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# Unveiling the Significance of A\*STAR's Contributions to Singapore's National Development Plan

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WORKING PAPER

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### Abstract

This paper explores the multifaceted role of the Agency for Science, Technology, and Research (A\*STAR) in creating value for Singapore through its comprehensive approach to research, development, innovation, commercialization, and economic development. As the major driver of Singapore's national Research, Innovation and Enterprise (RIE) plan, A\*STAR actively contributes to Singapore's development across four key domains: manufacturing, trade and connectivity (MTC); human health and potential (HHP); urban solutions and sustainability (USS); and smart nation and digital economy (SNDE). With its strategic initiatives, expertise, state-of-the-art technologies, and robust collaborative networks involving industry players, universities, and research institutes, A\*STAR plays a pivotal role in spearheading and shaping Singapore's research and development trajectory. Furthermore, by fostering a strong ecosystem of scientific excellence and industry partnerships, A\*STAR accelerates the translation of research outcomes into practical applications, enhancing Singapore's economic competitiveness and strengthening its position as an innovation-driven, knowledge-based economy. This paper provides insights into A\*STAR's contributions and highlights the importance of its endeavours in driving Singapore's research, development, innovation, commercialization, and economic growth.

**Keywords:** A\*STAR, research and development, innovation, commercialization

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## 1. National Priorities of Singapore

Covering an area of 646 square kilometers, Singapore is a wealthy island country located in the southern region of the Malay Peninsula in Southeast Asia (Asia Biz, 2021). As a high-income nation, Singapore's economy is ranked top three in competitiveness in 2022 (IMD World Competitiveness Center, 2022). The whole country has rapidly developed since its independence from Malaysia on 9<sup>th</sup> August 1965 (The World Bank, 2019). In the late 1960s, after its independence, Singapore was confronted with severe unemployment and poverty issues (Zhou, 2019). Furthermore, due to the lack of natural resources in Singapore, the nation has to rely on external sources for natural resources and basic necessities such as water, food, and energy (The World Bank, 2019). As a result, human capital development became crucial in developing and sustaining Singapore's economy (Zhou, 2019). Since its independence, the Government of Singapore shifted its focus from an import substitution strategy to an export-led industrialization approach, aiming to attract foreign investors and create more job opportunities for its citizens. This has contributed directly to Singapore's rapid industrial growth (Monetary Authority of Singapore [MAS], 2015). In fact, Singapore is strategically located at the heart of Southeast Asia, which is in an advantageous position that connects the world's major trade routes, providing a great extent of global connectivity (Economic Development Board [EDB], 2022). Specifically, Singapore's transportation hub is connected to 600 ports in 123 countries (EDB, 2022). As a result, the strategic location and established port system have successfully attracted a large inflow of foreign investments and brought about the rapid development of the manufacturing sector in Singapore (MAS, 2015; Zhou, 2019).

In the early 1970s, both the United States and Japan were major investors in Singapore's manufacturing firms. Due to Singapore's conducive investment environment, the country experienced rapid GDP growth from 1965 to 1972 (Zhou, 2019). In the 1980s and 1990s, the

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rapid expansion in manufacturing industries, such as electronics, petrochemicals, component and precision engineering, and pharmaceuticals, helped attract even more foreign investments to Singapore (Soon & Tan, 1993). Over this period, Singapore owes its GDP growth mainly to the manufacturing sectors (Soon & Tan, 1993). Increasingly, modern service sectors, particularly the information and communications industries, as well as the finance and insurance industries, began to play important roles in ramping up Singapore's GDP (Soon & Tan, 1993). Manufacturing sectors, particularly the construction, shipbuilding, pharmaceuticals, chemicals, electronics, and precision engineering sectors, contribute to more than 30% of Singapore's Gross Domestic Product (GDP) value (Asia Biz, 2021). From the 1990s onwards, the modern service sectors began to constitute a larger share of GDP than the manufacturing sectors in Singapore (Soon & Tan, 1993). To date, the manufacturing and services sectors remain the two pillars of economic growth in Singapore, which simultaneously features the government's efforts in recruiting and developing human capital, specifically the "Professional, Managerial, Executive, and Technical (PMET) workforce" (Matthew, 2020; Tan, 2019). For instance, the Ministry of Manpower Singapore has taken steps to adjust immigration policies to attract, recruit, and retain foreign workers who play important roles in the manufacturing and services sectors in Singapore (The Hindu, 2022). Singapore's GDP is expected to reach 425 USD Billion by the end of 2022, mainly contributed by the aforementioned two important sectors (Asia Fund Managers, 2022). Intriguingly, with these development efforts, Singapore has grown from a small nation lacking natural resources to one of the world's leading economies (Santhi & Saravanakumar, 2020).

Alongside human capital, science and technology (S&T) are fundamental enablers of Singapore's economy, particularly in the manufacturing and services sectors (National Research Foundation, 2021). In fact, Singapore's S&T efforts can be witnessed through its

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investments in research and development (R&D) activities. The establishment of the National Science and Technology Board in 1991 and the launch of the first five-year National Technology Plan in 1995 marked the beginning of Singapore's research and development journey. The objective was to develop S&T professionals who could contribute to the nation's economic development (National Research Foundation, 2021). As the nation's economy became more sophisticated, the government's investment in S&T began focusing on other areas, particularly biomedical sciences, biotechnology, computer science, and cybersecurity (SG Innovate, 2020). Since 1985, Singapore has spent approximately USD 44 billion to expand its research capacities, develop highly-skilled S&T talent, and build cutting-edge research institutions. For instance, the Agency for Science and Technology Research (A\*STAR), a public research organization, was established to drive and lead S&T development in Singapore. Complementing that, several technological research entities were established in a number of Singapore's tertiary institutions, such as the National University of Singapore and the Nanyang Technological University. To drive and enable the Science, Technology, and Innovation (STI) ecosystem, joint research collaborations between government agencies, tertiary institutes, and private sector players in Singapore were nurtured, with the main objective of developing research capabilities and driving economic growth (SG Innovate, 2020).

