SPECIAL DRONES REPORT

The NTU Professor Kin Huat Low (left) and Air Traffic Management Research Institute Deputy Director Mohamed Faisal Bin Mohamed Salleh discuss a NTU-developed air traffic simulation of drone traffic over Singapore

Critical Faculties

Singapore has limited airspace and dense population, making it vital to develop an unmanned traffic management system to handle ever increasing drone traffic

Researchers at Nanyang Technological University in Singapore are looking for ways to make sure unmanned aerial vehicales (UAV) can safely share the airspace.

The team at NTU Singapore is focusing on developing a system that features designated airways and controls, much like how cars have traffic lights and lanes.

The four-year project is called Traffic Management of Unmanned Aircraft Systems (TM-UAS) and is led by NTU's Air Traffic Management Research Institute (ATMRI), a joint research centre led by NTU and the Civil Aviation Authority of Singapore (CAAS) whose goal is to develop air traffic management solutions for Singapore and the Asia Pacific region.

"At NTU, we have already demonstrated viable technologies such as UAV convoys, formation flying and logistics, which will soon become mainstream," says NTU professor Kin Huat Low, who is leading the research. "This new traffic management project will test some of the new concepts developed with the aim of achieving safe and efficient drone traffic in our urban airways."

To ensure traffic is regulated throughout Singapore, researchers are looking at establishing coordinating stations for UAS traffic to track, schedule traffic flow, monitor speeds and ensure a safe separation between drones.

Various scenarios will be tested using computer simulations with the goal to optimise UAS traffic routes and minimise traffic congestion. Researchers will test several concepts such as geofencing and also work towards developing sensors for collision detection. Researchers are expected to complete the initial phase of conceptual design and software simulation by 2018.

Air Traffic Management caught up with Professor Low to find out more.

ATM As an expert in robotics and UAVs, where do you start in terms of developing a solution that is tailored to the future challenges faced by Singapore given the huge growth of UAV traffic expected over the next decade?

KHL We aim to develop a safe and efficient traffic management and monitoring system to enable large-scale and mixed-mode UAS operations in the future. In order to achieve this goal, we are first working on geo-fencing, command and control, detect and avoid, and efficient route finder technologies. All these will have to be integrated in order to maximise the economic benefits of the commercial and service applications of UAVs, while ensuring the safety of the airspace within an urban environment.

The TM-UAS programme is more than just the design of UAVs and the development and performance of the aircraft systems; it covers the traffic management of multiple UAVs operations in a specific area, especially in limited and complex urban airspace. The programme is about a system of systems. It is similar to how air traffic management is required for a huge number of manned aircraft operating in local and global airspace. Similar to how crucial traffic lights, signboards, speed limits, and rules are when it comes to high-volume road traffic in city areas, such considerations and features are essential in urban airspace too.

We are keen to partner with local and international government agencies, industry end-users, and technology enablers interested in UAV operations. In fact, we have been approached by many interested parties - industry, commercial, and government

bodies and we are in a process of exploring possible collaborations. These partnerships will allow us complement each other's strengths and achieve synergies. One such partnership is with Analytical Graphics which assisted in the development of a UAS Traffic Management (UTM) solution.

ATM How do you go about developing a scaleable solution capable of providing a system in an environment set for such explosive growth?

KHL The technology for CNS (Communication, Navigation and Surveillance) is well established for manned aircraft in controlled airspace. This enables separation standards to be prescribed across international waters. In contrast, the platform supporting small UAV operations in uncontrolled or urban airspace lacks the required CNS technology.

With these challenges in developing CNS technology, the solutions developed for this programme are structured to be modular and scaleable; starting from modelling and simulation to pilot studies and trials for a specific urban environment and specific Concept of Operations (ConOps) to extending the UAV operations island-wide.

Key enabling capabilities such as geofencing and detect and avoid are also critical in enabling efficient and safe operations. We are going to select a specific urban area as our test site to verify each identified technologies integrating with the traffic management system as well. We might also extend the system trials to other areas with different layouts and complexity, and eventually cover the whole island in different stages.

ATM In your work at NTU, you have already demonstrated viable technologies such as UAV convoys, formation flying and the associated logistics. Are there any favoured modes of operation where drone operations are concerned?

KHL The traffic management system that we are working on aims at satisfying various kinds of UAS application requirements. But at the end of the system demonstration phase, we may select main UAS operation types such as delivery, surveillance, inspections etc.

ATM You are planning to test various new concepts as part of this new traffic management project with the aim of achieving safe and efficient drone traffic in Singapore's urban airways. How will you go about designing these tests?

KHL In principle, a holistic risk and safety management system should be developed for TM-UAS, which would support multiple and mixed operations depending on various factors such as level of UAV traffic in the network, weather, complexity and layout of the operation areas, features of applications etc.

