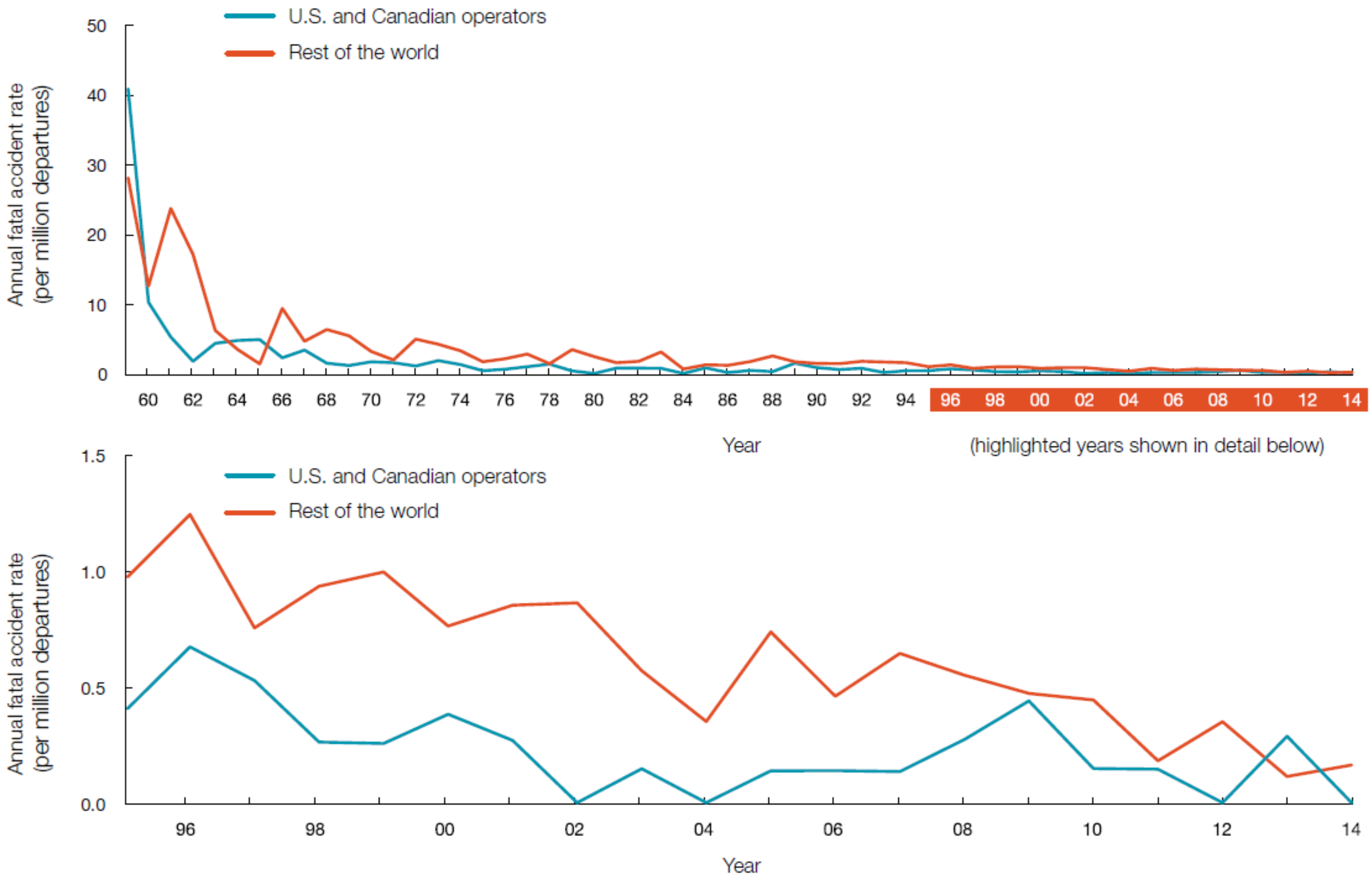
Flight Simulation for Tomorrow's Aviation

Dr.Umut Durak
DLR Institute of Flight Systems

ASIM STS/GMMS 2016 Workshop
Lippstadt, 10.3. - 11.3.2016

DLR

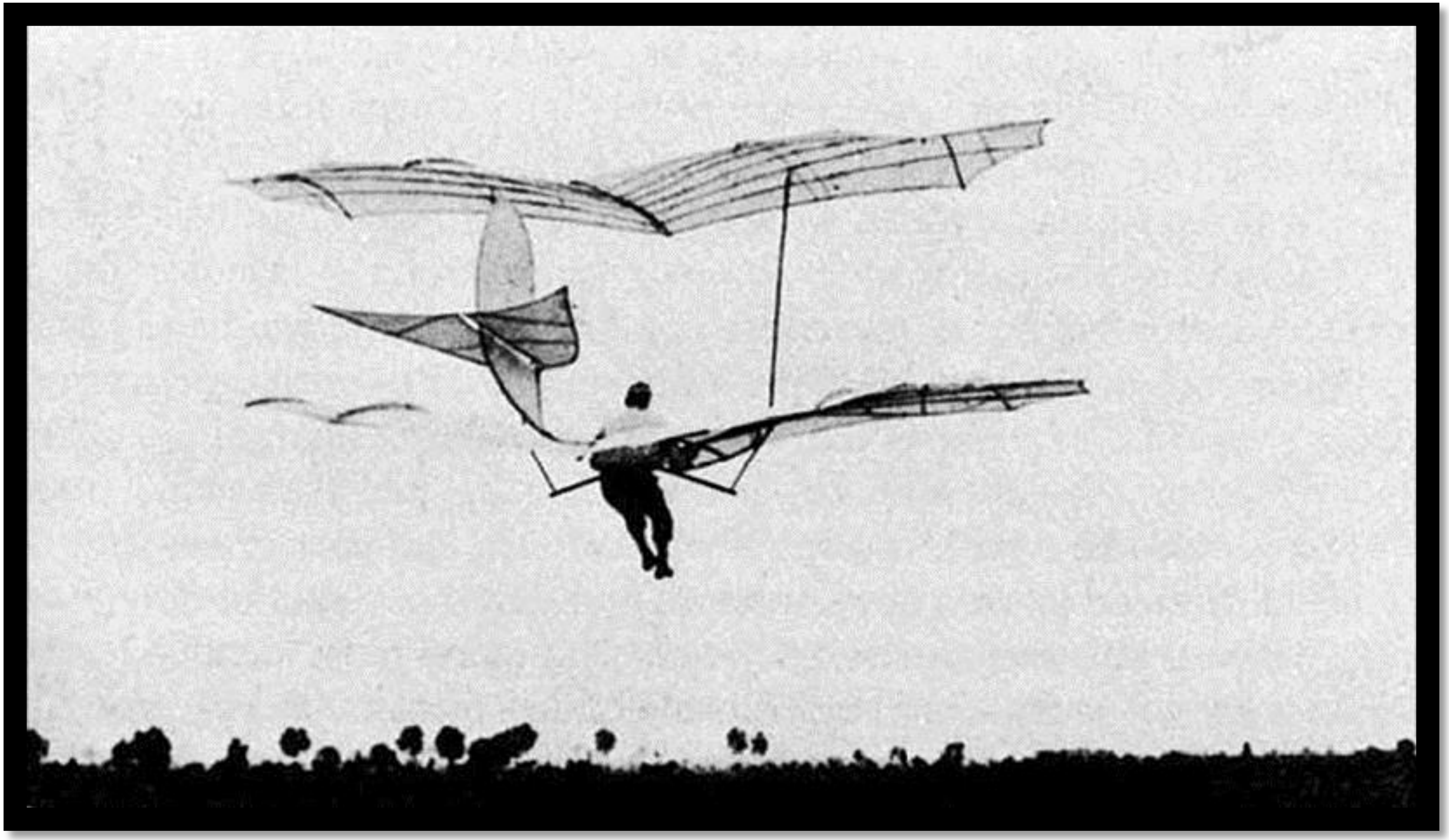
Flying is safer then ever!



Ref: Boeing, Statistical Summary of Commercial Jet Airplane Accidents
http://www.boeing.com/resources/boeingdotcom/company/about_bca/pdf/statsum.pdf

DLR

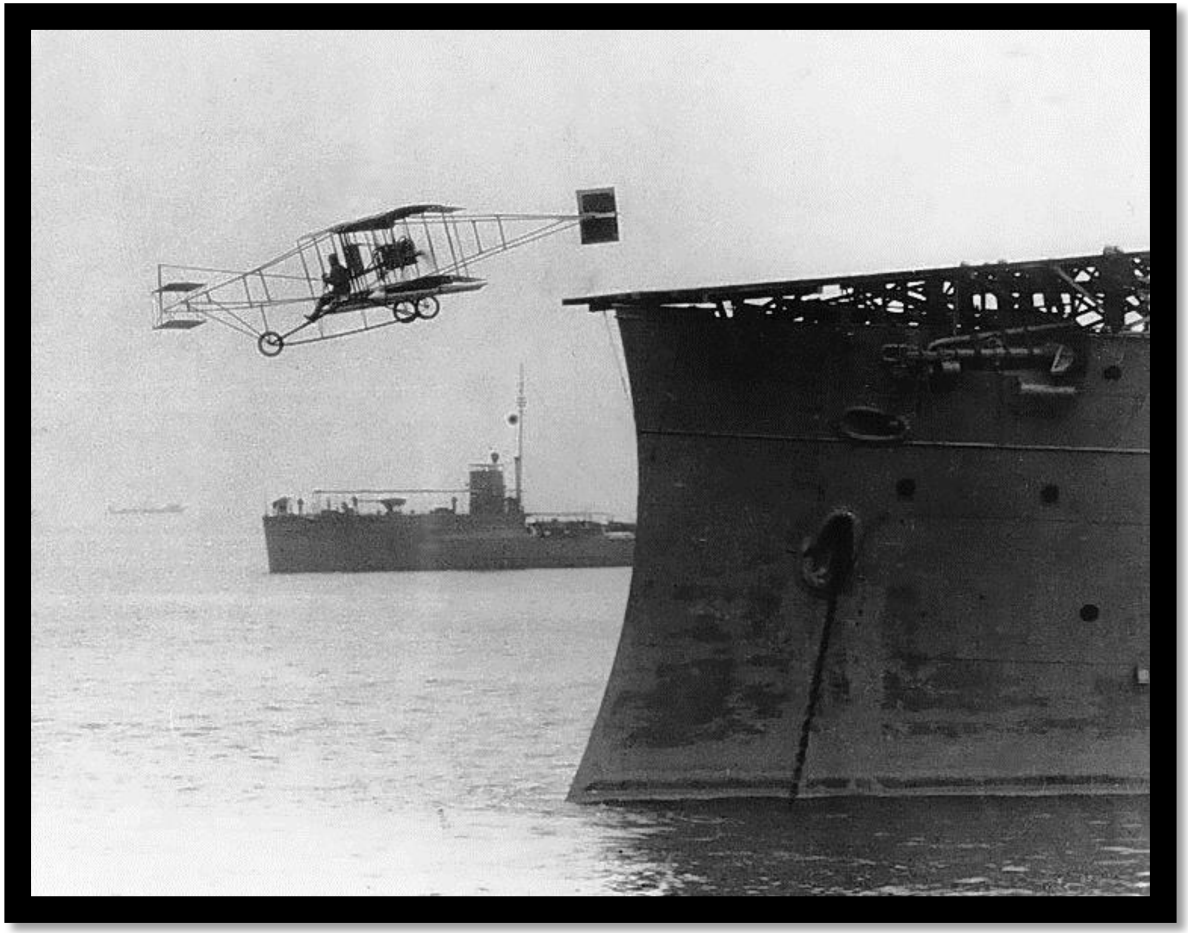
Aviation in the Pioneer Era



Otto Lilienthal in Flight - 1895

Ref: Otto Lilinethal, http://www.flyingmachines.org/lilthl.html

The Age of Ideas



Eugene Ely takes off from the USS Birmingham - 1910

DLR

The Antoinette Learning Barrel

What could be more obvious than to construct a truly ground-based simulator to prepare pilots to fly a plane?

