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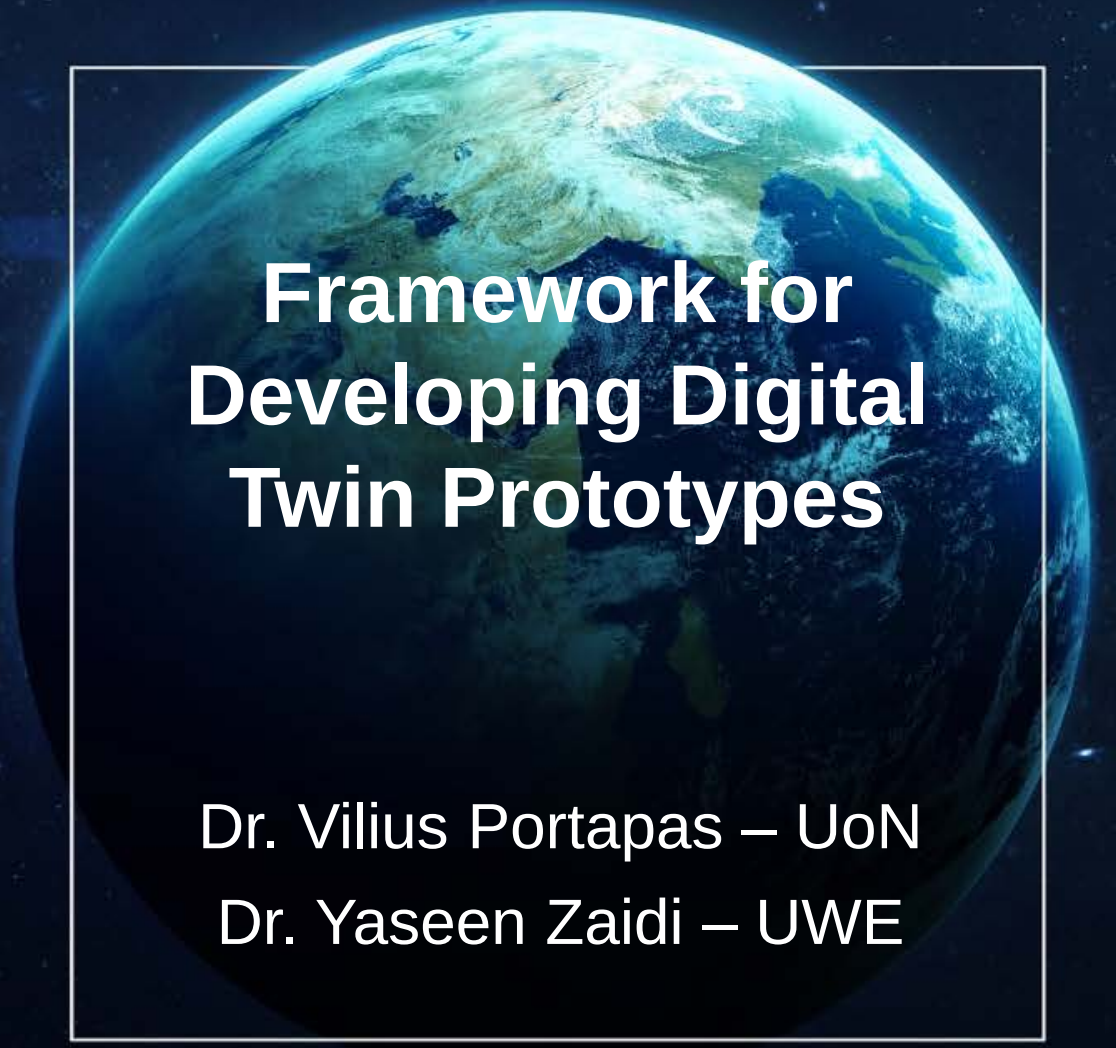

# Framework for Developing Digital Twin Prototypes

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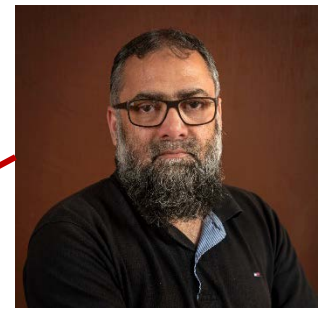
# Contents

