INAUGURAL ANNUAL REPORT

APRIL 2019 – MAY 2021
MISSION

To accelerate and drive the adoption of IIoT solutions beyond the factory floor

VISION

One-stop IIoT Innovation Centre
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IIoT INNOVATION (I³)

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MESSAGE FROM OUR PROGRAMME DIRECTOR AND ADVISOR

First and foremost, we want to take this opportunity to sincerely thank all our I³ consortium members and industry partners for their strong support since the establishment of the I³ programme.

At the beginning of our journey, significant time and effort was put into understanding the needs and requirements of the industry and working with our industry partners to build up the IIoT ecosystem. Just as we began to gain more traction in the industry, the economy took a beating from COVID-19, resulting in significant delays in many of our industry projects. Nevertheless, we have picked up the pace of projects in recent months and have now completed a total of six projects, with another four ongoing and several others that are in the pipeline.

We are also pleased to report that we have recruited 18 members to the consortium – 4 strategic, 9 standard and 5 SMEs. Once again, we are grateful for the strong show of support by the members.

On the engagement front, we held a successful preview and networking event in Aug 2019, but due to COVID-19, we were not able to host more of such networking events. Hence, we shifted our focus to monthly industry webinars, inviting consortium members and industry partners to share their digitalisation journey and technologies, with the aim of promoting knowledge exchange and collaboration between members and A*STAR.

We have also conducted IIoT learning tours for most of the Institutes of Higher Learning (IHLs) in Singapore, sharing with them real-life industry problems and how IIoT can applied to solve those problems.

Moving ahead, we look forward to strengthening our collaboration with our current members and build new relationships with industry partners to address the industry’s operational issues and build a more vibrant and successful IIoT ecosystem.
TECHNICAL COMMITTEE

Chairperson
1. Dr Daniel Cheong
   Programme Director, I³, A*STAR

Members
2. Dr Ang Joo Hock
   Senior Manager, R&D
   Sembcorp Marine
3. Mr Cheah Peng Huat
   Principal Technical Sales Specialist
   PTC Inc
4. Mr Christopher Lam
   Head, NEC Laboratories Singapore
   Vice President, NEC Asia Pacific Pte Ltd
5. Mr Iain Brown
   Research Engineer
   Central Technology & Strategy
   Rolls-Royce plc, United Kingdom
6. Mr Jack Goh
   Managing Director
   SICK
7. Mr Jason Soh
   IoT Technical Solution Architect, ASEAN
   Cisco Systems, Singapore
8. Mr Lam Kuet Loong
   Advisory System Engineer & Field CTO
   Dell Technologies
9. Mr Lim Yong Hwee
   Principal Sales Engineer
   Alps Alpine
10. Mr Nicholas Yeo Chang Yee
    Senior Director, Advanced Technology
    Asia Pacific Supply Chain
    Johnson & Johnson
11. Mr Terence Teo
    Managing Director
    Anewtech
12. Professor Tony Quek
    Head, Information Systems Technology and Design Pillar
    Singapore University of Technology and Design
13. Dr Sun Sumei
    Head of Department
    Communications & Network
    I²R, A*STAR
14. Dr Yuan Zhimin
    Deputy Director, Technology Group
    I³, A*STAR
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<th>OUR CONSORTIUM MEMBERS (18 Members + 3 Project Collaborators)</th>
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OUR ACHIEVEMENTS AT A GLANCE

- **18** Consortium Members
- **3** Project Collaborators
- **6** Completed Industry Projects
- **$1M** Savings & Man-months
- **4** On-going & Pipeline Projects
- **8** Technology Disclosures
- **23** Demo Stations in I³ Nexus
- **7** Webinars Attendees
- **138** Companies & Visitors Hosted
- **1059** IHL Students Attended 2-hr IIoT Learning Tours
- **2275**
MEMBERS TESTIMONIALS

“... unplanned downtime root causes were identified, and proactive maintenance actions were recommended. We are very pleased with the outcome of the project so far, and we plan to extend our collaboration to other machines in our plant....

... We strongly support I³'s Phase 2 RIE 2025 direction and look forward to continuing our collaboration with I³ in the coming years.”

Mr Michael Mok
Vice President of Operations for Greater Asia

“... I³ has also shared with us its Phase 2 RIE 2025 plans to develop capabilities in self-powered sensors, indirect sensing, and through-metal communications. These technologies are highly relevant to jnj's operational needs....”

