NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Air Traffic Management Research Institute

Data Requirement and Data-Driven Framework Contributing to Safe UTM Operations

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Drone Enable Symposium 2022; Panel on *UTM Data Requirements*
Wednesday, 16 November 2022; 9:05-10:05 @ ICAO, Montreal, Quebec, Canada

UTM Co-Exists with ATM in Urban Airspaces

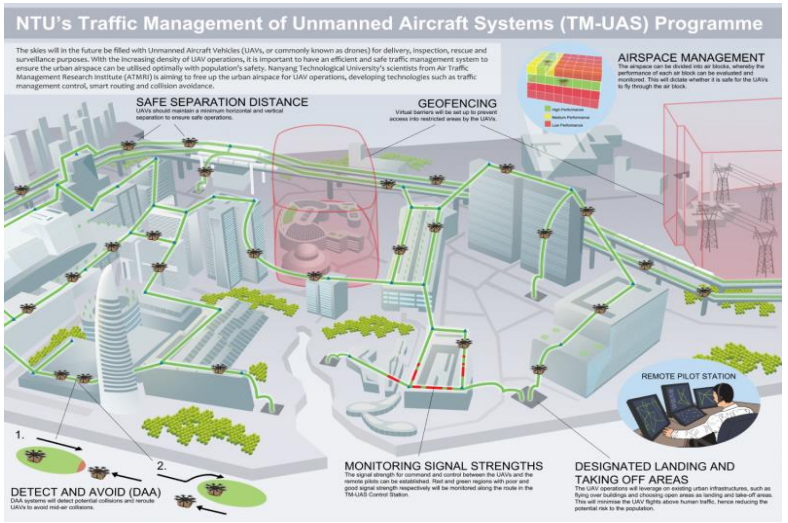
Air traffic management (ATM)

- Connects the world

https://www.weforum.org/agenda/2018/07/the-world-s-busiest-day-for-air-travel-mapped/

UAS traffic management (UTM)

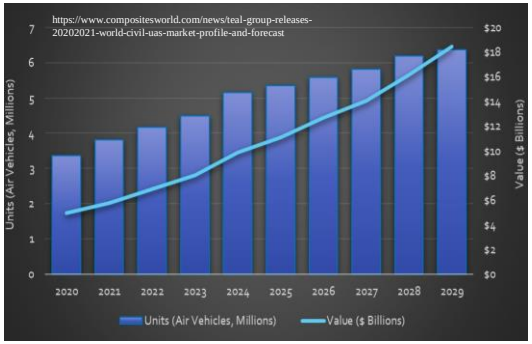
- Connects the community



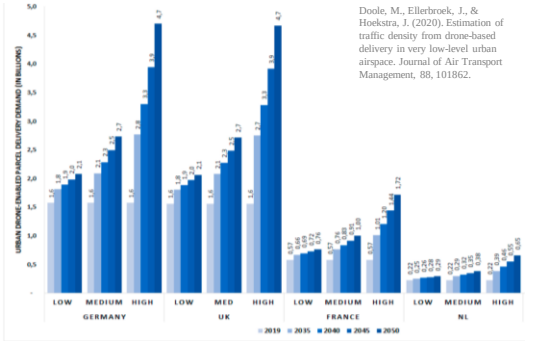
@Air Traffic Management Research Institute (ATMRI), NTU, Singapore

Emerging Demand for UAS Operations

- Significant growth in UAS traffic is forecasted by academia and industry
- Demand for UAS operations is already seen in many areas



Rapid development of the UAS industry (2020-2029)



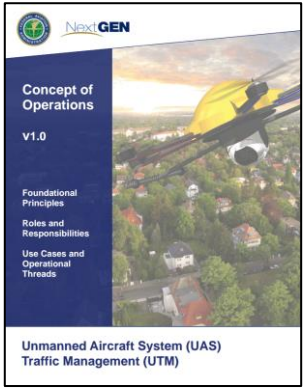
Parcel delivery in major European countries (2019-2050)

Parcel delivery

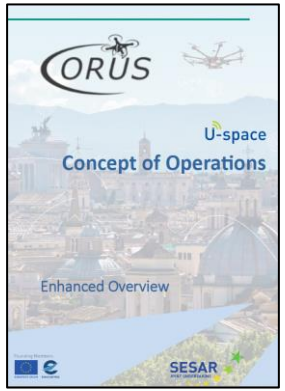
Shore-to-ship delivery

From Concepts to Real-World Operations

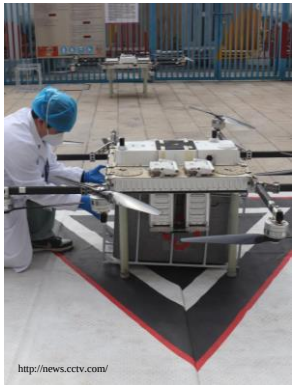
- **ConOps published by authorities**
  - Many countries and regions have published UTM ConOps
- **Initial flight operations are emerging**
  - Drones are used in food and package deliveries, emergent medical goods transportation
  - Multitude of use cases including reservoir monitoring and building façade inspection