- Personal introductions
- Introduction
- Modelling and simulation framework
- Aircraft and mission under analysis
- Results
- Conclusions

# Personal introductions



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# Introduction

- Digital twins are used across engineering domain more than ever
- Idea of advanced/urban air mobility is largely based on start-ups and never seen flying vehicles
- Hence, the tools enabling rapid prototyping, testing and certification are needed
- We propose a software framework, that enables prototype testing:
  - For flight dynamics and performance
  - For mission capability
- Hence, this framework may be useful for military application as well

# Mission and eVTOL

# Definition of a mission

## Mission

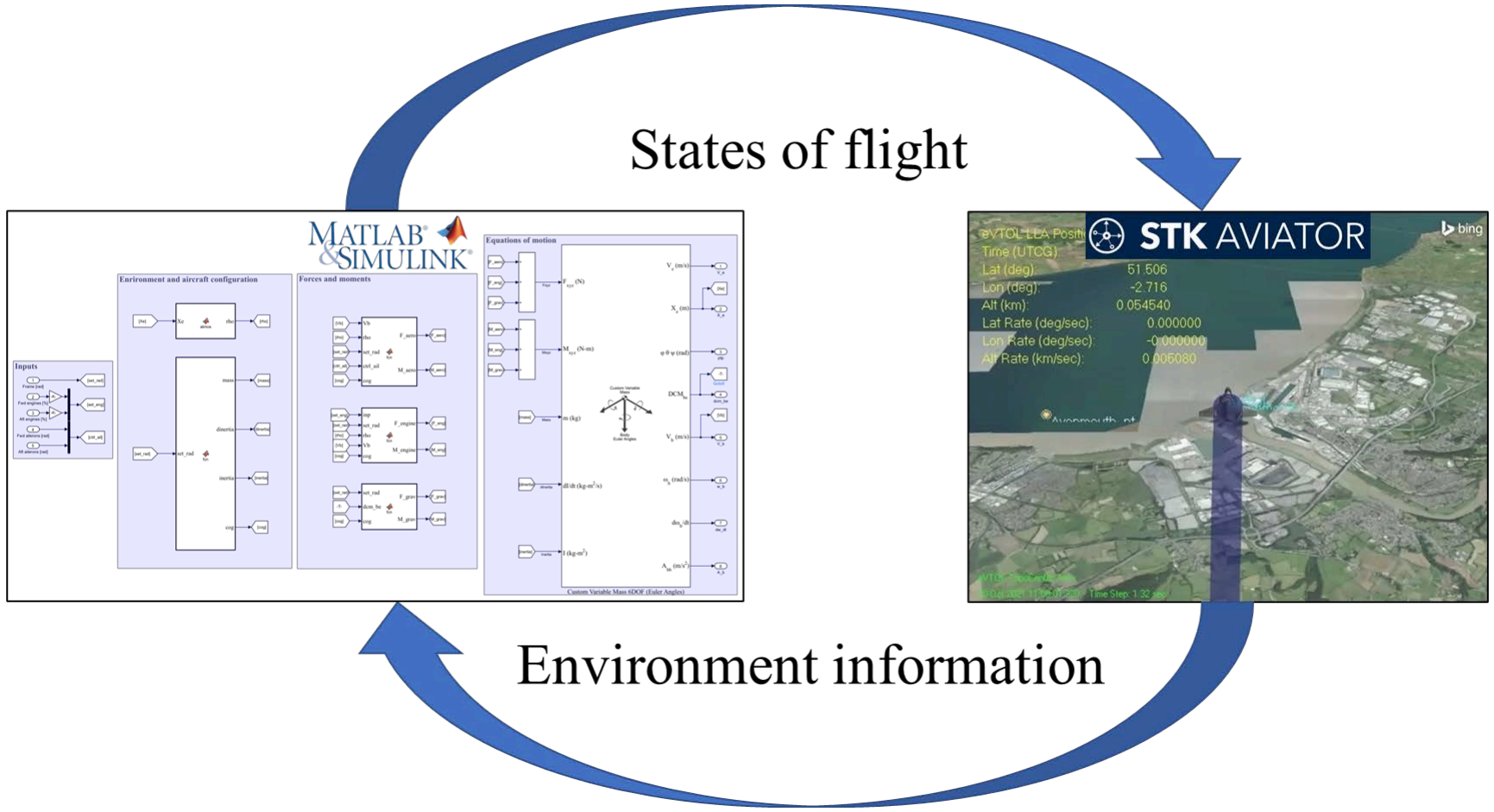
- Ferry flight Bristol – Cardiff
- Reduces travel time
- Safe proof of concept for using Neoptera's eOpter eVTOL in everyday operations

