

Industrial Internet-of-Things Innovation (I<sup>3</sup>)

APRIL 2019 – MAY 2021

# INAUGURAL ANNUAL REPORT



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## MISSION

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

## VISION

One-stop IIoT Innovation Centre



# ABOUT A\*STAR IIoT INNOVATION (I<sup>3</sup>)

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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 I<sup>3</sup> consortium members and industry partners for their strong support since the establishment of the I<sup>3</sup> 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 be 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.



Dr Daniel Cheong  
Programme Director

Mr Phua Han Tian  
Advisor

# STEERING BOARD

## Chairperson



**Dr Hazel Khoo**  
Executive Director  
SERC A\*STAR  
(Apr 2019 – Dec 2019)



**Prof Tan Beng Hee Reginald**  
Executive Director  
SERC A\*STAR  
(Jan 2020 – Present)



**Ms Fong Pin Fen**  
Vice President & Head,  
Advanced Manufacturing  
EDB  
(Apr 2019 – Apr 2021)



**Ms Glory Wee**  
Vice President & Head,  
Advanced Manufacturing and  
Resource Development  
EDB  
(May 2021 – Present)



**Mr Phua Han Tian**  
Advisor  
Industrial Internet-of-Things  
Innovation (I<sup>3</sup>)  
A\*STAR

# PROGRAMME ADVISORY BOARD

## Co-Chairpersons



**Dr David Smith**  
Director of Central Technology  
Rolls-Royce



**Mr Simon Kuik**  
Vice President and Head of R&D  
Sembcorp Marine



**Mr Andy Lee**  
Managing Director  
Cisco Systems



**Mr Ferry Chung**  
Vice President,  
Digital Transformation &  
Global Digital Cities (APJ)  
Dell Technologies



**Mr Lau Shaw Luen**  
Vice President,  
IoT/ AR Sales & Strategic  
Alliances, APAC  
PTC

# TECHNICAL COMMITTEE

## Chairperson



## Members

1 **Dr Daniel Cheong**  
Programme Director  
I<sup>3</sup>, A\*STAR

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  
I<sup>2</sup>R, A\*STAR

14 **Dr Yuan Zhimin**  
Deputy Director, Technology Group  
I<sup>3</sup>, A\*STAR

# OUR CONSORTIUM MEMBERS (18 Members + 3 Project Collaborators)

## Strategic Members



## Standard Members



## SME Members



## Project Collaborators



# OUR ACHIEVEMENTS AT A GLANCE

I<sup>3</sup>

Proj

Tech

Biz  
Dev

18

Consortium  
Members

8

Technology  
Disclosures

3

Project  
Collaborators

23

Demo Stations  
in I<sup>3</sup> Nexus

6

Completed  
Industry Projects

7  
681

Webinars  
Attendees

\$1M  
332

Savings &  
Man-months

138  
1059

Companies &  
Visitors Hosted

4  
21

On-going &  
Pipeline Projects

2275

IHL Students Attended  
2-hr IIoT Learning Tours

# 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 I<sup>3</sup>'s Phase 2 RIE 2025 direction and look forward to continuing our collaboration with I<sup>3</sup> 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 Jn's operational needs..."

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



We would like to thank I<sup>3</sup> for the excellent partnership over the past three years in Sembcorp Marine's digitalisation journey. We appreciate I<sup>3</sup>'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



"... Despite the challenges brought by COVID-19, SICK remains committed to continue our partnership with I<sup>3</sup>. We recognise the value I<sup>3</sup> brings in helping companies in their first mile of digitalisation and developing the ecosystem of IIoT for Singapore industry..."

**Mr Jack Goh**  
Managing Director



"... I<sup>3</sup> developed a working concept for energy harvesting on pallet dollies and we are pleased with the outcome of the first project. We are continuing the collaboration project with I<sup>3</sup> in the next phase to translate the concept into a deployable solution.

... This will enable us to collect more relevant data to further our digital transformation, as part of Changi's Digital Airside initiative.

As the lead agency for aviation, we want to accelerate digital transformation for the airport community. We look forward to continue the partnership with I<sup>3</sup> and support your next grant application in RIE2025."

