

This foresight was commissioned
by the Department of Science and Technology

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FOREWORD

The Department of Science and Technology (DOST) has always stood at the forefront of the country’s scientific and technological advancement, with the National Academy of Science and Technology, Philippines (NAST PHL) serving to honor and promote the nation’s science capital towards developing a truly Filipino productive science culture.

This complement came to my mind when, in 2018, I was invited by the Akademi Sains Malaysia (ASM) on the occasion of the Akademi’s presentation of its “Malaysia’s Outlook 2050” to their Prime Minister. Inspired by the ASM’s notable output, I challenged the NAST PHL to undertake a similar Foresight study for Science, Technology, and Innovation (STI) in our own country. The NAST PHL proposal to develop a 30-year STI Foresight, including strategic plans, was quickly approved for funding by the DOST Executive Committee the following year. The NAST PHL was able to complete the first and second versions of the country’s STI Foresight document, aptly entitled Pagtanaw—or “looking ahead”—2050, even despite the technical and other unprecedented difficulties brought about by the COVID-19 pandemic.

Pagtanaw 2050 includes a compendium of STI megatrends; global and national societal goals; transdisciplinary and interdisciplinary operational areas; and current and emerging technologies relevant to the nation’s development. A backcast from our shared vision of a desired future three decades hence to the pre- and peri-pandemic situation of today revealed valuable insights that suggest significant drivers of change and plausible STI development paths, moving forward. These pathways are laid out in Pagtanaw 2050’s STI Roadmap, a guide to national development that traces the trajectories of the enablers, drivers, and opportunities that are seen to shape Philippine STI for the next three decades.

This Foresight document is firmly grounded on the Filipino people’s aspirations within the context of our natural and physical endowments—an archipelago with abundant marine resources—as well as our shared Filipino values and skills, and other potentials as contained in our Constitution and other national institutions. By harnessing these strengths and potentials, we

FOREWORD

look forward to growing into an economically vibrant and outward-oriented “Prosperous Maritime Archipelago”.

My thanks goes out to NAST PHL President Academician Rhodora Azanza, the Foresight Project Leader; Academician William Padolina, chair of the Foresight Steering Committee; the members of the Steering Committee itself, comprised of National Scientists and past secretaries of the DOST; and so many others in the science community, stakeholders who contributed to the making of this NAST-PHL STI Foresight document. It is indeed an undertaking of immense responsibility, a decisive furthering of the aspirations of the DOST and the NAST PHL for a progressive Philippines anchored on science in service of the people.

This NAST-PHL initiative is a big step towards designing and implementing integrated yet time-specific strategies for a prosperous, inclusive, and agile Philippine future.



Honorable Fortunato T. De La Peña
Secretary
Department of Science and Technology

PREFACE

Despite a brief period of fast-paced economic growth in the first decades of the 21st century, the Philippines still lags behind its neighbors in Southeast Asia and is leagues behind the most competitive and best governed societies in the region and the rest of the world. The country also has yet to achieve most of the United Nations Sustainable Development Goals, which are part of a global call to action to end poverty, protect the planet, and ensure that all people experience peace and prosperity.

The Philippines faces two major challenges in relation to inclusive growth and competitiveness, and to being mainstreamed into the global economy: first, the internal need to address the science, technology, and innovation (STI) support required by the country's burgeoning population; and secondly, the need to address the continuing gaps in the level of science and technology (S&T) between the Philippines and other advanced countries.

Both these hurdles are key areas of concern for the National Academy of Science and Technology, Philippines (NAST PHL), which is mandated to advise the President and his Cabinet on S&T matters. We firmly recognize that decisions about the Filipino people and Philippine society should be based on evidence and logical analysis, hence the urgency of crafting this Foresight in order to forward our vision of a progressive Philippines anchored in science. We embarked on the development of a Philippine foresight and strategic plan for the next three decades (2019–2050) in order to address the country's future needs and demand for scientific and technological interventions. This document is the first solid step in this journey of progress. We are proud and honored to have been able to rally this collective effort from various stakeholders, public and private, from all across the country.

