Technische Universität Braunschweig

Institute of Flight Guidance

Evaluation of an automated taxi concept in a distributed simulation environment

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Motivation

- Air traffic in Europe is expected to have doubled within the next twenty years
- Major hub airports will become more and more the bottlenecks in the air transport network
- Two million flights will not be accommodated in 2030 → about 10% of the demand
- Bottlenecks
  - Complex runway and taxiway layout
  - Dependency on airfield view
  - Spatial and environmental restrictions
- Countermeasures
  - Change of current procedures
  - Integration of new ATM concepts and technologies

ROLF Project

- Funded by the German Federal Ministry of Economics and Technology
- Sub-project of iPort (innovative Airport) within the German Aeronautical Research Program (LuFo IV)

- Duration
  January 2009 - March 2012 (December 2012)
- Consortium

- Goal
  - Increase resources and safety
  - Reduce environmental pollution of ground traffic
  - Reduce the dependency on direct vision of the airfield

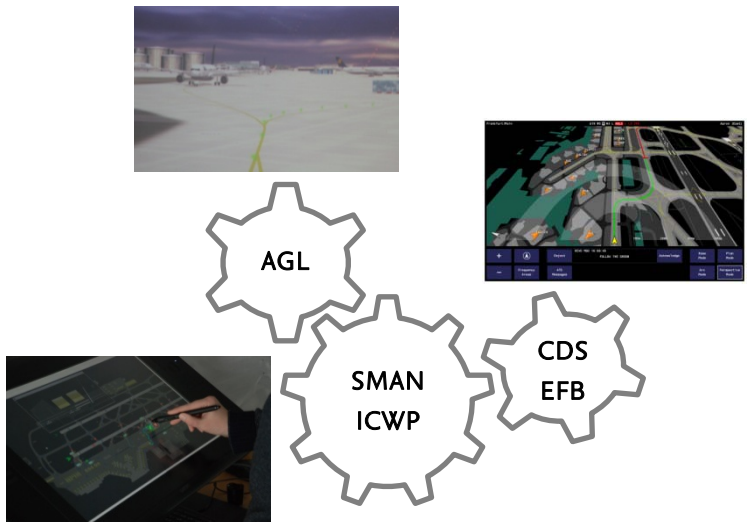
Concept of Operations

- Objectives
  - Introduction of an increased level of automation in ground traffic management and visual guidance
  - Submission of a complete and generic system concept

- Content

  Detailed description of
  - Systems and processes as well as their corresponding interactions and information flows
  - Concerned actors, their roles and responsibilities

- Ground and onboard systems
  - Surface Management System (SMAN)
  - Integrated Controller Working Position (ICWP)
  - Airfield Ground Lighting (AGL)
  - Cockpit Display System (CDS)
  - Electronic Flight Bag (EFB)



Ground Systems

- Surface Management System
  - Central A-SMGCS platform
  - Coordination of traffic on maneuvering area
  - Automation services for surveillance, routing, guidance and control

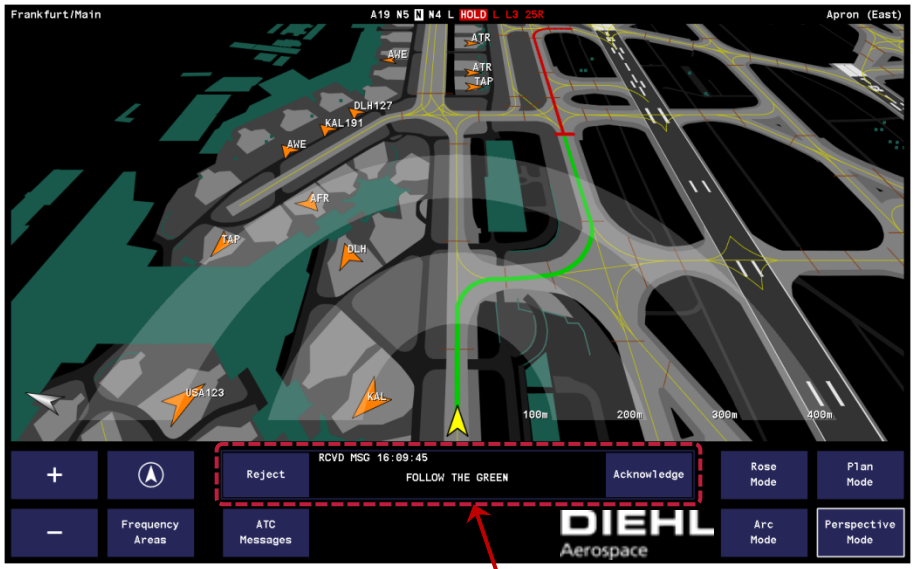
- Integrated Controller Working Position
  - Human-Machine Interface for ATC controller
  - Position and relevant information of aircraft and vehicles
  - Status of individual stop bars
  - Operated via pen touch display