In 2010, Singapore's R&D strategy has been extended across research, innovation, and enterprise (RIE), aiming to streamline research capacities, innovation, and commercialization, which can add to the economic development in Singapore (National Research Foundation, 2021). Under the RIE plans (2015 - 2020), the Government of Singapore has invested more than US\$ 30 billion to build the nation's competitive advantage in Advanced Manufacturing and Engineering, Health and Biomedical Sciences, Urban Solutions and Sustainability, and Services and Digital Economy. Activities in these four strategic technology domains are

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supported by three value-adding programs: Academic Research, Manpower, and Innovation and Enterprise (I&E). Essentially, these programs are crucial in supporting enterprises and industries to convert research and development into novel products and services, which are then available in the market (Research, Innovation, and Enterprise [RIE], 2020). As a result of these national R&D plans and platforms, some top-notch technology corporations, such as Facebook and Google, decided to establish their presence in Singapore. Furthermore, many local small and medium-sized enterprises and start-ups have established RIE partnerships to build stronger research capacities and gain access to a bigger pool of talent and networks, facilitating them to produce and offer novel products and services to the market (National Research Foundation, 2021).

The latest RIE 2025 Plan was launched in December 2020 with a massive budget of USD 25 billion, which is the biggest budget ever devoted to Singapore's R&D (A\*STAR, 2021a). This investment sum clearly reflects Singapore's sustained dedication to improving its R&D. Along with prior objectives, the RIE 2025 Plan aims to build and gain more value from previous RIE investments. First, under the RIE 2025, the Government of Singapore envisions addressing a wider range of national needs. In other words, RIE investments will be integrated with national initiatives to transform industries and drive economic growth (National Research Foundation, 2021). Secondly, RIE 2025 aims to build a stronger research base, create a healthy research ecosystem, and reinforce interdisciplinary research to tackle a broader spectrum of issues in new and emerging areas (National Research Foundation, 2021). The third objective of the RIE Plan is to strengthen the I&E platforms, hoping to reach out to more local enterprises and facilitate them in technology translation and commercialization (National Research Foundation, 2021). Moreover, these I&E platforms also serve as a central hub connecting key stakeholders across the research and development communities, as well as public and private



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sector players, so as to facilitate the exchange of ideas, expertise, and technologies (National Research Foundation, 2021). With such objectives and efforts, Singapore is strongly committed to bringing the whole nation to greater heights through its research and development clusters. In fact, A\*STAR, an important public sector R&D agency in Singapore, is the biggest driver of the RIE efforts. Further insights, background on A\*STAR, and its importance to Singapore's economic development are outlined in the section that follows.

## **2. About A\*Star**

As the national driver of scientific research, the Agency for Science, Technology and Research (A\*STAR) is a public research organization founded in Singapore on 11<sup>th</sup> January 1991 (A\*STAR, 2022a). Originally, the research institute, formerly known as the Science Council of Singapore, was established to provide support and advice to the Government of Singapore in research and development in 1967 (Moasi, 2019). In the late 1960s, the research council mainly worked with tertiary institutions and government agencies to drive research and development in Singapore. In the 1980s, it played a significant role in raising awareness for the adoption of science and technology in Singapore, organizing research seminars, and building networks with international research communities (Moasi, 2019). Subsequently, the council shifted its role from an advisor to being directly involved in navigating Singapore's research and development industry, meeting the nation's goal of driving high-tech research and development. In 1990, the council was upgraded to the National Science and Technology Board (NSTB), holding primary responsibilities for science and technology policies, building talent in essential industry sectors, and developing facilities crucial for research and development activities (Moasi, 2019). In 1991, the NSTB formulated Singapore's first five-year National Technology Plan, primarily focusing on developing research capacities in nine sectors, including medical sciences; biotechnology; energy, water, environment and resources;

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manufacturing technology; materials technology; information technology; food and agrotechnology; microelectronics; and electronic systems (Moasi, 2019).

In the 2000s, the research institute was officially divided into two primary research bodies, involving the biomedical field as well as the physical sciences & engineering field (Moasi, 2019). Subsequently, NSTB was renamed the Agency for Science, Technology and Research, or A\*STAR, in January 2002 (A\*STAR, 2022a). Serving as a statutory board under the Ministry of Trade and Industry of Singapore, the current goal of A\*STAR is to enhance and develop the knowledge-intensive biomedical sciences, physical sciences & engineering fields, which contribute substantially to socioeconomic development and improve the overall quality of life (A\*STAR, 2022b). Importantly, A\*STAR encompasses two broad research arms: i) The Biomedical Research Council (BMRC); ii) the Science and Engineering Research Council (SERC) (A\*STAR, 2022a). Specifically, the biomedical research entities are mainly situated at Biopolis, while the physical sciences & engineering research centers are situated at Fusionopolis, both of which are located at one-north in Buona Vista, Singapore (A\*STAR, 2022c). The capabilities of these research bodies extend across a wide array of fields, including but not limited to nutrition, food security, medical technology, pharmaceuticals and biologics, immunology, advanced manufacturing, computational sciences, robotics and automation, etc. (A\*STAR, 2022c). With regard to its mission, A\*STAR aims to bring together academia and industry players and integrate their research capabilities, which are essential in yielding impactful outcomes for society. In terms of vision, A\*STAR envisions becoming a “global leader in science, technology, and open innovation” (A\*STAR, 2022b). Specifically, it establishes partnership collaborations with a variety of entities, including public and private sector players (e.g., government bodies, start-ups, small and medium-sized enterprises, and multinational corporations), with the objective of creating impacts on industry sectors and

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society as a whole (A\*STAR, 2022b). It is also worth noting that A\*STAR is the major driver of the national RIE 2025 Plan across four domains, namely: manufacturing, trade and connectivity (MTC); human health and potential (HHP); urban solutions and sustainability (USS); and Smart Nation and digital economy (SNDE) (A\*STAR, 2021a). Further details on the role of A\*STAR and how it creates value for its stakeholders are discussed in the sections that follow.

