HORIZON 2020

EU-Japan Collaborative Research Project in Aeronautics

VISION

Validation of Integrated Safety-enhanced Intelligent flight cONtrol

Yoko Watanabe
ONERA/DTIS-Toulouse

European Commission

NEDO

ICAS Workshop, Winterthur, 11/09/2017

ONERA
THE FRENCH AEROSPACE LAB

Basic Information

w3.onera.fr/h2020_vision

Acronym :	**VISION**
Full name :	**V**alidation of **I**ntegrated **S**afety-enhanced **I**ntelligent flight c**ON**trol
Starting date :	**01/03/2016**
Duration :	**36 months**
Budget :	**1.8 M€ (EC) + 1.8 M€ (NEDO)**
Grant no :	(EU) EU-H2020 GA-690811 (JP) NEDO GA-628001
EC call ID :	H2020-MG-2015_SingleStage-A MG-1.8-2015 International cooperation in aeronautics with Japan
Keywords :	FCS Flight control system, Aircraft Avionics, Systems & Equipment AVS, Aeronautics and International cooperation
Project officers :	(EU) Mr. Miguel Marti Vidal (**EC/INEA**/Transport Research Unit) (JP) Mr. Hiroyuki Hirabayashi (**NEDO**)
Coordinators :	(EU) Dr. Yoko Watanabe (**ONERA**/Dept. of Information Processing and Systems) (JP) Prof. Shinji Suzuki (**the University of Tokyo**/School of Aeronautics and Astronautics)

Consortium

VISION
w3.onera.fr/h2020_vision

EU Participants		
1	**ONERA** Dept. of Information Processing and Systems	FR
2	**University of Exeter** College of Engineering Mathematics and Physical Sciences	UK
3	**University of Bristol** Department of Aerospace Engineering	UK
4	**SZTAKI** Systems and Control Laboratory	HU
5	**Unmanned Solutions**	ES
6	**Dassault Aviation** Flight dynamics department	FR

Japan Participants		
7	**University of Tokyo** Dept. of Aeronautics and Astronautics	JP
8	**JAXA** Aeronautical Technology Directorate	JP
9	**RICOH Co. Ltd.** Photonics R&D Center	JP
10	**Mitsubishi Space Software Co. Ltd.**	JP
11	**ENRI** Dept. of Air Traffic Management	JP

VISION Global objective

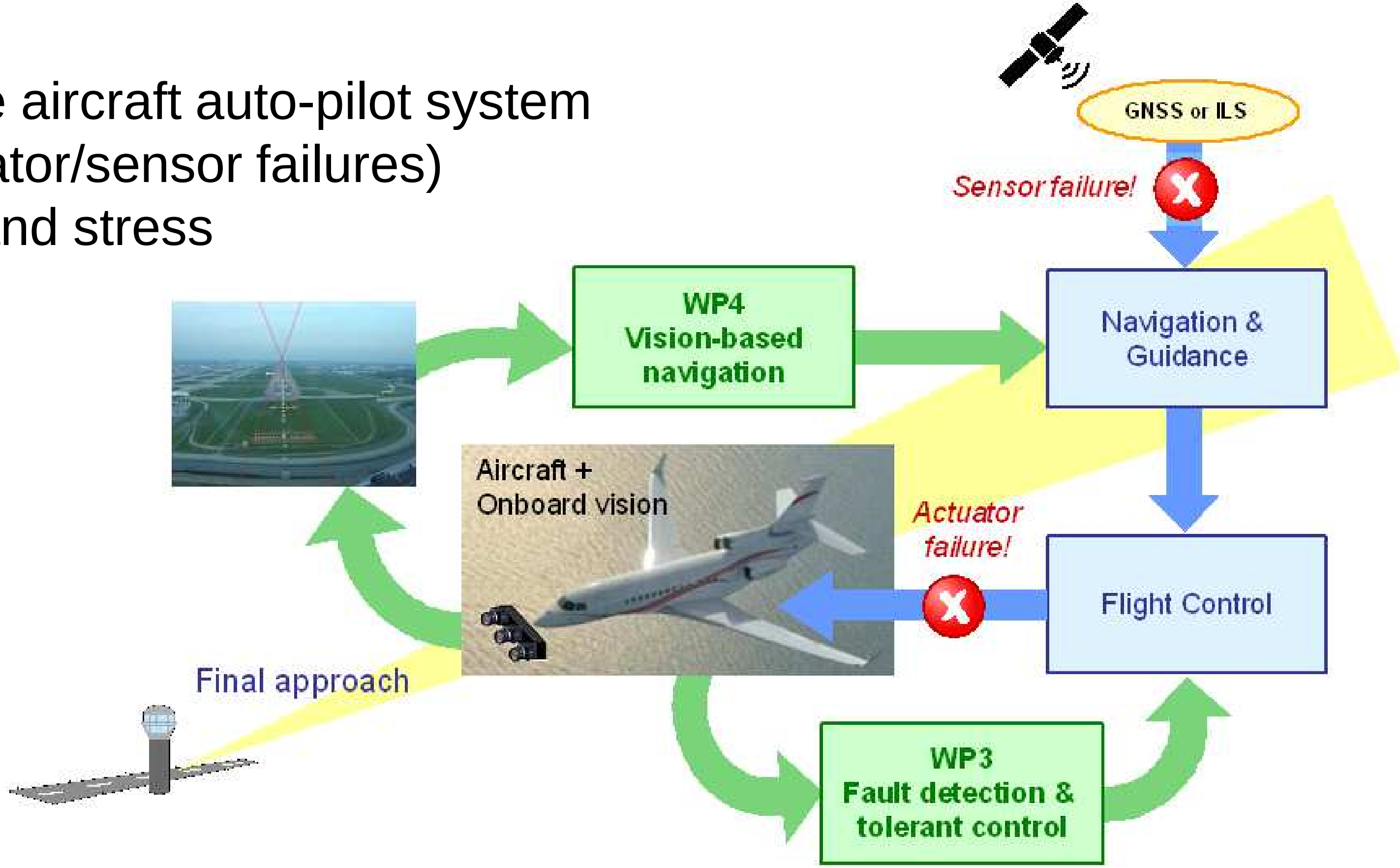
w3.onera.fr/h2020_vision

❖ Global objective

Investigation, development and validation of **“smarter” aircraft Guidance, Navigation and Control (GN&C) solutions** to automatically detect and overcome some critical flight situations

- Increase tolerance of the aircraft auto-pilot system to flight anomalies (actuator/sensor failures)
- Reduce the pilot’s task and stress in difficult situations