**Mr Ho Yuen Sang**  
Director (Aviation Industry)

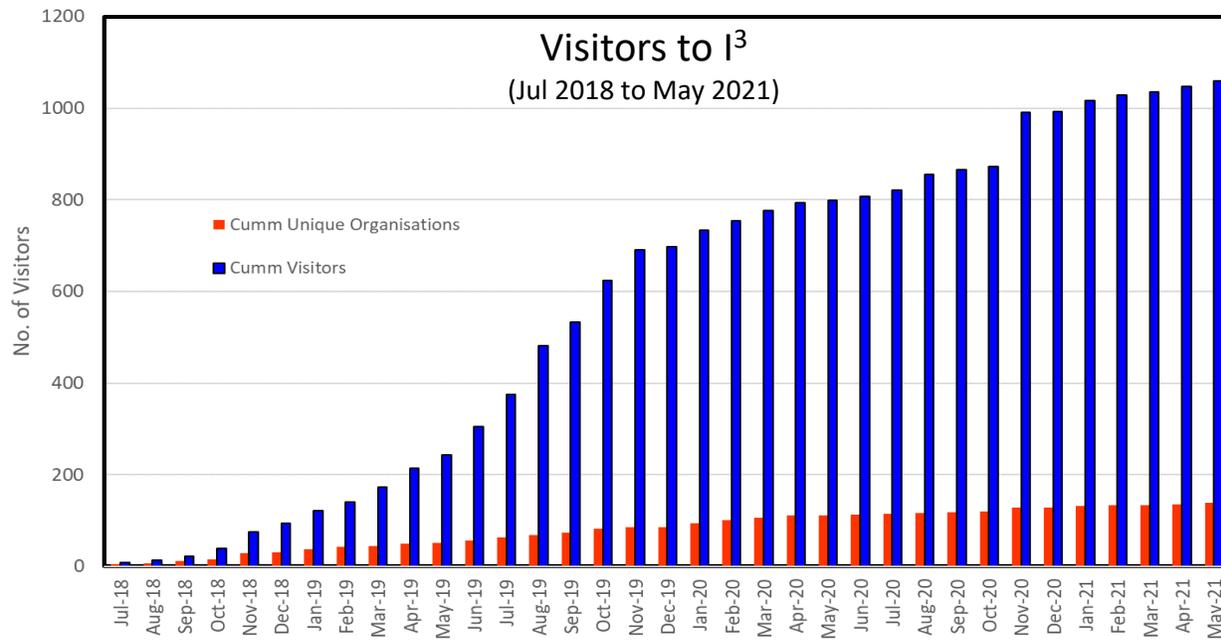
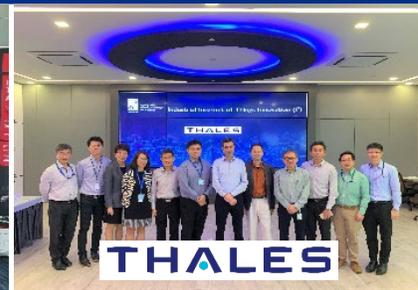


"... The three completed projects have been valuable to Rolls-Royce..."

... 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

# OUR VISITORS



**1,059**  
visitors

**138**  
entities



## 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



CNC Sheet Metal Cutting Machine at Sembcorp Marine Hull Shop

# 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.

I<sup>3</sup> 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.



Sheet metal parts lying in the Hull Shop

# KEY ACHIEVEMENTS – INDUSTRY PROJECTS



## Monitor Real-Time Seawater Pump Pressure using LoRaWAN

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 I<sup>3</sup> 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.



Sembcorp Marine Admiralty Shipyard

# KEY ACHIEVEMENTS – INDUSTRY PROJECTS



## Develop Energy Harvesting System For Non-Motorised Equipment

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.

I<sup>3</sup> collaborated with CAAS and SATS to develop an energy harvesting system that can charge and prolong the battery life of the tracking devices.

I<sup>3</sup> 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.



