

Frankfurt Airport Capacity Enhancement Program

The Role of Wake Vortex Reducing Measures

2nd WakeNet 2 - Europe Workshop, 30.11. – 01.12.2004, Langen, Germany

Stefan Mael

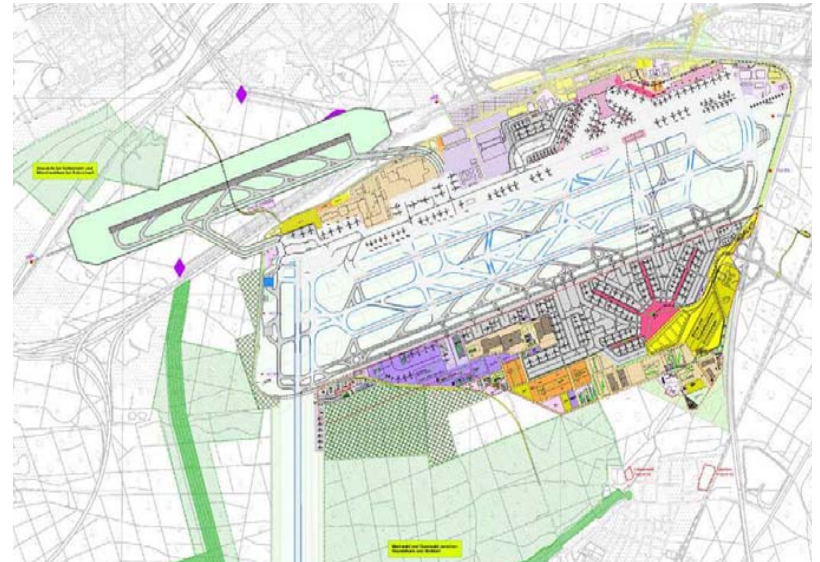
**Senior Executive Manager
Research & Development
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Development of the Airport Expansion Program

- ➔ **Definition of the necessary capacity elements and constructions for capacity enhancement programs 80, 80 plus and 120**
- ➔ **Development of an optimized runway system, taxiways, apron**
- ➔ **Development of taxiway-guidance concepts**
- ➔ **Realization of obstacle calculation / evaluation**
- ➔ **Planning of ILS / GPS navigation equipment**
- ➔ **Risk analysis and management**
- ➔ **Support for planning and evaluating results from the „Mediation Process“ and the following procedures**
- ➔ **Consulting projects for other airports (Egelsbach, Hahn, Kassel)**



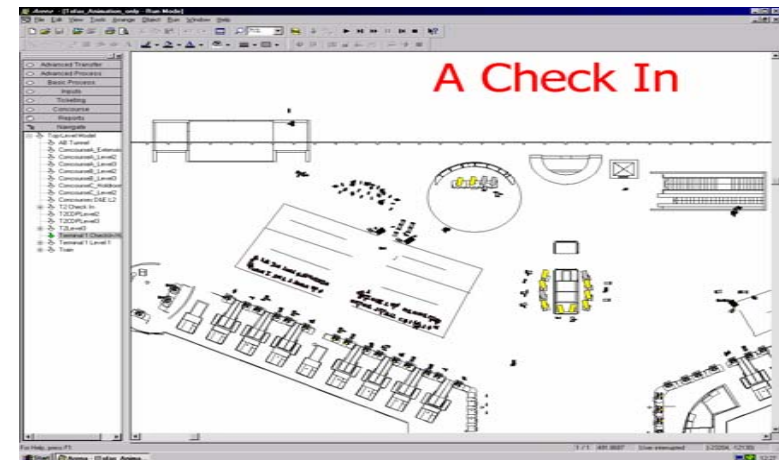
System Development and Aviation Technology

- ➔ ***Development, Implementation of capacity enhancement systems for the Fraport business unit FTP (HALS/DTOP, PAM)***
- ➔ ***Implementation and Adaptation of guidance systems such as ILS, MLS and Runway/Taxiway Marking and Lighting***
- ➔ ***Design and Implementation of surface movement guidance and control systems within the TACSYS-Concept (Multilateration, ETNA)***
- ➔ ***Supporting the development of satellite landing systems (GBAS) at FRA***
- ➔ ***Integration of Fraport-systems at TOWER FRA***
- ➔ ***Contribution to research projects for system development: DTOP (LUFO III), ISMAEL and SESAME***