- Research project part of UKRI's Future Flight Challenge Phases 1&2

# Definition of Neoptera’s eOpter eVTOL

# Framework and results

# Framework

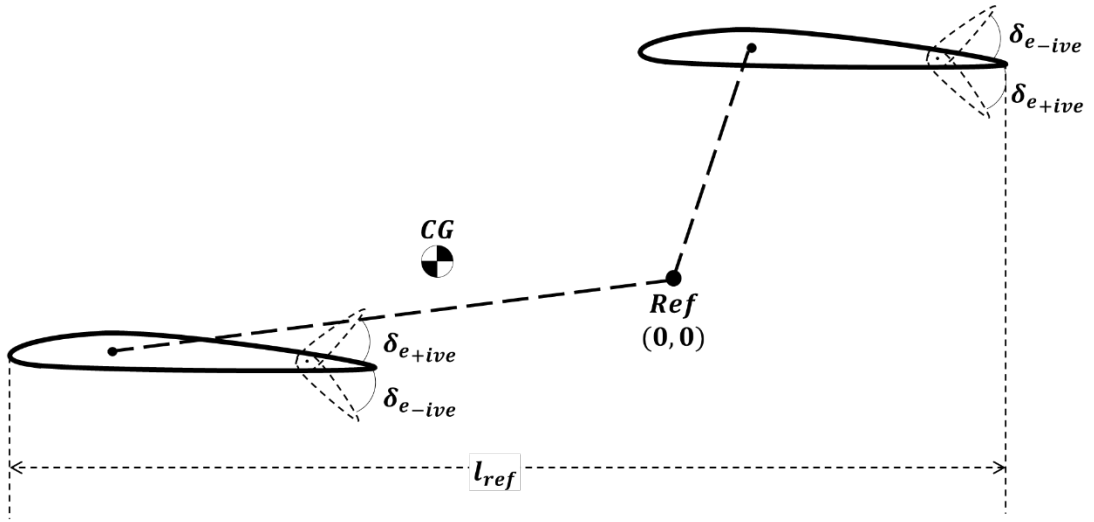

States of flight
MATLAB & SIMULINK
Environment and aircraft configuration
Forces and moments
Equations of motion
STK AVIATOR
bing
Lat (deg): 51.506
Lon (deg): -2.716
Alt (km): 0.054540
Lat Rate (deg/sec): 0.000000
Lon Rate (deg/sec): -0.000000
Alt Rate (km/sec): 0.005080
Environment information

