Proposal for Maneto-telluric (MT) Survey under National Magneto-Telluric Survey (NMTS) Programme of GSI & Procurement Proposal of MT instruments and Software through NMET

Introduction

Subsurface investigation for crustal architecture on the geodynamic setting and formation condition of productive ore-magmatic system in different parts of the globe provides important insights into regional tectonics and also offers guidelines to formulate strategies for mineral exploration. The application of concept and models based on the global plate tectonics, subsurface geo-electrical structure and potential filed heterogeneities have witnessed a rapid progress. Recent studies demonstrate that the mechanism of formation of major metallogenic provinces requires understanding of the deeper lithosphere and underlying asthenosphere layer through geophysical investigation

Geological Survey of India (GSI) have been systematically acquiring ground gravity and magnetic data and aerogeophysical data on national scale under the baseline geophysical data generation programmes like National Geophysical Mapping Programme (NGPM), National Aerogeophysical Mapping Programme (NAGMP). Magnetotelluric (MT) method which works on the principle of natural electromagnetic (EM) induction inside earth, is the most widely used geophysical method for 3D mineral system mapping, 3D geological and structural mapping, geothermal investigation, geohazard studies and also for hydrocarbon exploration. From the standpoint of GSI's mission-1(baseline data generation) and mission-2(mineral investigation) based activities, 3D mapping of conductivity/ resistivity distribution of the subsurface of the Indian landmass through MT survey is absolutely essential. Firstly, a pan-India MT programme would generate a first of its kind 3D baseline data. Secondly and perhaps even more importantly, it would serve as the foundation of the much-needed mineral system framework which will significantly augment the present mineral exploration scenario of the country and will help to meet future demands of metallic ore for sustainable industrialization.

Principle and applications of MT

Magnetotelluric (MT) surveys measure the electric and magnetic components of natural electromagnetic fields. The EM fields with periods shorter than 1 s are mainly originated by worldwide lightning discharges. The interaction between the Earth's magnetosphere (and ionosphere) and solar wind generates fluctuations with periods longer than 1 s. These natural external variations used in MT studies induce electric currents in the Earth and have periods between 10^{-3} s and 10^{5} s. The EM skin depth which depends on the electrical resistivity of the Earth and the period of the signal, controls the maximum depth of penetration.

The MT method is sensitive to the Earth's composition and temperature, making it useful for understanding geological phenomena. The MT method has a wide range of

applications, including mineral exploration, geothermal exploration, groundwater investigation, hydrocarbon exploration, crustal and geohazard studies etc. MT plays a crucial role in mineral system studies for delineating the mineralization source, pathways and the traps thereby significantly improving the understanding of the known mineralogical provinces and helps to explore deeper with greater confidence and cost reduction. Some mineral systems have even been imaged from the lower crust and upper mantle to the deposit scale increasing the overall success rate in mining. Imaging of the entire mineral system is essential for understanding source of mineralization, its vertical and lateral extent in the subsurface and 3D disposition. MT has the capability of imaging conductive body at great depths depending on the frequency of the received electric and magnetic fields. The horizontal resolution of a mineral body resolved through MT survey depends on the closeness of the MT station grid/profile or the survey design. Generally, denser are the stations in the grid/profile, better is the horizontal resolution.

Furthermore, MT data is complementary to seismic information, and can be integrated with other geoscientific data as well which can eventually help the geoscientist of GSI to understand the deep crustal structure within the India's complex geology which will not only propel the mineral exploration ecosystem but will also improve geohazard management activities.

Types of MT and Depth of investigation

MT surveys can investigate depths from few hundreds of meters to even hundreds of kilometers depending on the frequency recorded during acquisition. Lower frequencies or longer periods are required for greater depths and require longer recording times from weeks to months. These types of MT methods are termed as Long period MT (LPMT). For probing shallow to moderate depths, one requires to collect high and moderate frequencies and this type of MT are called Broad Band MT(BBMT). Recording time in BBMT can be upto a few days. Audio-magnetotelluric (AMT), predominantly used for shallower investigations utilize the higher frequency parts of the MT spectrum. The distance between sounding locations determines the horizontal resolution. Closer sounding locations increase the horizontal resolution. The frequency being measured determines the vertical resolution. Lower frequencies have greater depths of penetration, so vertical resolution decreases as the depth of investigation increases.

History of MT survey in India

Though the history of MT survey in India is old it has not been used extensively on a pan-India level. The National Geophysical Research Institute (NGRI) began using the MT technique in India in the 1970s.