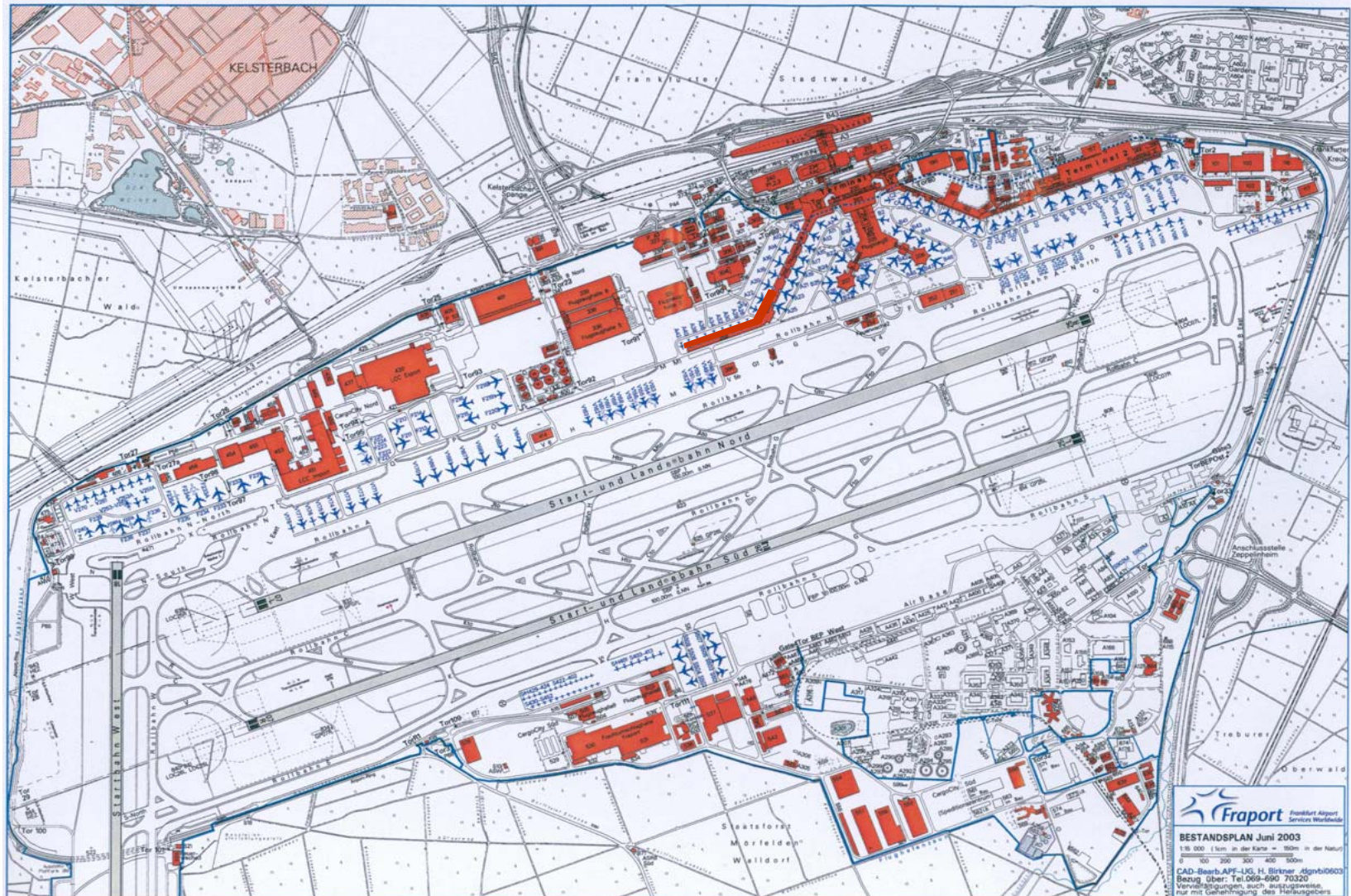


Simulation and Capacity Calculation

- ➔ **Optimizing, operating and developing simulation tools (Tofas, ObsCalc, PACELAB, Airport Machine, SIMMOD) for Capacity Enhancement Programs**
- ➔ **Simulations for the development of the airport expansion concept in consideration of targets and requirements**
- ➔ **Determination of necessary dimensions for the development of capacity-increasing steps in consideration of time**

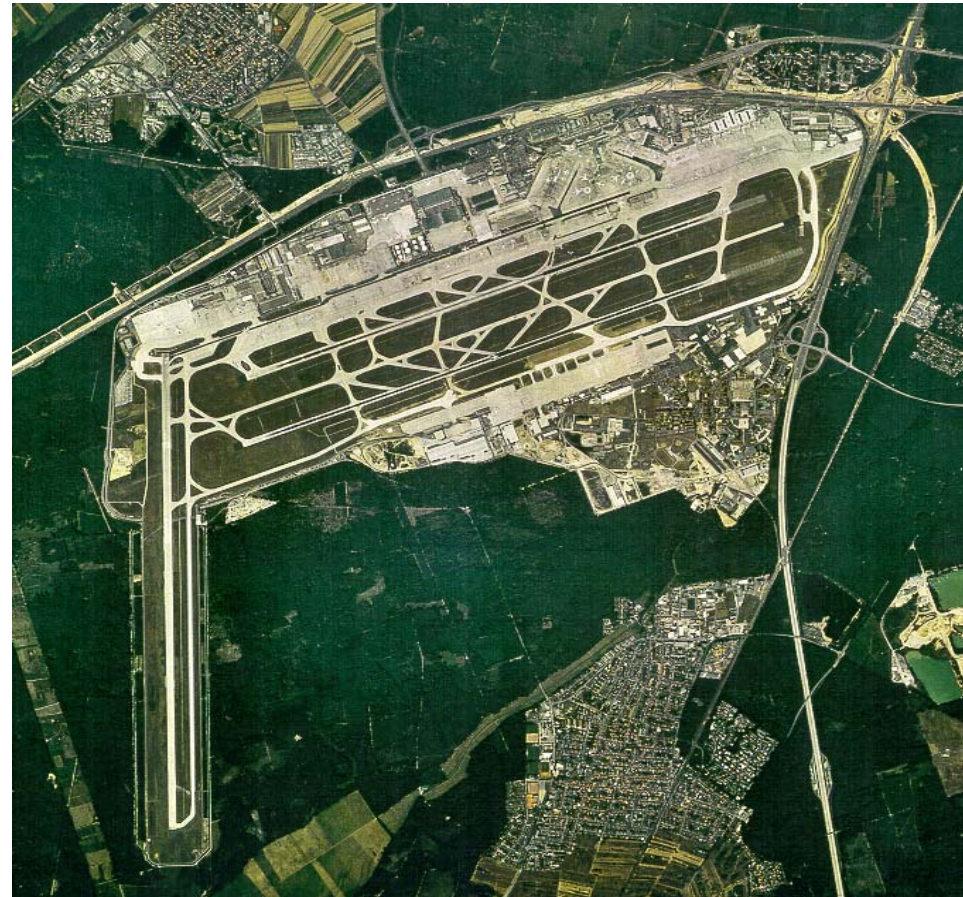


Layout of Frankfurt Airport



Frankfurt Airport – Traffic Figures 2003

Movements p.a.	458,865
Peak Day	1,415
Coordinated Movements / h	78 / 80
Aircraft Parking Stands	189
Scheduled Airlines	> 100
Passengers p.a.	48.36 Mio
Peak Day	170,322
Cargo p.a. (metric tons)	1.55 Mio
Employees (Fraport AG)	13,000