# Framework: flight dynamics – forces and moments

## Forces & moments

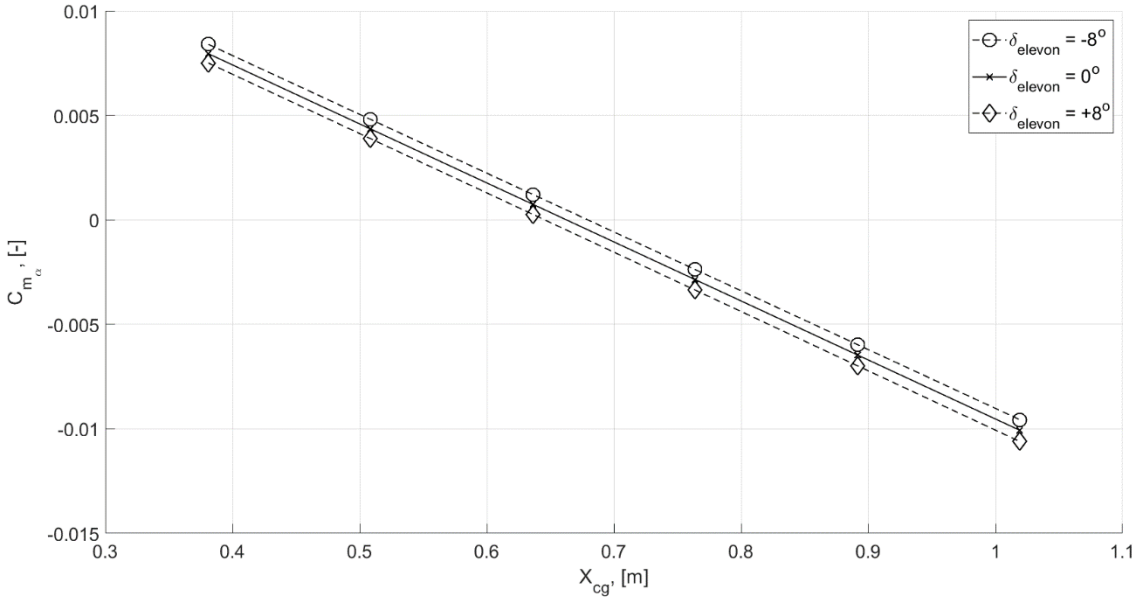
- Aero forces for wings
  - Look-up tables for $C_L$, $C_D$ and $C_m$ generated by Javafoil
  - Control surfaces as additional Δs towards the overall force of the wing
- Propulsive force – thrust
- Gravity force

## Control deflections

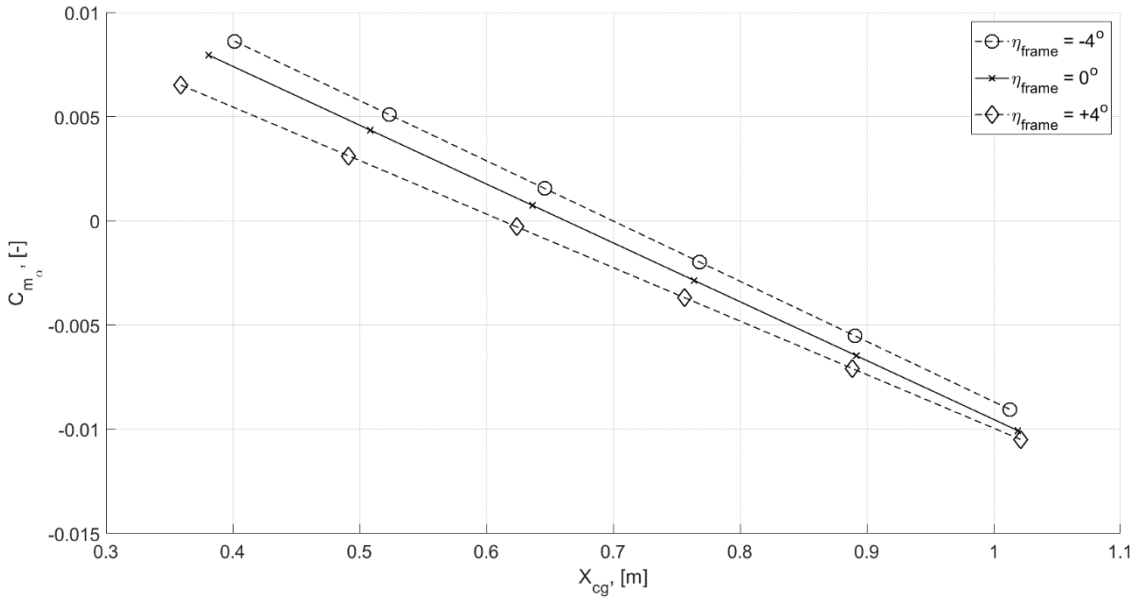



+ive deflection → negative moment

# Framework: flight dynamics – stability




$C_{m_\alpha}$ vs $X_{CG}$ graph showing statically stable airframe at 55 m/s with 0° frame setting angle




$C_{m_\alpha}$ vs $X_{CG}$ graph showing statically stable airframe at 55 m/s with 0° elevon setting angle

