

## ESC Subcommittee on Growing Knowledge Capital

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### INTRODUCTION

1. This Economic Strategies Sub-committee on Growing Knowledge Capital, co-chaired by Chairman A\*STAR, Mr Lim Chuan Poh, and CEO S\*BIO, Dr Jan-Anders Karlsson, was tasked to recommend strategies to enhance the impact of Singapore's Research-Innovation-Enterprise (RIE) framework by reviewing the knowledge creation, innovation and enterprise (I&E) value chain; identifying the key fields and areas in the value chain to focus our resources on; and proposing schemes to strengthen the commercialisation of R&D.

### AIM

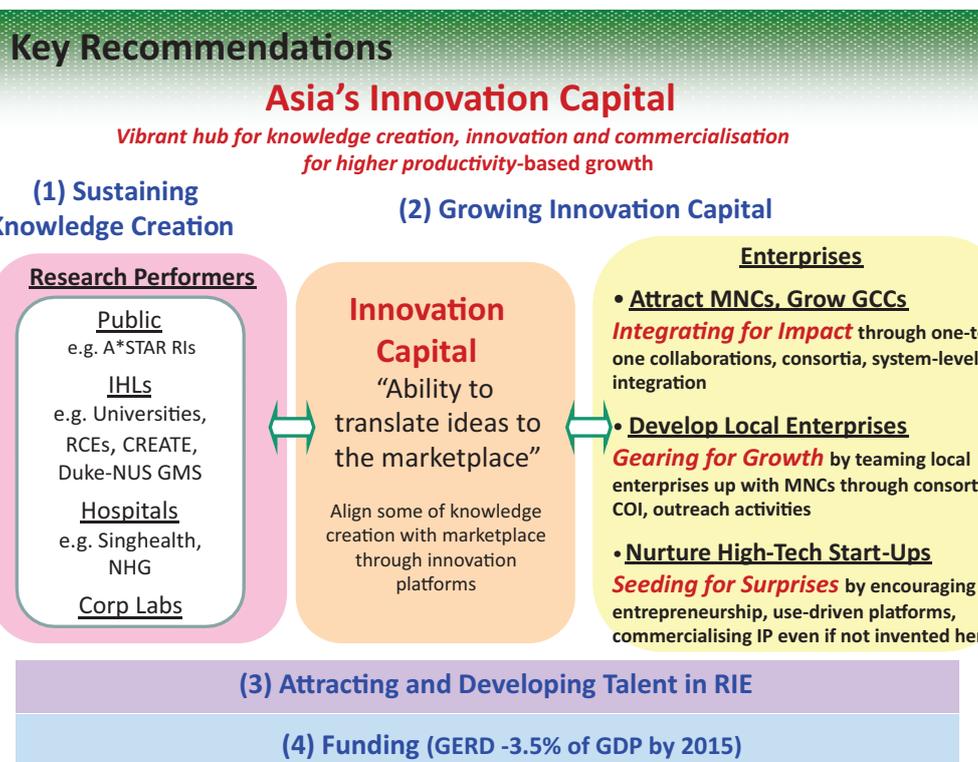
2. This submission presents this subcommittee's recommendations for ESC Main Committee's consideration.

#### **Our Vision**

Singapore is in an excellent position to become a key global R&D hub and an innovation capital of Asia. This subcommittee envisages Singapore to be the home for private sector R&D activities and innovation, in partnership and collaboration with world class public sector R&D institutes.

3. To achieve this vision, Singapore needs to:

- a. Nurture world-class research-intensive universities and institutions to attract and train top talent for the economy, develop excellent R&D capabilities and build international recognition for Singapore, so that we can continue to develop globally-competitive knowledge-intensive manufacturing sector; and
- b. Develop stronger partnerships between public sector and private sector research community. The public sector research institutes need to be mission-oriented and be active in engaging the private sector to drive innovations through a broad spectrum of capabilities, while adopting a flexible and responsive approach towards collaborations.