## **2.1 A\*STAR's Main Research Arms**

As mentioned above, the Biomedical Research Council (BMRC) and the Science and Engineering Research Council (SERC) are the two main research arms under A\*STAR (Moasi, 2019). These two research arms serve different objectives in different areas. Specifically, the BMRC supports, manages, and supervises Singapore's public sector research and development activities in biomedical research. Under the BMRC, several research entities oversee and second the development of research capacities in BMRC's core research clusters, including pharmaceuticals, biotechnology and biologics, medical technology, and personal care and nutrition clusters (A\*STAR, 2022b). For instance, the Institute of Bioengineering and Bioimaging (IBB), Bioprocessing Technology Institute (BTI), Genome Institute of Singapore (GIS), Bioinformatics Institute (BII), A\*STAR Infectious Disease Labs (ID Labs), and the Institute of Molecular and Cell Biology (IMCB) are some of the well-established research institutes under the BMRC (A\*STAR, 2022b). In addition to overseeing the development of core research capabilities in the abovementioned research clusters, BMRC also actively develops highly-skilled talent in biomedical science and promotes cross-disciplinary research, which contributes significantly to the development of Singapore's healthcare sector (A\*STAR, 2022b).

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The Science and Engineering Research Council (SERC), which serves as another research arm of A\*STAR, promotes and oversees the public sector research and development in the physical sciences and engineering. Similar to the BMRC, SERC's research area is divided into four research clusters: engineering; electronics; chemicals, materials and energy; and info-communications, media and computing. Likewise, its' primary goals involve actively promoting multi-disciplinary research and collaborations among physical sciences and engineering industries, research institutes, and sectors; establishing a wider network of industry partners and research institutes by offering a wide variety of funding schemes and programs to enable a smooth translation of research and development into commercialization; and lastly, building and cultivating talent in physical sciences and engineering (A\*STAR, 2022b). Some of the research institutes under the SERC include the Advanced Remanufacturing and Technology Centre (ARTC), Institute of Sustainability for Chemicals, Energy and Environment (ISCE<sup>2</sup>), Institute of High-Performance Computing (IHPC), Institute for Infocomm Research (I<sup>2</sup>R), Institute of Materials Research & Engineering (IMRE), etc. (A\*STAR, 2022b). In general, these research institutes are responsible for leading and managing a wide range of research and development activities, from idea generation and knowledge translation to industry-led programs (A\*STAR, 2022a).

## **2.2 The Role of A\*Star in Singapore's Economic Development**

As mentioned in the "National Priorities in Singapore" section, A\*STAR plays an instrumental role in spearheading and navigating Singapore's research and development direction. A\*STAR's primary goals align with the national Research, Innovation, and Enterprise (RIE) Plan. Specifically, the RIE plan is refreshed every five years to establish an ecosystem that accelerates the translation of research and development into innovation and commercialization (RIE, 2020). The five-year blueprint focuses on four broad strategic

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domains: advanced manufacturing and engineering (AME); health and biomedical sciences (HBMS); urban solutions and sustainability (USS); and Services and digital economy (SDE) (RIE, 2020). Of the RIE's budget, nearly 30% is utilized to enhance research capacities in A\*STAR's research institutes and universities in Singapore, highlighting the nation's dedication to improving its research and development ecosystem (A\*STAR, 2021a). In fact, each strategic domain addresses different economic issues and contributes directly to economic development. A\*STAR is one of the key research institutes involved in the entire research ecosystem, from research and development activities to the innovation and commercialization phase. Further insights are discussed in the sections that follow.

### **2.2.1 Advanced Manufacturing and Engineering (AME)**

The advanced manufacturing and engineering (AME) domain aims to “develop technological capabilities that support the growth and competitiveness of our manufacturing and engineering sectors” (RIE, 2020, p. 7). Due to its strategic location, Singapore has long been well-known for its manufacturing sector for decades (RIE, 2020). In fact, the manufacturing industry accounts for approximately 20% of Singapore's GDP and created job opportunities for more than 500,000 people (RIE, 2020). Hence, the manufacturing sector is of immeasurable value to the Government of Singapore (International Trade Administration, 2020). Research and development (R&D) are key in improving and strengthening the manufacturing and engineering sectors. This is where A\*STAR comes into play to guide the R&D's direction and promote an innovation-driven, knowledge-based economy (National Research Foundation, 2021). The following section discusses some case studies of how A\*STAR contributes to research and development activities in the manufacturing and engineering sectors.

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### 2.2.1.1 Research and Development (R&D)

The Future of Manufacturing (FoM) initiative is a concrete example of how A\*STAR brings value to Singapore's research and development in the manufacturing sector. Specifically, FoM was established in 2015 to empower local start-ups, SMEs, and multinational corporations to adopt smart manufacturing and automation technologies (A\*STAR, 2021b). There are three public-private partnership platforms under the FoM that drive knowledge transfer and innovation, namely *Tech Access*, *Tech Depot*, and *Model Factories*. First, *Tech Access* is a platform that enables industry players or companies to gain access to A\*STAR research infrastructure and expertise, such as advanced manufacturing and biotech/biomedical scientific tools, under the guidance of experts. For example, Sanwa-Intec (Asia) Pte Ltd utilized A\*STAR's 3D X-Ray Computed Tomography System to scan their insert molding samples in order to address design issues, which helped improve their overall product quality (National Research Foundation, 2021). Essentially, the *Tech Access* platform allows them to explore new technologies, experiment with new applications, and prototype new products (A\*STAR, 2021b). Through this platform, A\*STAR also provides SMEs with its intellectual property license so that they can utilize its technologies to produce and commercialize their new ideas/solutions (Johnston, 2018). Similarly, through the *Tech Depot* platform, companies can access and adopt plug-and-play technologies. To date, more than 600 companies have utilized the *Tech Depot* platform, resulting in greater productivity improvement (National Research Foundation, 2021). The *Model Factories* platform promotes research and development activities by providing a virtual manufacturing lab, which enables simulation of process planning and production. These processes allow companies to test and prototype their novel ideas before launching them in the real-world manufacturing environment, which helps in improving production and manufacturing efficiency (A\*STAR, 2021b). More than 100 companies have leveraged A\*STAR's *Model Factory* platform to test and improve their new

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ideas and products (National Research Foundation, 2021). For instance, Abrasive Engineering Pte Ltd, which mainly produces automated blasting and shot peening machines, adopted the Industrial Internet-of-Things (IIoT) technologies through the *Model Factory* initiative to improve their machine maintenance cycles and minimize failures, aiming to boost their sales by 20% in 2021 (Seow, 2018).