MT survey in India has seen applications in

- **Geothermal exploration:** MT surveys can help identify and study the thermal structures of geothermal hot spots e.g., in MT has been used in Bakreswar geothermal studies.
- **Oil explorations:** MT surveys have been used for oil explorations e.g. in Cambay basin,
- **Mineral exploration**: MT have been actively used for mineral system studies along the northern transect under the project UNCOVER.
- **Earthquake precursor phenomena:** MT surveys can be used to monitor earthquake precursor phenomena. In the Delhi-NCR region, an MT survey was conducted over three seismic zones.
- **Geo-engineering problems:** MT surveys have also been used in geo-engineering problems, urban and infrastructure planning.

National Scale MT Surveys in other Countries

Australia collects LPMT data at an interval of 55 km (1/2 degree). Australia also collects BBMT over important mineralization provinces such as Olympic dam at 1 to 2 km station spacing for detailing ore body. Similarly, China carries out wide band MT at 4 degrees and also at 1-degree interval. USA also collects LPMT at 70 km interval.

Proposal to Initiate National MT Survey Programme

A. Pilot Project

Geological Survey of India procured six number of 8-channel MT instrument those have entire range of MT data collection starting from 1km to hundreds of kilometers depending upon the nature of conductivity of the sub-surface. Training on magnetotelluric data acquisition for 25 days and data processing for 20 days were included with the procurement of MT instrument for 20 officers from GSI. Two pilot projects have been initiated by ER and SR covering three topo-sheets each of them in parts of Singhbhum and Dharwad craton respectively. The time line for the submission of the two reports is 31-07-2025 after completion of MT data acquisition, processing and interpretation. A report containing SOP for MT data acquisition and processing would be submitted by NMH-1B by 31-08-2025.

B. National Magnetotelluric Survey (NMTS)

Considering the success of MT survey across different countries and also in India by other organizations, a National Magneto Telluric Survey (NMTS) programme is hereby proposed. In this programme both LPMT and BBMT data will be acquired in grid fashion, primarily focusing on the brown field areas for the first five years. There are several mineralized provinces in India, major part of which are presumed to be continuing under cover. The extension and 3D configuration of these provinces would be addressed through the NMTS project. The aim of this programme would be to create a 3D mineral system framework of these known mineralized zones and to discover new deposit locations under the cover.

These mineral belts are basically based on surface exposures. Considering the mechanism of formation of mineral system, it is reasonable to conclude that these exposures are merely the tip of the 'Iceberg'. Majority of the ore bodies and their primary sources are supposedly concealed underneath and around the exposed parts of the mineralization provinces. The depths of these concealed deposits may vary from a few hundred meters to a few kilometers. The primary objective of the MT survey will therefore be to identify and locate these ore-shoots, the network of the mineral pathways and the mother source of the mineral system.

Objectives:

1. Baseline 3D conductivity data generation of the sub-surface of India up to lower crust-upper mantle.
2. Discovering shallow-to-deep concealed mineralization zones.
3. Modelling of the mineral systems of major mineralization provinces.
4. To image basement structures, crustal architecture, large conductive zones and Lithosphere-Asthenosphere boundary.
5. Geothermal zone delineation.

Priority Areas for MT survey (2026 onwards):

Since the principal objective of doing the MT survey is to model the mineral systems and discovering deeper concealed deposits, it is prudent to carry out the surveys over the well-known mineralized belts which already are home to surficial deposits as shown in FIG.1. These areas encompass about 47 degreesheets and should be covered on priority basis during the initial years after initiation of NMTS. Apart from these, there are few more known deposit locations found in sparse manner across different parts of India which should also be covered by MT in subsequent years.

