F. No. J/9/2021-PROJ .
Office of the Principal Scientific Adviser
to the Government of India.

328, Vigyan Bhawan Annexe,
Maulana Azad Road,
New Delhi-110011.

Dated: 29th October, 2021

To,

Prof. Govindan Rangarajan
Director
Indian Institute of Science, Bangalore

Subject: Request for deliberations to prepare a detailed project report (DPR) on a Centre of Excellence for 2D Material Based Future Technology research (2D Materials Innovation and Technology Centre)

Dear Sir,

I am writing to you regarding a proposal submitted by the IISc team, led by Prof. Mayank Shrivastava, to our office early this year. The proposal was to establish a Centre of Excellence (COE) for two-dimensional (2D) materials-based future technology research.

Given the immense potential of this emerging technology and how fast the world is moving at this front, the PSA office shared the proposal with Dr. V. K. Saraswat (Hon'ble Member, NITI Aayog), who also chairs the empowered committee for Semiconductor Fabs. A meeting with Dr. Saraswat, members from the S&T vertical of NITI Aayog, and the PSA's office was scheduled on September 23rd. The IISc team gave a detailed presentation on this proposal. The minutes of this meeting are enclosed as an attachment for your reference.

As a follow-up to the discussions held on September 23rd and inputs given to the IISc team, I am writing to you on behalf of this Office, to submit a detailed project report (DPR) on the proposed CoE. The deliberations required for the DPR are listed below:

Stage 1:

(a) Build a DPR drafting team consisting of experts from IISc Bangalore (lead institute), an industry expert, MeitY and PSA's office as primary Members.
(b) Organize meetings with stakeholders for laying out a roadmap. The deliberations required for the DPR will involve interactions with stakeholders from govt. (PSA Office, relevant ministries, etc.), strategic (ISRO, DRDO, etc.), academia in India and abroad, and potential industries having an interest to partner/collaborate in the future.
(c) Review and study such international centres (e.g., Manchester, Cambridge, IMEC, etc.) and their ongoing developments.
(d) Create a road map for the CoE along the lines of, if not better than, similar centers worldwide, with a focus on key technologies to be developed around a backbone.
(e) Align with industry for scale-up.
(f) Ascertain IP transfer needs for strategic players and commercial entities.

Stage 2:

(a) Layout the concept and design of proposed CoE including new infrastructure required and how existing infrastructure will be augmented.
(b) Derive a technology roadmap (Electronics, Sensors, Neuromorphic, Quantum, Optoelectronics, Photonics, THz, Packaging, etc.)
(c) Layout the governance structure, human resource availability in India and support required for its success.
(d) Model for financial sustenance beyond ten years.
(e) Detailed project timelines for five years and funding required for first five years.

Stage 3:

Submit the final version of the DPR to be evaluated by PSA and the Empowered Technology Group for FAB set up by MeitY.

The DPR must also account for the inputs summarized in the attached minutes of the meeting. Mr. Shirish Panda, from the PSA office, will assist the IISc team with the said deliberations and stakeholder meetings required. We request you to submit the DPR as early as possible, preferably within six weeks. We are looking forward to hearing from you and IISc team soon.

Attachment:
(1) Minutes of the meeting, held on September 23rd, 2021, chaired by Dr. V. K. Saraswat (Hon'ble Member, NITI Aayog)
(2) An initial draft of the 2D CoE proposal.

(Jitendra R Gaikwad)
Deputy Secretary (Admn)

Cc:

(1) Dr. V. K. Saraswat, Hon'ble Member, NITI Aayog
(2) Prof. K. Vijayraghavan, Principal Scientific Adviser to the Government of India,
(3) Prof. Mayank Shrivastava, Indian Institute of Science, Bangalore

Proposal to Establish a Centre of Excellence (CoE) & Consortium for Future Heterogeneous Technologies Using 2-Dimensional Materials

Indian Institute of Science, Bangalore (Contact*: Mayank Shrivastava, email: mayank@iisc.ac.in)

*IISc team consists of 30+ faculty members. The consortium would consist of the IISc team, 25+ experts from the rest of the world, and 10+ industries, who have already signed up.