FAA UTM ConOps



CORUS U-Space ConOps



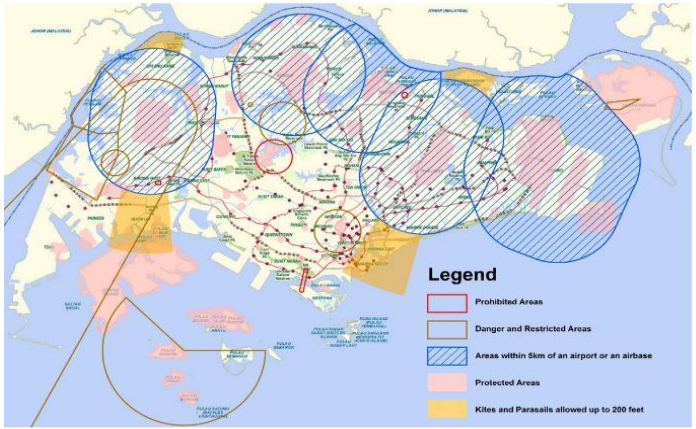
Transport of swab test samples using drones

UA delivery in Australia

Challenges: UTM Risk Management in Urban Environments

- **Singapore faces twin challenges of urban landscape with high population density and congested airspace environment**
  - Complex and restricted urban airspace
  - High ground risk due to high population density

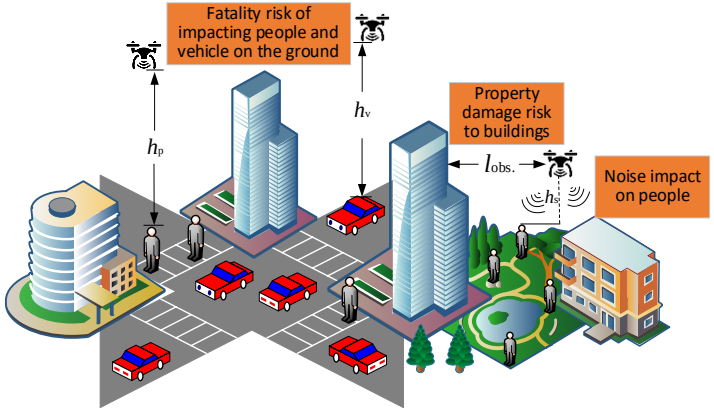
Air Risk: How to enable the safe and efficient integration of UAS into current airspace



Area limits map for UAV operation in Singapore airspace

https://www.caas.gov.sg/public-passengers/aerial-activities

Ground Risk: How to ensure the safety of UAS operations to third parties



Safety issues that UAV operates in urban environments

Pang, B., Hu, X., Dai, W., & Low, K. H. (2022). UAV Path Optimization with An Integrated Cost Assessment Model Considering Third-Party Risks in Metropolitan Environments. Reliability Engineering and System Safety, 1–18. https://doi.org/https://doi.org/10.1016/j.ress.2022.108399

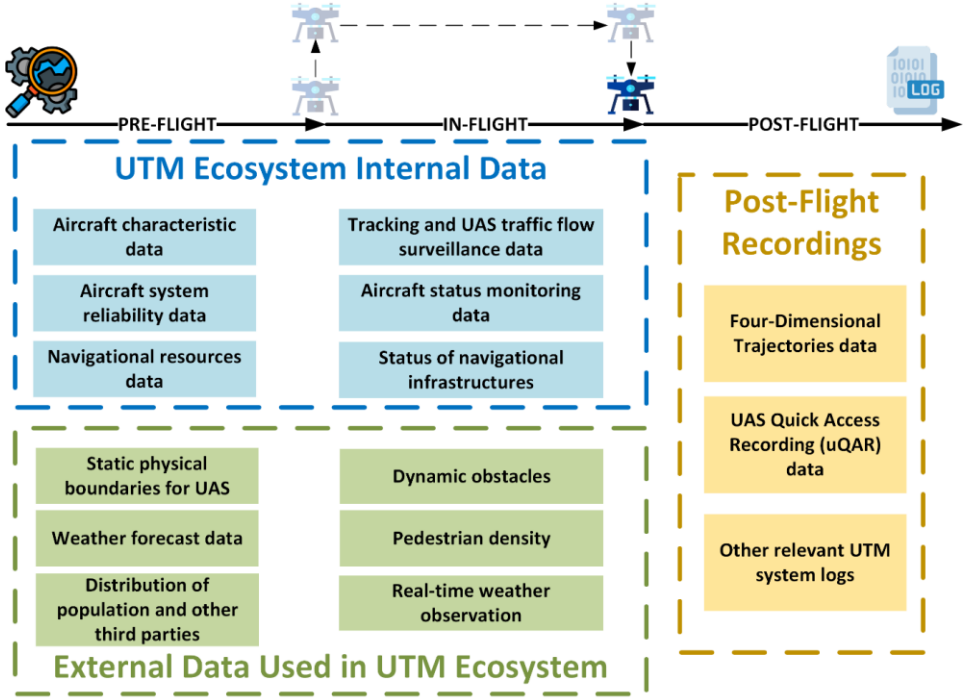
Opportunities (*Digital Era*): Data-Driven Approaches