Pallet dollies at Changi Airport



Wheels of a dolly



Electrical current measurement

# KEY ACHIEVEMENTS – INDUSTRY PROJECTS



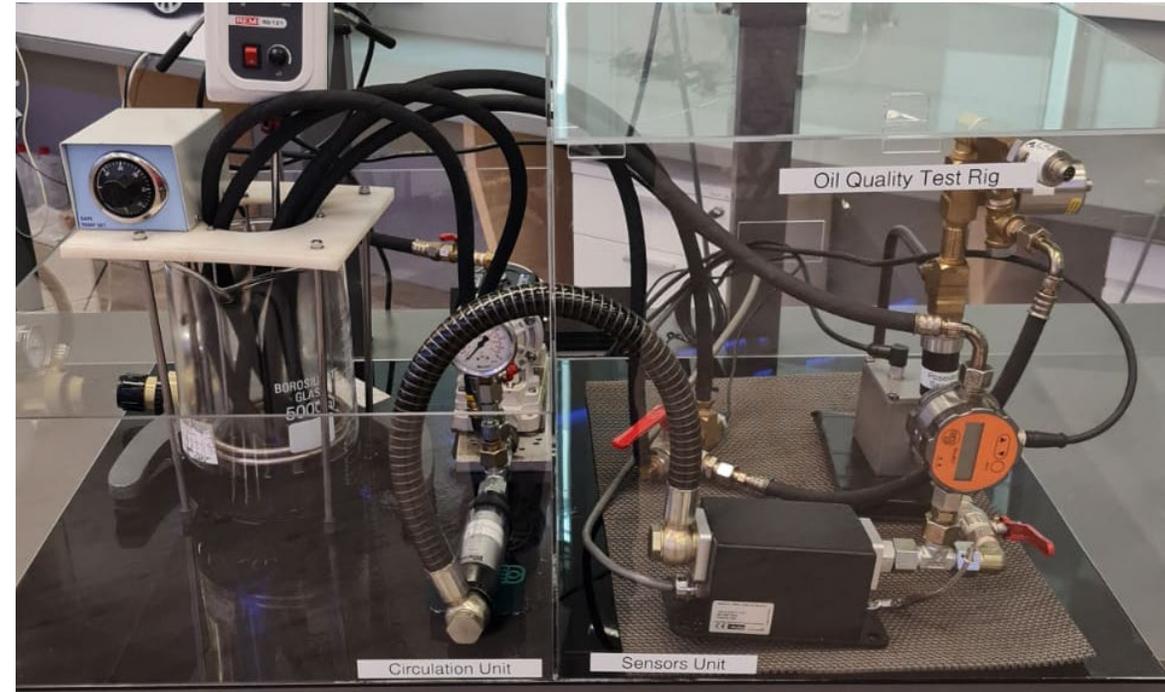
## Inline Oil Quality Monitoring System

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

I<sup>3</sup> 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. I<sup>3</sup> is exploring deployment of such systems for liquids such as lubricant oil.



Inline test fixture for oil quality

# KEY ACHIEVEMENTS – INDUSTRY PROJECTS



## Becton Dickinson Tuas Plant's SMART Factory

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.



BD plastic injection molding line

## KEY ACHIEVEMENTS – TECHNOLOGY

- 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, I<sup>3</sup> 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.



Low cost IP66 16-bit absolute magnetic encoder prototype

# KEY ACHIEVEMENTS – 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.

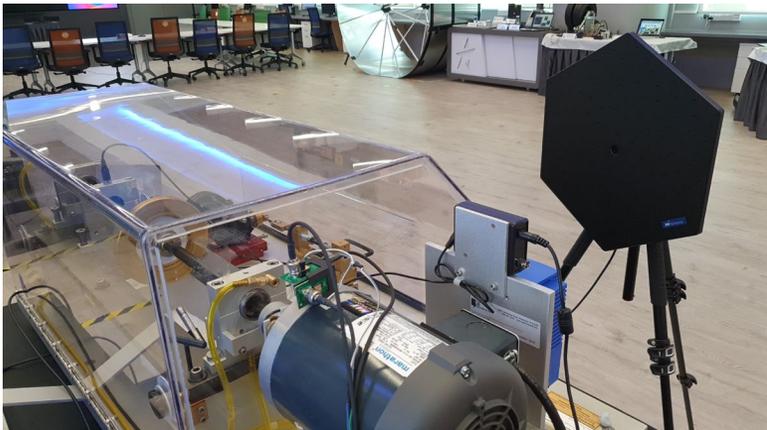
Non-contact sensors enables monitoring of these inaccessible machines. For example, utilizing audio signatures, and their areas of focus include,

- source detection
- feature engineering
- machine learning implementation
- edge deployment

I<sup>3</sup> 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.