1909 - the first ground based flight simulator (for Antoinette VII)

Ref: A History of Simulation: Part II - Early Days, http://halldale.com/insidesnt/history-simulation-part-ii-early-days

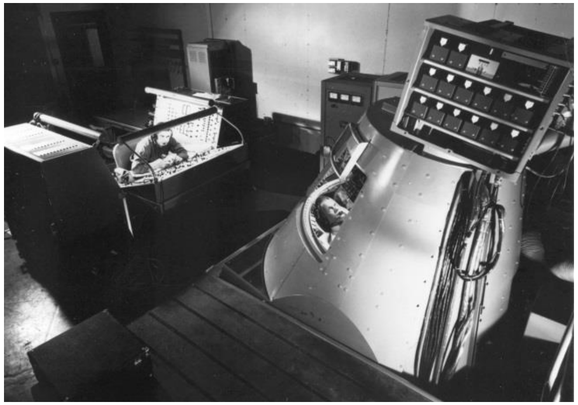
The Link Simulator

More than 10.000 produced between the early 1930s and early 1950s by the Link Aviation Devices, Inc. founded and headed by Ed Link.

Flight Simulators

- Since 1930s flight simulators have been important elements of aviation as training aids to enhance pilot skills.

- Since 1950s aerospace research community is using flight simulators for;
  - *Experimenting advanced concepts*
  - *Human factors research*
  - *Flight training and simulator research*



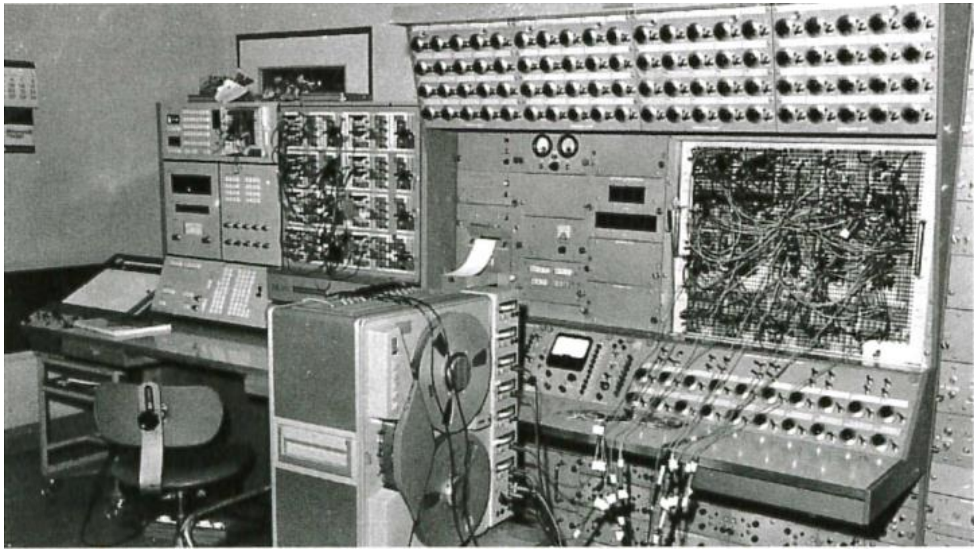
Agenda

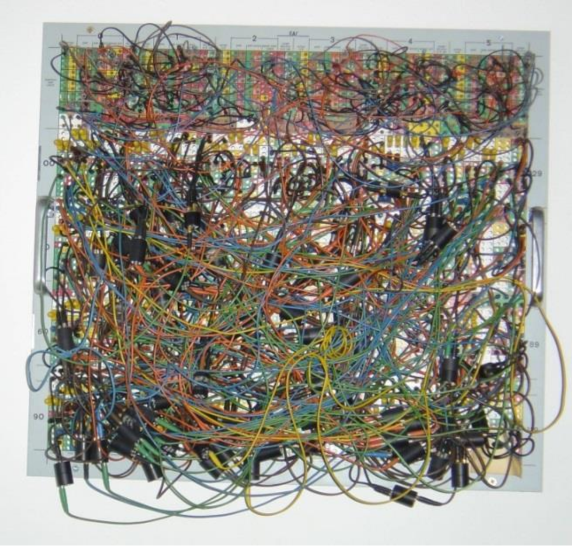
- A Short History of Flight Simulators in DLR Institute of Flight Systems
- DLR Air Vehicle Simulator (AVES)
- AVES Research Applications
- Simulation Infrastructure of AVES
- Simulation Engineering Research in AVES
- Concluding Remarks

History of Flight Simulators in DLR

First Generation
HFB320 Simulator (1975-1983)

- Hybridcomputer EAI PACER600
- Aerodynamics in FORTRAN
- 6-DOF Equations of Motion in Analog Computer





History of Flight Simulators in DLR

Second Generation

ATTAS Simulator (1985-2012)

- ADI AD10 (1983-1993),
  - Multiprocessor, ECL, 50 MIPS
  - MPS10, ADSIM
- ADI RTS (1993-2012) ,
  - MC88110, RISC, 70 MFLOPS
  - Upgrade: MVME1604, PowerPC, 200 MFLOPS
  - ADSIM

History of Flight Simulators in DLR

Second Generation

FHS Simulator (1995-2012)

- ADI RTS(1995-2012),
  - MVME1604, PowerPC, 133MHz
  - Upgrade: MVME2604, PowerPC, 400MHz
  - ADSIM

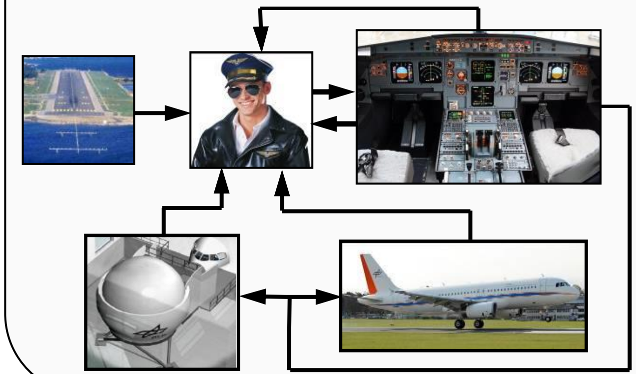
AVES – Air Vehicle Simulator

… the third generation ground based simulators, to represent both rotary-wing and fixed-wing aircraft

AVES Research Applications

New Air Vehicle Concepts

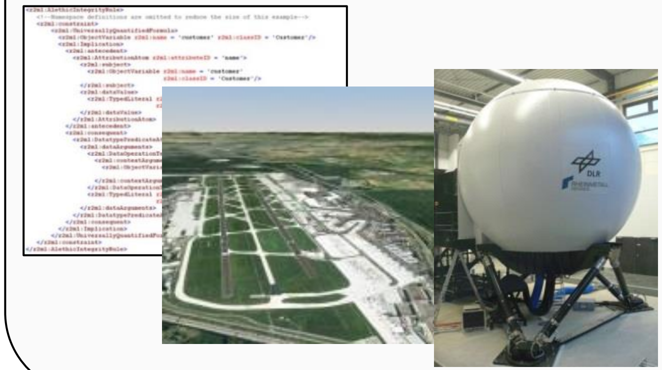
Flight Deck Automation



Research for Tomorrows Aviation

Advanced Modelling of Special Effects

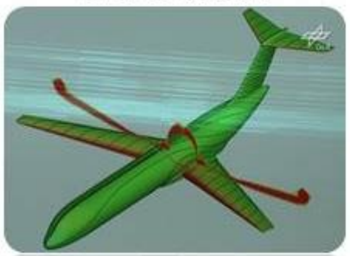
Simulation Technology

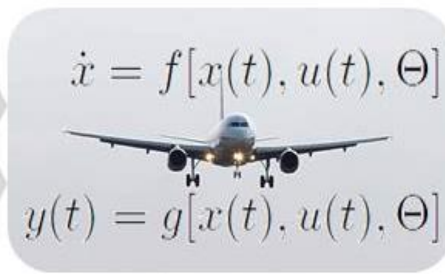


DLR

New Air Vehicle Concepts

CFD Simulation





$$\dot{x} = f[x(t), u(t), \Theta]$$

$$y(t) = g[x(t), u(t), \Theta]$$

Real Time Simulation Model

Flight Simulation

Wind Tunnel Tests

New Air Vehicle Concepts

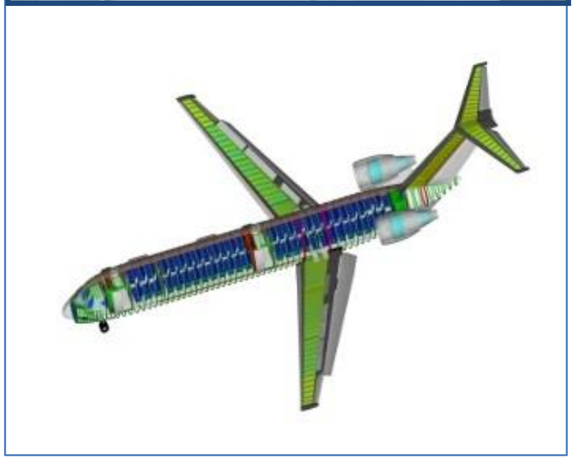
Forward Swept Wing Configuration

Handling Qualities

- Dynamic Control Checks
- Power and Flap/Slat Change Dynamics
- Longitudinal Trim
- Stall Speeds
- Short Period and Phugoid Dynamics
- Roll Response and Rudder Response
- Spiral Stability
- Dutch Roll
- Steady State Sideslip
- Engine In-Operative Trim
- Minimum Control Speed