## KNOWLEDGE CREATION

### Singapore's R&D Landscape

4. In the last ten years, Singapore's R&D landscape has been transformed significantly. Starting with pockets of R&D capabilities residing in research institutes and the universities, Singapore has now established an emerging and vibrant R&D ecosystem comprising a greater diversity of research performers, including public sector research institutions (A\*STAR RIs), institutes of higher learning<sup>18</sup> (IHL), hospitals and academic medical centres, and corporate R&D laboratories. In the same period, we have also witnessed the transformation of our local universities into more research-intensive institutions.

### The Role of Public Research Institutes (RI) and Institutes of Higher Learning (IHL)

5. As Singapore moves towards a knowledge-based innovation-driven economy, the sustained support for the wide spectrum of capabilities development in the universities and public sector research institutions over the years will become increasingly significant in translating knowledge into the marketplace and growing a competitive talent base to spearhead the I&E activities. The key drivers of these efforts are:

- a. **World-class research-intensive universities** – Universities play a prominent role in a knowledge-based, innovation-driven economy by developing the talent for the economy. Recruiting and retaining eminent scientists and faculties will be key to establishing the good international standing of our universities, which in turn will attract high calibre undergraduate, post graduate and postdoctoral level talent. The presence of world-class research intensive universities will be crucial to achieve and sustain this outcome. In addition, universities will play an increasingly important role in training talent across

<sup>18</sup> These include the universities, polytechnics, research centres of excellence (RCE) and international institutions under CREATE.

the I&E value chain, such as nurturing entrepreneurs by facilitating activities to support and incubate ideas, training students in various aspects of entrepreneurship, as well as providing mentorship at critical stages of a start up's development.

b. **Mission-oriented public sector research institutions** – Public sector R&D activities can help to attract and anchor high value-added knowledge-intensive manufacturing activities of MNCs and Globally Competitive Companies (GCCs), as well as to grow the latter's R&D activities in Singapore. Through various innovation platforms that are facilitated by the public sector RIs, we also create opportunities for the local SMEs to collaborate and engage the large enterprises to build business partnerships and network. Furthermore, the public sector RIs also attract and train R&D talent who are industry ready and will enable the private sector to grow their R&D activities over time.

6. Our universities and public sector research institutions are therefore the foundation that catalyses innovation-driven activities and high-value, knowledge intensive manufacturing. Their close alignment with industry interests and their ability to produce quality talent for both private and public sectors have enabled Singapore to attract high value-added R&D and manufacturing activities into the various sectors. Our manufacturing sector today employs about 600,000 people with a value add of S\$47 billion. These are 30 percent and 21 percent respectively more than what it was in 2000. In a similar way, the employment in the R&D sector has grown from 14,500 jobs in 2000 to 25,700 jobs in 2008, contributed in part by the corporate R&D laboratories that have been attracted to Singapore over the years, such as Novartis and Nikko Denko.

**It is recommended that Singapore sustains its commitment to public sector basic research (to build important foundations for downstream research) and mission-oriented R&D (which is closely aligned to industry development opportunities) in order to continue to develop our public sector capabilities, step up the pace of I&E and contribute towards Singapore's goal to achieve higher productivity driven growth.**

## INNOVATION CAPITAL

7. Our ability to translate ideas to the marketplace is the Innovation Capital, which is the means to create value from our R&D investments. To be differentiated and competitive, it is essential that our Innovation Capital supports approaches that are flexible and responsive to the various needs of enterprises, namely the MNCs and GCCs (**Integrating for Impact**), local companies (**Gearing for Growth**) and high tech start ups (**Seeding for Surprises**).

*"Integrating for Impact" – for MNCs and GCCs*

8. To attract MNCs and grow GCCs, a customised approach is needed; one that leverages on our intrinsic organisational strengths to responsively integrate capabilities, research institutions and public sector agencies to deliver customised solutions with a common purpose. The Aerospace cluster is a good example of one that has benefited from a customised and integrated approach. This cluster is on course to be defined by innovations that will drive future growth, create high quality jobs and strengthen the relationship between MNCs and the local companies. The box gives more details about the Aerospace cluster story.