The main goal of this Foresight document, entitled Pagtanaw 2050 (“looking ahead”), is to chart a strategic path by anticipating the factors that will influence the development of the Philippines' scientific capital in the years leading up to 2050. It is based on a rigorous evaluation of key trends in science, technology, and innovation (STI) in the Philippine setting. It is meant to serve as a planning device towards achieving concrete goals and

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designing strategic plans that shall transcend political periods whilst aiming for inclusive growth, sustainability, and competitiveness in STI.

Herein is a compendium of megatrends; global and national societal goals; and transdisciplinary/interdisciplinary operational areas, including current and emerging technologies with consideration of the pre-, peri-, and post-pandemic period. We delve into probable and significant drivers of change, and provide insights and reflections on the plausible development paths to the achievement of Filipino aspirations as expressed in the 1987 Philippine Constitution; the various Philippine Development Plans; the United Nations Sustainable Development Goals (SDGs); the Department of Science and Technology Harmonized National Research and Development Agenda; and AmBisyon Natin 2040, which was conducted in 2016, just four years before the pandemic.

It is the conclusion of the NAST PHL and the recommendation of this Foresight that the above aspirations can be achieved by acknowledging and enhancing our existence as a Prosperous Archipelagic, Maritime Nation, diplomatically asserting our rights over the resources in our marine environment.

To that end, we have identified 12 key operational areas, namely: Blue Economy; Governance; Business and Trade; Digital Transformation and Information and Communications Technology; Science Education and Talent Retention; Food Security and Nutrition; Health Systems; Energy; Water; Environment and Climate Change; Shelter, Transportation, and Other Infrastructure; and Space Exploration. It is our hope that with this Foresight, we can achieve the S&T aspirations of the Filipino people by 2050.

Pagtanaw 2050 would not have been possible without the assistance and guidance of the Department of Science and Technology and its various attached agencies, particularly the project monitoring agency, the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development. We are continually indebted to the Hon. Fortunato T. De La Peña, Usec. Rowena Cristina L. Guevara, Usec. Renato U. Solidum Jr., and Usec. Sancho A. Mabborang for their trust and support of this Foresight.



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LIST OF ACRONYMS

| Acronym | Meaning | Acronym | Meaning |
|-------------------|---|------------------------------|---|
| 1IR | First Industrial Revolution | BoC | Bureau of Customs |
| 2IR | Second Industrial Revolution | BOL | Bangsamoro Organic Law |
| 3IR | Third Industrial Revolution | BPO | Business Process Outsourcing |
| AANR | Agriculture, Aquatic and Natural Resources | BSGC | Budgetary Support to Government Corporations |
| ABNJ | Areas Beyond National Jurisdiction | CARP | Comprehensive Agrarian Reform Program |
| ADB | Asian Development Bank | CAT scans or CT scans | Computerized Axial Tomography |
| ADMU | Ateneo De Manila University | CCC | Climate Change Commission |
| AFP | Armed Forces of the Philippines | CCGT | Close Cycle Gas-turbine |
| AI | Artificial Intelligence | CHED | Commission on Higher Education |
| AQMF | Air Quality Management Fund | CHW | Community health worker |
| AR | Augmented Reality | CITES | Convention on International Trade in Endangered Species |
| ARISE | Access to Resources and Innovations in Science Education | cleantech | Clean Technology |
| ARMM | Autonomous Region of Muslim Mindanao (<i>see BARMM</i>) | CLSU | Central Luzon State University |
| ARPANET | Advanced Research Projects Agency Network | CoE | College of Engineering |
| ARWU | Academic Ranking of World Universities | COVID-19 | Coronavirus Disease 2019 |
| ASEAN | Association of Southeast Asian Nations | CRADLE | Collaborative Research and Development to Leverage Philippine Economy |
| ASEAN | Association of Southeast Asian Nations | CS | College of Science |
| ASM | Akademi Sains Malaysia | CW | Constructed Wetlands |
| ASTHRDP | Accelerated Science and Technology Human Resource Development Program | DA | Department of Agriculture |
| AUV | Autonomous Underwater Vehicle | DAP | Development Academy of the Philippines |
| BARMM | Bangsamoro Autonomous Region in Muslim Mindanao | DATOS | Remote Sensing and Data Science |
| BFAR-NFRDI | Bureau of Fisheries and Aquatic Resources - National Fisheries Research and Development Institute | DECS | Digital Ecosystem |
| BIST | Business Innovation through Science and Technology | DENR | Department of Environment and Natural Resources |
| | | DepEd | Department of Education |
| | | DICT | Department of Information and Communications Technology |
| | | DILG | Department of Interior and Local Government |

