PROJECT BLUEBIRD

AI and Digital Twinning
for Air Traffic Control

Marc Thomas

Project Bluebird, Digital Twin Lead at NATS

Visiting Professor at Queen Mary University London

NATS | The Alan Turing Institute | University of Exeter

Air Traffic Control

Issues instructions to aircraft to ensure **safe** and **efficient** flights

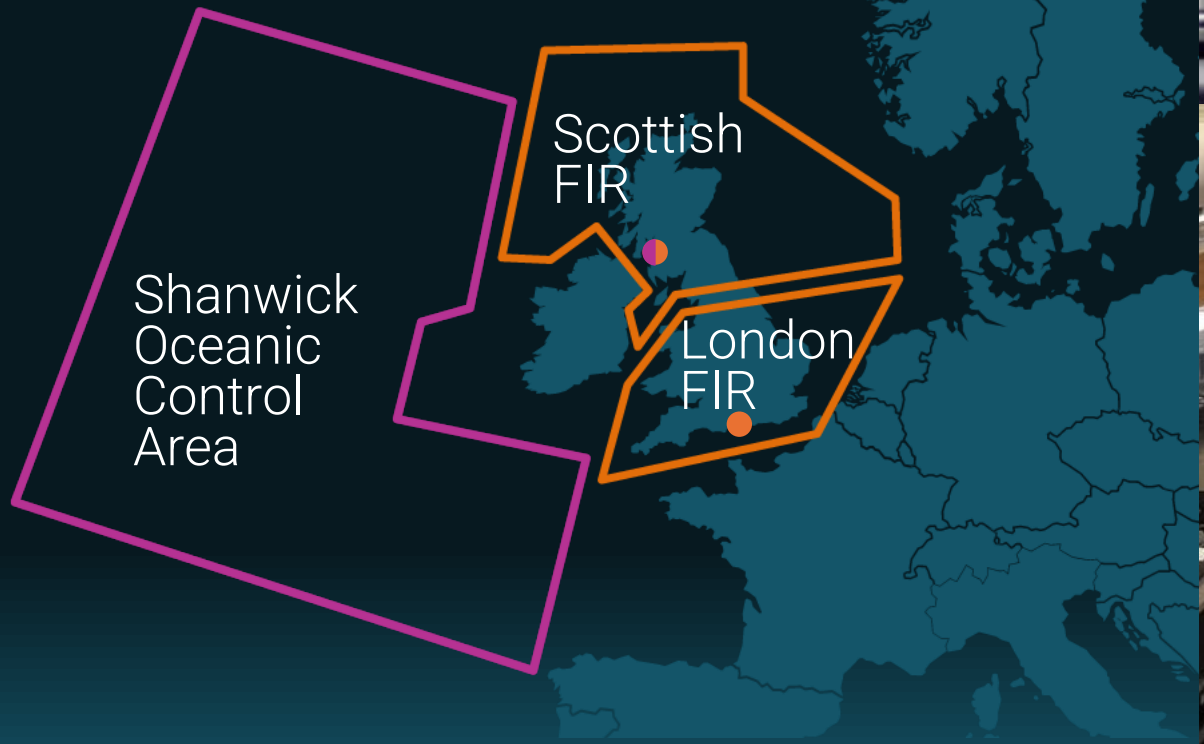
NATS (former "**N**ational **A**ir **T**raffic **S**ervices")

Provides Air Traffic Control for:

- UK skies (2.5 million flights/year)
- Eastern Atlantic
- 14 UK Airports, including
  - Heathrow, Gatwick, Stansted
- Military flights
- General aviation service
- Helicopters to oil-rigs
- Air traffic and consultancy services in Europe, Middle East, Asia, North America

NATS Airspace

- **London & Scottish**:
  1m km² – 11% of Europe's airspace and 25% of traffic
- **Shanwick**
  2.2m km² – 80% of North Atlantic traffic



Industrial Challenges

INCREASING CAPACITY

2.5M flights in 2024
30%-40% increase in traffic by 2040

CARBON REDUCTION (“Jet Zero Strategy”)