That is why risk management is also one of our important research areas. After that, we have to study how to improve efficiency since Singapore has such limited airspace. To study the real issues and challenges faced as much as possible, our concepts will be demonstrated in an outdoor test site. We are going to verify those identified technologies individually before integrating all of these technologies for a complete traffic management and monitoring system.

ATM What considerations will you apply and what do you hope to learn?

KHL The TM-UAS programme will consider: finite airspace with restricted, prohibited and danger areas; class of UAVs; types of applications and operations; urban infrastructures; CNS coverage; risk assessment and management for respective operations and applications; and the optimisation of limited airspace, balancing capacity and requirements and identifying the potential risk and contingency operation. We plan to verify our ideas in both simulation and experiments and hope to learn how the urban airspace can be optimally and dynamically managed.

Taking UAV traffic route optimisation as an example, it will be essential to simulate different operating UAV quantities, entry points and exit points to verify its efficiency. Also, we would consider multiple deliveries in different applications from designated take-off and landing sites in specific zones.

ATM Will you approach UAV operations differently depending on the eventual application of a drone application. For example, emergency service applications as opposed to parcel delivery?

KHL Yes, while the guiding principles can be applied broadly across all operations, each UAV operation should be assessed separately by taking into consideration the factors impacting its operation. This is because different UAV operations have different requirements for traffic management services and technology capabilities. Therefore, the UAV operations need to be approached differently.

ATM Given today's climate of uncertainty, how will your research effort address security and identification concerns?

KHL The tracking and monitoring module is an important part of the traffic monitoring system. Before flight, all commercial and civilian UAVs will need to be registered.

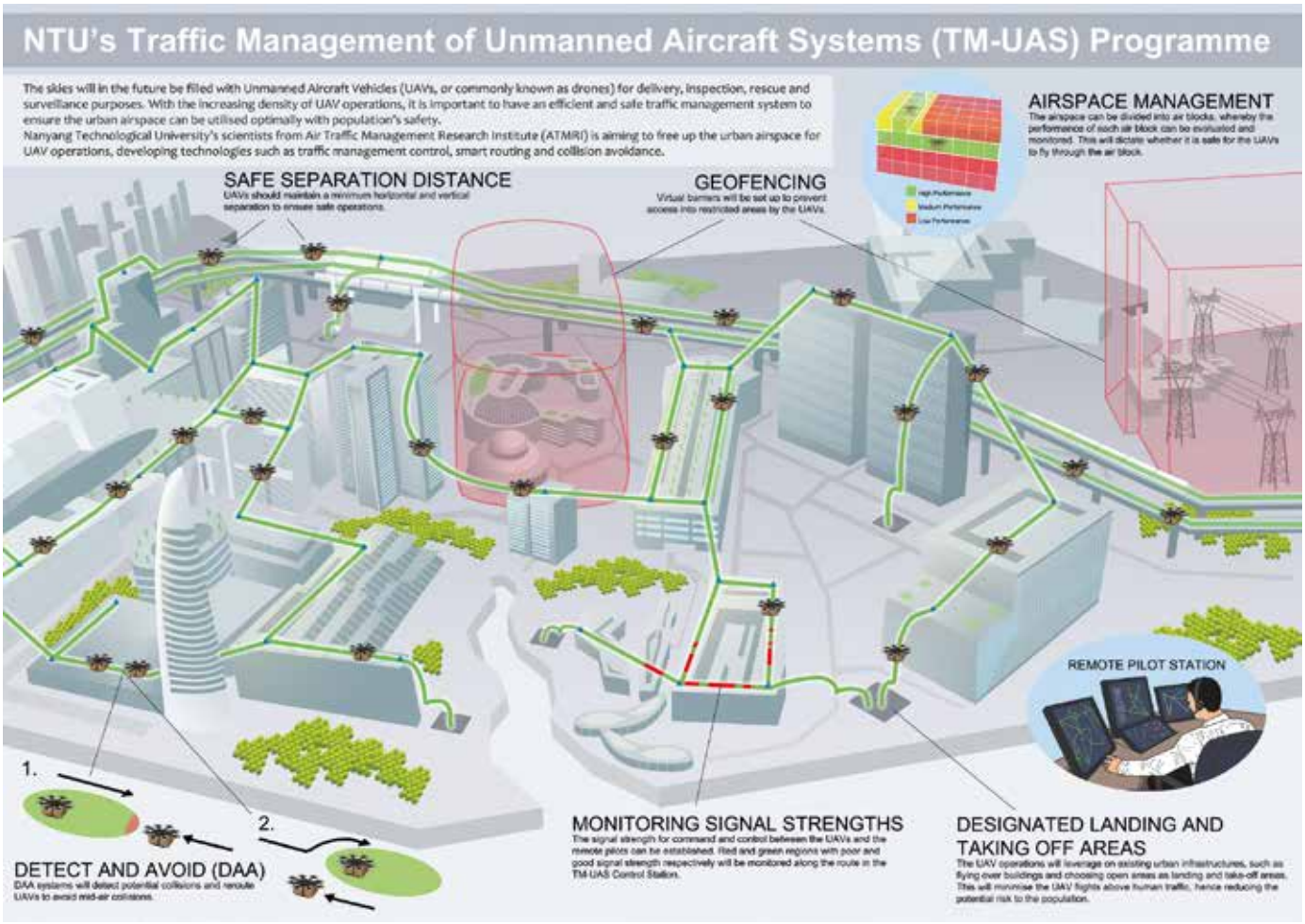
During flight, they have to continually report their status and position to the control centre. If any emergency occurs, the traffic control centre will know immediately and take appropriate actions to mitigate the potential risk. Weather information, for example, the wind speed surrounding UAVs, will be an important input of the traffic management system. Besides requiring UAVs to have some weather-resistance capacities, we are also considering having specific take-off and landing points for such kind of emergencies. In addition, there is an ongoing study to understand cyber security threats to traffic management and UAV systems.

