European Rotors

November 09, 2022

Fitness for Purpose and Absence of Unintended Function in Machine Learned Avionics

Ramanujam Kalale

Daedalean AG • 2022

Outline

1 Company Introduction

2 Our Products

3 Fitness for Purpose and Absence of Unintended Function

4 Certification Challenges for AI/ML components

5 Ongoing Certification - PilotEye

6 Our Roadmap

7 Question Time

We are Daedalean

100+ staff **11** PhDs **9** pilots

Google

SPACEX

AIRBUS

PILATUS

kopter

DLR German Aerospace Center

Rolls-Royce

Honeywell

CERN

FLARM

BCG
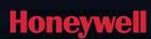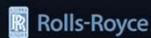
Carnegie Mellon University

Imperial College London

UNIVERSITY OF CAMBRIDGE

UNIVERSITY OF OXFORD

ETH zürich

STANFORD UNIVERSITY

UNIVERSITEIT VAN AMSTERDAM

TU Delft Delft University of Technology
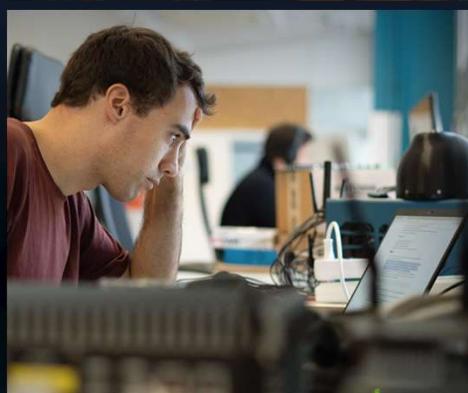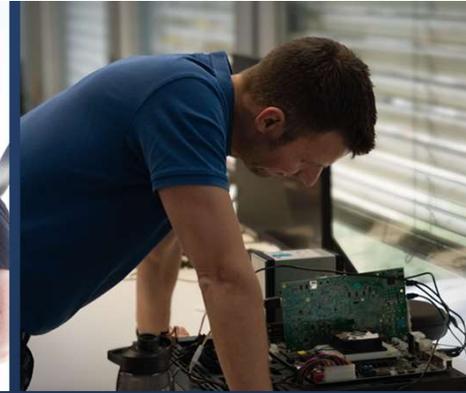
Our Mission

Provide certified AI systems to co-pilot and pilot the aircraft of today and tomorrow

In 2016, we set out to build the world's first fully autonomous flight control system...

...making flying safer, scalable and smarter by replacing and outperforming the human pilot on every measurable dimension

5 Plan
Plan the mission, modify the mission — pre-flight and en-route

4 Decide
Real-time decisions on board in normal and contingency situations

3 Communicate
Talk to air traffic controllers; understand other pilots

2 Navigate
Find optimal flight path, use existing air spaces, traffic patterns
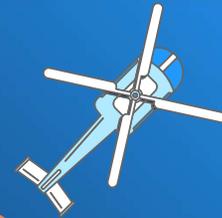
1 Aviate
Perception; control; aircraft state monitoring. Always know where to land and avoid obstacles

Source: FAA-S-8081-16B

Advanced Flight Maneuvers

FAA-S-8081-16B

Commercial Pilot
Practical Test Standards
for
Rotorcraft
(Helicopter and Gyroplane)

February 2013

Flight Standards Service
Washington, DC 20591

5

Key capabilities at key phases of flight

1. Detect and avoid hazards (on ground and airborne)
2. Emergency landing guidance to a safe site (known and unknown)
3. Detect and avoid airborne hazards (also non-cooperative)
4. Weather awareness
5. Position and navigate (also in GNSS-denied environment)
6. Precision landing on pre-marked site
7. Safe landing on unmarked site

Taxi, take-off and initial (vertical) climb

Cruise

Final approach, (vertical) landing, and taxi

6

Today...

- We have **proven solutions** and partnered with avionics providers.

- Validation over > **500 flight hours** in many environments and conditions, conducted by us and partners, and many more in visual simulation.

- In 2022, Daedalean has closed a **finance round of USD 58m** by a consortium of investors.

- Open **STC application** jointly with FAA and EASA for PilotEye. Issue paper and CRI closed..