2040: All domestic flights and airports net zero
2050: Net zero aviation by 2050

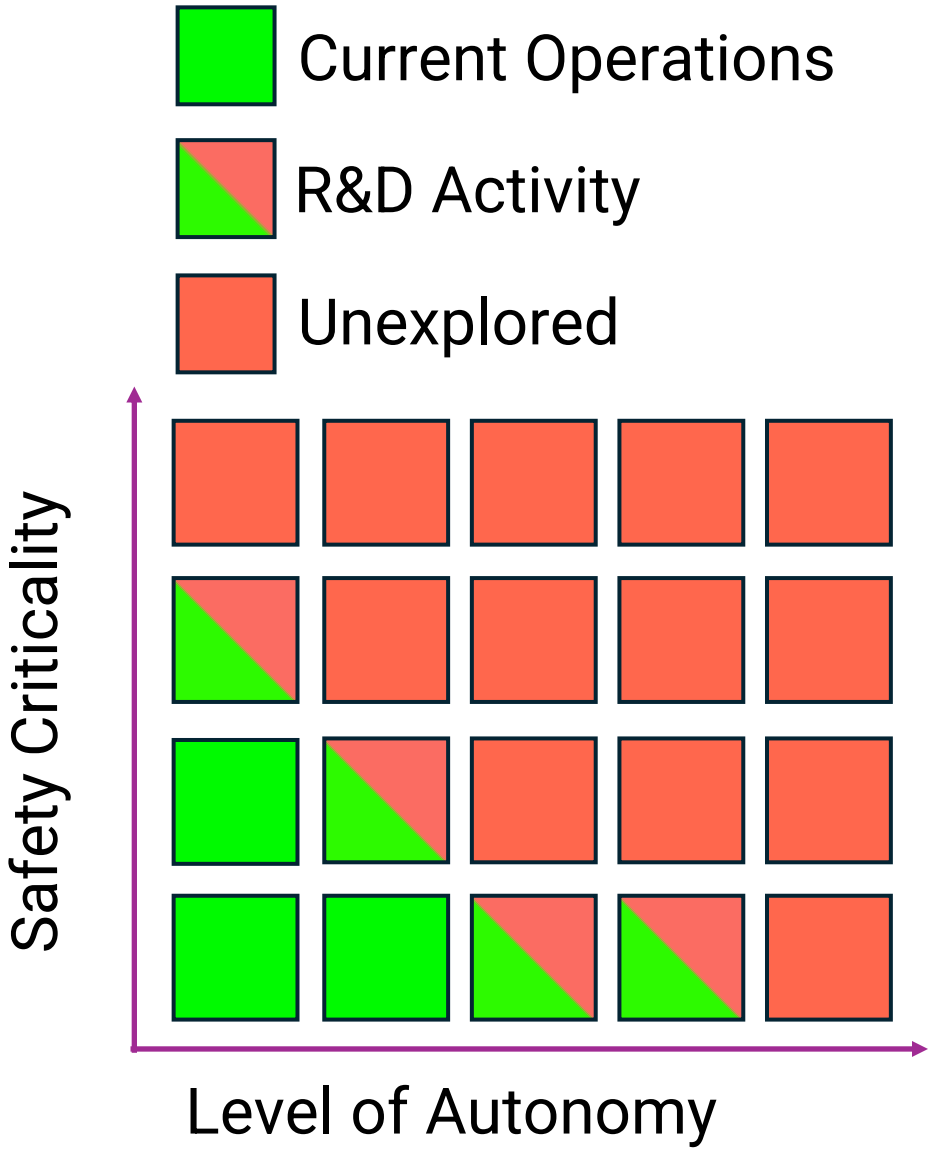
NEXT GENERATION AIR VEHICLES

Integrating drones, uncrewed aircraft systems (UAS), electric vertical take-off and landing vehicles (eVTOLS)

AIRSPACE MODERNISATION STRATEGY

Complete transformation of the route network to enable a simpler and safer future for air travel

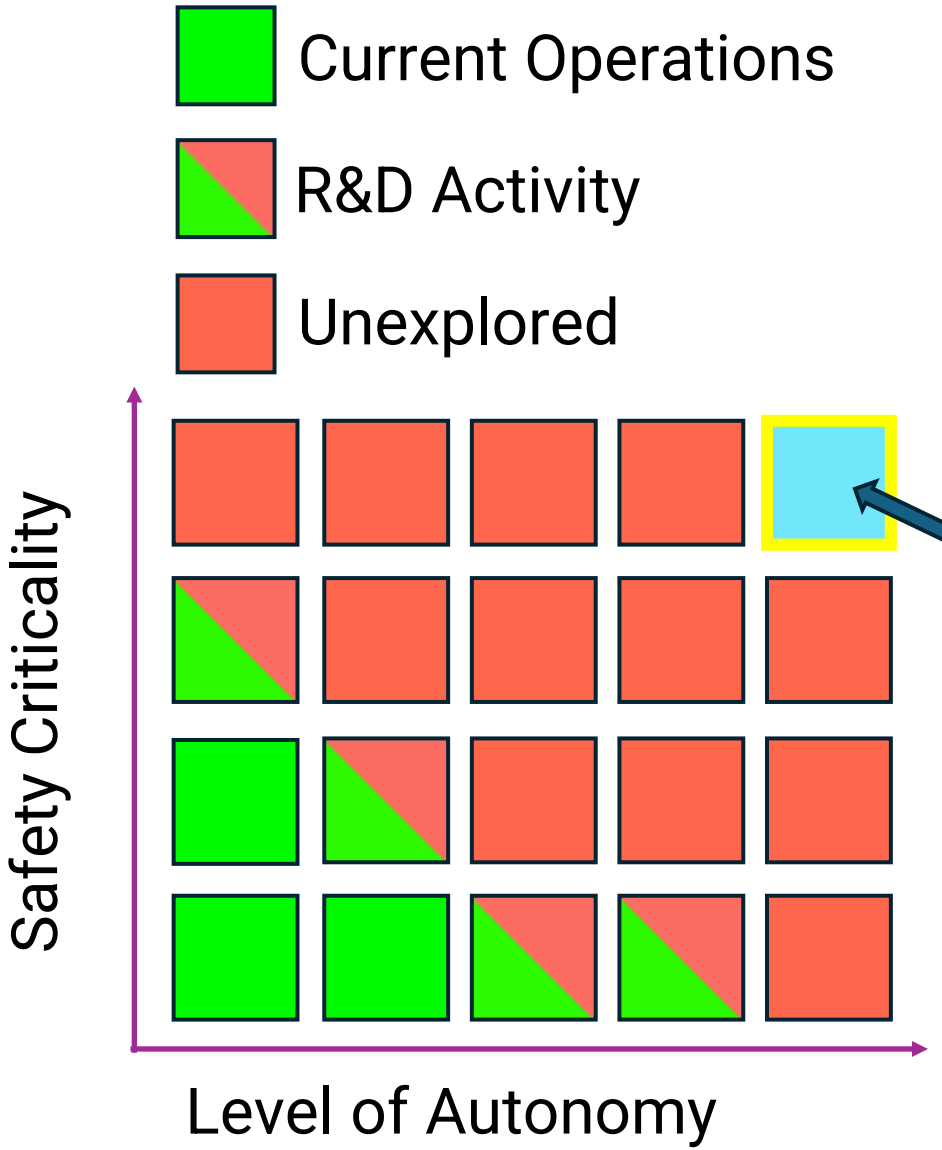
Research Landscape in 2019



Incremental Research in Safety Critical Industry

- Slow, incremental research
- 10 years+ from concept to operations
- Extremely expensive (£100M+) to develop and deploy high levels of automation
- Impossible to experiment across autonomy scale

Research Landscape in 2019



Incremental Research in Safety Critical Industry

- Slow, incremental research
- 10 years+ from concept to operations
- Extremely expensive (£100M+) to develop and deploy high levels of automation
- Impossible to experiment across autonomy scale

Project Bluebird

- Explore **Full Automation** with **AI taking actions independently**
- Pushes boundaries. Assess art of the possible.
- **Research and Development Enabler**
  - Data, Cloud, AI Expertise, Software
  - National and International Collaborations

PROJECT BLUEBIRD

NATS The Alan Turing Institute University of Exeter

5-year £15m partnership

- NATS
- The Alan Turing National Institute for AI
- The University of Exeter
- Funded by the partners, the Engineering and Physical Research Council and Microsoft

Research Goal: Build an AI agent to control a sector of UK airspace

Started in July 2021. Brings together a community of over 40 people

- Mathematicians, Engineers, Data Scientists, Research Software Engineers, Social Scientists, Air-Traffic Controllers (ATCO), ATCO Instructors, Safety Specialists, System Engineers, HPC specialists, Domain Experts, Statisticians, Analysts, Ethnographers, Cognitive Scientists, Concept Validation, Project Managers, ……..

