voltage than the Metro line will be using and ignoring other substantive data, and according to its forecast, is flawed and its results therefore have no basis. This is a dubious statement at best. The NTA did not provide accurate data but then states that the use of inaccurate data in the report invalidates its conclusions.

**Conclusions:**

* The objection’s claims and the consultant's report are inherently wrong – there is no significant EMC impact on sensitive instruments at the University. The NTA presents such statements but does not substantiate them with data. Indeed, NTA appears to reveal a troubling lack of knowledge and experience concerning the impact of railway electromagnetism.
* As aforesaid, the calculations conducted by the NTA expert Engineer Moshe Netzer show that the predicted effect on sensitive instruments at the University is insignificant and materially lower than the background radiation (expected to be absorbed within it) and the equipment sensitivity values. The NTA engineer did not prove anything regarding impacts in the appropriate frequency range. There is no evidence that the NTA engineer has knowledge and experience of electrified rail systems and railway EMC.
* It should be noted that in the detailed planning the impact will be verified, and if necessary, standard shielding will be installed to further reduce EM flux. The NTA suggests shielding is an effective solution but it is not at all clear that shielding can be achieved adequately, if at all.