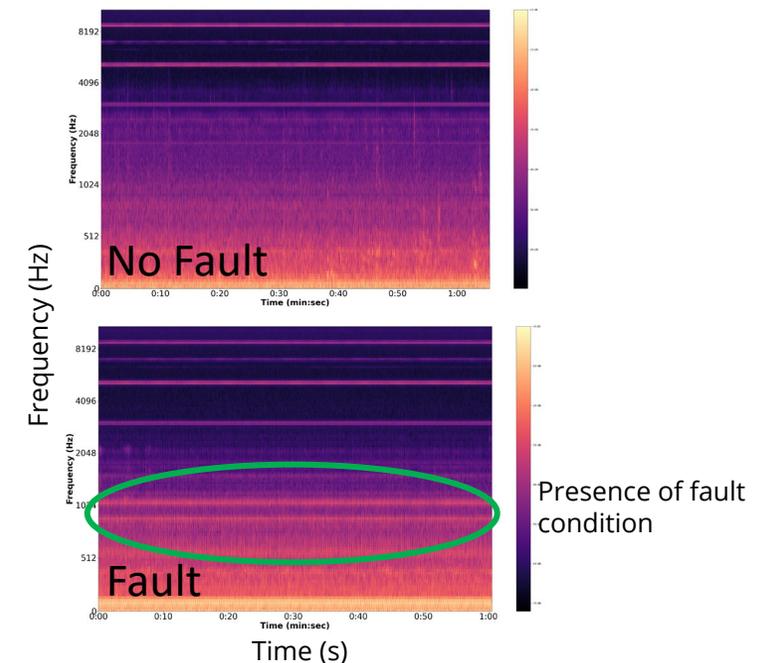
Feature engineering is another research area focusing on computationally small algorithms that can be deployed in edge devices for quick signal processing.



Acoustic camera deployed to detect noise source



Live feed indicating noise position and frequency



# KEY ACHIEVEMENTS – TECHNOLOGY

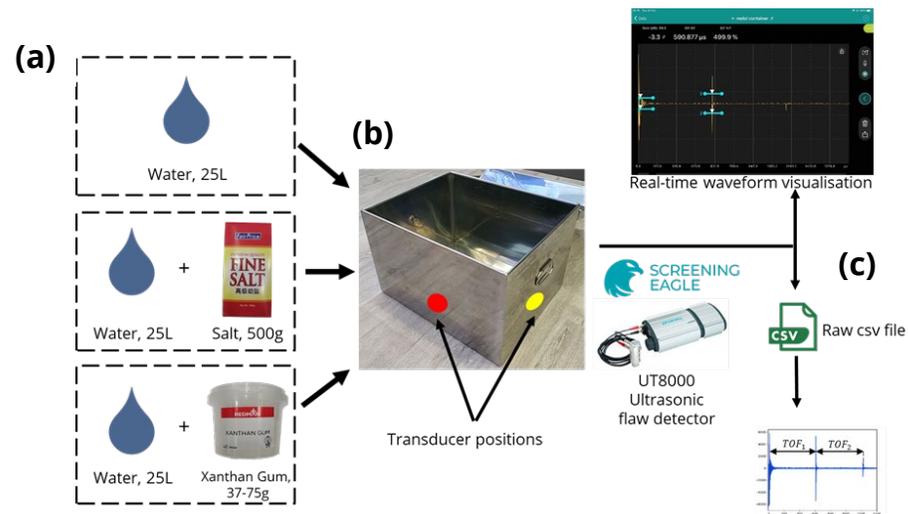
## Ultrasound Sensing For Liquid Property Measurement

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.