Microsoft SEPnet South East Physics Network DISCnet University of Cambridge The University of Warwick Queen Mary University of London UKRI Engineering and Physical Sciences Research Council

The University of Edinburgh University of Sussex University of Bristol Imperial College London University of Southampton University of Oxford The Open University

PROJECT BLUEBIRD

NATS The Alan Turing Institute University of Exeter

5-year £15m partnership

- NATS
- The Alan Turing National Institute for AI
- The University of Exeter
- Funded by the partners, the Engineering and Physical Research Council and Microsoft

Research Goal: Build an AI agent to control a sector of UK airspace

Main components:

- Data
- Probabilistic Digital Twin of UK airspace
- AI Air Traffic Control Agents
- AI Explainability, Trustworthiness, Transparency and Validation

DATA

Dataset

- Over **20 million flights** over the UK
- **50+ different dataset**
  - radar, flight plans, Air Traffic Controller commands, airspace details, routes, arrival management systems, airport systems data, …

Significant Data Preparation Task

- *"80% of real-life data science work is preparing datasets"*

Cloud Platform

- Data processing and storage
- Collaboration computing platform

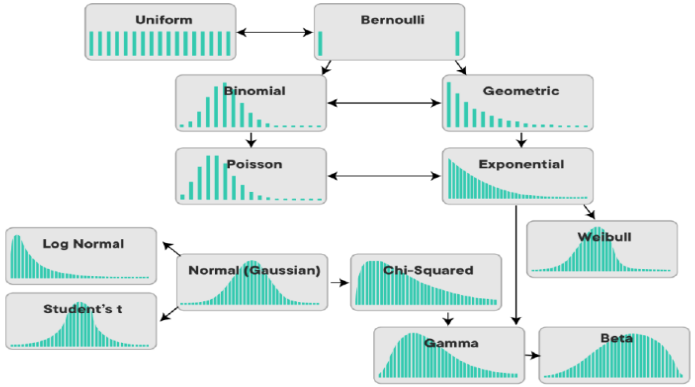
PROBABILISTIC DIGITAL TWIN

Simulator + Data from real-world counterpart → Digital Twin

High fidelity, data-driven, statistically calibrated digital representation

- Provides realistic simulations based on historic and live data
- Allows flexible “what if” scenario testing
- Provides visual outputs, which are interpretable by decision makers

Digital Twin + Probability → **Probabilistic Digital Twin**



More powerful Digital Twin which

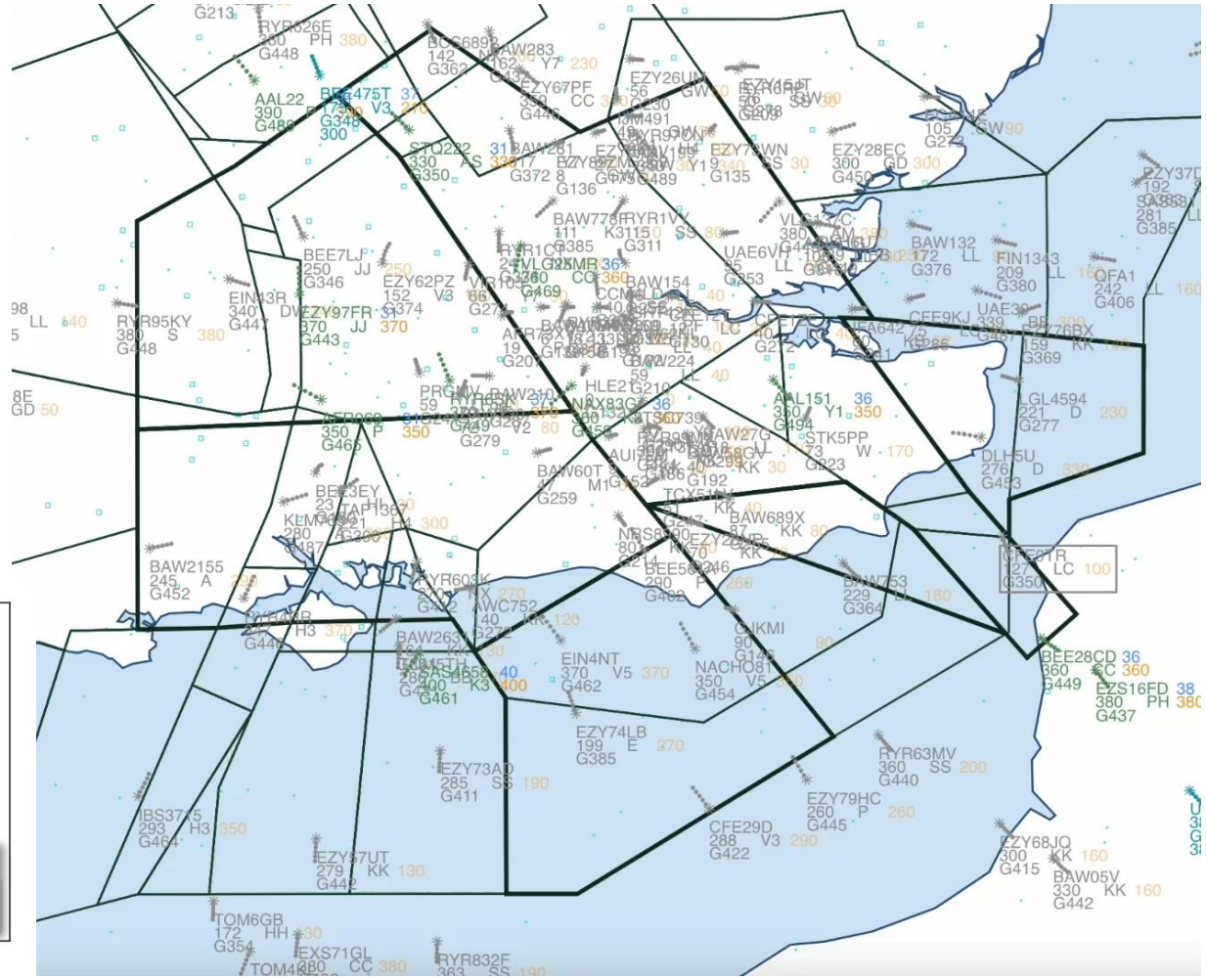
- **Quantifies risk in safety critical environments**
- Uses real-world data to calculate and model uncertainties
- Provides a range of possible behaviours with their likelihoods
- Can accurately model exceptional circumstances