- **Data availability**
  - Digitalization happening in many industries enables the import of data
  - Industrial practices providing experiences

- **Methodological readiness**
  - Exploding computational power
  - Maturity of data-driven methods

Required Data for UTM Safety in UAS Flight Life Cycle

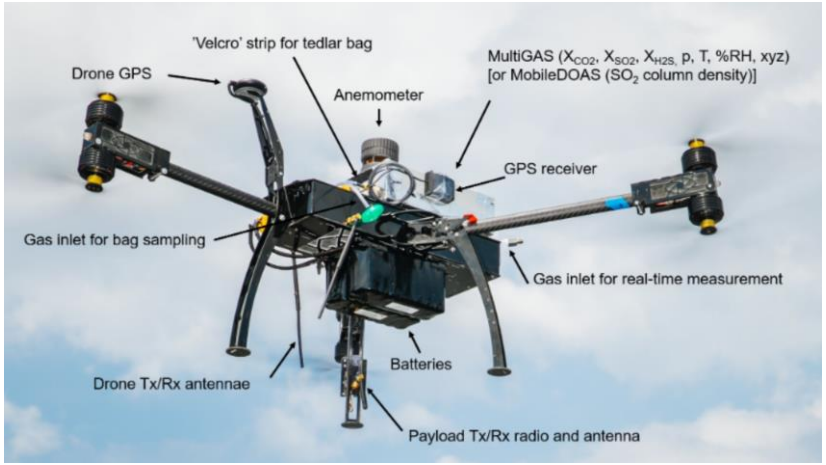
- **Pre-Flight Phase**
  - Initial screening of high-risk ops
  - Support robust flight plan
- **In-Flight Phase**
  - Conformance monitoring
  - Early prevention of hazard
- **Post-Flight Phase**
  - Empirical analysis
  - Performance review



Pre-Flight & In-Flight Phases: *Internal* Data Used in UTM Ecosystem

Data of UAS system

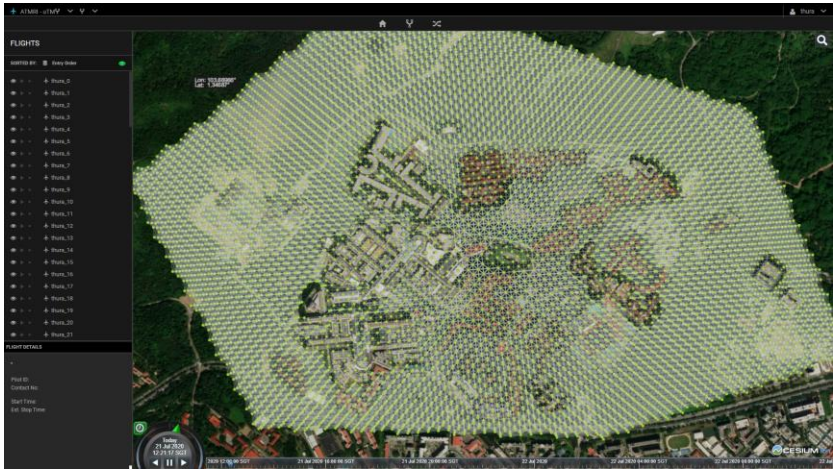
- Aircraft characteristic data
- Aircraft system reliability data
- Aircraft status monitoring data



Source: https://doi.org/10.5194/amt-14-4255-2021

Data of UTM system

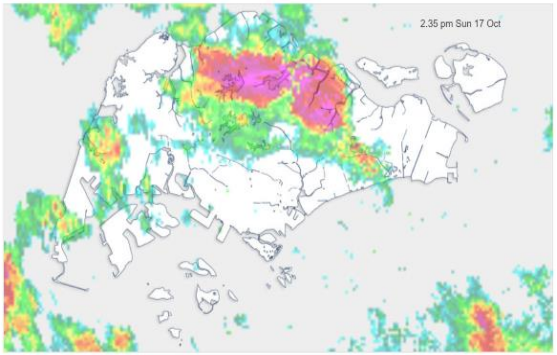
- Navigational resources data
- Tracking and UAS traffic flow surveillance data
- Status of navigational infrastructures