Takeoff and Landing

Go-Around incl. crosswind

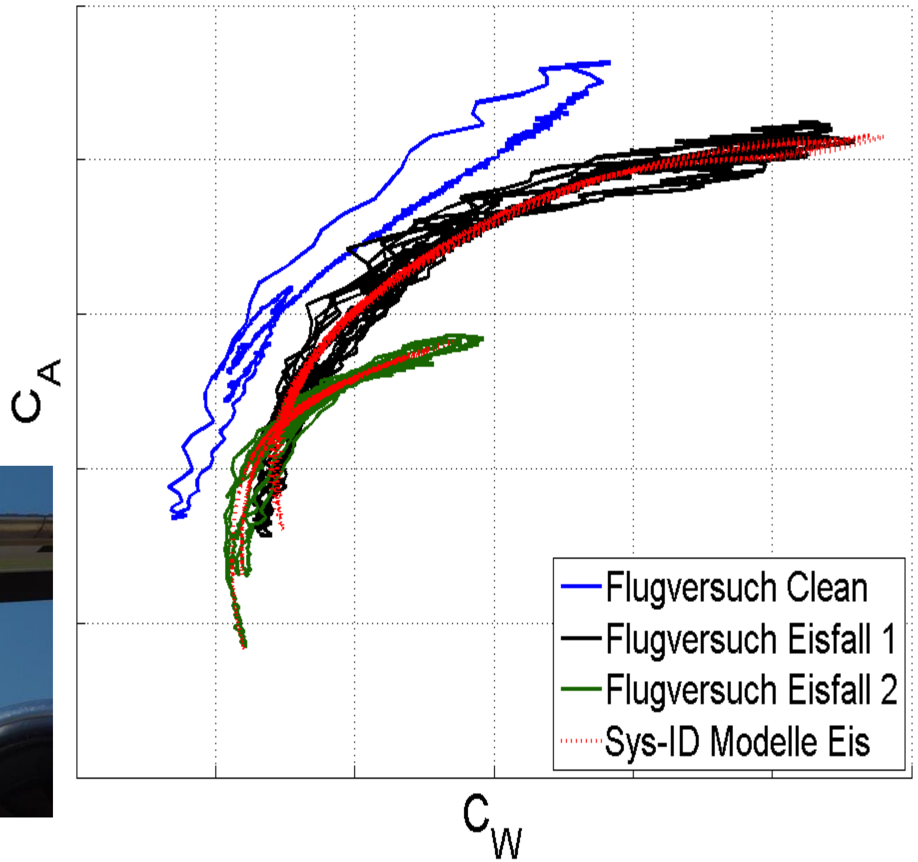


My Copter

What would be the optimal solution in creating a **Personal Air Transport System (PATS)** ?

Advanced Modelling of Special Effects

Aircraft Icing Modeling



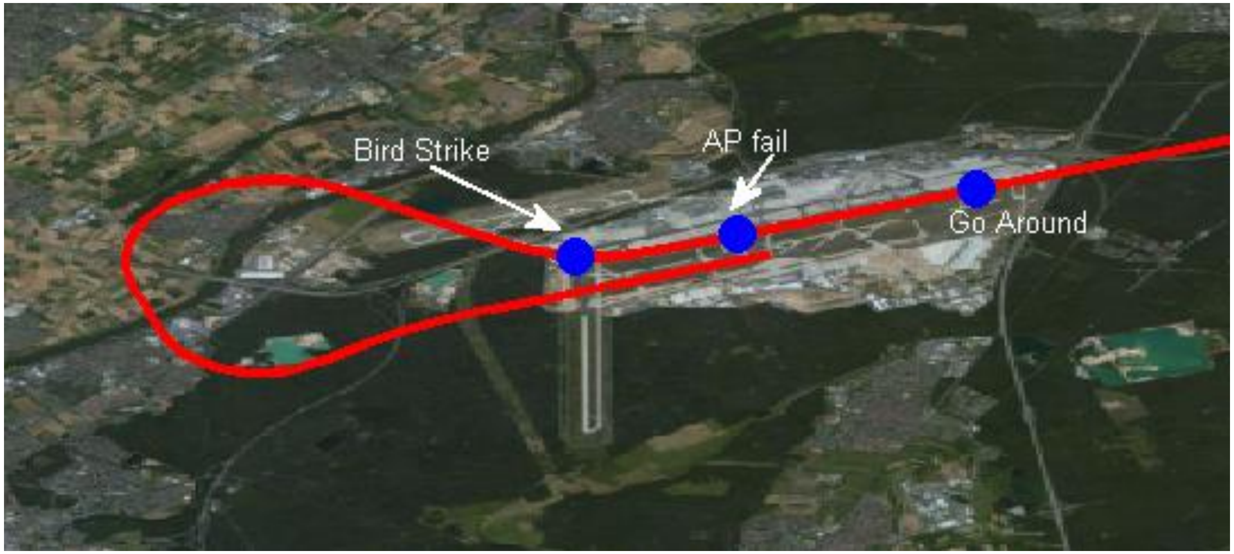
DLR

Flight Deck Automation Research

Manual Operations of 4th Generation Airliners

Identify the factors in **highly automated, 4th generation, aircraft** that affect the **ability of the flight crew and aircraft to handle unexpected events** and gradually deteriorating conditions to maintain effective control of the aircraft.

Simulator trials on AVES with 8 crews from different airlines

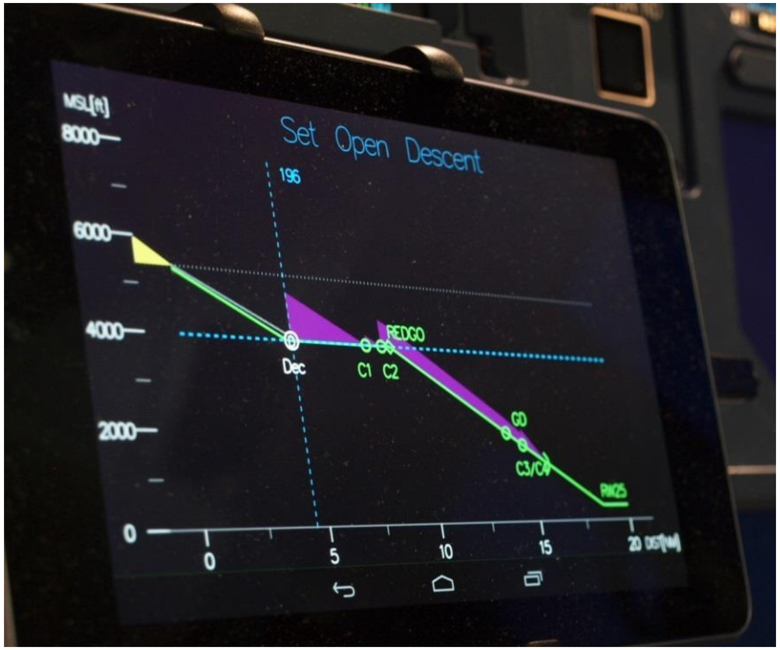


Flight Deck Automation Research

Energy Display for Precise Vertical Approach

Vertical situation display, showing

- Energy error
- Configuration change requests
- Speed deviation at 1000 ft gate



Reducing fuel consumption and noise

Successfully tested by 8 pilots from 3 different airlines on AVES

Flight Deck Automation Research

Go-Around Assistance System

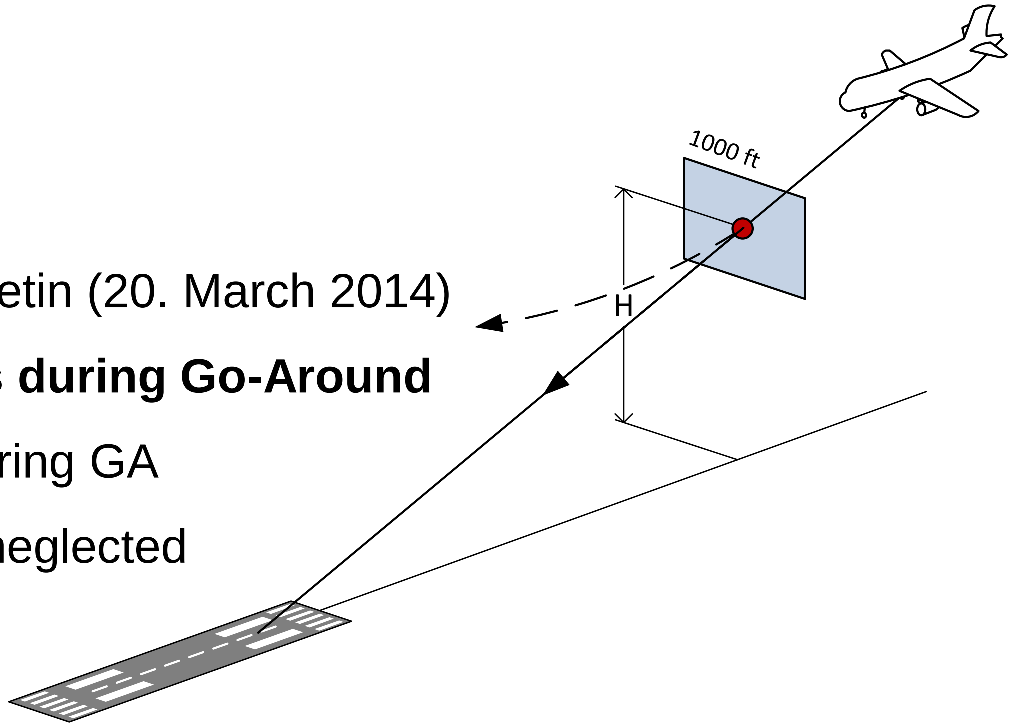
To be decided by the flight crew based on factors like

- Atmospheric conditions
- Runway conditions
- System status
- Stability at 1000 ft gate

EASA Safety Information Bulletin (20. March 2014)

