NATIONAL RESEARCH FOUNDATION

LIST OF AWARDED CENTRAL GAP FUND PROJECTS

Title	Project Lead	Host Institution
Automated Continuous Post-surgical Monitoring of Vascularized Grafts using Electrochemical Metabolite Detector	Tan Ngian Chye	National Cancer Centre Singapore
Product development and verification of a revolutionary solution for the treatment of glue ear	Jasmine Qiu	SGInnovate
SPEEDCARGO	Thomas Aulig, Suraj Nair	TUM CREATE
Satellite Quantum Key Distribution: A UK-Singapore Joint Mission	Alexander Ling Euk Jin	NUS
Innovative Hybrid Super Absorbent-Indirect Evaporative Water-Based Cooling System for All-Weather Air-Conditioning Without Compressors and Chemical Refrigerants	Ernest Chua	NUS
Green catalytic oxidation for industrial wastewater treatment and manufacturing processes	Yang Kun-Lin	NUS
Soft robotic sock for robot-assisted ankle-foot mobility in chronic bedridden patients	Yeow Chen Hua, Raye	NUS
New Silicon ICs	Kenneth E Lee	SMART LEES

Automated Continuous Post-surgical Monitoring of Vascularized Grafts using Electrochemical Metabolite Detector

Executive Summary

Flap (vascularized graft) transfers are used to surgically reconstruct a patient's body using his/her own skin and muscle (i.e. **auto-transplantation**), after trauma or cancerous tissue removal. However, post-surgical complications like vessel thrombosis (clotting) and ischemia can cause flap failures, requiring urgent surgical re-intervention within 8 hours, when the flap may still be salvaged. It is therefore essential to detect flap failures early. The current gold standard is manual observation, where junior surgeons or nurses inspect the flap hourly for the first 48 hours post-operatively for clinical signs of flap failure, then every 4 hours for the rest of the patient's stay. This is labour-intensive and subjective.

Using a prior NHIC I2D grant, we have developed the critical part of our solution to detect early flap failure: a **patch-like biocompatible sensor** assessing an identified combination of metabolites, which studies have shown are an accurate proxy for predicting flap viability.

Currently, a variety of flap monitoring methods are available, but they are not widely used due to cost, inconvenience, high learning curve, and/or low efficacy. Our device is **affordable**, automated, rapid, and **accurate**. It has been validated in benchtop and animal studies.

With the Central Gap Fund, we plan to optimize the sensor for high-volume production, refine and test the back-end system, run a first-in-man trial, and prepare for regulatory submissions. We plan to **spin out a company to commercialise** the product within two years.

Contact Person

Dr Sharron Bennett
Head of SingHealth Intellectual Property Office, SHIP
Sharron.bennett@singhealth.com.sg

Product development and verification of a revolutionary solution for the treatment of glue ear

Executive Summary

Glue ear, or otitis media effusion ("OME"), is an inflammation and excessive fluid build-up in the middle ear space for months or recurrently. It is a leading cause of children visits to doctors and hearing loss in children worldwide. Patients with 3 or more recurring episodes of OME in a year will undergo surgical procedure, which involves an incision in the eardrum followed by an insertion of a grommet tube into it to drain and aerate the middle ear.

In the US, Europe, China and South-east Asia, approximately 5.9 million grommet tube placement surgical procedures are performed every year, more than 90% are in children. In US alone, the estimated annual health care cost for grommet tube placement is more than USD 5 billion. Children undergoing this procedure require general anaesthesia (GA) which not only is costly but is associated with health risks to children. In Dec 2016, the USFDA warned that repeated or lengthy GA and sedation drugs used in children younger than 3 years of age may affect the development of children's brains and functions.

We aim to develop a hand-held, automated "point & click" grommet deployment applicator (CLiKX) that provides a quick, safe and consistent single-step grommet insertion procedure without the need for GA. The short procedural time of less than 1 second in deploying the grommet coupled with removing the reliance on GA means that the procedure can be shifted out of the operating theatre to the office or clinic of an ENT surgeon. This will reduce the economic burden on the patients and improve the allocation of hospital resources for more critical procedures. It is estimated that direct treatment cost saving ranges from 30% to 60%, depending on the types of healthcare institution, health economic and reimbursement in particular country. More critically, the success of this procedure will allow parents of young children to receive treatment without having to worry over the negative effects of GA.