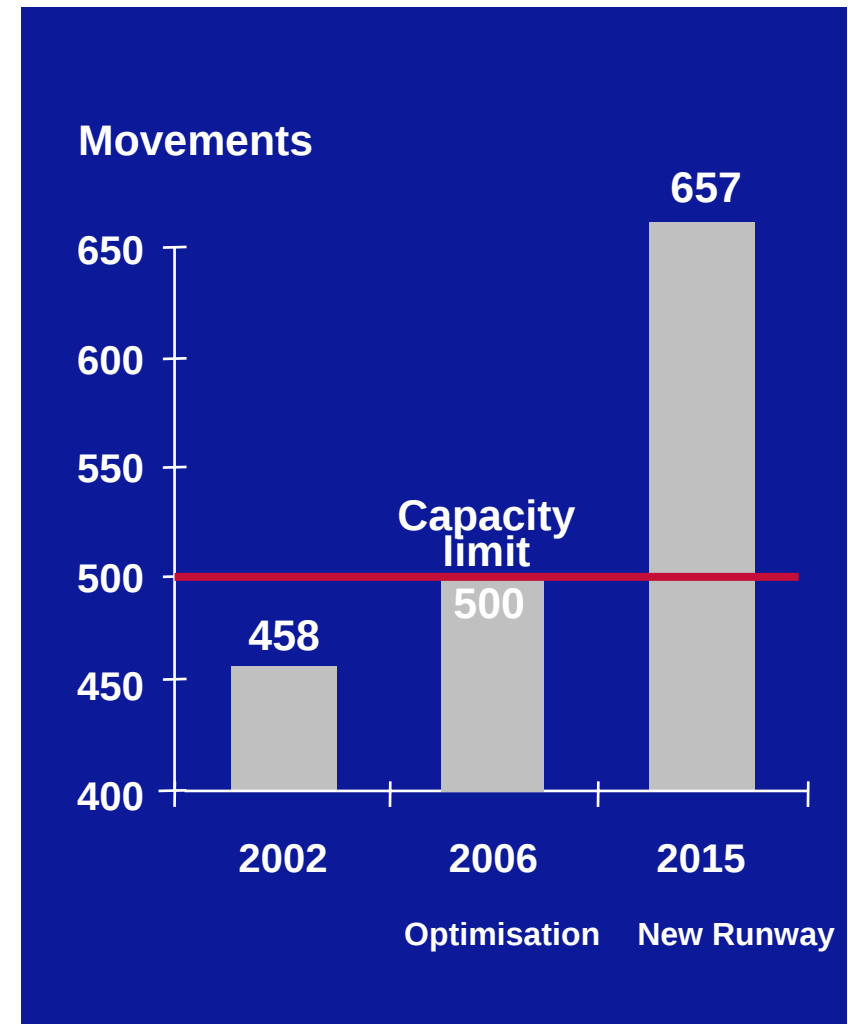
Capacity Enhancement in 2 Steps

1) Optimisation:

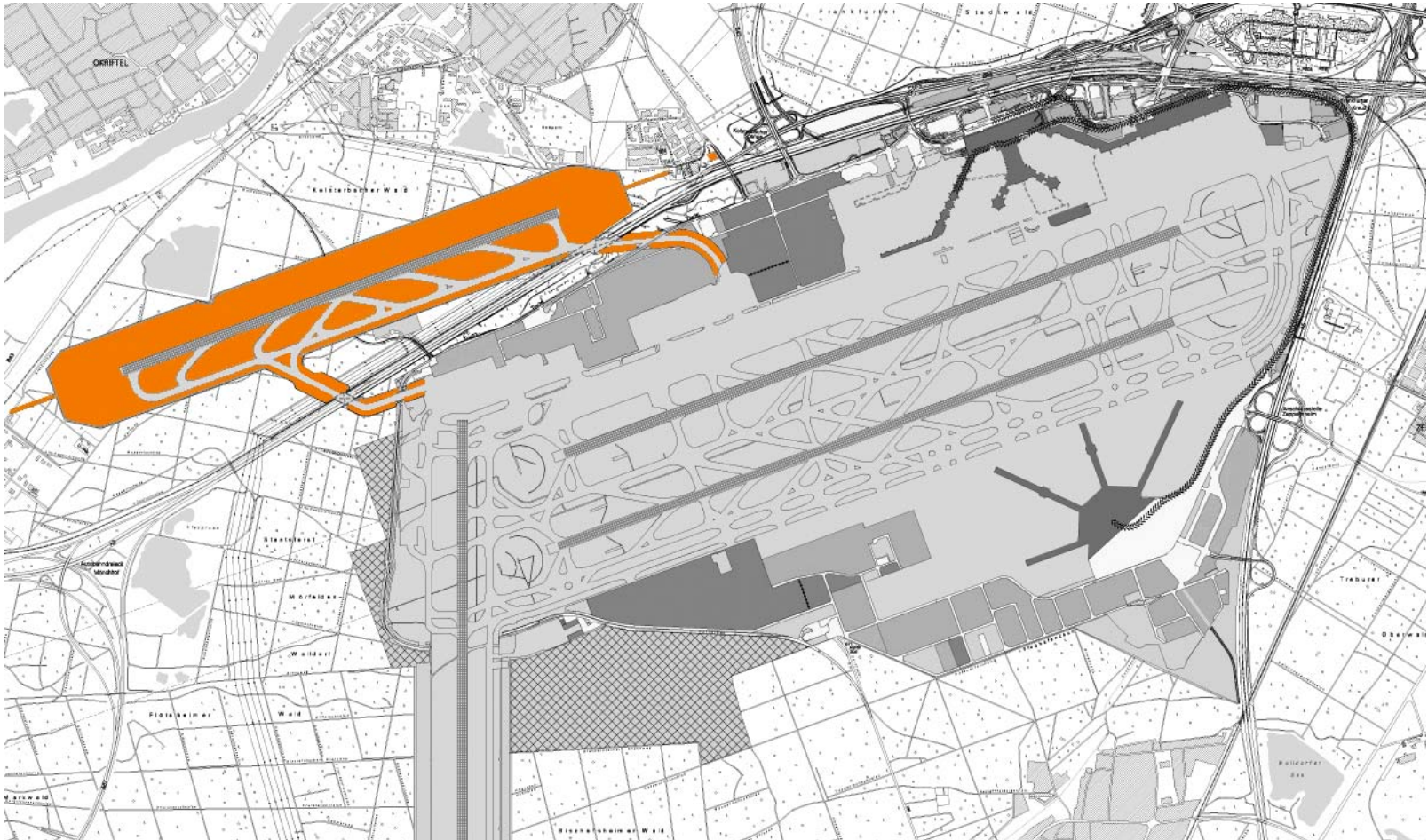
- Frankfurt will reach its capacity limit in 2006 – further optimisation is needed

2) Airport Expansion:

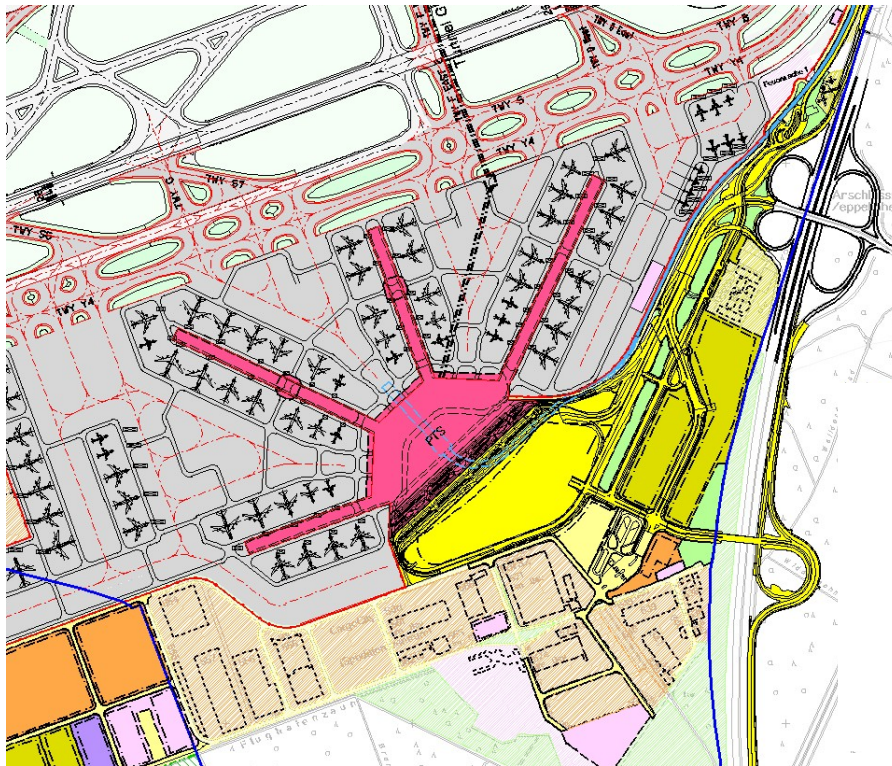
- Prognosis for 2015:
 - 82,3 Mio. passengers
 - 657.000 movements
 - 2,7 Mio. t cargo
- Construction of a fourth runway
 - 2.800 meters length
 - Bi-directional use
 - Precision Approaches only
- Construction of a third Terminal, completion in several steps till 2013



Airport Expansion Plans: New Runway Northwest (landing only)

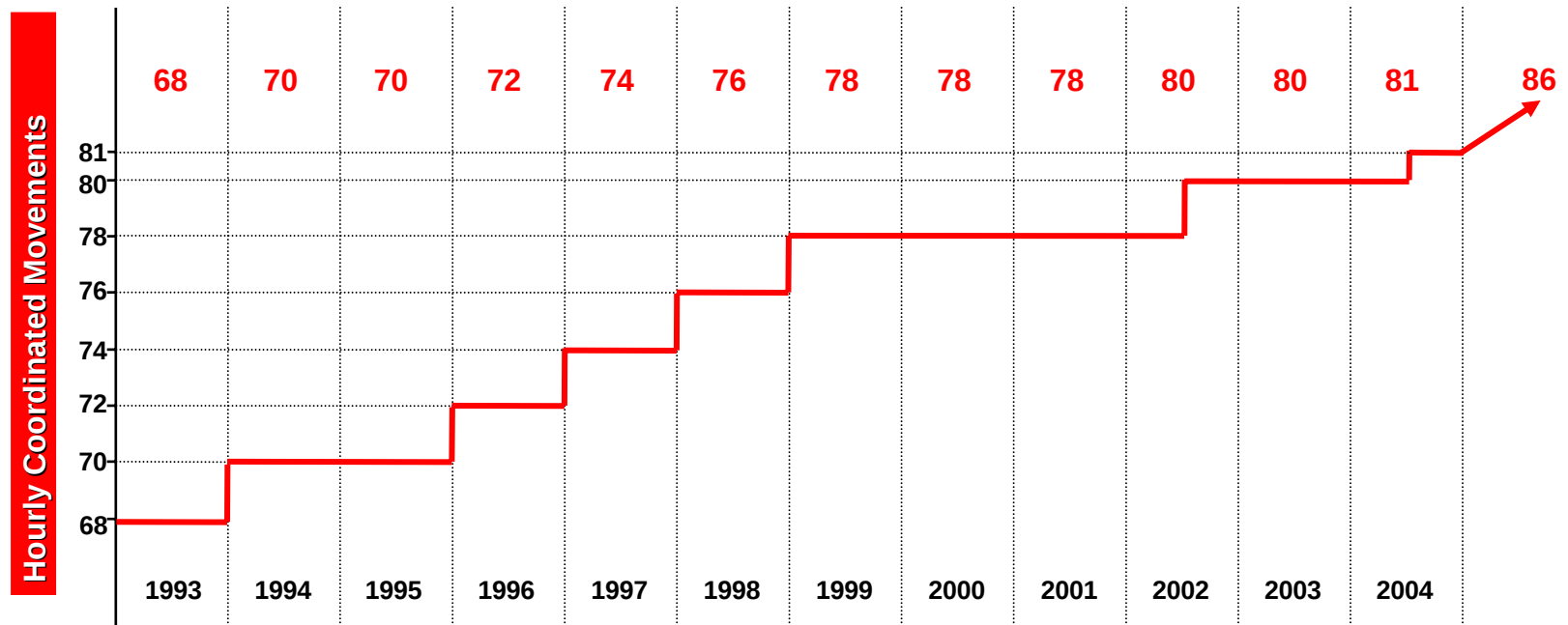


Airport Expansion Plans: New Terminal South (current area of US-Airbase)



- Construction of 75 new aircraft parking positions
- Increase of the current terminal capacity from 56 million to 81 million passengers
- Minimum Connection Time (MCT) between northern terminals (Terminal 1+2) and new terminal (Terminal 3) will not exceed 45 minutes due to an extension of the existing People Mover System