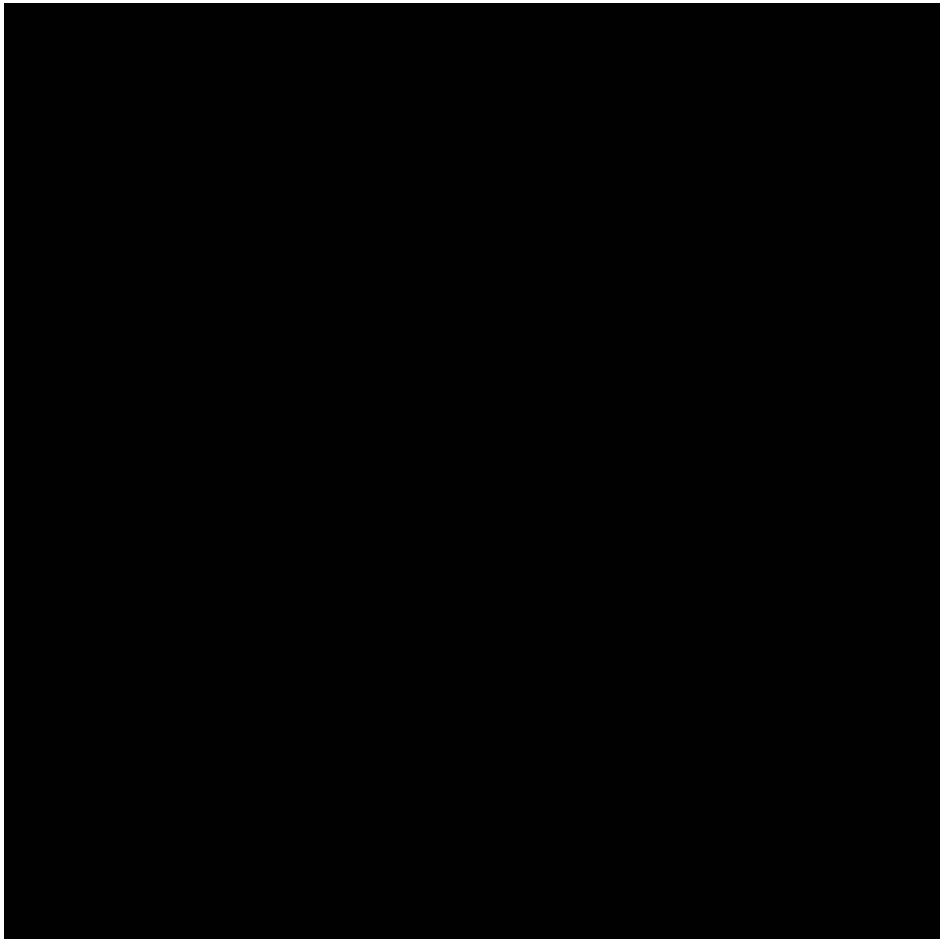
Aeroplane State Awareness during Go-Around

1. Very high workload during GA
2. Monitoring task often neglected



Flight Deck Automation Research

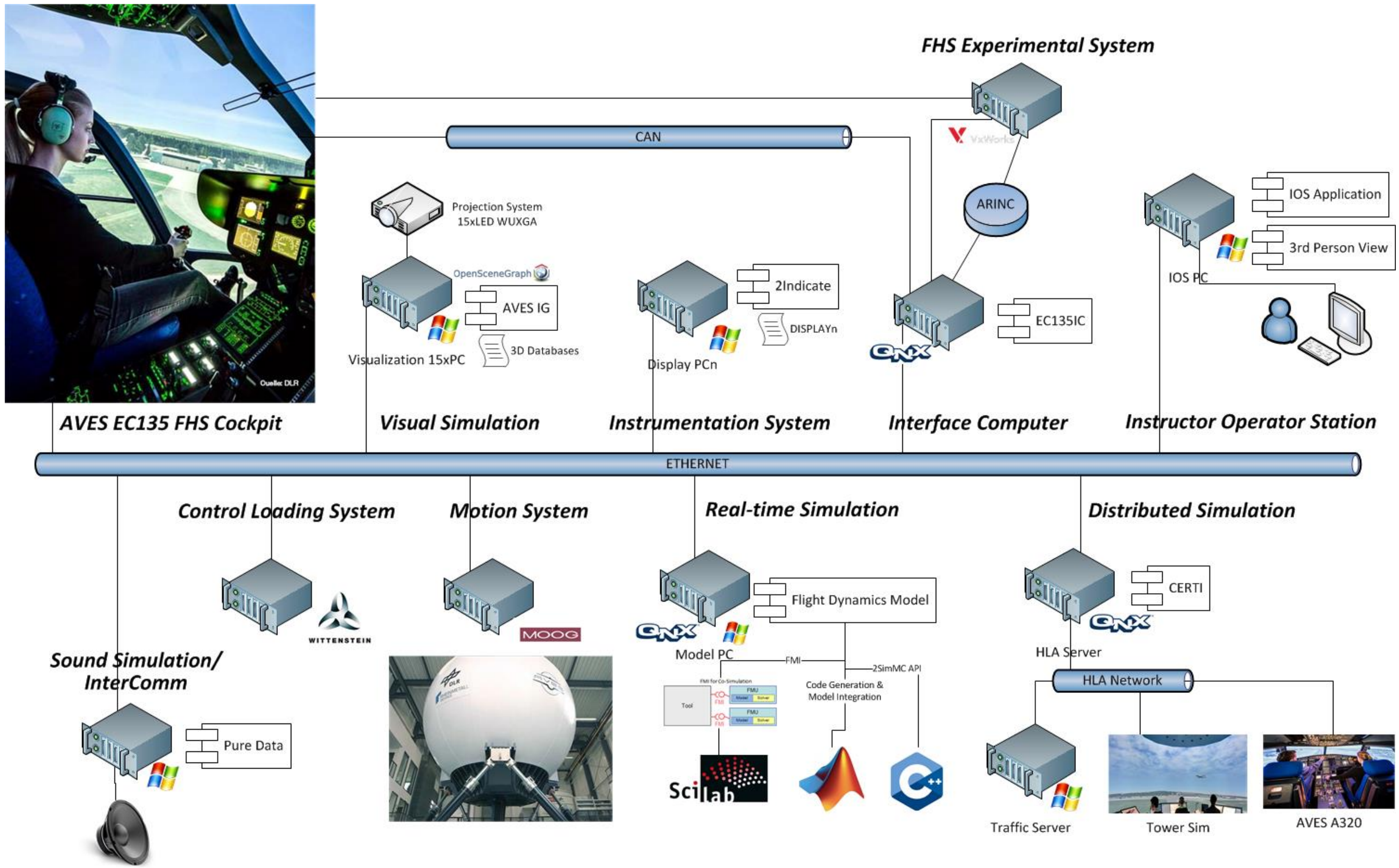
Go-Around Assistance System



The Challenge of Engineering the AVES

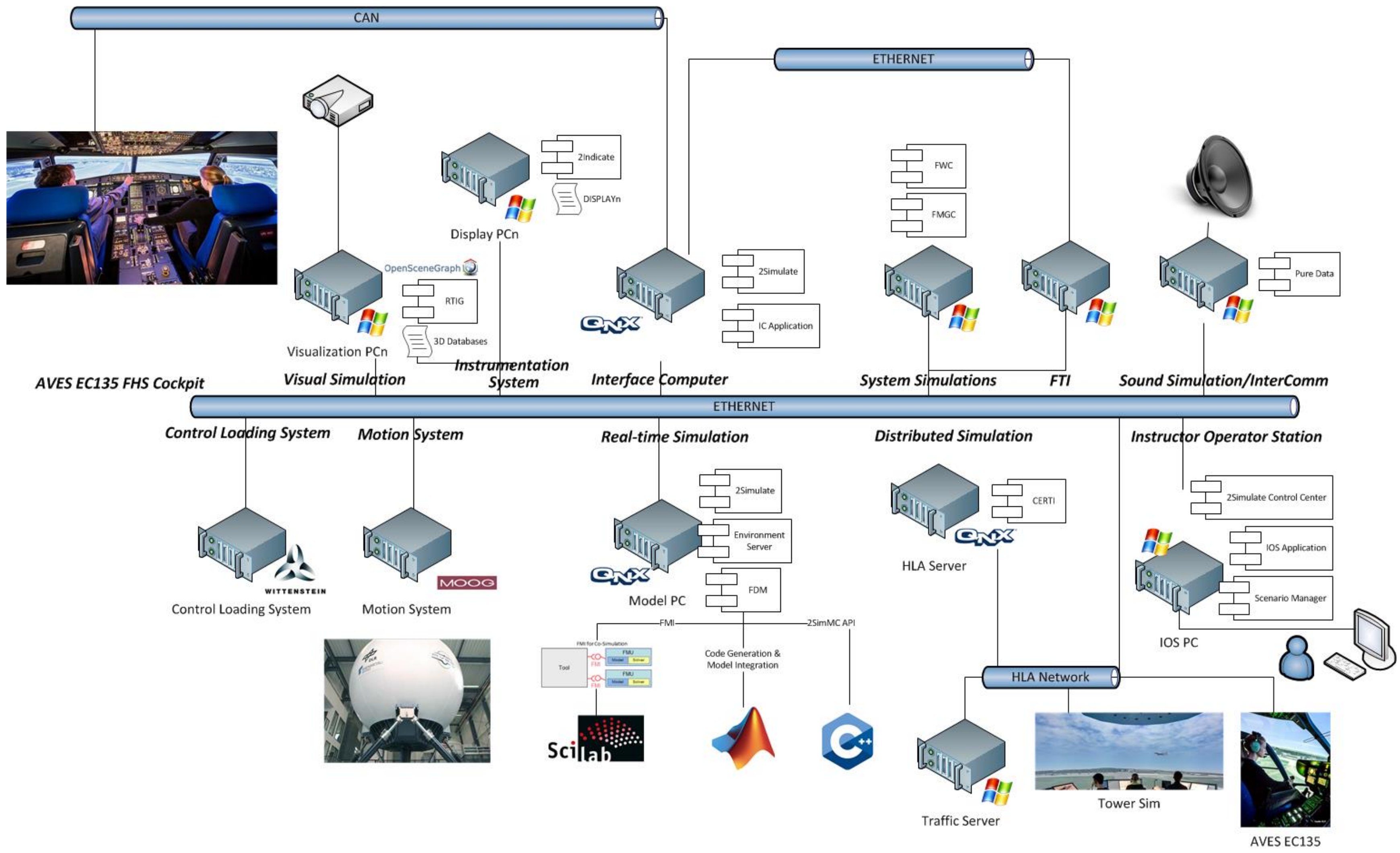
- **Supporting diverse research projects**
  - High **flexibility** and **adaptability** in almost all aspects
    - Cockpits
    - Flight systems and Flight dynamics models
    - Cockpit Displays
    - Visual Simulation
    - Control Loading System
    - Motion System
    - Instructor Operator Station

