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Connected Places


Throughput
Congestion
Pollution
Accidents
APL
COTUNAV


Throughput
Congestion
Pollution
Accidents


GREAT
BRITAIN

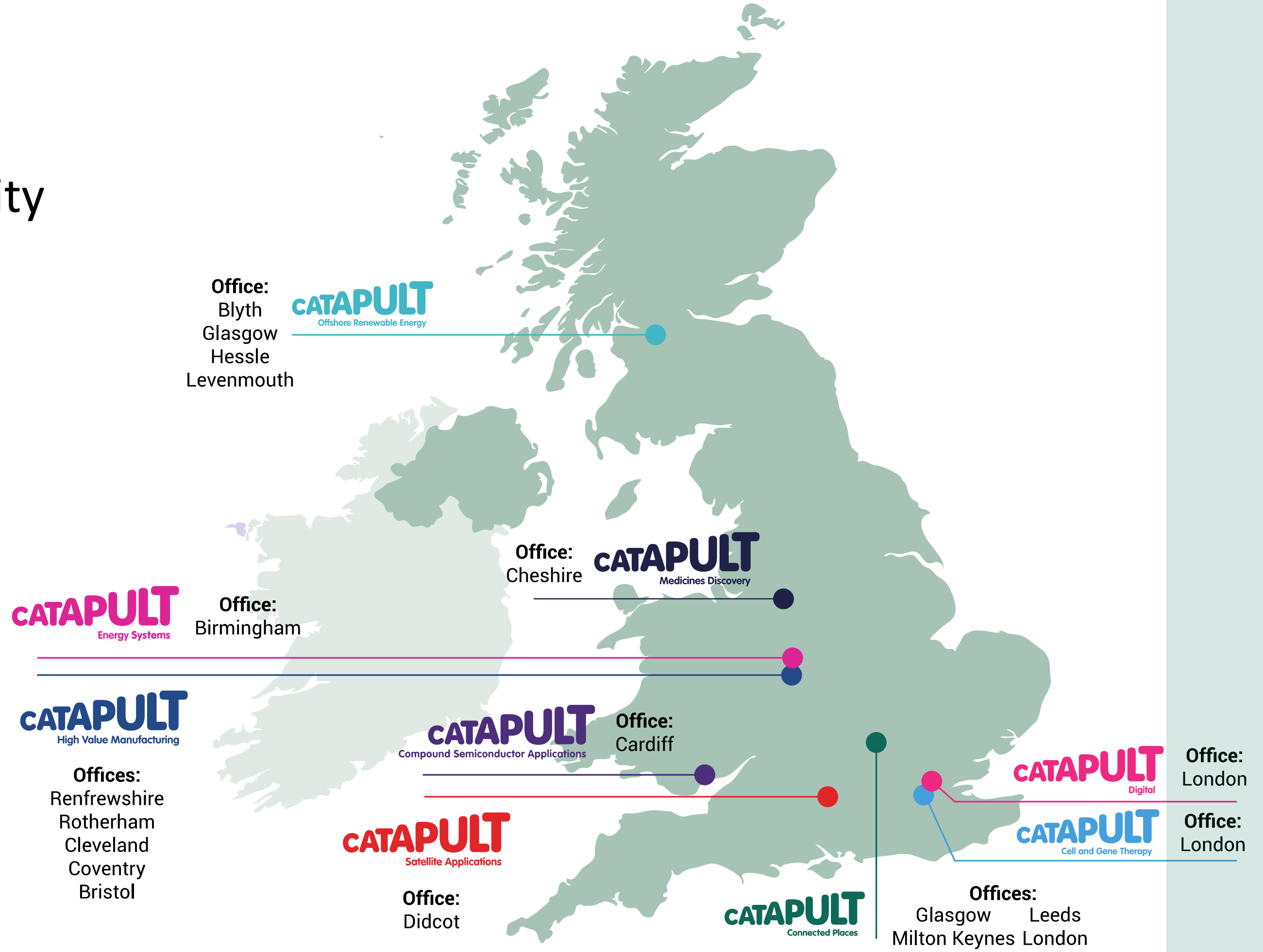

ASV
ASV

Multi-Modal Autonomy: Validation and Management

Connected Places Catapult

Catapults – a force for innovation and growth

A network of world leading centres designed to transform and accelerate the UKs capability for innovation and future Economic growth.



Our mission

To help British businesses address the grand challenges of today in order to create connected places, fit for the future.

9

Innovation Centres across the UK

Accelerating the industrial strategy

The Industrial Strategy outlines four Grand Challenges which places must address in delivering successful growth, but which also represent commercial opportunities for innovators. *These are:*

- The Future of Mobility
- Clean Growth
- Ageing Society
- AI and Data

With population and development both concentrated in urban areas, innovation in and around the places we live promises to positively impact each of these challenges, with the fourth (AI) playing a vital enabling role.

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Accelerating the Industrial Strategy

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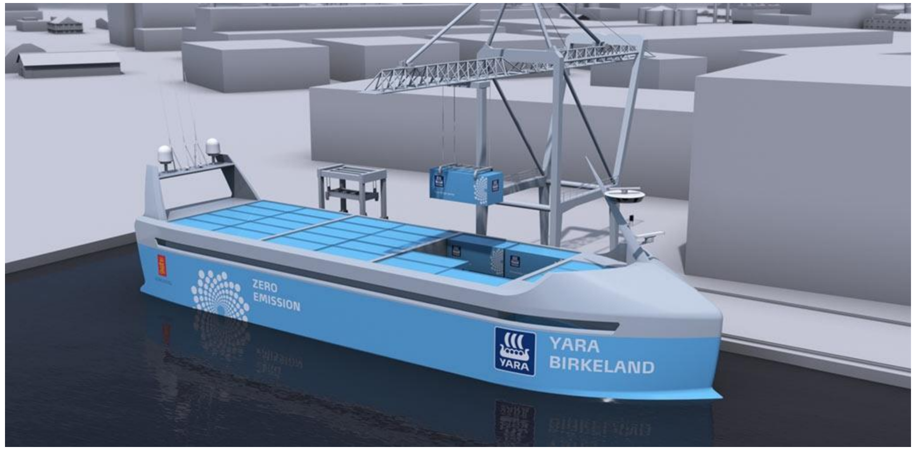
Accelerating the Industrial Strategy



Barriers to Technology

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1970s

Today

Barriers to Technology

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1970s

Today

Validation

Barriers to Technology

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1970s

Today

Validation

Barriers to Technology

1970s

Today

Validation

Management

Barriers to Technology - Validation

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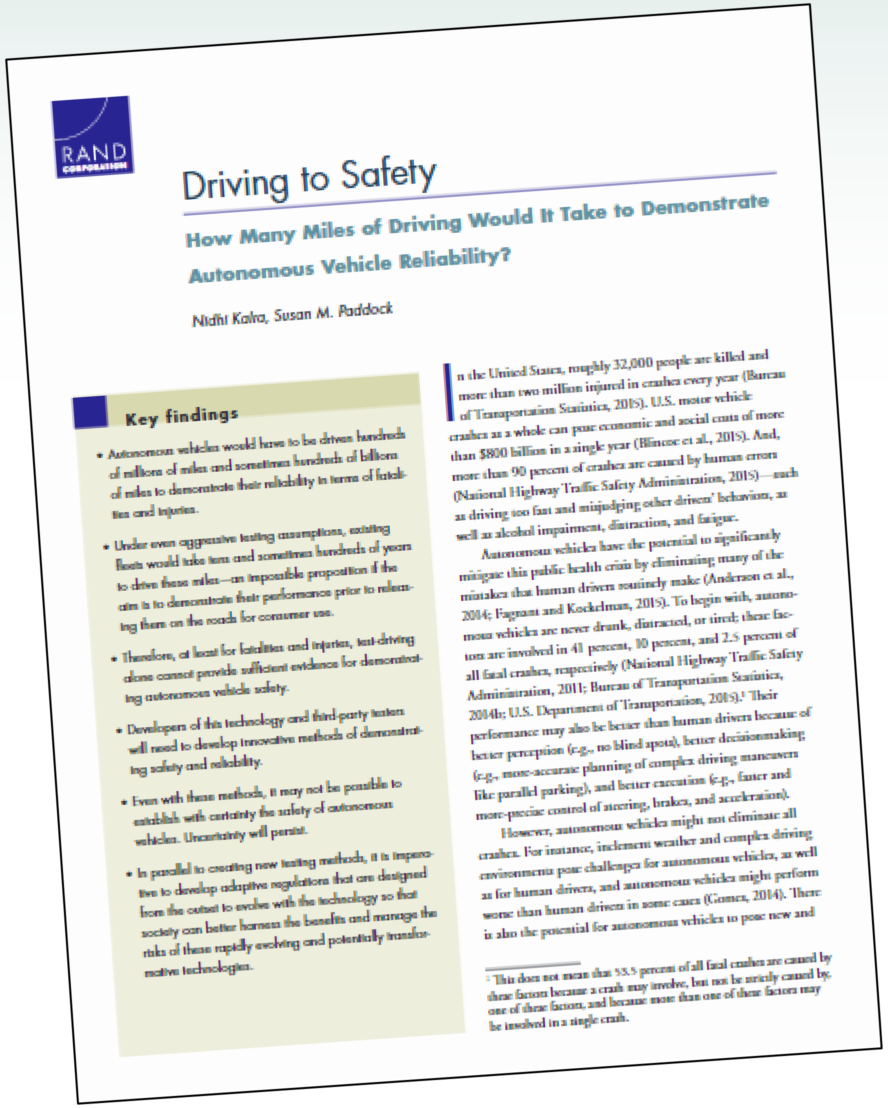


RAND CORPORATION

Driving to Safety

How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?