- Airfield Ground Lighting
  - Unambiguous guidance for each flight
  - Dynamically switches taxiway centerline lights → Follow-the-greens
  - Individual route segments are updated by SMAN

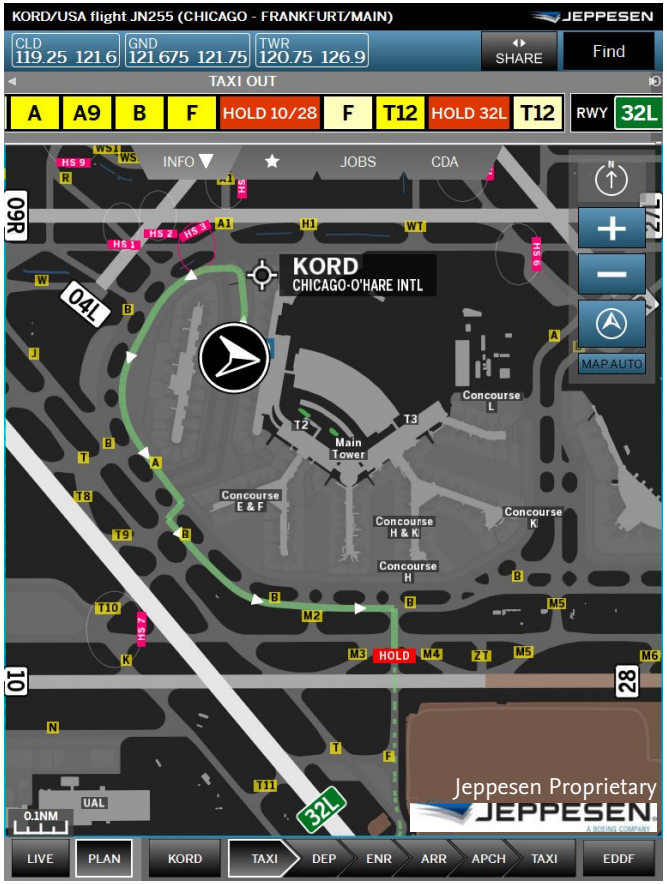
Onboard Systems – Cockpit Display System

- Integrated solution
- Represented by a Taxi Guidance Application
- Features
  - High-resolution airport moving map
  - Own-ship position and other traffic
  - Routing functionality

    Graphical and textual depiction of assigned route and cleared segment
  - Monitoring of route conformance
  - Full support of data link communication
  - Interactive text field for incoming messages
  - Interactive menu for outgoing messages
  - Interfaces to external systems (e.g. RMP)
  - Touch screen interaction



Onboard Systems – Electronic Flight Bag



- External solution (Class 2 EFB)
- Respresented by Gate-To-Gate application
- General features
  - Support in all phases of flight
  - Concept of paperless cockpit regarding of aeronautical information
  - Touch screen interaction
- Taxi phase features
  - High-resolution airport moving map
  - Own-ship position and surrounding traffic
  - Routing functionality
    Graphical and textual depiction of overall route
  - Limited data link functionality (reception of route messages only)
  - JOBS tab for incoming messages