# Framework: flight environment

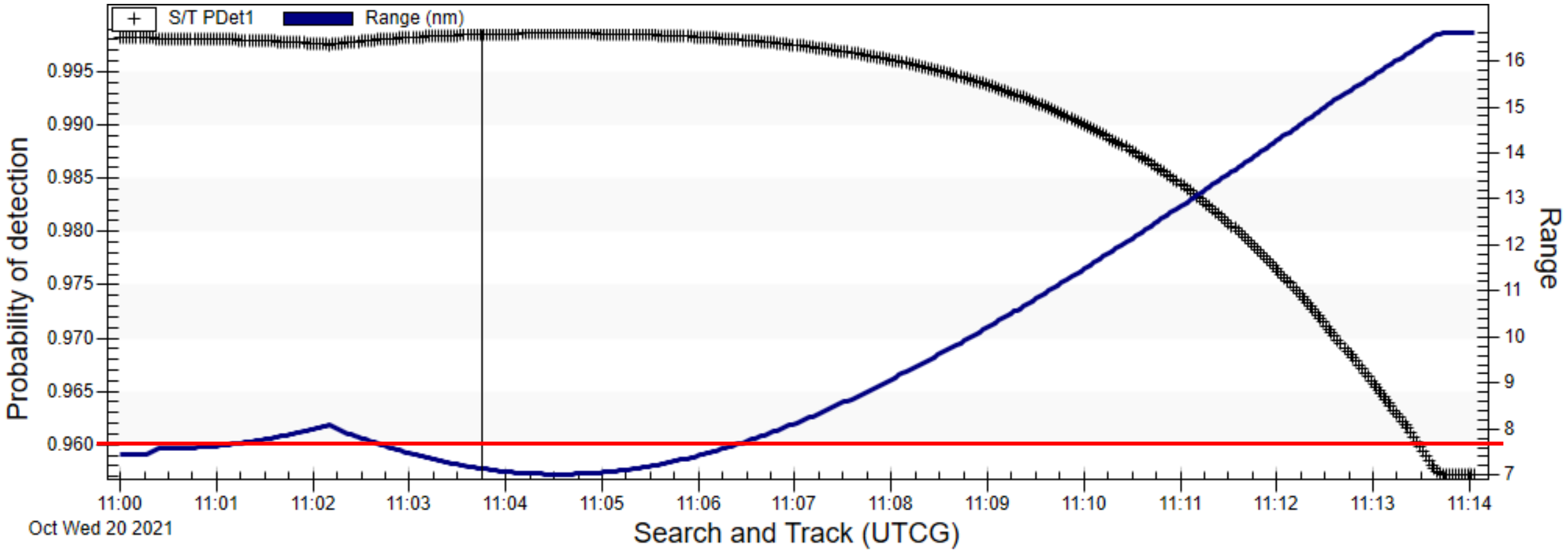
## Primary surveillance radar

- Bristol aerodrome radar
  - Modelled as aerodrome surveillance radar ASR-11 as defined by FAA
- Probability of detection >96% throughout the flight