Our device also has the potential to insert grommets using just a simple eye-loupe for visualization, without the need for a surgical microscope. This could increase the uptake of the treatment tremendously and allow many more disadvantaged patients in underprivileged areas, with limited access to proper health care infrastructure, to have the chance to receive quality and timely care. The market potential of our solutions for glue ears is significant, as it benefits many more paediatric patients by helping them to hear again.

There are competitors developing devices for the same intended use. But unlike the competitive devices, which are fully mechanical and significantly dependent on the surgeon's hand manipulation during the procedure, our system is automated and sensor-controlled, minimizing contact time with the eardrum to reduce trauma or

discomfort, potentially allowing the procedure to be done under local anaesthesia (LA) only. Furthermore, our system can deliver existing commercial grommets, without requiring unique custom-made grommets to go with the delivery device. This will allow our system to have a higher adoption rate among physicians.

This project will focus the resources on developing the key technology and innovation of a compact, cable-less, safe handheld automated CLiKX system to address the unmet market needs, with the aim of bringing the technology to complete human trials and subsequently be ready for product registration and commercialization in targeted markets such as the US, Europe, Southeast Asia and China.

Contact Person

Dr Jasmine Qiu
Project Lead
Jasmine.Qiu@sginnovate.com

SPEEDCARGO

Executive Summary

Problem

Figure 1 Manual labour packing aviation cargo pallets. Image Source: CAAS

The aviation sector in Singapore is experiencing rapid growth and therefore rapid expansion of its infrastructure and operations. In addition, with the global boost in e-commerce, cargo operation volumes are experiencing a sharp increase. This increase in the global air freight market is not only limited to the shipper-to-customer traffic, but also has opened a new market in terms of shipments being returned back from the customer-to-shippers (e.g. amazon, eBay, etc.). While Singapore strives to become the leader in global aviation, acquiring manpower for daily operations is becoming more and more challenging. As a result intelligent automation is becoming increasingly attractive. In the foreseeable future, given the fact the number of people wanting to do such arduous jobs is reducing, intelligent automation will become a necessity.

Solution

TUMCREATE has developed **SPEEDCARGO** - the world's first AI-powered robotics system that automates the build-up and breakdown of air cargo pallets. A high 'Technology Readiness Level (TRL)' automation system which combines sensor based robot technology, novel mechatronics and advanced control has been developed as a part of TUMCREATE's efforts for automating aviation cargo handling process. The integrated system consists of:

- Sensing system for measurement of incoming cargo (dimension, weight, centre of gravity, material and labels)
- Planning system for generating an optimal packing plan for the cargo where every requirement/constraint is met
- Gantry robot system with advanced gripping technology for precise manipulation of cargo

A key design aspect is the modularity of the hardware and software components, which ensures scalability in terms of different operation environments. At present, there is no robotic system in the world that can handle high-mix cargo in terms of weight, dimension and volume. Our system goes beyond the state of the art and will be the first deployable robotics system for cargo handling.

