TRANSFORMING AIRPORT OPERATIONS

LIKE CLOCKWORK:
THE WORLD BELOW THE WING

HIVES OF ACTIVITY AT THE CHANGI AIRSIDE

At all airports, the movement of baggage and cargo form a significant portion of activity at the airside.

1 Aircraft Stand

Upon arrival, baggage and cargo are unloaded from aircraft onto carts or trailers and are towed by tractors to the Baggage Handling Area under the Terminal Buildings, and the Air Freight Terminals respectively.

The reverse process takes place for departures.

DID YOU KNOW?

There are close to

2,000

specialised drivers supporting aircraft ground handing at Changi Airport

2 Baggage Handling Area

Arrival baggage is unloaded from the carts or trailers directly onto the baggage carousels which connect to the baggage claim belts in the terminals.

For departures, checked baggage travels through a series of conveyor belts and is routed to the baggage carousels, upon which airport staff will proceed to scan the baggage barcodes and sort the baggage into carts or trailers, to be sent to the respective flights.

3 Air Freight Terminals

Photo courtesy of Singapore Airport Terminal Service (SATS)

The Future of Airside Baggage & Cargo Transport: Autonomous Vehicles

- Airside drivers spend a significant amount of time plying the airside roads getting from point to point
- Autonomous Vehicles could transform the delivery of baggage and cargo and enable drivers to perform other more urgent and complex tasks, especially within the aircraft stand
- Drivers can also be upskilled to take on larger responsibilities, such as the role of a fleet supervisor to monitor and manage a fleet of autonomous vehicles from a remote work-station
- Automation will also support operations during inclement weather, contributing to the resilience of Changi's airside operations

WE'RE HERE!

2018

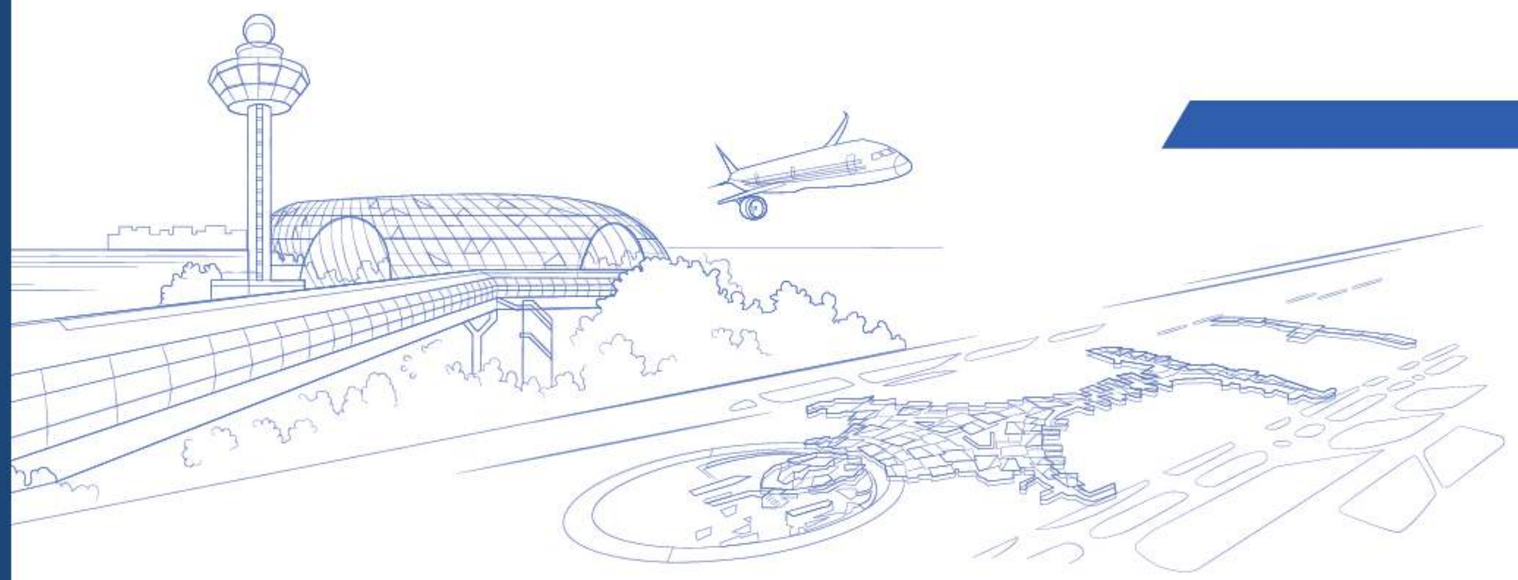
Changi Airport started testing autonomous solutions at the airside; the technology was determined to be not ready for implementation

2020/2021

COVID-19: With advancements made in AV technology as well as taking advantage of the reduced air traffic volumes, Changi Airport restarted its Autonomous Vehicle trials

TODAY

There are now six autonomous vehicles on trial at Changi Airport



THE CHANGI AV DEVELOPMENT JOURNEY

VIRTUAL SIMULATIONS

To prepare for the introduction of autonomous vehicles into the airside environment, the Civil Aviation Authority of Singapore took guidance from the Centre of Excellence for Testing & Research of Autonomous Vehicles NTU (CETRAN) framework. CAAS also worked with TNO, an independent research organisation in the Netherlands, to identify 19 scenarios to test the vehicles' ability to manoeuvre.

Overview of the safety assessment framework for autonomous vehicles established by CETRAN

SAFETY TESTS PRIOR TO ENTERING THE AIRSIDE

Once the Autonomous Vehicles could demonstrate their ability to perform and manoeuvre safely within the 19 scenarios, the next step was to put the actual vehicles through a comprehensive series of tests before they were issued with Airside Vehicle Permits to operate within the airside.

TRANSFORMING AIRSIDE CONNECTIVITY THROUGH 5G

5G Aviation Testbed @ Terminal 3 Airside

To catalyse the development of innovative use cases to enhance productivity of airport airside operations, the Civil Aviation Authority of Singapore (CAAS) and Singtel, with support from the Changi Airport Group (CAG), launched a two-year 5G Aviation Testbed at Terminal 3 airside from March 2023.

Under the testbed, 5G network infrastructure has been deployed to provide coverage at the Terminal 3 Apron and Baggage Handling Area.

Close to 4,000 Singtel 4G corporate mobile user lines at the airside from the various stakeholders were also given upgrades to 5G lines to facilitate such use cases and connectivity of aviation workers on the airside.

AVIATION USE CASES FOR 5G

5G unlocks many different use cases such as the use of video analytics and artificial intelligence to predict and drive on-time performance, and ensure optimal resource allocation.
Two use cases have already tapped on the 5G Aviation Testbed:

1 Secure ground transfer of critical flight data between aircraft and its data centres

Singapore Airlines (SIA) currently relies on a WiFi-based system to transfer data to the aircraft when the aircraft is docked at aircraft stands.

By tapping on the 5G Aviation Testbed, SIA can utilise 5G wireless data transmission without the need for extensive cabling and aircraft modification, enhancing the connection speed and allowing SIA to cut down on the long implementation lead time.

SIA Aircraft docked at aircraft stand

2 Remote Supervision of Autonomous Vehicles via Tele-operations

5G is an important enabler that unlocks the ability to trial procedures and systems for remote tele-operations of Autonomous Vehicles. It allows the continuous monitoring of autonomous vehicle operations in real-time at a remote location using high-definition video streams with low latency and high transmission stability.

This enhances the situational awareness of operators, allowing them to supervise AV operations remotely, and carry out actions for safe operations of the vehicle.