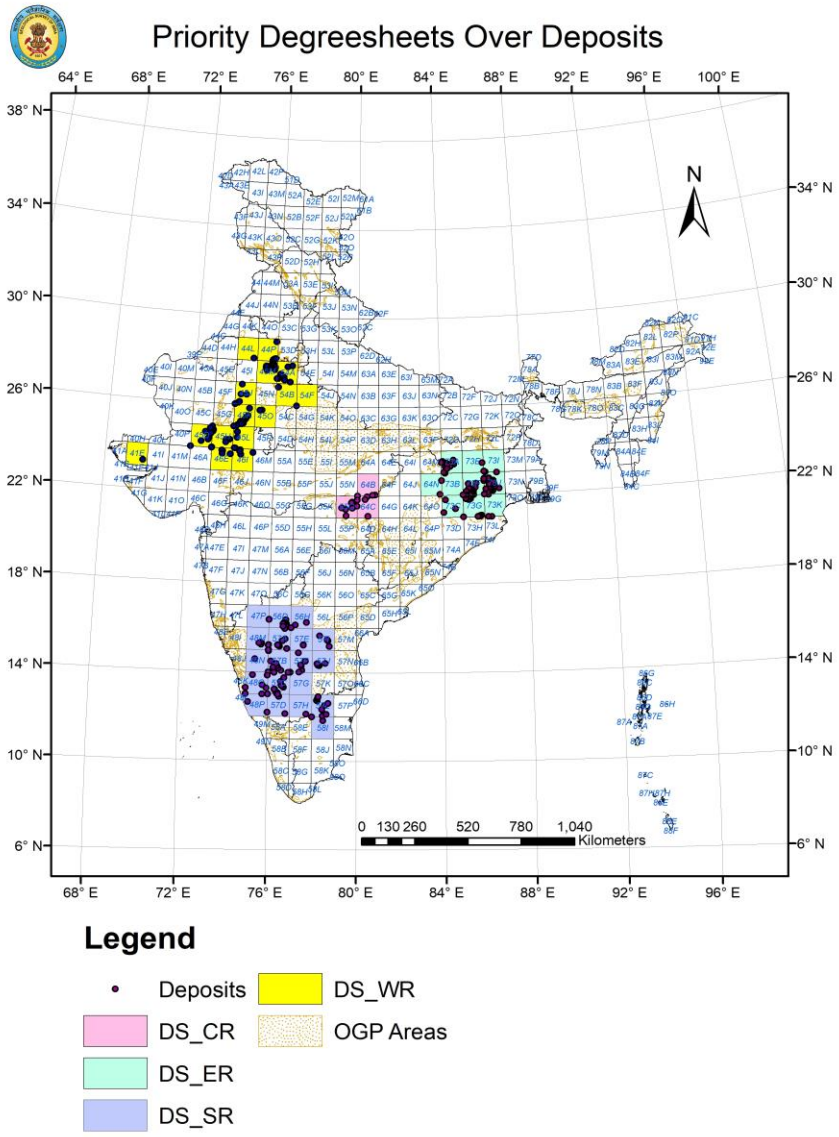

Figure 1: 47 Highest priority degreesheets of ER (10), CR (3), WR (15), SR (19) over known deposits