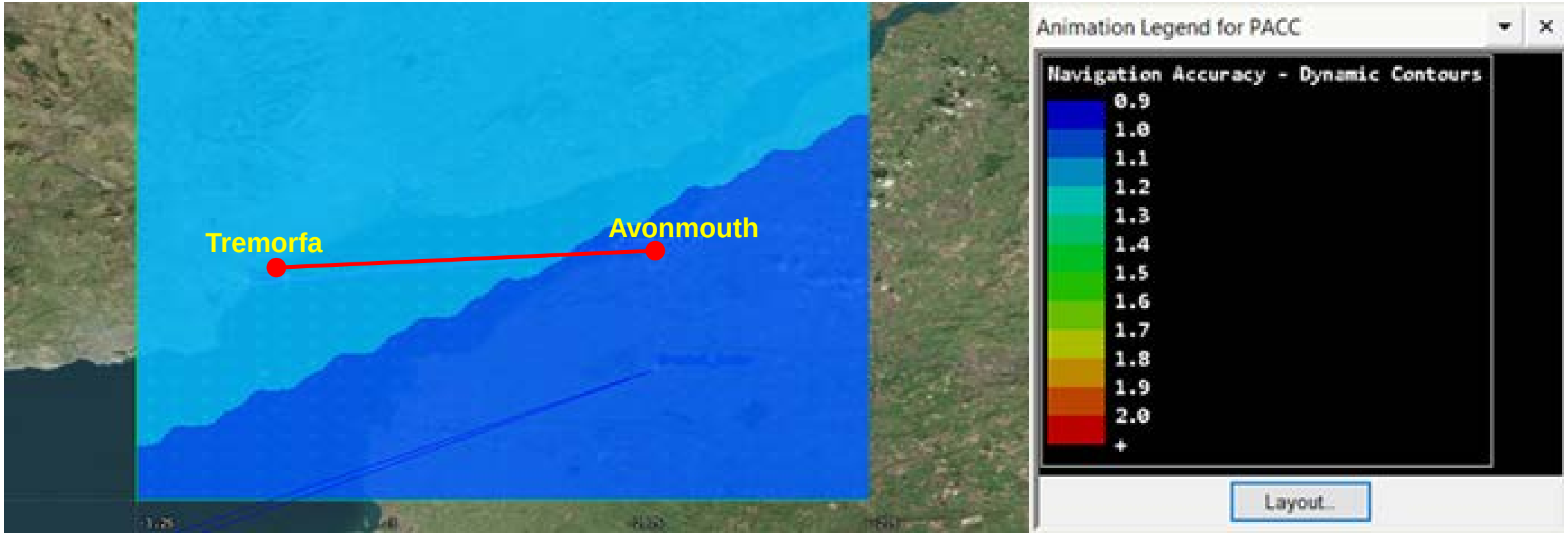
## Global positioning system

- Constellation of 31 satellites
- Accuracy 0.9-1.2 m

# Framework: flight environment – radar



# Framework: flight environment – GPS



# Discussion, conclusions and further work

# Discussion

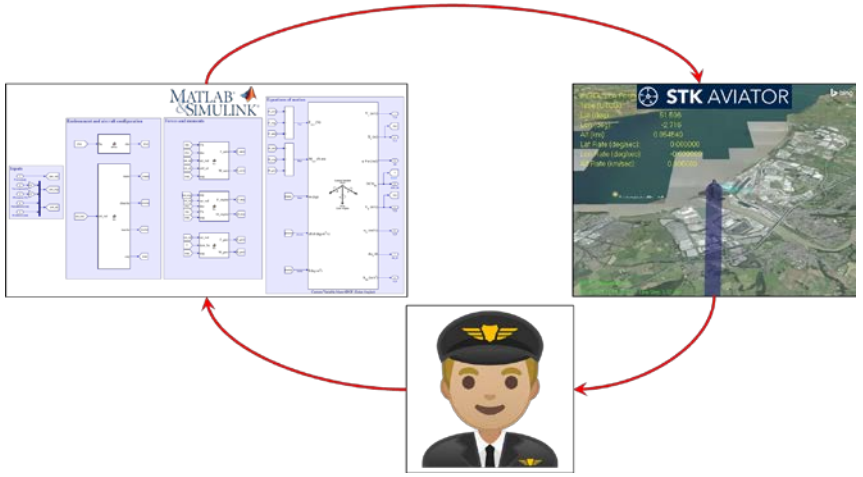
- MATLAB/Simulink package provides an easy-to-use math-based environment to develop a flight dynamics model of an eVTOL prototype aircraft
  - Aerodynamic model can be based on look-up tables or live computations, depending on the requirements, aircraft configuration and available computational power
- STK Aviator package provides visualisation and additional features, such as radar's probability of detection and GPS' position accuracy
  - Easy-to-use plug-and-play approach
  - Capability to interact with MATLAB/Simulink (in real time)
- Substantial amount of effort invested to develop the framework; however, once developed it is rather simple to use as a plug-and-play tool

# Conclusions

- Framework, coupling MATLAB/Simulink and STK Aviator, introduced
- Framework showed capability to:
  - Determine static stability of an aircraft under investigation (NP at 0.67 m)
  - Determine radar's probability of detection for a certain flight mission (>96%)
  - Determine GPS' position accuracy for a certain flight mission (0.9-1.2 m)
- Framework is easy and simple to use, although a substantial amount of effort was invested to develop it
- Framework can be adjusted based on changing mission requirements and equipment available