AVES – Helicopter Simulation Infrastructure



DLR

AVES – Aircraft Simulation Infrastructure

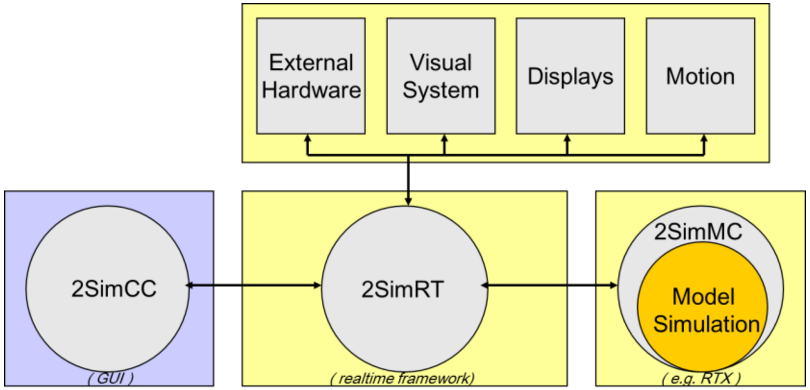


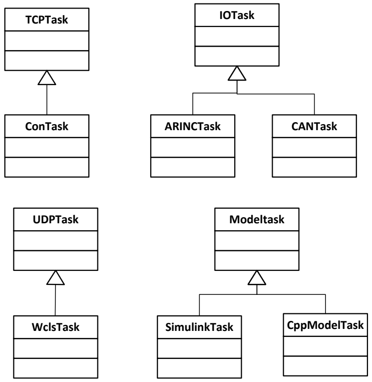
DLR

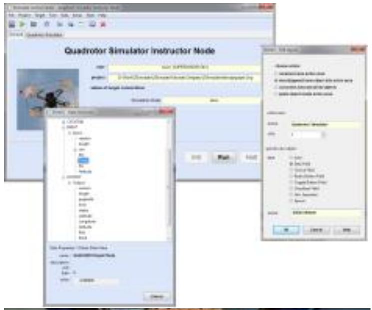
2Simulate: Enabling Simulation Infrastructure of AVES

2Simulate is an overall simulation framework

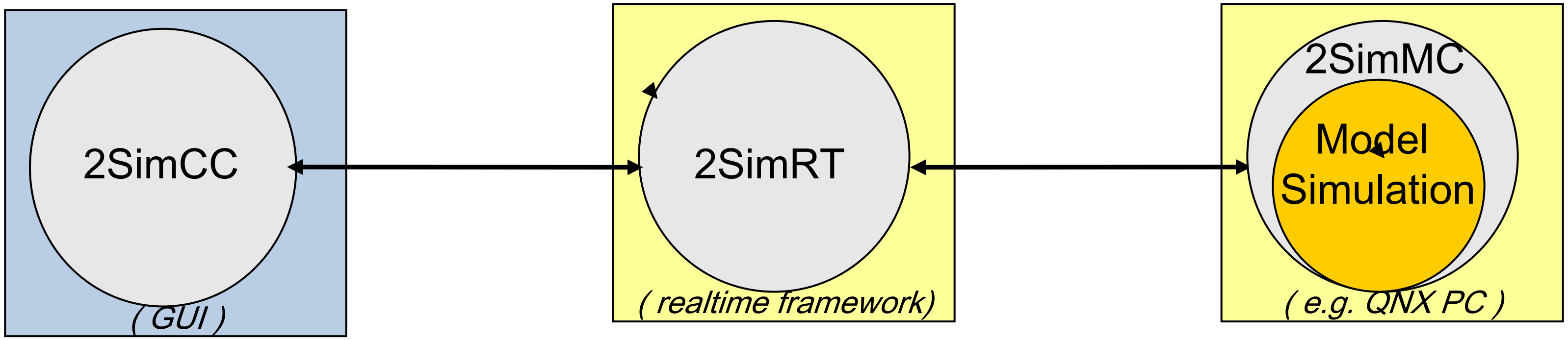
- Based upon 20 years of experience on real time flight simulation
- Supports MS Windows and QNX
- Integrates a wide range of models (Simulink, FMI, C++)
- Supports external I/O (UDP, TCP, ARINC, CAN)
- Supports external simulation components (image generators, data recorders etc.)
- Provides generic configuration and control tools







2Simulate – AVES Real Time Infrastructure



- **2SimRT** – 2Simulate Realtime Framework
  - Hard Realtime Task Scheduler (e.g. QNX)
  - Soft Realtime Task Scheduler (e.g. Windows, Linux)

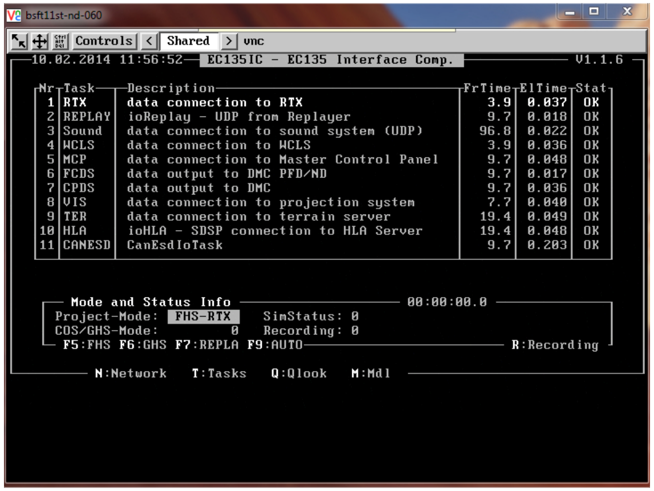
- **2SimCC** - 2Simulate Control Center
  - Graphical User Interface (wxWidgets)
  - Operating System: Windows, Linux

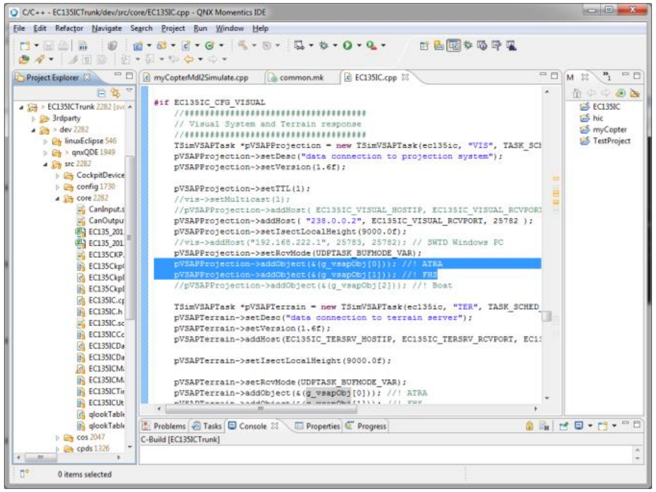
- **2SimMC** – 2Simulate Model Control
  - Model Control, Data Dictionary
  - C++, Simulink, FMI, …

DLR

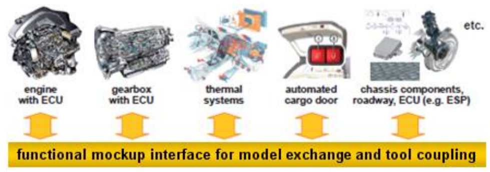
2SimRT – 2Simulate Real-Time API

- 2SimRT comes as MS **Windows or QNX images (Libraries) and API header** files
- Any **simulation application** that is based on 2SimRT is called a **Target**.
- Each Target runs various **real-time tasks** (typically 1ms-50ms range) utilizing the **2SimRT API**.
- 2SimRT also provides a **Common Database** to manage the **data** that **flow** through the internal and external interfaces.
- Callback functions for application specific data processing

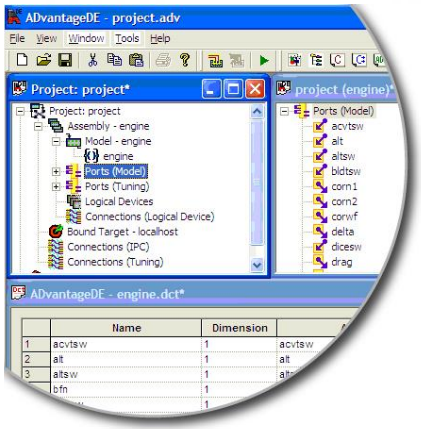




2SimMC – 2Simulate Model Control



- It works with **MATLAB/Simulink**, **FMI** or **native C++** models.
- Supports multiple models for **co-simulation**



- Supports real-time operating system **QNX** and **Windows**.
- Native C++ model development via **API**.
- MATLAB/Simulink and FMI integrated automatically into the models during the **code generation** process.

```
TSimMcModelCtrl* getModel( void ) { return(this); }

  void initDataDict( void ) {}
  void setIC( void ) {}
int doOneFrame( void )  { return 0; }
```