LIST OF ACRONYMS

| Acronym | Meaning | Acronym | Meaning |
|----------------|---|-----------------|--|
| DLSU | De La Salle University | FIC | Fully Immunized Child |
| DND | Department of National Defense | FIES | Family Income and Expenditure Survey |
| DOE | Department of Energy | FIRe | Fourth Industrial Revolution |
| DOF | Department of Finance | FMB | Forest Management Bureau |
| DOH | Department of Health | FO | Forward Osmosis |
| DOLE | Department of Labor and Employment | FSTPs | Foreign/Filipino Science and Technology Professionals/ Practitioners |
| DOST | Department of Science and Technology | GAA | General Appropriations Act also known as National Budget |
| DOTr | Department of Transportation | GCI | Global Competitiveness Index |
| DPWH | Department of Public Works and Highways | GCR | Global Competitiveness Report |
| DRR CCA | Disaster Risk Reduction and Climate Change Adaptation | GDP | Gross Domestic Product |
| DT | Digital Twin | GDP | Gross Domestic Product |
| DTE | Digitally Transformed Entity | GFA | Government Funding Agencies |
| DTI | Department of Trade and Industry | GHG | Greenhouse Gas |
| DTP | Digital Teaching Platform | GII | Global Innovation Index |
| DX | Digital Transformation | GIS | Geographic Information System |
| ECS | Extended Continental Shelf | GMO | Genetically modified organism |
| EEZ | Exclusive Economic Zone | GPG | Global Public Good |
| EGDI | E-government Development Index | GRDP | Gross Regional Domestic Product |
| EGDI | E-government Development Index | GRP | Government Regulatory Processes |
| EMB | Environmental Management Bureau | Gt | Gigaton |
| EMO | Earth and Marine Observation | GVA | Gross Value Added |
| EOS | Earth Observing Systems | HAPS | High Altitude Platform Systems |
| EPI | E-participation index | HDI | Human Development Index |
| EPIMB | Electric Power Industry Management Bureau | HEI | Higher Education Institution |
| EPIRA | Electric Power Industry Reform Act of 2001 | HIC | High Income Country |
| ERD | Energy Recovery Devices | HIT | Health Information Technology |
| ESA | European Space Agency | HIV/AIDS | Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome |
| ESEP | Engineering Science and Education Project | HNDA | Harmonized National Research and Development Agenda |
| ESET | Emerging Science, Engineering and Technology | HPSR | Health Policy and Systems Research |
| EST | Environmentally Sound Technology | HRH | Human Resources for Health |
| EU | European Union | IAS | Immersive Authentic Simulation |
| FAO | Food and Agricultural Organization | ICM | Integrated Coastal Management |
| FEC | Filipinovation Entrepreneurship Corps | ICT | Information and Communications Technology |
| FEPP | Future Earth Philippines Program | IEC | Information, Education, and Communication |
| FGD | Focus Group Discussion | IEEE | Institute of Electrical and Electronics Engineers |