Pre-Flight & In-Flight Phases: *External* Data Used in UTM Ecosystem

Weather information

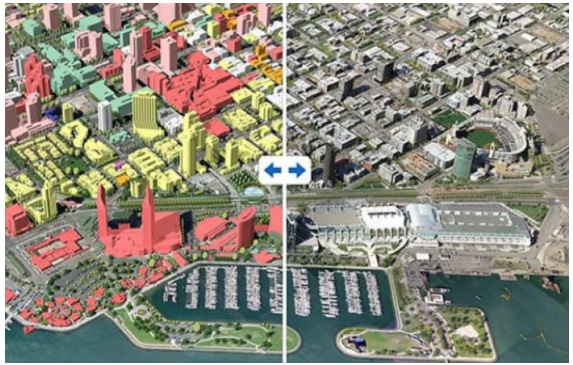
- Weather forecast data
- Real-time weather observation



http://www.weather.gov.sg/weather-rain-area-50km

Static & dynamic obstacles

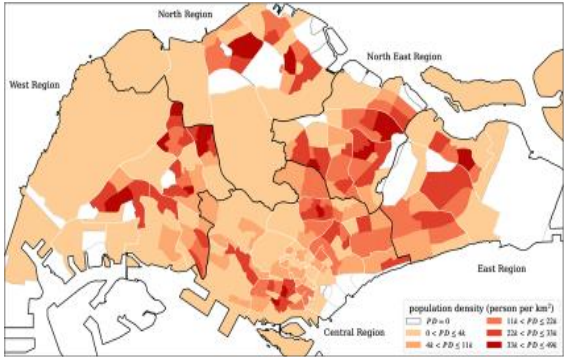
- Static physical boundaries for UAS
- Moving objects in the urban area



https://esrisingapore.com.sg/esri-cityengine

Data of UTM system

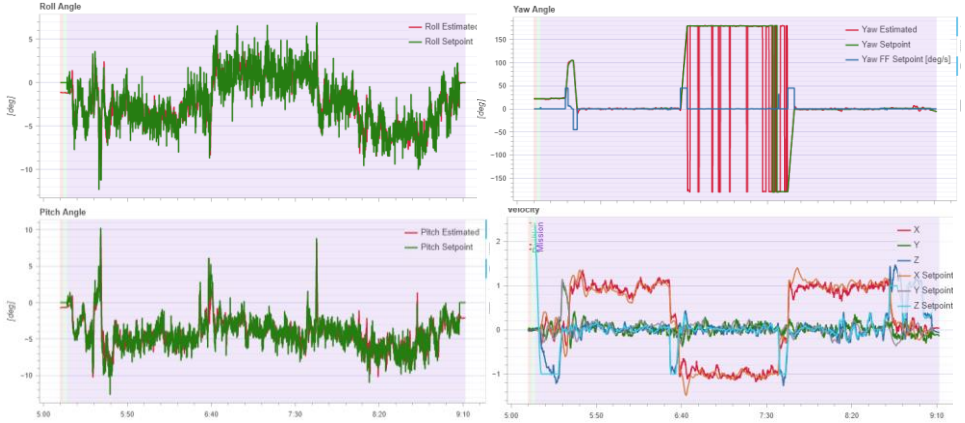
- Census population distribution
- Observed density of pedestrians and other third parties



Post-Flight Phase:
Recorded Data Used in UTM Ecosystem

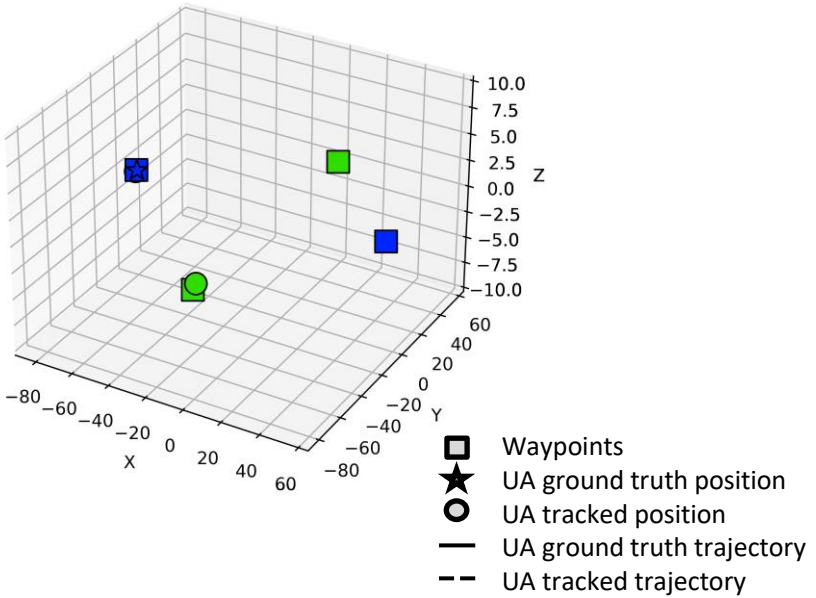
UAS Quick Access Recordings (uQAR)