The *Model Factory* initiative's contribution to Singapore's R&D can also be demonstrated through the partnership between Racer Technology (a local firm) and A\*STAR's Singapore Institute of Manufacturing Technology (SIMTech). In 2006, Racer Technology leveraged A\*STAR's research capabilities and expertise in engineering and technological solutions to develop and manufacture its own medical products (A\*STAR, 2020). As a result, this partnership enabled Racer Technology to research and co-develop a medical device that improves the storage of blood plasma (A\*STAR, 2020a). Another example involving A\*STAR's *Model Factory* is the collaboration between A\*STAR's SIMTech and Fong's Engineering and Manufacturing (FEM). Specifically, FEM visited A\*STAR's Model Factory and discovered its Real Time Dashboard technology, which can help capture data more accurately and optimize its shopfloor connectivity (A\*STAR, 2020b). The company's engineers were then trained by A\*STAR's researchers to use and familiarise themselves with the technology over nine months. After adopting A\*STAR's smart technology, FEM's output rose by 40%, indicating a significant improvement in their production outputs. This shows that knowledge sharing and transfer are essential for successful technology adoption. Besides its technologies, FEM also tapped into A\*STAR's network of contacts that can help with the installation of the machines (A\*STAR, 2020b). As can be seen, from the discussion above, the initiatives introduced by A\*STAR indeed help contribute to research and development

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activities across industry players, private and public sector research institutes, and broader research communities in Singapore.

### **2.2.1.2 Innovation and Commercialization (I&C)**

A\*STAR also actively collaborates with industry players (e.g., local enterprises, SMEs, MNCs) to drive innovation and commercialization in Singapore. For example, STMicroelectronics, a global semiconductor company, entered into a partnership with A\*STAR to establish a leading-edge R&D line in its Singapore manufacturing facility in 2020 (National Research Foundation, 2021). Through this partnership, the world's first "*Lab-in-Fab*" was jointly created to produce the piezoelectric microelectromechanical system, which is applicable in diverse market segments, such as 3D printing, healthcare devices, virtual/artificial reality applications, and smart glasses (STMicroelectronics, 2020). In fact, industry players often work with research institutes at a very theoretical level and often find it difficult to convert ideas/concepts into high-volume production. Endowed with research capacities and competencies from A\*STAR and STMicroelectronics, *Lab-in-Fab* aims to address this challenge by integrating R&D and high-volume production capacities to efficiently translate new ideas/concepts into products/services (STMicroelectronics, 2022). In other words, *Lab-in-Fab* provides a platform that allows industry players to test their new ideas and products before mass production takes place (STMicroelectronics, 2020).

As another illustration, A\*STAR and Sembcorp Marine, a pioneer in Singapore's offshore and marine sector, signed a Master Research Collaboration Agreement (MRCA) in 2020 to work together to seek innovation in Digital Design and Advanced Manufacturing. (Sembcorp Marine, 2020). This collaborative research project's main goal is to hasten the transition of novel offshore, marine, and renewable energy solutions from the "research and development" stage to the "commercialization" stage. Specifically, a research laboratory –



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Joint Lab @ TBY, has been jointly established by Sembcorp Marine and A\*STAR to provide a platform for test-bedding, which aims to facilitate and accelerate the commercialization of novel advanced manufacturing technologies in Singapore (Sembcorp Marine, 2020). Likewise, the National Additive Manufacturing Innovation Cluster (NAMIC), which is a national platform spearheaded by A\*STAR, plays an important part in the innovation phase of new ideas/concepts (National Research Foundation, 2021). In the RIE 2025, NAMIC aims to provide test-bedding facilities (which include technologies that involve artificial intelligence and robotics) for research institutes and companies in the Advanced Manufacturing sectors. This effort facilitates researchers and industry players to pilot new technologies and solutions, which can efficiently and significantly help shorten the period needed to commercialize innovative solutions for the markets (National Research Foundation, 2021).

### **2.2.2 Health and Biomedical Sciences (HBMS)**

The main objective of the health and biomedical sciences (HBMS) strategic domain is to “be a leading centre that advances human health and wellness, and creates economic value for Singapore and Singaporeans through the pursuit of excellence in research and its application” (RIE, 2020, p. 7). The key strategies of this domain involve developing new approaches to support the conversion of research ideas/concepts into healthcare solutions, better health outcomes, and greater economic value; establishing a holistic Innovation and Enterprise (I&E) ecosystem for pharmaceutical, biopharmaceutical, and medical technologies; and provide support to other health and biomedical sciences-related sectors, such as food and nutrition, as well as personal care (RIE, 2020). In fact, Singapore relies heavily on external sources for its food (more than 90% of its food is imported from more than 170 countries), and hence its food supply is vulnerably influenced by the volatile global supply chain (A\*STAR, 2021c; National Research Foundation, 2021). Therefore, the Government of Singapore has established a

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national goal on food security, that is, to produce food locally sufficient to meet 30% of the nutritional needs in Singapore in a sustainable manner by 2030 (30 by 30 food security plan). Simultaneously, sustainable local food production will translate into greater economic opportunities for Singapore (Ministry of Sustainability and the Environment, 2021). A\*STAR's Food and Consumer cluster brings together industry partners, researchers, and regulators to create innovative solutions for sustainable food production, which helps address the nation's challenges in food supply and production (A\*STAR, 2021d). As can be seen, the above strategies perfectly fit into A\*STAR's core research expertise, including medical technology, pharmaceuticals and biologics, food and consumer, and biomanufacturing (A\*STAR, 2021e). That is to say, as the nation's largest public research institute, A\*STAR holds crucial responsibilities in leading the HBMS strategic domain and addressing the aforementioned national plans. The sections below will illustrate how A\*STAR contributes to the Research & Development and Innovation & Commercialization of the sectors mentioned in the HBMS strategic domain.