DLR

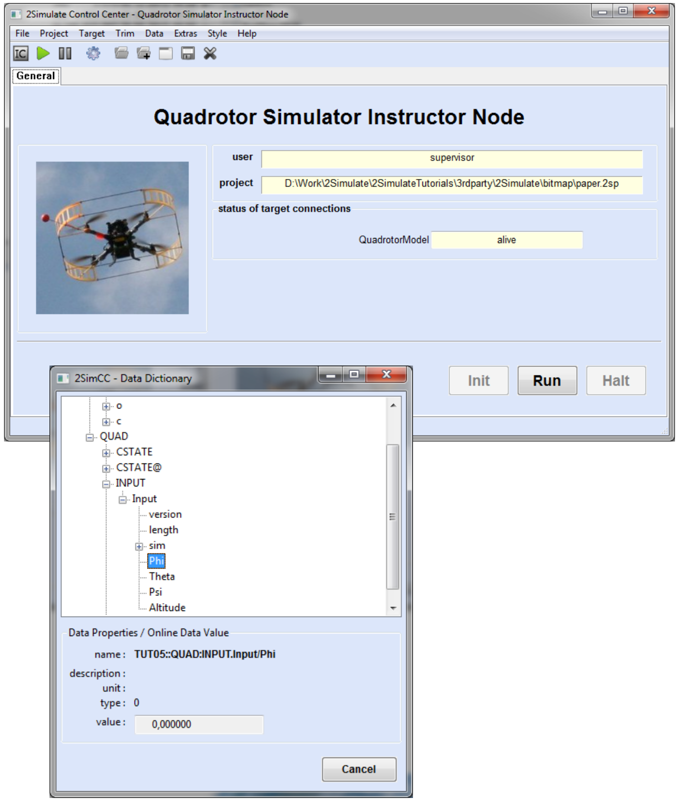
2SimCC – 2Simulate Control Center

- **MS Windows executable** which can be customized via configuration files

- **Controls** (Runs, Pauses or Stops) various **Targets**

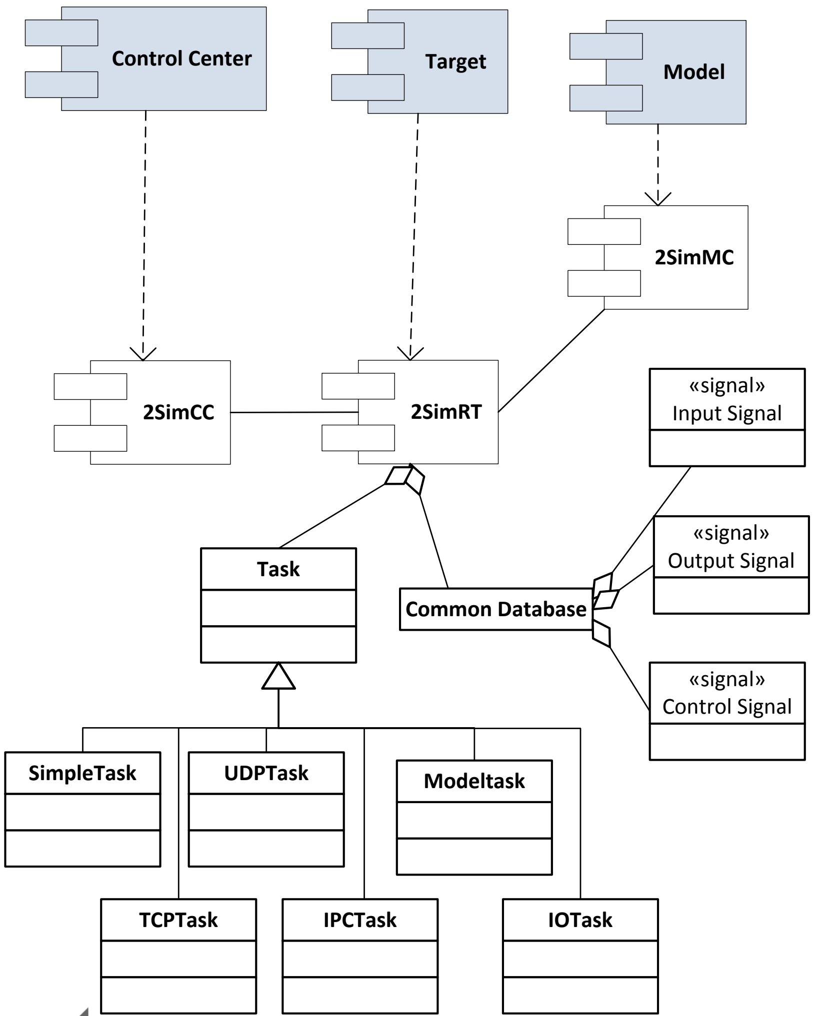
- Accesses the **Target Data Dictionaries**
  - Data access mechanisms for **presenting** or **editing Target Data** at **runtime**

- Enables **user management**
  - Define and enforce user access rights

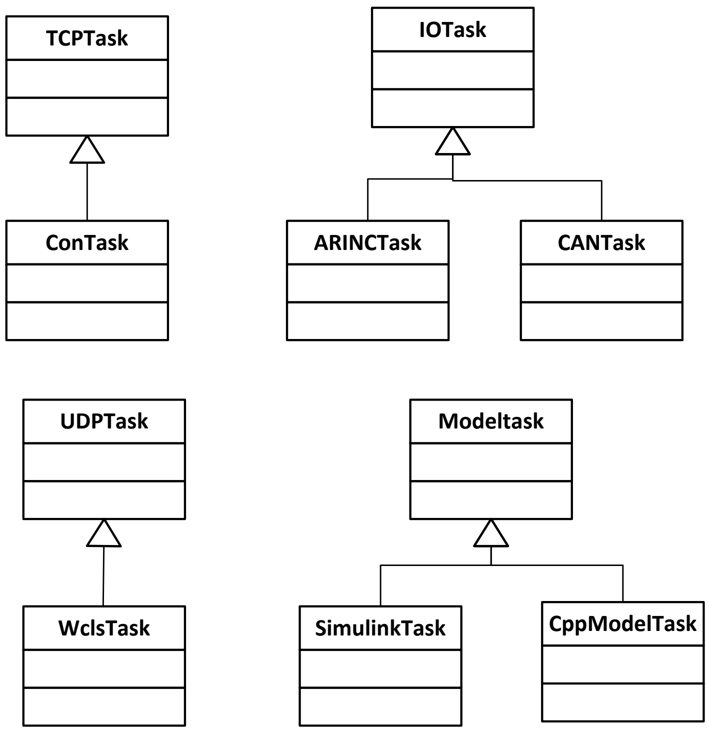


DLR

Component Architecture



Task Hierarchy



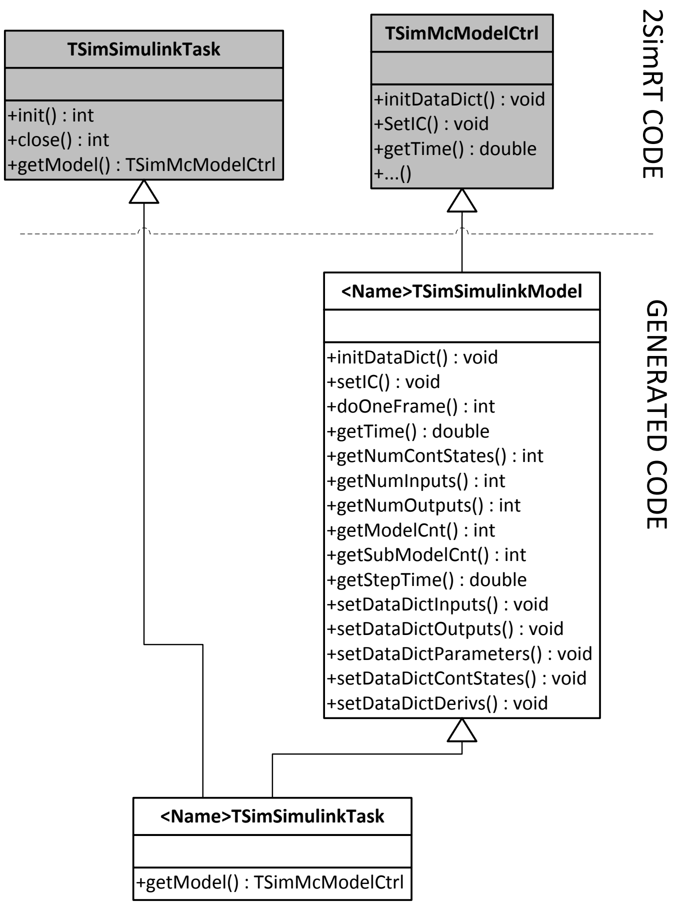
DLR

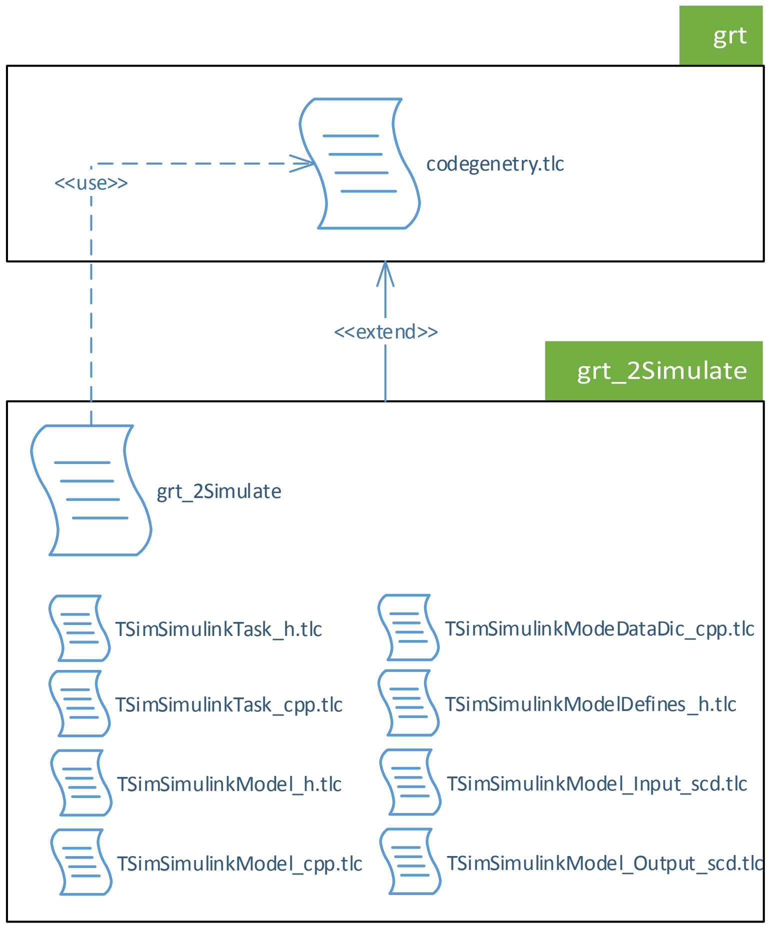
Recent Simulation Infrastructure Research

- Code Generation for Integration of MATLAB/Simulink Models
- 2Simulate Modeling Language for Modernization of Legacy ADSIM Models
- MATLAB/Simulink 2Simulate Blockset for Model-in-the-Loop testing
- 2Simulate Functional Mock-up Interface (FMI) Support
- 2Simulate High Level Architecture (HLA) Support