| Acronym | Meaning | Acronym | Meaning |
|---------------|---|--------------------|--|
| IFPRI | International Food Policy Research Institute | LMIC | Low- and Middle-Income Country |
| IMPACT | Intellectual Property Management Program for Academic Institutions Commercializing Technologies | LMS | Learning Management System |
| IMTA | Integrated multi-trophic aquaculture | maglev | magnetic levitation |
| INSEAD | Institut Européen d'Administration des Affaires | MDG | Millennium Development Goal |
| INSEAD | Institut Européen d'Administration des Affaires | MF | Microfiltration |
| IOM | Integrated Ocean Management | MGI | McKinsey Global Institute |
| IoT | Internet of Things | MGR | Marine Genetic Resources |
| IP | Intellectual Property | MILF | Moro Islamic Liberation Front |
| IPBES | Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services | MNR | Ministry of Natural Resources |
| IPCC | Intergovernmental Panel on Climate Change | MODIS | Moderate Resolution Imaging Spectroradiometer |
| IPR | Intellectual Property Rights | MPA or MPAs | Marine Protected Areas |
| ISA | International Seabed Authority | MR | Mixed Reality |
| ISIS | Islamic State of Iraq and Syria | MRA | Mutual Recognition Agreements |
| ISO | International Organization for Standardization | MRP | Malnutrition Reduction Program |
| IT | Information Technology | MSME | Micro, Small, and Medium Enterprise |
| ITPS | Intergovernmental Technical Panel on Soils | MSP | Marine Spatial Planning |
| ITS | Intelligent Transport Systems | MSW | Municipal Solid Wastes |
| ITU | International Telecommunications Union | MSY | Maximum Sustainable Yield |
| IUUF | Illegal, Unregulated and Unreported Fishing | MTOE | Millions of Tonnes of Oil Equivalent |
| IWB | Interactive Whiteboard | MVNO | Mobile Virtual Network Operator |
| JAXA | Japan Aerospace Exploration Agency | NAPC | National Anti-Poverty Commission |
| JICA | Japan International Cooperation Agency | NASA | National Aeronautics and Space Administration |
| JRC | Joint Research Centre | NAST PHL | National Academy of Science and Technology, Philippines |
| K-12 | From kindergarten to 12th grade | NCD | Non-Communicable Disease |
| KAPs | Knowledge to Action Programs | NCR | National Capital Region |
| KIG | Kalayaan Island Group | NDRRMC | National Disaster Risk Reduction and Management Council |
| KISTEP | Korean Institute of Science and Technology Policy | NEDA | National Economic and Development Authority |
| kph | kilometers per hour | NF | Nanofiltration |
| LAN | Local Area Network | NGDLE | Next Generation Digital Learning Environment |
| LED | Light Emitting Diode | NGO | National Government Organization |
| LGU | Local Government Unit | NGP | National Greening Program |
| LIDAR | Light Detection and Ranging (Technology) | NIBRA | National Integrated Basic Research Agenda |
| | | NICER | Niche Centers in the Regions for Research and Development |
| | | NISMED | National Institute for Science and Mathematics Education Development |

LIST OF ACRONYMS

| Acronym | Meaning | Acronym | Meaning |
|-------------------|--|------------------------|---|
| NISTEP | National Institute of Science and Technology Policy | PISA | Program for International Student Assessment |
| NLP | Natural Language Processing | PMB | Philippine Mobile Belt |
| NOAH | Nationwide Operational Assessment of Hazards | POPCEN | Census of Population |
| NPHW | Non-Physician Health Workforce | PPH | Precision Public Health |
| NQI | National Quality Infrastructure | PRO | Pressure Retarded Osmosis |
| NRCP | National Research Council of the Philippines | PSA | Philippine Statistics Authority |
| NSTVET | National System of Technical Vocational Education and Training | QS | Quacquarelli Symonds |
| NTFP | Non-Timber Forest Product | R & D | Research and Development |
| NWRB | National Water Resources Board | RA | Republic Act |
| OCGT | Open Cycle Gas-turbine | RDF | Refuse-derived fuel |
| ODA | Overseas Development Assistance | RDI | Research and development institutions |
| OECD | Organization for Economic Cooperation and Development | RDLead | Research and Development Leadership |
| OTEC | Ocean Thermal Energy Conversion | RE | Renewable Energy |
| PAAC | Presidential Anti-Corruption Commission | RFID | Radio-Frequency Identification |
| PAGASA | Philippine Atmospheric, Geophysical and Astronomical Services Administration | RIIC | Regional Inclusive Innovation Center |
| PCAARRD | Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development | RO | Reverse Osmosis |
| PCC | Philippine Carabao Center | ROV | Remotely operated underwater vehicle |
| PCHRD | Philippine Council for Health Research and Development | RPA | Robotic Process Automation |
| PCIEERD | Philippine Council for Industry, Energy and Emerging Technology Research and Development. | RPS | Renewable Portfolio Standard |
| PCP | Primary Care Physician | RSE | Research Engineers and Scientist |
| PDP | Philippine Development Plan | RSM | Regional Scientific Meeting |
| PEMSEA | Partnerships in Environmental Management for the Seas of East Asia | S & T | Science and Technology |
| PGUIRR | Philippine Government University Industry Research Roundtable | S4C | Science for Change |
| PHC | Primary Health Care | SDG | Sustainable Development Goal |
| PHD | Planetary Health Diet | SDN | Software-Defined Networking |
| PHILRICE | Philippine Rice Research Institute | SEAMEO-INNOTECH | Southeast Asian Ministers of Education Organization - Regional Center for Educational Innovation and Technology |
| PhiISA | Philippine Space Agency | SEC | Specific Energy Consumption |
| Phil-WAVES | Philippine Wealth Accounting and the Valuation of Ecosystem Services | SEEA | UN System of Environmental-Economic Accounting |
| PHIVOLCS | Philippine Institute of Volcanology and Seismology | SETUP | Small Enterprise Technology Upgrading Program |
| PHNET | Philippine Network Foundation, Inc. | SK | Sangguniang Kabataan |
| PIA | Philippine Innovation Act | SLR | Sea Level Rise |
| | | SMEs | Small and Medium Enterprises |
| | | SOC | Soil Organic Carbon |
| | | SRA | Social Reform Agenda |
| | | SST | Sea Surface Temperature |

