# Autonomy

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# Contents

- Why do we need Autonomy for civil UAS?
- Requirements for Autonomous Systems
- UAS Virtual Certification System Architecture
- Key Functions and Mode of Operation
- The ASTRAEA Autonomous Systems Technologies

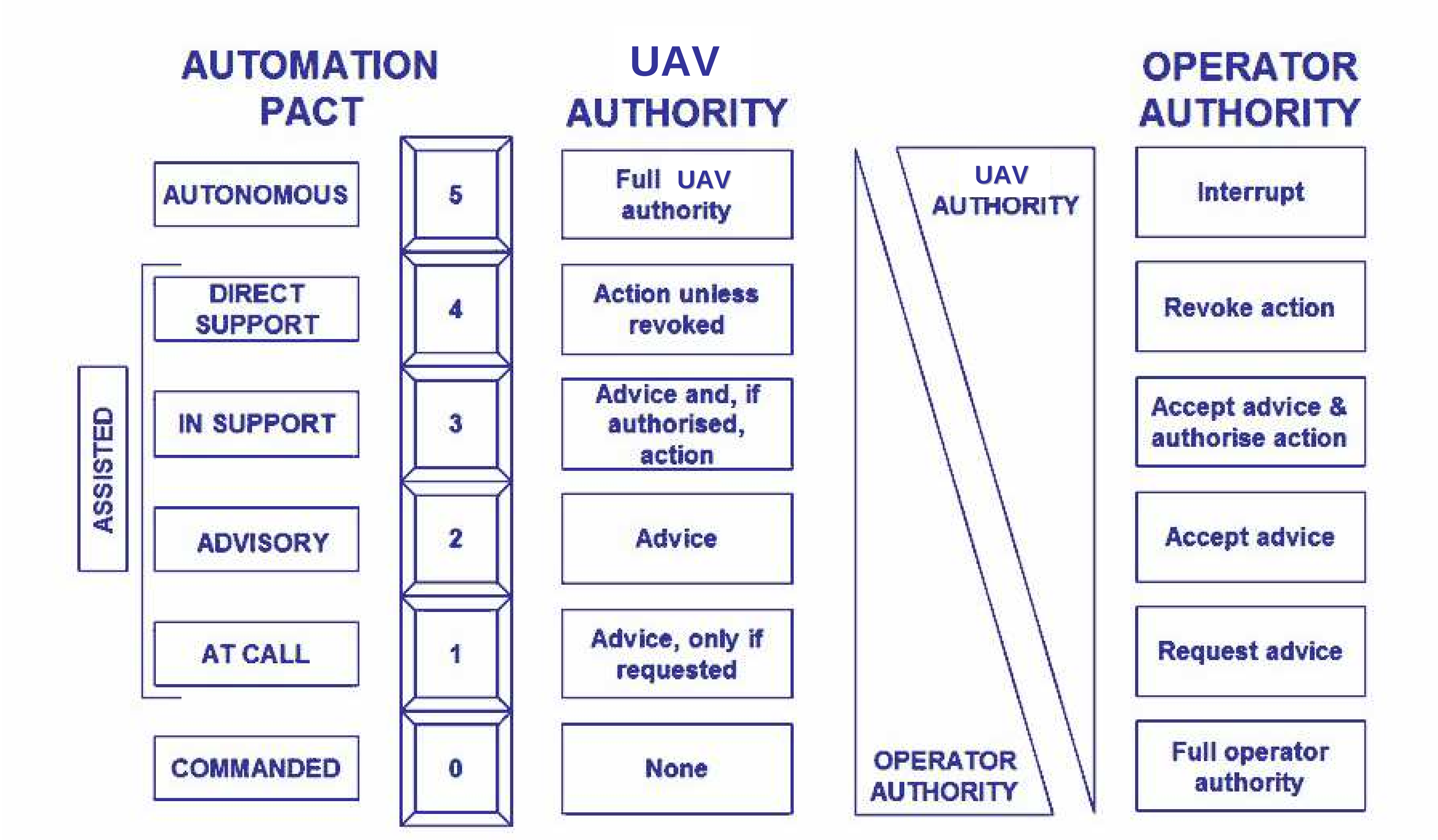
# Some useful definitions

- What is autonomy?