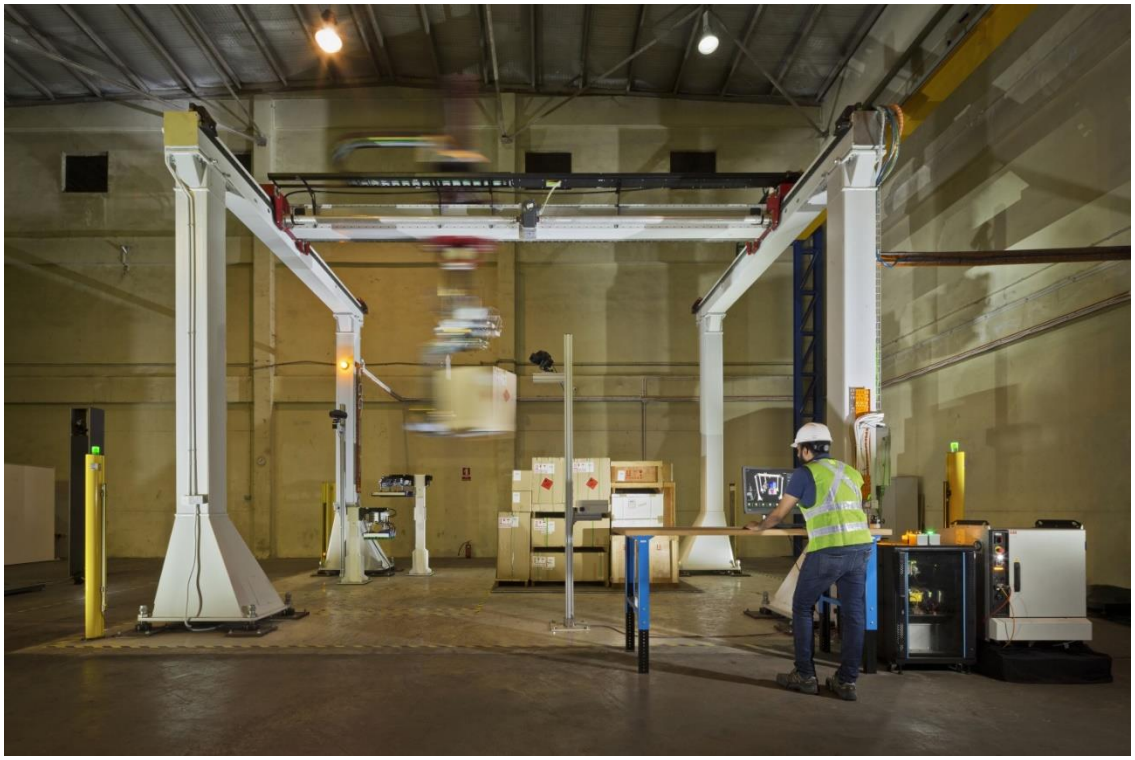


Figure 2 Current working prototype

Prototype to Product

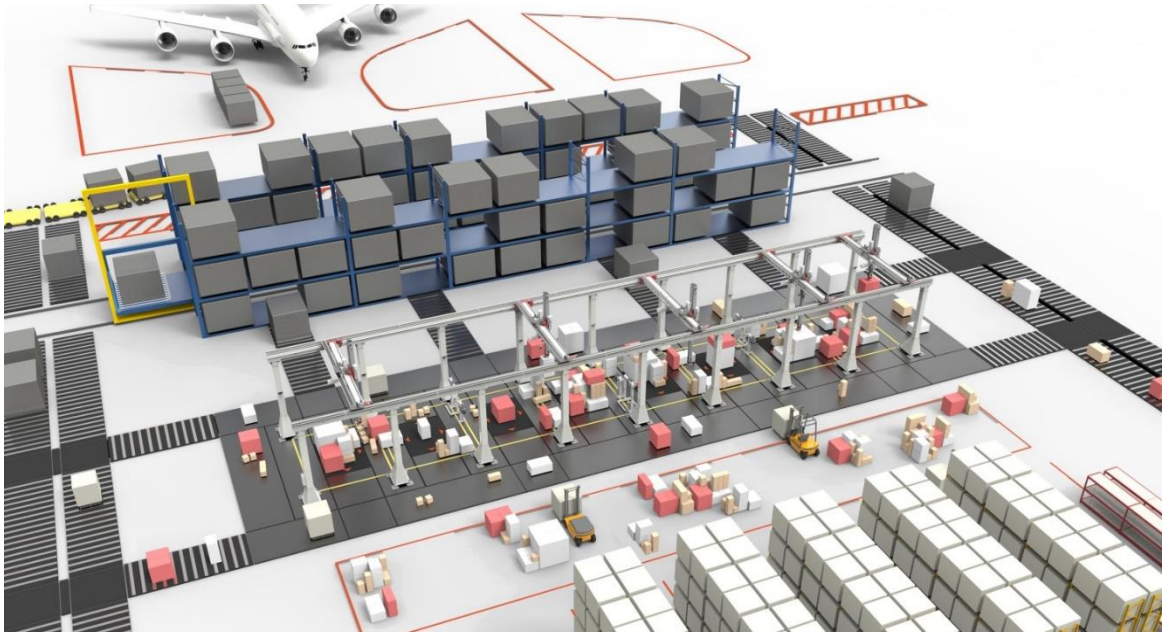


Figure 3 Vision of SPEEDCARGO powered Airfreight Terminal

Going forward our primary objective is to transform the existing working prototype to a product which can be deployed at cargo handling facilities in Singapore and worldwide. Using this technology and knowhow we would like to establish a Singaporean company specializing in air cargo process automation technology. With Singapore as its base, the company shall provide technology and services to air cargo handling facilities worldwide.

The Central Gap Fund will enable us to develop the technology and business required for the transformation of the existing SPEEDCARGO prototype to a robust and marketable product. The existing prototype was developed adhering to the strict specification of the Aviation Challenge. These specifications were framed around the general challenge statement and are limited in capturing ground level operations and complexities. Through a structured product and technology development cycle, we will accelerate the prototype from TRL7 to TRL9 by developing an optimized turnkey system integrated into the workflow of actual operations at the Changi Airfreight Terminal (AFT). In addition, the exiting software will go through a series of optimisation and industry standard test cycles for production quality code. It will also be interfaced with the existing partial automation and IT systems at the AFT. The focus will be on meeting operational requirements such as yield, speed, efficiency and usability of the system. In order to quantify and validate the value proposition of our system, the final test cycles will be conducted under real environmental conditions. Having achieved this upgrading, the optimized system will be able to produce the first robot packed airfreight pallet, leaving in a freighter aircraft from Singapore.

Contact Person

Dr Suraj Nair
Project Lead – Technology
Suraj.nair@tum-create.edu.sg

Dr Thomas Aulig
Project Lead – Commercial
Thomas.aulig@tum-create.edu.sg

Satellite Quantum Key Distribution: A UK-Singapore Joint Mission

Executive Summary

Securing our networks from space: A UK-SG satellite QKD mission