Where am I?
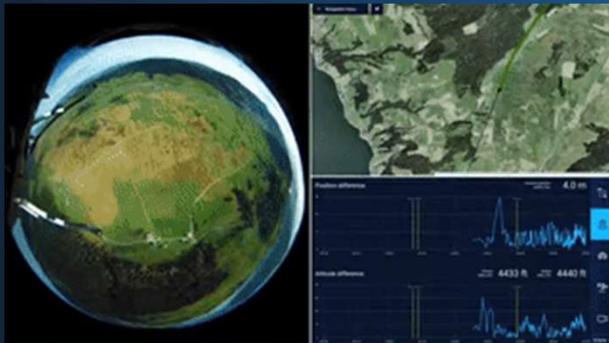
Visual Navigation

Where can I fly?
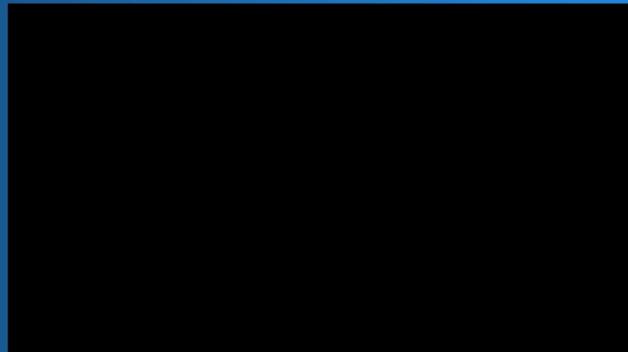
Visual Traffic Detection

Where can I land?

Visual Landing Guidance

Visual Positioning

Camera-based navigation and landing guidance

Functions

- Continuously outputs position, heading, velocities, height above ground, landing guidance and corresponding uncertainties

Properties

- Navigation data on par with high-end INS/GNSS and ILS is designed to integrate with existing INS-/GNSS-based navigation systems while being dissimilar

Safety certification level

- DAL-C+

Visual Landing Guidance

Onboard GNSS-independent landing guidance for VTOL and fixed-wing aircraft

Daedalean VLS

Functions

- Lists runways, helipads or landing markers in view
- Provides guidance on final approach to touchdown to the selected runway, helipad or landing marker

Properties

- Continuous real-time tracking of ownship position relative to the runway, helipad or landing marker
- No equivalent instrument exists

Safety certification level

- DAL-C+ target

Visual Traffic Detection

Noticing all fixed wing, rotorcraft and drones in time

Functions

- Detects and tracks traffic
- Classifies traffic
- Identifies size, position, direction of movement, time to collision

Properties

- Better accuracy than human pilots
- Detection range up to 3.5 km
- Up to 10 Hz
- Integration with existing flight deck instruments as a pilot-aid

Safety certification level

- DAL-C+

Evaluation Kit

Software function demonstrator for the upcoming product

Using COTS industrial components tested in the field

- 2 integrated camera & IMU sensors (VCU)
- 1 computing box (VXP)
- 1 GNSS antenna
- 2 antennas for ADS-B IN and FLARM IN
- 1 tablet computer as user interface
- Requires 24-28VDC supply which can be provided at two independent inputs (one is enough, two for redundancy)

Installation is up to the customer

- We provide standardised brackets/interfaces and support as required

- Optionally, we are able to design & manufacture a complete custom mounting solution if required or assist with customer-led enclosure design

What I mean by 'Fitness for purpose and Absence of Unintended Function'

The All Important Certification Paragraphs for Aircraft Systems:

|	
23.2500 and 2x.1301 Summary	• The Equipment must deliver Intended Function • No More No Unintended Function • No Less Deliver all required Function
23.2510 and 2x.1309 Summary	• The Equipment, systems and installations must be designed to ensure that they perform their intended functions • Under any foreseeable operating conditions (Normal & Abnormal conditions)

Why Machine Learning/Neural Networks?