1. What? – Hunt for Future Nanoelectronic, Sensing, Optoelectronics, Neuromorphic & Quantum Technologies

The evolution of semiconductor technology, particularly Si technology, has been a critical driver for the technological advancements that we see around us. The Si industry has come a long way from using 2250 transistors in Intel's 4004 (1971) to 11.8 billion transistors in Apple's A14 Bionic microprocessor (2020). A lot has changed over the years, not just in terms of the number of transistors per unit area & frequency of operation, but also in terms of desired functionalities and applications given the nature of products that demand heterogeneous capabilities. Going further, conventional bulk semiconductor technologies find it challenging to meet future technology requirements. Therefore, the end of Moore's law and the emergence of beyond-Si electronics, optoelectronics, and quantum technologies are well-accepted directions of the last decade. Heterogeneous integration of various functionalities, including sensing, neuromorphic, Optoelectronics, and Quantum technologies, is projected to be the driving force for industries in the coming decades. The projected future requirements demand technologies such as flexible & wearable electronics, bio-implantable & flexible neuromorphic processors, THz electronics, multi-dimensional sensors and sensory systems, and quantum-enhanced systems for computation, sensing, and communication. This has pushed stakeholders to think of universal technology platforms and better ways to meet future applications' needs. Among various emerging materials, 2-Dimensional (2D) materials like graphene and TMDCs promise to offer solutions to existing issues/bottlenecks with conventional bulk platforms. Besides, they open opportunities for a plethora of new/disruptive applications and, henceforth, possibilities of new markets. Keeping in mind the promises of 2D materials and various applications it can cater to, a 2D material-based universal technology platform for heterogeneous integration is inevitable. These are the reasons why the world has moved too fast on 2D materials research and leading industries like Intel, TSMC, and industrial R&D centers like IMEC have made significant investments on this technology. On the other hand, efforts in India are relatively small.

2. Why? – Industry Roadmap for Heterogeneously Integrated Nanoelectronic & Quantum Enhanced Technologies

Worldwide efforts using 2D materials though cover the entire spectrum from beyond-Si electronics to quantum technologies (See Fig. 1, the Year 2004 – 2015); the approach followed until recently has been disconnected. From an industrial perspective, a universal platform would be the most efficient and cost-effective way to enable heterogeneous integration. Keeping this in mind, the industry has started focusing on this direction (See Fig. 1, the Year 2017 – 2020). Fig. 2 depicts a projected heterogeneously integrated system, expected to be enabled by a universal 2D material technology platform. This would require dedicated science and engineering efforts to enable a universal technology platform catering to a range of 2D materials-based products and heterogeneous integration, as projected in Fig. 1 (The year 2020 – 2030).

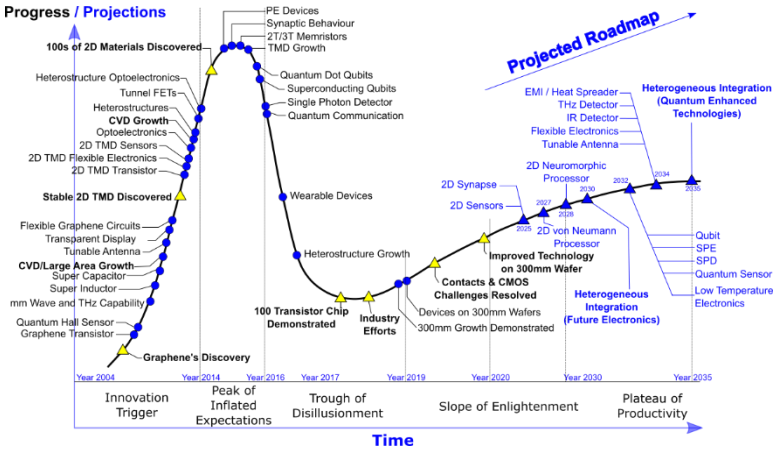

Figure 1: A projected roadmap for 2D materials and 2D material-based technology enablement.

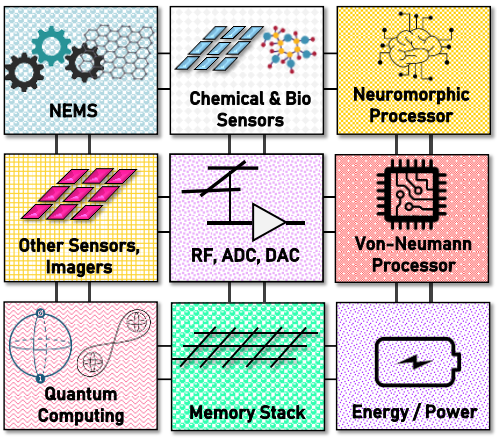

Figure 2: Projected possibility and ability of 2D material-based universal technology platform to enable heterogeneous integration of future electronics, optoelectronics, and quantum enhanced technologies.

Keeping in mind that India can encash 2D materials-based technologies, efforts in India need to be scaled up. Therefore, we envision and propose efforts like existing international 2D/graphene centers (in USA/UK/EU) in a consortium mode, however, with a focused effort on enabling technology platforms that would cater to a range of future products based on 2D materials. These products, IPs, know-how developed, and research conducted would place India at the forefront of 2D

material-based nanoelectronic, sensing, optoelectronics, neuromorphic, and quantum technologies. Besides, it should generate enough traction to encourage industries to establish technology development efforts in India.