Nidhi Kalra, Susan M. Paddock

Key findings

- Autonomous vehicles would have to be driven hundreds of millions of miles and sometimes hundreds of billions of miles to demonstrate their reliability in terms of fatalities and injuries.
- Under even aggressive testing assumptions, existing fleets would take tens and sometimes hundreds of years to drive these miles—an impossible proposition if the aim is to demonstrate their performance prior to releasing them on the roads for consumer use.
- Therefore, at least for fatalities and injuries, test-driving alone cannot provide sufficient evidence for demonstrating autonomous vehicle safety.
- Developers of this technology and third-party testers will need to develop innovative methods of demonstrating safety and reliability.
- Even with these methods, it may not be possible to establish with certainty the safety of autonomous vehicles. Uncertainty will persist.
- In parallel to creating new testing methods, it is imperative to develop adaptive regulations that are designed from the outset to evolve with the technology so that society can better harness the benefits and manage the risks of these rapidly evolving and potentially transformative technologies.

In the United States, roughly 32,000 people are killed and more than two million injured in crashes every year (Bureau of Transportation Statistics, 2015). U.S. motor vehicle crashes as a whole can pose economic and social costs of more than $800 billion in a single year (Blincoe et al., 2015). And, more than 90 percent of crashes are caused by human errors (National Highway Traffic Safety Administration, 2015)—such as driving too fast and misjudging other drivers' behaviors, as well as alcohol impairment, distraction, and fatigue.

Autonomous vehicles have the potential to significantly mitigate this public health crisis by eliminating many of the mistakes that human drivers routinely make (Anderson et al., 2014; Fagnant and Kockelman, 2015). To begin with, autonomous vehicles are never drunk, distracted, or tired; these factors are involved in 41 percent, 10 percent, and 2.5 percent of all fatal crashes, respectively (National Highway Traffic Safety Administration, 2011; Bureau of Transportation Statistics, 2014b; U.S. Department of Transportation, 2015).[1] Their performance may also be better than human drivers because of better perception (e.g., no blind spots), better decisionmaking (e.g., more-accurate planning of complex driving maneuvers like parallel parking), and better execution (e.g., faster and more-precise control of steering, brakes, and acceleration).

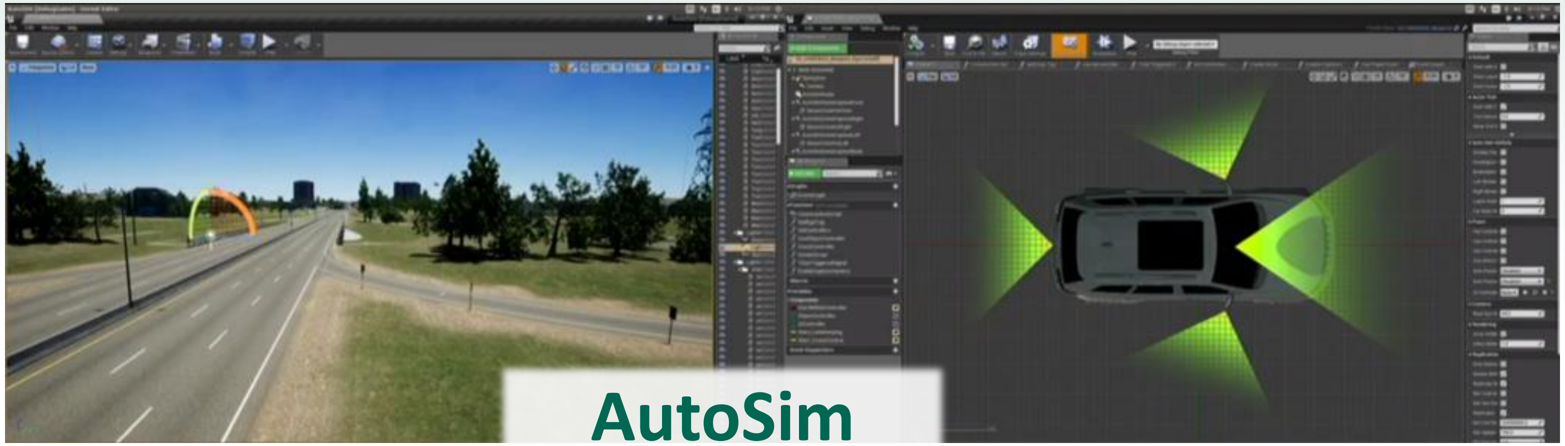
However, autonomous vehicles might not eliminate all crashes. For instance, inclement weather and complex driving environments pose challenges for autonomous vehicles, as well as for human drivers, and autonomous vehicles might perform worse than human drivers in some cases (Gomes, 2014). There is also the potential for autonomous vehicles to pose new and

[1] This does not mean that 53.5 percent of all fatal crashes are caused by these factors because a crash may involve, but not be strictly caused by, one of these factors, and because more than one of these factors may be involved in a single crash.

"In the U.S., approximately **one fatality occurs for every 100 million miles** driven. To prove with **95% confidence** that a driverless car achieves, at least, this rate of reliability by driving them around to see, it would require they be driven **275 million miles without a fatality.** With a fleet of 100 autonomous vehicles (larger than any known existing fleet) driving 24/7**, it would take more than 12 years to drive these miles.**"

The challenge within the automotive industry is **how to demonstrate 'correct' performance**.

Simulation and Virtual Validation



AutoSim

Example vehicle simulation tools

RfPro

CarMaker

MUSICC
Multi User Scenario Catalogue for Connected Autonomous Vehicles

Objectives and approach

Department for Transport

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Objectives:

- Create a standard language to describe scenarios
- Build an open, extensible library of scenarios for CAV certification
- Focus on simulation testing environments

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Multi User Scenario Catalogue for Connected Autonomous Vehicles

Objectives and approach

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Objectives:

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Approach:

- 12-month proof-of-concept demonstration project
- Close collaboration with vehicle manufacturers, developers, organisations with expertise in CAV validation and international regulators
- Define a scenario format based on a wide consultation
- Enable openly-accessible scenario platform

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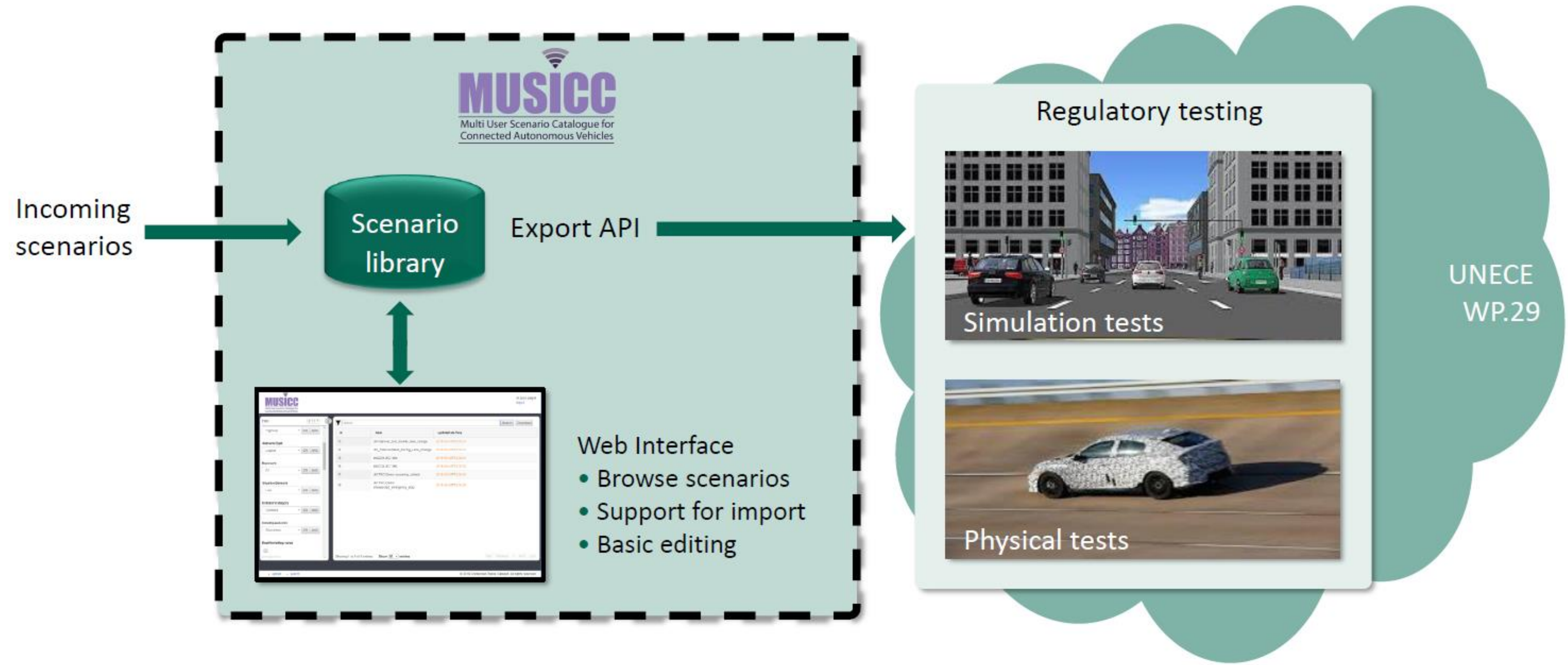
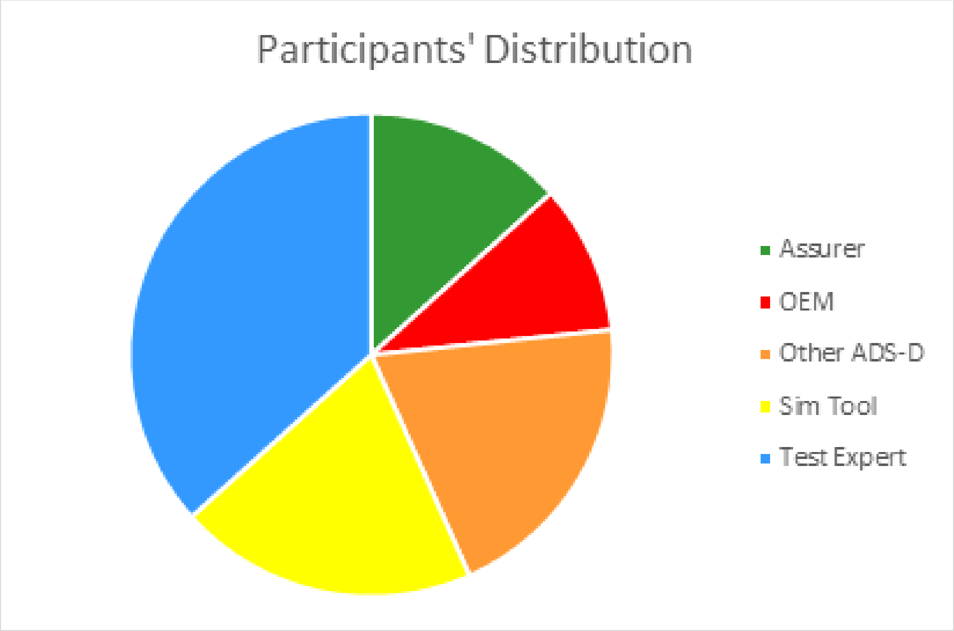