2448 x 2048 px

612 x 512px

Hi-res RGB
Camera

Preprocessing

CNN

Post-processing
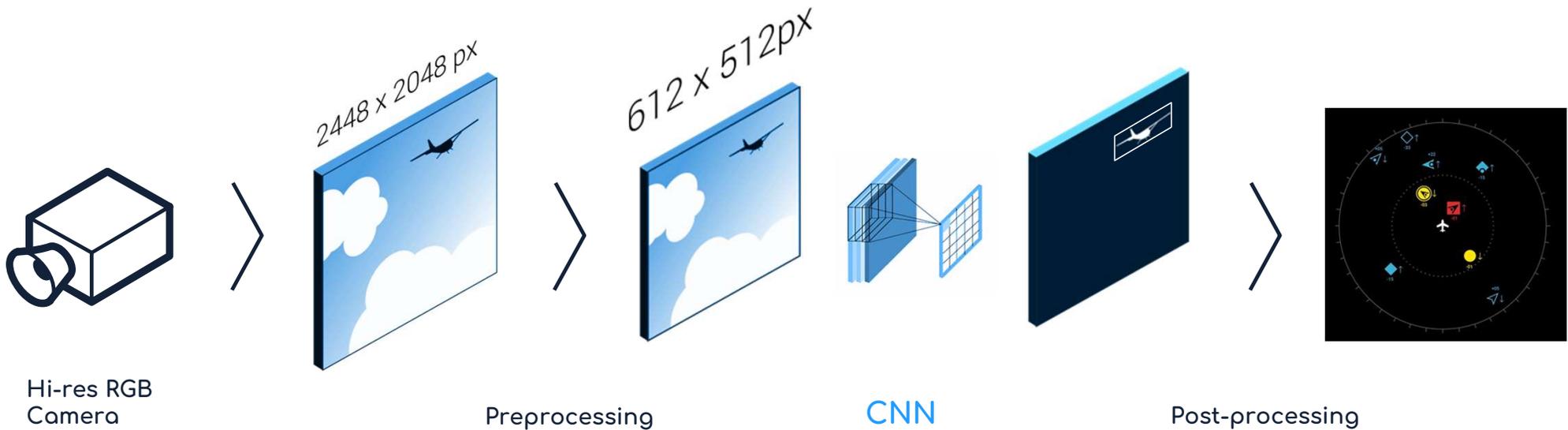
- The only way to obtain super-human performance in perception tasks

- Requires significant work to match development assurance standards of classical software

- Significant part of Daedalean's work

13

# Certification Challenges for ML: Current Design Assurance Process
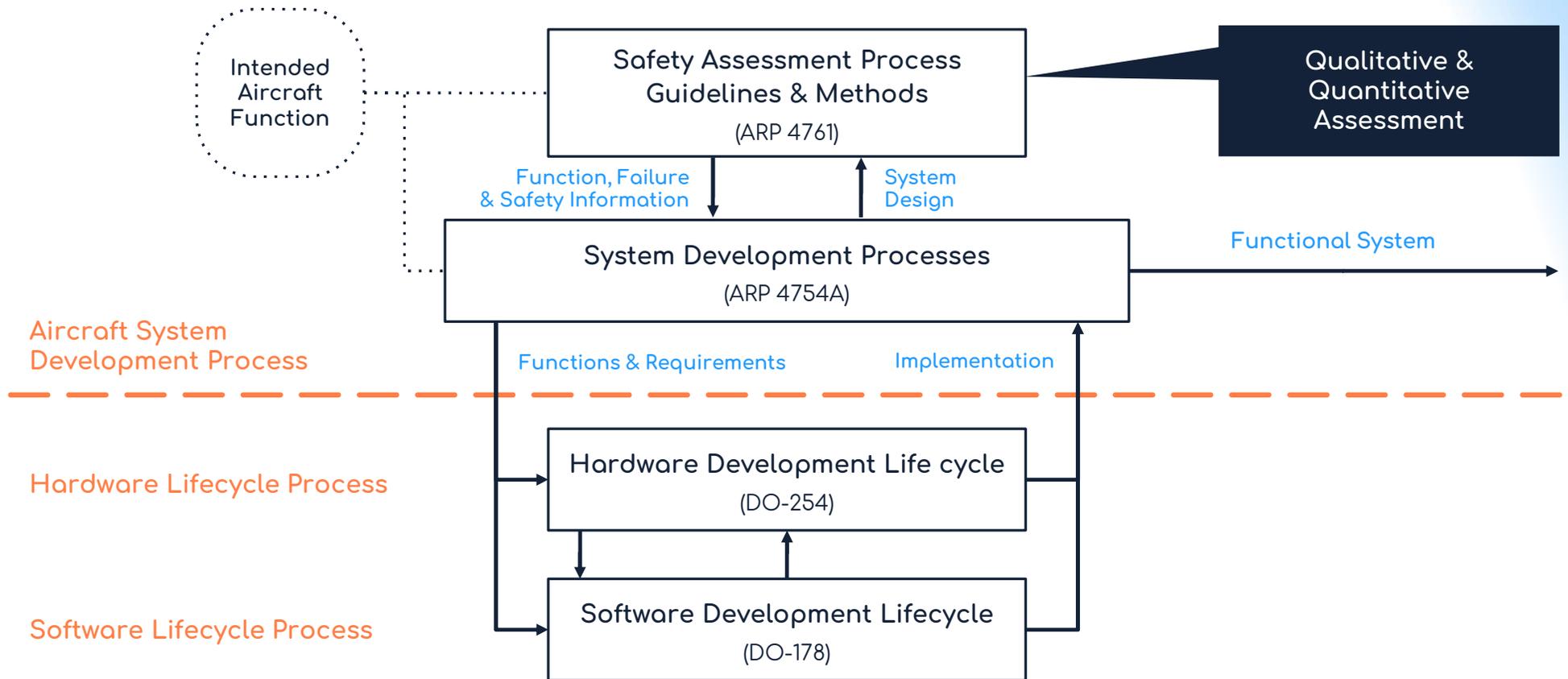
Diagram copied from the FAA's public archives

Where does AI fit?