| Acronym | Meaning | Acronym | Meaning |
|------------------------------|---|-------------|--|
| SSTA | Space and Science and Technology Applications | UV | Ultraviolet (rays) |
| STAMINA4Space Program | Sustained Support for Local Space Technology and Applications Mastery, Innovation and Advancement program | VOC | Volatile Organic Compound |
| STE schools | Science, Technology and Engineering-Implementing schools | VR | Virtual Reality |
| STEM | Science, Technology, Engineering and Mathematics | WEF | World Economic Forum |
| STI | Science, Technology, and Innovation | WEP | Western Equatorial Pacific |
| SUC | State Universities and College | WESM | Wholesale Electricity Spot Market |
| SWOT | Strengths, Weaknesses, Opportunities, and Threats | WFH | Work from Home |
| SWRO | sea water reverse osmosis | WFO | Work from Office |
| TELCO | Telephony and Data Communications Provider | WHO | World Health Organization |
| TESDA | Technical Education and Skills Development Authority | WiFi | Wireless Fidelity |
| TFEC | Total Final Energy Consumption | WIPO | World Intellectual Property Organization |
| THE | Times Higher Education | WWT | Wastewater Treatment |
| TISEC | Tidal Instream Energy Conversion | | |
| TOD | transit-oriented development | | |
| TOWS | Threats, Opportunities, Weaknesses, and Strengths | | |
| TPES | Total Primary Energy Supply | | |
| UAV or UAVs | Unmanned Aerial Vehicles | | |
| UF | Ultrafiltration | | |
| UHC | Universal Health Care | | |
| UN | United Nations | | |
| UN ECOSOC | United Nations Economic and Social Council | | |
| UNCBD | United Nations Convention on Biological Diversity | | |
| UNCCD | United Nations Convention to Combat Desertification | | |
| UNCLOS | United Nations Convention on the Law of the Sea | | |
| UNCTAD | United Nations Conference on Trade and Development | | |
| UNDP | United Nations Development Programme | | |
| UNESCO | United Nations Educational, Scientific, and Cultural Organization | | |
| UP | University of the Philippines | | |
| USAID | United States Agency for International Government | | |
| USD | US Dollars | | |
| UST | University of Santo Tomas | | |

EXECUTIVE SUMMARY

Towards a Prosperous, Archipelagic, Maritime Nation

As the Philippines moves into the future, it faces challenges both old and new: the country continues to struggle with poverty alleviation even as it faces the challenges of the ongoing COVID-19 pandemic as well as the looming threats of climate change and regional geopolitics, among others. In 2018 alone, it is estimated that close to one out of every five Filipinos lives below the poverty line. Meanwhile, the country's population is expected to burgeon from some 110 million people as of this writing to over 144 million by 2050. Science, technology, and innovation (STI) will be fundamental in addressing these complex and interrelated problems—hence the need for this Pagtanaw 2050.