- Aircraft performance review
- Aircraft maintenance review



Four-dimensional Trajectory Data

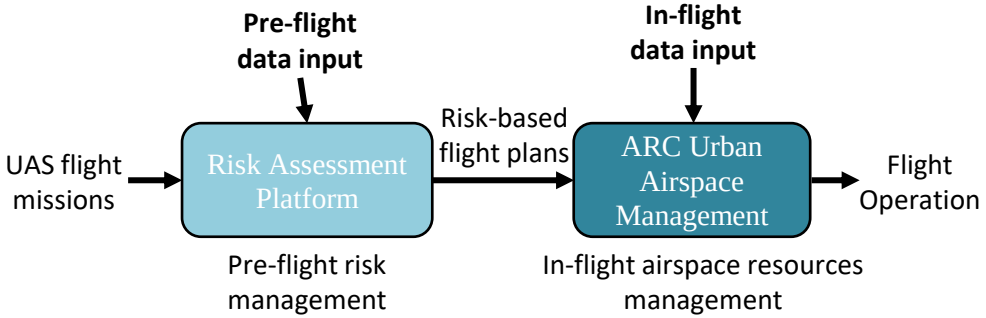
- Post-flight TSE verification
- Post-event causal analysis



Framework of Data-Driven Urban UTM

- **A framework is established to overcome the challenges by using**
  - A quantitative risk management strategy
  - Data-driven methods

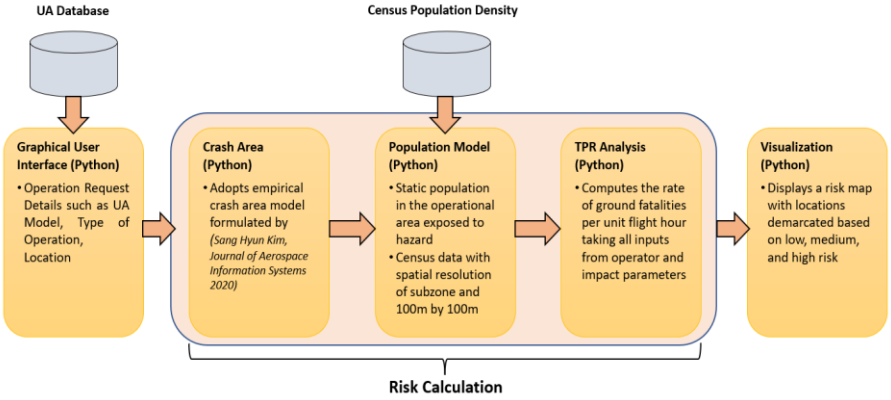
- **The framework consists of:**
  - Risk Assessment Platform
  - Airspace-Resource-Centric (ARC) urban airspace management



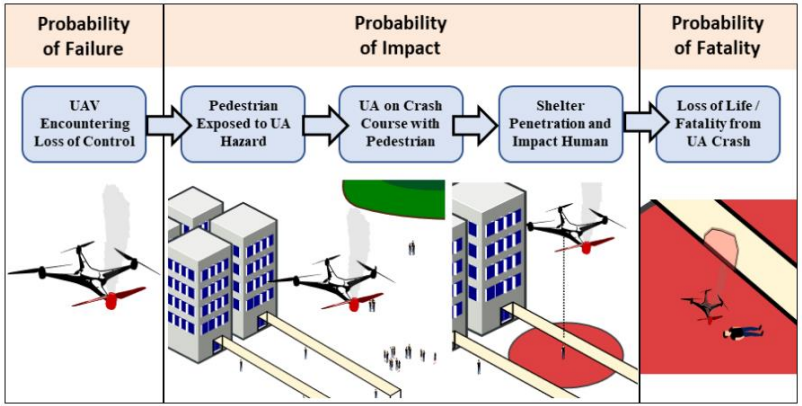
Risk Assessment Platform: Data-Driven Flight Risk Quantification

- **Risk Assessment Platform provides risk estimations at strategic and pre-tactical phases for urban UAS operations.**
  - Quantitative assessment of Third-Party Risk (TPR) uses aircraft reliability, population density, geographical, and other data
  - Preliminary version focuses on the risk of ground fatalities