MUSICC: Workshop

International Workshop

- Industry and academic delegates invited to a workshop
- Introduce the project
- Get industry consensus on key questions around scenario database



MUSICC: Workshop

Session 1: Scenario Representation

- Rich detail in scenarios is important
- Variation of scenario parameters is essential
- Scenarios as a layered description (e.g road network, traffic, moveable objects, weather)
- Non-intelligent actor vehicles

MUSICC: Workshop

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Session 2: Implementation by a Regulator

- Simulation is essential to address the testing challenge. Some level of physical testing still required
- Simulation tools used would need to meet some minimum, validated standard of performance
- Test scenarios would need to be agnostic to the implementation (i.e. of sensors and actuators)
- Tests need have variation within bounded limits, but should be repeatable

MUSICC: Workshop

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Session 3: Next Steps

- OpenScenario format the overwhelming recommendation for the language
- Extend language to include meta-data search fields

Language: OpenScenario

“**p**roject for the **e**stablishment of **g**enerally **a**ccepted quality criteria, tools and methods as well as **s**cenarios and **s**ituations for the release of highly-automated driving functions”

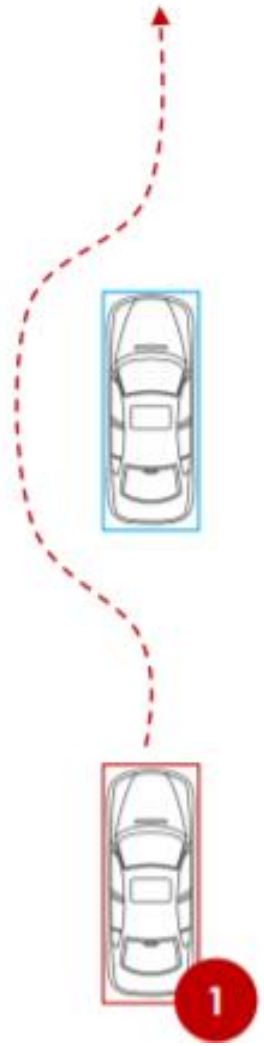
https://www.pegasusprojekt.de/en/about-PEGASUS

“OpenSCENARIO is an open file format for the description of dynamic contents in driving simulation applications”

http://www.openscenario.org/

Language: OpenScenario
Example - Overtaking

- **storyboard**
  - **story: owner** = player 1
    - **act 1: condition** = start of simulation
      - **sequence 1.1: actor** = $owner
        - **maneuver 1.1.1: name** = accelerate, stay in Ego lane
          - **event 1.1.1.1: condition** = upon start of act
            - **action 1.1.1.1.1:** acquire $v_{Target} = v_{Ego}$ + 5.6m/s with 4m/s²
            - **action 1.1.1.1.2:** keep lane
          - **event 1.1.1.2: condition** = after termination of action 1.1.1.1.1
            - **action 1.1.1.2.1:** keep speed
    - **act 2: condition** = TTC to Ego < 0.742s
      - **sequence 2.1: actor** = $owner
        - **maneuver 2.1.1: name** = perform two lane changes
          - **event 2.1.1.1: condition** = upon start of act
            - **action 2.1.1.1.1:** perform lane change to the left within 2s
          - **event 2.1.1.2: condition** = longitudinal distance to Ego > 2m
            - **action 2.1.1.2.1:** perform lane change to the right within 1.89s



Example language structure from openscenario.org

Implementation

To make the implementation of OpenScenario more useful in the context of a database, we added:

- **Metadata**
  - – Allows queries to find the correct set of scenarios corresponding to the ODD of the ADS under test
  - – Scenario-specific data (e.g. situation demand ≈ difficulty)
  - – ODD-aligned data (e.g. weather, road features)
  - – Ego and actor actions (e.g. turn across traffic, emergency stop)
  - – Additionally, support ‘tagging’ scenarios

- **Parameter stochastics**
  - – Allows variables in the scenario to have values chosen according to a probability distribution
  - – Prevents design-to-test
  - – Increases test space coverage

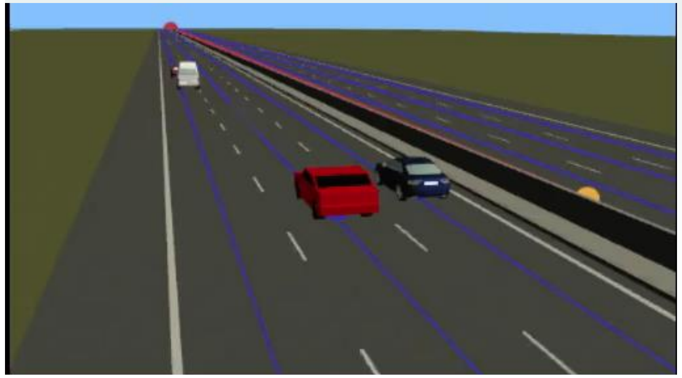
MetaData: Link functionally equivalent scenarios

Used to manage scenarios with the same ‘story’

Example:

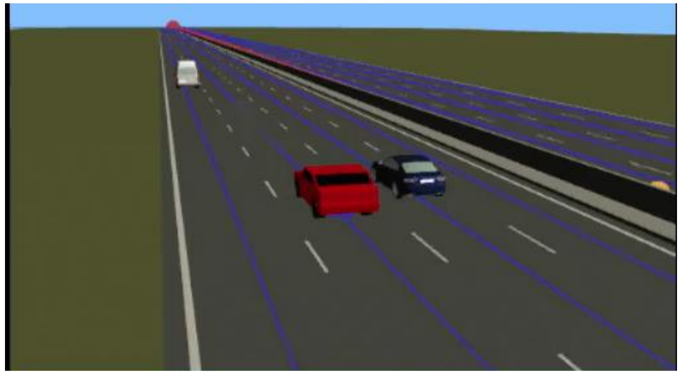
ADS updated to improve performance in cut-in scenario

3 lane – GB



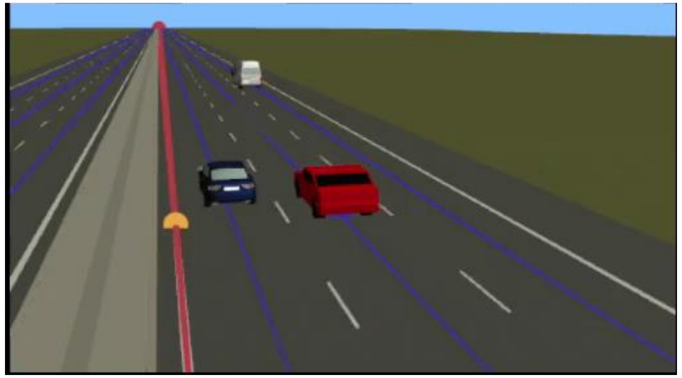
Search for other scenarios with the same label