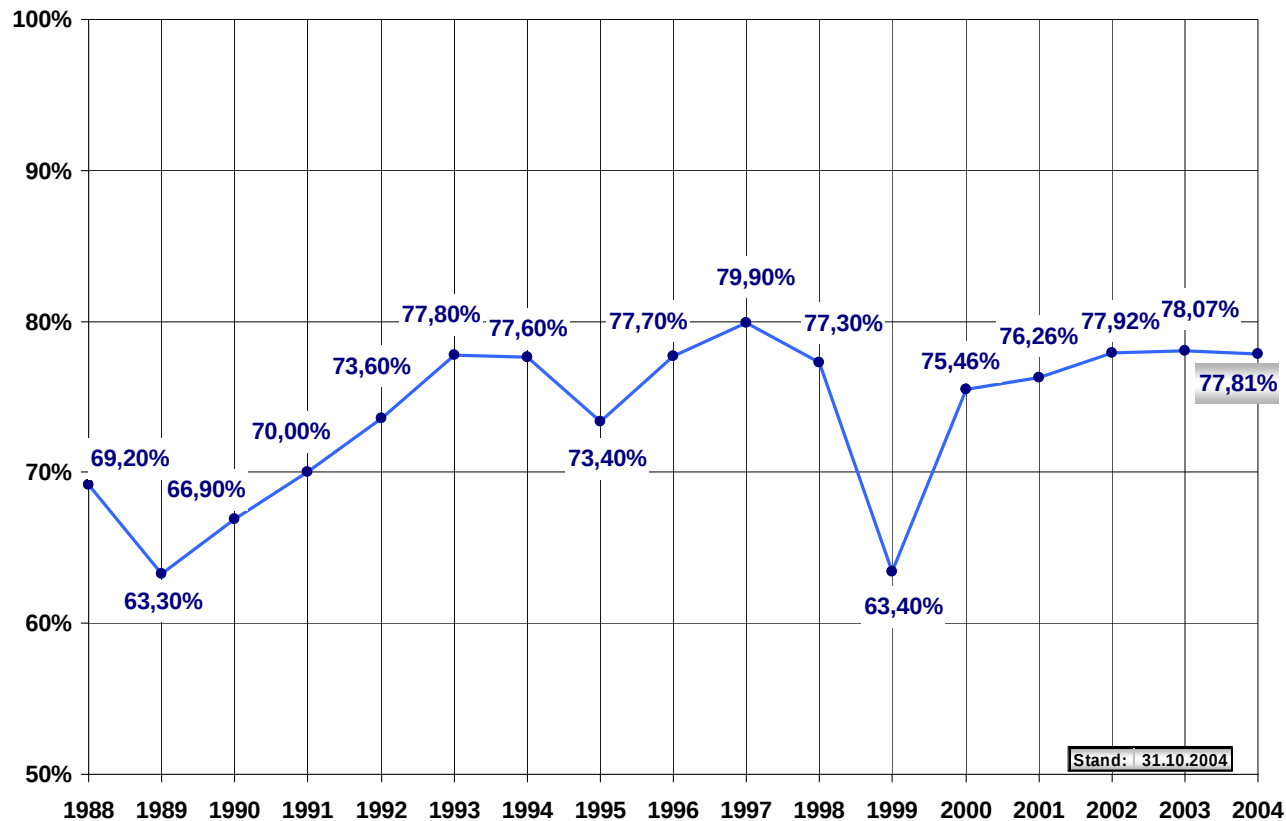
Strategic Goals: Capacity Enhancement



Development of hourly declared capacity in Frankfurt (1993 – 2004)

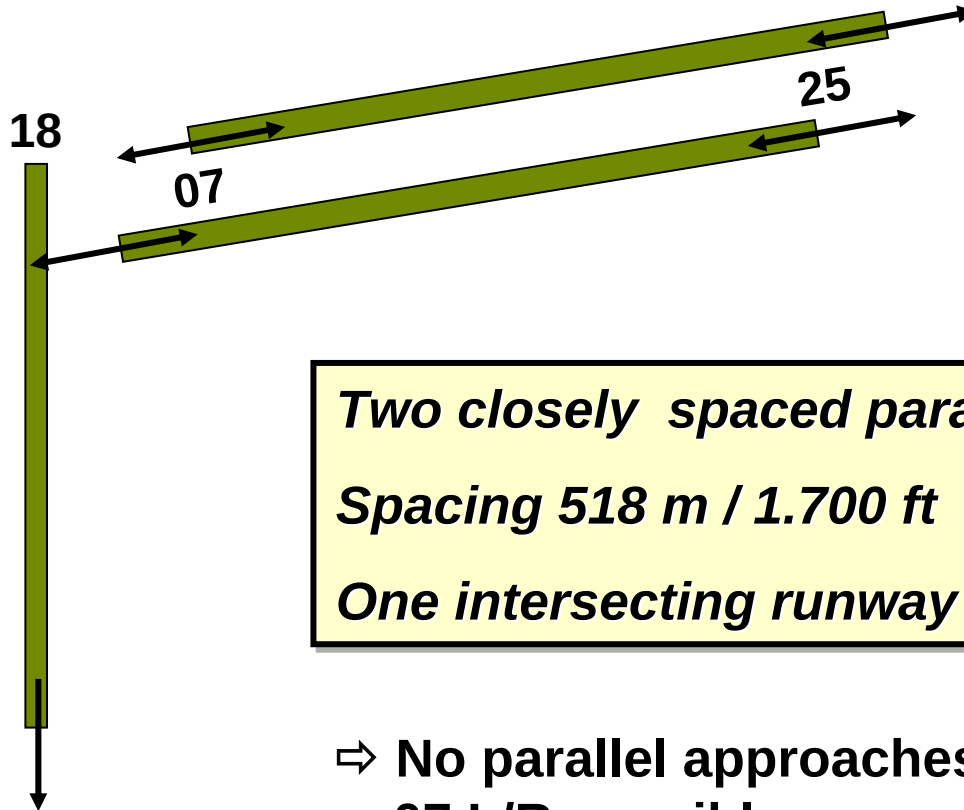
Strategic Goals: Punctuality

Frankfurt is one of the leading hubs in Europe concerning punctuality



Development of Punctuality in Frankfurt (1988 – 2004)