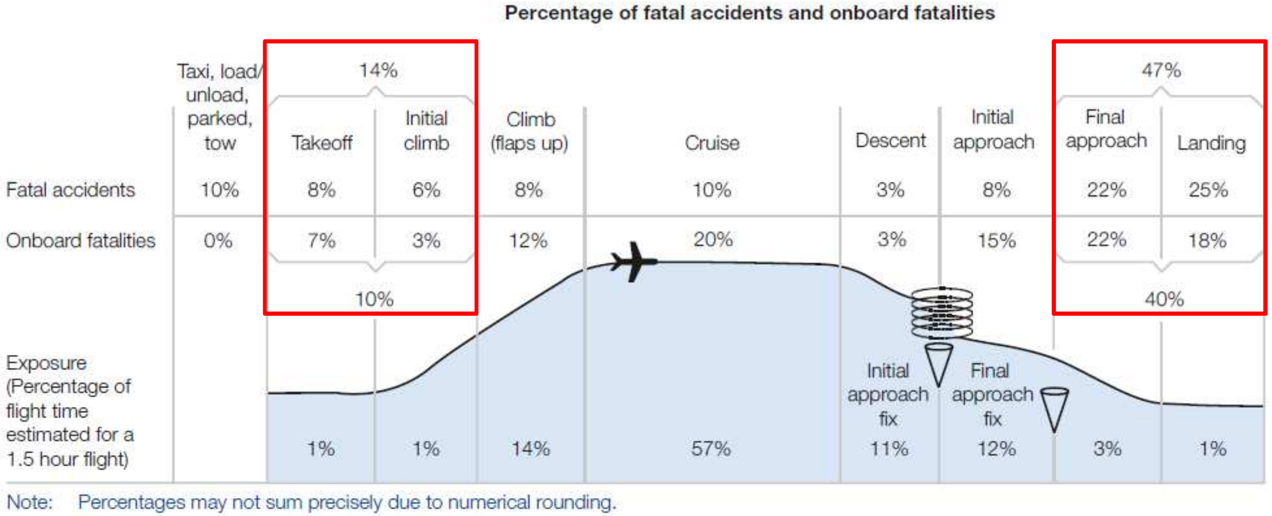
Contribute to the aircraft accident rate reduction

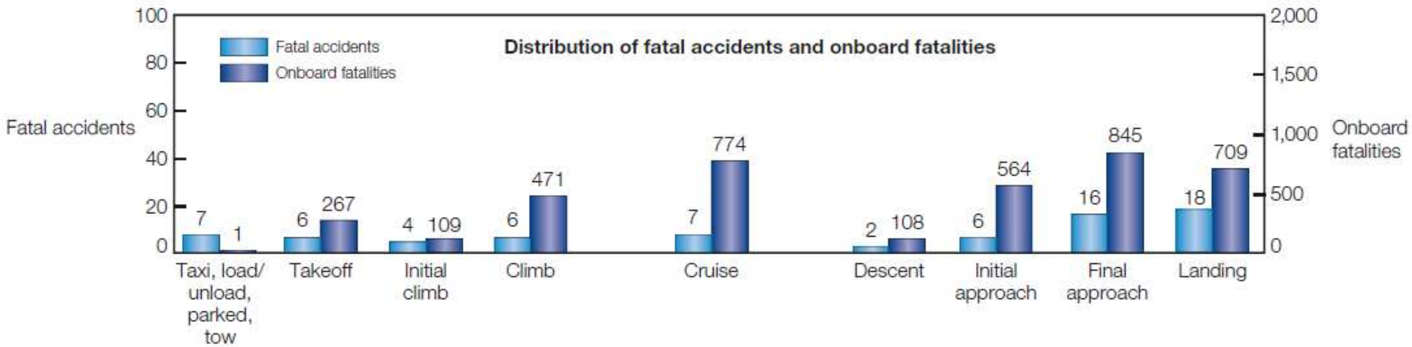


Motivation

w3.onera.fr/h2020_vision

- More than half of the commercial aircraft fatal accidents occurred during near-ground operations (take-off, final approach, landing).
- Enhancing airplane flight safety during such critical operation phases is an important key to the accident rate reduction.





Motivation

w3.onera.fr/h2020_vision

❖ Two accident types

1) Accidents due to **flight control** performance failure

← **Loss of aircraft controls due to bad weather, mechanical failures, etc.**

ex.) AF447 (Rio-Paris) crash in June 2009 (228 fatalities)
- Airspeed indicator error due to Pitot tube icing
- Pilot's incorrect reaction resulted in aerodynamic stall

2) Accidents due to **navigation and guidance** performance failure

← **Lack of visibility, pilot's situational awareness**

ex.) OZ162 (Seoul-Hiroshima) crash landing in April 2015 (27 minor injuries)
- Manual approach guidance with GNSS navigation data
- Bad visibility condition with rain

Needs to imorove robustness and self-adaptabilty of the current aircraft flight system to **both** types of failures

Motivation

VISION
w3.onera.fr/h2020_vision

❖ Onboard **vision** sensors

- Effective tool to increase the pilot's situational awareness during near- or on-ground aircraft operation

  ex.) Wing-tip cameras for on-ground anti-collision
  Fin-tip and belly cameras for taxi-aid on A380

- Used for cockpit display only
  Not used in the flight GN&C system

- Significant potential of 3D Lidar and IR camera in degraded visibility condition (night, fog, etc.)

European Commission
NEDO
ONERA
THE FRENCH AEROSPACE LAB

Technical Objectives

w3.onera.fr/h2020_vision

❖ Recovery from flight anomaly during the **final approach** phase

1) Flight control performance recovery
   - Actuator failure (jamming, authority deterioration)
   - Sensor failure (loss of airspeed data)

2) Navigation and guidance performance recovery
   - Sensor failure (lack of SBAS, lack of ILS)
   - Obstruction (object/aircraft on a runway, air traffic cut-in on the final path)

❖ "Smarter" GN&C technologies

1) Fault Detection and Diagnostic / Fault Tolerant Control (FDD/FTC)
2) Vision-based control surface monitoring system
3) Vision-aided local precision navigation system
4) Vision-based obstacle detection and missed approach guidance

Background

w3.onera.fr/h2020_vision

❖ Fault Detection and Diagnostic / Fault Tolerant Control (FDD/FTC)

EU-FP7 ADDSAFE (2009-2012) / **RECONFIGURE** (2013-2016)

- Integrated FDD/FTC solutions
- Validations through pilot-in-the-loop simulations with real flight avionics
- Airbus's participation to define real and wide-covered fault scenarios

METI-SJAC Autonomous Flight Control and Guidance for Civil Aircraft (2002-2003) / Intelligent Fault Tolerant Flight Control for Civil Aircraft (2009-2010)

- Integrated FDD/FTC solutions
- Flight validation on JAXA MuPAL-alpha aircraft

Background

w3.onera.fr/h2020_vision

❖Vision-based guidance and navigation

EU-FP6 PEGASE (2006-2009)

- Vision-based runway (helipad) detection and relative navigation
- Automatic landing guidance
- Evaluation through simulations with synthetic images

EU-FP7 ALICIA (2009-2014)

- Visible / IR cameras and 3D Lidar systems for runway and obstacle detection during the taxi phase in all conditions
- Cockpit display only