4 lane – GB



Test ADS on similar (but not identical) scenarios

3 lane –- FR



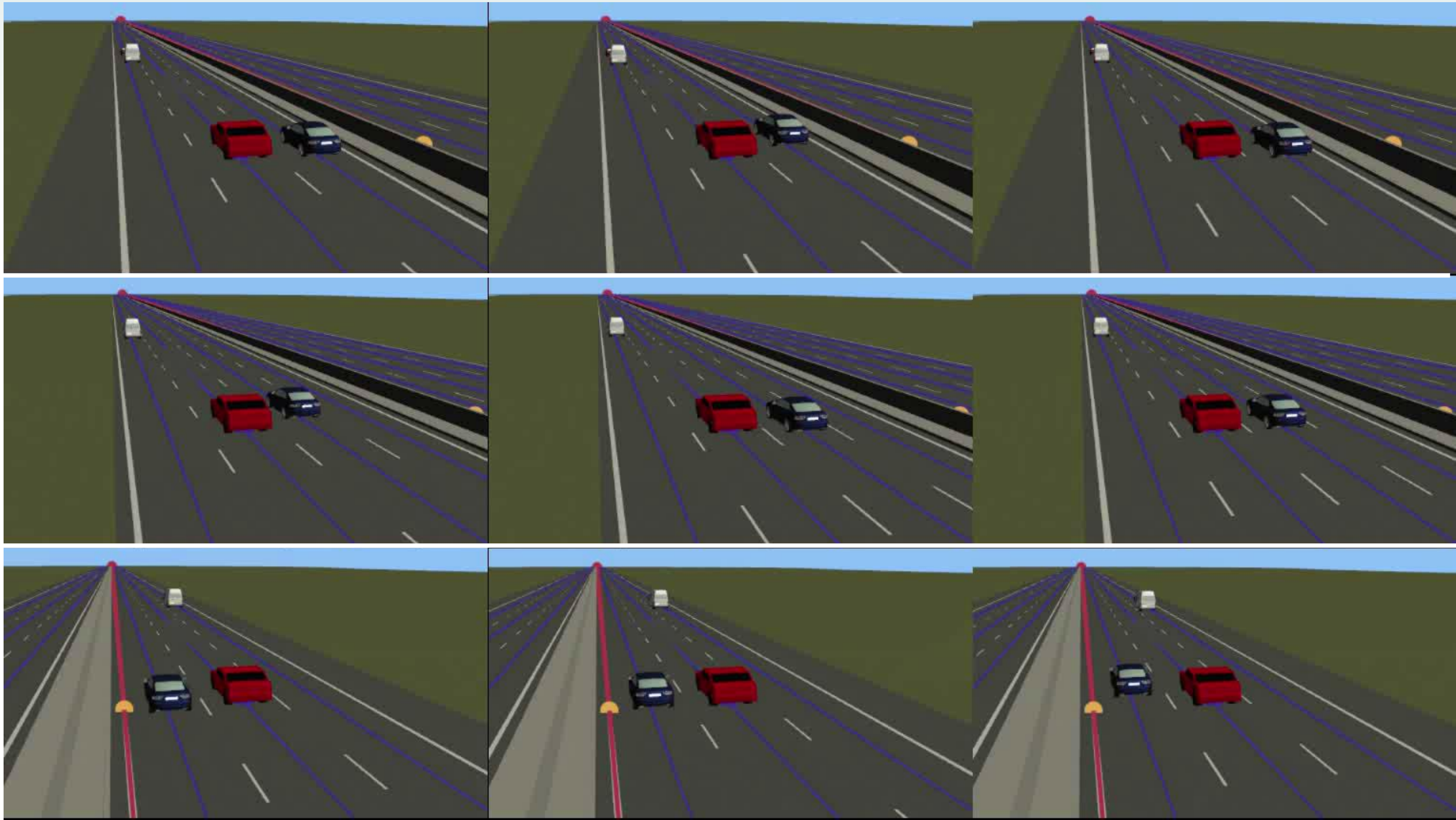
Parameter Stochastics: Randomisation

Generates multiple concrete scenarios from each logical

3 lane – GB

4 lane – GB

3 lane – FR



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Multi User Scenario Catalogue for Connected Autonomous Vehicles

Objectives and approach

Department for Transport

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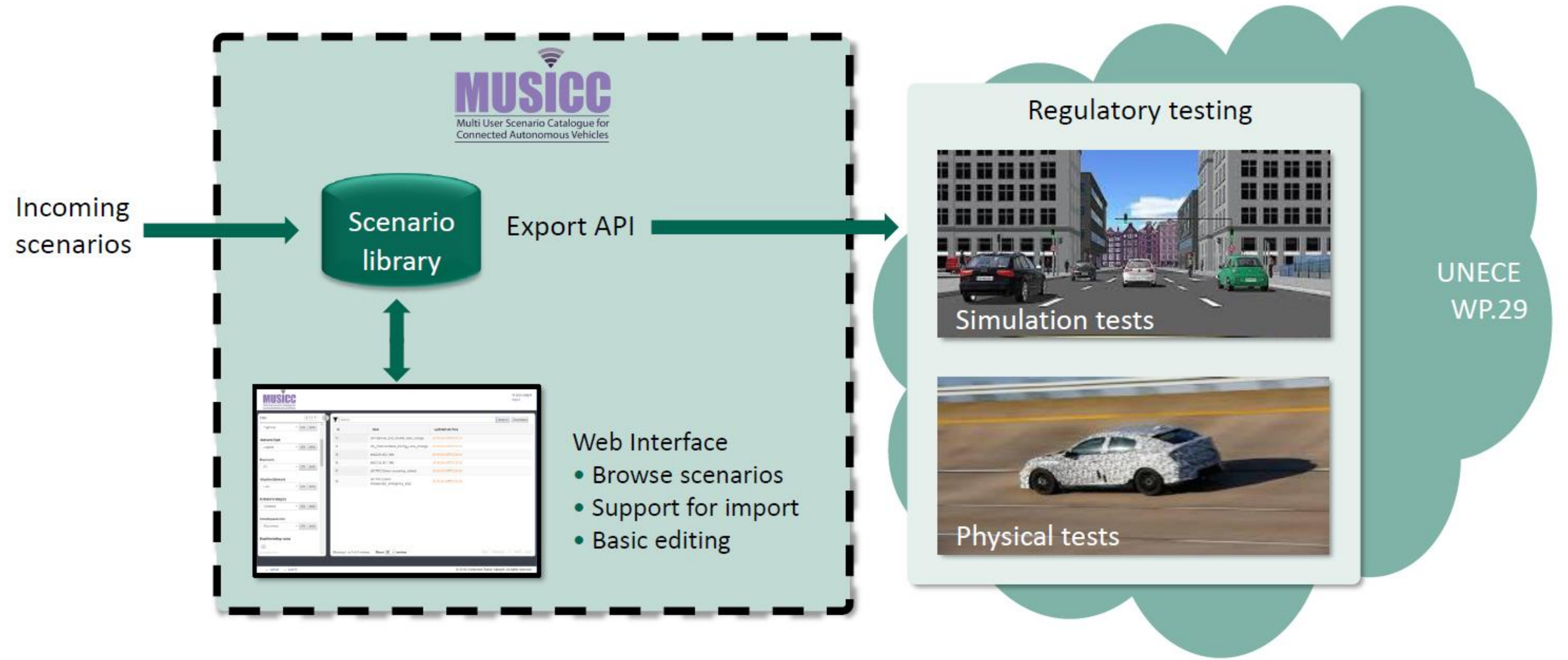

Ongoing Questions

There are still a number of questions to address in respect of virtual validation approaches:

- How should the scenarios be captured, curated and accessed?
- Separate tests for the perception systems / hardware?
- How can we ensure confidence in the simulation tools?
- What should be the balance of simulation, closed-road testing and public road testing?
- Can simple pass / fail criteria work in this context?

More general challenge:

- Integrating autonomous vehicle fleet with conventional vehicles

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Unmanned Traffic Management

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The integration of unmanned drone flight with each other and with conventional aircraft is a **barrier to deployment**

- 1 year project laying the groundwork for how unmanned craft could be integrated with each other and with conventional aircraft
- Sponsored by Department for Transport
- Worked alongside industry and academia:
  - NATS
  - Altitude Angel
  - ANRA Technologies
  - Cranfield University
  - Satellite Applications Catapult
  - Thales UK

Department for Transport

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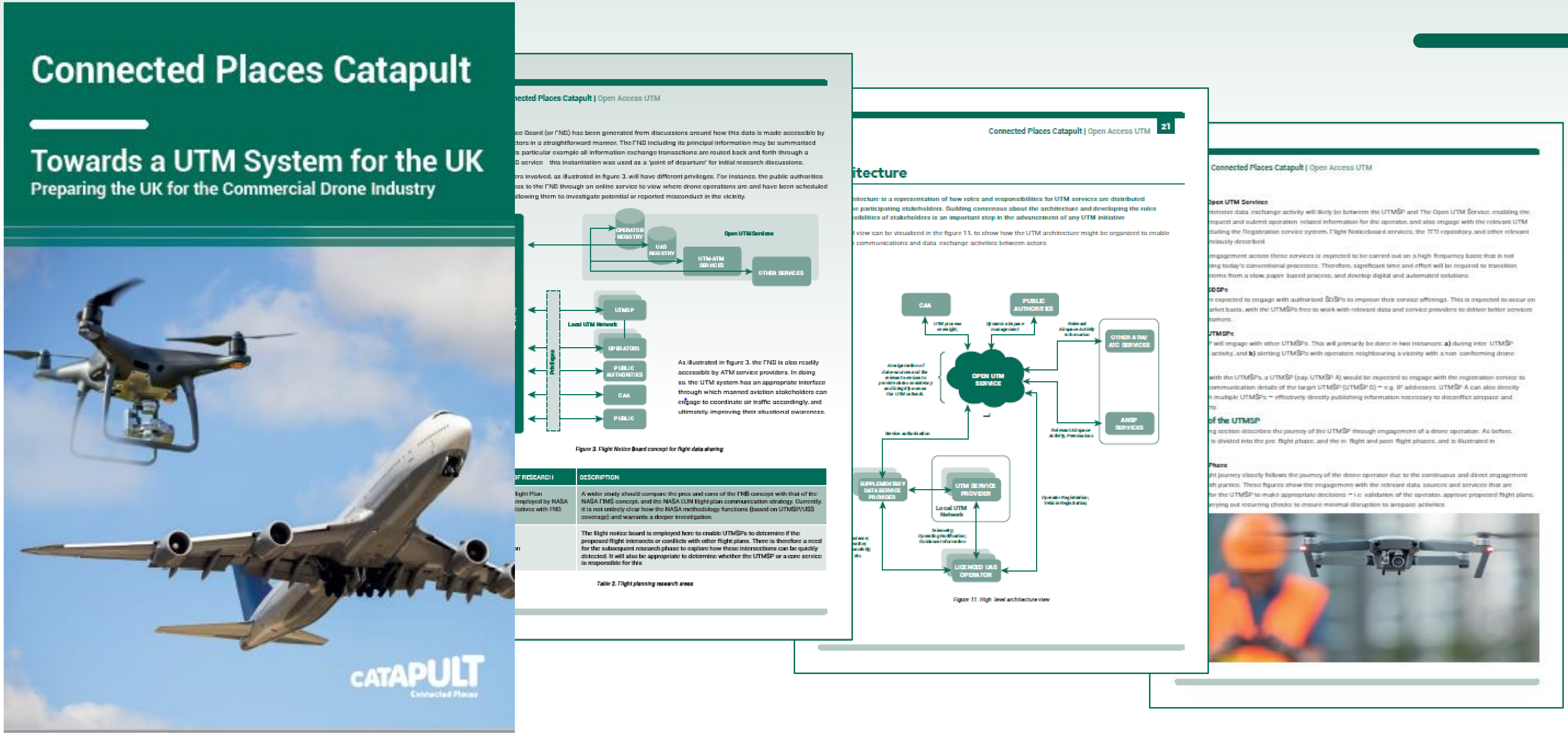
Unmanned Traffic Management



Architecture for **an open access UTM system** and scenarios for important areas such as **managing permissions** to fly drones in restricted airspace and multiple drone operations in in uncontrolled airspace.