5G-enabled remote tele-operation of autonomous vehicle

ABOUT 5G

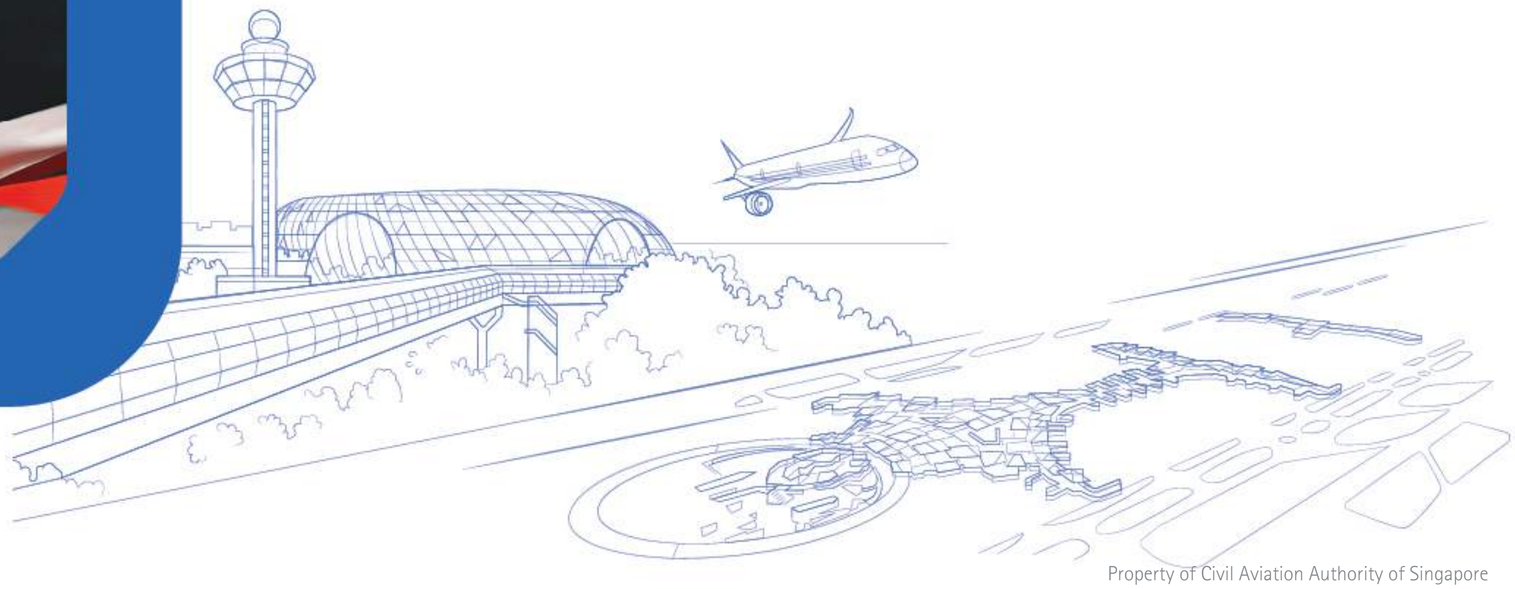
5G provides high connectivity speed, ultra-low latency and high bandwidth, and has potential to enable airport stakeholders to trial and adopt new innovative solutions.

	SPEED	LATENCY	CONNECTIONS	MOBILITY	NETWORK ARCHITECTURE
5G	**10 Gbps** Per Connection	**<3ms** E2E Latency	**1mil** Connections per km²	**500km/h** High speed railway	**Slicing** Ability
	10x	**10x**	**100x**	**1.5x**	Virtualized Network
4G	100Mbps - 1Gbps	30-50ms	10k	350km/h	Discrete

FLIGHT SAFETY

While 5G can unlock new possibilities for airport operations, the safety of flight operations remains a key priority.

CAAS has, in consultation with the Infocomm Media Development Authority (IMDA), engaged CAG and local telecommunications companies in developing safety guidelines and mitigation measures to enhance safety in flight operations, such as restrictions on transmission power and down-tilting of 5G base stations' antennae.



BAGGAGE HANDLING TRANSFORMATION

GLOBALLY, THE BAGGAGE HANDLING PROCESS HAS REMAINED LARGELY UNCHANGED OVER THE LAST FEW DECADES

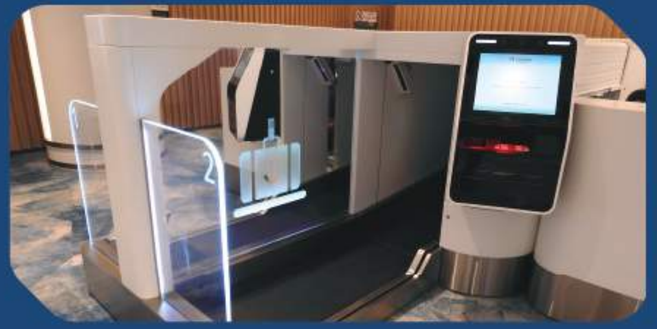
The aviation sector has to grapple with similar manpower challenges faced by other industries, including that of an ageing workforce. Baggage handling is also labour-intensive, and there is risk of injury with the handling of heavy baggage.

PROCESS FLOW

After baggage is tagged and dropped off at the check-in counters, the bags enter a sortation system before being sent to the baggage carousel assigned to the flight

Baggage handlers would then need to load the bags into carts or trailers for transfer to the aircraft

Upon arrival at the aircraft, the baggage handlers would need to load the baggage into the aircraft



This process is repeated in reverse for arrival flights

At Changi Airport, we are trialling new technologies, concepts and equipment, so as to enhance efficiency, drive manpower productivity and improve the working environment for baggage handling staff

INITIATIVES IN THE WORKS

POWER STOW ROLLERTRACK

Ground support equipment which is more ergonomically friendly

- Changi Airport's ground handlers, SATS and dnata, are trialling the equipment
- Belt loader with extendable snake-like roller belt
- Ability to extend far into aircraft's bellyhold, assisting staff to move bags to aircraft's door
- Staff no longer need to form human chain to carry bags
- Reduces fatigue and manpower needed for task

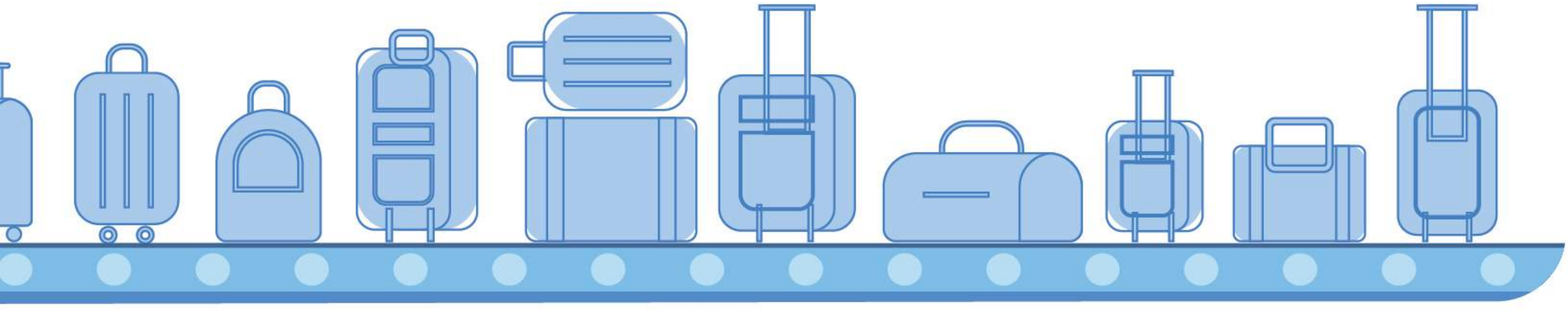
BULK BAGGAGE HANDLING SYSTEM (BBHS)

A new innovative concept that could transform baggage loading and unloading

- An innovative concept and system invented in Denmark
- Undergoing trial in Changi Airport
- A semi-automated baggage handling system which utilises specially designed baggage carts and receiver station
- Removes most of the repetitive baggage lifting activities
- Reduces fatigue and increases efficiency and in turn, reduces overall manpower requirements for baggage handling

Image by BBHS A/S

Image by BBHS A/S

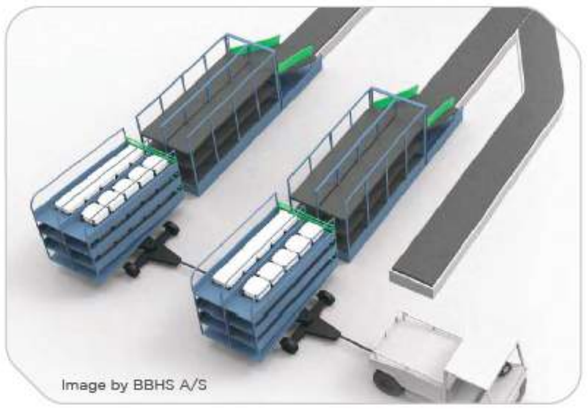


BBHS: REDEFINING ARRIVAL BAGGAGE HANDLING

BENEFITS:

- **Productivity** — Estimated manpower savings of up to 25%
- **Efficiency** — Reduction in baggage delivery time
- **Job nature** — 95% reduced manual baggage handling
- **Workplace Safety** — Workplace injuries minimized

MORE ABOUT THE INNOVATION



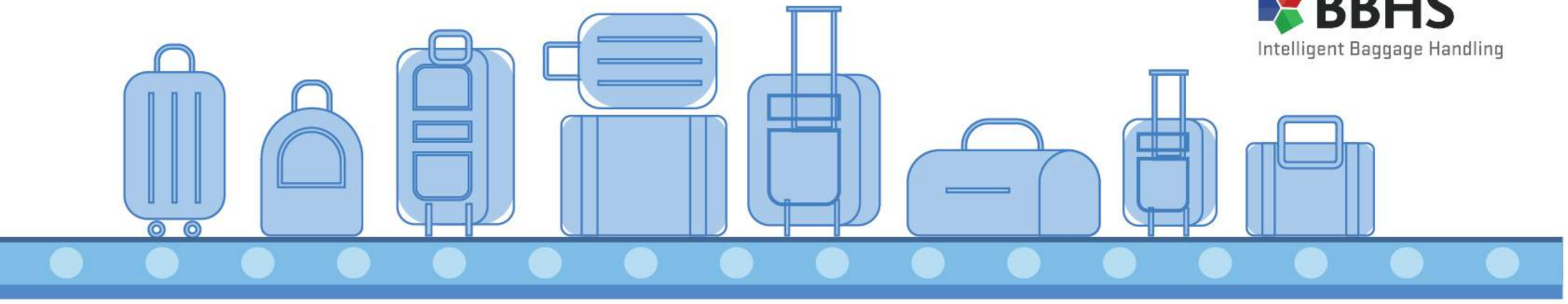
Visual representation of baggage being deposited from the BBHS tiered carts into the Arrival Receiver Station

The "Bulk Baggage Handling System" (BBHS) was brought into Changi Airport for trials in 2019. The concept leverages gravity, and ergonomically designed baggage carts and equipment to assist baggage handlers.

HOW IT WORKS

- Baggage from arriving aircraft is loaded onto ergonomically designed tiered baggage carts using a conveyer belt known as a belt loader
- Baggage staff do not need to lift the baggage and stack them. Instead, they operate the belt loader controls to feed the baggage directly into the carts
- At the Baggage Handling Area, the process of baggage unloading is done at the touch of a button. With the help of gravity, bags from the tiered carts slide down into the Receiver Station
- Human intervention is only needed to manoeuvre the baggage carts into position and to operate the controls at the last mile

EXISTING PROCESS → **WITH BBHS SYSTEM**

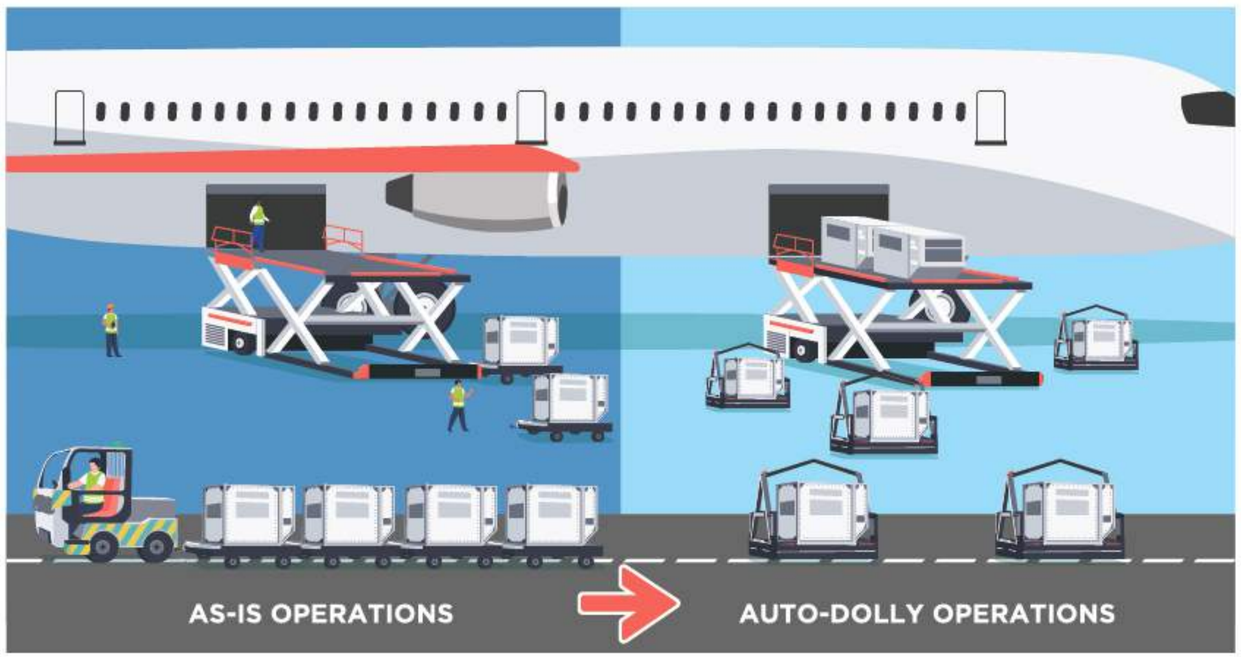


BBHS
Intelligent Baggage Handling

AUTO-DOLLY™

BY AURRIGO

A REDESIGN OF THE "1 TRACTOR + 4 TRAILERS" CONCEPT



Current operations involve a manually-driven baggage tractor towing up to four carts or trailers

→

Individual Auto-Dollies each act as an independent cart or trailer transporting baggage to/from the aircraft stand

FUTURE PLANS

- Subsequent trial phases will see newer iterations of the Auto-Dolly vehicle, incorporating several design changes
- Future versions of the vehicle will have the "crabbing" ability - besides moving forward and backward, it will be able to turn on its axis to move sideways in order to increase its manoeuvrability, allowing it to operate efficiently within an aircraft stand

WE'RE HERE!

May 2021
- Commencement of Phase 1 trials

Feb 2022
- Arrival of 1st Auto-Dolly @Changi

May 2022
- End of Phase 1 trials
- Confirmed basic safety features & driving mobility of vehicle

Aug 2022 - Oct 2023
- Continued trials with 2 vehicles
- The trials are co-funded by CAAS & CAG
- Testing of Auto-Dolly's ability to manouvre around tight spaces within aircraft stand

2024
- Continued enhancements of vehicle technology
- Development of a fleet management system to support future operational deployment

From May 2021 - May 2022, the Civil Aviation Authority of Singapore, Changi Airport Group and Aurrigo embarked on a joint Autonomous Baggage Automation for Changi Airport Stakeholders (ABACAS) project to trial the Auto-Dolly at Changi Airport, funded by the United Kingdom's innovation agency under the Eureka programme.

Auto-Dolly at the Baggage Handling Area

Photo courtesy of Changi Airport Group (CAG)

Auto-Dolly at the Aircraft Stand

TRACTEASY™

BY EASY MILE SAS

AUTOMATING THE DRIVING OF TRACTORS AT CHANGI

TractEasy (TEZ) is a collaboration between Easymile, which specialises in autonomous vehicle technology and TLD, a leading manufacturer of aviation Ground Support Equipment.

The vehicle is equipped with a suite of sensors that allows it to travel autonomously along a pre-mapped route and detect obstacles along its path.

The TEZ commenced proof of technology trials in October 2020 to determine its ability to integrate into Changi's environment.

SUPPORTING RAMP-UP OF CHANGI AIRPORT OPERATIONS

From July 2021 to June 2022, the TEZ became the first Autonomous Vehicle to be deployed to support baggage transport for certain flights, supporting the ground handling companies over the ramp-up period for air travel.