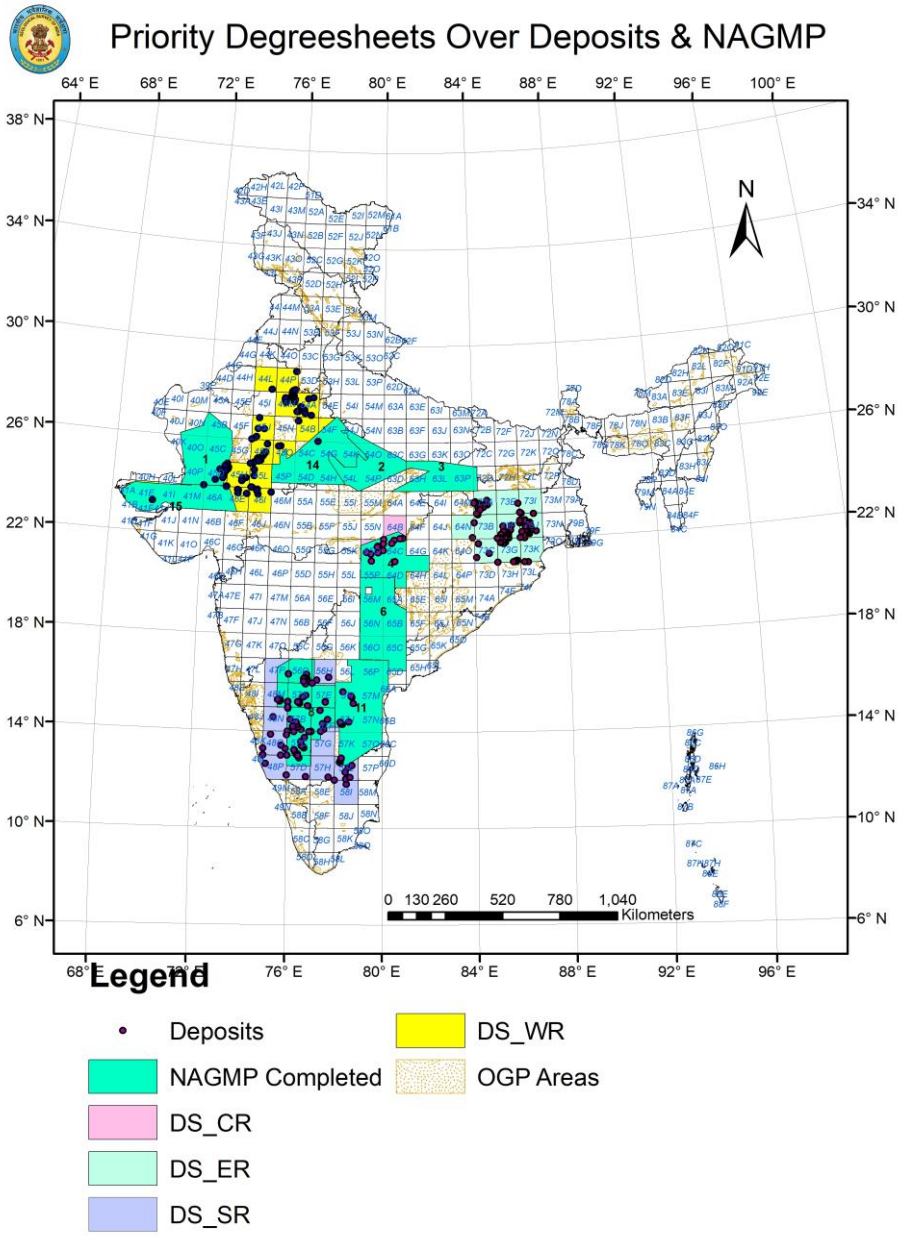

Figure 2: 84 High priority Degree-sheets over NAGMP blocks and/or known Deposits

For a more holistic approach towards mineral system study, with robust integration with NAGMP aero-geophysical data and also NGPM data, wherever available, the priority areas can further span the areas over NAGMP blocks. This amounts to about 84 degreesheets. These degreesheets may also be covered on priority basis.

Proposed Survey Design and Target for five years (2026-2030):

Considering the available manpower of Geophysics division and other FSP items across different missions, following survey design is proposed as shown in FIG.3. It is also proposed to cover one degreesheet per year per region considering the constraints of number of available manpower of Geophysics division. Thus, total 20-degree sheets can be covered in five years by GSI. GSI may also explore the possibilities of covering another five-degree sheets in five years, through outsourcing by engaging organizations having experience and expertise in BBMT and LPMT survey. A tentative time line of how the stations would be occupied are shown in FIG.4.

Survey Design

- BBMT station interval = 13.5 km[1]
- LPMT station interval = 55 km
- Average BBMT data acquisition duration = 5-7 days
- Average LPMT data acquisition duration = 25-34 days
- Desired BBMT time/frequency scale = 10 kHz to upto 2000 s or better
- Desired LPMT time/frequency scale = 10 Hz to upto 40000 s
- Number of BBMT stations in a degreesheet (DS)= 64
- Number of LPMT stations in a degreesheet (DS)= 4

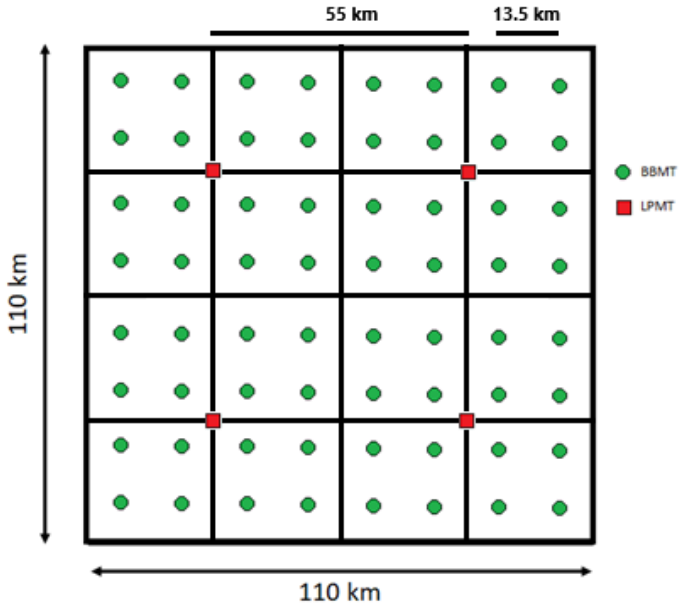

Figure 3: Survey Design in a degreesheet

[1] Since finding a noise free station may often be difficult, it is recommended that a BBMT station may be placed anywhere within a 13.5X13.5 window (A Toposheet would have such 4 windows) wherever the field party finds the least noisy location. LPMT stations should also be decided on a similar fashion.