# Further work

- Automatic and real-time data exchange between MATLAB/Simulink and STK Aviator
- Flight dynamics model to be integrated with FNPT II flight simulator to provide cockpit environment
- Introduction of a pilot as a third element, hence closing the loop



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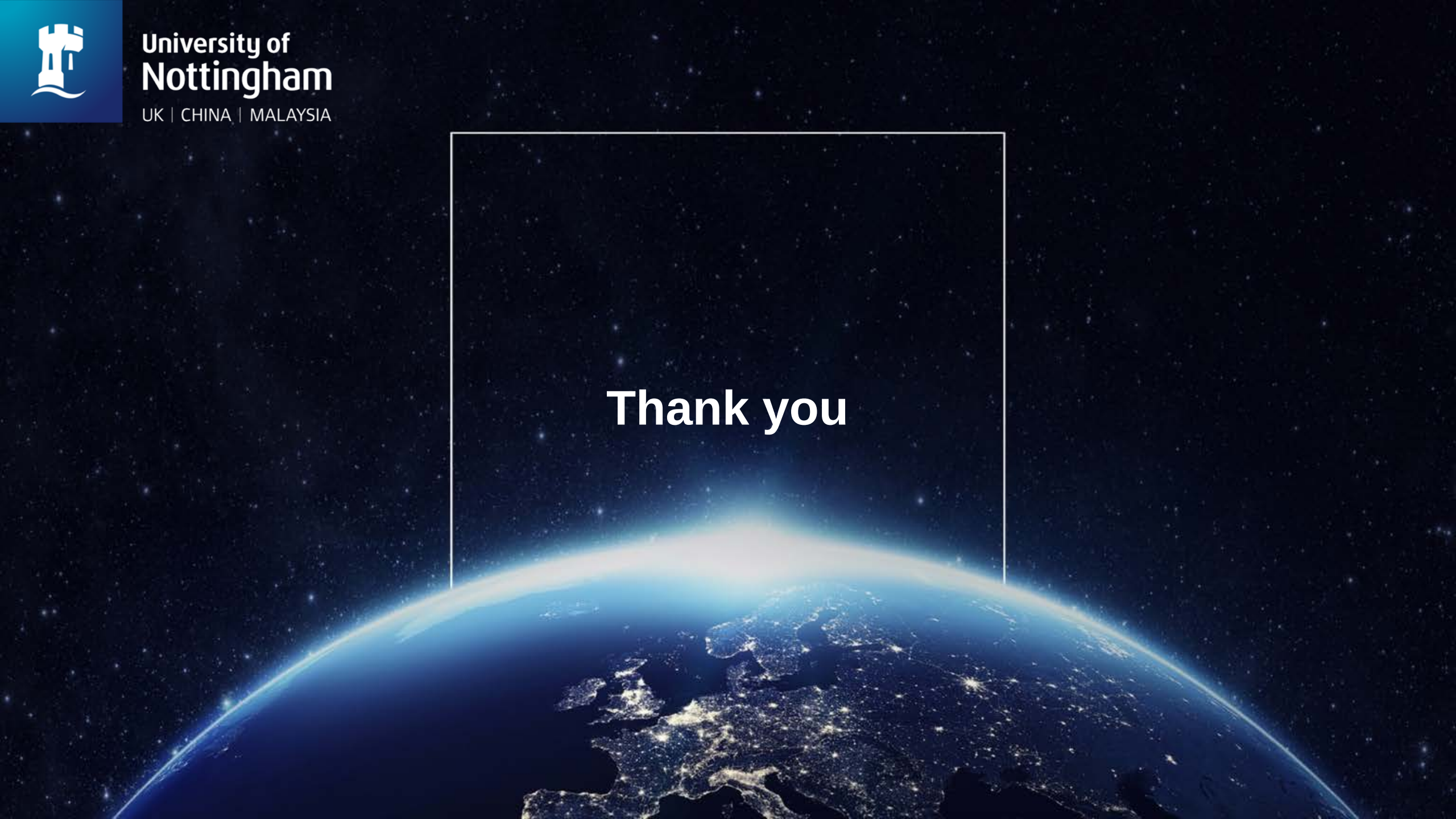

# Thank you