ATM You have said that to ensure that traffic is regulated across the whole of Singapore; one possible solution would be to establish co-ordinating stations which can track, schedule traffic flow, monitor speeds and ensure a safe separation. What CNS infrastructure are you envisaging here?

KHL To be able to realise as soon as possible the safe integration of UAS into national airspace system, one should make good use of the existing infrastructure. This will definitely save time and cost as well. In contrast to many countries, Singapore has a very good network coverage. We may consider the use of cellular network or ADS-B for communication and surveillance. Most of the current UAVs are already using GPS for navigation. We might also study non-GPS navigation since the GPS signal is often weak at low altitude due to a lot of obstructions. The safe separation between UAVs in lateral, horizontal, and vertical directions are different for every operation and application. Ultimately, we envision a central control station that will manage UAV traffic operations, safely and efficiently in Singapore's urban airspace.

ATM Your researchers will also be looking into proposing safety standards, for instance how high UAVs should fly and how far they should be flying above buildings, taking privacy concerns and local laws into consideration.

KHL The programme will consider technology capabilities, constraints, and aircraft performance alongside appropriate traffic management. The relevant risk assessment and management can then be translated into formulation of safety requirements for UAV operations. Of course, safety is always our first priority. Various measures to tackle privacy concerns may include implementation of appropriate regulations, restriction and special requirements of components installed on the UAV. ▶



ATM Will these considerations be unique to Singapore or do you think there will an effort to standardise on an international basis?

KHL Singapore would be an ideal test bed to demonstrate the integration of UAV operations with the established urban infrastructure. This could act as a reference for international guidelines for other urban cities. We hope that Singapore will be the pioneer in this area and lead the way for other densely populated cities.

ATM One proposed strategy in Singapore is to use the current infrastructure such as open fields for take-off and landing and buildings and tower blocks acting as emergency landing sites to minimise risk to the public. Does that require designated UAV operational areas?

KHL Yes. Besides that, there might also be a designated UAV control centre in appropriate locations.

ATM Will these need a safety perimeter for operations?

KHL Yes, it is definitely necessary, especially in an urban environment. Also, the safety perimeter might vary for each operation because of the condition and layout of the operational site. In addition, the design and study of flight routes and layers in different zones - or sectors - will be introduced for safe and efficient UAV operations at low altitude in the urban environment.

ATM Restricted airspace and zones where UAV operations are prohibited have been identified, such as near airports and military facilities. How will you go about testing concepts that support this, such as geofencing where virtual fences will force UAVs to automatically reroute around a restricted geographical location such as an airport?

KHL The concept of geofencing will be simulated and the platform required for testing will be included in a future demonstration phase. All of these restricted zones will be pre-programmed into the UAV's flight control system. The flight control system is like the brain of the UAV, it will know which areas are prohibited etc. We will test these concepts in real flight demonstrations.

ATM UAVs will need to have sensors that enable detection and collision avoidance. This will allow UAVs to avoid mid-air incidents, such as flying above, below, or around other UAVs. What sorts of technology will you be examining here?

TM-UAS: For detection and avoidance, there are two kinds of technology: co-operative and unco-operative. ADS-B is one option for co-operative technology. For unco-operative technology, vision-aided detection or LiDAR may be considered. Also, the technology could be both onboard UAV and ground-based.

ATM Finally, this multidisciplinary research initiative will bring together researchers from many different fields within NTU, from aerospace engineering and air traffic management to robotics and electronic engineering. How will this effort be best organised if the actual test bedding of solutions using UAVs developed by NTU is to lead to solutions being ready for 2018?

KHL The formulation of ConOps and associated technologies will be developed jointly with key strategic partners - commercial end-users, industry enablers, and government agencies - so as to ensure the solutions are relevant and feasible for field operations. We have also identified faculty and researchers in various research areas for such a multi-disciplinary programme. For example, people from electronic engineering will focus on communication, while people from air traffic management will work on UAV traffic management. ATM