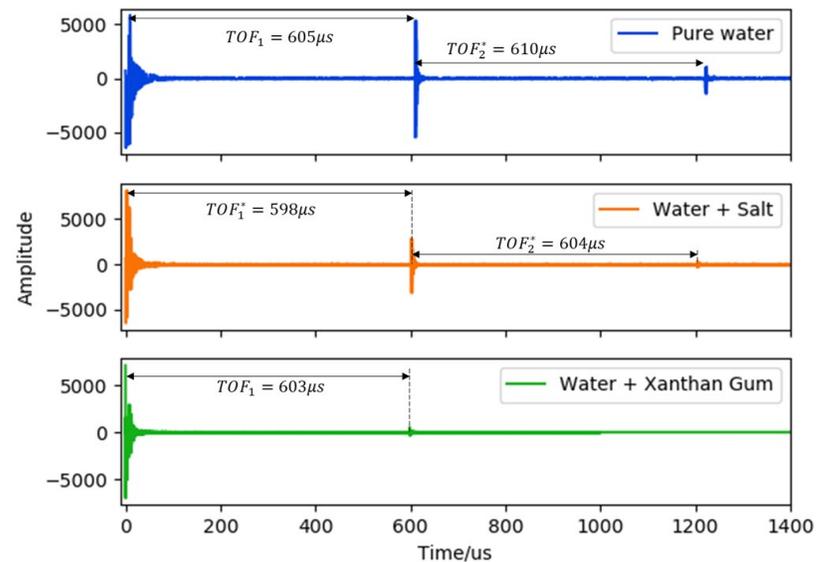
I<sup>3</sup> has evaluated an ultrasound system from Screening Eagle (I<sup>3</sup> Member), meant for non-destructive testing for built environment, to non-invasively measure liquid properties.

- 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.



(a) Different liquid mixtures used, (b) ultrasound measurement, (c) output data



Comparison of output data with different mixtures. Change in time of flight and amplitude detected.

# KEY ACHIEVEMENTS – TECHNOLOGY

## 5G Landscape Report

Industry and society have interest in 5G, given its great promises. I<sup>3</sup> 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/1km<sup>2</sup>) 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.

### 1 The Promises of 5G ...

1. **Fast (eMBB), 20Gbps**  
Enhanced **Mobile Broadband**
2. **Real Time (uRLLC), 1ms**  
**Ultra Reliable Low Latency Communications**
3. **High Density (mMTC), 1 million/km<sup>2</sup>**  
**Massive Machine Type Communications**

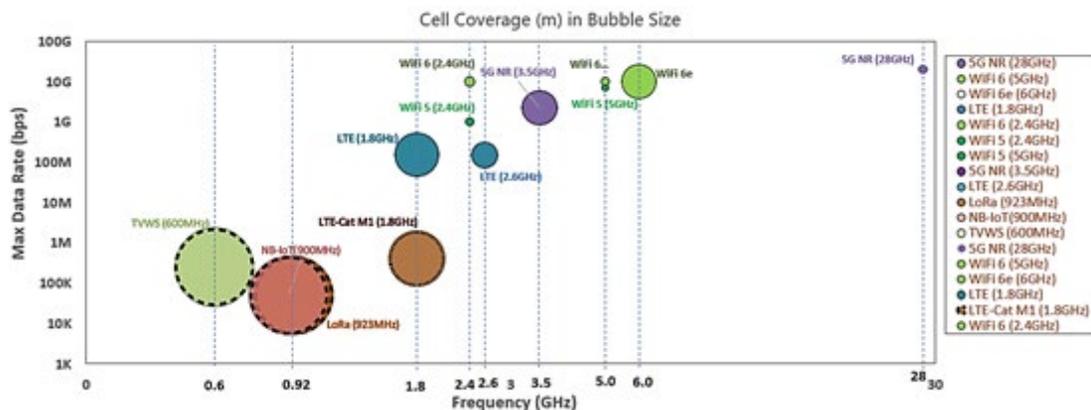
### 2 ...vs 4G, WiFi 5 & 6...