Intended Function is independent of the implementation

Intended Aircraft Function

Safety Assessment Process Guidelines & Methods

(ARP 4761)

Function, Failure & Safety Information

System Design

System Design allocates Function to Items independent of the implementation

Functional System

System Development Processes

(ARP 4754A)

Functions & Requirements

Implementation

Aircraft System Development Process

AI Development

Hardware Development Lifecycle

(DO-254)

Hardware Lifecycle Process

Software Development Lifecycle

(DO-178)

Software Lifecycle Process

Why doesn't traditional Design Assurance suffice?

A shifting focus:
Data drives the function

Part of the requirements traceability needs to go through data

The development process must be iterative in nature, and doing so correctly is essential for the verification of requirements

In addition to "operational" software, there is software used for training, which might only be qualified and on different platforms

Paving the way to certify the use of AI in safety-critical avionics

Federal Aviation Administration
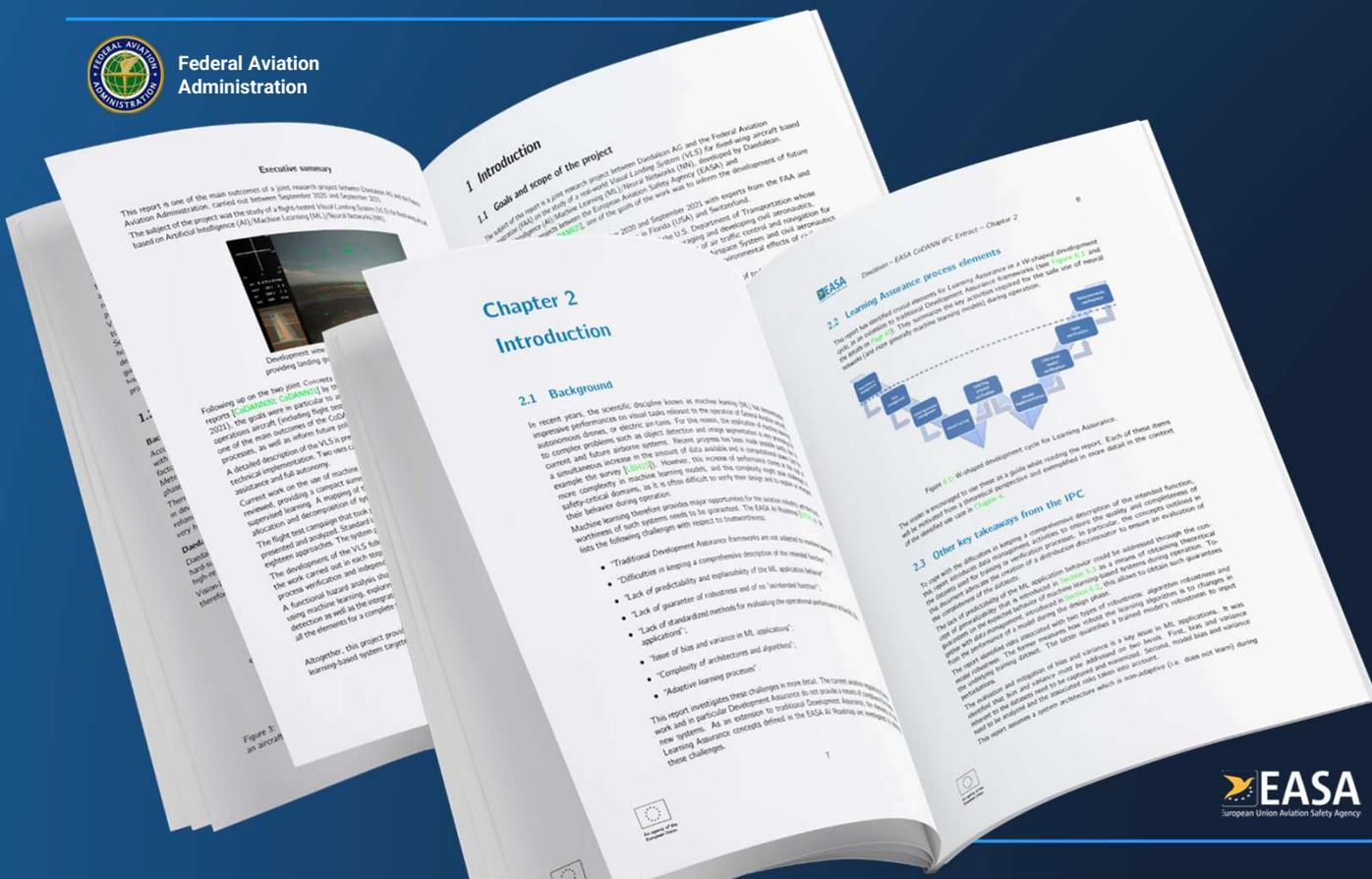
EASA and Daedalean' joint reports:
CodaNN 2020, CodaNN 2021
introduce the W-shaped Learning Assurance process for validation of deep neural networks in safety-critical applications.