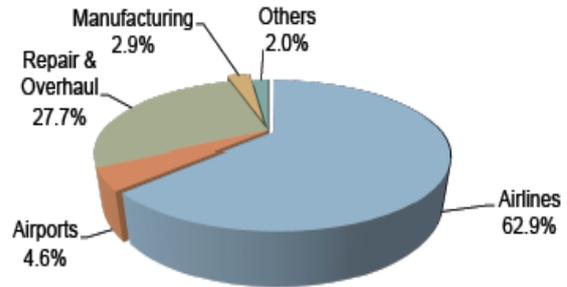
**BOX**

Aerospace Cluster Example

The Aerospace Cluster in Singapore is a fast growing one with good sustainable prospects. Singapore’s aerospace industry grew from US\$13 billion in 2000 to more than double in 2008 with an estimated figure of approximately US\$27 billion, with CAGR of over 10 percent.

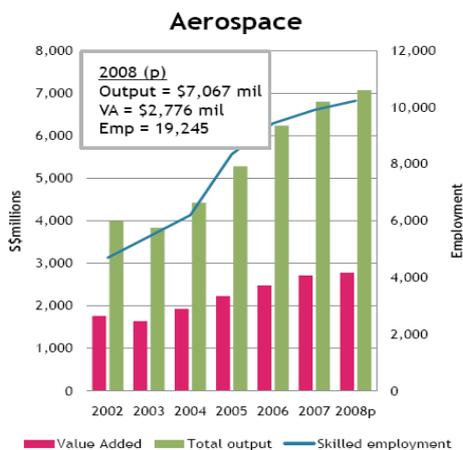
This sector is anchored by world leading companies such as ST Aerospace, Pratt & Whitney, GE and Rolls-Royce. In particular, Singapore is well recognised as an MRO (Maintenance-Repair-Overhaul) hub with a quarter of Asia Pac’s market share, or 7 to 8 percent of the global market.

**Singapore Aerospace Industry Revenue Breakdown, 2008**



Source: EDB, Annual Reports and Frost & Sullivan Analysis

The success of the sector is tied closely to the early-years investment in technologies such as materials sciences, physics, precision engineering and electronics. These traditional strengths enabled Singapore to enter into the high value-add activities of manufacturing the engine parts, avionics and airframe parts, and provide the supporting services such as inspection and testing. As a consequence, the skilled employment in this cluster has tripled to over 10,200 in the past 6yrs (2002 – 2008), of which 80 percent of the workforce is made up of Singaporeans and Permanent Residents.



With the high VA activities in the aerospace industry expected to continue to grow substantially (estimated CAGR of VA by 2020 to be about 10 percent), there will be more business and technological opportunities for aerospace companies, as well as the supporting industries, including the SMEs in the precision engineering and electronics sectors, for instance.

**A\*STAR Aerospace Consortium**

To further strengthen the strategic alliances of the players within cluster, and sustain technology leadership and efficacy through R&D, the A\*STAR Aerospace Consortium was launched in Jan 2007. This is the world’s first-of-its-kind aerospace consortium comprising the four aerospace giants of Boeing, Pratt and Whitney and Rolls-Royce and ASTSR Research Institutes as founding members, and it is the first time that the in-competition giants are collaborating on a common platform to chart R&D strategy and direction in the aerospace industry. In the past 2 years, more companies have joined the consortium, including local SMEs such as TruMarine and IDI Laser Services.

This consortium not only actively engages industry players as well as R&D community, but also taps on existing capabilities, infrastructure and resources in all the research institutes under the Science & Engineering Research Council of A\*STAR to conduct pre-competitive research and address technological challenges in the following:

- Inspection and non-destructive testing
- Manufacturing processes and automation
- Advanced materials
- Information and communications
- Computational modelling and dynamics

Members, including the SMEs, have full access to the R&D results developed under the programme and have the option of attaching their company staff to the programme to work on joint projects with researchers from SERC research institutes. This lays the ground for innovation in the global aerospace industry through Singapore-made technologies, facilitates eventual technology transfer of the research conducted, and presents opportunities for our local supporting industries to build new capabilities that will anchor global players in Singapore.