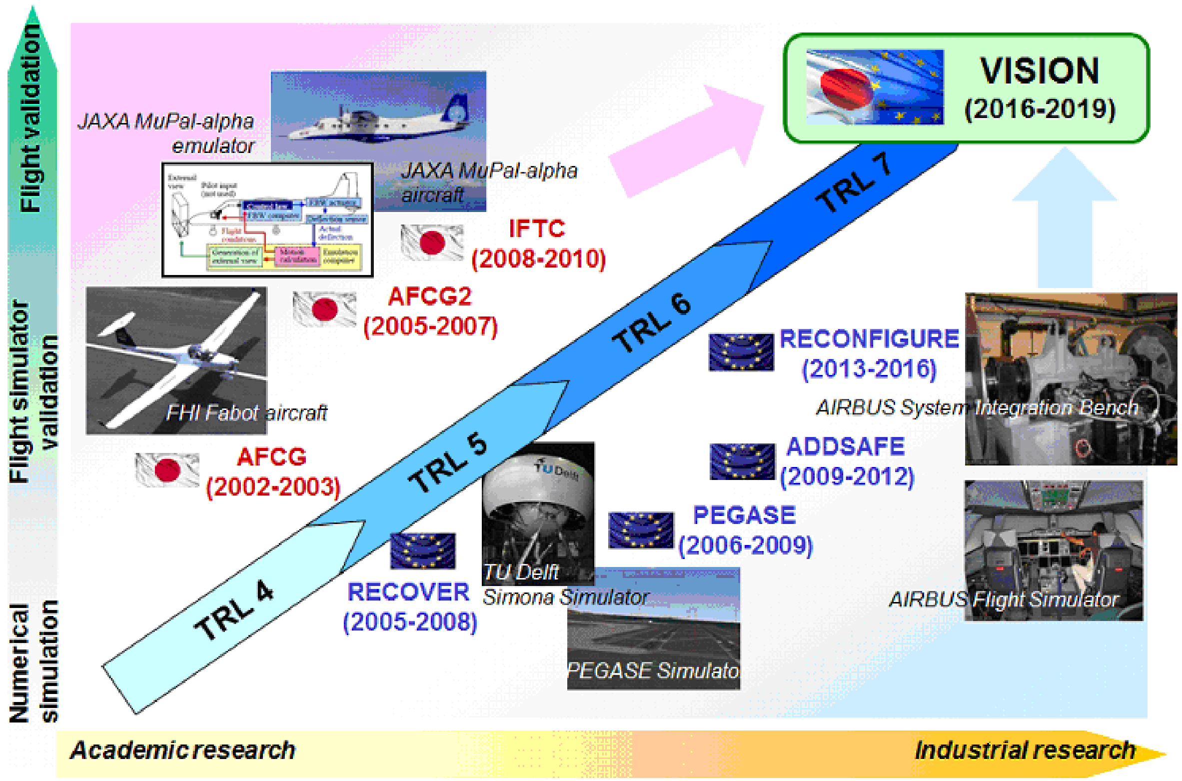
METI-SJAC Autonomous Flight Control and Guidance for Civil Aircraft (2005-2007)

- Online flight trajectory optimization and collision avoidance guidance
- Flight validation on FHI FABOT RPA

Project Aims

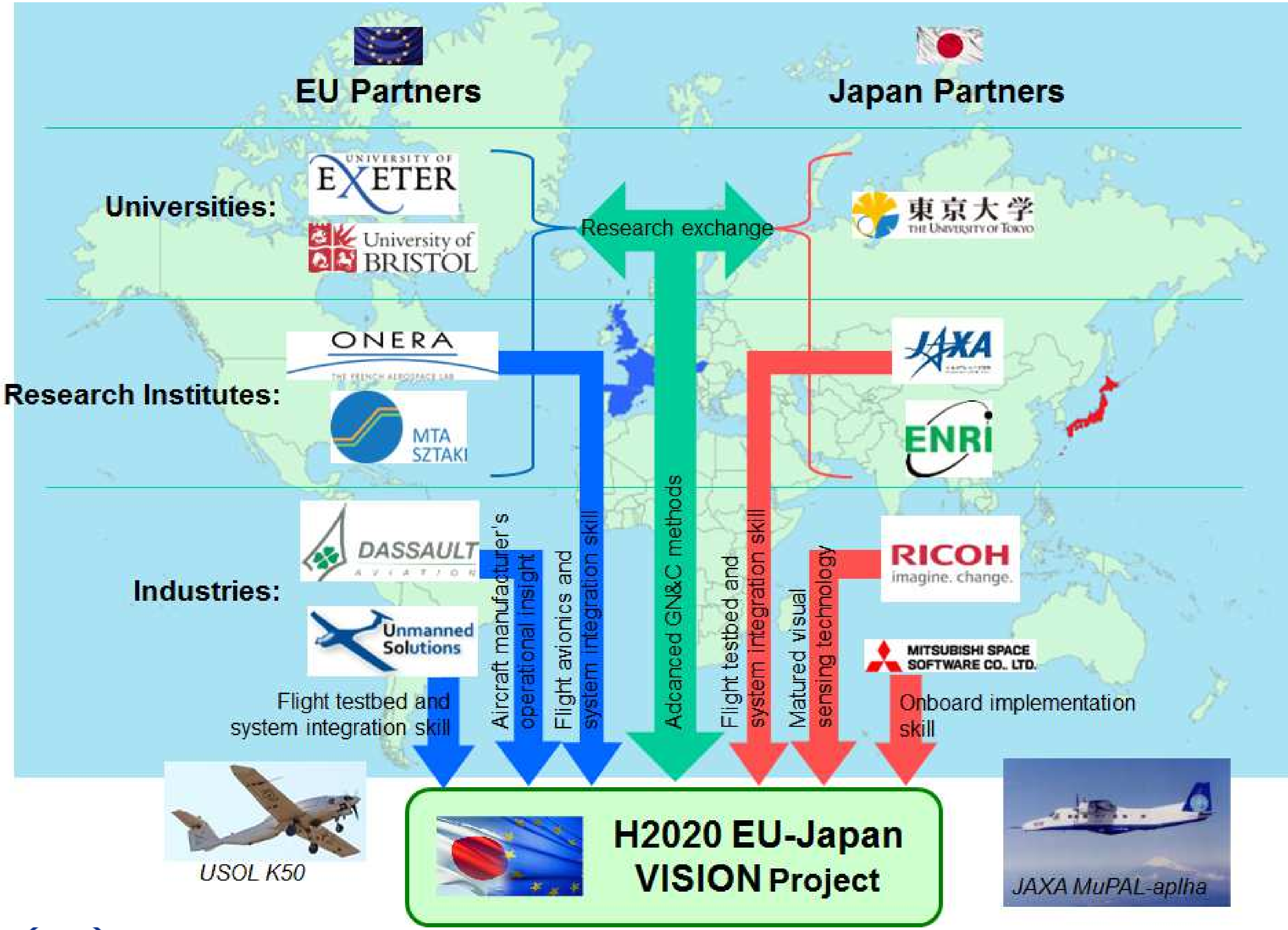
w3.onera.fr/h2020_vision

- To capitalize on both **Europe and Japan's complementary research activities and experiences**, as well as their industrial strengths
- To propose **operation-oriented integrated GN&C solutions** for each of the scenarios
- To **mature the TRL** of the proposed GN&C solutions by performing **flight validations on real aircraft platforms**
- To **promote the collaboration between EU – Japan researchers and students**