The FAA and Daedalean joint report: evaluates how the W-process fits the FAA's future certification policy.

❝ System engineering has its V — now machine learning has its W

Graham Warwick
Managing Editor,
Technology with Aviation Week,
aka The Woracle

EASA first usable guidance (2021)
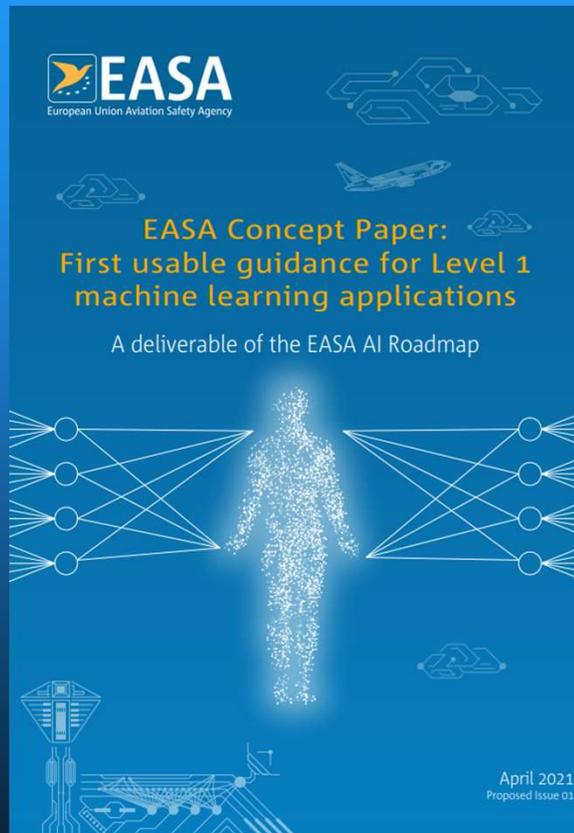

Drawing from the CoDANN reports and other partnerships with industry and academia.
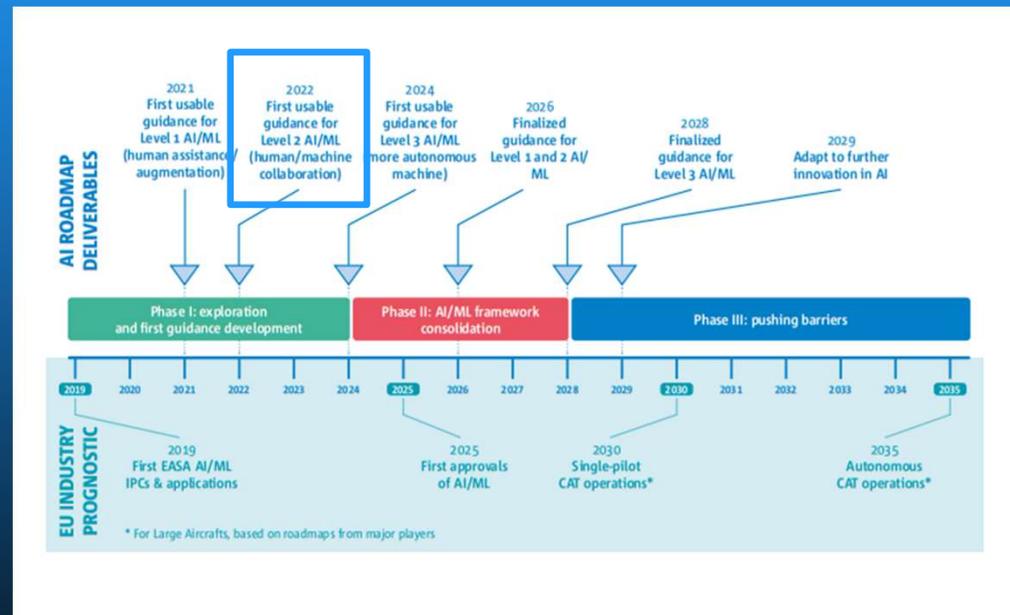
Learning assurance: look inside the box