The global telecoms market is estimated at USD1.1T (2015), rising at 2.2% PA. These international networks will require secure communications in the era of quantum computers when powerful computing techniques will render existing encryption schemes obsolete. Quantum Key Distribution (QKD) provides a means of securing communications, both space-based and terrestrial. QKD technology is computationally unbreakable and will remain so against all possible future improvements in computing (forward security). Satellite-based QKD will enable the secure distribution of cryptographic keys over globe-spanning distances, overcoming existing range limits for ground-based distribution. The work outlined in this proposal will support the translation of research at the Centre for Quantum Technologies (CQT) into high-value products and services and build capacity within Singapore's emerging quantum and space industry.

The United Kingdom (UK) and Singapore (SG) have established a collaboration to develop and fly a satellite QKD test-bed. This collaboration is aimed to take prime-mover advantage in this emerging QKD market, building on both countries' efforts to grow the space and quantum technologies sectors. This test-bed will comprise QKD receiving stations in the UK and SG, and a QKD transmitter from a small satellite platform. This bilateral collaboration is the broader context in which this proposal sits.

CQT seeks a total of SGD3M under this proposal towards a bilateral mission of total value SGD18M. The UK STFC will contribute SGD9M. The GAP funding will support the development of CQT's quantum light source for the bilateral mission. CQT will seek the remaining SGD6M from sources as outlined in the budget. This proposal outlines a work-package valued at SGD3M, towards designing and developing the quantum transmitter and detector apparatus that will enable satellite QKD. The remaining SGD6M for designing and establishing the optical station by which QKD signals will be relayed between satellite and ground, as well for supporting Singapore-based mission control. The quantum apparatus that will be developed in this proposal is broadly useful for all types of free-space QKD implementations, and not strictly confined to the Singapore-UK project.