9. The focus of the customised and integrated approach is to develop the appropriate models for interaction and collaboration between and among the public and private sector institutions. These models or innovation platforms create value for the industries in a way that caters to the unique needs of the particular industry. Examples of such innovation platforms include:

a. **Bilateral collaboration platforms.** These are direct research collaboration arrangements between the companies and the public sector research entities. The MNCs and GCCs benefit from acquiring technologies and know-how from the public sector research institutions which have developed a suite of vertically-integrated capabilities. The growth of high value added activities in the Microelectronics and Data Storage industries are proven examples of how companies have benefited from the capabilities of IME and DSI<sup>19</sup> over the years. This model has also been extended to grow the BMS sector, particularly in Biologics where a wide spectrum of integrated capabilities resides in BTI<sup>20</sup>. In the Biologics sector, the results so far have been encouraging; within the last three years, leading companies in Biologics have invested about US\$2 billion, which is a strong endorsement of the bio-processing capabilities and skilled manpower;

b. **Consortia-type platforms.** Industry players who may otherwise not collaborate are brought together to work on a common space, especially one that is pre-competitive. This is done through the consortium approach which provides a common platform for the players to discuss their areas of interest and develop the agenda for research collaboration, as in the case of A\*STAR Aerospace Consortium. The platform also serves to inform the consortium members on the broader development within the sector as well

<sup>19</sup> Institute of Microelectronics and Data Storage Institute

<sup>20</sup> Bioprocessing Technology Institute

as facilitate bilateral or multi-lateral collaborations among the members. Such platforms will be especially useful in new growth areas such as clean energy and urban solutions; and

c. **System-level integrated platforms.** One illustrative example of system-level integrated platform is in the BMS sector where this approach is key to the translation of research into application. Here, it is not enough to have a drug discovered in the lab. It is only of value when it has been validated through a properly conducted clinical trial. The process of drug discovery is a long and expensive one for the pharmaceutical companies and involves many institutions, agencies and regulators. The ability to create a platform that is much better coordinated and efficient will create a lot of value for the industries all the way from bench collaborations to the conduct of clinical trials. Hence, an integrated approach comprising the multiple R&D performers (including the industry partners), hospitals, academic medical centres and government agencies to ensure that we have the necessary capabilities in place; the facilitative arrangements to build complex collaborations; and the program management structure and process to execute the trial efficiently is critical to this sector.

10. In each innovation platform, the complexity involved in customising for different industry cluster escalates when more capabilities, performers, and organisations are required to be involved and integrated. Singapore is better able to do this well because of how we have evolved as a small country with no natural resources. Over time, we have developed a strong appreciation for the Singapore Inc or whole of government approach among the people and organisations with a clear focus on effective delivery on the outcomes. This is a mindset and attitude that is part of our differentiating advantage and we should always play to our strength. As we use these innovation platforms to attract more manufacturing related research and innovation activities to Singapore, we should also look at how to capitalise on them to develop new opportunities in the convergence of manufacturing and services sectors.

11. Infrastructure that offers state-of-the-art facilities, test beds, pilot plants and living laboratories for companies are also compelling innovative platforms for public-private sector partnerships. Examples of these include:

a. **Infrastructure for R&D** – Sophisticated infrastructure in our public sector research institutions, such as the proposed 12-inch facility; nanofabrication and characterisation facility, will offer the private sector the use of advanced processing equipment and expertise to innovate and develop new products;

b. **Infrastructure for Piloting** – Pilot scale-up processes such as the Kilo Scale laboratory in ICES<sup>21</sup> will facilitate companies' effort to test and evaluate new processes before deciding on full scale manufacturing; and

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<sup>21</sup> Institute of Chemicals and Engineering Science

c. **Infrastructure for Testbedding** – large scale infrastructure, such as CleanTech Park or the Smart Grid, serves as living laboratories for companies to test new technologies and showcase their products.

12. In order for any customised and integrated platforms to be effective, it will be necessary for the private sector research performers to be partners to define and shape the research agenda for collaboration. Further, both public and private sector research performers should be incentivised to actively collaborate so as to capitalise on opportunities in emerging spaces, which often involve multi-disciplines and capabilities.