DID YOU KNOW?

The TEZ has transported more than 100,000 bags between July 2021 to June 2022!

KEY MILESTONES

Oct 2020
Proof of technology & concept

Jun 2021
Commencement of Phase 1 trials

Sep 2021
1 TEZ operating on flights

Jan 2022
2 TEZs operating on flights

Jun 2022
End of phase 1 trials

WE'RE HERE!

Present - Nov 2023
Continued trials & development of tele-operations and fleet management system

Early 2024
Target deployment of small fleet to support ground handling operations

SUSTAINABLE AIR HUB

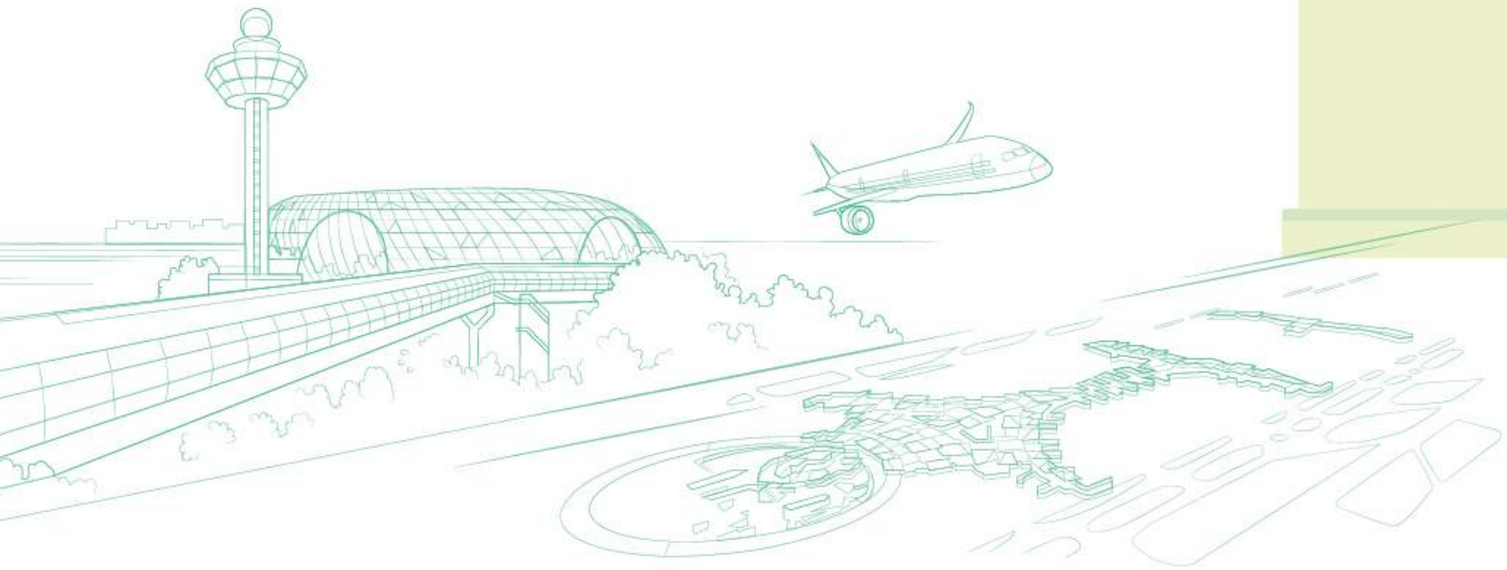
OUR VISION

Our vision is to make air travel more sustainable and to build Changi as a sustainable air hub. In doing so, CAAS will:

1 Create a conducive environment for developing and introducing sustainable aviation products

2 Encourage greater use of Sustainable Aviation Fuel (SAF)

3 Enhance international partnerships on sustainable air travel



Recommendations of the International Advisory Panel on Sustainable Air Hub

Airport

a. Airfield solar deployment
b. Renewable electricity
c. Building energy efficiency
d. Clean energy airside vehicles
e. System optimisation with digital twin project
f. Resource circularity through on-site waste-to-energy facility

Airline

a. Roadmap to create long-term secured Sustainable Aviation Fuel (SAF) supply ecosystem
b. Corporate Buyers' Club
c. Structural offtake mechanism for SAF
d. Aviation vertical offerings in carbon markets, support ecosystem for and encourage uptake of aviation carbon offsets
e. Technical centre for capability-building in aircraft technology

Air Traffic Management

a. Advanced demand-capacity balancing
b. Performance-based navigation
c. Gate-to-gate trajectory optimisation
d. Trajectory-Based Operations and Free Route Airspace in collaboration with stakeholders and partner Air Navigation Service Providers

Enablers

a. Policy and regulation
b. Industry development
c. Infrastructure planning and provision
d. Workforce transformation

SCAN ME TO DOWNLOAD THE REPORT

AIRPORT:

CLEANER ENERGY AIRSIDE VEHICLES

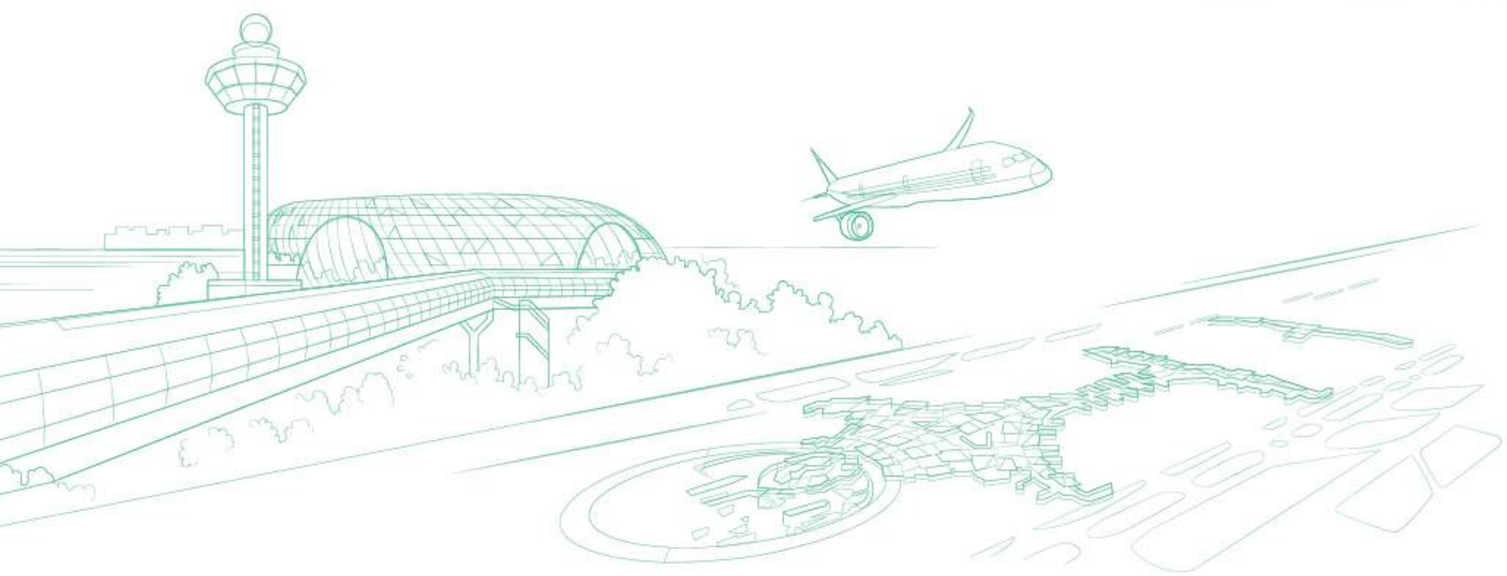
SINGAPORE IS COMMITTED TO ENSURING ALL AIRSIDE VEHICLES AT CHANGI AIRPORT RUN ON CLEANER ENERGY BY 2040

All new light vehicles to be electric from 2025

Certain new heavy vehicles with viable electric models available to be electric from 2025

The charging network on the airside will increase to more than 300 charging points in the coming years to support stakeholders' electrification efforts

The airside community will commence trials on the use of renewable diesel, especially for specialised airport ground handling vehicles with no electric models



AIRLINE:

SUSTAINABLE AVIATION FUEL

WHAT IS SUSTAINABLE AVIATION FUEL (SAF)?