- ICAO 328 circular- definition of autonomy:
  - "Autonomous aircraft – an unmanned aircraft that does not allow pilot intervention in the management of the flight"
  - "Autonomous operation – an operation during which a remotely piloted aircraft is operating without pilot intervention in the management of the flight"

- ASTRAEA Autonomy (slightly different…)
  - The decision making system component which takes the role previously occupied by the pilot in a manned aircraft.
  - Operates as a decision making partnership between UAV systems and GCS Operator.
  - Autonomous system is there to provide safe flight at all times

# Autonomy Levels – A decision making partnership



# Why Autonomy?

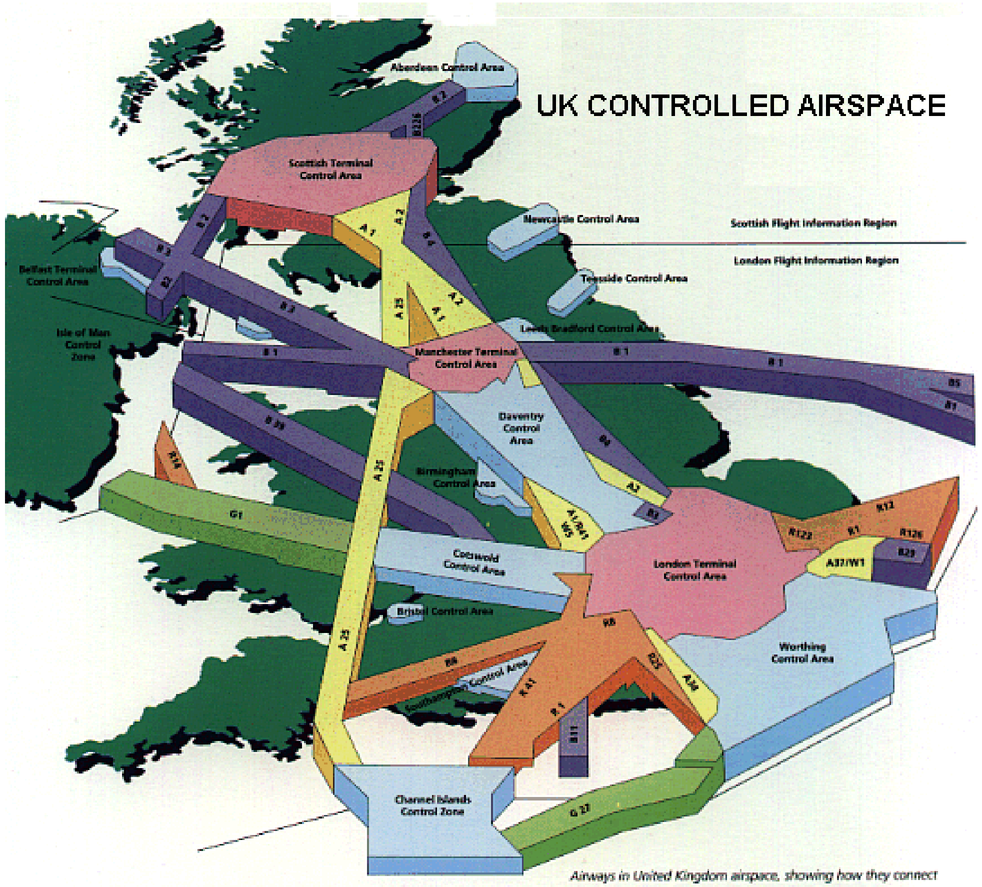
- Why is Autonomy an important part of a civil UAS solution?
- Key differences between future civil and existing military operations
  - Safety levels / acceptable risk
  - Infrastructure
  - Cost of operations
  - Control of airspace
- Autonomy is required to take the place of some of the functions of an onboard pilot
- Issues:
  - No accepted process to Certification of Autonomous Air Systems
  - Regulatory authorities (CAA) have provided guidance:
    - Transparency
    - Equivalence
    - As safe as manned aviation