**It is recommended that public sector R&D institutions continue to develop mission-oriented programs to attract MNCs and corporate laboratories, as well as to grow GCCs, and contribute towards developing Singapore as a location of choice for the world’s leading, innovation-driven companies. The private sector could also play a more active role in helping to define and shape the research agenda of these institutions, for example through CTO/CSO forums. Furthermore, appropriate incentives should be in place to foster public-private sector partnerships and multidisciplinary research activities, and to provide companies with ready access to state-of-the-art infrastructure and facilities.**

“Gearing for Growth” for Local Enterprises

13. Gearing for the growth of local enterprises must take a different approach from that of attracting MNCs or growing GCCs. Public sector R&D capabilities need to be adequately broad-based and the institutions should be facilitative in engaging local enterprises through R&D partnerships, technology development efforts, manpower training and outreach efforts.

14. A broad-based, facilitative approach is needed because there are numerous local enterprises across many sectors. Our local enterprises form a significant portion of our manufacturing sector and they play a major role in supporting MNCs. In 2007, local enterprises in the manufacturing sector, specifically in Precision Engineering, Biomedical Manufacturing, Electronics, Logistics, Engineering & Environment Technology and Chemicals, collectively employed some 170,000 skilled people and contributed to a VA of S\$19.1 billion<sup>22</sup>, which was about 38 percent of the total VA of the key manufacturing sectors<sup>23</sup>.

15. We should create more opportunities to further develop the capabilities of our local enterprises and gear them for continued growth, and support upgrade of their capabilities to keep pace with the rapidly changing technological landscape. This can be achieved through innovation platforms such as:

a. **Consortia-type Platform** – This platform, mentioned previously in Para 9b, will benefit not just the MNCs and GCCs, but also the local enterprises through facilitating interaction and building of relationships between the two segments of industry players.

<sup>22</sup> Source: SPRING Singapore

<sup>23</sup> Source: EDB

Having a mix of MNCs and local enterprises will cultivate a strong local supplier base and help the local enterprises develop keen market sense and capabilities that may eventually be exportable;

b. **Centres of Innovation (COI)** – Centres of Innovation (COI) at Polytechnics or research institutions can help local enterprises upgrade their capabilities, acquire advanced manufacturing expertise and gain access to strategic manpower training. The National RFID Centre and the 5 COIs<sup>24</sup> supported by SPRING are good examples and more of such centres should be established, especially in growth areas such as MedTech and Clean Energy;

c. **Outreach platforms** – Proactive outreach programs to the local companies will help to raise their awareness on the various ways in which they can leverage on the public sector research infrastructure to upgrade themselves technologically to move up the value chain and be more competitive. Platforms such as joint A\*STAR- SPRING GET-UP<sup>25</sup> programme has reached out more than a thousand local enterprises. Many of these local enterprises have benefited from the program via the secondment of researchers and engineers (about 245 researchers and engineers have been seconded to 162 local enterprises since inception) as well as the technical advice and customised technology roadmaps that have been provided. Nanyang Optical is one such company that has benefited. Through the GET-UP program, the company developed its environmentally-friendly ‘LinkSkin’ spectacle frame product range and has successfully penetrated major markets such as Germany, France and Italy since 2008. Such outreach platform can be further scaled up and multiplied through the involvement of the Polytechnics.

16. Local enterprises with good products and expertise often need to establish a credible track record in addition to securing access to patient capital and in some instances financing options to support internationalisation. It is recommended that the Government as a large consumer should also play an active role in being the lead reference user of such capabilities. This can be done by establishing government co-innovation platform through the extension of the current PSIF<sup>26</sup> scheme<sup>27</sup>.

17. It is also recognised that the transition from SMEs to GCCs requires support that goes beyond capabilities building and training. Dedicated financing and organisational support from the Government to identify and nurture such potential “champions” may also be needed.

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<sup>24</sup> COI for Environment and Water Technology (Ngee Ann Poly), Food Innovation Resource Centre (Singapore Poly), Marine & Offshore Technology Centre of Excellence (Ngee Ann Poly), Precision Engineering COI (SIMTech, and COI for Electronics (Nanyang Poly).