EU-Japan Mutual Contribution

VISION
w3.onera.fr/h2020_vision



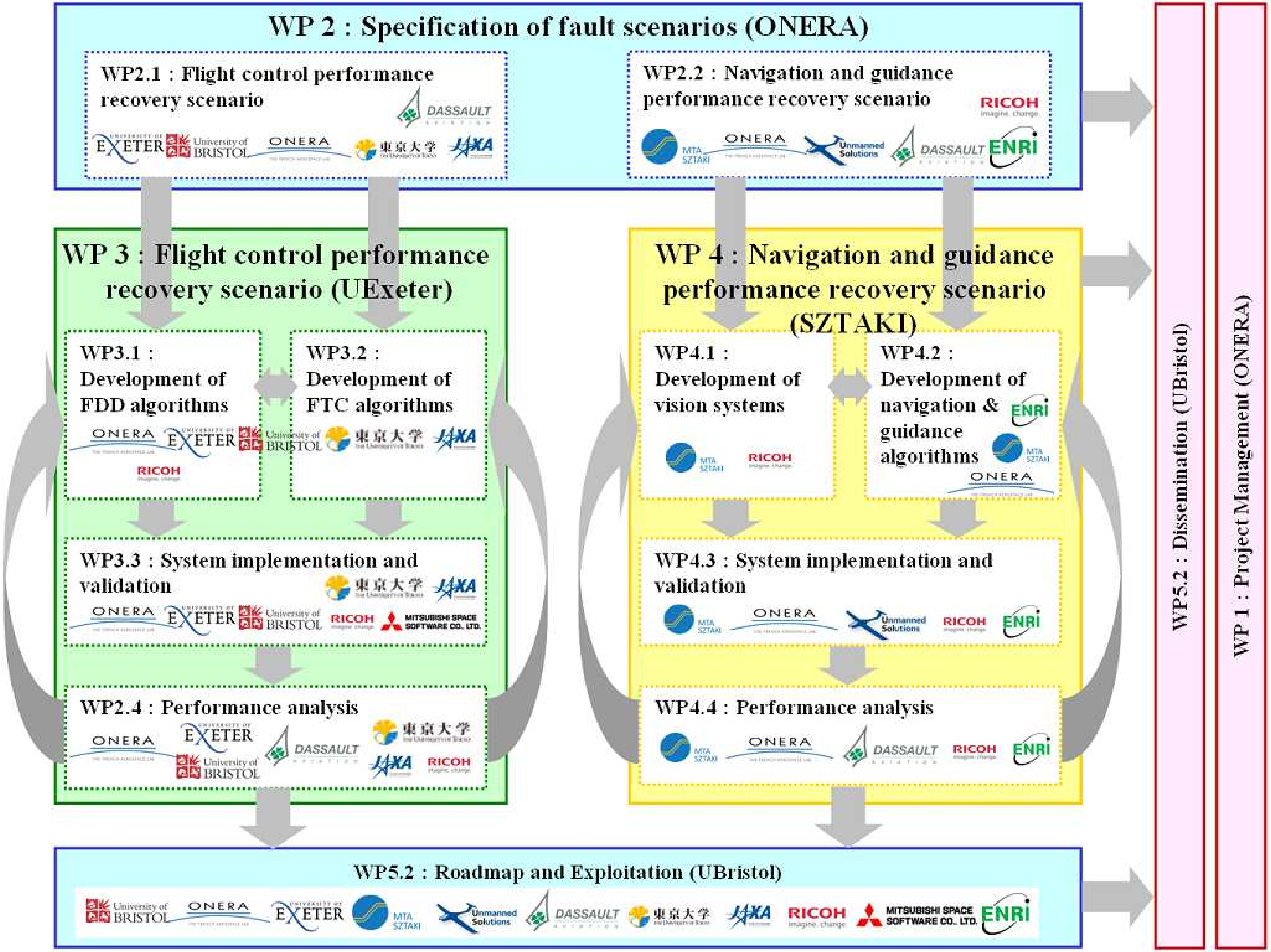
European Commission

NEDO

ONERA
THE FRENCH AEROSPACE LAB

Organization

w3.onera.fr/h2020_vision



WP3: FDD/FTC controller designs

❖ Development of advanced FDD/FTC controllers

- University of Exeter — Sliding-mode **FDD/FTC (Fault Tolerant Control)** controller design for aileron & rudder actuator failure (loss of efficiency)
- University of Bristol — Structured H-infinity **FDD/FTC** controller design for aileron & rudder actuator failure (saturation, constant bias)
- ONERA (The French Aerospace Lab) — Adaptive gain-scheduled **FTC** controller with online parameter estimation for **FDD (Fault Detection and Diagnostic)** for elevartor actuator failure (loss of efficiency) / sensor failure (loss of airspeed)
- 東京大学 The University of Tokyo — Neural Network-based simple adaptive **FTC** controller design for actuator failures and CG shift

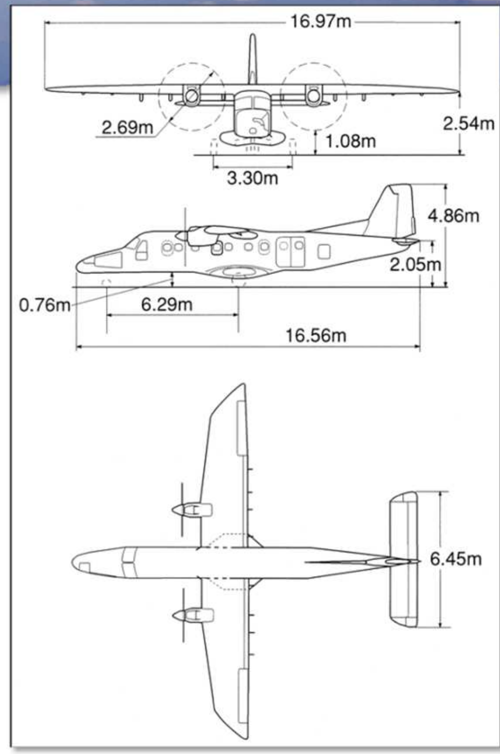
Implementation and in-flight validation on real aircraft for raising TRL of those techniques

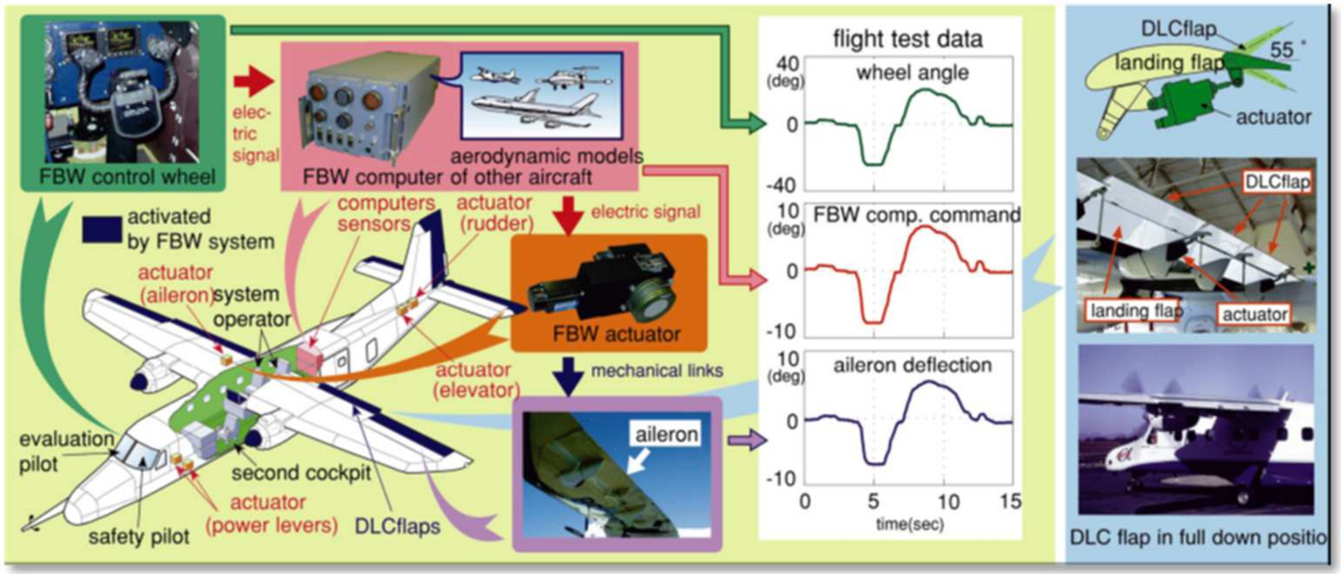
WP3: Flight experimental platform

w3.onera.fr/h2020_vision

❖ MuPAL-alpha aircraft

- Dornier Do228-200
- Experimental Fly-By-Wire system
- Hardware-in-the-Loop Simulation (HILS) setup
- First operation at Chofu airfield in Tokyo, Japan