Procedures & Use Cases

- Each phase of the taxi process defines a distinct use case

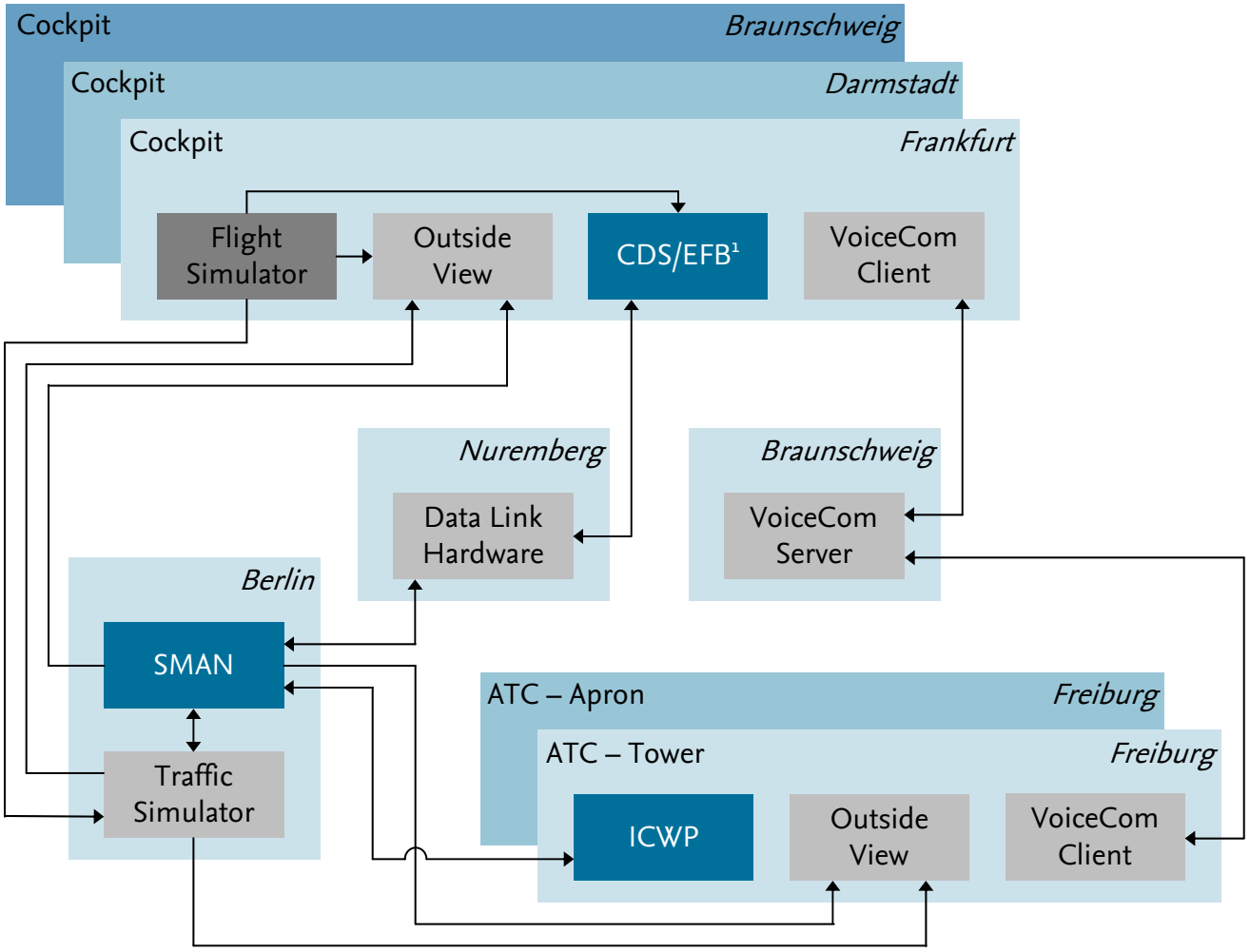
- Automation levels
  - Semi-automated procedures
    - Cooperative/non-cooperative traffic
    - Controller is supported by SMAN but responsible for action selection and execution
  - High-automated procedures
    - Cooperative traffic only
    - General procedures and route assignments are automatically processed via SMAN

- Communication
  - Aircraft is 'equipped' (full data link functionality)
    → Data link communication
  - Aircraft is 'not equipped' (no or limited data link functionality)
    → Voice radio communication

Procedure type	Use case (inbound)	Use case (outbound)
General	▪ Final approach & landing ▪ Taxi clearance ▪ Taxiing ▪ Handover ▪ On-block	▪ Clearance delivery & start-Up ▪ Taxi clearance ▪ Taxiing ▪ Handover ▪ Line-up sequencing ▪ Take-off
Optional	▪ Taxiway sequencing ▪ Hold & continue ▪ Route modification ▪ Runway crossing	▪ Taxiway Sequencing ▪ Hold & continue ▪ Route modification ▪ Runway crossing ▪ Pushback
Abnormal	▪ Route deviation ▪ HPID[1] overrun ▪ RPID[2] overrun ▪ Deadlock ▪ Landing conflict	▪ Route deviation ▪ HPID[1] overrun ▪ RPID[2] overrun ▪ Deadlock ▪ Take-off conflict