Frankfurt Airport Runway Situation



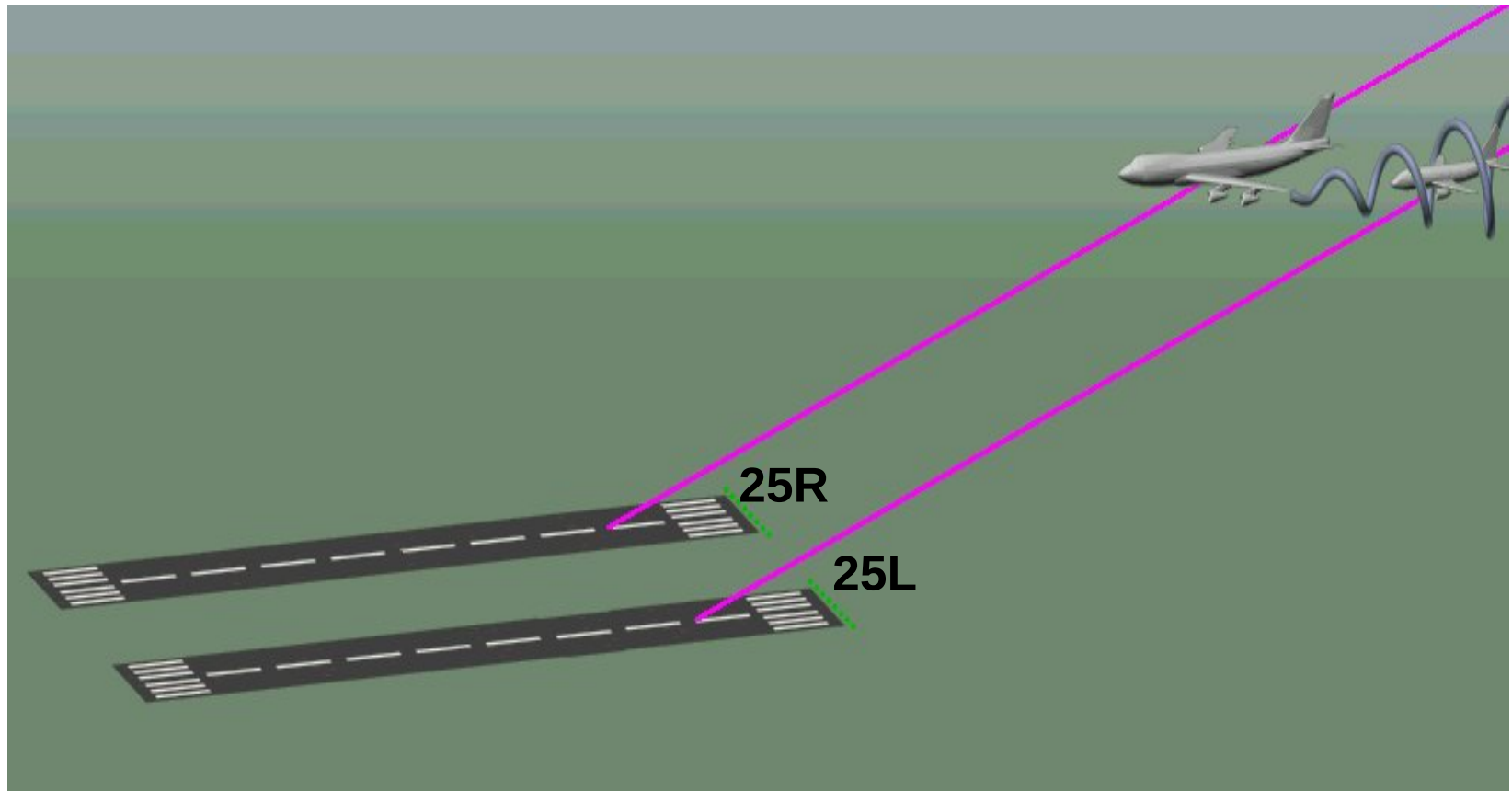
*Two closely spaced parallel runways (4000 m)
Spacing 518 m / 1.700 ft
One intersecting runway for take-off only (4000 m)*

⇒ No parallel approaches on runways 25 L/R and 07 L/R possible

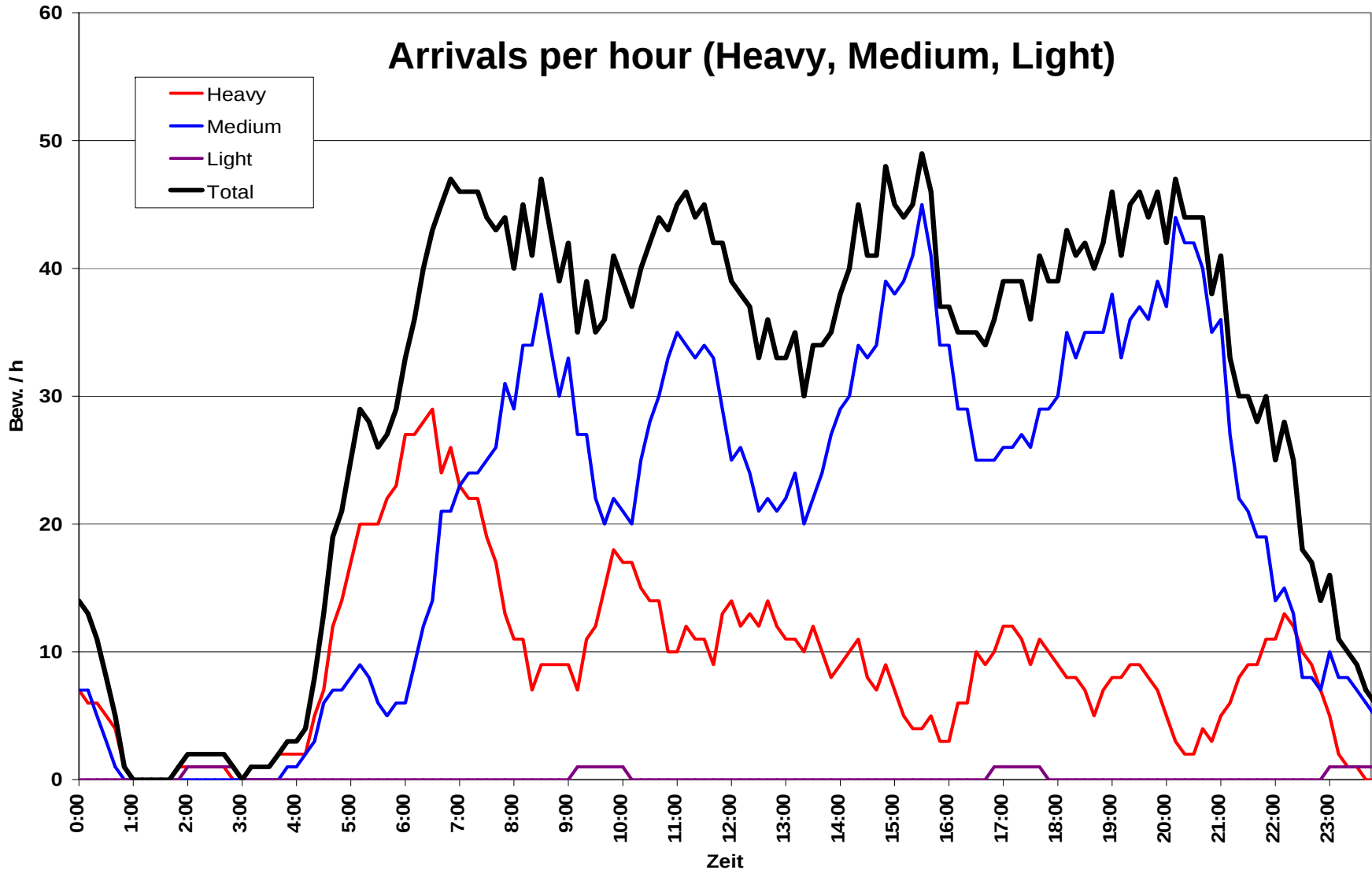
Frankfurt Airport Runway Situation (2)