Workflow of TPR assessment

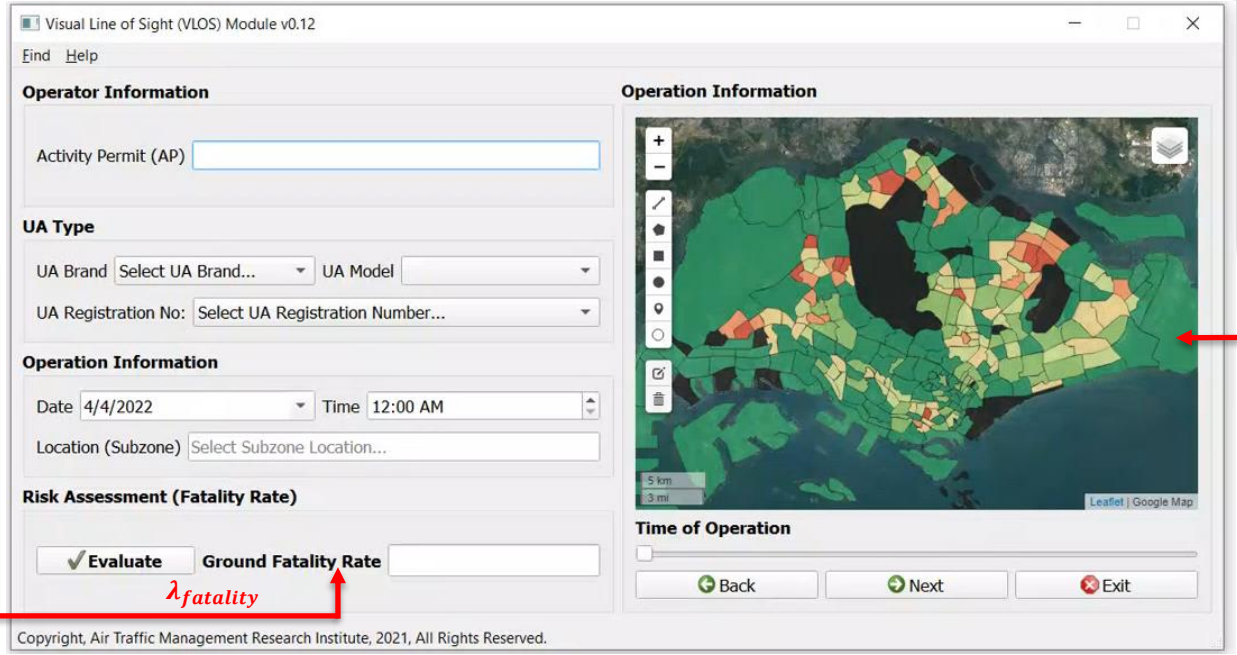


Decomposition of ground fatality risk



Risk Assessment Platform: Graphical User Interface (GUI)

- **Ground fatality rate estimation ($\lambda_{fatality}$) by given flight mission information**



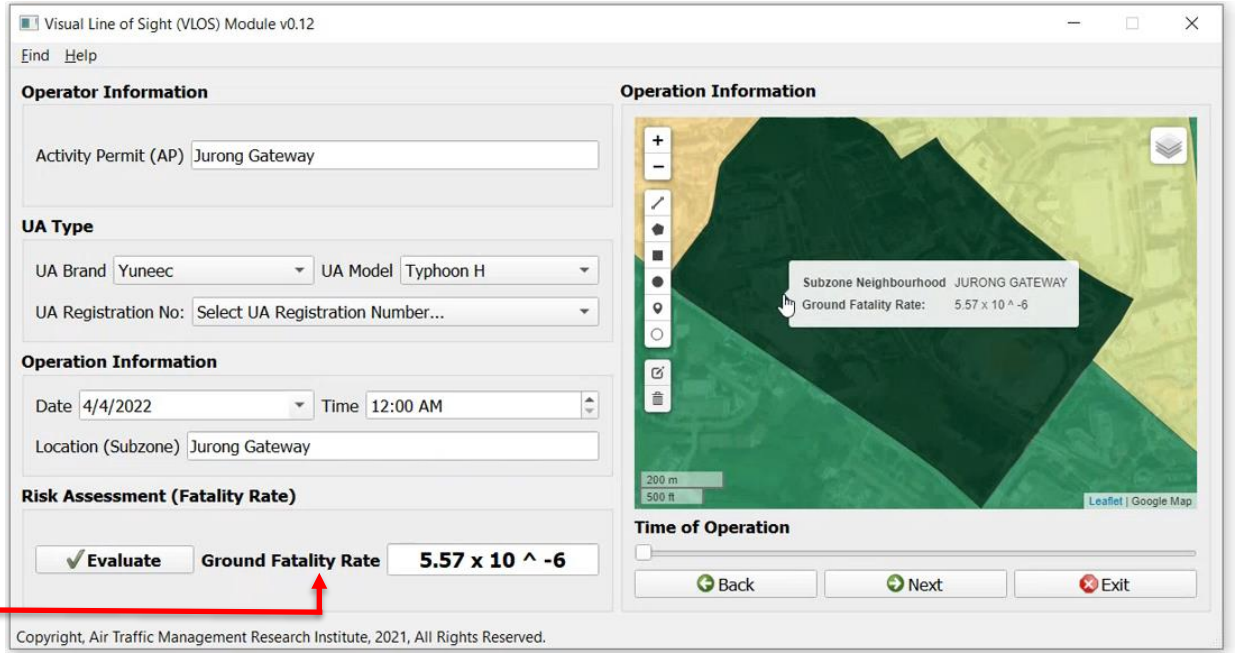
- $\lambda_{fatality}$ computed given census population density, crash area, shelter and probability of fatality
- Model adapted from **JARUS SORA**

- Colors on risk map display population density.
- Ground fatality rate indicated when a rone hovers over region.