DIGITAL TWIN OF UK AIRSPACE

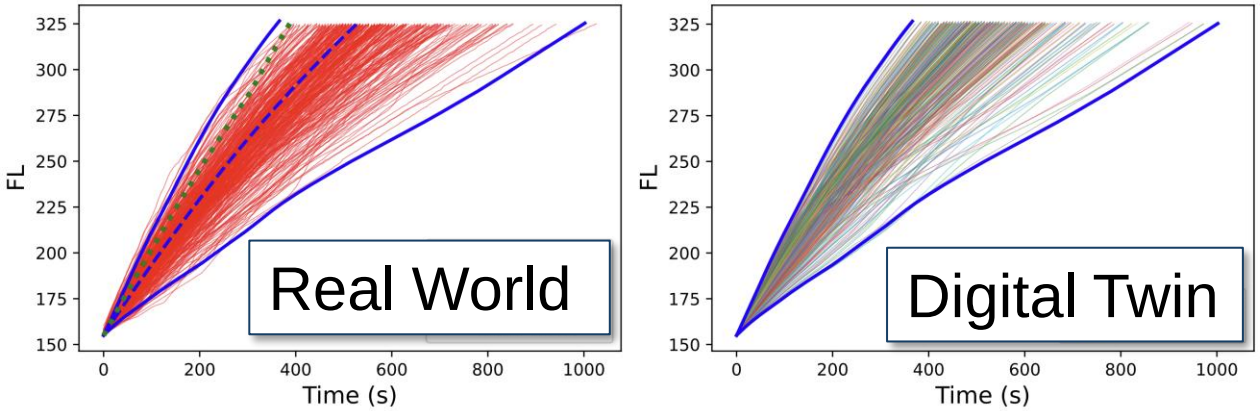
Multi-component Probabilistic Digital Twin of UK airspace

Components that can be modelled from **real data** or **artificially** altered:

- Airspace
- Aircraft
- Airports
- Procedures
- Routes
- Weather
- Controller (Human or AI)