Unmanned Flight

Unmanned Flight

Unmanned Traffic Management

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UAS Operator

Individual or enterprise responsible for the safe control and operation of their vehicle

ATM Service Provider

Interface to the conventional ATM

Public Authorities

May need to coordinate access to airspace and if needed impact operations of UAS

UTM Service Provider

Enable UAS operators to integrate unmanned vehicles into the national airspace (flight planning)

Supplementary Data Service Provider

Supplimentary information, for example weather

Regulator

Ensure safe operation of the airspace through regulatory and operational frameworks

Unmanned Traffic Management (UTM)

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UAS Operator

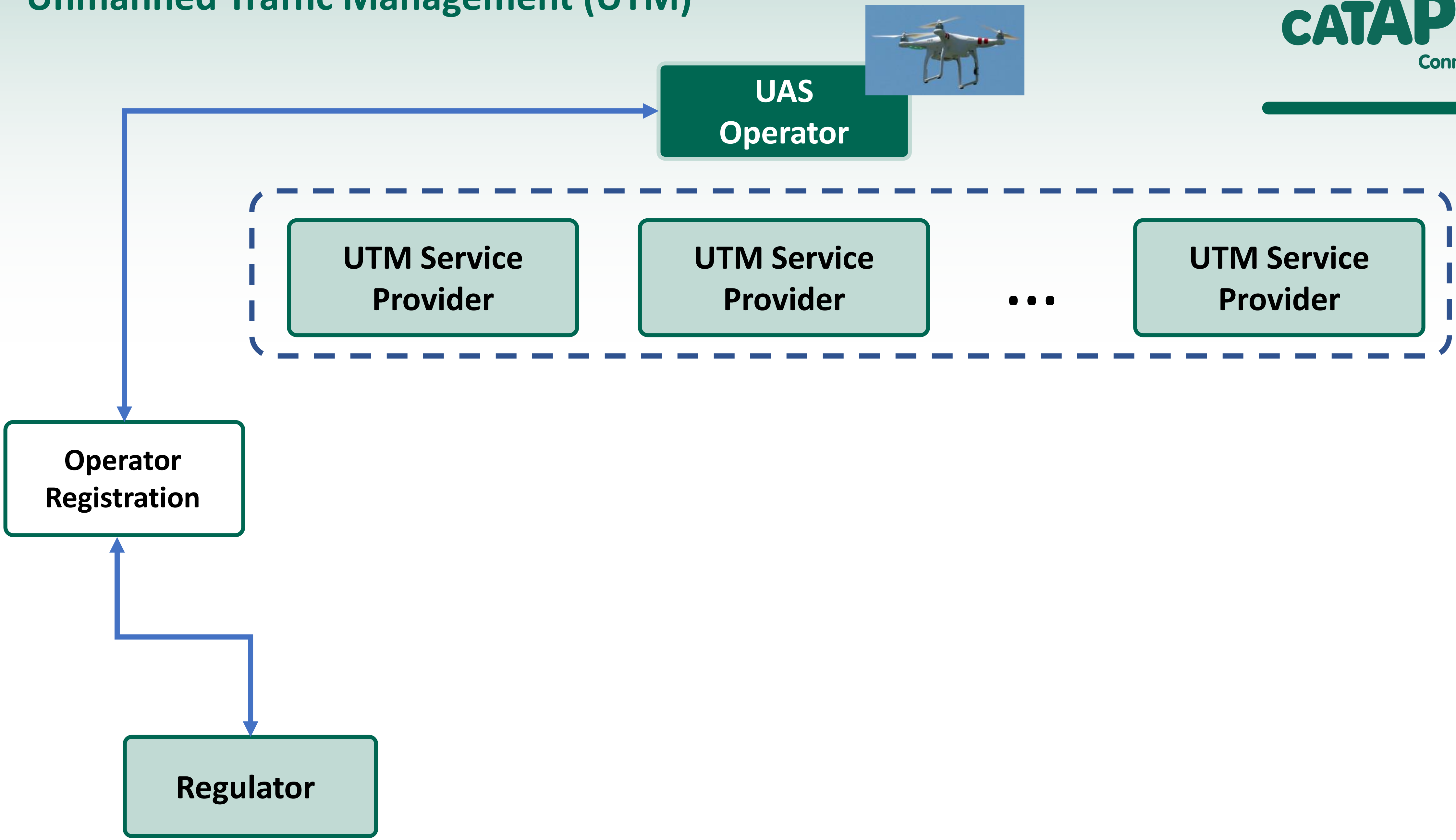
Unmanned Traffic Management (UTM)

UAS Operator

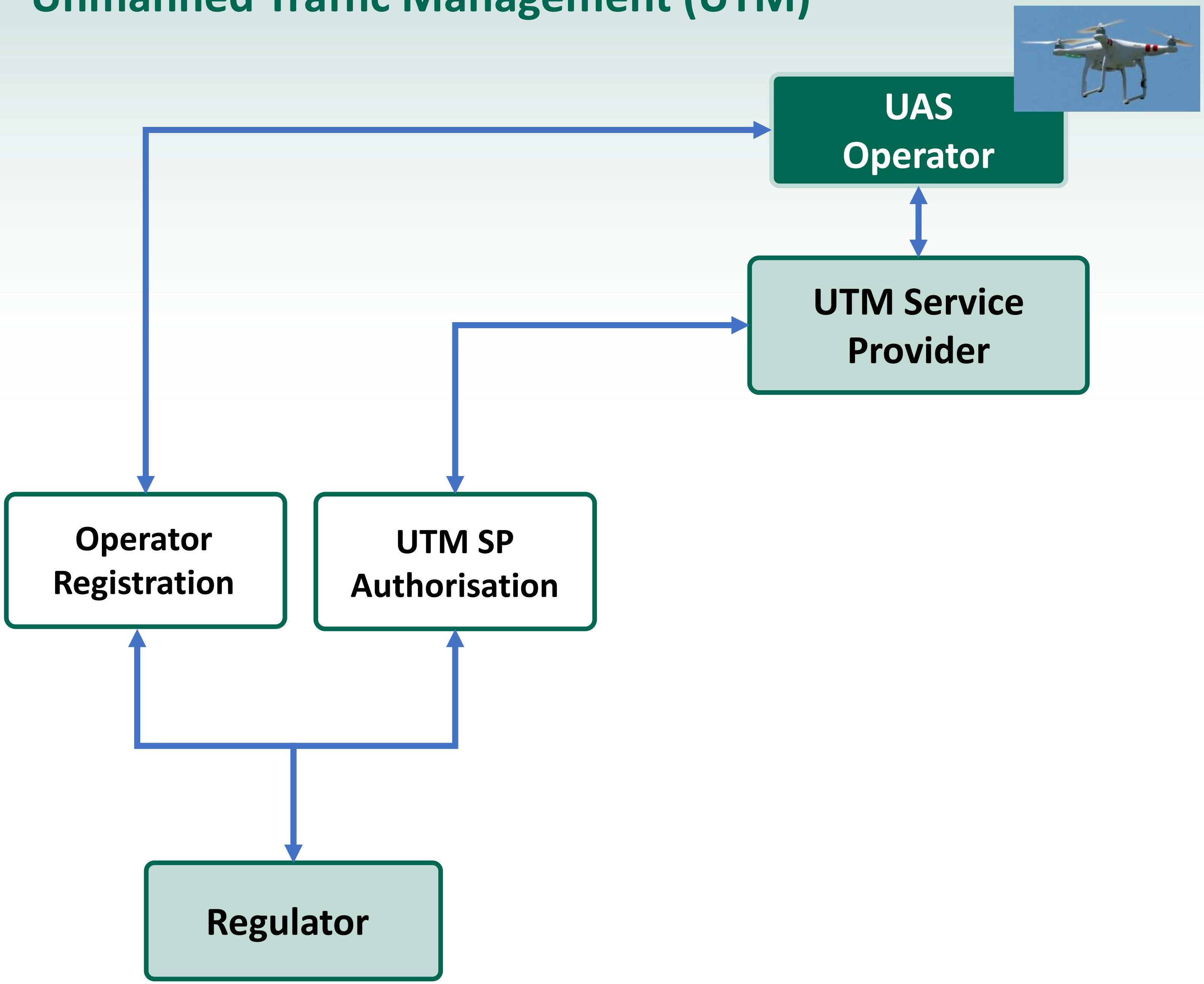
Operator Registration

Regulator

Unmanned Traffic Management (UTM)



Unmanned Traffic Management (UTM)