# Key System Requirements

- **Transparency**
  - Transparent in operation to an external viewer (such as ATC) in comparison to other air users
- **Equivalence**
  - Equivalent in adherence to operational regulations as other air users
- **As safe as manned aviation**
  - Current accident rates (accidents per 100,000 hours) are:
    - **Large Airliners ~ 0.01**
    - **Regional Commuter Airliners ~ 0.1**
    - **General Aviation ~ 6.5**
- **In order to get from existing UAS accident rate to future civil UAS requirements will require a step change in technology**

# Transparency

- In order to operate in non-segregated airspace, a UAS must:
  - be fitted with the equipment specification applicable to the class of airspace it intends to operate in
  - comply with ATC instructions using the same infrastructure as manned aircraft
  - operate with no adverse effect on other air users
  - not require special or extra services



*Airways in United Kingdom airspace, showing how they connect*

# Equivalence

- In order to operate in non-segregated airspace, a UAS must:
  - be capable of complying with all existing operational procedures, rules and regulations
  - be certified to operate which includes:
    - The vehicle, including the systems on board the vehicle
    - The operator, pilot or commander (licensing)
    - The off board systems used by the operators
    - The communications infrastructure linking them and other users
  - have functions that the human pilot inherently provides e.g. lookout

# Safety Challenges

- Remotely situating the pilot creates challenges:
  - loss of immediate situational awareness – the data to achieve this must be transmitted to the ground, which leads to higher bandwidth or restricted data
  - data latency – data may be up to 2 – 4 seconds late
  - pilot consoles are only just beginning to reach the same standards as manned aircraft
  - loss of communications leading to lost link procedures which are often inflexible and may be insufficient to result in a safe landing
  - the inherent senses of the pilot (seat of pants!) are lost to the UAS <u>and</u> lost to the pilot

- The above can compromise UAS pilots in the use of their:
  - special skills in reasoning and experience,
  - ability to successfully identify and react to unforeseen or complex situations

# UAS Safety – Positives

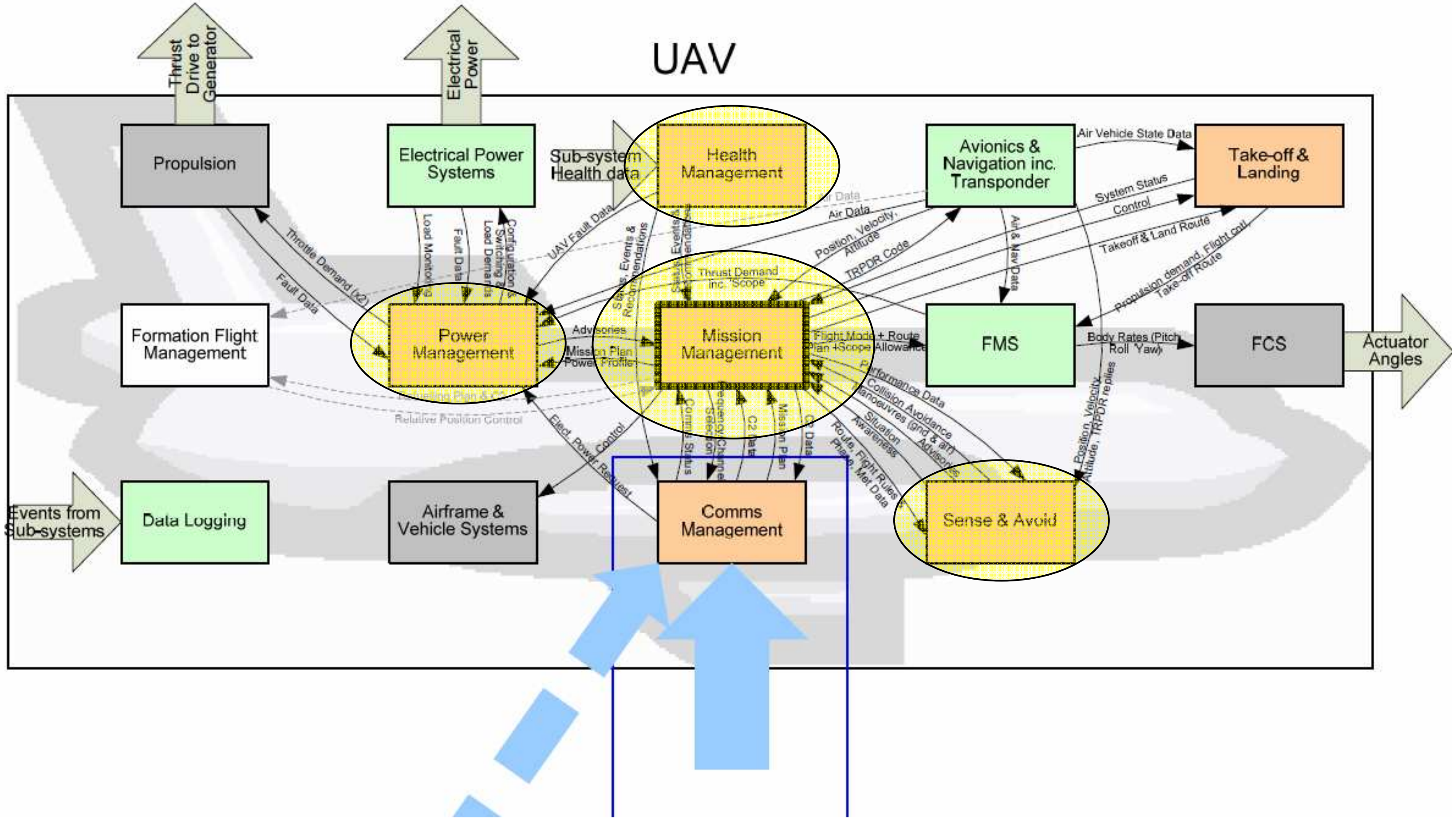
- UAVs, especially autonomous ones, possess inherent attributes that can contribute to flight safety:
  - They do not suffer from memory loss, lack of concentration, or boredom.
  - They react extremely fast to recover situations – very important in the take-off and landing phases of flight where most manned accidents occur.
  - They do not take chances, violate regulations or dodge safety procedures
  - They can be forced to objectively re-evaluate situations – no human type “confirmation bias”
  - Pilot disorientation is less likely to lead to an accident
  - Automatic take off and landing reduces losses due to manual loss of control