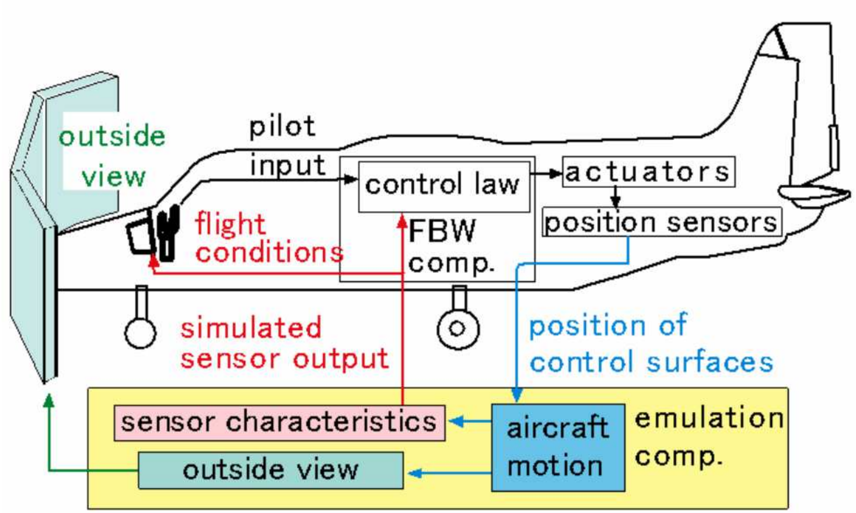


WP3: Flight test campaigns

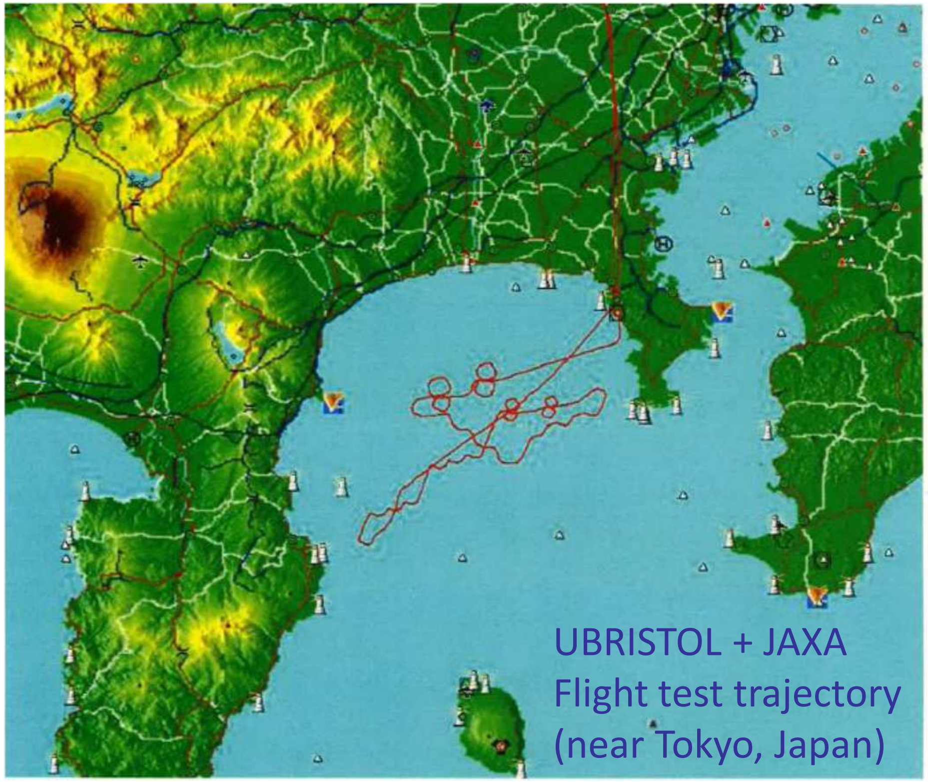
w3.onera.fr/h2020_vision

❖ First flight test campaigns (12/2016 – 03/2017)

- 3 EU partners had 2-weeks flight test sessions at JAXA
- C-code implementation and HIL simulation validation
- Preliminary flight tests (fault-free cases)
- 4 scientific EU-Japan joint publications



Hardware-In-The-Loop Simulation (HILS)



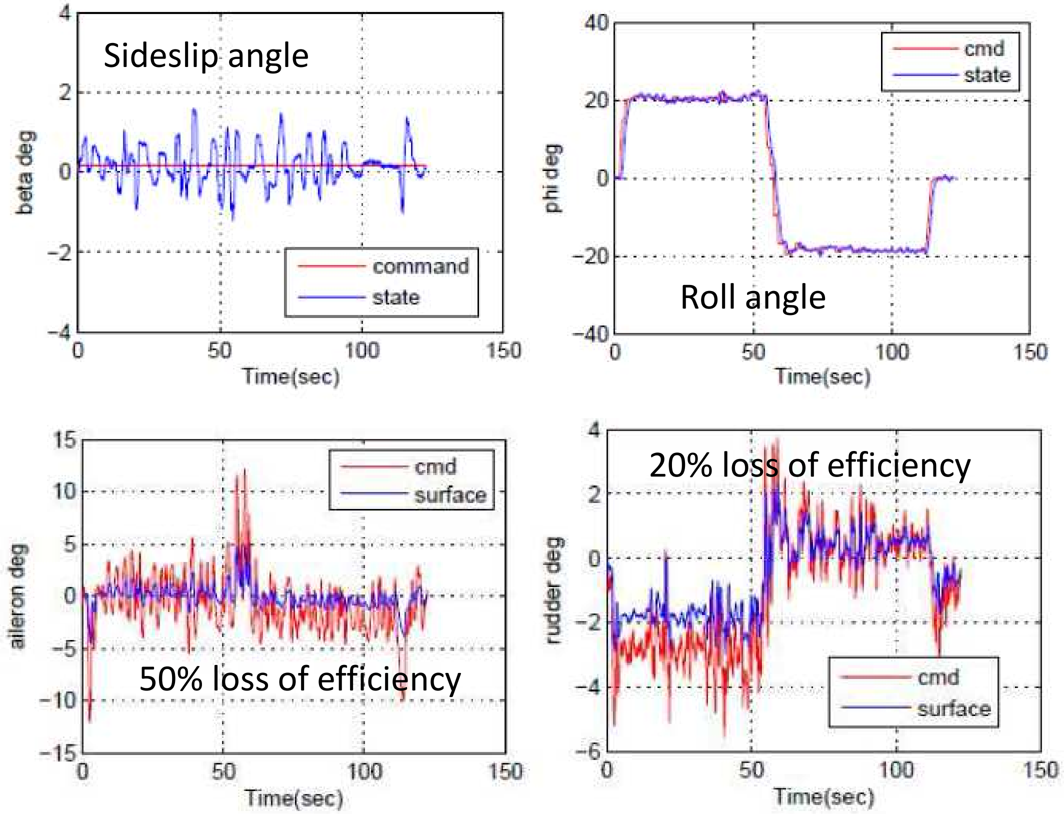
UBRISTOL + JAXA
Flight test trajectory
(near Tokyo, Japan)