Risk Assessment Platform: Graphical User Interface (GUI)

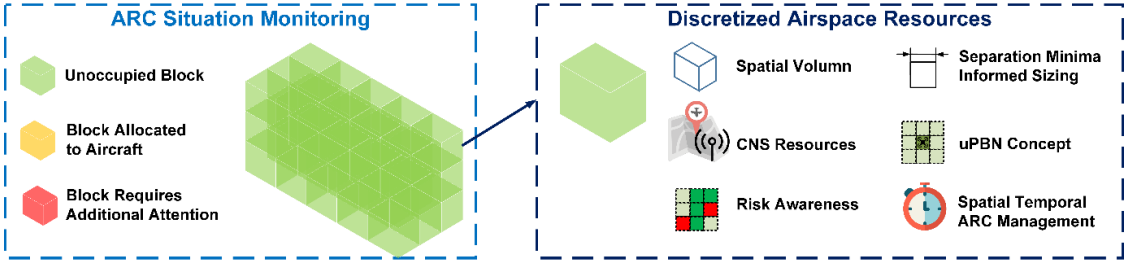
- **UA reliability threshold estimation via given Target Level of Safety (TLOS) guideline**

- Risk assessment differs when 'Other' or Custom UA selected
- UA reliability threshold estimated for **TLOS of 10^{-7}**
- Equations adapted from JARUS SORA

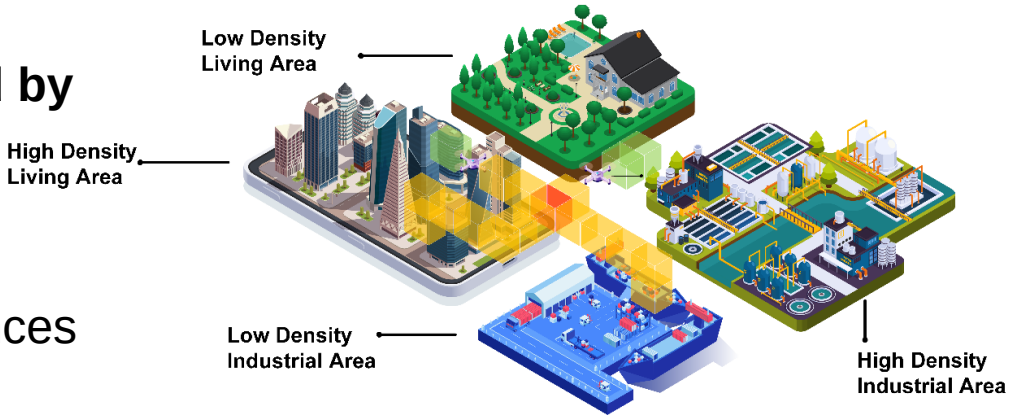


ARC Urban Airspace Management: Management Strategy

- **Discretization of urban airspace resources**
  - Spatial volume
  - CNS resources
  - Non-extreme weather and low-risk regions



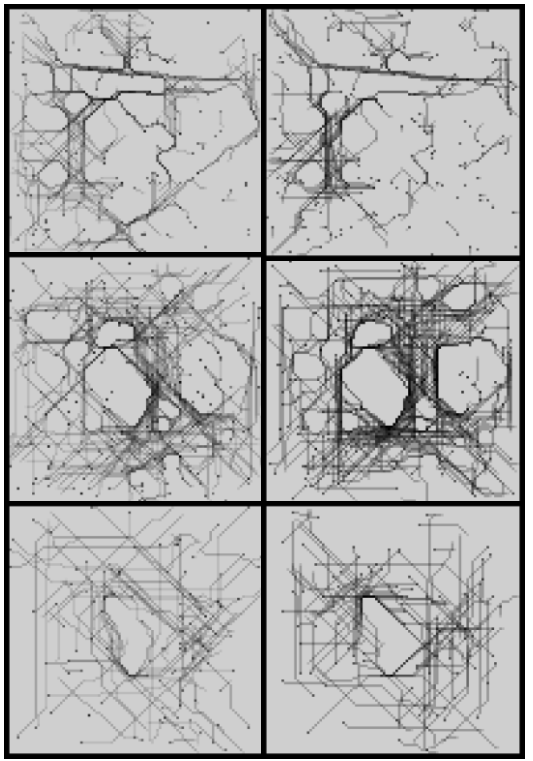
- **Safe UAS operations supported by**
  - Terrain data and ground infrastructures data
  - Weather data
  - CNS coverage and performances data
  - More other data



Conceptual illustration of the ARC approach for urban airspace management

ARC Urban Airspace Management: Illustrative Application

- The ARC approach **maximizes the utilization** of constrained urban airspace resources
- A uniform approach for **dynamic management** of airspace including resource allocation and conformance monitoring
- Compatible with advanced operational concepts
  - Risk-based flight management
  - Separation management
  - uRNP concept
  - 4D TBO
- Support quantitative analysis of airspace resources utilization effectiveness