Probabilistic Predictions



11

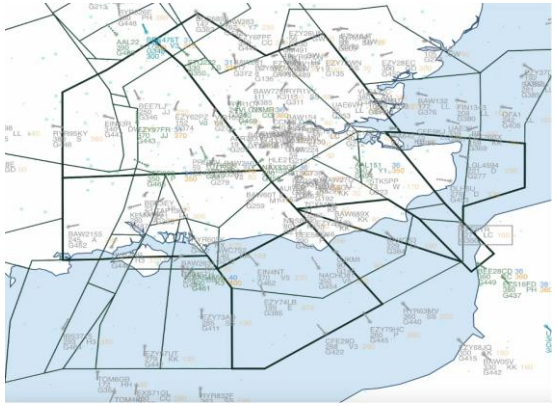
PROJECT BLUEBIRD

Real-world Operations

Multiple Screens for each
Air Traffic Controller

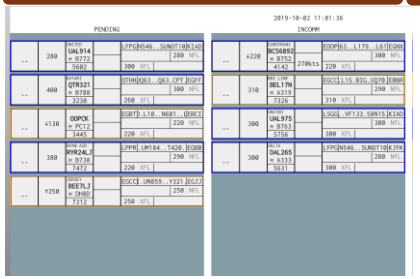
Digital Twin Interface

Screen1
Radar Map

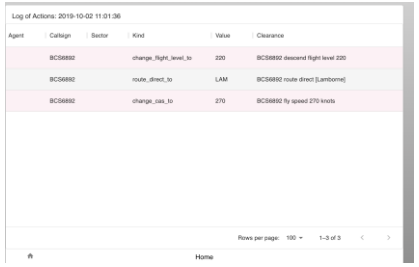


Screen 2
Control Panel

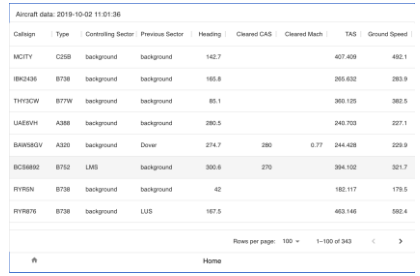
Screen 3
Flight Strips



Screen 4
Instruction Log

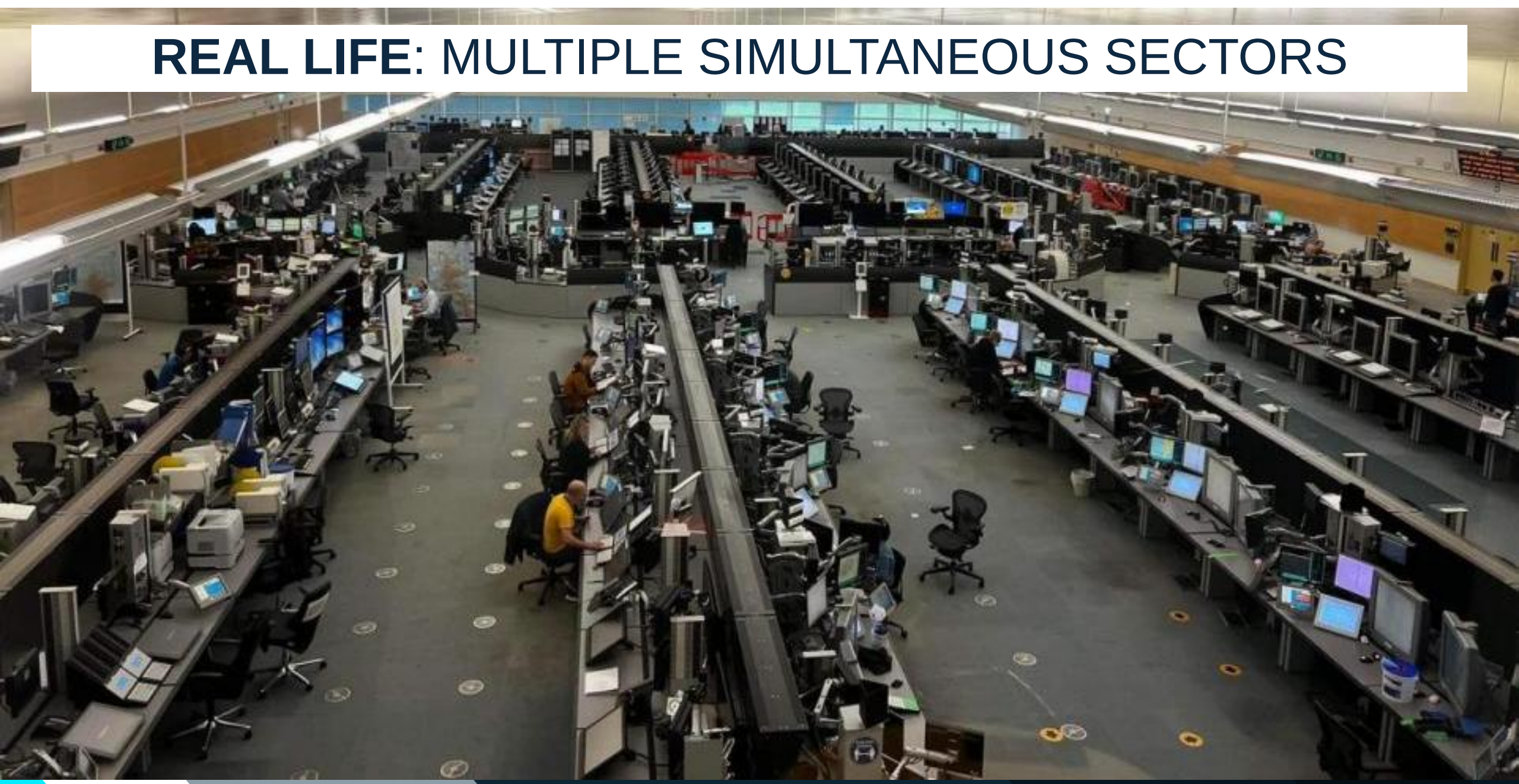


Screen 5
Aircraft Info

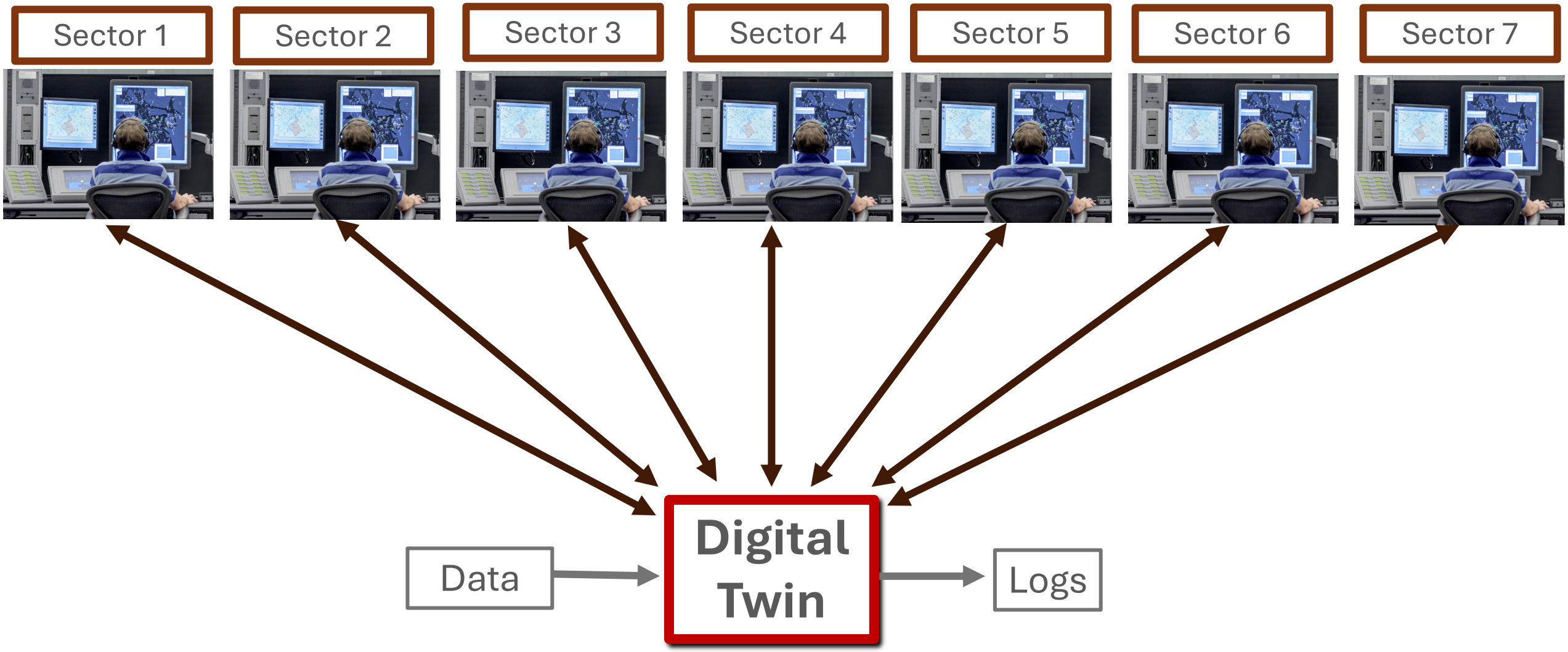


Multiple Screens Available
in Digital Twin

REAL LIFE: MULTIPLE SIMULTANEOUS SECTORS



DIGITAL TWIN: MULTIPLE SIMULTANEOUS SECTORS

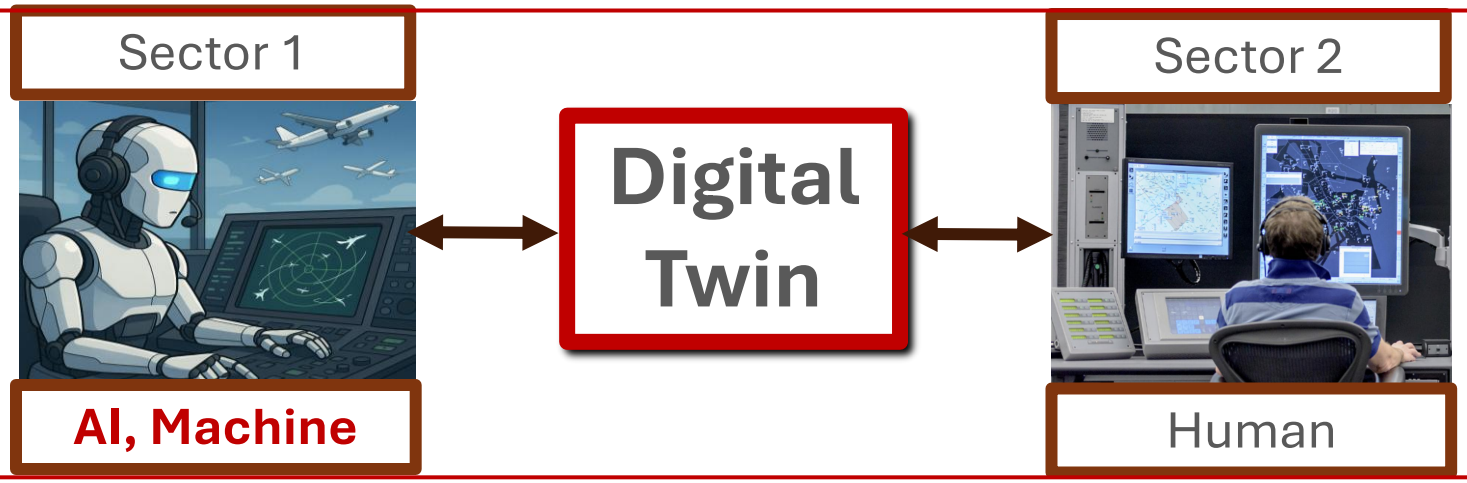


14

AI AGENTS

Virtual Air Traffic Controllers, computer programs which automate decision making

Trained and tested within the Digital Twin



What do they need to do?

PRIMARY: maintain safety

SECONDARY

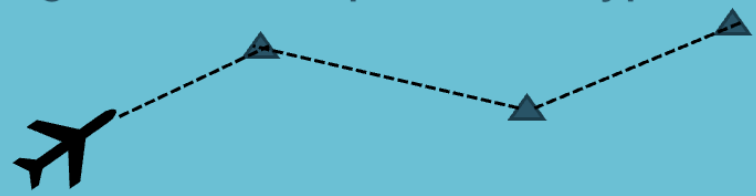
More nuanced

- Safe even if communication fails