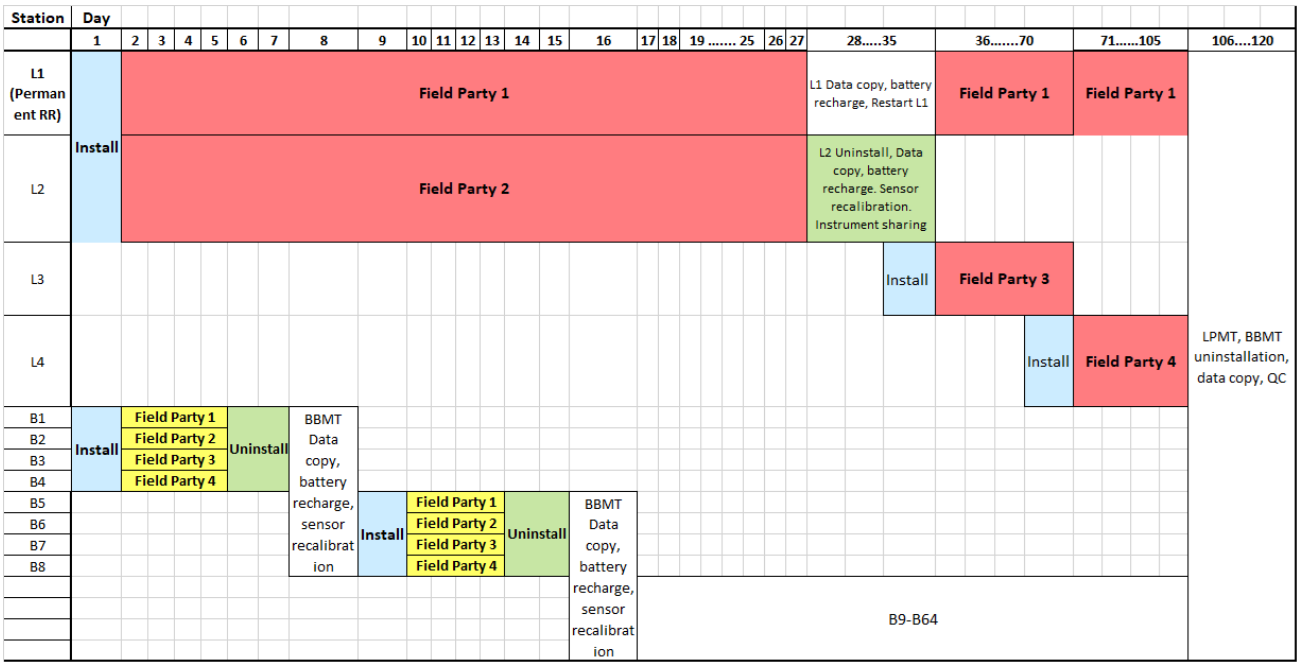

Figure 4: Tentative timeline of survey. L1, L2… indicate LPMT stations and B1, B2… indicate BBMT stations. L1 is kept as a permanent Remote Reference station for every other LPMT station of that degreesheet, throughout the survey

It may be noted that one LPMT stations should be running throughout the survey in a degreesheet, being the remote reference (RR) for other LPMT points (FIG.4). It is also assumed that any BBMT station is using any one of the three LPMT stations as its RR. It is further assumed that multiple field parties will be deployed in a degreesheet in a given FSP and they have to initiate field simultaneously for ensuring RR. All the parties are to share their LPMT and/or BBMT data with each other whenever necessary. Assumption is also made that all BBMT, LPMT data are collected with induction coil sensor as well as flux gate sensor with 8-channel instruments.

In the following, details of field party composition, instrument requirement, manpower and vehicle requirement, estimated cost of instrument and software/hardware requirements are given in Table-1, 2 and 3. The specifications of the instruments along with accessories, acquisition software (pre-installed on rugged laptop) is given in Annexure-I. The specifications for processing, interpretation and inversion software (pre-installed in workstation) along with the specification of workstations is given in Annexure-2. Procurement for items given in Annexure-I and for items given in Annexure-II, are to be done separately.