The commercial landscape surrounding QKD is rapidly evolving. Much of this change has been driven by the exquisite Chinese Micius satellite which has successfully implemented several quantum communication protocols from space. While these proof-of-principle experiments are important milestones, the QKD demonstration is not commercially viable due to its significant costs. The Singapore-UK proposal follows the New Space approach of using small cost-effective spacecraft that can be used to build a constellation for servicing global locations, enabling Singapore to play a role in setting international standards for satellite quantum communications.

Singapore has a competitive advantage in this field by being the first country to demonstrate a quantum light source in space (launched Dec 2015 on the nanosatellite Galassia). This project will support the translation of CQT technology towards commercial deployment while building advanced capabilities in the satellite and quantum technology ecosystem.

Contact Person

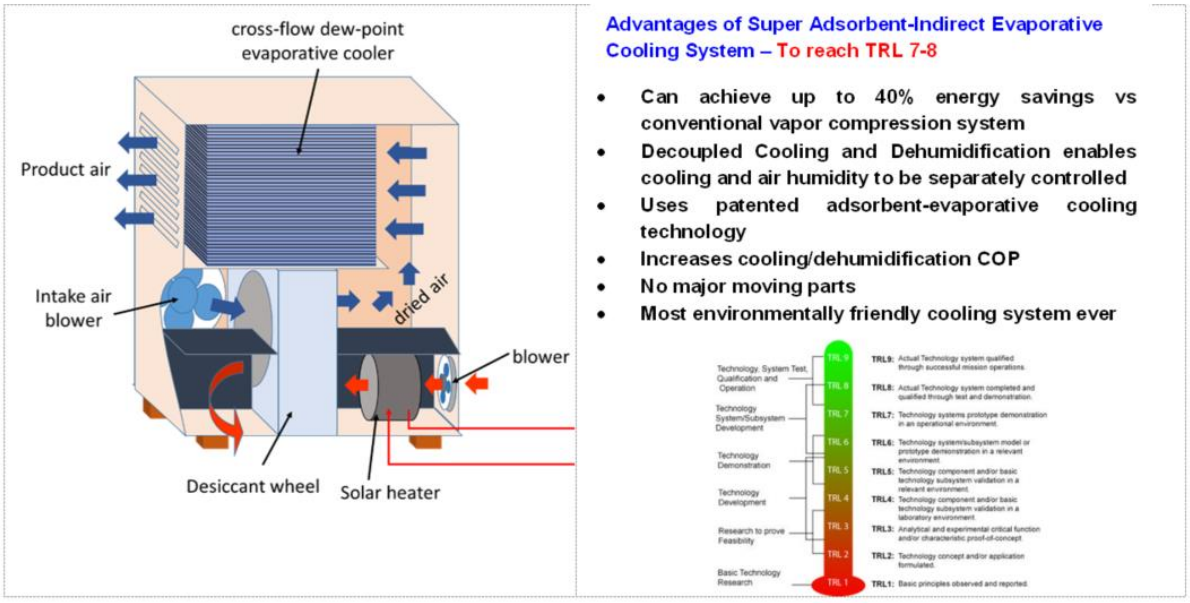
Assoc Prof Alexander Ling Euk Jin
Project Lead
cqtalej@nus.edu.sg

Innovative Hybrid Super Absorbent-Indirect Evaporative Water-Based Cooling System for All-Weather Air-Conditioning Without Compressors and Chemical Refrigerants

Executive Summary

In Singapore's hot and humid climate, the energy consumed by Heating, Ventilation and air-conditioning (HVAC) typically comprises up to 50% of total energy consumption in a building. Of which, 55% of HVAC's energy consumption is for the chiller. This highlights the importance of improving energy efficiency of the air-conditioning and its impact on the environmental well-being.