<sup>25</sup> Growing Enterprise Technology Upgrade programme

<sup>26</sup> Public Service Innovation Framework

<sup>27</sup> Or adopting an approach similar to that of the US SBIR (Small Business Innovation Research)

It is recommended that a broad based, facilitative strategy be taken to gear local enterprises for growth through the upgrading of their capabilities. In this regard, the Polytechnics can play a bigger role through both the COI and Outreach platforms. Whenever possible, we should also want to network our local enterprises with the MNCs as part of an industry cluster approach to develop research and innovation activities in a synergistic way, e.g. Aerospace Program. In addition, we should also look at how the public sector itself can provide the innovation platforms for the local enterprises by playing the role of lead reference users.

*“Seeding for Surprises” – for Startups*

18. A knowledge-based innovation-driven economy must also have a vibrant entrepreneurial sector. Here our research-intensive universities can play a significant role in cultivating and training entrepreneurs through seed funding, supporting small scale incubators and recruiting faculty with entrepreneurial skills and track record as mentors and role models. For example, the University Innovation Fund (UIF) could be extended to the alumni to leverage on their extensive networks. In addition, public sector research institutions can develop a more directed approach in encouraging startup activities originating from their R&D. The bioengineering field (such as MedTech), for instance, presents many opportunities for institutions to effectively translate cross-disciplinary (BMS and S&E) research into value-creating innovations.

19. Other ways to nurture and support start ups include:

a. **Use-driven platforms that bring together practitioners and researcher** – For example, the Boston-based Centre for Integration of Medicine and Innovation Technology (CIMIT) successfully connects clinicians, who define the practical problems, to the engineers, who in turn develop the solutions, which have led to many new technologies and successful start ups. Such use-driven innovation platforms can be replicated in many other areas of the economy;

b. **“Queen Bee” approach to attract foreign-based knowledge capital and to nurture start ups for success** – This involves attracting fully-managed premier service incubators, such as Seattle-based Accelerator Corp which focuses on the biomedical area, to bring about a step change in how we incubate start-ups “Marquee” incubators will also naturally attract foreign knowledge capital to add to the marketplace of ideas in Singapore; and

c. **Marketplace for ideas** – This marketplace should provide ease of access to a range of ideas and intellectual properties (IP) from both public and private sectors to be exploited for commercialisation. This should also include the knowledge capital from overseas as part of the strategy of “not invented here but commercialised here”. We should therefore seek to internationalise the Technology Transfer Networks to greatly facilitate the flow of knowledge capital to Singapore. Taken together, this will create greater intellectual vibrancy and more innovation opportunities.

**It is recommended that the universities, having become more research-intensive, play a bigger role in encouraging and supporting entrepreneurial activities including training talent with appropriate entrepreneurial skills; employing faculty that are good mentors and role models of entrepreneurship; and supporting start-ups in the universities. Public sector agencies should also consider adopting or adapting proven models for initiating and accelerating multi-disciplinary research through use-driven platforms to develop breakthrough solutions and products such as the CIMIT model. In addition, we should develop Singapore as a marketplace of ideas in synergy with the growth of “queen bee” and other incubators.**

## TALENT

20. The underpinning of a knowledge-based economy is the availability of relevant talent. World-class research-intensive universities and research institutions play a key role in the training of high quality research and innovation talent. Figures show that the compound annual growth rate, or CAGR, signals a strong demand for RSEs in both public and private sector, at 6.1 percent and 8.5 percent respectively. Singapore compares well against other benchmark countries in terms of the normalised number of RSEs. However, in terms of the number of PhDs (FTE) per 1000 labour force<sup>28</sup>, Singapore still has some gap vis-a-vis the other R&D intensive economies such as Finland and Sweden. (Finland – 3.6 (2006), Sweden – 3.0 (2005), Singapore – 1.5 (2007)). At the same time, only about 35 percent of the PhDs in our universities are Singaporeans and Permanent Residents today.