- Data drives function → guaranteeing proper and safe function requires assurance on proper and complete data

- Strong mathematical and practical basis in Learning Theory

- Require guarantees that what was developed in the lab is what is deployed in the field
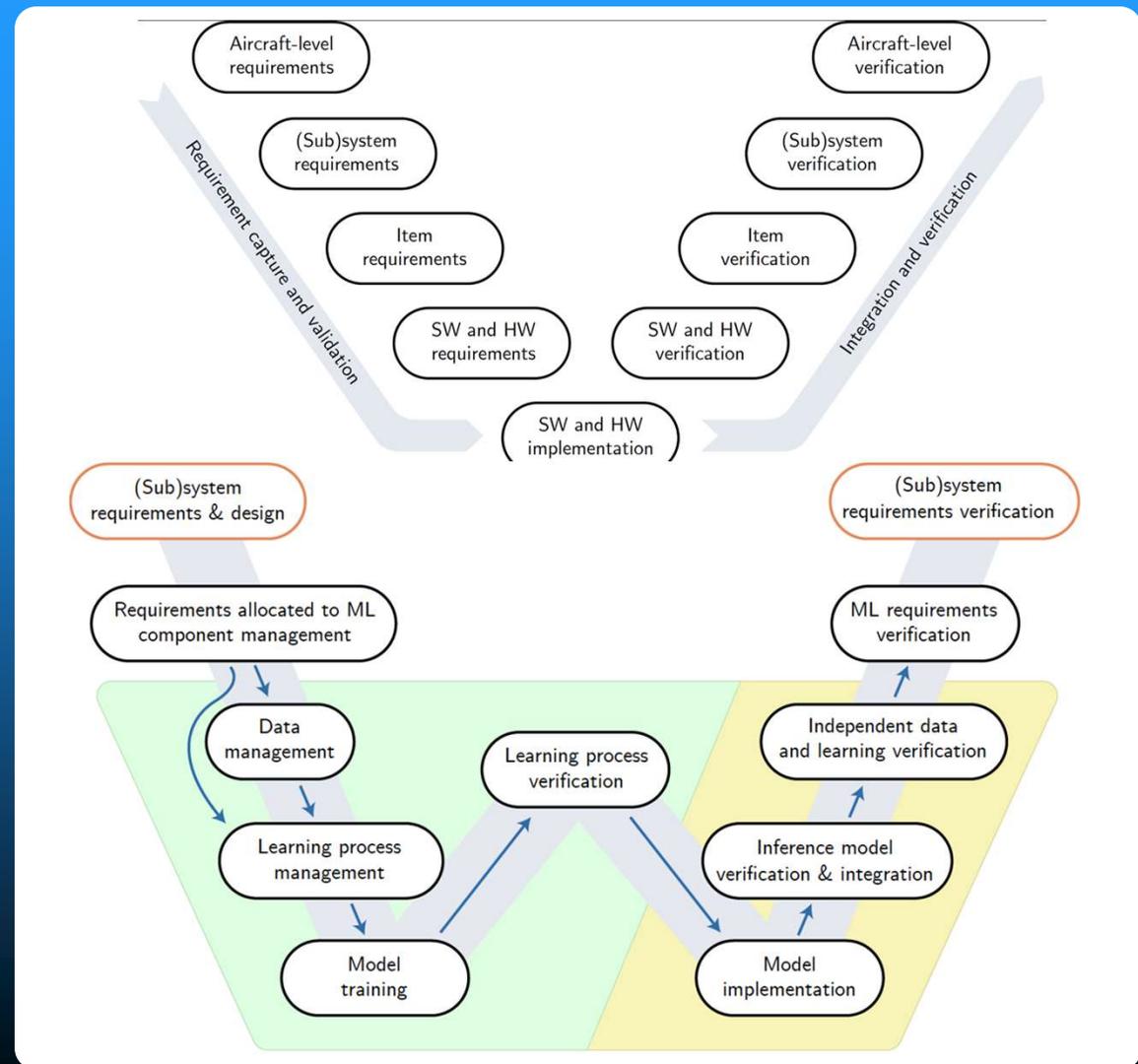
Learning Assurance vs Design Assurance