This Foresight underscores the archipelagic nature of our country and its implications and potentials for development: with 220 million hectares of marine environment and 29.8 million hectares of land, the Philippines' many societies and cultures have been mostly coastal in nature. Moreover, some 60% of the population resides along the coast, with a long history of use of the marine environment and resources. The observations, aspirations, and recommendations contained in this Foresight are firmly grounded on a shared vision of a Prosperous, Archipelagic, Maritime Nation.

The full measure of the intellectual weight of the National Academy of Science and Technology's experts, thought leaders, and allies across various fields has been brought to bear on this Foresight. We are thankful for the copious time that they volunteered and their in-depth participation in the many phases of this project—from comprehensive reference scanning and the Delphi method, to focused group discussions and scenario planning, and beyond. From these emerged many diverse perspectives, trends, opportunities, and particularly valuable insights on STI at both the national and international levels.

Marine Resources, Maritime Heritage, and Science, Technology, and Innovation

We look back on our long maritime history and close relationship with the marine environment, from our precolonial balangays of centuries ago to today, with respect and an eye to the future. STI empowers our maritime traditions to encompass both the old and new: for example, a multi-hull “trimaran” boat, inspired by traditional designs yet powered by hybrid sources, was recently designed and built locally for passenger and cargo transport. Such innovations, informed by local culture and traditions but with modernity and the future in mind, should be further encouraged and supported towards the realization of a comprehensive Philippine Nautical Highway. The judicious planning and development of land, coastal, and marine resources through STI can facilitate the economical and efficient operation of shipbuilding and other industries. Further, our vast marine waters lend themselves perfectly to renewable energy initiatives that tap into waves, tides, thermal vents, and other natural marine resources. And, though our societies have progressed over the centuries, our vulnerabilities have only escalated: fisheries, aquaculture, and coastal industries are beset by increasingly severe seasonal typhoons. Climate change impacts such as stronger winds, excessive rainfall, and ocean acidification have made things worse. This situation is further aggravated by physical impairments from land reclamation and from chemical and solid waste pollution from watersheds. These problems call for integrated and harmonious planning and development via a “Highlands-to-Oceans” approach to land, coastal, and marine management, which should be a top government priority. The modernization of Philippine fisheries and aquaculture and the proper maintenance of Marine Protected Areas, are extremely potent in increasing marine productivity and the well-being of marine biodiversity. For example, our Marine Genetic Resources (MGRs)—situated as they are within the Coral Triangle, a global center of marine biodiversity—can potentially produce novel biologically active compounds for various pharmaceutical and other purposes. MGRs from marine organisms like bacteria, fungi, algae, other plants, and animals should thus be screened, studied, and isolated for drugs that have anti-pain, anti-infection, and anti-cancer effects. Further, while the extraction of minerals and other materials from our seas could be profitable and gainful if sustainably managed, other benefits and costs—to both the public and private sector—should be factored into the calculus of their exploitation.

The Philippines also boasts almost a hundred seaports—all of which, though invaluable to society and the economy, could still be improved and modernized in order to make them disaster resilient. We also need to strengthen national maritime standards and compliance with regional and global maritime agreements and international maritime conventions; and embark on the development of a Coastal and Inland Waterways Transport System and a Maritime Innovation and Knowledge Center, among others.

In this Foresight, we have framed the nation’s aspirations firmly within the context of our natural and physical endowments—an archipelago with abundant marine resources—as well as our shared Filipino values and skill sets, and other potentials. This STI Foresight builds on current national aspirations and goals as outlined in the 1987 Philippine Constitution, AmBisyon Natin 2040, the Philippine Development Plans, the United Nations (UN) Sustainable Development Goals (SDGs), and the DOST Harmonized National Research and Development Agenda (HNRDA).