WP3: Flight test campaigns

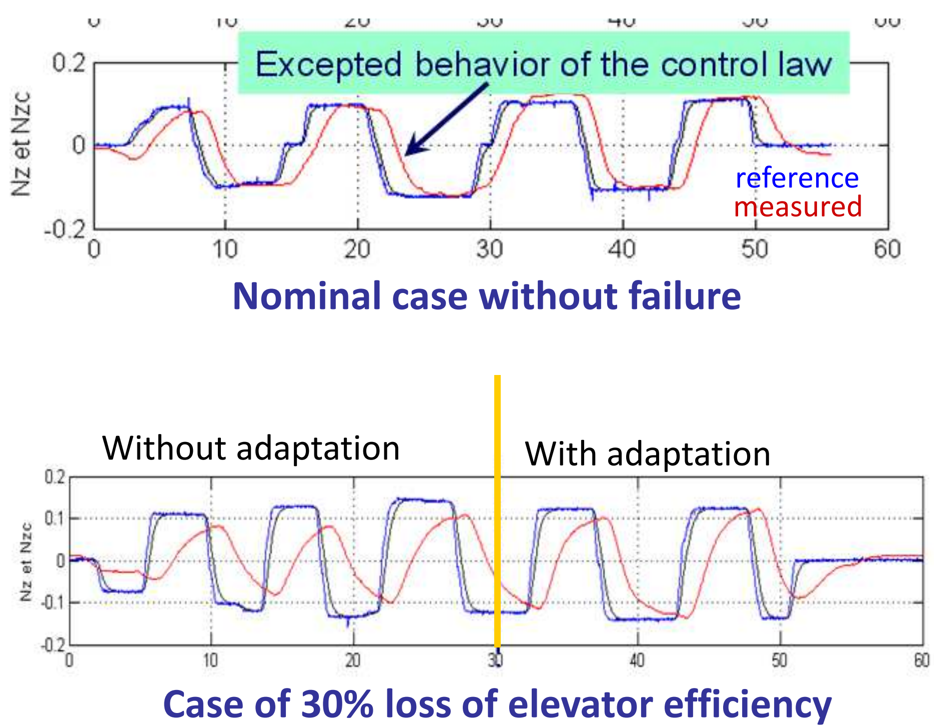
w3.onera.fr/h2020_vision

❖ Example of test results

- UNEXE: Flight test with emulated aileron & rudder actuator faults



- ONERA: HILS test with emulated elevator actuator fault



European Commission

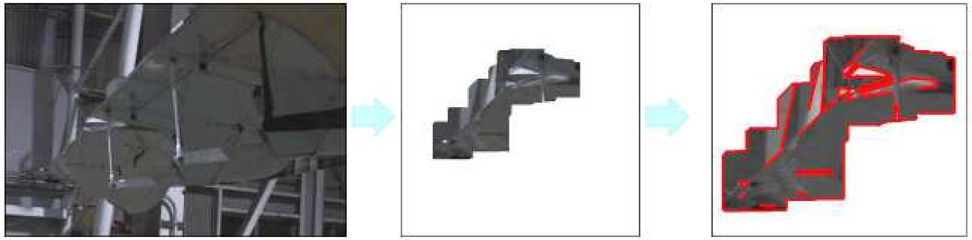
NEDO

ONERA THE FRENCH AEROSPACE LAB

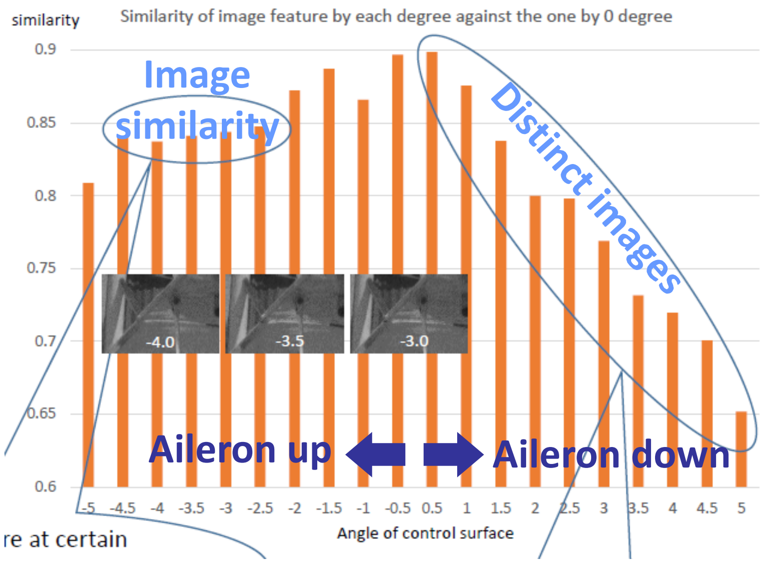
WP3: Vision-based control surface monitoring

❖ RICOH imagine. change. Aileron deflection angle detection by onboard camera to assist pilots and/or FDD/FTC controller

- On-ground test with a camera installed on JAXA MuPAL-alpha aircraft
- Preliminary results of image processing



(a) Input image
(b) Detected control surface
(c) Extracted features (line segment feature)

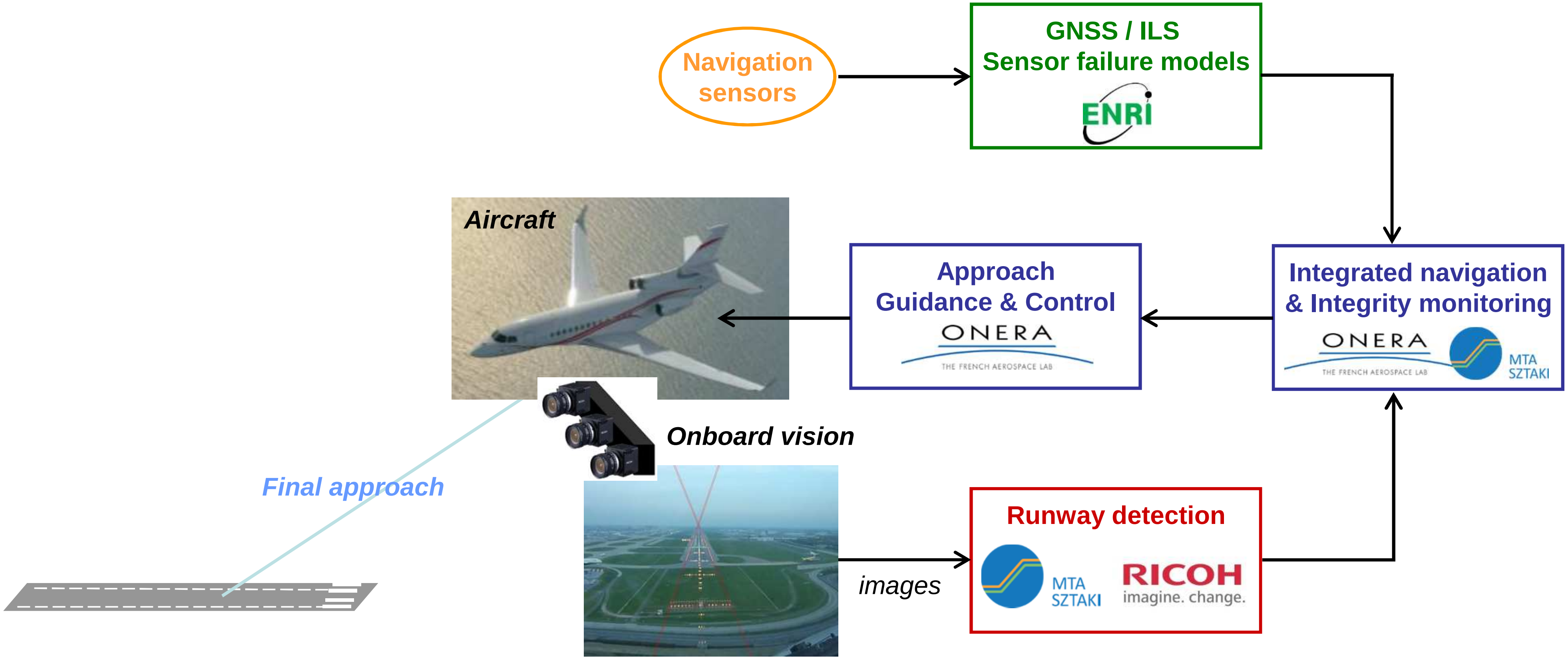


WP4: Onboard vision-based navigation

w3.onera.fr/h2020_vision

❖ Development of integrated Vision/ILS, Vision/GNSS navigation system for cases of sensor failure