Application example: ARC-based visualization of airspace utilization heatmap (in *different altitudes*)

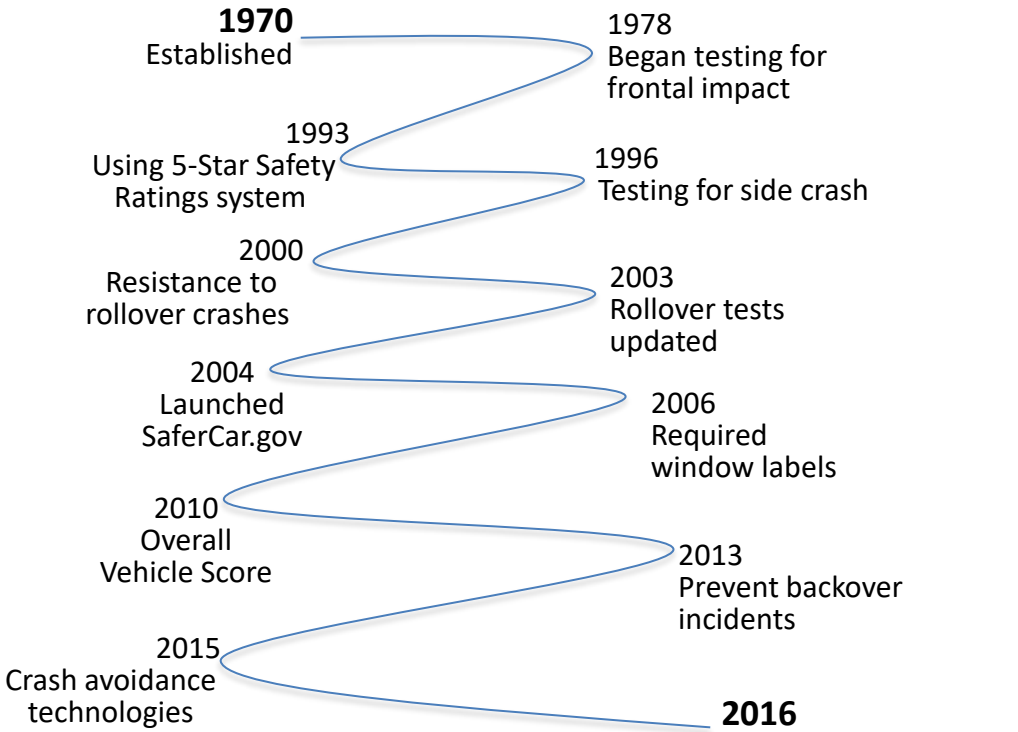
Key Takeaways

- **Data is needed in UTM to improve flight safety**
  - Applied to the pre-flight, in-flight, and post-flight phases
  - Assist the planning, monitoring, and decision-making in UTM operations
- **A data-driven framework towards a total flight phases solution has been established**
  - Pre-flight risk assessment
  - In-flight ARC approach for urban airspace management
- **Standardization of data is essential in the future UTM deployment**
  - Unify the heterogeneous data
  - Data interfaces and adaptations

Closing Remarks

Data Acquiring and Testing: Long Journey of Car Industry

Timeline of establishing standards



Source: nhtsa.gov/ratings

Supporting Tests

- Frontal crash tests
- Side crash tests
- Roof strength test
- Head restraints & seats test
- Front crash prevention tests
- Headlight evaluation
- Seat belt reminder evaluation
- LATCH evaluation
- Verification

2021 INTERNATIONAL CAR SALES

66.7m units

PASSENGER CARS ARE THE LARGEST CATEGORY OF MOTOR VEHICLE PRODUCTION

57m

Data Acquiring and Testing: Aviation Industry (IATA)

Safety and Flight Operations Data Solutions

Established to support a safe, secure, efficient, and economical air transport industry that is environmentally sustainable.

Source: iata.org/en/services/statistics/safety-data/#tab1

- **Aviation Operations Data**
  - Incident Data eXchange (IDX)
  - Flight Data eXchange (FDX)
- **Meteorological Data**
  - Turbulence Aware
  - Roof strength test
- **Maintenance Data**
  - Repair and overhaul (MRO) SmartHub
- **Safety & Quality Data**
  - Aviation Safety Culture Survey (I-ASC)
  - Integrated Management solutions (IMX)

In comparison, there is still some times and many steps away for acceptable unmanned aircraft system (UAS) operations, specially in urban environments

Like manned aircraft, cars, & driverless cars,

Mature, reliable, and sustainable UAS eco-system & implementations for safe multiple-drone operations take times,

and require several rounds of iterations, as well as collective effort and mutual "trust" among different stakeholders.

Thank you for your interest!

Feel free to reach out for feedback and collaboration:

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