DLR

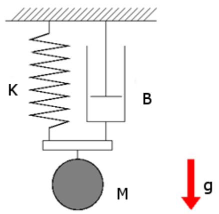
Code Generation for Integration





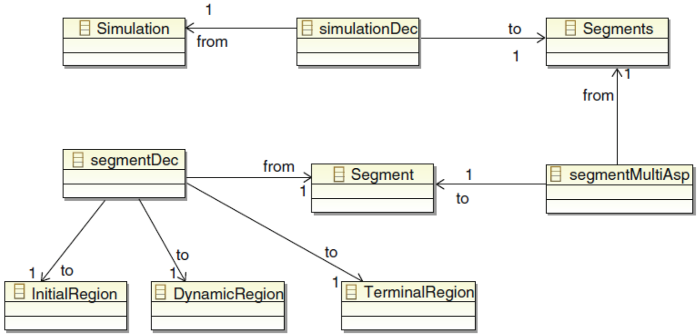
DLR

2Simulate Modeling Language

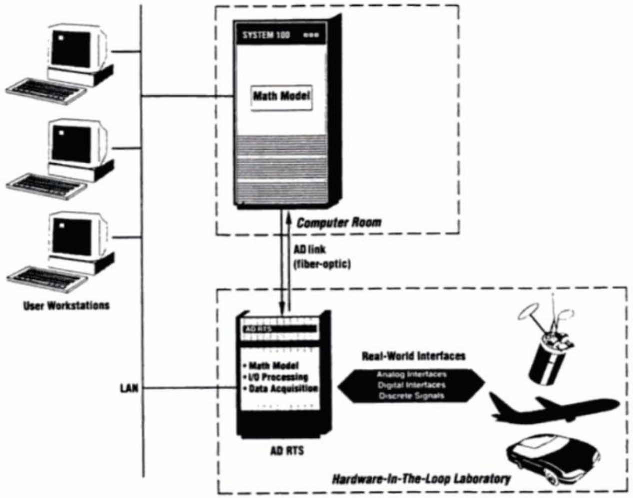



```
TITLE „Mass-Spring-Damper system in ADSIM"

REGION initial

     x@ = 0,      y@ = 0.3

END REGION

DYNAMIC continuous

     y' = x

     x' = - (K/M * y) - (B/M * x) + g

END DYNAMIC

DATA   M = 1.0, K = 10.0, B = 9.81
```

Continuous System Simulation Language (CSSL)



ADSIM Language



Kheir, Naim, ed. *Systems modeling and computer simulation*. Vol. 94. CRC Press, 1995.

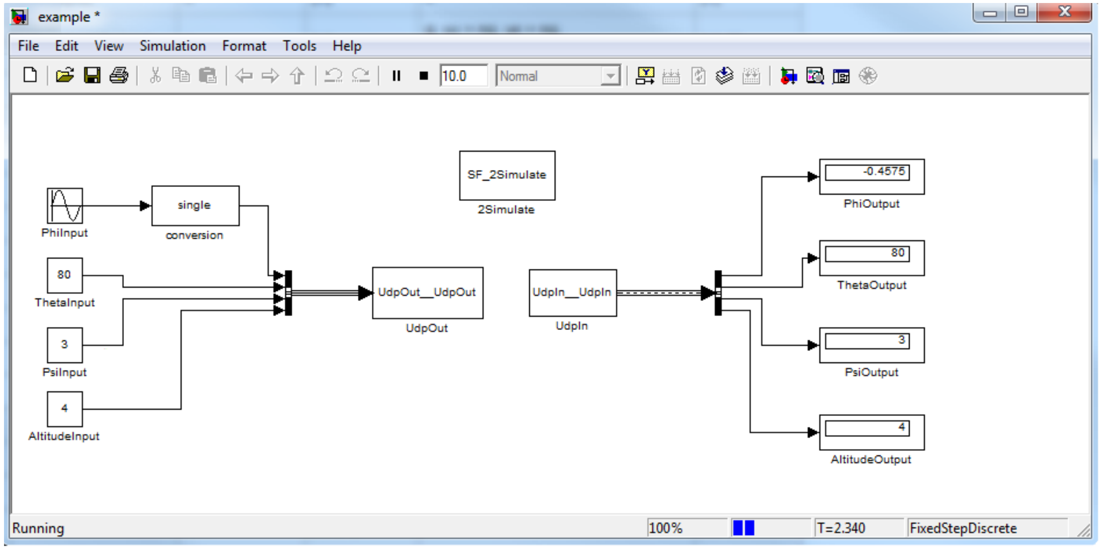
2Simulate Modeling Language

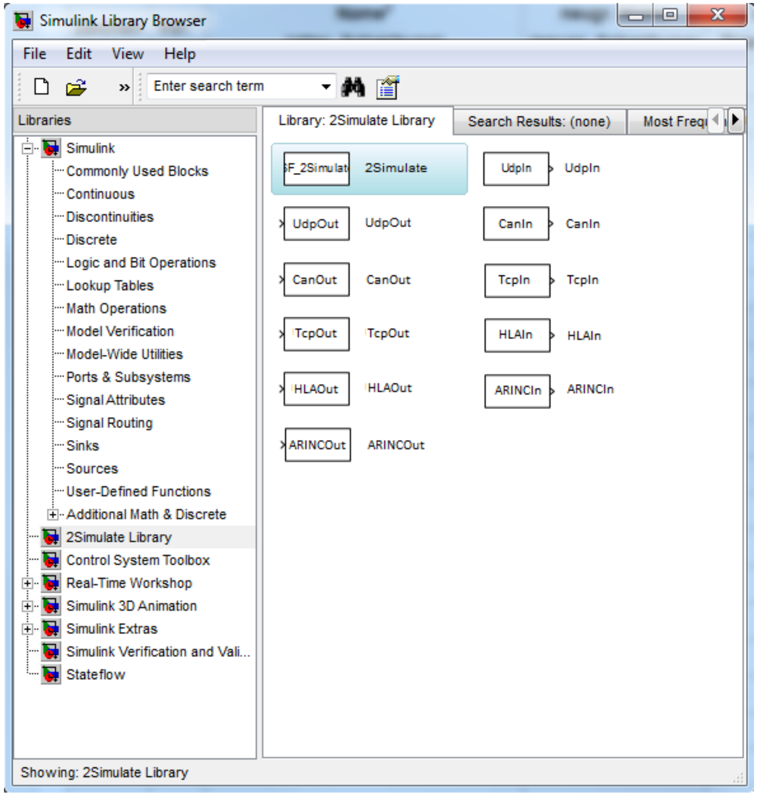
- Modernization of legacy ADSIM models to 2Simulate compliant C++ models
  - An ADSIM like C++ API

2SimML	ADSIM
setIC()	(interne Steuerung)
doOneFrame()	DYNAMIC continuous
initDataDict()	(nicht vorhanden)
defineStates()	(interne Steuerung)
initData()	REGION initial
initSubModels()	MODEL xxx
initFunctions()	INTERPOLATION_FUNCTION xxx
getInputData()	routine_interface with C : getInputData()
putOutputData()	routine_interface with C : putOutputData()

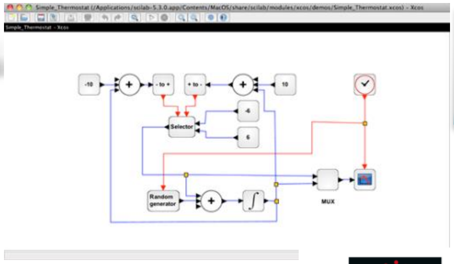
MATLAB/Simulink 2Simulate Blockset

- Enable Model-in-the-Loop testing in AVES
  - Integrating MATLAB/Simulink models to AVES without code generation
    - Model Debugging
    - Quick testing

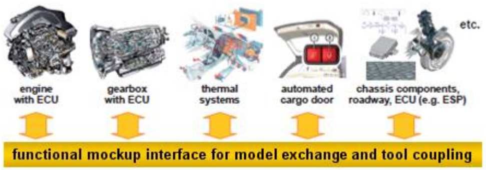


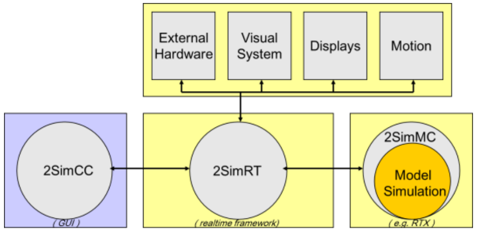


2Simulate Functional Mock-up Interface (FMI) Support



Code Generation and Deployment

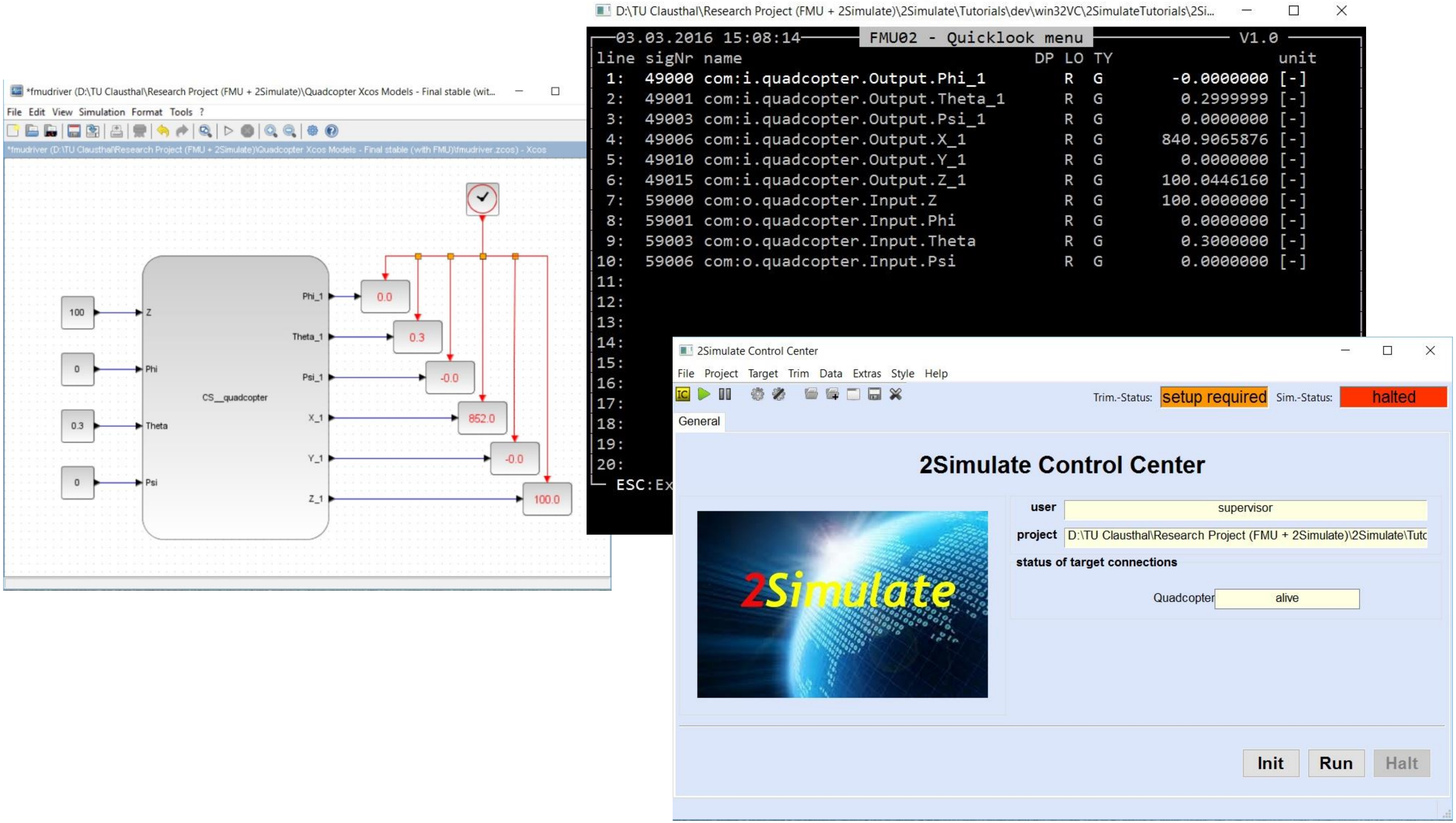




DLR Air Vehicle Simulator (AVES)

