Technische Universität Braunschweig

Institute of Flight Guidance IFF

An integrated Wake Vortex Visualization Concept for existing Cockpit Display Systems

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Content

- Motivation
- Simulation Environment
- Wake Vortex Awareness System (WVAS)
- Conclusion and Outlook

Motivation

- Current forecasts predict a heavy growth in air traffic worldwide

- Air transport network almost reached its capacity limit

- Bottlenecks
  - Heavy workload of air traffic controllers
  - Runway layout and interdependencies between different runways
  - Complex taxiway system
  - Spatial and environmental restrictions
  - Conservative wake vortex separations
  - …

Motivation

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  - **Conservative wake vortex separations**
  - …

Simulation Environment

- To obtain the required capacity and efficiency
  - Change of current operational procedures
  - Development and integration of new ATM concepts and technologies

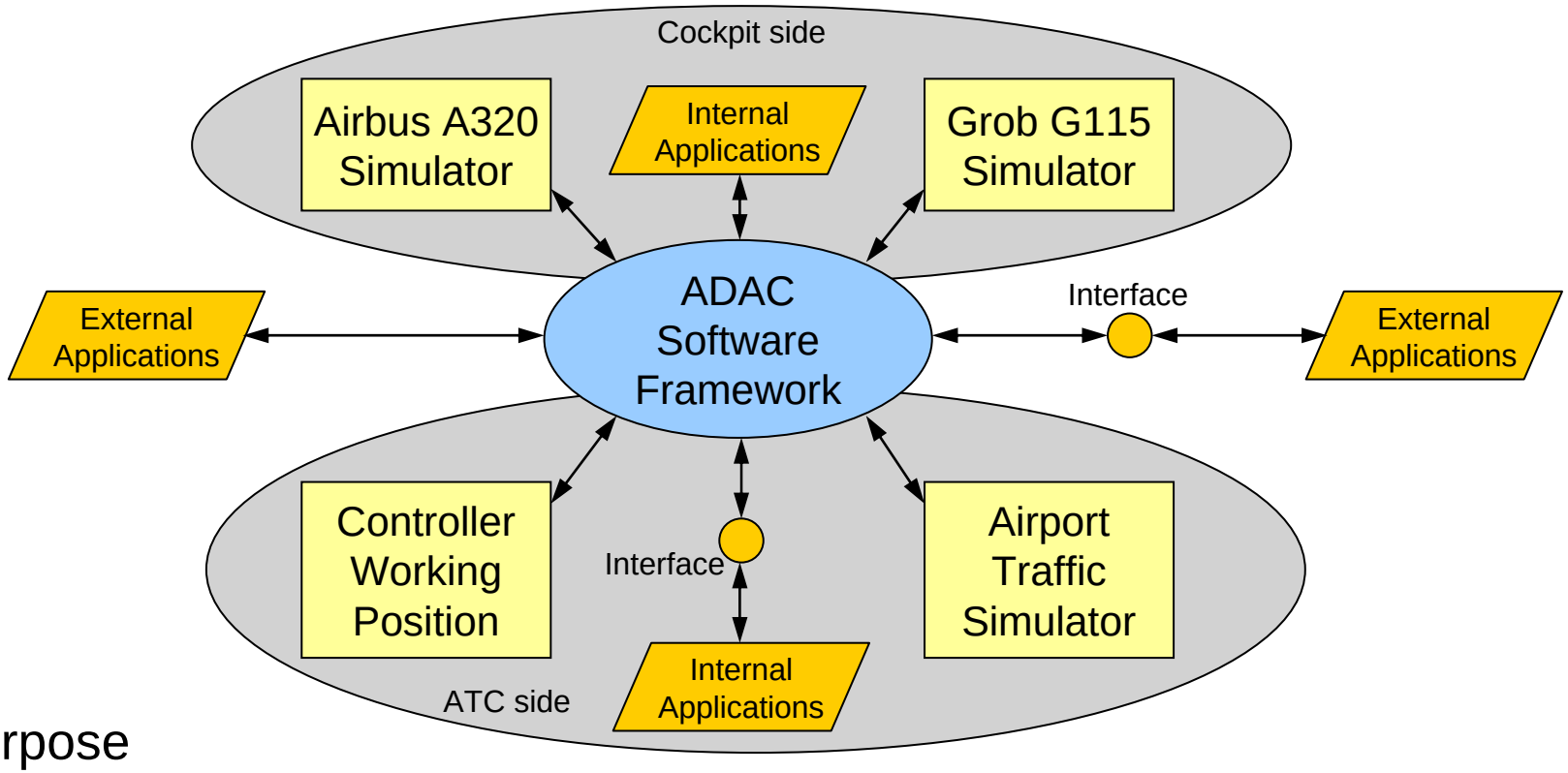
- Future ATM concepts
  - Imply more complex avionics and a higher degree of automation
  - Provide an immense amount of information to the controllers and pilots

- Human-Machine Interface (HMI) design has to meet high standards in terms of usability and interpretability