#### ***2.2.2.1 Research and Development (R&D)***

In response to the Covid-19 pandemic, A\*STAR's Infectious Diseases Labs (ID Labs) was established in April 2021 to gather a multi-disciplinary team of researchers to conduct research and develop new technologies for the detection, prevention, and elimination of the Corona Virus and other infectious diseases (A\*STAR, 2021f). This initiative encouraged cross-disciplinary collaboration among industry players, clinical researchers, and public and private sector research institutes. Moreover, a wide range of cutting-edge research facilities and expertise were made readily available through ID Labs for researchers to drive translational research on infectious diseases (A\*STAR, 2021f). Partnering with the National Centre for Infectious Diseases (NCID), ID Labs is also responsible for looking into the effectiveness of

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the Covid-19 vaccines in the Singaporean population. In addition, ID Labs also plays an important part in identifying emerging pathogens and conducting research to discover potential drugs and vaccines to protect against the transmissions of pathogens (Audrey, 2021). Other than that, the Fortitude Kit, Singapore's first ready-made Covid-19 self-test kit, was jointly researched and co-developed by A\*STAR's research entities and Tan Tock Seng Hospital in Singapore (Audrey, 2021). The effectiveness and accuracy of the newly developed test kits were jointly tested and assessed by the Diagnostics Development Hub (DxD Hub) and the National Centre for Infectious Diseases before mass production took place (National Research Foundation, 2021). As a result, the Fortitude Kit was efficiently developed within a month from the idea generation to the product development phase, which is mainly attributed to the strong collaborations between researchers and the public health community (A\*STAR, 2020c). Besides that, Boehringer Ingelheim (BI) signed a global licensing agreement with A\*STAR to develop innovative antibodies for targeted cancer therapies. Under this agreement, BI possesses exclusive rights to research, develop, and commercialize its products by making use of A\*STAR's tumor-specific antibodies for safer and more efficacious cancer treatments (ACN NewsWire, 2022). Essentially, BI conducts research, clinical trials, and commercialization of targeted cancer medicines using antibodies from A\*STAR. Based on the accomplishment of the development and commercialization goals, A\*STAR might receive more than EUR 100 million as compensation (ACN NewsWire, 2022). This is how A\*STAR brings value to the health sector through knowledge transfer and licensing agreements.

In addition to pharmaceutical and medical technology, biomedical sciences also involve the R&D of food and nutrition, which is essential in ensuring healthy living and food security in Singapore (RIE, 2020). As an example, led by A\*STAR, the Singapore Institute of Food and Biotechnology Innovation (SIFBI) was established in 2020 to promote joint research

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collaborations on the development of innovative food solutions in Singapore (A\*STAR, 2022d). Specifically, through its Taste Receptor Platform, SIFBI supports the R&D activities in local food production companies and provides innovative solutions to their food and ingredients (A\*STAR, 2021g). Other than that, A\*STAR also collaborates with the Singapore Food Agency (SFA) and Nanyang Technological University Singapore to jointly develop the Singapore Food Story R&D Programme, which aims to improve and strengthen food security and supply in Singapore (A\*STAR, 2021h). The Future Ready Food Safety Hub (FRESH), which is a national research and support platform established under this R&D program, aims to build and enhance Singapore's food safety science and R&D capabilities, contributing to the national goal of achieving the "30 by 30" food security plan by 2030. Specifically, this platform allows the development of optimized food formulations through various laboratory experimental designs (A\*STAR, 2021i). Furthermore, FRESH also aims to integrate food safety risk assessment into the research and development process to control the quality of food products for commercialization in Singapore (A\*STAR, 2021i). Undeniably, A\*STAR indeed serves an instrumental role in guiding and promoting the R&D activities in Singapore's food production industry.

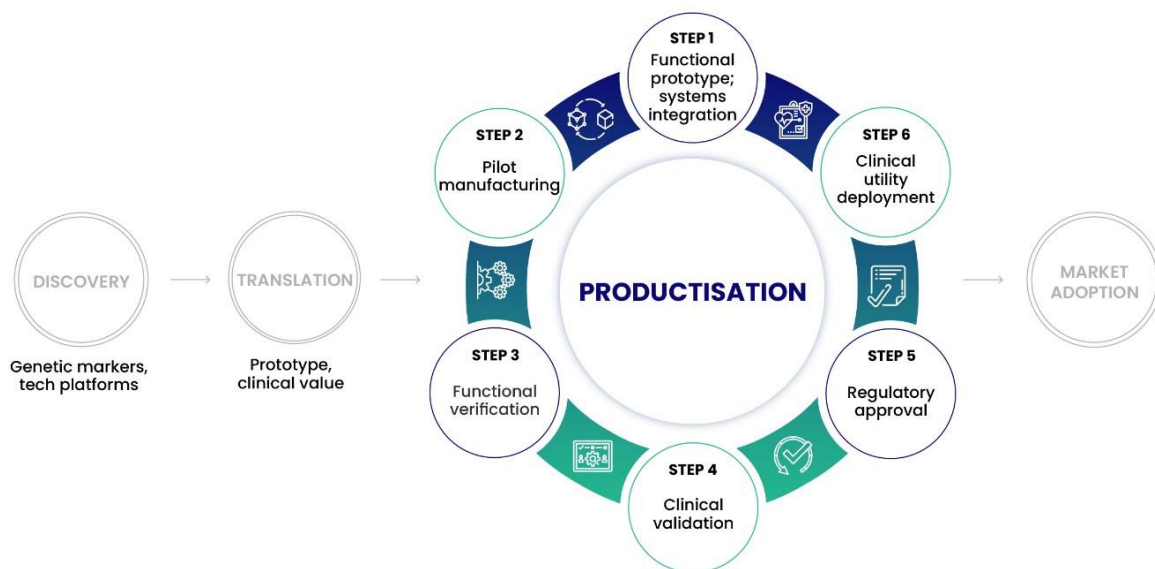
#### ***2.2.2.2 Innovation and Commercialization (I&C)***

Located in Biopolis and established in 2014, the Diagnostics Development Hub (DxD Hub) is another national initiative spearheaded by *A\*ccelerate*, which is the commercialization arm of A\*STAR. The DxD Hub is committed to guiding medical technology innovation through partnerships and collaborations with industry players and research institutes. Its' goal is to accelerate the translation of diagnostic-related concepts and intellectual properties into clinically approved and registered diagnostic tools, which are readily available for adoption by local start-ups, SMEs, and MNCs (A\*STAR, 2021j). In fact, the process of getting novel drug

discoveries to clinical trials and achieving final approval from relevant authorities can take up to ten years. However, DxD Hub steps in to shorten the cycle needed to commercialize drug discovery while assuring the quality of the newly discovered drugs (Chan, 2015). Furthermore, the development of medical technology products is closely monitored by the review panels selected by the DxD Hub, involving clinicians, venture capitalists, and other relevant industry professionals (Chan, 2015). The DxD Hub also helps local start-ups ensure that their new diagnostic products meet regulatory compliance and standard requirements. In turn, this can speed up the process of getting the products approved for sale in the global market (Chan, 2015). Figure 1 demonstrates the DxD Hub's productization process.