- Follow set routes and procedures
- Fuel efficiency
- Orderly transition to next Air Traffic Controller, etc

AI AGENTS

What instructions can they issue?

Air Traffic Control Command Basics:

“Fly route…”	Fly along a series of specified waypoints 
“Fly heading…”	Fly in a specified compass direction until told to return to route, e.g. “Fly heading 125 degrees” 
“Climb/descend…”	Climb/descend to a given altitude 
“Fly speed…”	Fly at a specified speed. Given in knots (nautical miles per hour) at low levels (<24,000 feet) and in decimal mach at higher levels

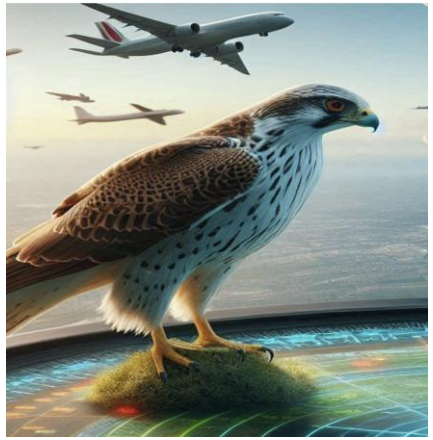
MULTIPLE AI AGENTS

Exploring **advantages and disadvantages** of multiple **different AI technologies**

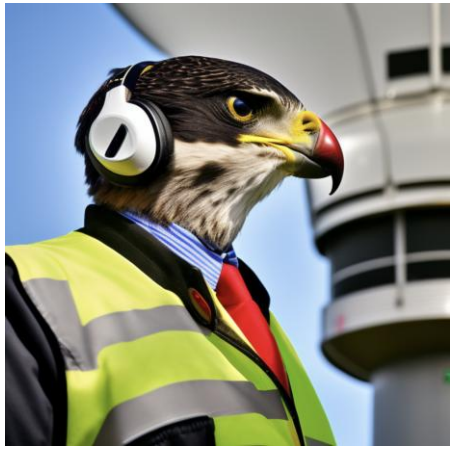
Trade-off of **flexibility versus explainability**

Rules Based

Search Based



Optimisation Based



Reinforcement Learning

Simplest → Complex

Least Flexible → Most Flexible

Most Explainable ← Least Explainable

How do we know how well the AI Agents are performing?

