



Steps Towards the Virtual Tower: Remote Airport Traffic Control Center (RAiCe)

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Overview

- Introduction
- Work Analysis & Scenarios
- Simulation
- Remote Tower Experimental System
- Field Testing
- Outlook and Conclusion



Future Tower Control

Reduce Cost of Airport Surface Movement Management

Improve Situation Awareness

Increase Safety

Reduce Weather Dependence



Solution: "Virtual Tower"

Sensor Based (Windowless) Control Center with **Video Reconstruction of Far View**

Concept Study *ViTo* (2002 – 2004)

Project *RapTO*r (2005 – 2007)

Project *RAiCe* (2008 – 2012)



German Airports



Motivation for Remote Tower Center (RTC) Research:

- meet request of low **cost carriers** by providing cost efficient controlled airspace to **small airports**
- **Capacity increase** of Hubs by Coordinated central control of **RWY Networks**

RAiCe Research Goal:

Methods & Technologies to provide centralized controlled Airspace for Several Airports from a Remote Tower Center (RTC)



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The Role of Visual Surveillance: Present ... Future?



Vision based Ground Traffic Control: "**Controllers most used Tool**" (25 – 70%)

Problems:

⇒ High Cost of Conventional Tower Control

⇒ Head Down Times increase with Computer Assistance & with Traffic Load



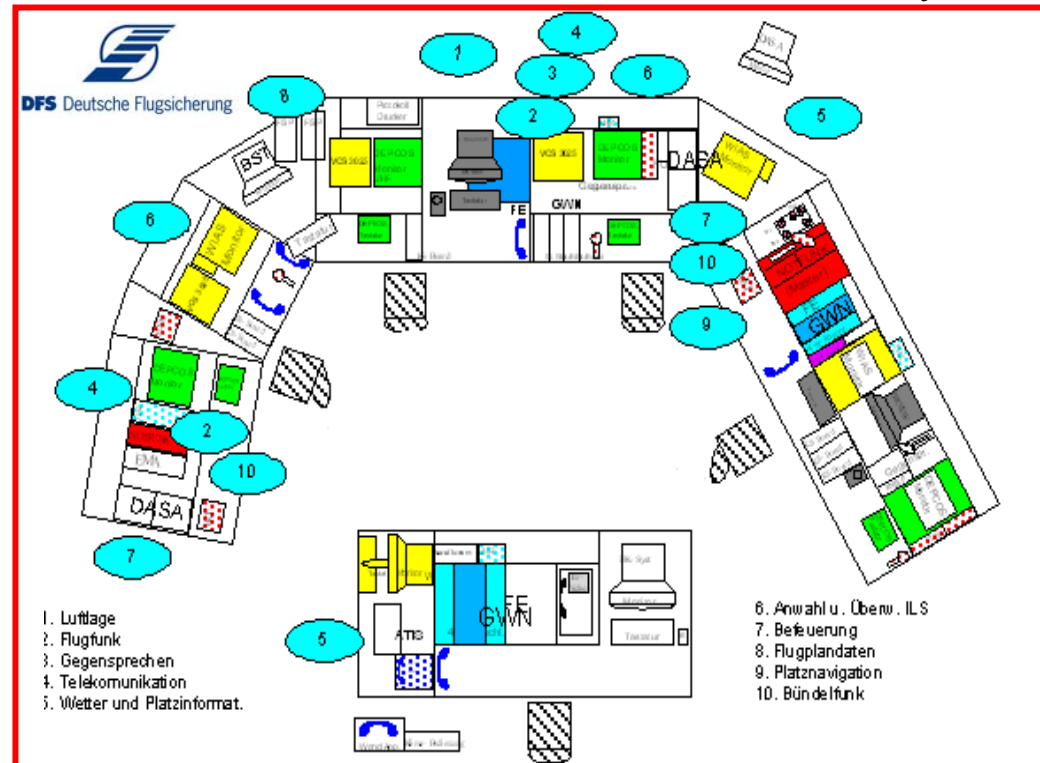
Wind 6 kt 270°
09:38:57

FR8926
★

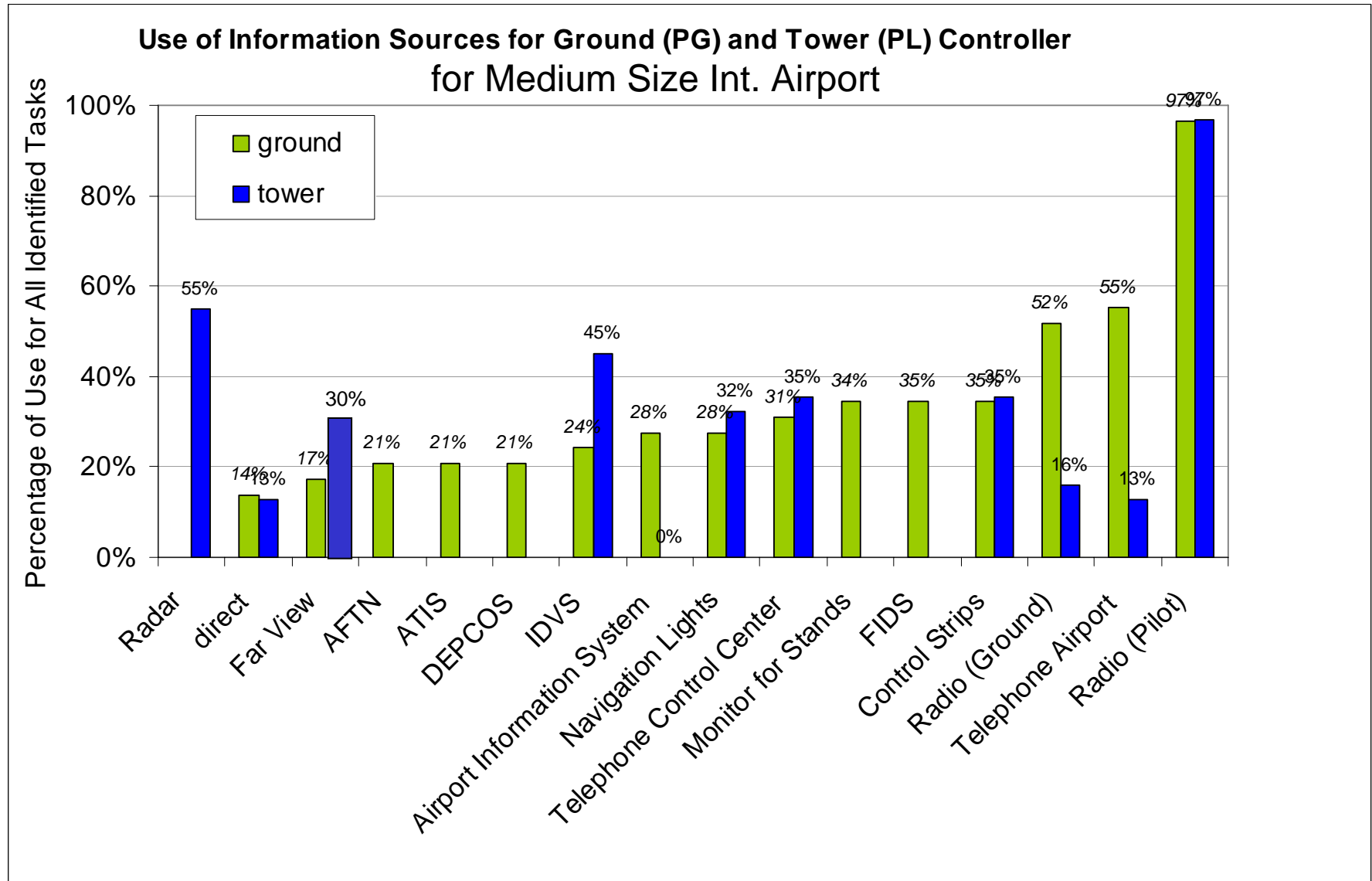
DFS Tower Layout

RTC – HMI Design Task:

- Integrate Controller's Information / Interaction Equipment into **High Resolution Video Panorama HMI**
- Reduce Head-Down Time by **Augmented TWR Vision**



Work Analysis: rel. no. of **Access to Information Sources** for All Tasks (Decision & Support Tasks (clearances, communications etc): 29 (PG), 31 (PL))





Local large Airport

Scenario 1: Remote Control of Small Airport from Local Tower

Remote small Airport :
Controlled Airspace

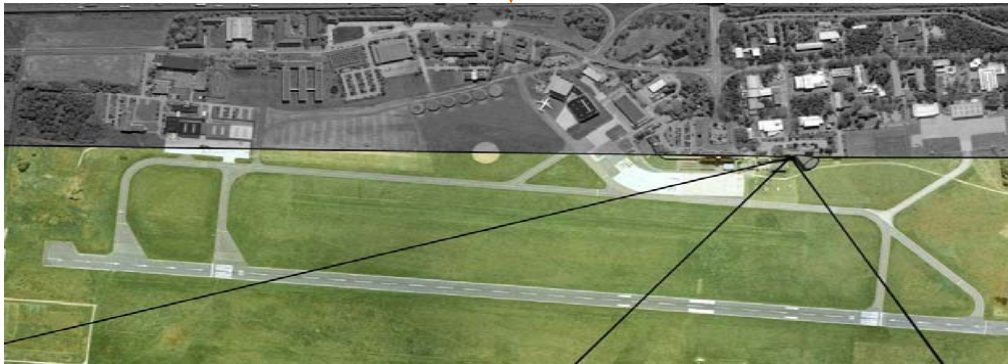
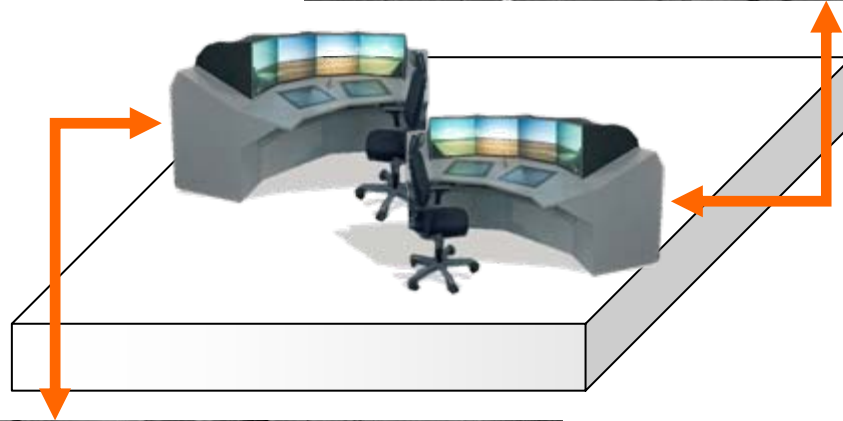
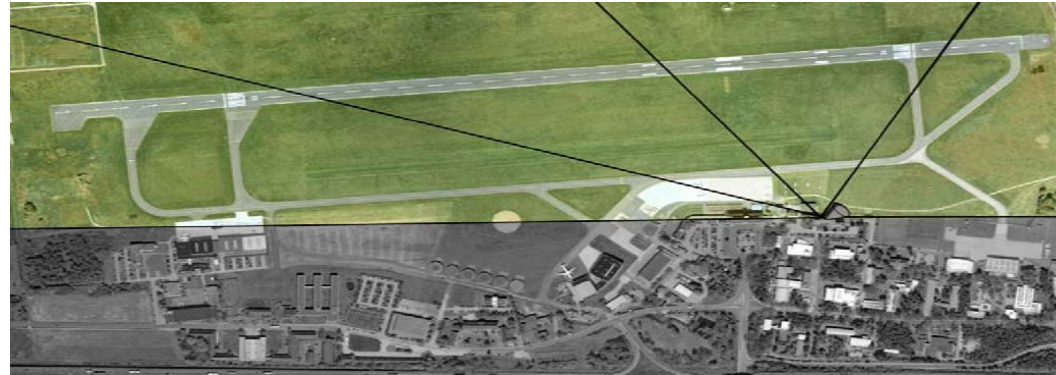
Gbit/s
Datalink