WiFi 6 has similar speed and latency performance

	WiFi 5 (802.11ac)	4G (LTE)	4.5G (LTE-A Pro)	5G (New Radio)*		WiFi 6/6e (802.11ax)	WiGig2 (802.11ay)
				< 6GHz	mmWave		
Release (Year)	2014	2010	2016	2020	2020	2019	2022
Frequency (GHz)	2.4/5	1.8/2.6	1.8/2.6	3.5	28	2.4/5/6	60
Data Rate (Mbps)	1,000	150	1,000	2,200	20,000	10,000	40,000
Latency (ms)	5	30	10	1	1	2	<1
Cell Radius (m)	150 (2.4GHz) 100 (5GHz)	300 (2.6GHz) 500 (1.8GHz)	300 (2.6GHz) 500 (1.8GHz)	300	100	150 (2.4GHz) 100 (5GHz) 80 (6GHz)	30
Infra Cost	\$	\$\$	\$\$	\$\$\$	\$\$\$	\$	\$\$

### 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.

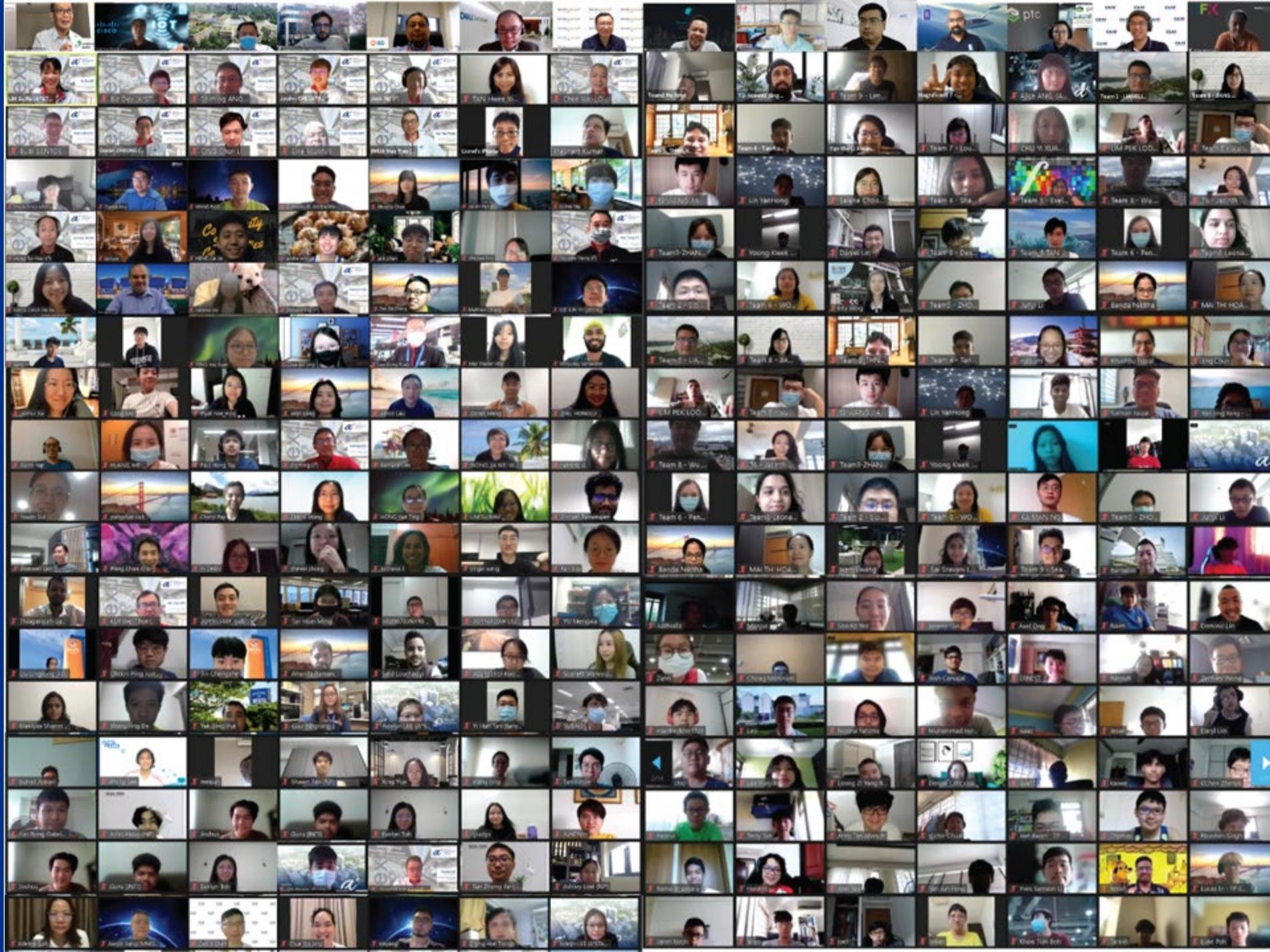


### Range (m)

10000  
2000  
500  
200  
100



# ENGAGING OUR PARTNERS



# ANNOUNCING THE PROGRAMME AT IIoT WORLD TOUR IN 2017



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.

# PARTICIPATING IN INDUSTRY TRANSFORMATION ASIA-PACIFIC (ITAP)



I<sup>3</sup> 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.



I<sup>3</sup> Membership Signing Ceremony at ITAP 2019



I<sup>3</sup> consortium members with A\*STAR Chairman Ms Chan Lai Fung at ITAP 2019