Key Operational Areas, Clusters, and Foresighting

At the core of this Foresight are 12 key operational areas, outlined below, which can enable the realization of our societal aspirations through a unified STI agenda:

Blue Economy. The “blue economy” approach is imperative in the Philippines, an archipelagic country with territorial seas that are twice the size of its total land area. Scientific and technological innovations are expected to play a crucial role in the preparation and implementation of a comprehensive action plan for a National Coast and Ocean Strategy.

Governance. Having effective and well-governed institutions are essential to establishing an environment of high rates of investment and improved workforce performance in both the public and private sectors. Strategic technologies can be harnessed for both the government and private sectors to provide quality services, minimize human errors, reduce unreasonable bureaucratic procedures and unnecessary expense, and ultimately achieve administrative efficiency and timely response.

Business and Trade. While the Philippines has yet to establish a track record of translating scientific research into commercial products, the prospects can be improved dramatically by considering the business community’s fundamental capacity as both beneficiary and enabler of innovation. In particular, we should provide a level playing field for our agriculture, industry and service sectors whose processes are especially friendly to innovation and research and development (R&D). However, this will not happen if the high cost of doing business—which includes the cost of energy—stemming from the poverty of public goods is allowed to persist.

Digital Technology/Information and Communications

Technology. In this section, information and communications technology (ICT) is seen as a linchpin for achieving proficiency in STI in the Philippines. The full realization of the benefits of ICT will necessitate a shift towards a robust and accessible Digital Ecosystem, in which Digitally Transformed entities interact with

each other, mutually benefit each other, and promote the greater good. Technologies like blockchain, cognitive systems, robotics, and quantum computing including last-mile connectivity to serve users in rural and remote areas are required of this ecosystem.

Science Education and Talent Retention. The importance of the Science, Technology, Engineering, and Mathematics (STEM) system of education in producing competitive STEM talent in the Philippines is vital in enhancing, maintaining, and monitoring the knowledge infrastructure in STEM. We need to adopt new out-of-the-box pedagogies that emphasize learning by doing.

Food Security and Nutrition. This operational area highlights the ability of agriculture to increase and diversify production towards the improved nutritional status of the population through new and science-based food system paradigms. In order to achieve desired nutritional outcomes, a sustainable food system should be characterized by green and inclusive growth, economic and social progress, and resilience to multiple risks.

Health Systems. Foresighting the Philippines' health STI is anchored in achieving an efficiently working and properly funded Universal Health Care Program, which addresses needs that are real, palpable, and which immediately improve human lives. At the moment of writing this Foresight, the Philippines' response is focused towards managing the COVID-19 pandemic. Many of the health system technologies accelerated by the pandemic are quite useful for strengthening the healthcare delivery system.

Energy. Since the Philippines is dependent on imported fossil fuel for its energy needs and the energy sector is among the major contributors to greenhouse gas emissions and climate change, it is essential for the country to transition to clean and affordable energy technologies to meet future needs. Priority should be given to solar, wind, and ocean waves energy systems, energy storage, smart grids and networks, biofuels, and energy from wastes.

Water. Water resources, water uses, and regional water quality, demand and supply in the Philippines must be managed with regard to their use for domestic water supply, irrigation, flood control, power generation, and pollution control. Clean technologies will be adopted to improve the delivery of affordable clean water, minimize or prevent the production of wastewater effluents, and reduce the cost of water and wastewater treatment.

Environment and Climate Change. The Philippines is a hazard-prone country and periodically suffers from extreme weather conditions, earthquakes, volcano eruptions, and other natural hazards. It is also one of the countries that are most vulnerable and at risk to climate change. Consistent with Goal 13 of the United

Nations' Sustainable Development Goals, the Philippines must adopt global and local actions to combat climate change and manage its impacts by strengthening resilience and adaptive capacity to climate-related hazards and other natural hazards.