Mr Nicholas Yeo
Senior Director, Advanced Technology, Asia Pacific Supply Chain

“... Despite the challenges brought by COVID-19, SICK remains committed to continue our partnership with I³. We recognise the value I³ brings in helping companies in their first mile of digitalisation and developing the ecosystem of IIoT for Singapore industry....”

Mr Jack Goh
Managing Director

“... The three completed projects have been valuable to Rolls-Royce....

... Despite the challenges brought by COVID-19 to the aerospace industry, Rolls-Royce strongly believes in the importance of R&D and remains committed to continue our partnership....”

Dr Kurichi Kumar
Head of Technology - Asia Pacific

“... We are very pleased with the outcome of the project so far, and we plan to extend our collaboration to other machines in our plant....

We would like to thank I³ for the excellent partnership over the past three years in Sembcorp Marine's digitalisation journey. We appreciate I³'s commitment in marine and offshore engineering sector's digitalisation needs and driving solutions development leading to successful operational deployments in the industry.

Mr Simon Kuik
Vice President and Head, Research & Development

Mr Ho Yuen Sang
Director (Aviation Industry)

Mr Nicholas Yeo
Senior Director, Advanced Technology, Asia Pacific Supply Chain

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Director (Aviation Industry)

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Mr Simon Kuik
Vice President and Head, Research & Development

Mr Ho Yuen Sang
Director (Aviation Industry)
KEY ACHIEVEMENTS – INDUSTRY PROJECTS

12 Improve Shipyard Production Efficiency by Tracking the Location of Sheet Metal

13 Monitor Real-Time Seawater Pump Pressure using LoRaWAN

14 Develop Energy Harvesting System For Non-Motorised Equipment

15 Inline Oil Quality Monitoring System

16 Becton Dickinson Tuas Plant’s SMART Factory
KEY ACHIEVEMENTS – INDUSTRY PROJECTS

Improve Shipyard Production Efficiency by Tracking the Location of Sheet Metal

Misplaced sheet metal is an operational challenge faced by many shipyards – manpower is spent searching for the misplaced parts and if it cannot be found, the metal parts must be refabricated, resulting in material wastage.

I³ collaborated with Sembcorp Marine on a project to tackle this operational challenge. A proof-of-value was demonstrated using weather-resistant 2D barcodes printing to replace handwritten part numbers, an algorithm to automatically track parts’ locations based on Wi-Fi RSSI, and a web application to improve the visibility of parts’ location and its process completion status.

We estimated an annual savings of more than $300,000 in productivity gains and reduced material wastage.
Seawater pumps are important infrastructure in a shipyard and must be maintained above a pressure threshold to ensure smooth operations, both within the shipyard and onboard ships. Typically, workers check on these pumps every 3 hours.

Sembcorp Marine and I³ embarked on another project to monitor pressures at seawater pump stations using LoRaWAN communications. A single LoRa gateway can cover the entire shipyard and enable real-time visibility of the pump pressures. Whenever the pressure falls below a certain threshold, SMS will be sent to alert the operations support team to check on the pumps.

The monitoring system improves productivity of workers and minimises the risk of vessels' equipment failing due to insufficient pump pressure. This saves manpower used for manual monitoring and time wastage due to stop work orders by more than 10,000 man-hours per year, and an estimated annual savings of more than $100,000.
There is a large fleet of non-motorised equipment (NME), such as pallet dollies, operating at the airport apron to transport Unit Load Devices (ULD) to and from the aircraft. To improve the operational handling efficiency of these NME, battery-powered tracking devices are installed on them.

I³ collaborated with CAAS and SATS to develop an energy harvesting system that can charge and prolong the battery life of the tracking devices.

I³ has started the next phase of the project where the system will be installed on actual dollies at the airport and a field trial will be conducted to test the operational performance and reliability of the solution.

If the field trial is successful, it could potentially be deployed onto the entire fleet of around 4,000 pallet dollies at the airport, leading to an estimated annual savings of more than $100,000 in productivity gains.
Smooth engine operation requires good engine oil quality. Over time, oil will degrade to a point where oil change is necessary. In current industry practice, oil changes are based on scheduled maintenance cycles and samples are sent to offsite labs for analysis.

Such an approach is not ideal, as it could take a long time to obtain oil quality information, and may be logistically challenging to send the oil samples to the test labs.

I³ and ARTC collaborated to design and develop an inline oil quality monitoring system for Rolls-Royce, by integrating different types of oil quality, temperature, and flow control sensors within a single system. The purpose of such a system is to test oil quality and identify the types of contaminants present in the sample.