- Potential for spin off technologies back into manned aviation to further increase safety

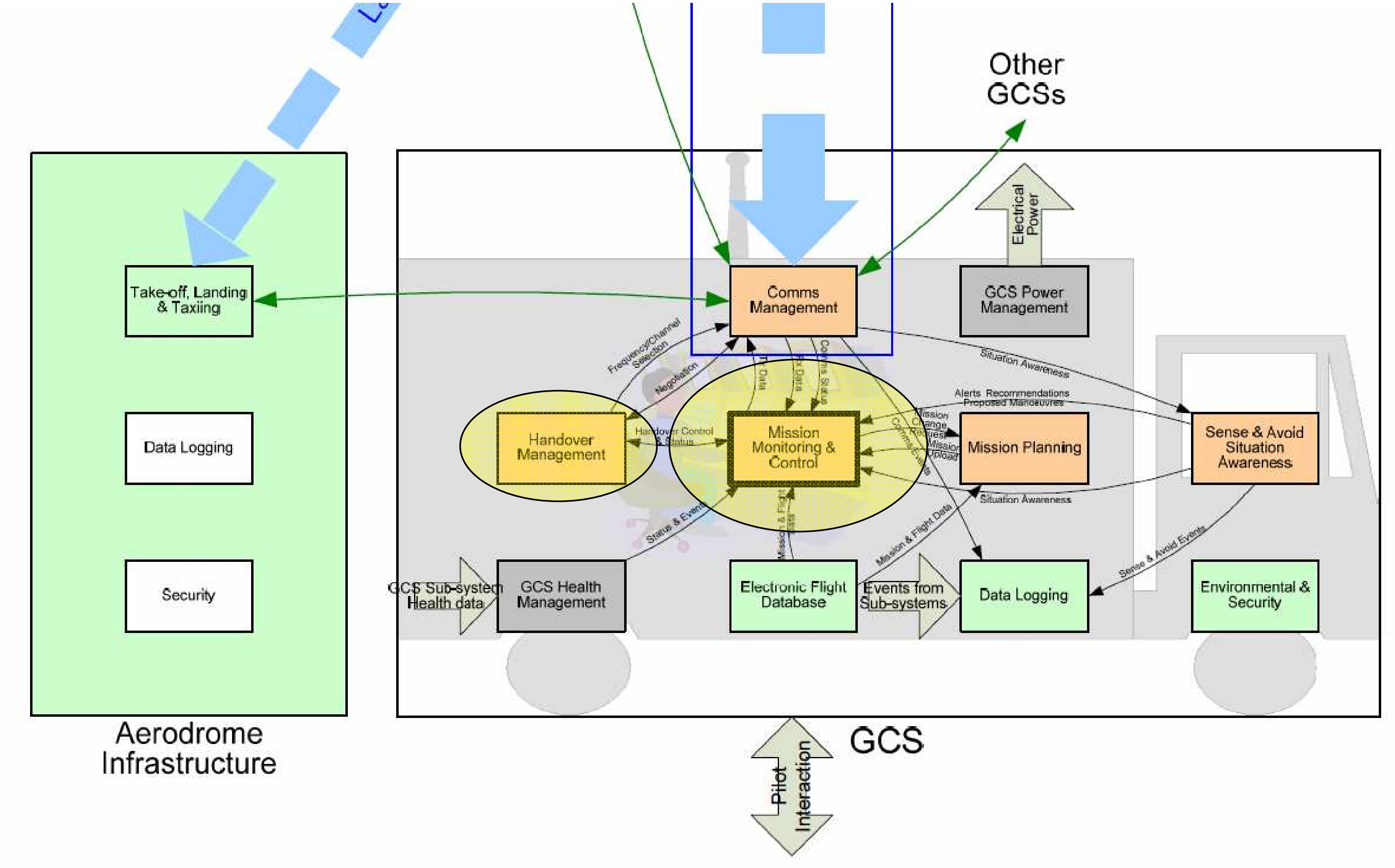
ASTRAEA

# ASTRAEA Virtual Certification System Architecture

# UAS System Architecture - UAV



# UAS System Architecture - GCS



# High Level Functional Specification

## Key Functions

- **Mission Execution**
  - Centralised decision making executive acting as top level decision arbiter/gatekeeper
  - Mission Plan execution
  - Delegation of authority to relevant sub-systems e.g. power management
  - Conflict resolution

- **Safety Monitor**
  - Maintain safe flight of the UAV
  - Safe flight termination (emergency)

- **Command and Control interface with GCS**
  - Variable autonomy levels for a manageable Command and Control (C2) workload, time criticality and loss of communications
  - Shared Situation Awareness picture
  - Cognitive engineering based Human Machine Interaction for UAV pilot
  - Handover management

# Mode of Operation

**Two key modes of decision making proposed**

- **Human in the loop (data link present; non-time critical decisions)**
  - **Full system functionality; UAV pilot is in the C2 loop and authorises every decision (exception for time critical e.g. D&A)**
  - **Integrity level defined with UAV pilot as final authority**

- **Machine based decisions (data link not present; time critical decisions)**
  - **Restricted decision making set focussing on safety functions**