Design of RTO Controller Workplace
within local Airport TWR
or
Remote TWR Center for several small Airports

Szenario 2

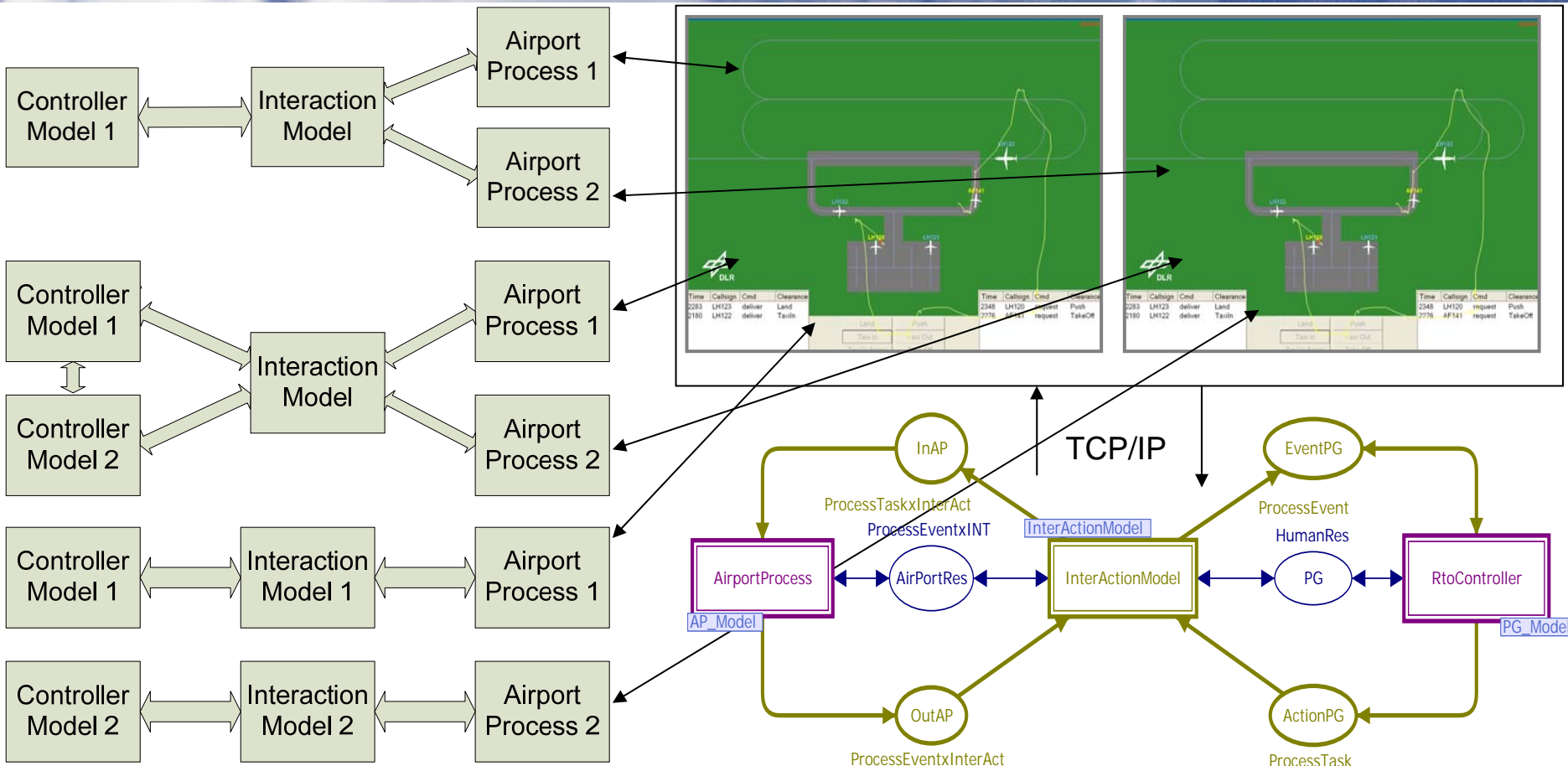
RTC for Surveillance of several Small Airports



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Different Possibilities of RTC Work Organization

A/P Traffic Model Interaction Model Human Model

RTC Microworld Simulation with Colored Petri Nets

180° RTO Panorama HMI

- Live Stream
- Live Replay
- Traffic Simulation
- Synthetic Vision with live Data