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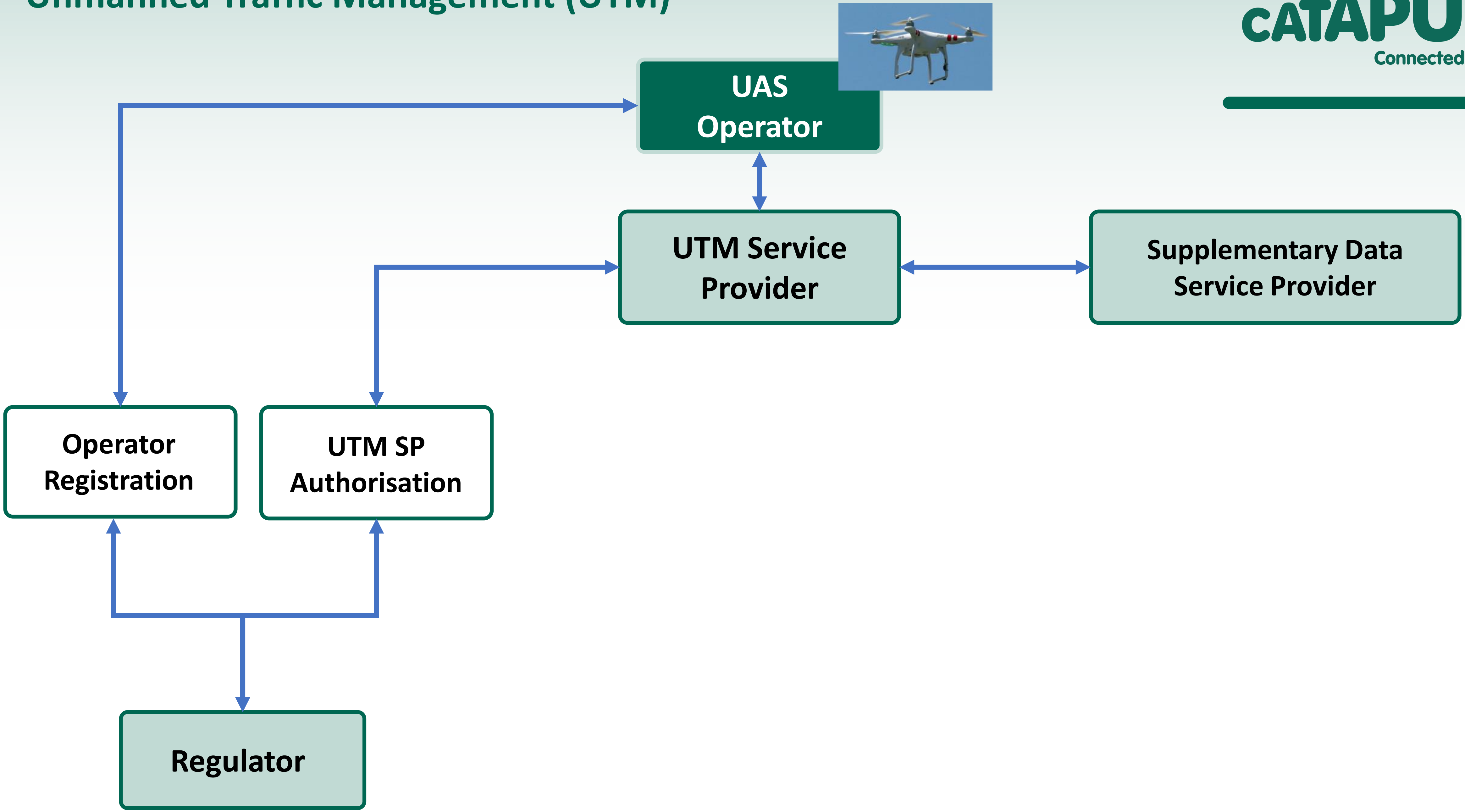
Unmanned Traffic Management (UTM)



Unmanned Traffic Management (UTM)

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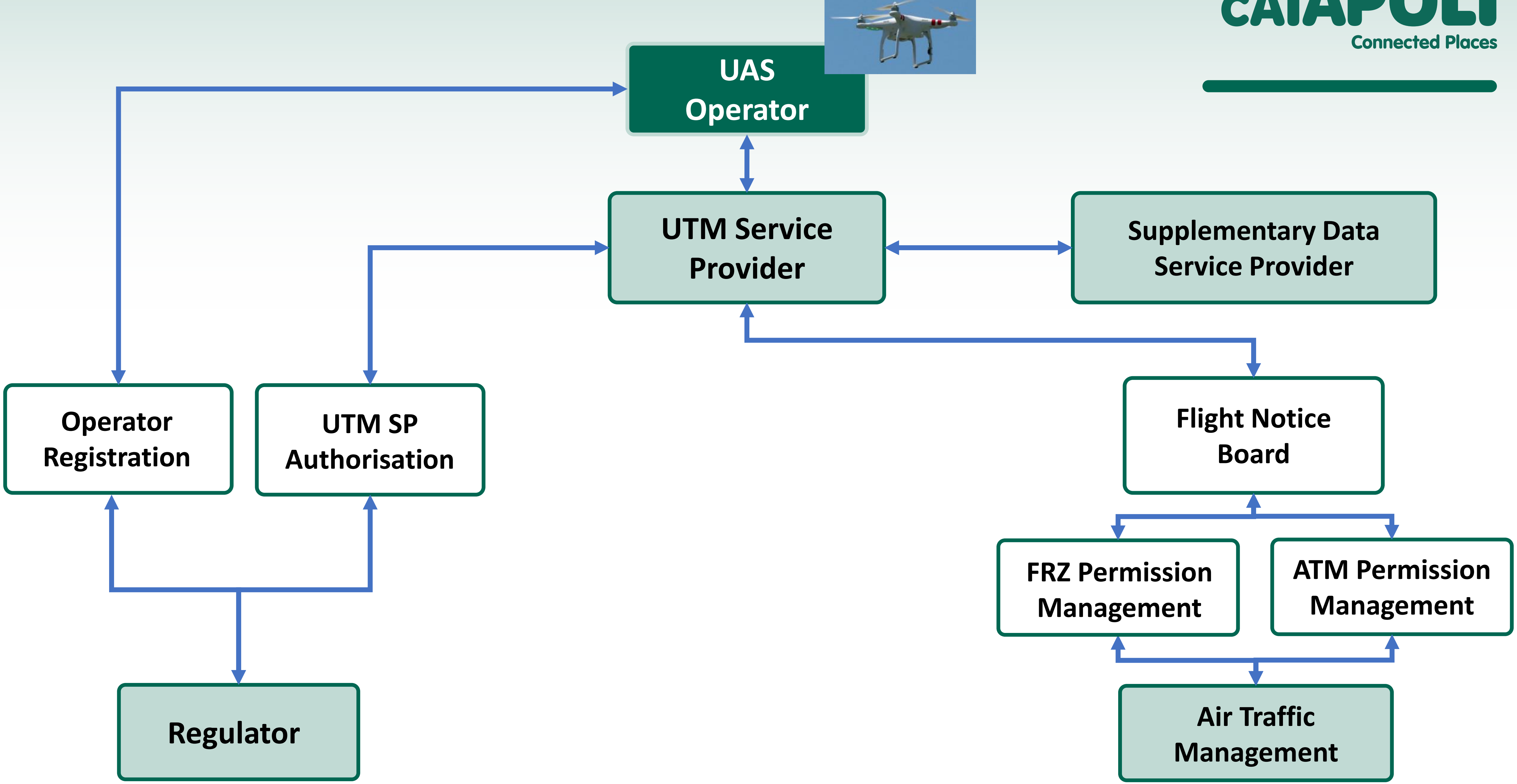
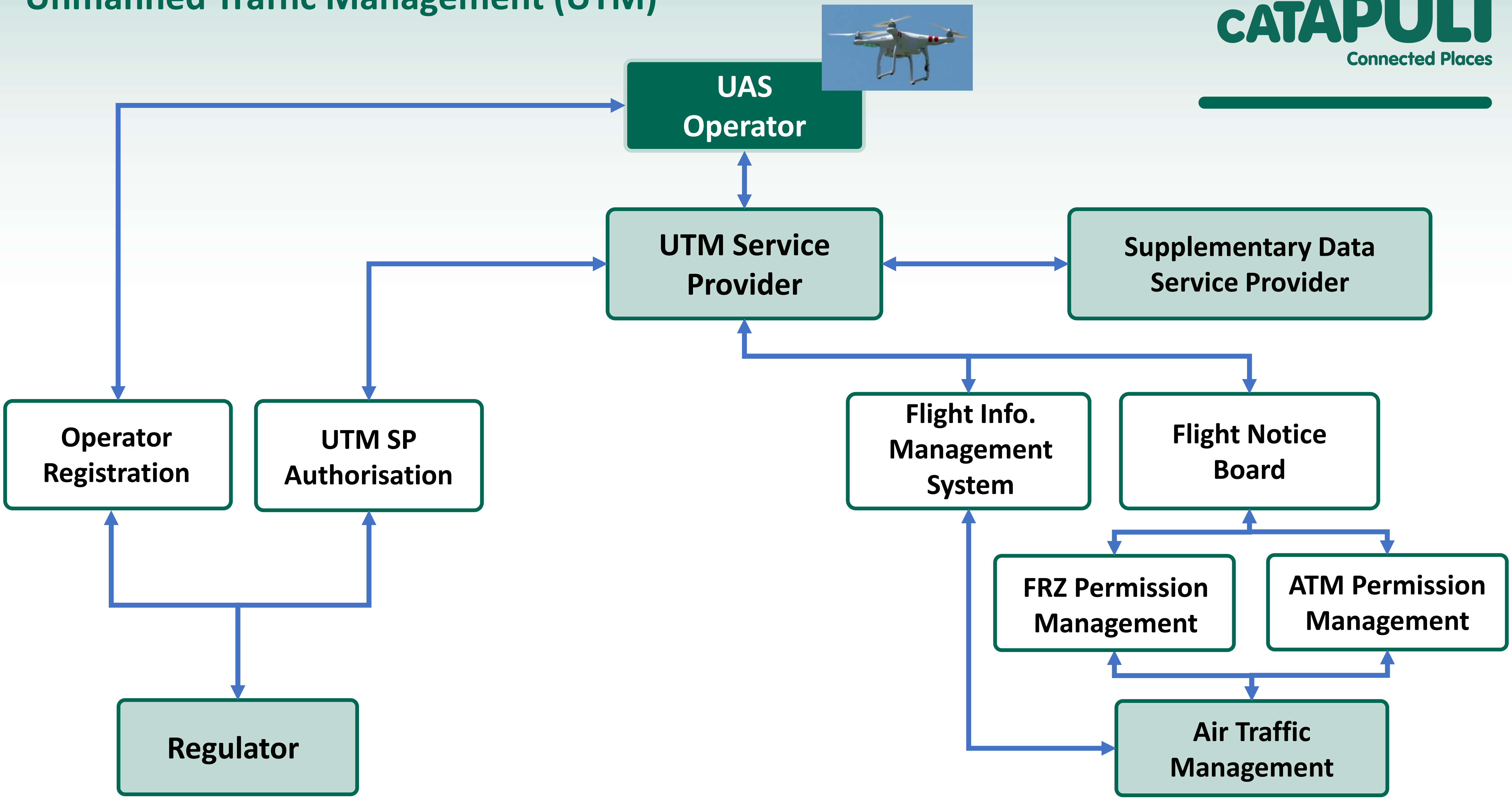