3. How? - Consortium Details, Funding Required, Engagement, Operational & Revenue/Sustenance Model

We envision efforts like existing international 2D/graphene centers (in USA/UK/EU) in a consortium model (Fig. 3) through a Centre of Excellence (CoE) proposed to be established in IISc. This CoE will have a charter to (i) build capacity and technology knowhow, (ii) work with leading experts and industries in a consortium mode, (iii) develop technology platforms for 2D material based products, which would also cater to R&D on various 2D material threads and needs of different groups/industries around the world, (iv) demonstrate a few 2D material-based products – as a technology demonstrator – involving heterogeneous integration, (v) use the universal technology platform to enable other/quantum applications and (vi) strengthen and expand 2D material-based technology development efforts in India to put India at the forefront of 2D materials-based nanoelectronic, sensing, optoelectronics, neuromorphic, and quantum technology research/development.

The consortium will consist of experts from IISc and several other leading institutes worldwide. Besides, we also envision vibrant industry participation. The IISc team consists of 30 faculty members with expertise ranging from 2D materials growth, device physics/processing, and modeling and circuit/system design. This expertise has been complemented by faculties from top institutes in India (various IITs), the USA (UCSB, Rice, Penn State, UT Austin, Vanderbilt, UC Florida, and UCLA), and UK (Cambridge and Manchester). We have received expressions of interest to join the consortium from 23 leading graphene/2D experts worldwide. Various modes in which these experts can engage within the consortium have also been worked out. Similarly, the team has also reached out to 18 leading/global industries that may have an interest or ongoing development in Graphene or 2D materials-based applications. These are Intel, Texas Instruments, Samsung, Cadence, Applied Materials, AIXTRON, OXFORD, etc. To begin with, we have invited such industries to sign-up for the proposed consortium by expressing interest in Graphene and 2D material-based technologies, technology development, or its products. In the future, when the center is established, we envision that such industries being part of the consortium will be engaging with the center directly under various modes bringing revenue, facilities, or knowhow. Besides, we have also triggered dialogues with already established graphene/2D centers (Cambridge, Manchester, NUS, and IMEC) to learn from their experiences and seek cooperation. Among these, Cambridge and Manchester have already expressed interest in partnering with India graphene/2D center. Finally, it is also envisioned that the consortium will be guided by an International Advisory Board, which will comprise top academicians and key players from leading semiconductor industries (Fig. 3).

This effort would require an initial investment of the order of 500 Cr. from the govt. However, after this initial investment, we envision self-sustaining the activities (beyond 5 years) through this center's services and technology licensing, and eventually achieving break-even in less than 10 years. These products, IPs, know-how developed, and research conducted would also place India at the forefront of 2D material-based nanoelectronic, sensing, optoelectronics, neuromorphic, and quantum technologies. Besides, we expect this effort to generate enough traction for leading industries to invest in 2D material-based technology efforts in India along the lines of investments IMEC attracts (Fig. 4).

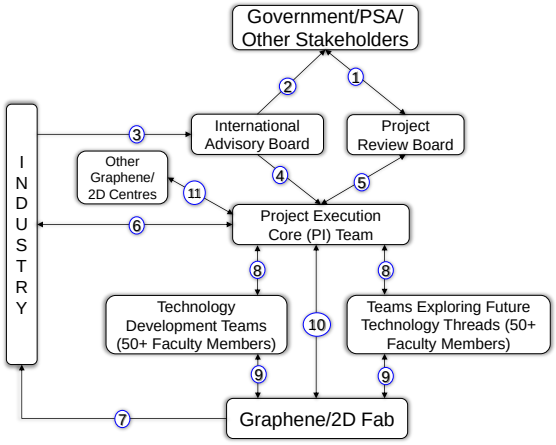

Figure 3: Consortium Structure & Operational Model of the CoE.

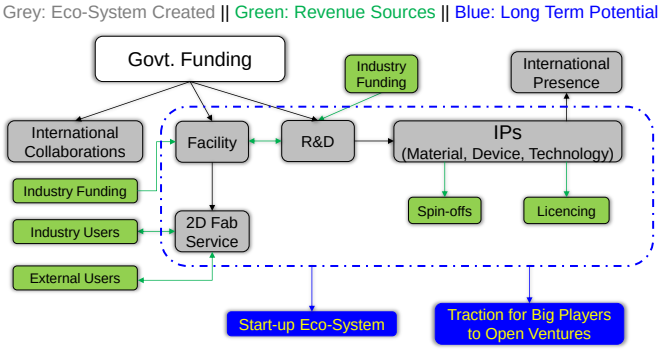

Figure 4: Eco-system expected to be created by this effort (Grey). Expected tangible outcomes of the CoE and revenue sources (Green). Long term growth potential (Blue).