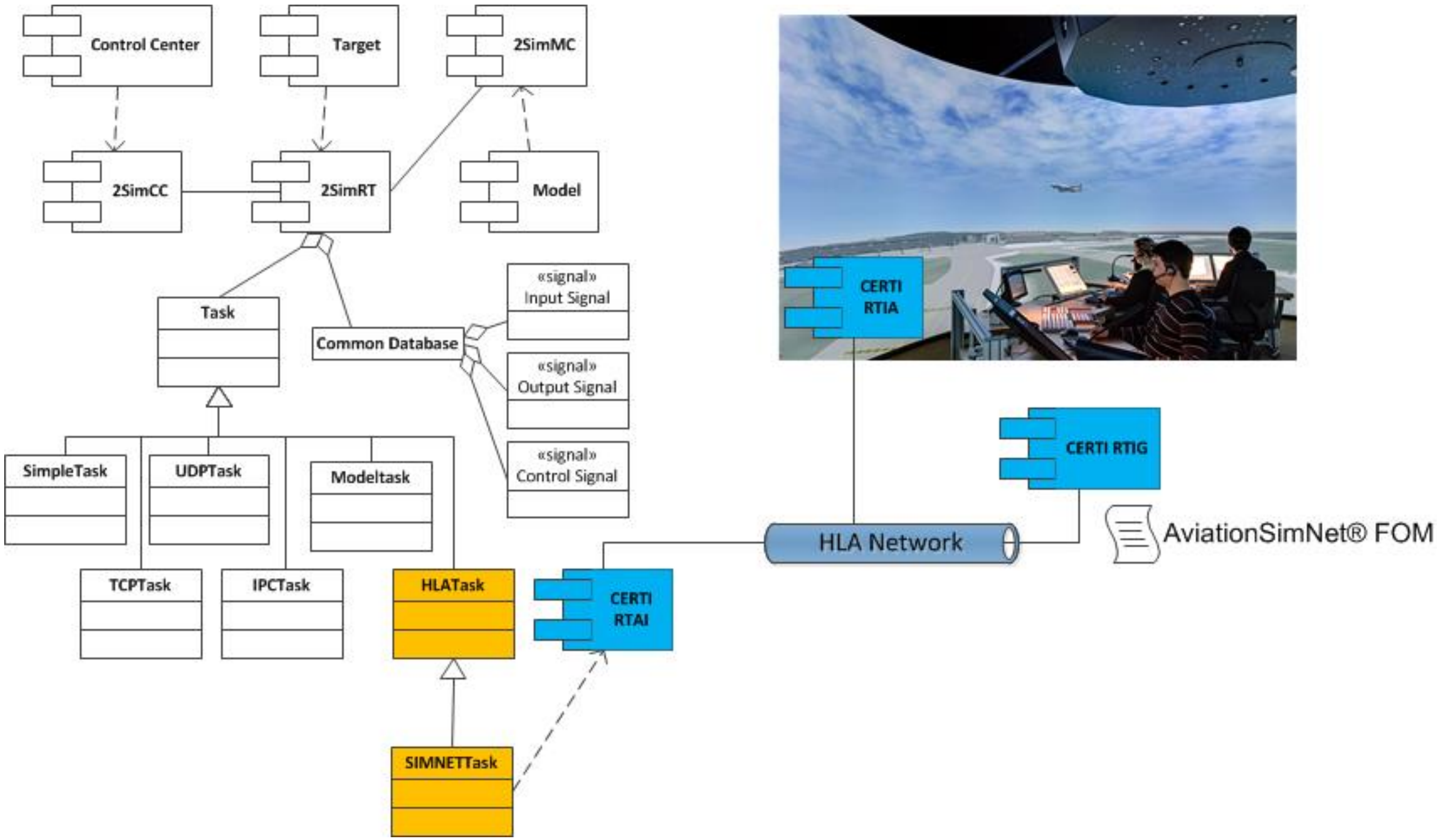
DLR

2Simulate Functional Mock-up Interface (FMI) Support



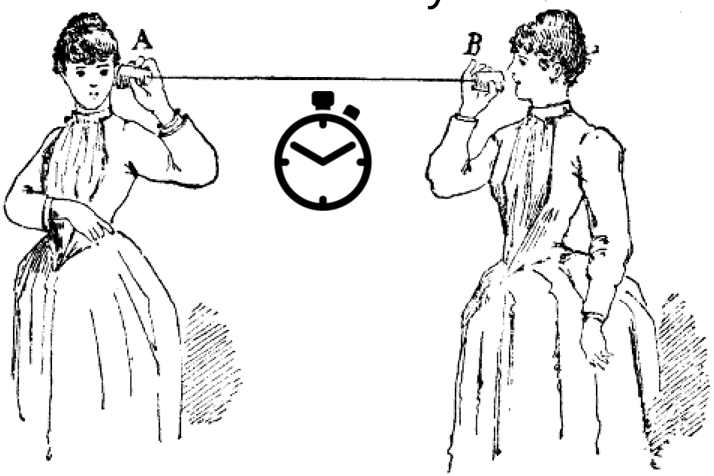
2Simulate High Level Architecture (HLA) Support

AVES WORLD **OUTER WORLD**



2Simulate High Level Architecture (HLA) Support

- Challenges and Achievements
    - CERTI was not readily available for QNX
        - Ported to QNX
    - Performance of CERTI
        - Configuration for real-time execution
        - Validate real-time constraints of flight simulator integration using AviationSimNet® FOM based federation
            - Worst Case Transfer Time Analysis

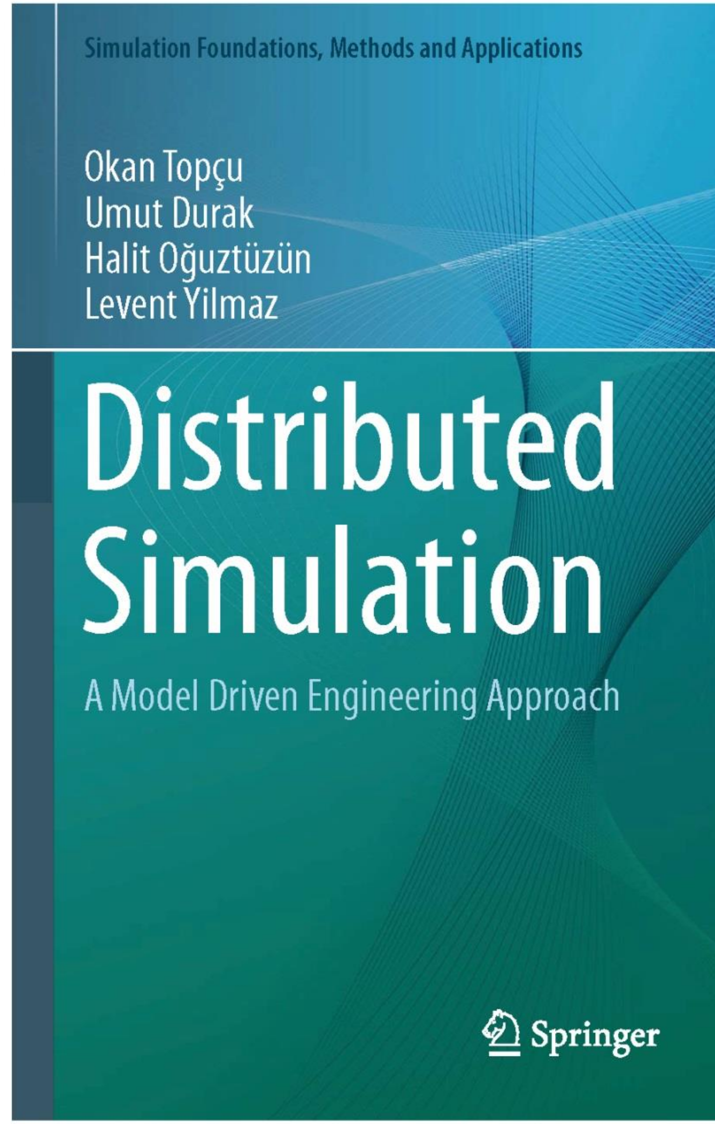


Further…

Distributed Simulation

A Model Driven Engineering Approach

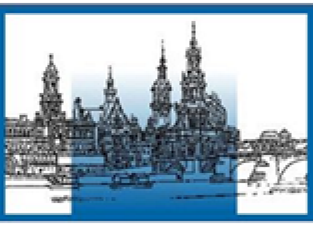
A recent book that references various simulation engineering research activities from AVES



Special Track in ASIM 2016

ASIM 2016 – 23. Symposium Simulationstechnik

http://www.asim2016.de/



Call for Papers

Special Interest Track

Modelling and Simulation in Aviation

Track Chairs: Umut Durak and Torsten Gerlach

Since decades, the philosophy of modelling and simulation is widely employed in the aviation community. The applications cover a wide range from modelling small sub systems up to developing large flight simulators. New standards, techniques and methodologies have been developed to tackle the complexity of problems and solve the challenges of tomorrow. Now, this Special Interest Track endeavours to establish a platform under the umbrella of ASIM to share modelling and simulation efforts from the aviation community. Authors are encouraged to submit papers as applied to the fields of aviation and aerospace systems.

Last Words

- **Flight simulation** is an **indispensable** tool for aviation research
    - In order to meet the requirements of aviation research community

For Tomorrow's Aviation

Simulation Engineering Research is **Indispensable**!

Flight Simulation for Tomorrow's Aviation

Dr.Umut Durak

DLR Institute of Flight Systems

Questions and Answers

ASIM STS/GMMS 2016 Workshop

Lippstadt, 10.3. - 11.3.2016