Unmanned Traffic Management (UTM)



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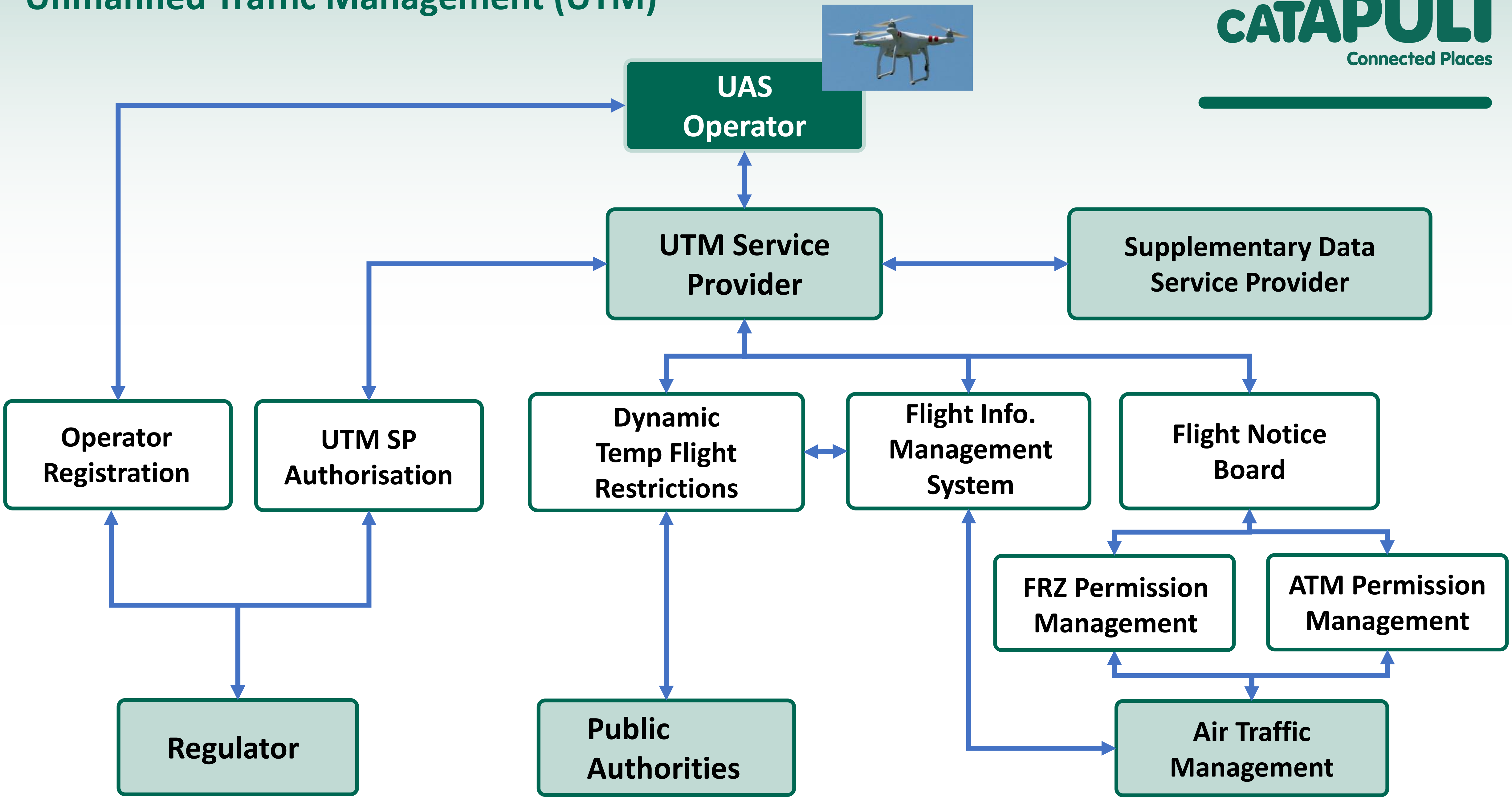

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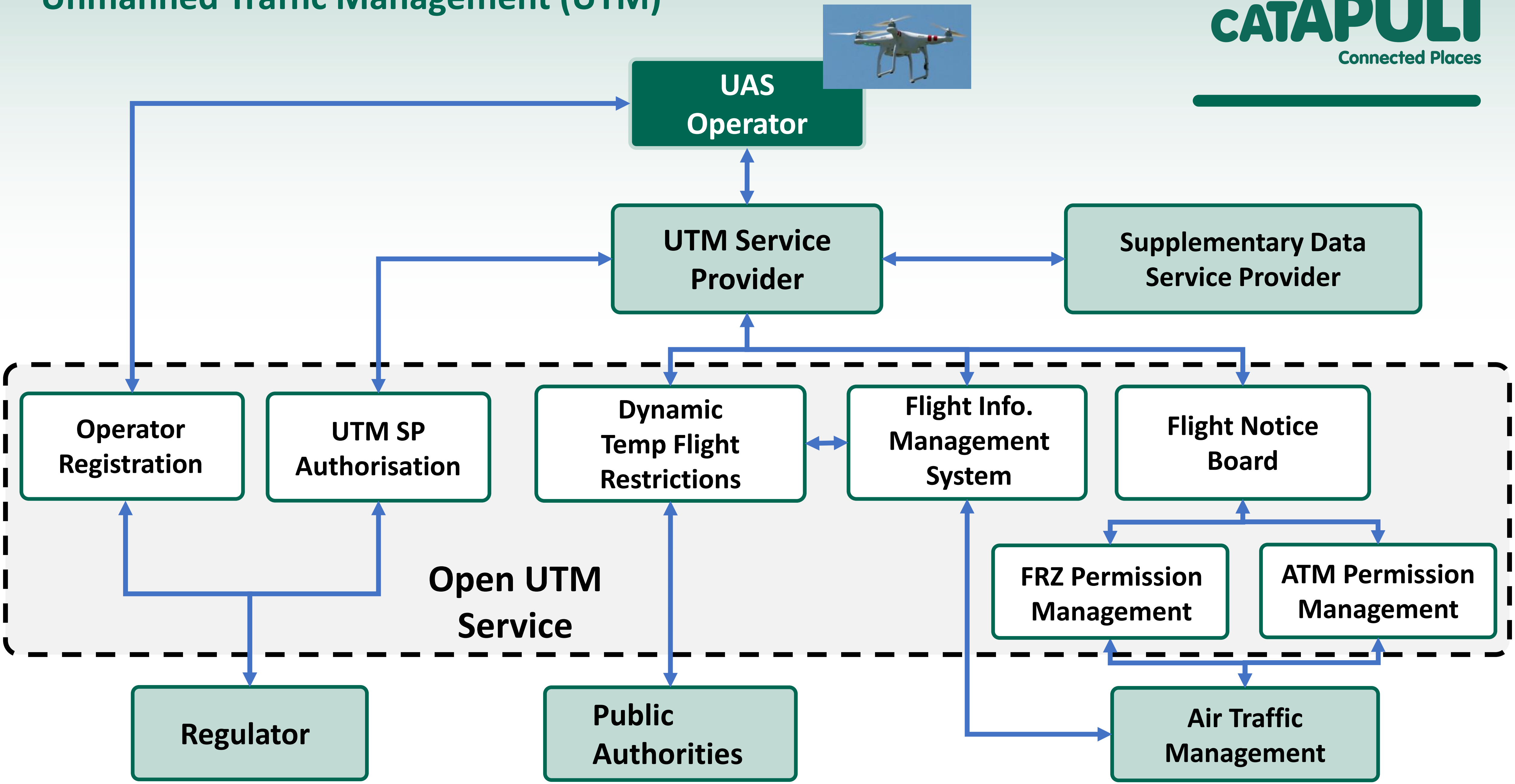
Unmanned Traffic Management (UTM)



Unmanned Traffic Management (UTM)