[1] Holding Position Indication Device
[2] Runway Protection Indication Device

Simulation Environment



[NordNordWest, http://commons.wikimedia.org/wiki/File:Germany_location_map.svg]

[1] CDS: Darmstadt & Frankfurt
EFB: Braunschweig

Simulation Environment

Cockpit simulator in
Frankfurt with integrated CDS

Cockpit simulator in
Braunschweig with integrated EFB

Simulation Study

- Focus on semi-automated procedures from flight deck point of view
- High level objectives
  - Safety
  - Capacity & efficiency
  - Usability & work performance
- Participants
  - Eleven male airline pilots
  - Five captains, two senior first officers and three first officers (one not stated)
  - Avg. flight experience: 5,063 h (300 h - 11,000 h)
- Scenarios & missions
  - Four scenarios in total
  - Eight missions per scenario (five inbounds and three outbounds) based on authentic flight plan with dense traffic
  - Predefined start and end points

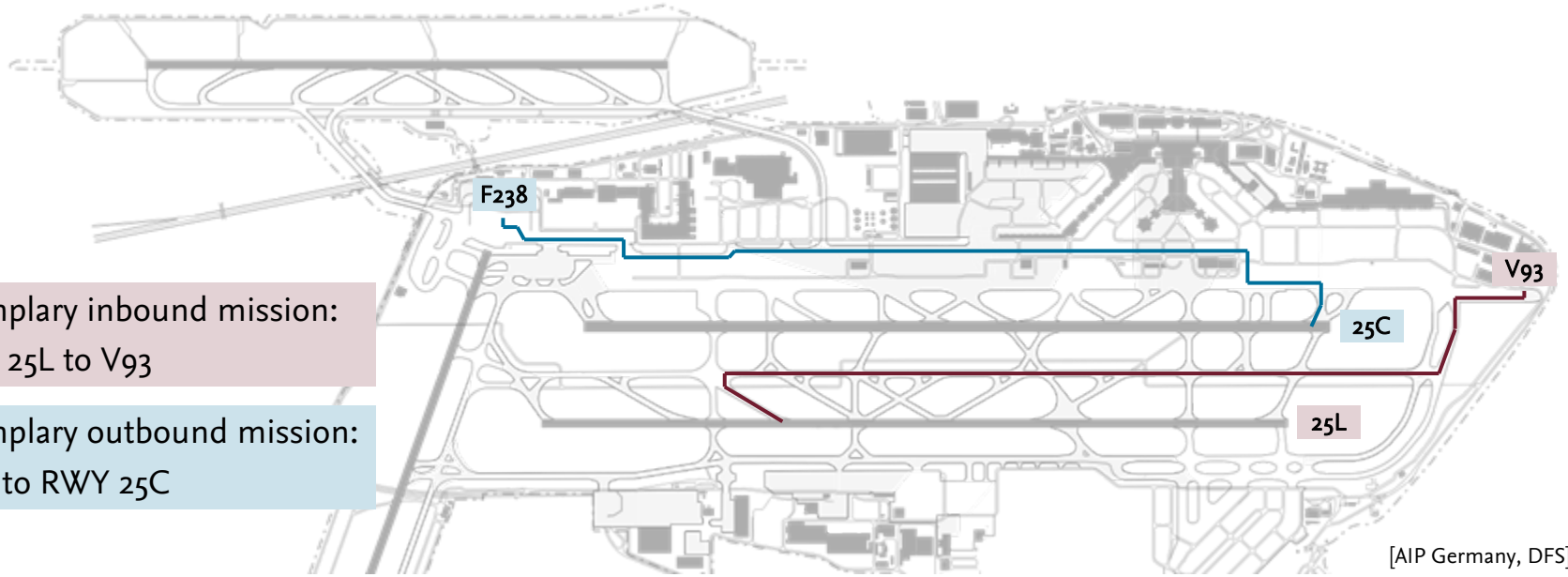
Scenario	Visibility	Procedure
HighVisBase	10,000 m	Baseline[1]
LowVisBase	300 m	Baseline[1]
HighVisAuto	10,000 m	Semi-automated[2]
LowVisAuto	300 m	Semi-automated[2]

[1] No individual AGL, CDS/EFB with airport moving map only & voice radio communication

[2] Individual AGL (300 m segments), CDS/EFB with depiction of other traffic and routes on airport moving map & data link communication