200° Airport Traffic Simulator



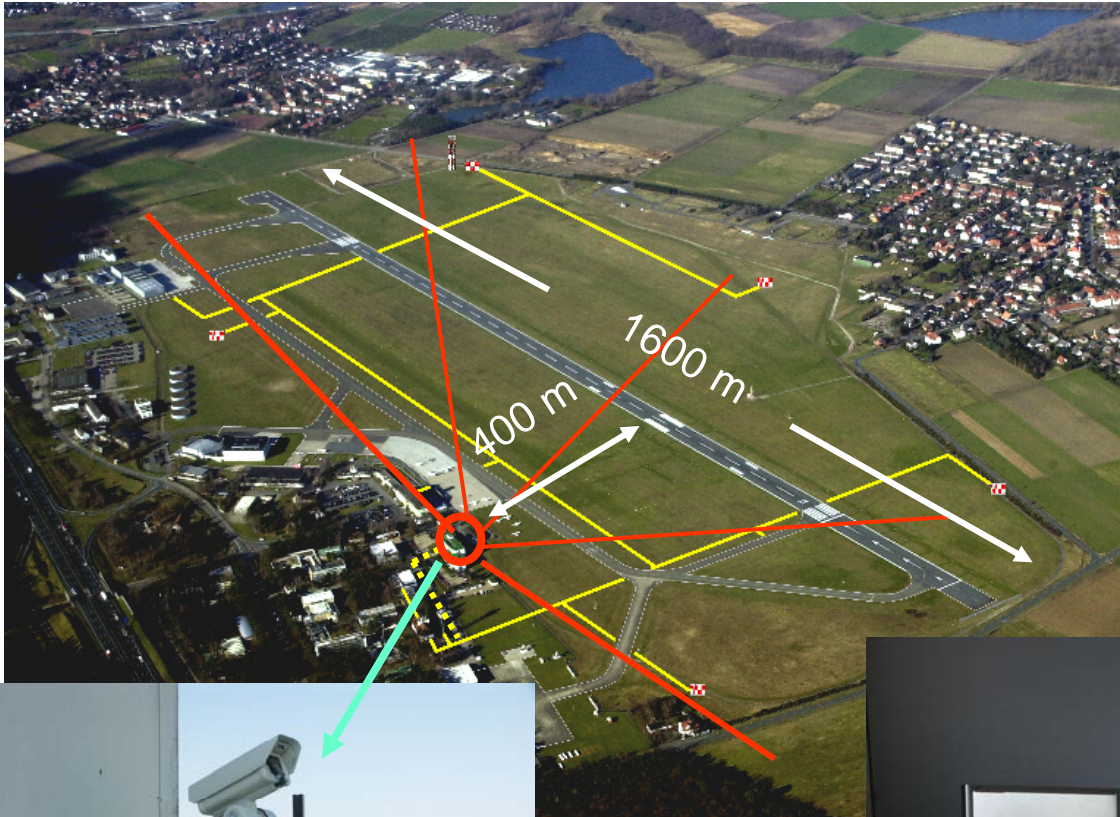
Airport Towersimulator with RTO-Console



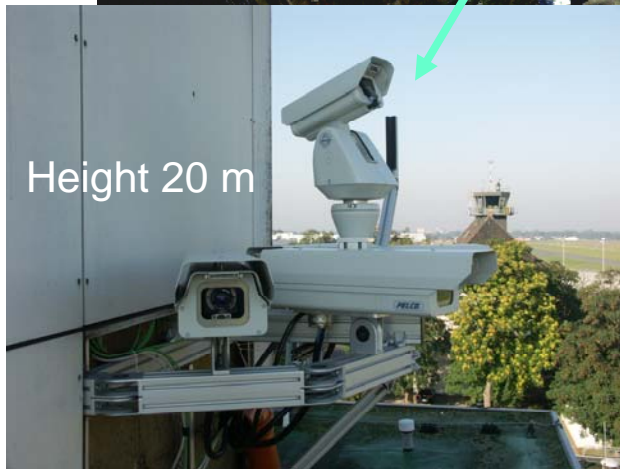
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Augmented Vision Video Panorama System at Braunschweig Airport



- ▶ Video system for panorama and image processing
- ▶ Gbit/s - Fibre optic LAN
- ▶ Experimental Augmented Vision HMI