The conventional work-driven compressor air conditioning systems have a thermodynamic limit of 0.45 kW/Rton at a standard rating condition where the outlet temperature of chilled water and inlet cooling water temperature are 12.2o C and 29.4°C, respectively. Additionally, there have been big concerns about ozone depletion and greenhouse effect caused by HCFC/CFC refrigerants. Recently, we developed a dew-point evaporative cooling system without the need to use mechanical compressors. It is based on the evaporative potential of water to cool the supply air. It is capable of achieving temperatures below wet bulb temperature. Without the use of compressors and CFC refrigerant, the energy efficiency ratio (EER) of our evaporative cooling system is attainable to be as high as 40 and the electricity consumption is up to 90% less than the conventional air conditioners. The Technology Readiness Level (TRL) of our innovative dew-point cooler is around 4-5.



In general, evaporative coolers have been widely used in industrial and domestic cooling systems, especially in arid climate conditions. However, they do not perform well in tropical countries like Singapore, where the air is highly humid. It is because, the evaporative cooling potential decreases at higher supply air humidity. In order to enlarge the evaporative cooling potential, we have recently developed a

dehumidification technology. It is based on a newly developed super absorbent. Compared with commercial silica-gel, our super absorbent has much high water sorption capacity and can be regenerated at lower temperature. This thermal source for the regeneration can be obtained from solar collectors or low quality waste heat. Presently, our absorbent is deemed to have a TRL of 4-5.

In this proposal entails the development of an operating hybrid prototype comprising our dew-point evaporative cooler and super absorbent-based dehumidifier. By using this hybrid system, the locality limitation of the evaporative cooler is overcome. The supply air is firstly dry by the dehumidifier and then sensibly cooled by the cooler. The dehumidifier not only dramatically reduces humidity of the supply air to the human-thermal comfort level, but also synergistically enhances the evaporative cooling potential for the cooler. With the help of the dehumidifier, the evaporative cooler is widely suitable for all-weather conditions. The key objective of this proposal is to realize a world's first commercial game-changing air-conditioning system with a TRL of 7-8. Additionally, the design of the prototype is highly versatile such that it has the option to be operated with and without solar-assisted powered. It can be used as a mobile aircon unit for outdoor uses (e.g. in a NEA designated hawker centre), which is highly in demand for outdoor activities in Singapore.

Contact Person

Prof Ernest Chua
Project Lead
mpeckje@nus.edu.sg

Green catalytic oxidation for industrial wastewater treatment and manufacturing processes

Executive Summary

Singapore must be able to reach water self-sufficient before the long-term water supply agreement with Malaysia expiring in 2061. Meanwhile, water demand in Singapore is expected to double from 380 to 760 million gallons per day between 2010 and 2060, according to an official forecast. The increase is expected to come from industrial water usage, which will account for 70% of water demand by 2060. Therefore, it is important to develop advanced wastewater treatment technology for industrial wastewater. In a worldwide context, the total market size for industrial wastewater treatment is reaching $11 billion per year (by 2020) and growing fast (7.5% a year).

The main objective of the projects is further development of catalytic oxidation processes for industrial wastewater treatments and manufacturing processes through pilot studies. The oxidation process is based on peroxidase-inspired, copper-based catalysts and related technologies disclosed under two Non-Provisional Singapore patent applications (No. 1021708774Q and 1021708769R). The catalysts are able to activate hydrogen peroxide under a broad range of pH and oxidize pollutants quickly to benign products (e.g. CO2). The process is ideal for the reduction of chemical oxygen demand (COD) and colours in industrial wastewaters, especially recalcitrant organic compounds. Compared to advanced oxidation processes (AOPs), the catalytic oxidation process is a homogenous reaction and it can be used to degrade pollutants more efficiently than traditional AOPs on a large scale. It will be a cost-saving, environmental-friendly treatment technology that can be broadly applied to different kinds of industrial wastewater and manufacturing processes in Singapore and other countries.

In addition, the catalytic oxidation process can also be used in a wide range of applications, including laundry, fabric bleaching, waste reduction, soil remediation and manufacturing processes, etc. We will work with our partners to scale up and test the feasibility of the catalytic oxidation processes in real applications.