Such a system can potentially provide accurate quality information without the need for lab tests. I³ is exploring deployment of such systems for liquids such as lubricant oil.
To improve the yield of one of their injection molding lines, we collaborated with Becton Dickinson (BD) on a data & predictive analytics project to capture and analyse the operating parameters from the line's various machines.

Machine-to-machine (M2M) communications were implemented to connect various devices/equipment and capture parameters from the line's various machines, and a dashboard was developed to present real-time information.

In addition, we further identified some of the root causes of the line unplanned downtime and recommended predictive maintenance actions for production.
18 High-Resolution, Low-Cost Magnetic Encoder
19 Audio Sensing for Non-Contact Monitoring
20 Ultrasound Sensing for Liquid Property Measurement
21 5G Landscape Report

KEY ACHIEVEMENTS – TECHNOLOGY
**High-Resolution, Low-Cost Magnetic Encoder**

Encoders are sensors that provide positional information for motor control. They have a wide range of applications, from low-resolution encoders used in lift positioning and steering wheels to high-resolution encoders used in CNC machines and robotic arms.

The higher resolution encoders are usually optical based and are more expensive than magnetic ones, which are lower in resolution. However, the magnetic encoders are more robust and hence more suitable for use in harsh environment.

To meet the industry needs of a robust, low-cost and high-resolution encoder, I³ has developed an encoder prototype using TMR (Tunnel magnetoresistance) technology and its own unique algorithm.

The key advantages of this encoder are:
- improved resolution from traditional 12-bit to 16-bit,
- lower cost,
- robustness for use in harsh environment (IP66-rated) and
- ability to measure absolute angular position

The prototype is ready for deployment and several companies are in discussion with Enterprise A*STAR to license this technology.
Audio Sensing For Non-Contact Monitoring

For brownfield sites, there are restrictions on mounting locations and power sources. As such, it is not always possible to directly mount sensors on the machines. Non-contact sensors enables monitoring of these inaccessible machines. For example, utilizing audio signatures, and their areas of focus include,
- source detection
- feature engineering
- machine learning implementation
- edge deployment

I³ has embarked on audio-based sensing, to achieve comparable results to that of contact sensors.

Our machine learning algorithm compared non-contact versus contact sensors; we managed to achieve 94% accuracy in detecting the correct fault condition using the non-contact sensors compared to 96% for the latter. Future research will focus on beam forming to include noise cancellation and multiple assets monitoring with a single system.

Feature engineering is another research area focusing on computationally small algorithms that can be deployed in edge devices for quick signal processing.
Ultrasound Sensing For Liquid Property Measurement

In biochemical and pharmaceutical manufacturing, it is common to find bioreactors with numerous sensors installed on them. Most of these sensors are invasive and may cause disturbances in the bioreactors, hence there is a need to deploy non-invasive/non-contact sensors.

I³ has evaluated an ultrasound system from Screening Eagle (I³ Member), meant for non-destructive testing for built environment, to non-invasively measure liquid properties.

1) Ultrasound transducers are deployed on the walls of containers and pulses are sent through the liquid.
2) The changes in time-of-flight and amplitude of the received signals correlate to changes to density and viscosity.
3) Using Screening Eagle's UT8000, we have been able to detect 1% changes in the liquid properties.

Subsequent work include further characterisation and repeatability tests. Signal processing of the received data will be performed to improve accuracy and correlation to other properties of the liquid.

Comparison of output data with different mixtures. Change in time of flight and amplitude detected.
Industry and society have interest in 5G, given its great promises. I performed a study to capture the current 5G landscape and testbeds in Singapore (and other regions) in a 50-page landscape report. 5G promises significant performance improvements from LTE for fast (eMBB, 20Gbps), real-time (uRLLC, 1ms) and high-density (mMTC, 1million/1km²) communications. Such improvements are realised with the use of millimetre wave (mmWave) communications spectrum, new radio (NR) access technology and standalone (SA) infrastructure. New network infrastructure for 5G are being rolled out by telcos over the next few years. Its mmWave technology will enable critical real-time operations – especially in outdoor environments where Wi-Fi is not available.

For Singapore, the full island-wide coverage of 5G SA will only be ready in 2025. The current non-standalone (NSA) roll-out for 5G is an intermediate step to test out its coverage and performance. Alongside 5G, Wi-Fi 6/6e communications may provide similar speed and latency performance and it is a complementary technology to 5G for indoor connectivity.