Data selected to Cover all Normal and Abnormal requirements

Training Data

Independence

Validation Data

Independence

Verification (Test) Data

Model

Hardware

Model implementation

Software

Learning Assurance

Design Assurance
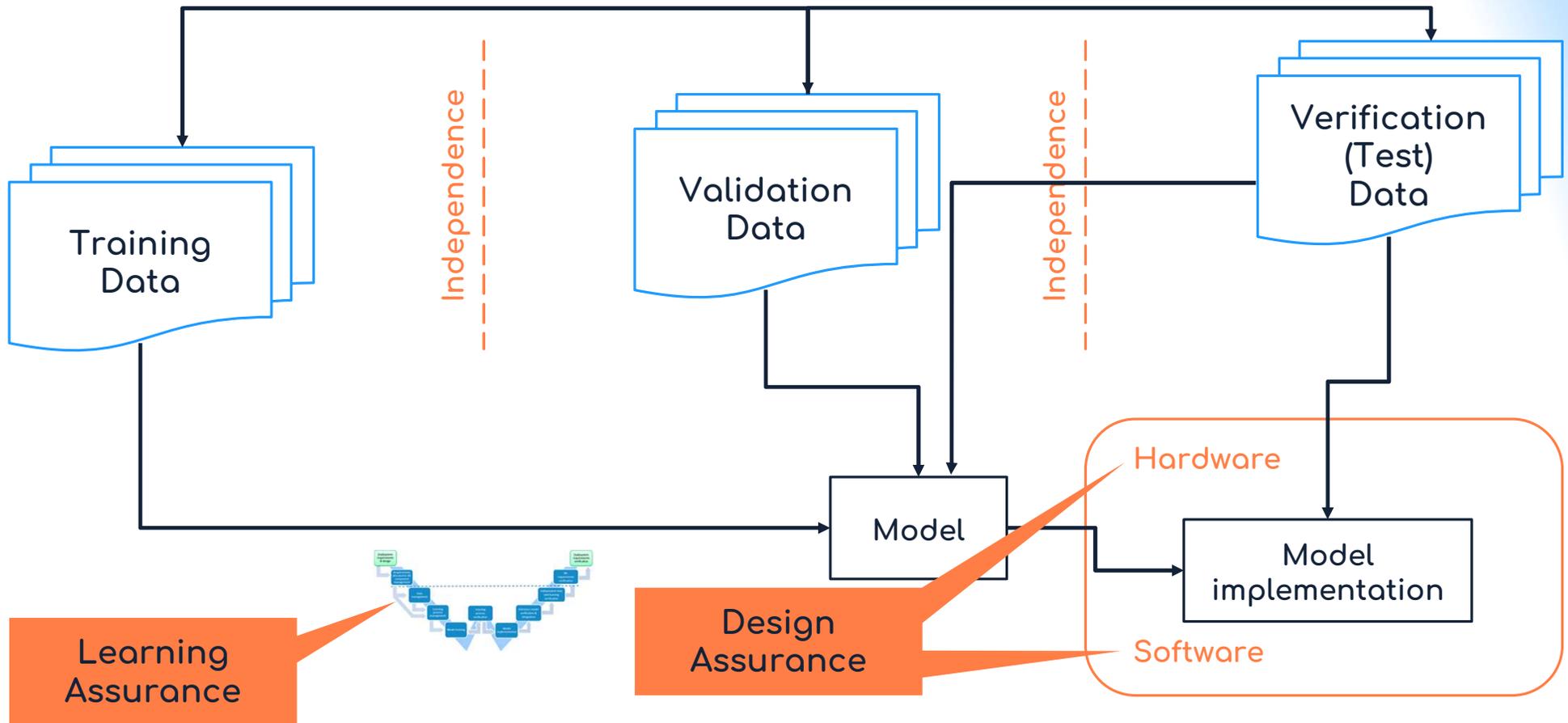
'PilotEye' Traffic Detection System Ongoing Certification (with Avidyne)

- DAL-C certification of Traffic Detection - The first vision-based ML application (2023)