In-flight validation on real aircraft



WP4: Flight experiment platform

w3.onera.fr/h2020_vision

❖ Unmanned Solutions « *K50-Advanced* » UAV platform

- Manufactured within the project
- High payload capacity (100L, 20kg)
- ONERA flight avionics
  - GPS RTK (dual antennas)
  - AHRS (Attitude & Heading Reference System)
  - Pressure sensors
  - Inclinometers
- First flight expected in Oct. 2018

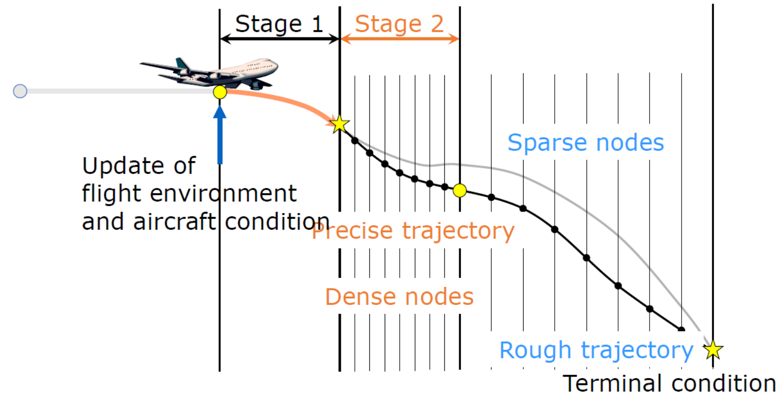
Dimensions		**Weights**	
Wingspan	4.00 m	Max Take-off Weight	50 kg
Length	3.09 m	Max Zero-fuel weight	30 kg
Typical Speeds at 1500m ISA and 50 kg		Useful load	20 kg
Dash Speed	142 km/h	**Take-off at 0m ISA and Flap 0º**	
Loiter Speed	72 km/h	Take-off distance	90 m
Stall Speed Flap 0º	65 km/h	Take-off rotation speed	79 km/h
Endurance	5 hours		

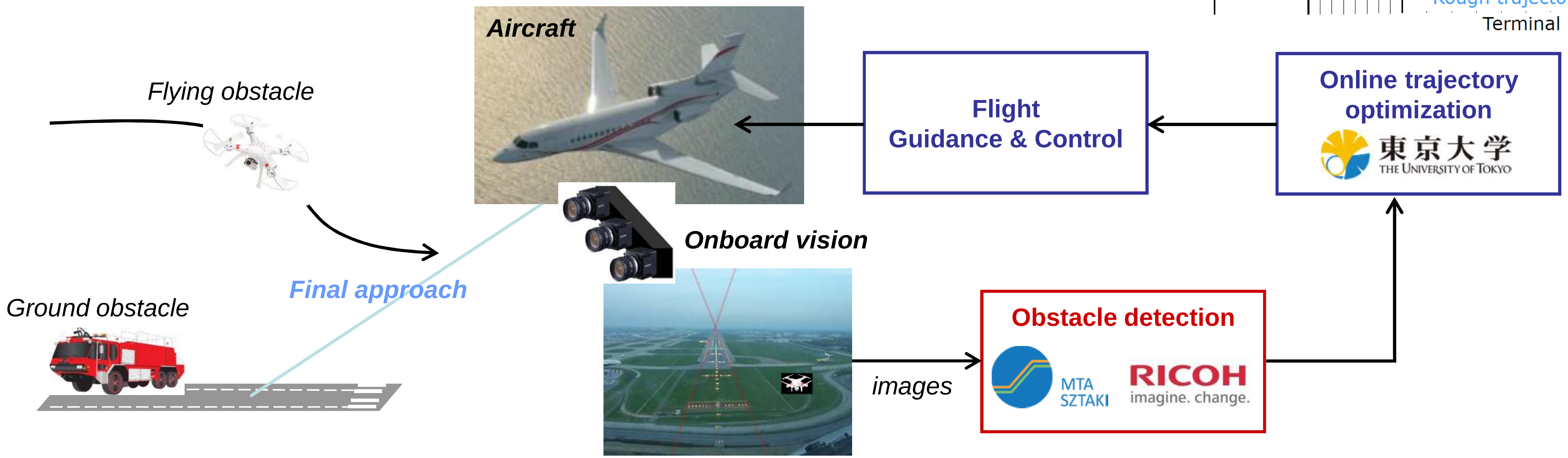
WP4: Obstacle detection & avoidance

w3.onera.fr/h2020_vision

- Development of vision-based obstacle detection and trajectory modification/go-around decision for collision avoidance

Numerial simulation
In-flight validation on small UAVs





European Commission
NEDO

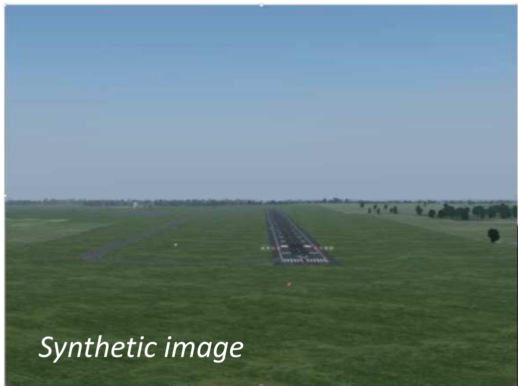
ONERA
THE FRENCH AEROSPACE LAB

WP4: Onboard vision system

w3.onera.fr/h2020_vision

- RICOH: Stereo-vision system under the belly
- MTA SZTAKI: Monocular-vision systems under each wing

• First camera installation on K50 and calibration test
• Preliminary flight tests for image recording
• Preliminary validation of image processor for runway marker detection