### Figure 1.

*The productization process of DxD Hub.*



Source: DxD Hub (2022)

Many local enterprises, MNCs, and research institutes have partnered with A\*STAR in getting their new diagnostic devices and drugs developed and commercialized. TIIM Healthcare, X-Zell, Advanced MedTech, Parkway Laboratories, Respiree, and ASEAN-NDI

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are some of A\*STAR's partners (A\*STAR, 2021k). For example, X-Zell, a global medical technology start-up specializing in cancer cell detection, signed a research collaboration agreement with A\*STAR to enhance its research capacities, accelerate the product development phase, and scale up its commercialization process (X-Zell, 2018). Specifically, in phase one of the collaboration, DxHub will conduct stringent testing on X-Zell's novel cancer cell detection technology (X-ZELL Prostate™) for safety and quality assurance. In phase two, prospective, blinded, multi-center clinical trials will be carried out by DxHub to test and validate the efficacy, accuracy, and safety of X-Zell Prostate™. This is followed by the global commercialization of X-Zell's unique cancer cell detection technology (X-Zell, 2018). As can be seen, DxHub is strategically involved in every stage of X-Zell's productization of its cancer cell detection technology, bringing value to the entire innovation and enterprise ecosystem. As another example, following the R&D phase involving collaboration between A\*STAR research entities and Tan Tock Seng Hospital, A\*STAR has partnered with various biotechnology corporations (e.g., MiRXES) in Singapore to mass-produce and commercialize the Fortitude Kit to meet global demand (National Research Foundation, 2021). To date, the Fortitude Kit has been distributed to more than 45 countries worldwide as a result of the innovation and commercialization efforts among A\*STAR research institutes and other industry players (MiRXES, n.d.).

Regarding food and nutrition, A\*STAR established a Food Tech Innovation Centre (FTIC) with Temasek, an investment company owned by the Government of Singapore, aiming to accelerate the development and commercialization of food technologies to meet Singapore's "30 by 30" food security goal (Ovais, 2020). The main purpose of FTIC is to provide food production companies with support in the pilot manufacturing activities and food production process. FTIC offers essential facilities such as Wet Labs, Test Kitchens, and pilot-scale

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facilities for product testing and development. That is to say, local start-ups can utilize this platform to testbed their food products in small batches before the actual commercialization phase (Ovais, 2020). Beyond facilities and equipment, FTIC also provides a wide range of advisory support for local food start-ups to facilitate rapid commercialization. The advisory support ranges from food production based on consumer insights, product and process development, regulatory affairs, and sales and marketing support (Asia-Pacific Agri-Food Innovation Summit Singapore, 2020). These facilities and advisory supports can efficiently help shorten the innovation and commercialization process of novel food technologies or products. Essentially, A\*STAR's and Temasek's research capabilities and strong network collaborations in the food and biotechnology area can definitely bring the "30 by 30" food security goal to reality by 2030, bringing value to Singapore's economic development.

### **2.2.3 Urban Solutions and Sustainability (USS)**

The urban solutions and sustainability (USS) strategic domain aims to "develop a sustainable and liveable city through integrated solutions for Singapore and the world (RIE, 2020, p. 7). This strategic technology domain focuses on developing and strengthening five key pillars: Infrastructure, Built Environment, Clean Energy, Water & Environment, and Urban Mobility (Singapore Economic Development Board [SEDB], 2022). The Government of Singapore has invested approximately USD 220 million into national research initiatives focusing on the USS (Cheryl, 2022). Through USS, the government aims to turn Singapore into a smart and sustainable city with a robust infrastructure ecosystem that integrates developers, engineering consultancy, project financing, legal advisory services, and other professional services (SEDB, 2022). Additionally, Singapore envisions promoting smart and sustainable building solutions that can help develop and maintain infrastructures sustainably in a resource-efficient manner. It also aims to have "at least 80% of buildings (by floor area) in

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Singapore to be green by 2030” through the USD 50 million Green Mark Incentive Scheme. In fact, more than 40% of buildings in Singapore received the Green Building Product Certification by 2019, signifying that the building structures and construction processes involved are resource-efficient and environmentally friendly (Jacqueline, 2020).

To address the climate change issue, Singapore’s energy sector has begun focusing on clean power generation and increasing the adoption of renewable energy sources, aiming to turn Singapore into a global clean energy hub (National Research Foundation, 2021). In addition, Singapore is also taking extra steps to reduce its carbon emissions, although it only contributes around 0.10% of global carbon emissions (Ministry of Foreign Affairs Singapore, 2022). For instance, the government strongly encourages industry players to utilize low-carbon energy technologies and renewable energy sources to minimize carbon emissions, which can help address the climate change issue (National Research Foundation, 2021). Other than that, due to the lack of natural water resources, Singapore signed the 1962 Water Agreement with the Government of Malaysia, which agreed to supply 250 million gallons of water to Singapore at 3 cents per thousand gallons of raw water from the Johor River on a daily basis (Amir, 2021). To safeguard against water scarcity, Singapore has to build its capabilities and capacities in water management and treatment technologies, as well as reduce daily water consumption (SEDB, 2022). In fact, there are around 180 water companies and 26 water research centers driving the growth of the water sector in Singapore, striving to make Singapore a global hydro hub (RIE, 2020).

Regarding urban mobility, as one of the smallest and most densely populated countries, Singapore has to rely heavily on efficient transportation infrastructure to optimize its town planning and enable smart urban mobility (SEDB, 2022). Therefore, the Land Transport Master Plan (LTMP) 2040 was established by the Government of Singapore, envision creating a green



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and holistic transport ecosystem that enables its citizens to get around the country within 45 minutes (Daniel, 2020). As can be seen, research and development play the biggest role in optimizing transport systems in Singapore. Generally, the USS sustainability goals can be achieved through research collaborations between USS agencies, public and private sector researchers, and industry players. In turn, these research efforts are vital in creating sustainable urban solutions and bringing economic value to Singapore. Clearly, A\*STAR, a government link research organization, also plays a substantial role in catalyzing the translation of R&D, deployment, commercialization of USS-related research outcomes, and promoting industry adoption.