We are here 2022-11

1 → **2** → **3** → **4**

1 A concept for Learning Assurance proposed, used by EASA in their "First usable guidance for Level 1 AI/ML application"

2 STC application for Traffic Detection

3 FAA issues Issue Paper, EASA issues a Certification Review Item

4 A specific application gets certified, referencings the NN policy among alternative means of compliance
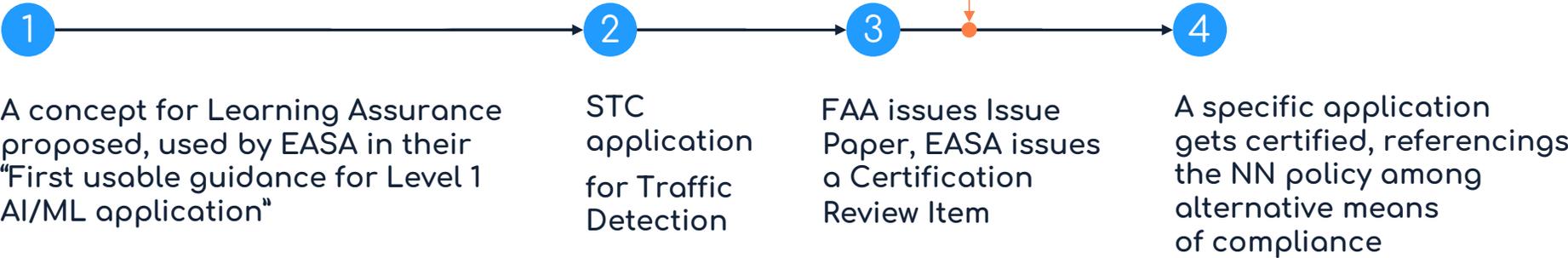
Daedalean Roadmap (Situational Awareness)

Sensing

Semantic Understanding

Risk Management

Actuation

- Camera (visual)
- Camera (visual)
- Camera (LWIR)
- GNSS
- Altimeter .....
- ADSB, FLARM
- .....
- RADAR
- LIDAR
- Terrain & Obstacle DB
- Landing site DB

Federated 3D Sensor Data Point Cloud

- positioning
- coarse terrain awareness
- runway/helipad recognition
- ground obstacles (wires, masts)
- landing safety
- debris / tail hazards
- traffic awareness
- weather awareness

Dynamic Mission Risk Map

Hazard Avoidance
- Ground Collision / (Tail-)Rotor Strike R/A
- Traffic Collision R/A
- ...

Safe Guidance
- Regular Landing Guidance
- Emergency Landing Guidance
- Waypoint Following / Return To Base
- ...

DAL-C

DAL-B

CREW HMI

Aircraft Flight Control Systems

Secure V2V Broadcast Comms

Risk map

Fine Grained Flight Plan

- shared risk awareness
- intention awareness

Flight plan & intentions

Logging & Telemetry

VXS/IXS/XXS System Boundary

Daedalean IXS Functional Concept Architecture v 2022-04

22

Daedalean Roadmap in alignment with DFR future

Developing the product from pilot assistance to monitored autonomy:

- Sustaining the persistent Dynamic Mission Risk Map during the route
- V2V Shared Risk and Intention Awareness
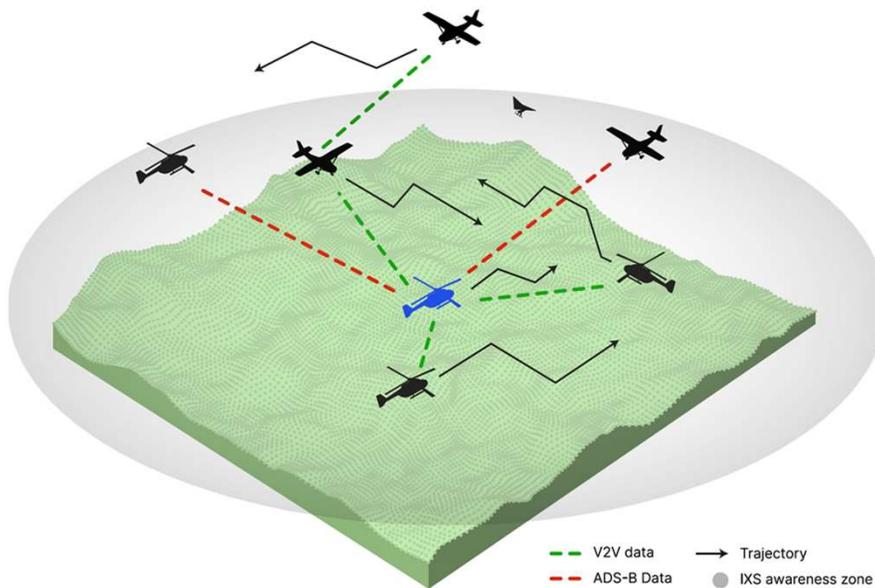
NASA/TM-20220013225   September 2022

Digital Flight:
A New Cooperative Operating Mode to Complement VFR and IFR

Two weeks later, NASA outlined the future aerospace operation:

- Digital Flight Rules to complement VFR and IFR
- cooperative practices, including Shared Traffic Awareness and Vehicle-to-Vehicle communications
- automated self-separation

V2V data ---- → Trajectory
ADS-B Data ---- ● IXS awareness zone

23

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