1. Assessment on **Game Version** of the digital twin
    - Capture basics of Air Traffic Control
    - Number of aircraft increases with time
    - ***Game Over*** of when aircraft gets too close
    - Allows comparison to human players


00:00:06
VECTORS: 5 MINS
10 NM
FLIGHT LEVEL OVERLAY
HEADING OVERLAY
AUTO DISPLAY PLANS
GLOBAL
OFF
RESET ALL
FL+
L
FL-
R
University of Exeter
NATS
The Alan Turing Institute
AIRSPACE READY
START
fABYSS
fHAUNT
fSIREN
FL 220
FL 250
FL 230
FL 210
XFL 220
FSANTA
FL 240
XFL 220
FSANTA

How do we know how well the AI Agents are performing?

1. Assessment on **Game Version** of the digital twin
   - Capture basics of Air Traffic Control
   - Number of aircraft increases with time
   - Game Over of when aircraft gets too close
   - Allows comparison to human players

How do we know how well the AI Agents are performing?

1. Assessment on **Game Version** of the digital twin
   - Capture basics of Air Traffic Control
   - Number of aircraft increases with time
   - Game Over of when aircraft gets too close
   - Allows comparison to human players

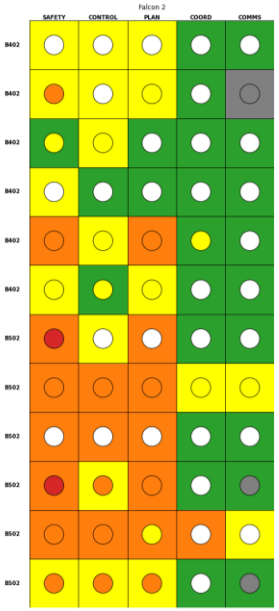
2. Assess on **human Air Traffic Controller Examination**
   - ”Basic Course” sat by all trainee Air Traffic Controllers after 4 months
   - Assess agents on **the same exam assessment**
   - Allows direct comparison and assessment of performance
   - **62 x 30 minute assessments** for 2 AI agents over 3 months

How do we know how well the AI Agents are performing?

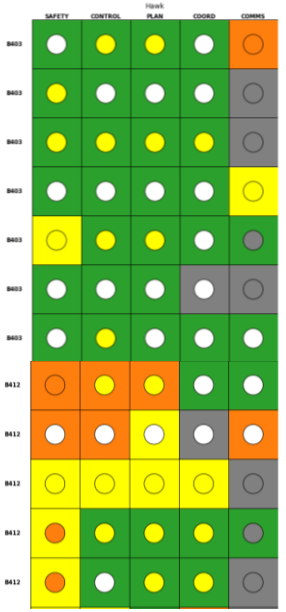
1. Assessment on **Game Version** of the digital twin
   - Capture basics of Air Traffic Control
   - Number of aircraft increases with time
   - Game Over of when aircraft gets too close
   - Allows comparison to human players

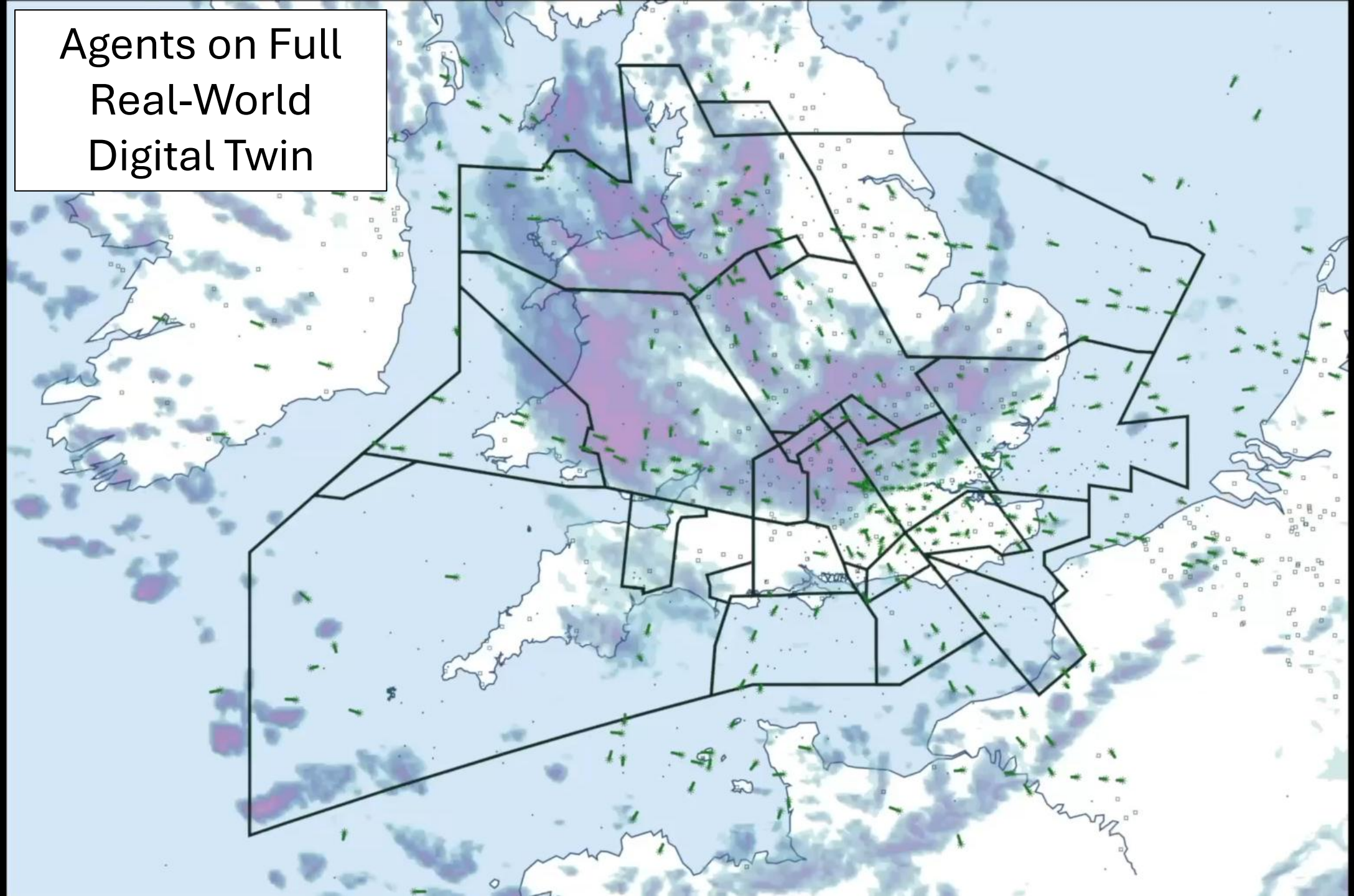
2. Assess on **human Air Traffic Controller Examination**
   - ”Basic Course” sat by all trainee Air Traffic Controllers after 4 months
   - Assess agents on **the same exam assessment**
   - Allows direct comparison and assessment of performance
   - **62 x 30 minute assessments** for 2 AI agents over 3 months
   - **Benchmark set. Will be reassessed in 1 year.**