- Validation and evaluation
  - Essential part of the development process
  - Testing in real environment might be complicated and cost-intensive

    → Simulation is an alternative approach

Simulation Environment – Overview



- Purpose
  - Education
  - Demonstration of existing and future ATM concepts and operational procedures
  - Research activities within national and international projects

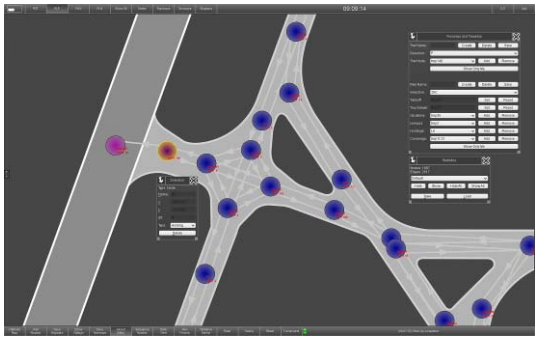
Simulation Environment – A320 Simulator

- System simulation
  - Proprietary software package
  - Cockpit displays, switches, levers, electronics, hydraulics, ...
  - Fixed-based
  - Triple-channel external view
    - Viewing angle > 180°
- Architecture
  - Overall system runs on nine computers
  - Allows replacement of individual modules

Simulation Environment – Further components

- Second aircraft:
  Cockpit of GA aircraft (Grob G115)

- Airport Traffic Simulator

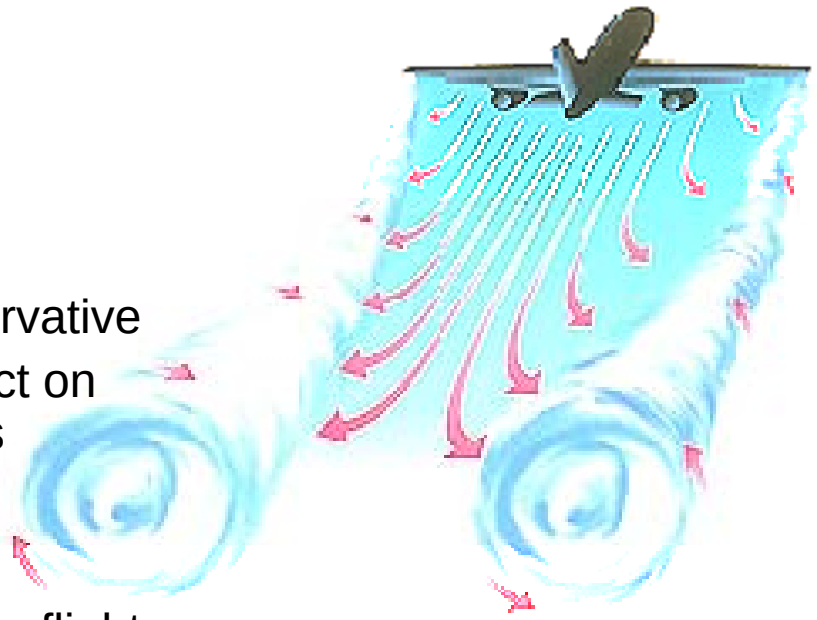


- Apron Controller
  Working Position

Wake Vortex Awareness System – Overview

- Wake turbulence is a result of lift

- Wake vortex encounter can lead to catastrophic consequences



- ICAO separation regulations
  - Based on maximum take-off weight
  - Have proved to be safe, but are very conservative

  → Limit capacity and have a significant impact on economic efficiency of commercial airlines

- Possible approach
  - Delegation of separation responsibility to the flight crew

  → Safe operation must still be guaranteed

  → Visualization of potential hazardous wake vortex traffic

WVAS - Considered Aspects for Display Design

Consideration of modern airliner cockpit concepts

Interviews with pilots

Pilote dans le cockpit d'un A320

Pilot in an A320 cockpit

Photo : Guillaume GRANDIN Réf : 22774

iew of existing concepts
wake vortex visualization

WVAS - Considered Aspects for Display Design

Conclusion:

The display should…

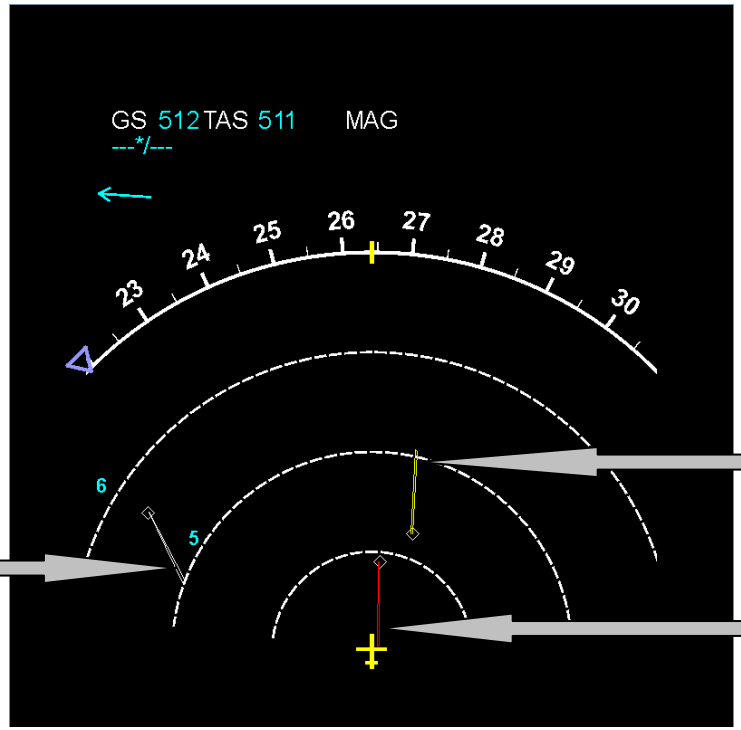
- contain only absolutely necessary information
- be placed in the focus of the pilot
- not cover or distract from other indicators
- fit into the design concept of airliner cockpits
- not look too similar to other indicators to prevent mistake
- be easy to understand

WVAS - Concept of the Wake Vortex Awareness System

- Integration of the display in the ND and PFD
- Indicating in the PFD only in dangerous situations (wake vortex encouter in less then 40 seconds possible)
- Indicating in the ND only if selected by pilot or in dangerous situations
- Symbols, colors and warning steps according to windshear warning system and TCAS
- No resolution advisory, only information
- No detailed depiction of the wake vortex, only a danger zone which must not be encountered

WVAS - Concept of the Wake Vortex Awareness System

Indication on the ND



More than 40 seconds until intrusion (grey)

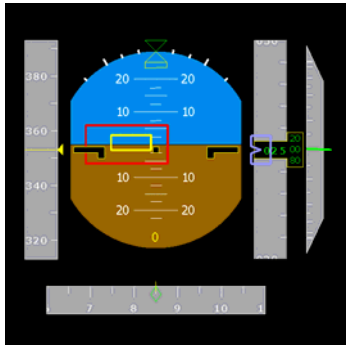
Less than 40 and more than 25 seconds until intrusion (amber)

Less than 25 seconds until intrusion (red)

WVAS – Concept of the Wake Vortex Awareness System

- Warning levels
  - Each danger zone is assigned to one warning level
  - Overall operating status equates to the most critical warning level

Warning Level	Display on ND	Display on PFD	Acoustic Warning
NORMAL ($t_{WV} > 40s$)	No display or white polygon if requested by the pilot	–	–
CAUTION ($25s < t_{WV} \leq 40s$)	Amber polygon	Amber rectangle	WAKE AHEAD played once
WARNING ($t_{WV} \leq 25s$)	Red polygon	Red and amber rectangle	WAKE played repeatedly



WVAS – Wake Vortex Determination

- Graphical depiction of wake vortices requires real-time information about the temporal evolution of their strength and position

- Wake vortex determination
  - Physical detection by dedicated sensors
  - Prediction by mathematical models
  - Fusion of sensor and model data

- Used prediction model
  - D2P algorithm [1][2]
  - Based on physical principles underlying the wake evolution mechanism calibrated with empirical data
  - Effects of wind, stratification and ground proximity are taken into account
  - Model inputs: weather data and aircraft parameters

[1] Holzaepfel, F., Probabilistic two-phase wake vortex decay and transport model, Journal of Aircraft, Vol. 40, No. 2, American Institute of Aeronautics and Astronautics, 2003, pp. 323-331.

[2] Holzaepfel, F., Probabilistic two-phase aircraft wake-vortex model: further development and assessment, Journal of Aircraft, Vol. 43, No. 3, American Institute of Aeronautics and Astronautics, 2006, pp. 700-708.

WVAS – Evaluation

- First tests with pilots of commercial and general aviation
  - Investigate usability aspects
  - Analyze potential increase in situational awareness
  - Mission
    - Extended final approach on research airport Braunschweig-Wolfsburg, Germany
    - Preceding aircraft acted as wake turbulence generator

- HMI concept was considered useful and intuitive
  - Especially visualization in the ND

- Further development
  - Visualization of only one rectangle in the PFD in case of warning mode
    → Wake vortex trajectory is already displayed in the ND
  - Simultaneous use of amber and red rectangles
    → Might lead to misinterpretation

Conclusion and Outlook

- Modular ATM simulation environment
  - Airbus A320 and Grob G115 cockpit simulator
  - Airport traffic simulator
  - Controller working position
  - Support of data exchange and HMI creation

- Integrated applications
  - Wake Vortex Awareness System (WVAS)
  - Taxi Guidance Application

- Next steps:
  - Integration of WVAS into the research aircraft of IFF
  - Development and integration of further onboard assistance systems into the simulation environment (e.g. GBAS based Wake Vortex avoidance procedures)

Thank you for your attention!