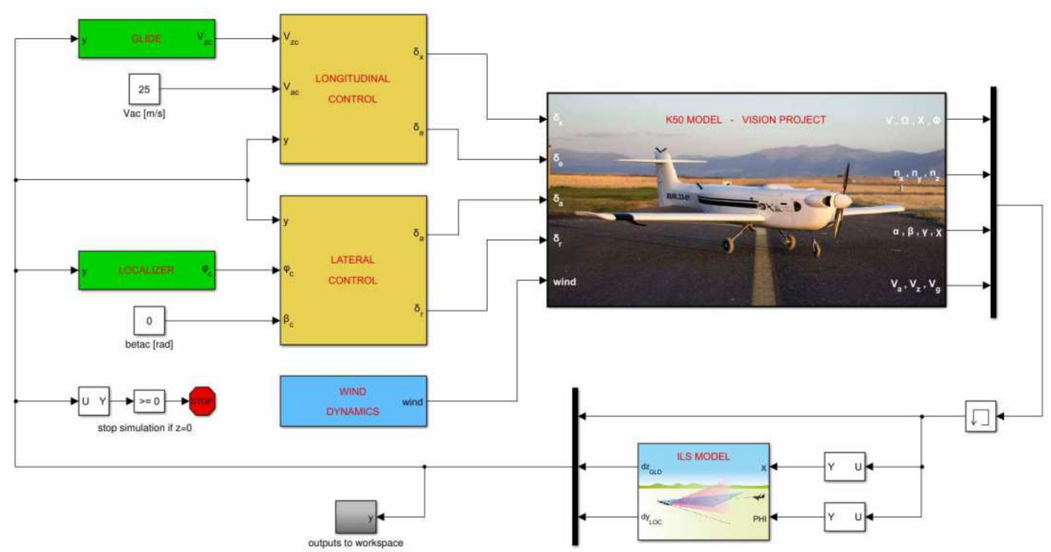


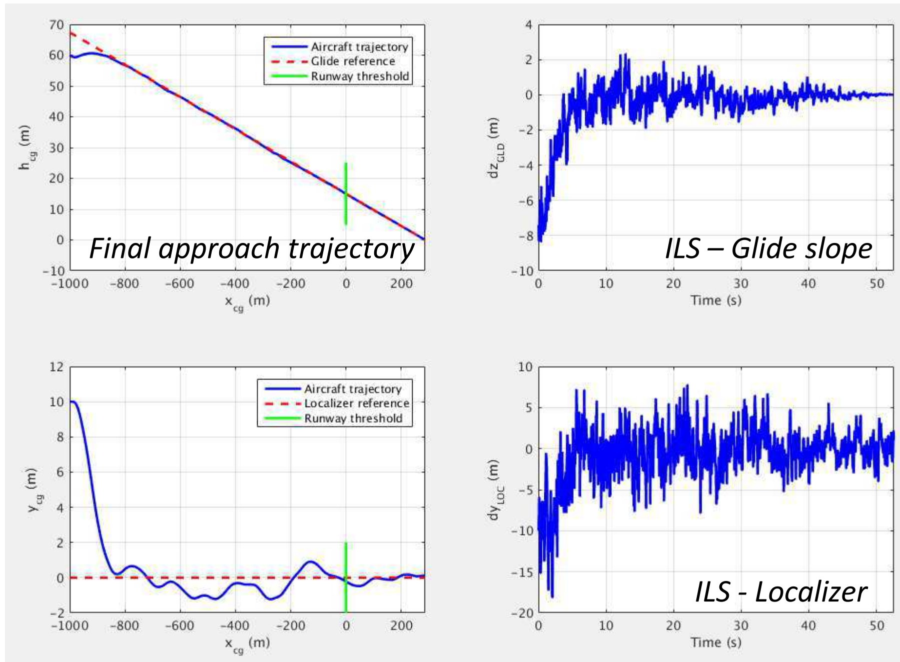
ONERA THE FRENCH AEROSPACE LAB

WP4: K50 flight controller

ONERA — Approach guidance & flight controller design

- ILS-based approach guidance and basic flight controller design
- Nonlinear simulation framework
- Refinement of the aircraft dynamic model by flight test data and re-adjustment of the flight controller (early 2018)





European Commission
NEDO
ONERA THE FRENCH AEROSPACE LAB

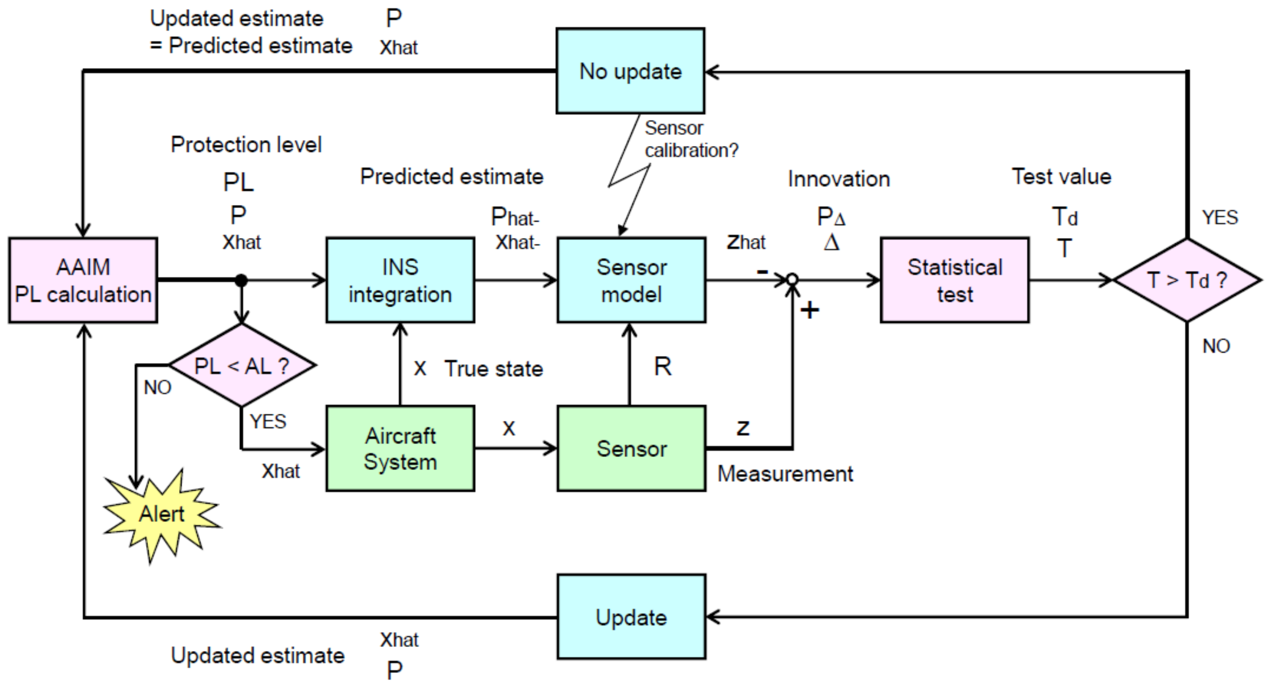
WP4: Integrated navigation

w3.onera.fr/h2020_vision

ONERA THE FRENCH AEROSPACE LAB

Integrated Vision/GNSS, Vision/ILS navigation systems with Integrity monitoring function

- Multi-sensor fusion by Error-State Kalman Filter (ESKF) with time-delayed measurements
- Tight integration of GNSS / INS / Vision
- Integrity monitoring function by AAIM (Aircraft Autonomous Integrity Monitoring) algorithms



European Commission NEDO ONERA THE FRENCH AEROSPACE LAB

Next steps…

VISION
w3.onera.fr/h2020_vision

❖ System development and Flight test campaigns continue …

- Further flight test campaigns planned to start early 2018 at JAXA for FDD/FTC algorithms validation
- First flight test campaign of K50 with the vision systems onboard planned in early 2018

❖ Analysis of indurstial operational relevance

- Participation of Dassault aviation
- Invitation of EU and Japan external experts (Airbus, Mitsubishi HI, EASA, etc.) to the progress meetings

❖ Dissemination

- EU-Japan joint publication on the validation results
- EU-Japan co-organization of special session in international conferences
- Organization of final international workshop at the end of the project

Thank you!

VISION
w3.onera.fr/h2020_vision

ONERA
THE FRENCH AEROSPACE LAB

UNIVERSITY OF EXETER

University of BRISTOL

MTA SZTAKI

Unmanned Solutions

DASSAULT AVIATION

東京大学
THE UNIVERSITY OF TOKYO

JAXA

RICOH
imagine. change.

ENRI

MITSUBISHI SPACE SOFTWARE CO., LTD.

European Commission

NEDO

ONERA
THE FRENCH AEROSPACE LAB