Optimisation AI Agent



Rules Based AI Agent




Agents on Full
Real-World
Digital Twin

NEXT STEPS: 2025/26

Unexpected events

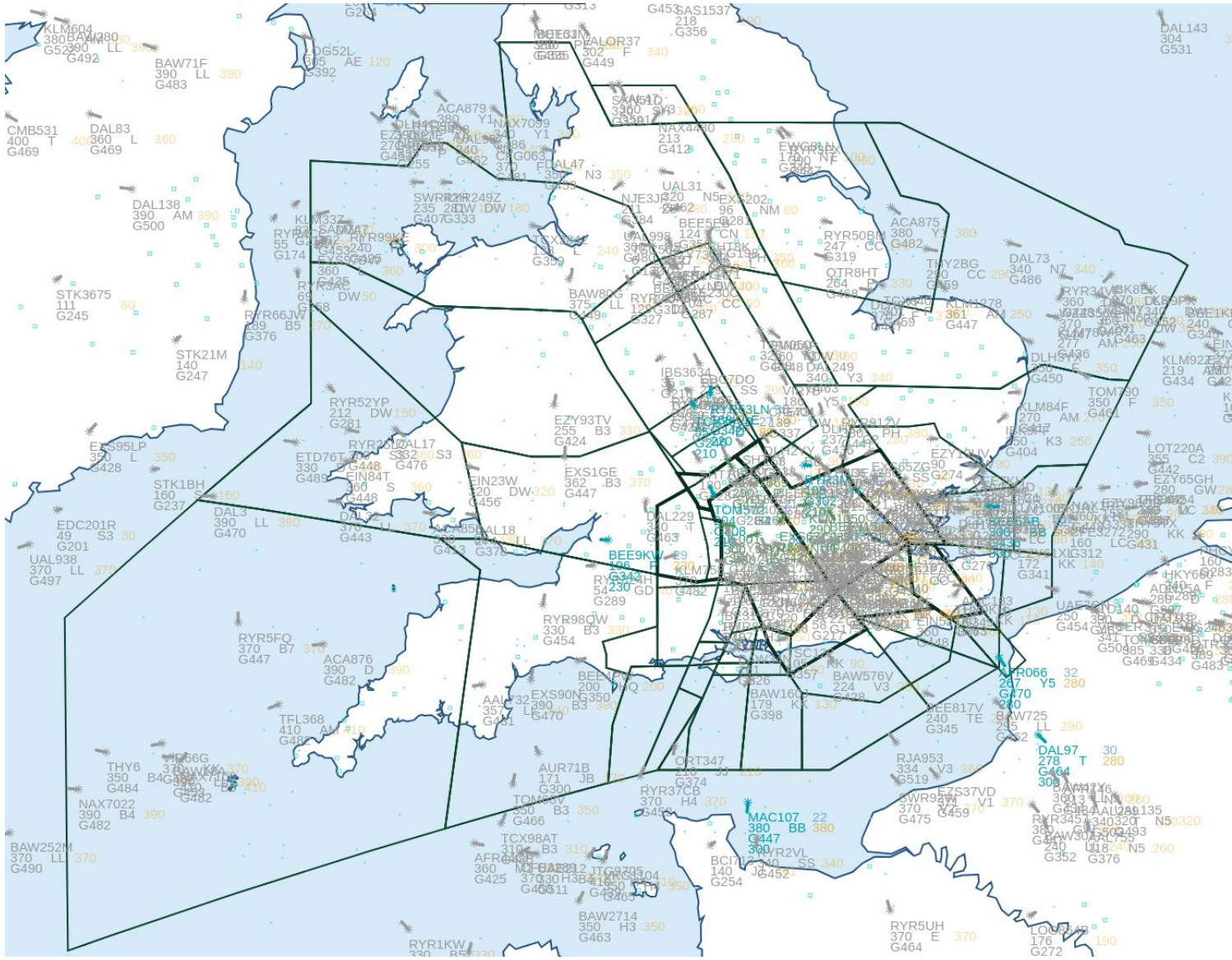
- Storm avoidance

Large Scale Trial

- 31 sectors available
  - multi-sector, multi-agent
  - multi-sector, single agent

Live Trials

- Live, one-way data stream from operational system
- Live shadow-mode trials
- World’s first



INDUSTRIAL ADOPTION

Air Traffic Control is **highly regulated**

How the regulator views automation is still evolving, but some things are clear

- For the foreseeable future, machines will have to coexist with humans
- Project Bluebird is **exploring the benefits and limitations** that different approaches bring

Short term (0 to 5 years)

- Research dataset and collaboration platform
- Tools for NATS training college
  - Automated scenario generation
  - Automatic assessment and metrics of trainee Air Traffic Controllers

Medium term (5 to 10 years)

- Advanced decision support and advisory tools
- Advanced safety tools

Long Term (10 to 30+ years)

- High levels of automation
- Full automation of easy situation or quiet periods

PROJECT BLUEBIRD

Prof Marc Thomas

Bluebird Digital Twin Lead, R&D, NATS

marc.thomas@nats.co.uk

4000 Parkway, Whiteley,
Fareham, Hants PO15 7FL

www.nats.co.uk

NATS | The Alan Turing Institute | University of Exeter