### Key Highlights

1. 5G will consist of wide area macro base-stations (3.5GHz) and spot coverage cells (mmWave).
2. The promises of “fast, responsive and massive” will be enabled through Standalone (SA) Infrastructure.
3. 5G has superior design features such as the distributed core and network slicing.
4. 5G will enable many critical real-time applications such as remote surgery, connected drones and vehicle-to-everything (V2X).
5. 5G enables enterprise to expand its business and enhance operations.
6. WiFi 6 (& 6e @ 6GHz) may complement 5G for indoor connectivity.
ENGAGING OUR PARTNERS
MoU Signing Ceremony with 13 companies witnessed by Snr Parliamentary Secretary for Ministry of Trade & Industry Ms Low Yen Ling (center) and her Germany counterpart at IIoT World Tour 2017. It was organised by A*STAR together with the USA’s Industrial Internet Consortium (IIC) and Germany’s Industrie 4.0 on 15 September 2017.
I³ chaired the IIoT session at ITAP 2018 with invited speakers (L-R) from Dell, Rolls-Royce, HP Enterprise, Changi Airport Group, Continental Automotive and Autodesk.

I³ membership signing ceremony at ITAP 2019

I³ consortium members with A*STAR Chairman Ms Chan Lai Fung at ITAP 2019
HOSTING PARTNERS & SENIOR MANAGEMENT

I³ consortium members with ED SERC Prof Tan Sze Wee at I³ Nexus Preview & Networking, Aug 2019

Familiarization tour for A*STAR CEO Mr Frederick Chew with SERC management, Mar 2019

(Left) Visit by Prof Lye Kin Mun (ED, I²R) and staff. (Right) Visit by Dr David Low (CEO, ARTC), Prof Ric Parker (Chairman, Aerospace Programme) and Dr Lim Keng Hui (ED, IHPC)

(Left) Visit by Singapore Airlines SVP Mr Lau Hwa Peng. (Right) Visit by Mr Ling Keok Tong (SERC), Ms Fong Pin Fen (EDB) & Mr Dennis Ling (IDG)
ENGAGING TRADE ASSOCIATIONS & CHAMBERS (TAC)

Singapore International Facility Management Association (SIFMA) visited I³ Nexus on 13 April 2021 (masks removed temporarily for photo taking)

Mr Vincent Wong, Chairman of Technology and Transformation Function Committee, Singapore Manufacturing Federation (SMF), visited I³ Nexus on 19 April 2021

I³ scientist Dr Lionel Wong has served in Singapore Industrial Automation Association (SIAA) as a council member since June 2020 - a trade association for companies and professionals in the Automation, Internet-of-Things (IoT) and Robotics sectors.
SHARING LATEST TRENDS AND TECHNOLOGY

Industrial Internet-of-Things Innovation (I³)

Industry Webinar Series

1st
Digital Transformation (Sembcorp Marine) | IT & OT Convergence (Cisco)

2nd
Tuas Plant SMART Factory (BD) | 5G Edge Computing (Dell)

3rd
Supply Chain Innovation (J&J) | Digital Twins Asset Management (SICK)

4th
Airport Ops Innovation (CAAS) | Digital Twins & Remote Collaboration (SFX)

5th
Master System Integrator Approach (SJ) | Asset Tracking (Alps Alpine)

6th
Co-innovation for Smart Cities (CapitaLand) | Protecting Built Env (SE)

7th
Electrification & Digitalisation (Rolls-Royce) | Industrial AR (PTC)

59 entities
681 attendees
ENGAGING ALL 12 IHLS IN SINGAPORE TO PREPARE FUTURE WORKFORCE

Nov ‘20  Apr ‘21
142 BS & MS Students

Mar ‘21
266 BS Students

Apr ‘21
91 MS Students

Apr ‘21
1000+ Students

May ‘21
60 BS & MS Students (Biz)

May ‘21
68 BS & MS Students (EE)

Coming up...

2200+ students
STAY CONNECTED WITH INDUSTRY PARTNERS

I³ Nexus Preview and Networking Event (27th August 2019)

33 organisations
110 attendees
THANK YOU
FOR YOUR KIND SUPPORT
ORGANISATION DETAILS
Industrial Internet-of-Things Innovation (I³)
Agency for Science, Technology and Research
3 Cleantech Loop, #05-06, CleanTech Two, Singapore 637143

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