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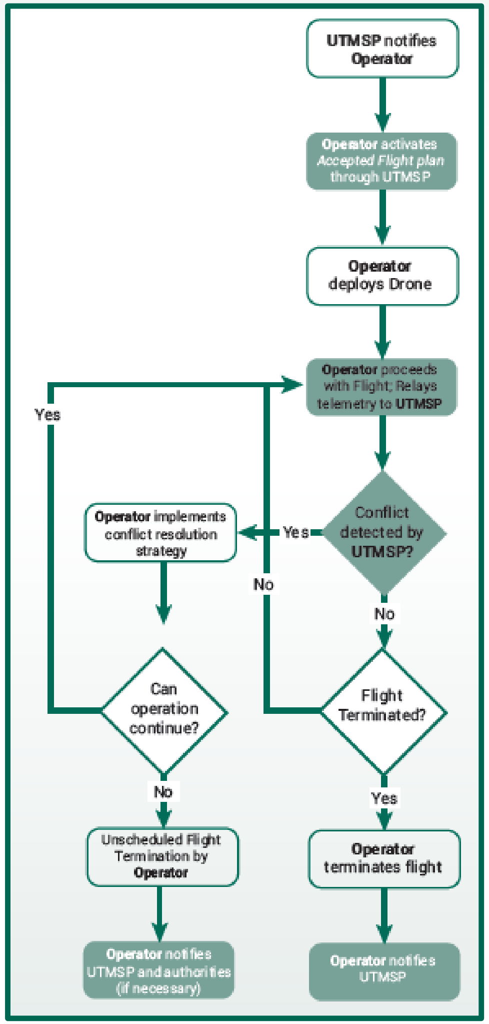
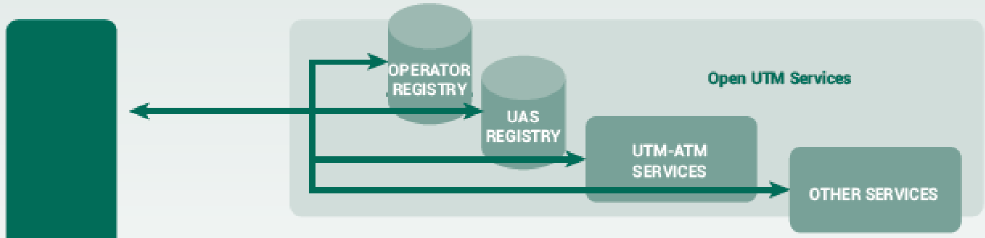
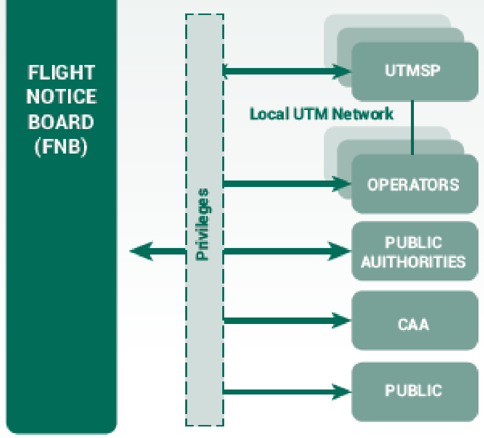
Figure 4. Flight plan submission







As illustrated in figure 3, the FNB is also readily accessible by ATM service providers. In doing so, the UTM system has an appropriate interface through which manned aviation stakeholders can engage to coordinate air traffic accordingly, and ultimately, improving their situational awareness.

Figure 3. Flight Notice Board concept for flight data sharing

FUTURE AREAS OF RESEARCH	DESCRIPTION
Comparison of Flight Plan communication employed by NASA and U-Space initiatives with FNB Concept	A study should compare the pros and cons of the FNB concept with that of the NASA FIMS concept, and the UTMSP Network flight plan communication strategy. Currently, it is not entirely clear how the NASA methodology functions (based on UTMSP/USS coverage) and warrants a further investigation.
Flight Intersection	The flight notice board is employed here to enable UTMSPs to determine if the proposed flight intersects or conflicts with other flight plans. There is therefore a need for the subsequent research phase to explore how these intersections can be quickly detected. It will also be appropriate to determine whether the UTMSP or a core service is responsible for this

Application in Maritime

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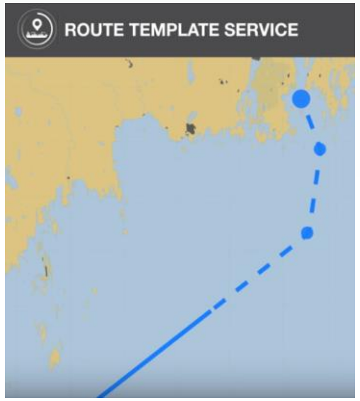
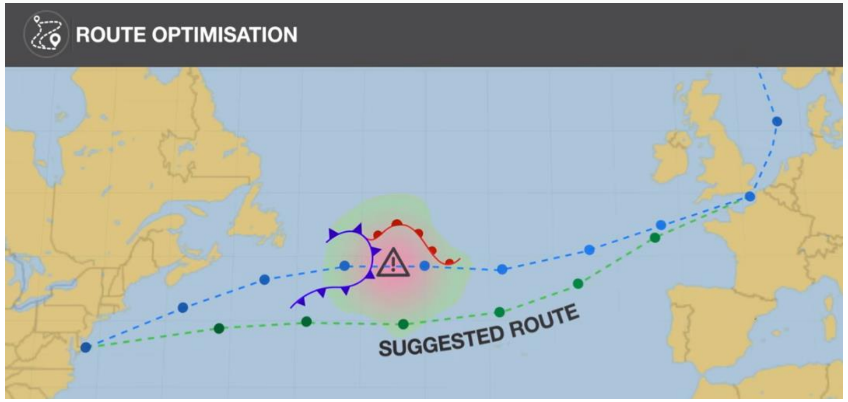
Elements of this are already being addressed – Sea Traffic Management

SEA TRAFFIC MANAGEMENT

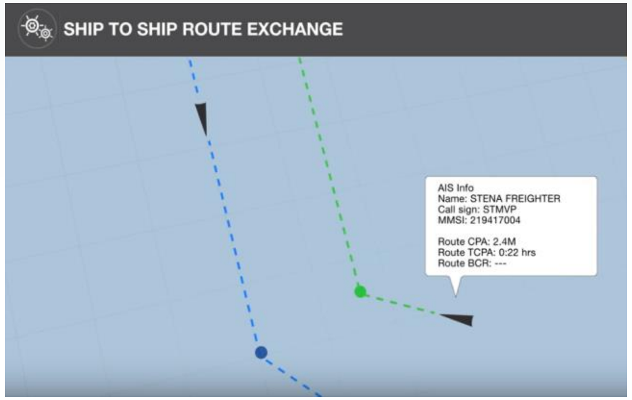


Route Planning

Route Sharing



Route Optimisation



Route Information Exchange

Application in Maritime

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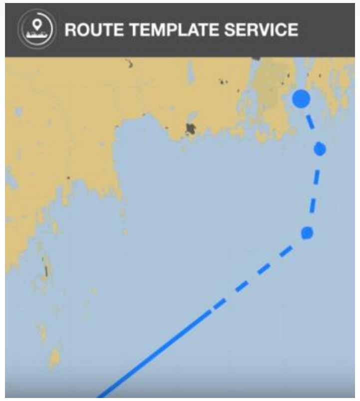
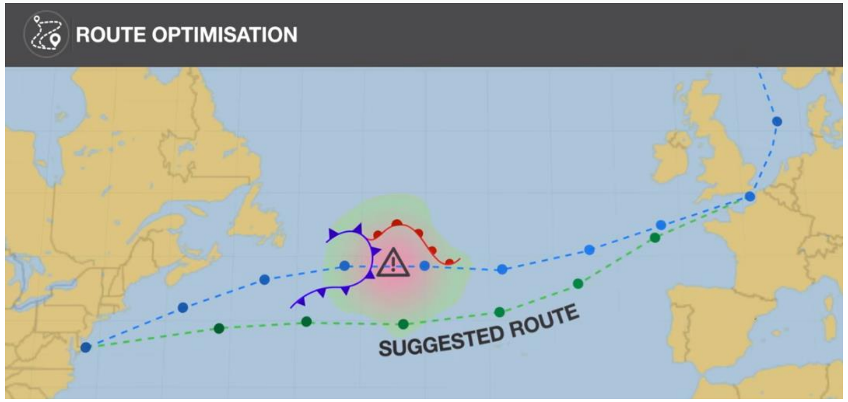
STM
SEA TRAFFIC MANAGEMENT



Route Planning

Route Sharing



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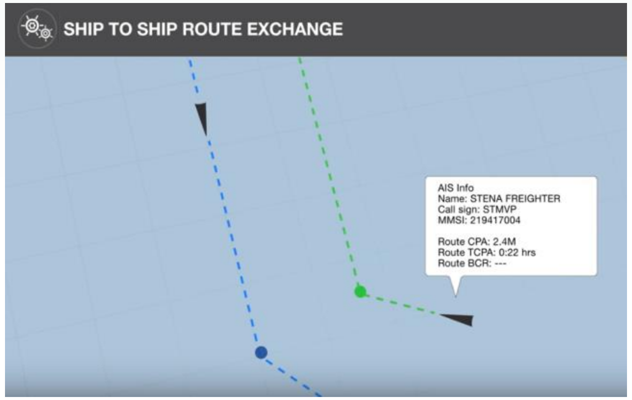

Route Information Exchange

- Digitalisation of all data to ensure machine readability
- Anonymisation of critical pieces of information
- Robust and reliable communications infrastructure
- Real-time checking of operators and service providers
- Regulated or enforced adoption of the necessary technologies and processes

Multi-Modal Autonomy: Validation and Management

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