21. Our studies indicate that our local universities supply sufficient numbers of Masters level talent to meet public and private sector demand, and that the demand for PhDs remains strong in both sectors. On the latter, our universities should both seek to increase the number of PhDs that we produced, albeit to better align with industry needs, and the percentage of Singapore Citizens and Permanent Residents (SC/PR) pursuing them. In addition, universities can work with the private sector on mutually interesting and relevant PhD research topics. This will both open up better employment opportunities in the private sector for the PhD graduates as well as enable the private sector to grow their R&D activities in Singapore.

22. It is recognised that there is also a need to attract and train a broad spectrum of talent in the I&E value chain particularly those with knowledge and expertise relevant to the Asian markets. Some of the other talents include patent agents, technology brokers and experienced entrepreneurs and innovators. In addition, we should also look at how to enable this different expertise to work together to speed up the translation from knowledge creation through innovation to the market. In this regard, much can be learnt from the systematic approach that California-based Stanford Biodesign has taken to train researchers, practitioners, entrepreneurs, and other technology transfer professionals to more effectively commercialise their biomedical innovations.

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<sup>28</sup> Based on figures from OECD

**It is recommended that the universities can work towards producing more industry relevant PhDs and also encourage greater participation of Singaporeans and Permanent Residents in such programs. At the same time, Singapore should place greater emphasis and focus on attracting and developing the other talents that are needed to realise the translation from knowledge creation through innovation to economic impact.**

## FUNDING

23. With MNCs increasingly investing in R&D in this region to respond to the Asian markets and consumers, Singapore is well poised to leverage on our growing public sector R&D capabilities to become a key global R&D hub and an innovation capital of Asia. Singapore's strengths include our strong and sustained public sector commitment to R&D with excellent public research infrastructure; ready access to both local and international talent pool; our representative Asian make up of the population; and our conducive business environment including the use of English, respect for IP and clear legal framework.

24. Singapore's Gross Expenditure on R&D (GERD) grew from 1.9 percent of GDP in 2000 to 2.77 percent<sup>29</sup> of GDP in 2008, and the proportion of the private sector's component (BERD) increased from about 63 percent to 71 percent in the same period. Clearly the private sector has responded well to our continued investments in public sector R&D and to our vision of becoming a knowledge-based innovation-driven economy.

25. The S&T2010 Plan had set a target of 3 percent GERD by 2010 to propel Singapore into the league of research intensive countries. Although Singapore is on track to achieve this target, many of the benchmarked countries have since set higher goals for GERD. For instance, the targets set by Korea (5 percent by 2012), U.S. (3 percent), Finland (4 percent) and Sweden (4 percent) strongly indicate that R&D and innovation-driven activities are important in sustaining economic competitiveness.

**It is recommended that we aim, by 2015, for 3.5 percent GERD as a percentage of GDP to signal our intent to be an Innovation Capital of Asia. At the same time, we should sustain our investments to continue to strengthen our public research infrastructure to catalyse even more growth in private sector R&D and innovation activities thereby creating many meaningful and high value jobs for Singaporeans and foreigners alike.**

## CONCLUDING REMARKS

26. Singapore has done an excellent job in growing public sector R&D capabilities in the last decade, although some of them are still in the nascent stage of development. It has also successfully leveraged on the public research infrastructure to stimulate the growth of private sector R&D and innovation activities which now constitutes over 70 percent of GERD.

<sup>29</sup> Source: National R&D Survey 2008. GERD as percent GDP in 2008 is 2.77 percent (accurate as of 13 August 2009).

This has also served to grow and anchor the higher value added manufacturing activities in Singapore.

27. Singapore is now well poised in Asia to benefit from the growing opportunities to attract even more private sector R&D and innovation activities as well as higher value added manufacturing as a result of the shift in demand to the Asian markets. Our strong commitment to sustain and develop our public research infrastructure and our ability to work closely with the private sector to create a strong value proposition and deliver on the proposition is what will differentiate Singapore from the other competitors. With this continued focus and efforts, Singapore can emerge as a key global R&D hub and a leading Innovation Capital in Asia.