Height 20 m

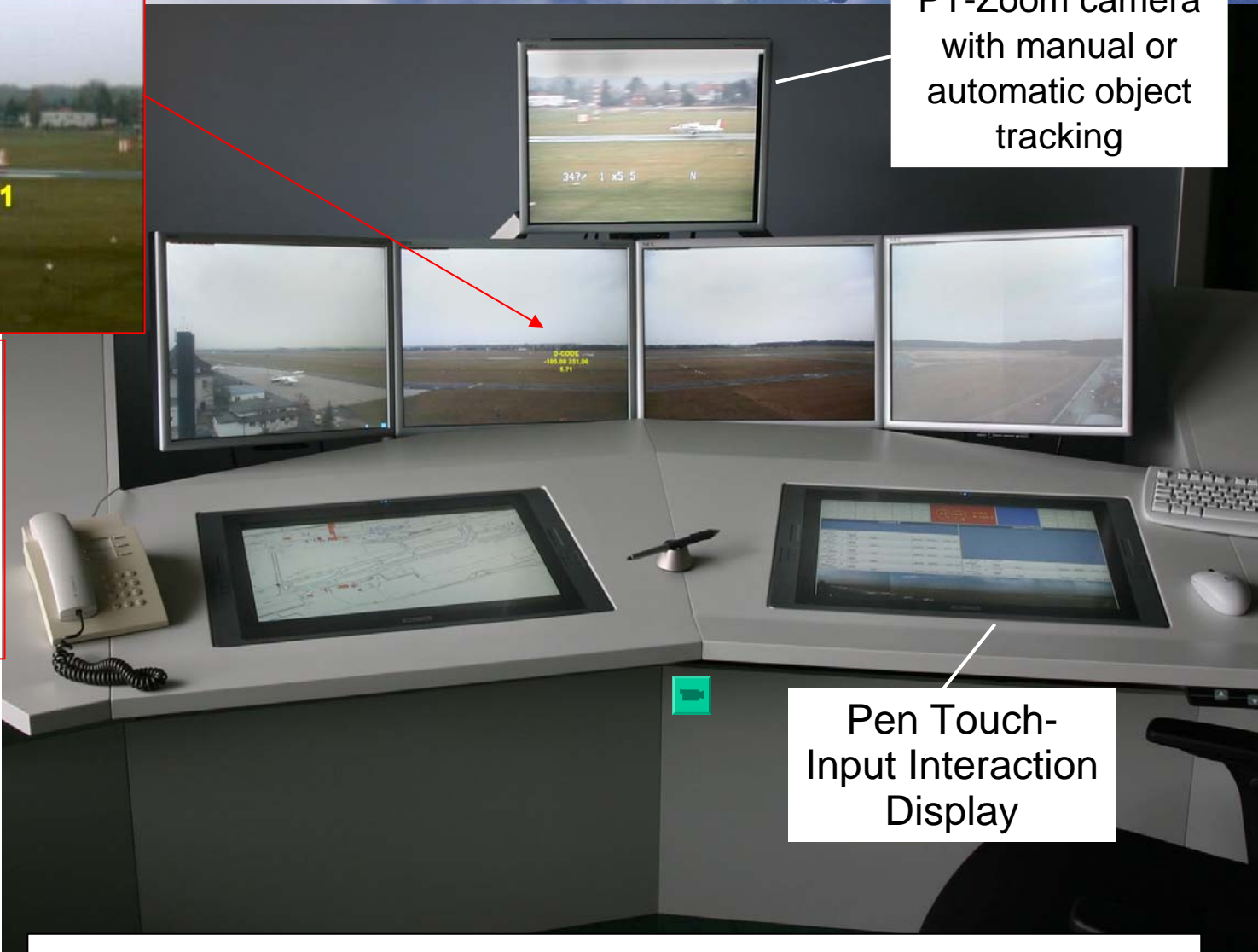
Camera Resolution ca. 2 arcmin



PT-Zoom camera with manual or automatic object tracking



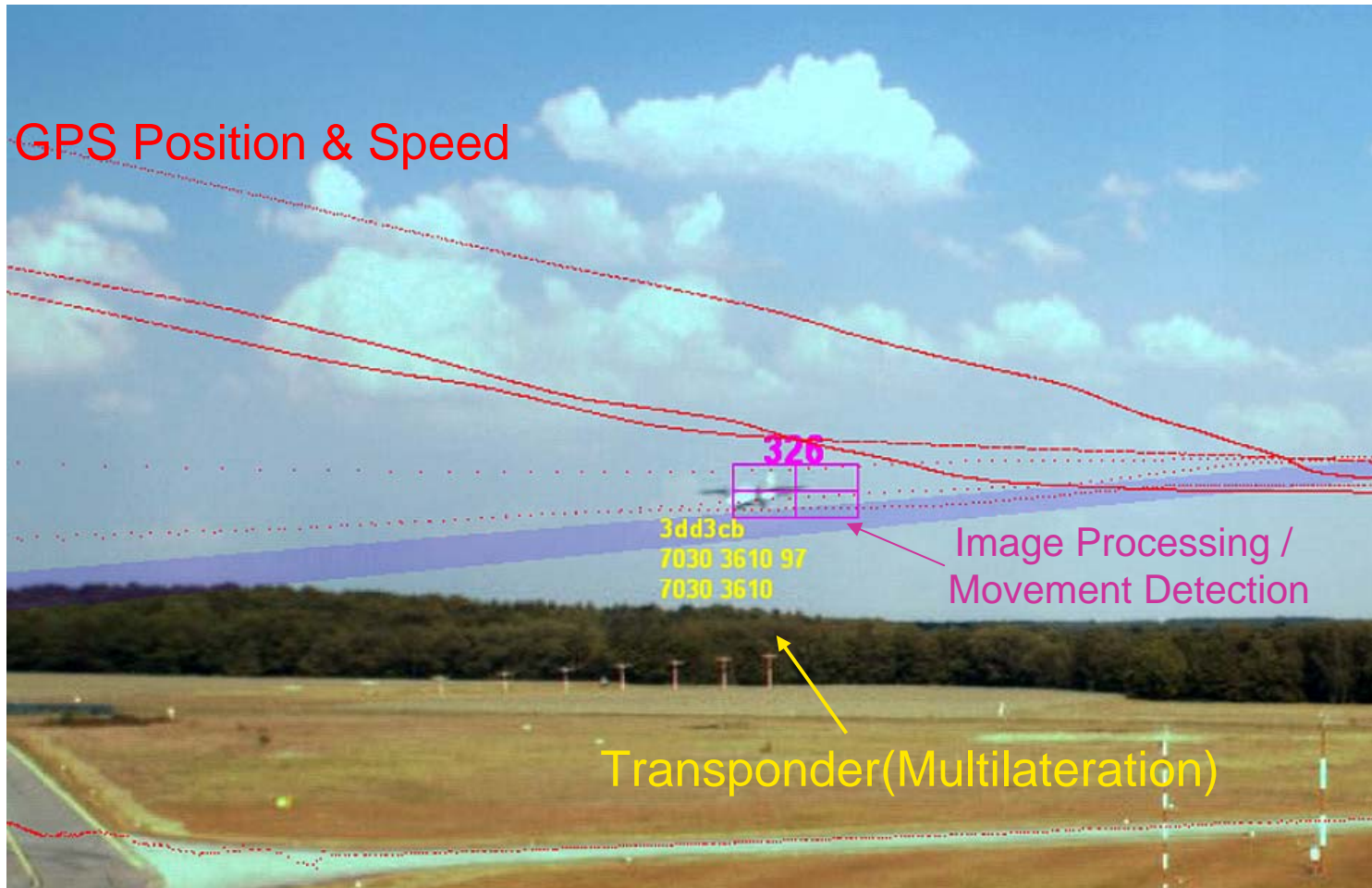
Augmented Vision:
Multilateration
Position and A/C-
Label /
Transponder Code