Contact Person

Assoc Prof Yang, Kun-Lin
Project Lead
cheyk@nus.edu.sg

Soft robotic sock for robot-assisted ankle-foot mobility in chronic bedridden patients

Executive Summary

Chronic bedridden patients are highly susceptible towards developing ankle joint contracture and deep vein thrombosis (DVT). Current treatment methods are able to mitigate deep vein thrombosis with some side effects, but not ankle joint contracture, which can eventually lead to poor ankle mobility post-stroke and reduced quality of life. These patients usually have to rely on regular physiotherapy sessions that provide therapist-assisted ankle exercises to prevent ankle joint contracture and reduce the risk of DVT. However, given growing manpower constraints and a greying global population, there is an increasing workload on physiotherapists, resulting in insufficient time to complete their physiotherapy routines.

Our soft robotic sock (TRL-6) provides an automated robot-assisted ankle exercise solution that can save time, cost and effort for physiotherapists in preventing ankle joint contracture and reducing DVT risk, without specialized physiotherapy training.

Building on our prior pilot clinical trial and interview feedback, we seek to refine the capability of the soft robotic sock system through sensor integration and data visualization. We will also conduct a multi-site clinical trial on 100 chronic bedridden patients across different healthcare institutions, so that we can establish the efficacy of our soft robotic system in preventing ankle joint contracture and reducing DVT risk, and investigate the effect of our system on the potential time-cost savings and workload reduction for the physiotherapists.

Contact Person

Assoc Prof Yeow Chen Hua, Raye
Project Lead
rayeow@nus.edu.sg

New Silicon ICs

Executive Summary

SMART LEES has developed a CMOS + III-V integration platform ("Platform") to enable the integrated circuits of the future. The genesis of the technology was a US$65M DARPA COSMOS grant to prove that CMOS + III-V integrated circuits were realisable, and possessed significant performance and functional advantages. The efforts in LEES were funded by NRF to converge research on the right methods of process integration and on demonstrating the most needed "lowest-hanging-fruit" chip applications. LEES operates at initial wafer scale to build "test chips" showing the attributes of this Platform. Initial steps towards commercialization have been taken, with the SMART Innovation Centre having funded one Innovation and three Ignition Grants to design test chips using the Platform.

SMART LEES' Platform enables the creation of advanced IP-rich lighting, photonic and wireless integrated circuits and electronic systems with minimal additional CapEx required over existing semiconductor manufacturing infrastructure in Singapore. The technology has been proven at the lab-scale (low-10s of wafers/year) using a combination of: a) semiconductor processing equipment in local and foreign research institutes and universities; and b) volume production manufacturing facilities in commercial wafer fabs in Singapore and overseas.

However, the semiconductor industry relies on scale and high-yield volume manufacturing to reach low chip costs and profitability. Numerous wafers and design/test cycles are necessary to transition to a commercial production phase. As an example, commercial products by wafer fabs such as GlobalFoundries require volumes in excess of 10,000 wafers/year to be viable.

There is therefore a critical need for LEES to build a Development Supply Chain (DSC) that can produce 100s to 1000s of wafers/year so that market-specific prototype chips can be manufactured in sufficient quantity for multiple design/test cycles to build commercial confidence in the Platform. Recognising this, LEES' Scientific Advisory Board strongly recommended that LEES seek additional funding to build the DSC and use it to exercise the Platform (see attached reference letter), which would be a key step towards the commercialisation of LEES' research output, at a cost which is effectively incremental to the amount of R&D investment used to develop the Platform.

This Central Gap Funding proposal will enable 2-3 market-specific chips (with customer input and feedback) to be designed and tested, resulting in the Platform being proven to scale to production in a commercially reliable manner. This will bridge the gap towards scaling to full commercial production in partnership with CMOS foundries such as GlobalFoundries. It will also allow capital to be raised so that a new company can be built in Singapore based on the Platform, which will herald the rebirth of a new silicon industry anchored in Singapore.

Contact Person

Ms Candy Yeo, SMART
candy@smart.mit.edu