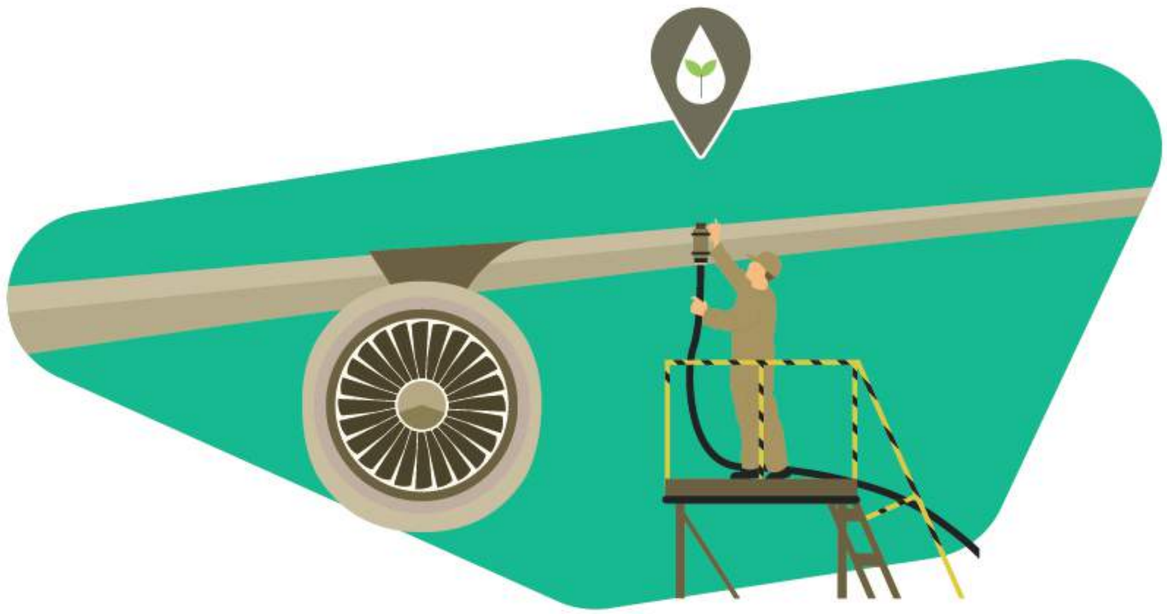
SAF is a form of alternative, non-fossil based, aviation fuel that can reduce up to 80% of carbon emissions compared to fossil jet fuel. SAF is traditionally produced from feedstocks like waste oils and agricultural waste, but these have diversified in recent years.

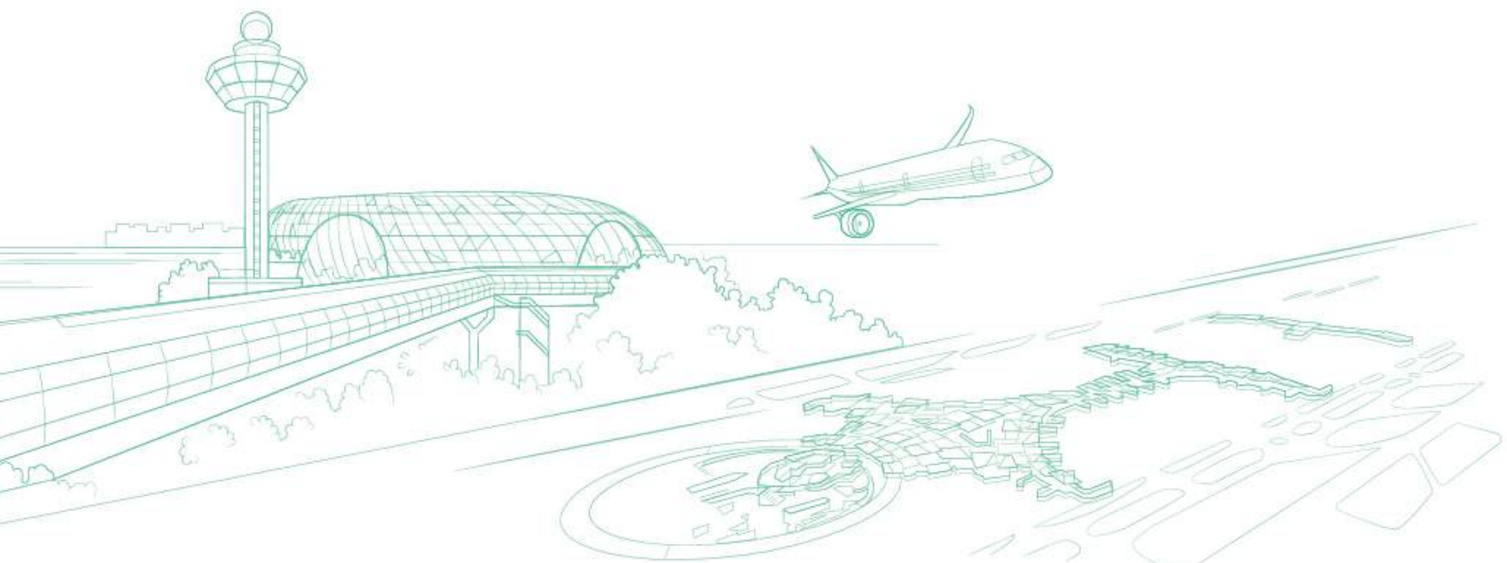
Feedstocks suitable for SAF production

- Oil seed plants and energy grasses
- Algae
- Municipal solid waste
- Fats, oils, and greases from cooking waste and meat production
- Agricultural and forestry residue
- Industrial carbon monoxide waste gas

SAF PILOT IN SINGAPORE

CAAS partnered with Singapore Airlines, Changi Airport Group, Temasek Holdings, ExxonMobil and Neste to conduct a pilot to uplift SAF at Changi Airport in July 2022. As part of the pilot, Singapore Airlines has piloted the sale of SAF credits to encourage corporates and cargo users to reduce their carbon footprint and stimulate the demand for SAF.





AIR TRAFFIC MANAGEMENT:

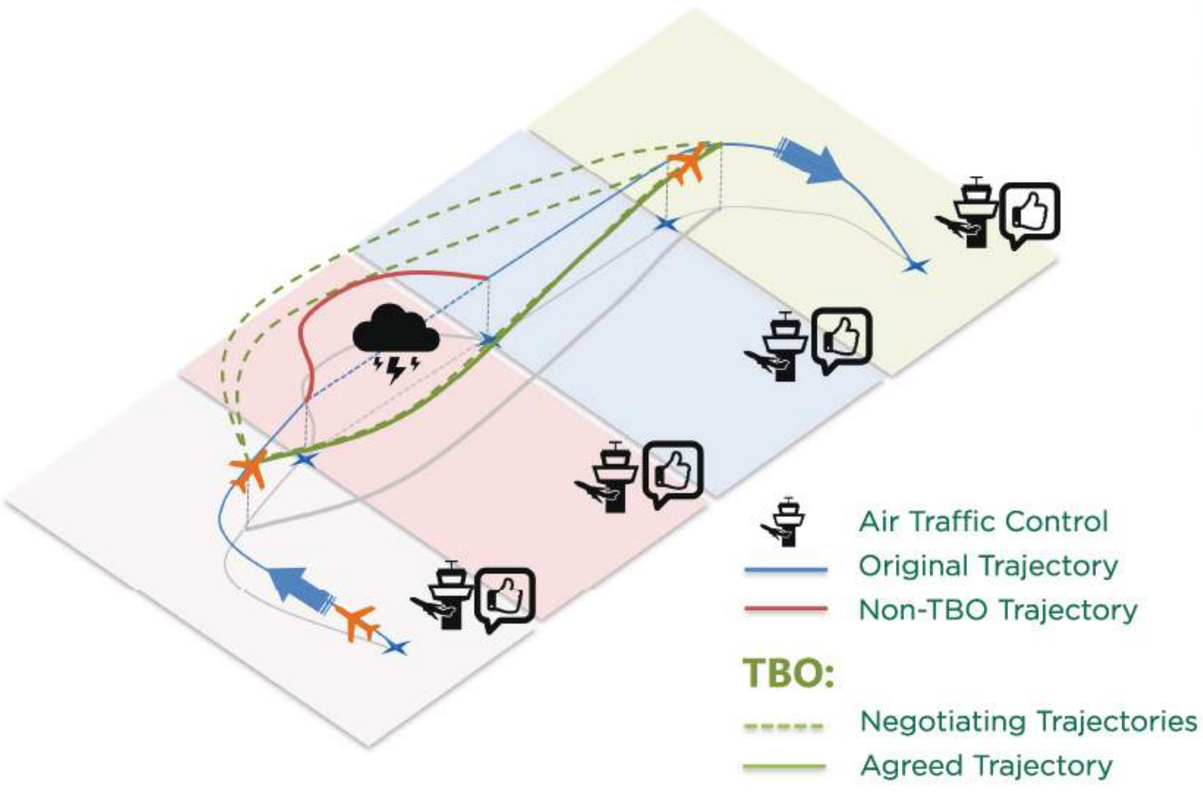
TRAJECTORY BASED OPERATIONS

Trajectory Based Operations (TBO) presents significant sustainability benefits by optimising flight efficiency, which will reduce delays, fuel burn and emissions.

TBO allows flight trajectories to be planned and executed more precisely to improve Air Traffic Management (ATM).

Today, international flights are coordinated through multiple Flight Information Regions (FIRs) by respective Air Navigation Service Providers (ANSPs), with each ANSP focusing on providing air traffic control services in their respective areas of responsibility independently.

Under TBO, ANSPs and airspace users will share information such as detailed flight intent, weather and aerial activities, and work together to plan and optimise an aircraft's flight trajectory across FIRs from take-off to touchdown.



Singapore, Japan, Thailand and the United States successfully conducted the world's first-ever Multi-Regional TBO demonstration flight in June 2023.

The demonstration flight was part of a three-year collaboration programme aimed at improving flight efficiencies and reducing carbon emissions. TBO and other sustainable ATM initiatives, have the potential of cutting an aircraft's additional fuel burn by up to 10%.

Technical capabilities developed for the project enabled functions such as air and ground exchange of live flight information and the negotiation of flight trajectory between multiple ANSPs and the aircraft.

CAAS and Boeing celebrating the successful MR-TBO flight in June 2023

UNMANNED SYSTEMS

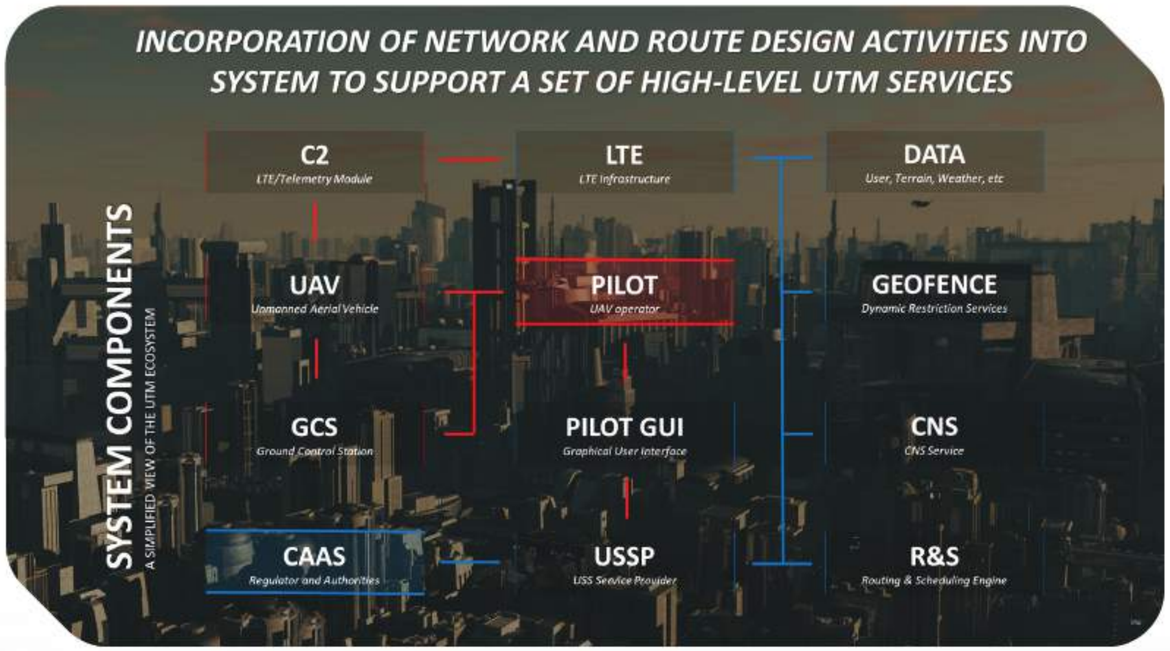
UNMANNED AIRCRAFT SYSTEMS TRAFFIC MANAGEMENT OPERATIONS

The Civil Aviation Authority of Singapore supports innovative and beneficial uses of drones and adopts transformative unmanned aircraft technologies.

One such technology is the Unmanned Aircraft Systems Traffic Management (UTM) system, which CAAS is driving to support the growing use of drones in operations and applications across industries such as Drone Aerial Photography and Videography, Surveying and Mapping of terrain, and Infrastructure Inspection.

In order to carry out drone operations, drone operators need to know where their drones are flying in real-time, and authorities and airspace managers need to know likewise in order to manage aviation safety and public security.

This system helps to manage these drone traffic, allowing operations to happen in a safe and efficient manner, and provide airspace situational awareness.