Pen Touch-
Input Interaction
Display

**180° Augmented Vision Videopanorama RTO-HMI:
Visual Resolution 2 arc min or 0.35 m / 588 m**

GPS Position & Speed



Augmented Vision

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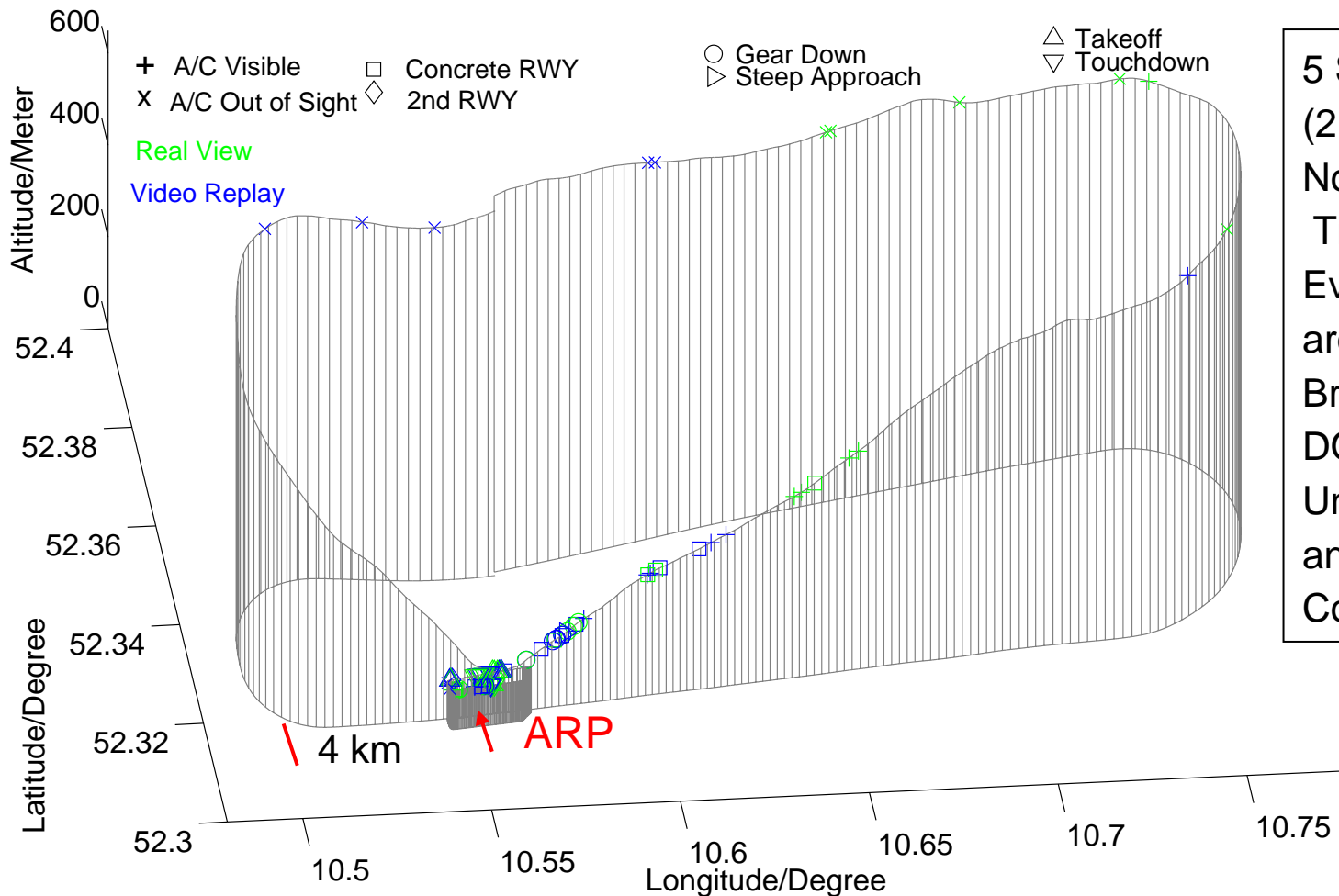


3 series of flight tests with pre-defined events during 10 rounds of Aerodrome Circling (12/06 & 5/07)

Validation Experiments: Comparing Real View and Videopanorama



GPS-Trajectory D-CODE 21.05.07: 10th Round (all Participants)



5 Subjects
 (2 Controllers, 3 Non-Experts)
 Time Stamp 11 Events /10 rounds around Airport Braunschweig with DO-228 (D-CODE) Under Real View and Video Replay Conditions

D-GPS Trajectories with Event Observation Time Stamps

Evaluation of **Real View** – **Video Replay** of Event-Time Observation confirms **2 arcmin visual Resolution** for Panorama, 1 arcmin for PTZ (Z = 4)

Video Replay: Deviation from Routine Operation



PTZ: $Z \approx 20$



Replay: 1 TB High Res. Video / Day



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Summary / Conclusion

- **Structured Work Analysis** \Rightarrow Requirement for Visual Surveillance \Rightarrow
Concept: High Resolution Augmented Vision Videopanorama with PTZ & Tracking
Scenarios: RTO Console at large Airport TWR; RTC for several small Airports
- **Simulation Environment:** supporting Work Analysis & Designing RTC Work Organisation
- **Experimental Environment** at Braunschweig Research Airport provides facilities for testing of Vision Based Remote Tower Center Concepts
- **Augmented Vision HMI:** Compact RTC Console & Reduced Head Down Time
- **Initial Field Testing:** Visual Resolution of Videopanorama System meets Specs
- **Perspectives** (Project RAiCe 2008-2012):
Experimental RTC with 2 Small Airports for Shadow Mode Testing

RAiCe Team (at 2nd RTO Workshop, DLR 04/2008)





FAirControl Visualization

Land	Taxi In	Taxi In Apron
Start Up	Enroute	Push
Taxi Out	Departure Sequence	Take Off