### ***2.2.3.1 Research and Development (R&D)***

To contribute to Singapore's sustainability and climate change goals (including the Singapore Green Plan and Zero Waste Masterplan), A\*STAR recently established the Institute of Sustainability for Chemicals, Energy and Environment (ISCE<sup>2</sup>), focusing on R&D in areas involving low-carbon technologies, carbon capture and utilization, green materials, products, and manufacturing processes, etc. ISCE<sup>2</sup> looks to collaborate with various industry players, as well as private and public research institutes, to jointly achieve Singapore's sustainability goals (A\*STAR, 2022e). For example, IHI Corporation, a multinational corporation, has entered into an agreement with A\*STAR's ISCE<sup>2</sup> to establish a joint centre for research and development specializing in carbon solutions development (IHI, 2022). Specifically, this collaboration aims to research ways to recycle carbon dioxide by transforming it into methane and olefins, which can be used to produce polymers. This can substantially help reduce the emission of carbon dioxide from manufacturing plastics and protect the environment (IHI, 2021). Through joint R&D with ISCE<sup>2</sup>, IHI corporation has successfully developed the catalyst, which is essential for producing olefins (IHI, 2021). Another R&D example of carbon solutions is the

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partnerships between A\*STAR, the Singapore EDB, and the Jurong Town Corporation (JTC). This partnership involves working with 13 ecosystem partners, such as ExxonMobil, Keppel Infrastructure Holdings Pte Ltd, Nanyang Technological University, IHI Asia Pacific Pte Ltd, etc., to study the development of a Carbon Capture and Utilisation Translational Testbed (CCUTT). Located on Jurong Island, the CCUTT enables companies to speed up the test-bedding process and efficiently scale up the production of Carbon Capture and Utilization (CCU) technologies (SEDB, 2021). These CCU technologies are crucial in capturing carbon dioxide and transforming them into functional and harmless substances, such as methanol and formic acid, thereby minimizing air pollution and slowing down climate change (SEDB, 2021). Regarding water issues in Singapore, Xylem, a global water technology company, collaborates with A\*STAR's Institute of High-Performance Computing (IHPC) to develop water distribution and water treatment technologies in Singapore (Xylem, 2020). Specifically, this partnership involves the combination of Xylem's expertise in water technologies and IHPC's strong capabilities in computer modelling and simulations for sustainable water technologies, aiming to develop a new computational fluid dynamics model. This model will then be used for designing and testing products/solutions that will be installed in water treatment plants and water distribution networks, improving water security issues in Singapore (Xylem, 2020).

### ***2.2.3.2 Innovation and Commercialization (I&C)***

A\*STAR plays an essential role in exploring and developing smart city solutions with its stakeholders. For instance, A\*STAR is teaming up with Surbana Jurong, an urban and infrastructure consultancy firm, to co-develop value-adding and cost-effective digital solutions for Sustainable Smart Cities planning. Digital capabilities in urban planning, designing and simulating buildings, and creating technologies for inspection are some of the missions under this partnership (A\*STAR, 2019a). Moreover, this collaboration will help market the

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technologies commercialized by the SMEs under A\*STAR. As a result, the SMEs in its supply chain will be able to reap benefits from this partnership, as they will be exposed to more business opportunities overseas. A\*STAR also partners with ST Engineering in co-developing innovative solutions for smart cities. In fact, ST Engineering has been involved in 500 smart city projects in 70 cities, indicating that it is highly experienced in providing smart city solutions (Shamini, 2019). Building on the R&D capabilities of A\*STAR's research institutes, A\*STAR and ST Engineering will focus on R&D as well as the adoption and commercialization of robotics (e.g., advanced material-handling robots), smart mobility (e.g., all-weather autonomous vehicles), smart communications (e.g., satellite communications), and health tech (e.g., intelligent workflows and analytics) (Shamini, 2019). As can be seen, it can be observed that A\*STAR is actively involved in the entire Research, Development, Innovation, and Commercialization (RDIC) value chain, which eventually contributes to economic development.

#### **2.2.4 Services and Digital Economy (SNDE)**

The services and digital economy (SDE) domain aims to “develop, integrate and leverage Singapore’s digital innovation capabilities to meet national priorities, raise productivity and support key services, create sustainable economic opportunities and quality jobs” (RIE, 2020, p. 7). One of Singapore’s national plans is to promote whole-of-nation digitalization in government agencies, industry players, and society (National Research Foundation, 2021). As such, the SNDE strategic domain strives to develop, apply, scale, and commercialize high-tech digital solutions to cater to market demands. This requires collaborations and knowledge sharing between public research institutes, enterprises, and government agencies in order to develop technology leadership to drive Singapore’s Smart Nation goals (National Research Foundation, 2021). Furthermore, Singapore is on its way to

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installing full-fledged 5G networks, which can accelerate a new wave of Internet-of-Things (IoT) applications and better achieve the Smart Nation goals (National Research Foundation, 2021). A report by The World Economic Forum (2020) states that approximately 22 million jobs will be created in the 5G value chain worldwide, signifying that 5G can contribute substantially to global economic development. Besides that, the Government of Singapore plans to transform Singapore into a global artificial intelligence (AI) leader by 2030, with the primary objective of delivering strong economic and societal impacts for its citizens (Free Malaysia Today, 2019). Specifically, it aims to provide AI solutions to address issues and challenges in a wide spectrum of areas, including government services, logistics planning, healthcare, education, smart estates, border security, and financial services (Smart Nation Singapore, 2022). Other than that, to reinforce Singapore's position as a trusted digital innovation hub, R&D capabilities are much needed in developing digital trust, which plays an important role in safeguarding digital platforms and technologies. In addition, these technological solutions need to be commercialized immediately to benefit industry players and society. These national strategies fit well into A\*STAR's R&D capabilities in info-communication technologies, which involve Artificial Intelligence (AI) and data science; digital trust (blockchain and privacy preservation technologies); cybersecurity; modeling & simulation / digital twinning; and communications and Internet-of-Things (A\*STAR, 2021). A\*STAR partners with various local enterprises and SMEs to strengthen their R&D capacities in the aforementioned info-communication technologies. In fact, A\*STAR's technological innovations have been commercialized and leveraged by its' industry partners and government agencies. As such, A\*STAR's roles in R&D and I&C in Singapore's SNDE's strategic domain should not be neglected. Some good examples of how A\*STAR contributes to R&D and I&C will be discussed in the following sections.