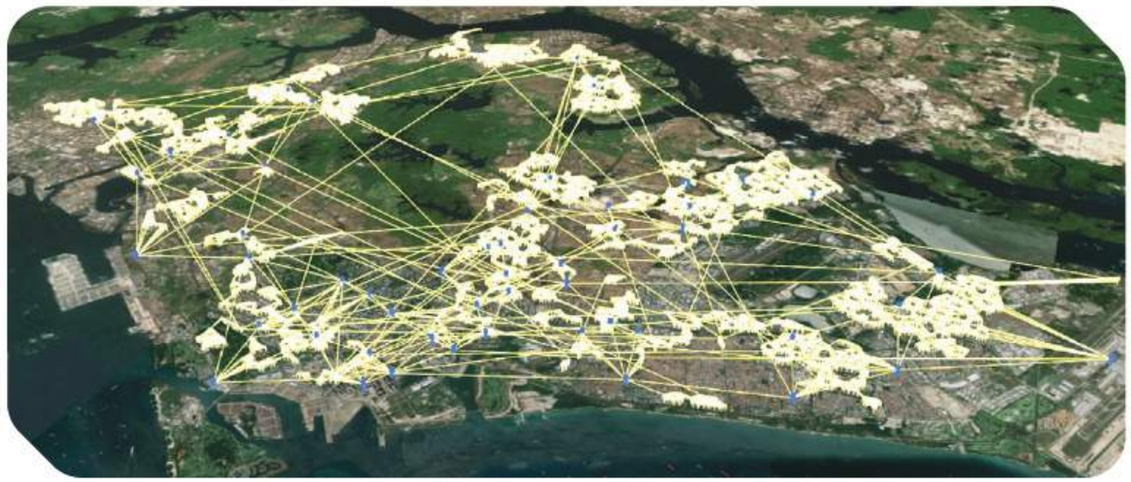


UNMANNED AIRCRAFT SYSTEMS TRAFFIC MANAGEMENT OPERATIONS

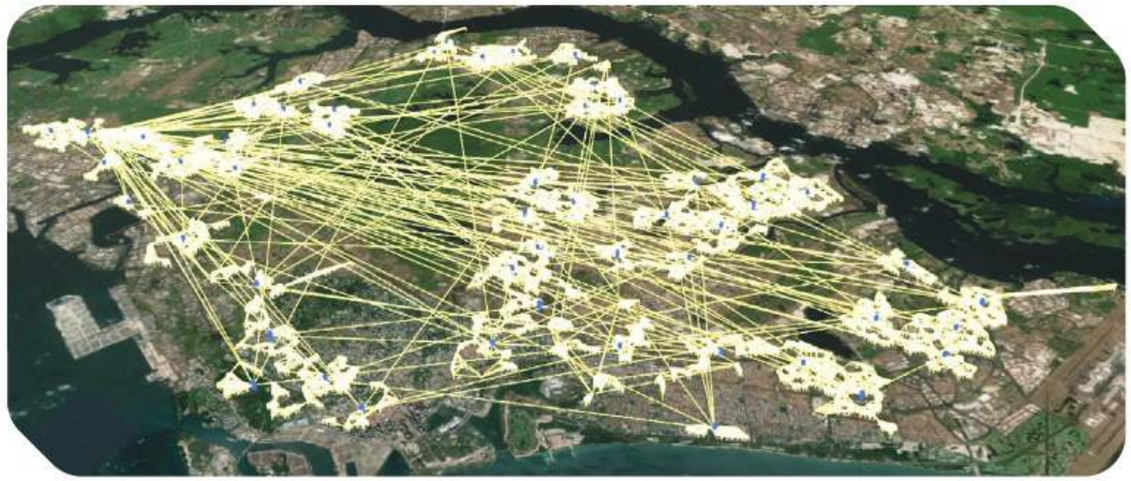
To ensure that the UTM system is able to perform optimally and efficiently, it is vital to have a secure and capable cellular network.

Heron Tech conducted several drone flight trials using the 4G/LTE cellular network to assess its suitability for various UTM system applications, investigate the impact of increased drone traffic on the overall performance of the UTM system, and to examine the network's capacity to handle the increased drone traffic in the air.

Two hub-and-spoke traffic networks were also developed by Heron Tech for simulation tests to enable strong network connections between drones. These networks encompassed a Collision Risk and Routing Modelling (CRRM) system, which focused on minimising drone collisions with obstacles and optimising flight routes. The outcomes from the trials provided valuable insights for further development and enhancement.



Baseline hub-and-spoke Unmanned Aircraft traffic network with SingPost offices as hubs and HDB buildings as spokes



Optimised hub-and-spoke Unmanned Aircraft traffic network with cluster centers as hubs and HDB buildings as spokes

MYDRONEFLEETS FOR AIRSPACE SITUATIONAL AWARENESS

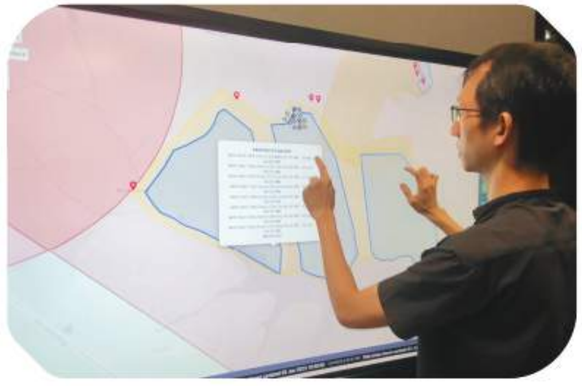
The Civil Aviation Authority of Singapore (CAAS) plays a vital role in supporting and driving the use of drones for various applications. CAAS Unmanned Aircraft (UA) regulatory requirements ensure UA operations can be facilitated while maintaining aviation and public safety.

CAAS recognises the diverse uses of UA in Singapore and has worked closely with UA operators to facilitate the deployment of innovative drone technology and applications such as infrastructure inspections and critical facilities surveillance.

In 2023, CAAS facilitated the International XPRIZE Rainforest competition, where various industry applications were showcased and demonstrated.

MyDroneFleets by Garuda Robotics enables tracking and visualisation of drone flights, making it easy for airspace and drone fleet managers to manage drone operations safely, in compliance with local regulations.

It enabled Beyond Visual Line of Sight (BVLOS) flights for 100 drones at the XPRIZE Rainforest semifinal competition, where 13 international teams showcased their drone technologies for assessing rainforest biodiversity.

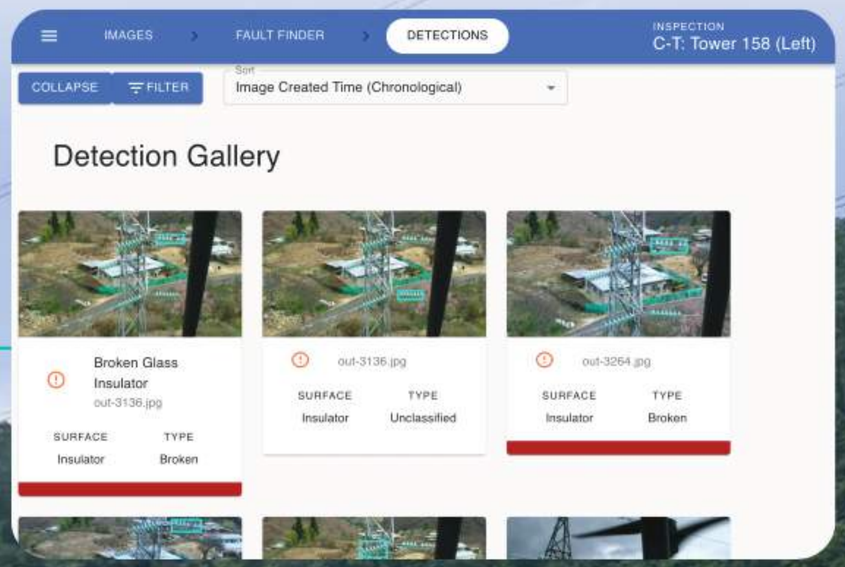


AI-POWERED DRONES FOR INSPECTION AND SURVEILLANCE

Overwatch by Garuda Robotics is an AI-powered inspection and surveillance system for critical infrastructure.

Using drones and AI enable safety inspections for difficult-to-reach areas and surveillance of critical facilities to be conducted more efficiently and safely.

Overwatch is used by enterprise and government customers in Singapore, Malaysia and Bhutan.



AIR TRAFFIC MANAGEMENT

CAAS ON THE FOREFRONT OF ATM INNOVATION

The Civil Aviation Authority of Singapore (CAAS), a leading Air Navigation Services Provider, has embarked on its research and development programmes to achieve 3 key strategic objectives:

1. Provide safe and efficient Air Navigation Services to meet current and future needs
2. Ensure resilience
3. Develop capabilities to maximise capacity and ensure business continuity

CAAS has delivered new concepts of operations and implemented prototypes, built an ecosystem of research institutions supporting technology developments, and grown local capabilities in key Air Traffic Management (ATM) R&D areas.

The projects showcase the key capabilities that CAAS has achieved with research institutions:

(i) Airspace and Aerodrome modelling
(ii) Airspace design
(iii) Open ATM architecture
(iv) Machine Learning and Artificial Intelligence applications

CAAS – THALES
AVIATION INNOVATION AND RESEARCH LAB (AIR LAB)

AIR TRAFFIC MANAGEMENT (ATM) TWIN

PROJECT BACKGROUND

The ATM Twin supports ATM application research and development. It is a virtualised replica of the live operational CAAS ATM system in a cloud environment.

The ATM Twin allows for new applications and tools to be tested and trialled in an operating environment without disrupting live Air Traffic Control (ATC) operations. It also allows interactions / communication with the ATM System via Application Programming Interfaces (APIs) to ease the development of new applications.