Simulation Study

- Setting & procedure
  - Scenarios were conducted at Frankfurt airport in a planned expansion stage for 2014
  - Each cockpit simulator was manned with two pilots
  - SMAN was operated by pseudo-controllers
  - Three test days in total
  - Three scenarios on one test day



Exemplary inbound mission:
RWY 25L to V93

Exemplary outbound mission:
F238 to RWY 25C

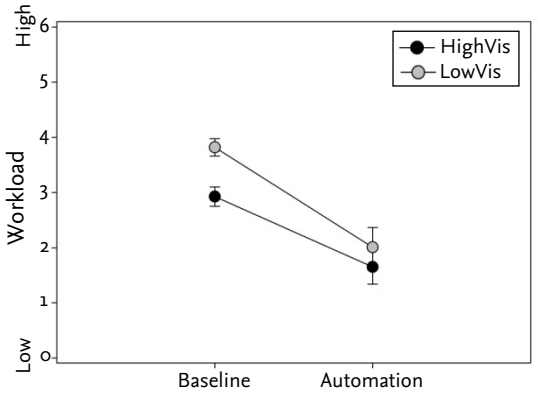
[AIP Germany, DFS]

Results

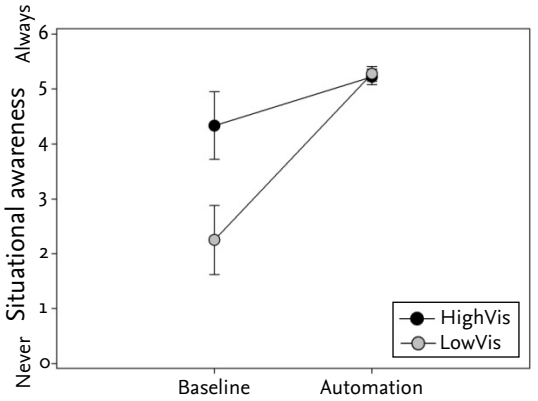
- Visibility only effected workload and awareness of other traffic
- Automated procedures were frequently rated more advantageous than baseline procedures

Objective / theme	Factor visibility	Factor procedure
Perceived safety	–	Δ
Automation trust	–	n/a
Mental effort	Δ	Δ
Situational awareness ▪ Own-position ▪ Other traffic ▪ Unexpected events	 – Δ –	 Δ Δ –
Mental effort ▪ Maintain taxi speed ▪ Wait for clearance	 – –	 Δ (tendency) Δ

Δ Effect
– No effect
n/a Not applicable



Average ratings for workload: interaction between visibility and procedures



Average ratings for situational awareness: interaction between visibility and procedures for item *I was aware of other traffic*

Results

- Comments
  - Positive ratings for onboard systems in baseline and automated procedures
  - Mostly positive feedback for CDS regarding touch screen interaction and design
  - Positive comments for AGL
  - Critical statements regarding communication between pilots and pseudo-controllers especially in baseline procedures
  - Pilots were skeptic to rely on data link communication only (→ expected reduction in situational awareness)

"Moving map improves situational awareness compared to conventional charting."

"No. Everything is clearly allocated. It is kept very simple. No complex submenus were used."

"With further integration of glass-cockpits into the working environment it's the best solution."

"Intuitive lighting guidance."

"Taxi clearance given (above moving map) is too small and hard to read"

"Controllers were not completely used to standard phraseology"

- Suggestions for improvements
  - 'Hold short' and 'give way to' instructions should be transmitted and read back via voice radio
  - Acoustic feedback when new/revised taxi clearance was received via data link
  - More possibilities for requests in automated communication

Conclusion & Outlook

- Conclusion
  - A concept of operations was introduced focusing on higher level of ground traffic management and visual guidance
  - A simulation study was conducted in a distributed simulation environment in order to validate certain aspects of the operational concept from flight deck perspective
  - The distributed simulation was assed as feasible and sufficiently realistic for research regarding operational procedures
  - Semi-automated procedures were frequently rated more advantageous in terms of perceived safety, workload and efficiency compared to baseline procedures
  - Valuable feedback and suggestions for improvements regarding automated procedures and design
  - Positive effects in automated procedures may have been due to misunderstandings between pilots and controllers in standard procedures

- Outlook
  - Supplementary study with controllers or full study with operators from air and ground site
  - Evaluation of the operational concept with high automated procedures
    → Especially drawbacks of a high level of automation have to be thoroughly explored

Thank you!


Any questions?
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