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#### **2.2.4.1 Research and Development (R&D)**

As one of A\*STAR's research arms, Artificial Intelligence Analytics & Informatics (AI3) manages and catalyzes A\*STAR's R&D efforts in data science and AI technologies to address economic and societal needs in Singapore (A\*STAR, 2021m). Besides utilizing its' AI capabilities to support Singapore's national AI strategies, A\*STAR also offers AI solutions to help transform and expand the businesses of its' industry players (A\*STAR, 2021m). For instance, A\*STAR entered into a partnership with DSO National Laboratories to strengthen Singapore's defense system through co-developing R&D solutions in additive manufacturing, advanced electronics, AI, etc. (Stephen, 2020). Through this collaboration, DSO can draw on A\*STAR's R&D capacities, expertise, technologies, talent, and facilities to develop technologies in defense and national security (Stephen, 2020). Similarly, SIIX-AGT, a local robotics start-up, collaborated with A\*STAR's Institute for Infocomm Research (I2R) to co-create smart robotics technologies to serve market demands and enhance productivity (A\*STAR, 2019b). The launch of the robotic base products, SIIX-iCUBE AGT's 200 and iCUBE 500, was made possible by the incorporation of A\*STAR's AI technology into its' service robots. One of the most remarkable AI products co-researched and co-created by SIIX-AGT and A\*STAR is the security patrol robot on the street for crowd control and security purposes, making a positive impact on society (A\*STAR, 2019b).

In 2017, A\*STAR launched an Industrial Internet of Things (IIoT) Initiative, in which an association (including 13 companies) with capabilities extending across the IIoT value was formed to bring academia and industry players together and develop IIoT solutions, such as industrial data analytics, sensors, cybersecurity, and gateways (Priyankar, 2017). This initiative involves MNCs (e.g., Rolls-Royce, Hewlett Packard Enterprise), local enterprises (e.g., Singtel, Starhub), SMEs (e.g., Concorde Security), and start-ups (e.g., Wismut Labs) (Priyankar, 2017).

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Likewise, the IIoT Research Programme was established by A\*STAR to promote cross-disciplinary collaboration and learning between A\*STAR's research institutes, Singapore University of Technology and Design (SUTD), Nanyang Technological University (NTU), and National University of Singapore (NUS). Specifically, this program aims to drive R&D in IIoT technologies, such as advanced data analytics, industrial cyber-physical security for cognitive, and secure IIoT systems. The newly invented IIoT technologies will then be test-bedded at A\*STAR's SIMTech's Model Factories and Advanced Remanufacturing and Technology Centre (ARTC). Under the RIE 2020 plan, A\*STAR also established two model factories, which SMEs can use for experimenting and learning new advanced manufacturing technologies with support and guidance from A\*STAR's researchers (Priyankar, 2017). As can be seen, A\*STAR's efforts in Singapore's SNDE's R&D ecosystem are valuable, bringing economic value to industry players and society as a whole.

#### ***2.2.4.2 Innovation and Commercialization (I&C)***

A\*ccelerate, which is A\*STAR's commercialization arm, helps drive innovation and commercialization of its stakeholders' research outcomes (A\*STAR, 2018). In 2018, A\*ccelerate entered into partnerships with investors, such as Startup-O, Hafnium Hafaway, Marvelstone, Trendlines, and Dymon Asia Ventures, to raise USD 85 million, with the main purpose of co-creating deep-tech start-ups and commercializing deep tech innovation in areas such as the IoT and AI (Ng, 2018). In addition, A\*STAR's SERC's Industrial Internet-of-Things Innovation (I<sup>3</sup>) program aims to speed up and promote the translation of Industrial Internet of Things research into industry-ready solutions that can be commercialized and adopted by SMEs, local enterprises, and MNCs (A\*STAR, 2022f). For example, PTC Japan, a digital transformation corporation that offers software and industrial service solutions, has joined as a strategic member of A\*STAR's I<sup>3</sup> program to leverage IIoT R&D and drive digital

transformation initiatives (PTC, 2021). This partnership enables the exchange of IIoT knowledge and research resources between PTC and A\*STAR's research institutes. Moreover, it also allows their stakeholders to grasp benefits from the entire research ecosystem, from co-development of IIoT and Industry 4.0 technologies to test-bedding research outcomes towards commercial scale-up, providing digital innovation solutions to the market. As a result, this collaboration brings substantial value and benefits to their industry partners and local enterprises, such as manufacturing optimizations, cost efficiencies, and quality assurances of their business (PTC, 2021).

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## About Sunway IGSC

Sunway Institute for Global Strategy and Competitiveness (Sunway IGSC) is dedicated to extending its research focus beyond the traditional economic boundary of competitiveness and draws into its coverage social and environmental considerations as explicit factors of competitiveness.

Based on a more inclusive and holistic consideration, Sunway IGSC identifies three primary pillars of competitiveness: Economic, Social, and Environment. The three pillars of competitiveness provide direction and focus to the type of questions asked and the work conducted within IGSC:

- **Economic health** - This pillar investigates drivers of competitiveness from the vantage point of firms, industry, and national ecosystems, with a particular focus on policies and drivers of structure and competitive strategies to create positions of sustainable advantage.
- **Social health** - This pillar focuses on issues of distribution of wealth, equity, and unity within ecosystems as a consequence of economic policies and strategies at the firm, industry, and national levels. The lens scrutinizes who creates value, for whom, and how is this value distributed among the diverse stakeholders operating within the ecosystem. It stresses the need for inclusive creation and sharing of value creation to ensure shared prosperity.
- **Environment health** - This pillar scrutinizes how actions of individuals, firms, industry, and government impact the environment and draws into explicit consideration the need to go beyond the simple mantra of firm profit maximization and short-run economic development and competitiveness by holistic consideration of the costs to the natural environment and life of species, including that of the human race over the long run.

The mission of the Sunway IGSC is to conduct meaningful fundamental and translational research exploring global strategy and competitiveness to contribute to the strategic transformation and competitiveness of governments, industries, and society in the context of rapidly changing global dynamics.

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