Table 1: Field Party Composition

Field Party	8 Channel Instrument	No. of BBMT Stations	No. of LPMT Stations	BBMT Duration (Av. 5-7 days/station), including installation, uninstallation	LPMT Duration including installation, uninstallation	Total Effective Field Duration (With 15 days for data repeatability check, QC, logistical management)	No. of Geophysicists	No. of Labourers
1	2	16	1	80-112	80-112	95-127	4	16-20
2	1+1(shared)	16	1	80-112	25-34	95-127	2+2(PT)	16-20
3	1+1(shared)	16	1	80-112	25-34	95-127	2+2(PT)	16-20
4	1+1(shared)	16	1	80-112	25-34	95-127	2+2(PT)	16-20
Total	6 (5+1 shared)	64	4				10+2(PT)	

Table 2: Instruments required to be Freshly Procured

Regions (Excluding NER)	No. of 8 Channel Instruments Required
SR/ER[2]	6
CR	6
WR	6
Total	**18**

Table 3: Software and hardware to be Freshly Procured

Software Required (To be purchased with equipment)	Fresh License Requirement	Total Numbers Required (Fresh)	Hardware requirement	Total Numbers Required (Fresh)
MT Processing	1/instrument	18	Rugged Laptop **(To be purchased with equipment)**	18
MT 1D/2D inversion (Winglnk)	3/region	6[3]	64 GB RAM/ 16 core Processor Workstation (3 numbers/ region)	6

[2] Assuming all the existing 8-channel MT instruments (6 numbers) are handed over to a particular region (ER or SR). Since, we have six eight channel instruments. So, we require another (24-6)=18 set of new instruments.

[3] Assuming all the existing 1D/2D inversion WinGLink licenses (6 numbers) are handed over to a particular region (ER or SR)

Outcome from MT survey

The outcome of the MT survey is manifold because of its depth of investigation starting from near-surface (approximately 50m) to hundreds of kilometers. They are

1. Delineation of resistivity/ conductivity distribution of the sub-surface from near-surface to LAB.
2. Modelling of mineral systems of India in conjunction with data acquired with NGPM and NAGMP data resulting in confident decision making for concealed and deep-seated mineral targeting.
3. Delineation of geothermal sources and its spatial distribution
4. Dissemination of the MT data through NGDR portal to all the stake holders.

Value addition

1. The geophysical input to the mineral exploration techniques in GSI based on density and magnetic susceptibility parameters at large and resistivity/conductivity parameter in few shallow and localized zone. Resistivity/ conductivity horizons covering all spectrum of depth starting from near-surface to Lithosphere-Asthenosphere boundary will add an important parameter for discovering mineral system and its pathways.
2. The proposed MT survey will bring out 3D resistivity/ conductivity model of sub-surface of the entire country.
3. Delineation of concealed mineral systems enhancing mineral exploration capabilities of India.
4. Locating geothermal resources to revamp the Green Field exploration in the country.

Timeline for the procurement

The tentative timeline for the completion of the procurement process is as follows

1. Make in India exemption from DPIT: 1.5 months
2. Tendering process: 2.5 months
3. Lead time: 8 months
4. ICT: 2 months

   Total duration: 14 months

Submitted to Chairman NMET for kind necessary approval of the followings:

1. GSI's proposal for

   A. Procurement of 18 Nos. of 8-channel MT instruments and same Nos. of rugged field laptop with two years' warranty and five years CAMC through NMET Fund.

   B. Procurement of six Nos. of WinGLink software with seven years warranty and six Nos. of Workstations with two years warranty and five years CAMC through NMET Fund.

2. If approved the competent authority may kindly accord the administrative approval and financial sanction from NMRT for the followings:

   A. An amount of Rs. 223200000 (Rupees twenty-two crore thirty-two lakh only) plus 18% GST of Rs. 40200000 (Rupees four crore two lakh only), with a total amount of Rs. 263400000 (Rupees twenty-six crore thirty-four lakh only) for procurement of MT Instruments and rugged field laptop.

   B. An amount of Rs. 40900000 (Rupees four crore nine lakh only) plus 18% GST of Rs. 7400000 (Rupees 74 lakh only), with a total amount of Rs. 48300000 (Rupees four crore eighty-three lakh only) for procurement of WinGLink software and Workstations.

3. The proposals have the approval of Director General, GSI for submitting to NMET.

19.02.2025

(Bijay Krishna Nandi)

DDG(GP), STSS & NMH-1B (Add. Charge)

GSI, Kolkata