Shelter, Transportation, and Other Infrastructure. Secure shelter and good transport facilities are minimum basic needs that are fundamental to what Filipinos aspire for as “maginhawang buhay” (comfortable life) and “panatag na buhay” (secure life), as discussed in AmBisyon Natin 2040 and which still remains relevant within the extended 30-year timeframe of the Foresight. Considering the archipelagic setting and maritime nature of the country, the national aspiration to balance urban and rural development can only be achieved through the improvement of ports, roll-on-roll-off facilities, expressway and road networks, and public transport, coupled with a strategic combination of various water, land, and air transportation modes. Shelter is needed in different forms as residence, refuge, and building as a vital component in organizing smart communities in both urban and rural settings.

Space Exploration. Space-based technologies have important applications in communications, weather forecasting, disaster management, natural resources and land use management, and in monitoring the environment. Current upstream and downstream space initiatives and future plans on space technologies must continue to be enhanced.

To facilitate the foresighting process, the above operational areas were grouped into four clusters that underscore their interrelatedness and interconnectivity: **Food, Nutrition, and Health; Water and Energy; Environment and Space Exploration; and Built Environments.** Over and above these clusters, the operational areas of Digital Technology/ICT, Blue Economy, Business and Trade, Climate Change, Governance, and Science Education and Talent Retention are considered critical influencers and enablers that cut across all operational areas.

The “Blue Economy” is an overarching operational area that highlights the Philippines’ inherently archipelagic nature and resources, pointing towards the sustainable use of marine resources—living and non-living—for the improvement of people’s livelihoods while preserving the overall health of our marine ecosystems.

‘Black Swans’ and Hope for the Future

Integrative and future-responsive resilience is fundamental to this Foresight, as it should be for all development plans now and into perpetuity. Particularly relevant to this Foresight is the careful consideration and development of upcoming STI for the provision of goods and services; and land, coastal, and marine planning. This proactive stance is vital not just for anticipated crises such as typhoons and earthquakes, but also for unforeseen crises

such as pandemic outbreaks and threats to water safety and security—all of which can all too easily stem from the mismanagement of marine and other resources. Hence, we include in this Foresight a cautionary but optimistic note on **Black Swans**: the threat of unpredictable future shocks—whether truly exogenous or stemming from the country’s still developing institutional framework, human capital, and innovation capacity—can be subverted into positive drivers and opportunities: the proper development and implementation of plans to meet long-term integrative goals can do this.

In this regard, it is imperative to have proper governance at all levels and a whole-of-government approach anchored in STI and doing away with “business as usual” approaches at every turn. This necessitates a comprehensive and iterative review of laws, policies, and guidelines, so as to eliminate gaps, contradictions, and redundancies on the way to inclusive Philippine prosperity that makes full sustainable use of our natural endowments.

Strategically Mapping the Future

This STI Foresight would be incomplete without an **STI Roadmap** to guide national development toward our preferred future. This unified and integrated map can be broken down into four complementary sub-maps—one for each of the previously-mentioned technology clusters—that visually trace the foresighted trajectories of the enablers, drivers, and opportunities that are seen to shape Philippine STI for the next three decades.

Given the current pandemic, the Food, Nutrition, and Health map highlights the present emphasis on harnessing technologies towards providing universal healthcare and ensuring affordable and nutritious food through a transformation of food systems practices; artificial intelligence and ICT are seen to eventually play dominant roles in decision-making for health and nutrition. The roadmap for Energy and Water sees the emerging dominance of low-cost, large-scale renewable energy technologies and sources. Meanwhile, the map for Environment and Space Exploration outlays the path towards an improved capability to mitigate or altogether prevent natural hazards and disasters by utilizing appropriate, adaptive, and clean/green technologies; space technologies will play a key role in this regard, for monitoring large-scale patterns for assessing climate resiliency and environmental protection. Lastly, the Built Environments map plots the evolution of work and living spaces through the measured adoption of construction- and transportation-related technologies, such as smart materials and electric vehicles, all of which will be interconnected via ICT such as the Internet of Things and virtual/augmented reality.

Ultimately, the development of a globally-competitive Philippine knowledge economy with a maritime base will enable the Philippines to finally break out of its stagnation behind more scientifically-advanced nations, allowing it to grow from a mere service economy into the Prosperous, Archipelagic, Maritime Nation, united and inclusive as it was always meant to be.