# HOSTING PARTNERS & SENIOR MANAGEMENT



I<sup>3</sup> consortium members with ED SERC Prof Tan Size Wee at I<sup>3</sup> 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, I<sup>2</sup>R) 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 I<sup>3</sup> 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 I<sup>3</sup> Nexus on 19 April 2021



I<sup>3</sup> 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 (I<sup>3</sup>) 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



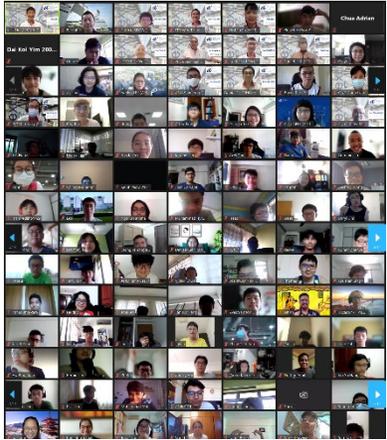
Apr '21



1000+ Students



May '21



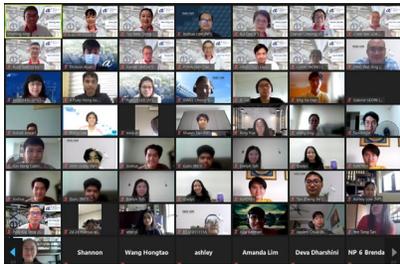
570 Students

**2200+**  
students

Coming up...



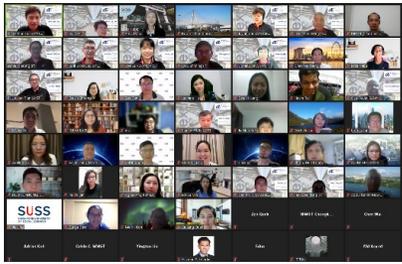
May '21



78 Students



May '21 Jun '21



60 BS & MS Students (Biz)  
68 BS & MS Students (EE)

# i<sup>3</sup> NEXUS BRINGS TOGETHER A\*STAR'S AND MEMBERS' CAPABILITIES (2019)



# I<sup>3</sup> NEXUS EXPANSION FOR NEW CAPABILITIES AND INDUSTRY PROJECTS (2021)



# STAY CONNECTED WITH INDUSTRY PARTNERS



33 organisations  
110 attendees

I<sup>3</sup> Nexus Preview and Networking Event (27<sup>th</sup> August 2019)

**THANK YOU**  
FOR YOUR KIND SUPPORT

Sunset at Sembcorp Marine Admiralty Shipyard  
Photo by : Phua Han Tian



## ORGANISATION DETAILS

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 : [www.a-star.edu.sg/iiot](http://www.a-star.edu.sg/iiot)