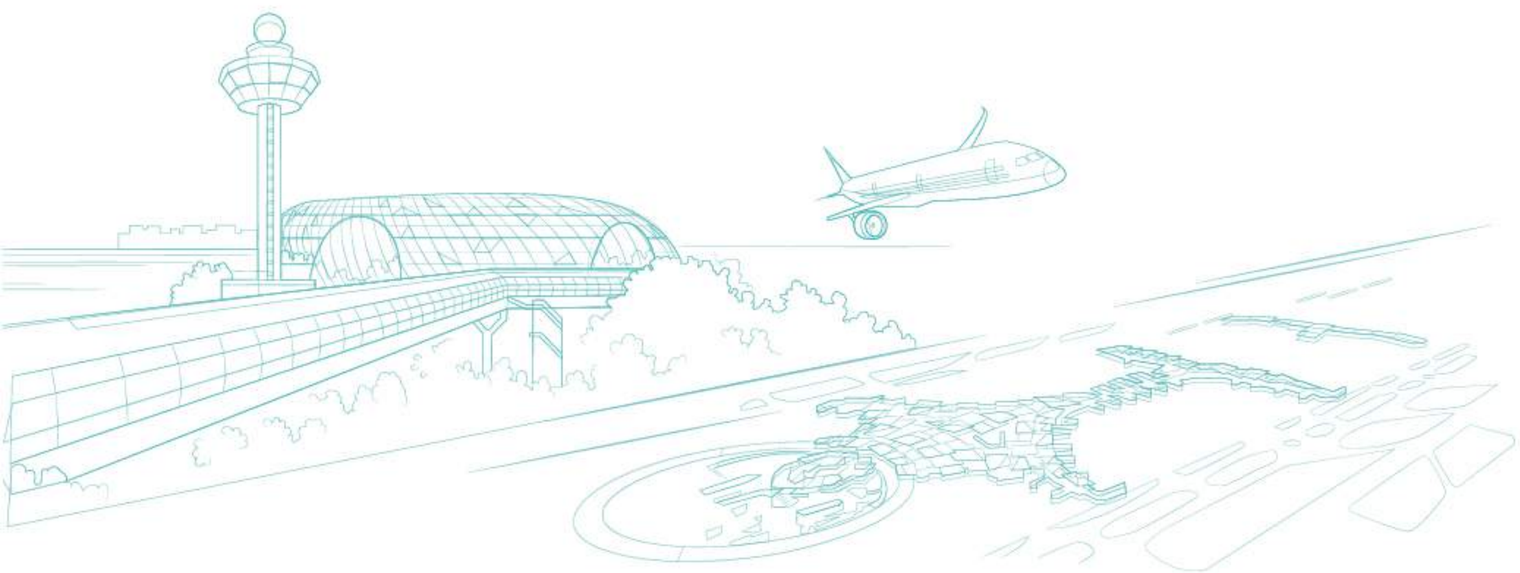
PROJECT OUTCOMES

The ATM Twin project will deliver a high-fidelity digital twin for ATM System in a cloud environment with live data.

A prototype Continuous Descent Operations (CDO) Advisory Tool (CAT) was developed with the aid of the ATM Twin.

CDO is an aircraft operating technique which enables the pilot to execute an optimised arrival descend profile using instrument flight procedure design and ATC procedures.

The CAT prototype provides the Air Traffic Control Officer (ATCO) with advice on which arriving flights are most suitable for CDO operations.



ABOUT AIR LAB

CAAS and Thales jointly established AIR Lab in 2019, to conduct R&D into open ATM concepts and the development of an ATM Twin to test and validate new concepts of operations.

AIR LAB
Powered by CAAS and Thales

SUTD – ASI
(AVIATION STUDIES INSTITUTE)

AIRSPACE DESIGN GAME

PROJECT BACKGROUND

Route networks exist for air traffic to fly safely and efficiently.
When designing these routes, there are some trade-offs. The Airspace Design Game was designed as a tool for engagement to help raise awareness and appreciation amongst students, build understanding of the various design trade-offs and the challenges in developing optimal airspace designs.

PROJECT OUTCOMES

ASI developed a software prototype that posed design challenges and required users to make iterative design decisions, with scoring on interdependent metrics.

It aided also in the engagement of students - including raising awareness of how the aviation industry adopts technology (modelling and simulation) to design solutions for complex airspace challenges.

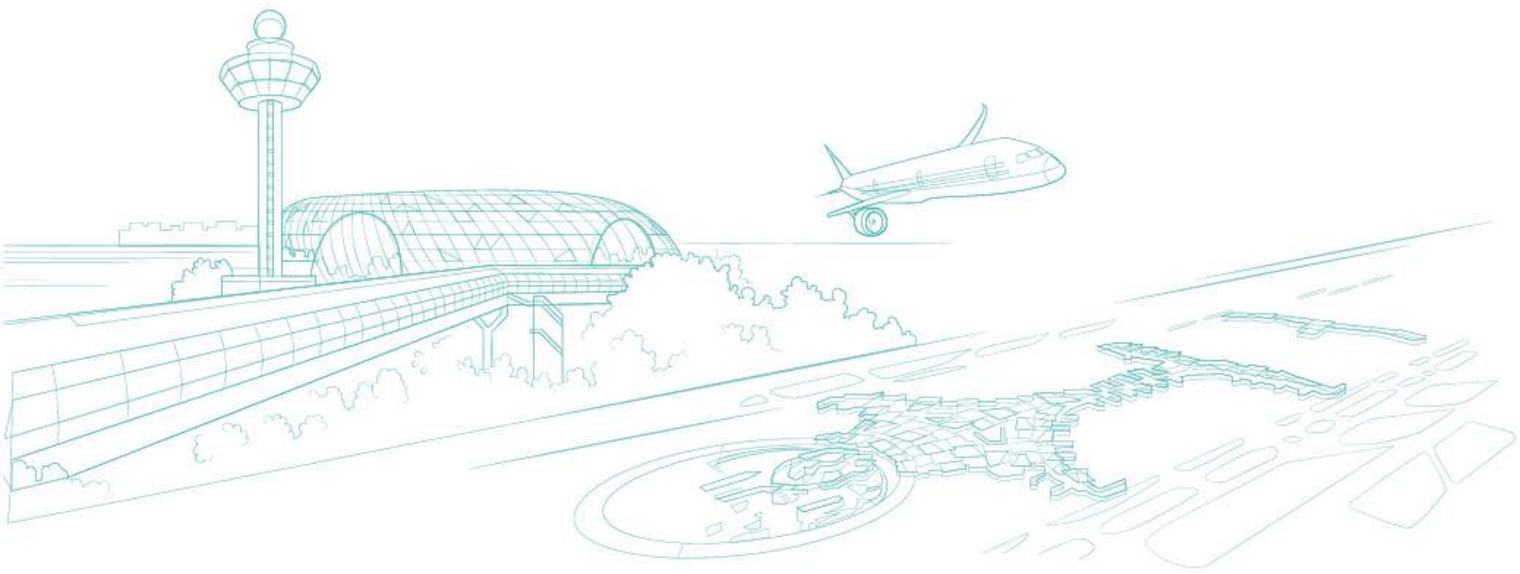
ABOUT THE AVIATION STUDIES INSTITUTE

The Aviation Studies Institute in the Singapore University of Technology and Design was established jointly with the Civil Aviation Authority of Singapore in 2019. Its goal is to establish a world-leading centre of aviation policy research and thought leadership.

It is dedicated to address the needs of aviation stakeholders in general and ATM policymakers in particular to advance the development of aviation in the Asia Pacific region.

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN | Aviation Studies Institute

ASI Aviation Studies Institute



NTU – ATMRI
(AIR TRAFFIC MANAGEMENT RESEARCH INSTITUTE)
A DEEP REINFORCEMENT LEARNING APPROACH FOR INTELLIGENTLY MANAGING AIRPORT AIRSIDE CONGESTION

PROJECT BACKGROUND

Airport taxi-way delays adversely affect airports and airlines around the world. Such delays waste fuel, lower operational efficiency and may cause poor travel experiences and missed connections.

Airport Departure Metering (DM) is an airport surface traffic management procedure in which departures are held at gates and are released at appropriate times to reduce airside congestion.

PROJECT OUTCOMES

The DM helps the departing aircraft reach the runway just-in-time for take-off while preventing long queue formation.

The learnt DM policy was evaluated under different traffic densities. In medium-density traffic scenarios, it shows a reduction of ~44% in taxi-out delays. This corresponds to a 2-minute saving in taxi-out time per aircraft.

ABOUT AIR TRAFFIC MANAGEMENT RESEARCH INSTITUTE

The Civil Aviation Authority of Singapore and Nanyang Technological University jointly established the ATMRI in 2013, with the vision to set up a renowned ATM research institute, finding innovative solutions and catalysing ATM transformation in the region.

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