Time : 733

Time	Call	Cmd	Dur
346	LH120	acGoal,taxied_in	
340	LH120	message,d,MovRWY,...	
340	LH120	landed	50
323	LH125	deacGoal,pushed	
319	LH125	deliver,PushCL	4
313	no...	observe,ApronArea1	4
309	no...	observe,TaxiField2	4
305	LH125	acGoal,pushed	
289	LH125	deacGoal,enrouted	
285	LH125	deliver,EnRCL	4
281	LH125	acGoal,enrouted	
265	LH120	deacGoal,landed	
261	LH120	deliver,LandCL	4
255	no...	observe,RunwayArea	4
251	LH120	acGoal,landed	
239	LH125	deacGoal,started_up	
235	LH125	deliver,STUpCL	4
231	LH120	message,d,ReadyLan...	
230	LH120	approached	110
227	LH125	acGoal,started_up	
220	LH125	requested,STUpEnPB...	
220	LH125	ready	200
80	LH120	bounded_in	150
0	LH125	parkedST1	

Scripted FAirControl Process

Microworld

Cognitive + Interaction + Process Model

FairControl Model (CPN Tools)

Scenario Simulations for Supporting Work Analysis & System Design

Formal **Airport Control** Model for simulating interaction between Operator, HMI, and Process with **Airport Microworld** of controlled process. Active goal of Human Model: **blue frame** (**orange arrow**). Communication with pilot (white arrow) changes colour of call sign (LH120). [Werther, Möhlenbrink et.al. 2007]

RTO Video Panorama Experimental System: Simplified Block Diagram

Technical Data

Cameras:

4 x (1600x1200), 25 frames/s
PTZ: f = 3.6 – 82.8 mm, 23 fold

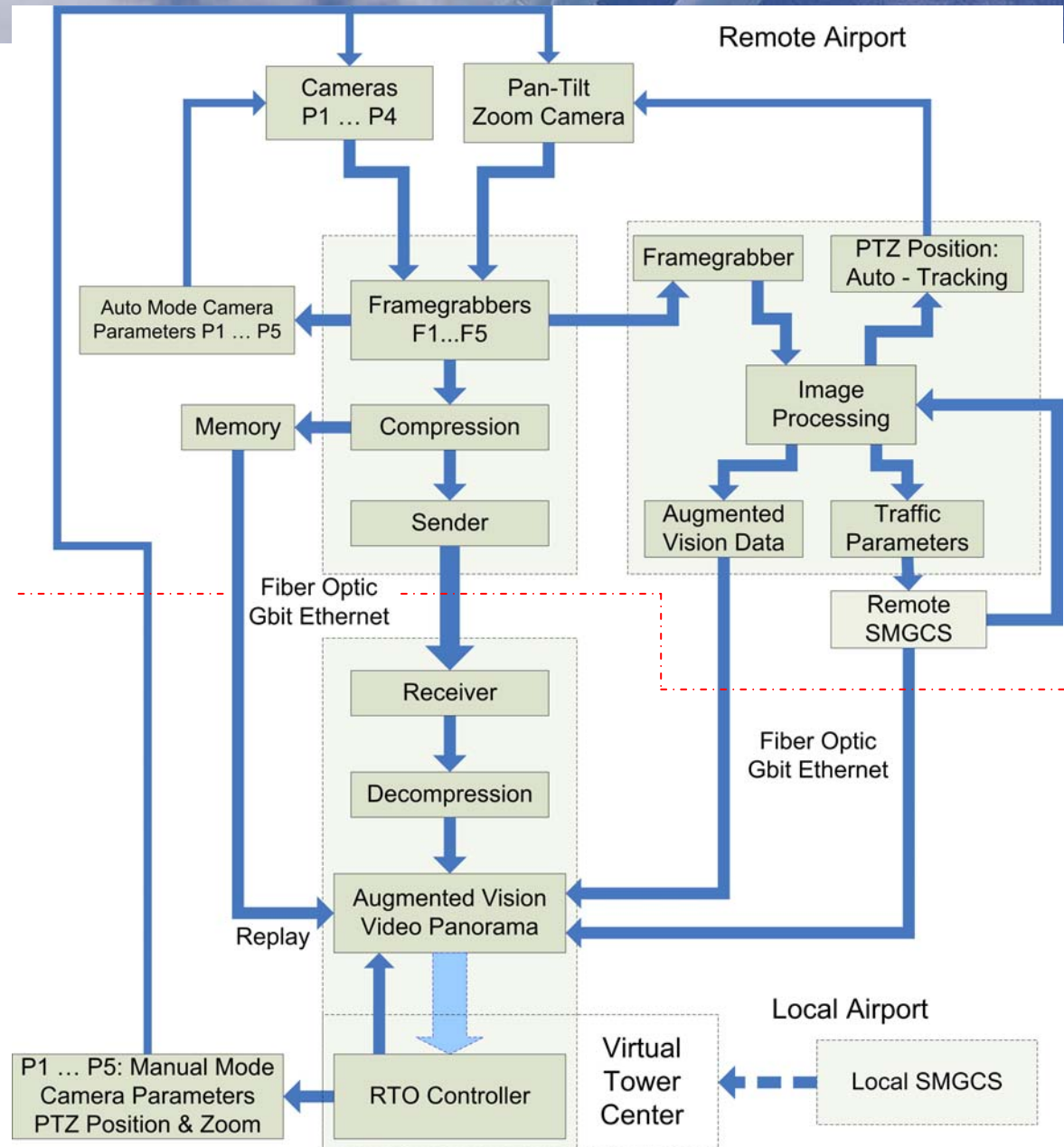
Panorama:

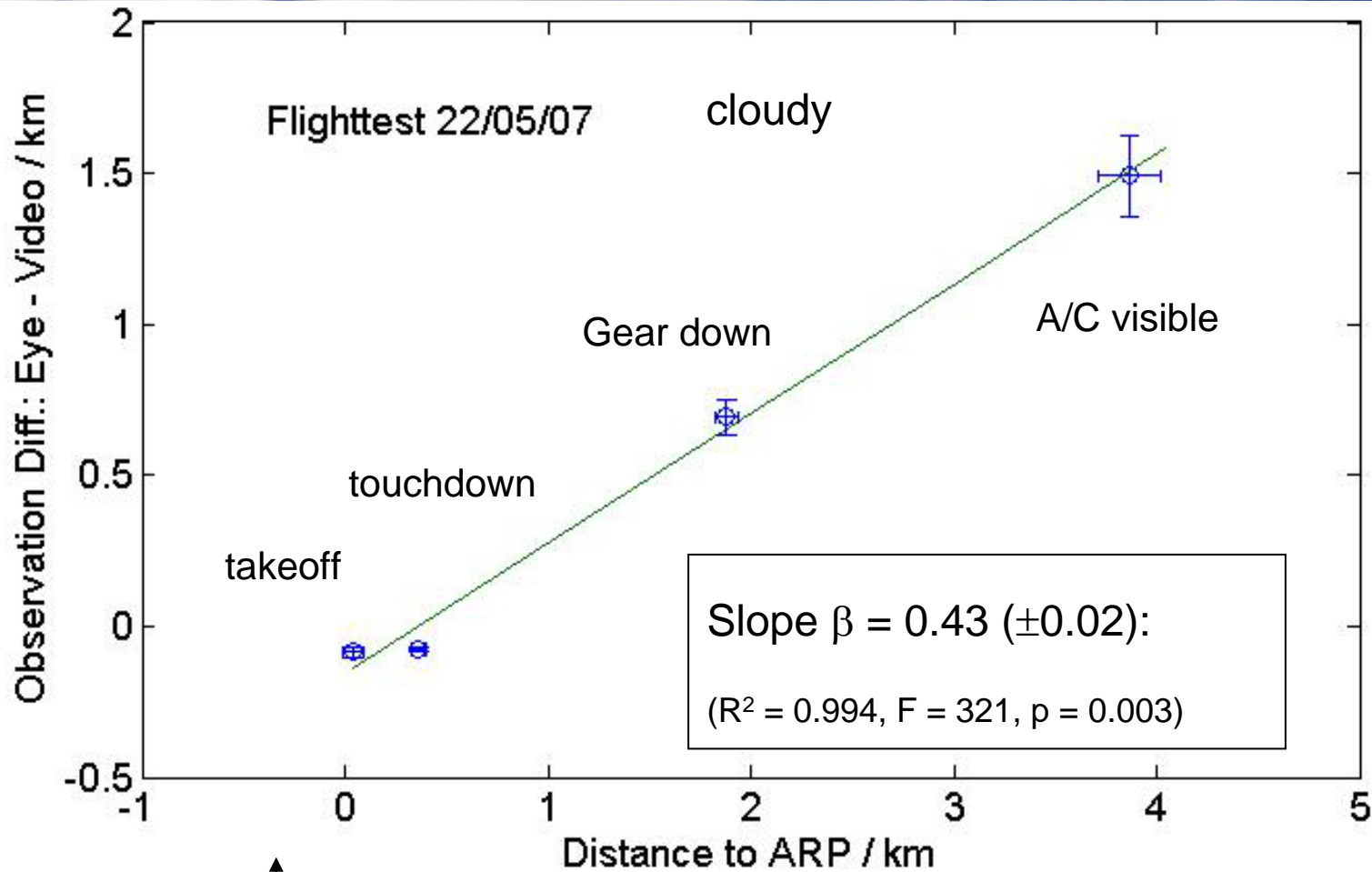
5 UXGA Monitors 1600 x 1200
alternatively:
Wide angle tiled projection with
4x2 SXGA (1280 x 1024)

Data Transfer:

Gbit Ethernet, Average 100
MBit/s, MJPEG compressed

Storage Capacity: 5x 500 GB





Video Resolution / arc min

$$\Delta x(\text{eye} - \text{video}) = (1 - \alpha_E / \alpha_V) x_E$$

$$\alpha_V = \alpha_E (1 - \beta_1)^{-1} = 1.75 \alpha_E$$



Mini
Panorama
& PTZoom
positioning

Altivieren!	Altivieren!	B738 M TVS401 A1404	1902	FMS	LKPR	ESSA	009	29	Zoom In	Zoom Out	Wipe
Altivieren!	Altivieren!	B735 M CSA617 A5640		FMS	OKBK	LKPR	008	29	Focus Near	Focus Far	Zoom Speed Focus speed
Altivieren!	Altivieren!	B738 M TVS821 A1403	1808	FMS	LKPR	LHBP	007	29	Open Iris	Close Iris	
Altivieren!	Altivieren!	B762 M ELY523 A5612		FMS	LLBG	LKPR	006	29	Virtual Joystick		
Altivieren!	Altivieren!	A310 M CSA109 A4321		FMS	CYUL	LKPR	005	29			
Altivieren!	Altivieren!	B752 M BCS918 A1410	1807	FMS	LKPR	EDDF	004	29	Weather		
Altivieren!	Altivieren!	B752 M BAW854 A2541		FMS	EGLL	LKPR	003	29			
Altivieren!	Altivieren!	A321 M DLH3265 A1405	1804	FMS	LKPR	EDDF	002	29	202.5 - 202.5 T: 19.1 0.1 / 202.5 P: 1012.9 0.1 - 0.1		

PTZ
Camera &
Position
Control:
*Virtual
Joystick*

Weather

Communication
& RWY / TWY
Lights

Electronic Flight Strips

RTO Touch-/Pen Input Interaction Display



RTO Image Processing



Moving Object detection by Static Background Subtraction.
Determination of Traffic Parameters (Position, Speed) and Detection of Debris & Dust