Medium aircraft is affected by wake vortices of a preceding Heavy aircraft

⇒ 5 NM separation H→M leads to reduced capacity



Frankfurt Airport Traffic Structure



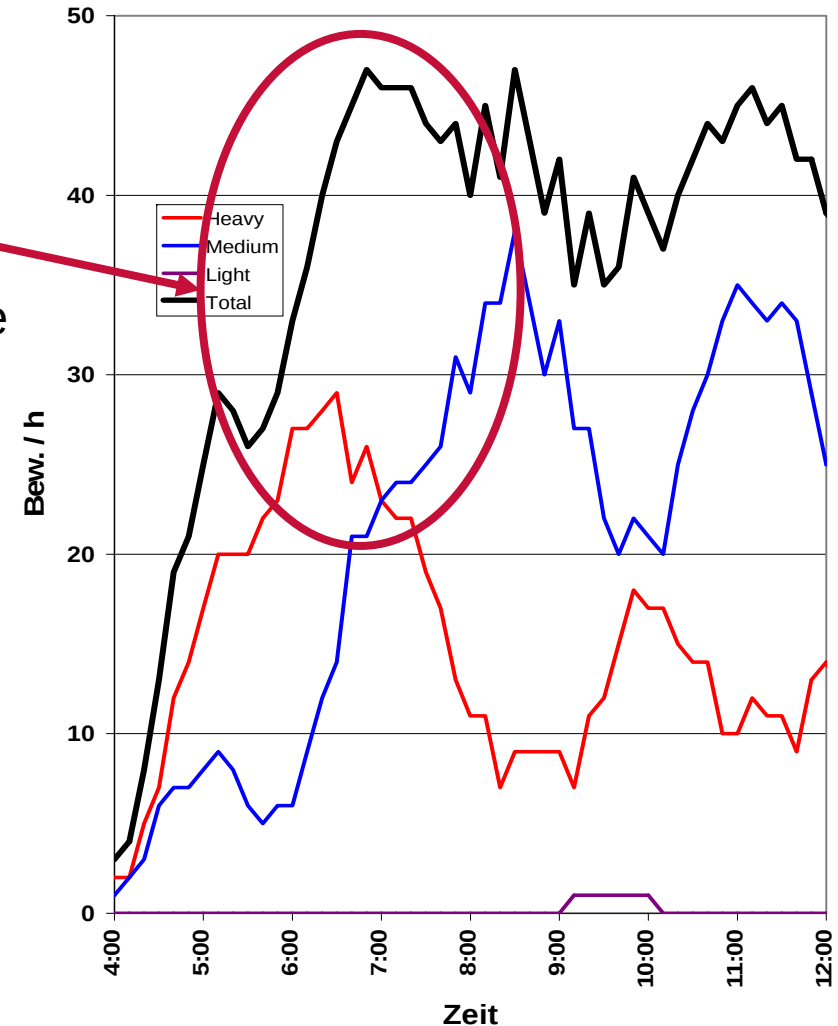
Frankfurt Airport Traffic Structure (2)

Problem

- During the morning peak the proportion of arriving Heavy aircraft rises up to 60 % of the overall traffic
- Lack of inbound capacity due to high wake vortex separation minima ($M \Rightarrow H = 5 \text{ NM}$)

Potential Solutions

- Measures to predict the occurrence of wake vortices (WVWS / WTR)
- Measures to avoid wake vortex encounters (HALS / DTOP)
- Measures to reduce minimum radar separation between 2 Medium aircraft (PAM)



WVWS - Wake Vortex Warning System

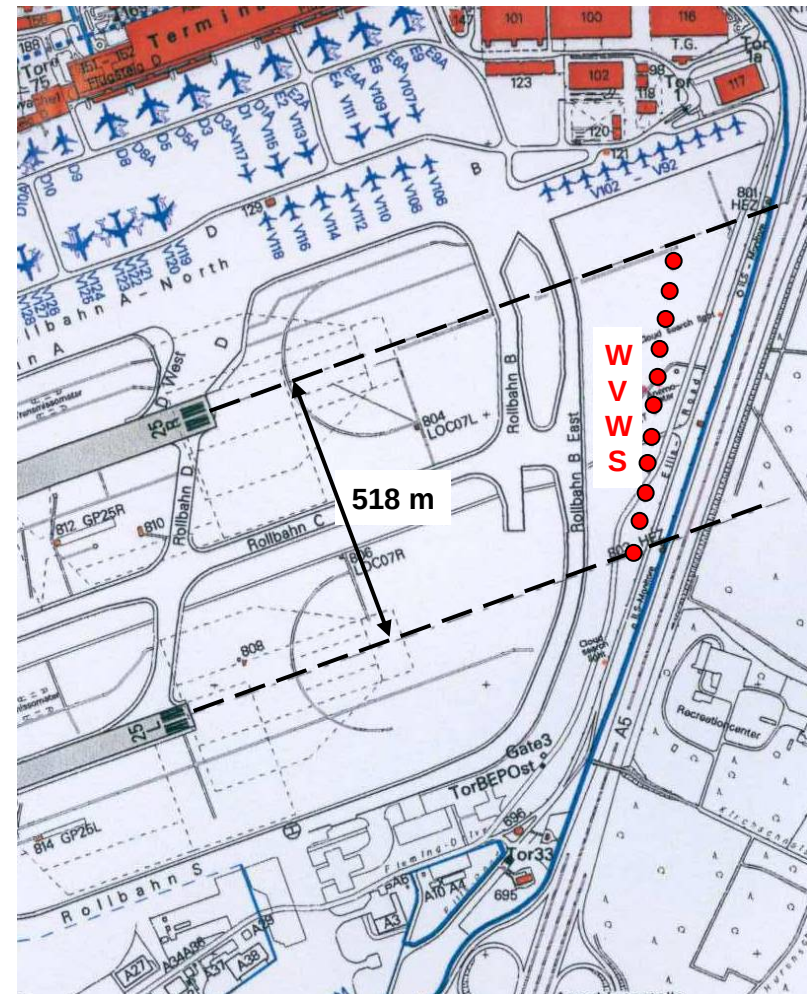
History

- **1992-1994:** First studies and operational concept by DLR, IABG and DWD on behalf of DFS
- **1995:** Installation of anemometer masts (800-880 m short of thresholds 25 L/R)