  - **Predictable i.e. in accordance with flight plan**
  - **Transponder code (#7601?)**
  - **Detect and Avoid**
  - **Integrity level defined with onboard systems as decision making authority**

**The decision making architecture inherently provides a solution to managing a variable quality data link, through the PACT framework.**

# ASTRAEA:
# Decision Making Technologies

- **ASTRAEA is continuing to research a number of aspects of decision making:**
  - **UAS Decision Making Architectures (UAV and GCS components)**
  - **Delegated authority autonomous sub-systems e.g. intelligent power management**
  - **Agent based decision making toolsets**
  - **Basis for certification**
- **Synthetic Environment (SE) trials evaluation throughout the project, e.g.**
  - **ATC integration**
  - **GCS handover**
  - **Multiple vehicle / single GCS pilot workload**

# Summary

- Purpose of Autonomy is to make decisions through partnership between UAV and Operator, including safe flight when Operator is unavailable
- Emerging regulatory guidance on system requirements for civil UAS
- Decision making system shall be as safe as manned aircraft
- ASTRAEA developing an autonomous systems architecture to support centralised decision making function on UAV
- Engagement with UK CAA to develop a basis for certification of proposed architecture for autonomous system
- ASTRAEA continues an ongoing programme of SE trials to experiment and de-risk autonomous system solutions