Targets

Increasing the approach capacity at FRA:

- Prediction of “safe” time periods where no lateral movement of wake vortices occurs due to current wind and weather conditions
- Reduction of existing minima for diagonal separation based on this prediction



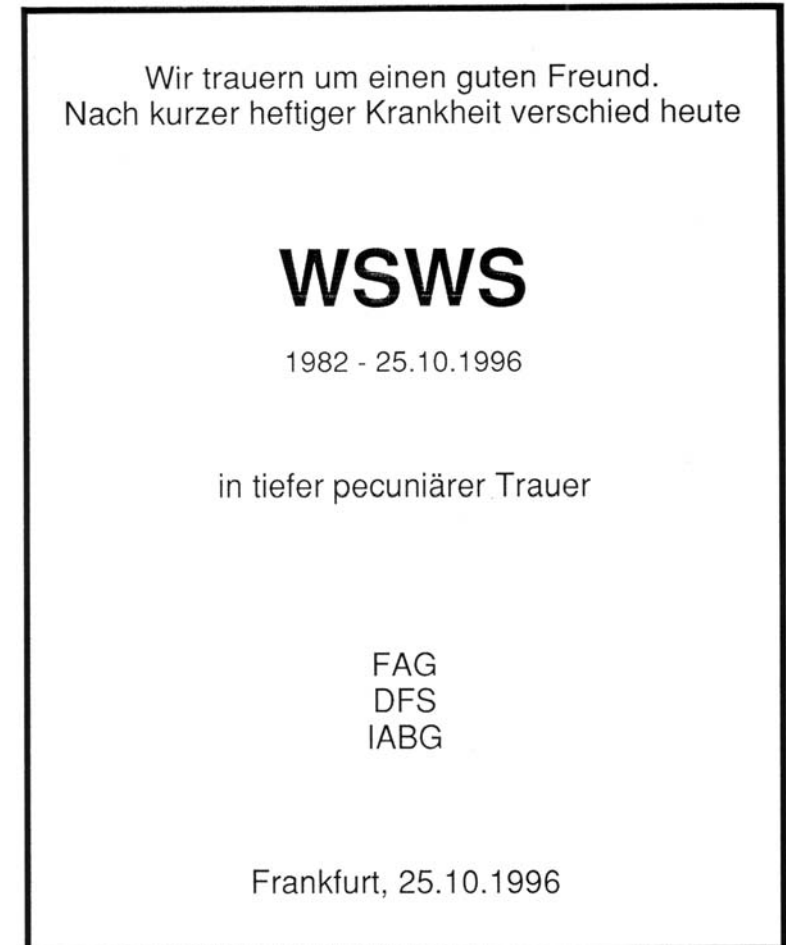
WVWS - Wake Vortex Warning System (2)

Functionality

- Anemometer park to measure wind and occurring vortices close to touchdown
- Prediction algorithm based on surface wind calculation and wake vortex drift model
- Calculated potential capacity enhancement:
⇒ 1-3 additional landings / hour

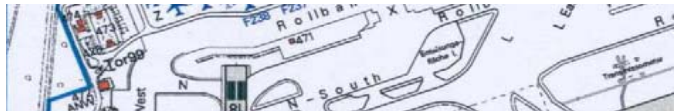
Problems

- German Pilots Unit (VC) judged the system insufficient for reduction of separation
- Measurement and prediction has to be valid for total approach path to reduce separation
⇒ Reduced WVWS separation not applied



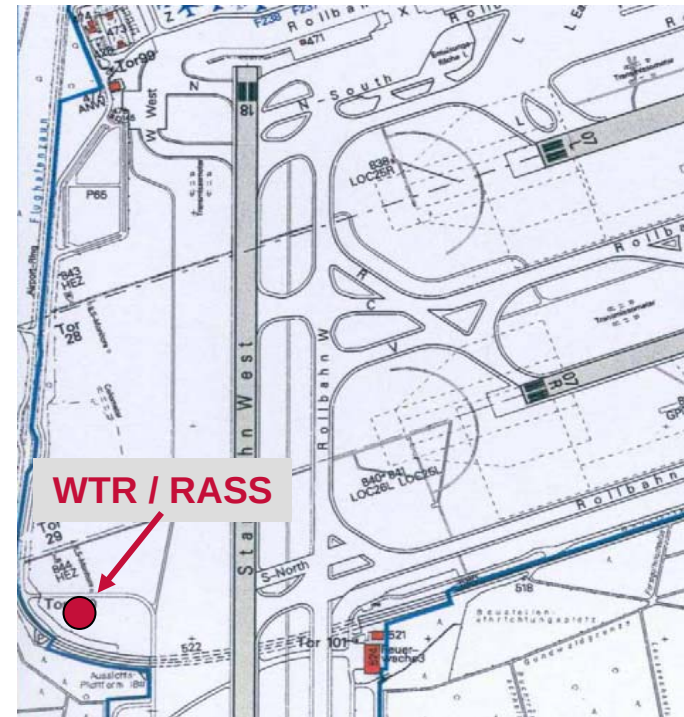
WTR – Wind Temperature Radar

History / System requirements

- After WVWS was rejected as a means to reduce separation alternative systems had to be developed to reach that aim
 - Goal: extension of wake vortex prediction throughout complete approach path
 - ⇒ System must be able to measure wind up to an altitude of 1500 m with a prediction valid for the whole approach
- 

Fraport Involvement

- In 2001 a site survey for the WTR was conducted covering 3 potential sites
- Construction of the fundament (24 x 24m) started in spring 2002 near runway 18
- System hardware was completed late 2002



WTR – Wind Temperature Radar

WTR System Performance

- Combination of Doppler-Radar for clear air measurements and Radio Acoustic Sound System (RASS) for measurements in bad weather
- Measurement of wind (from 100m to 1500m altitude) with a precision of 0.5 m/s and temperature (from 100m to 1000m altitude) with a precision of 0.5°C /100m

Trial operations

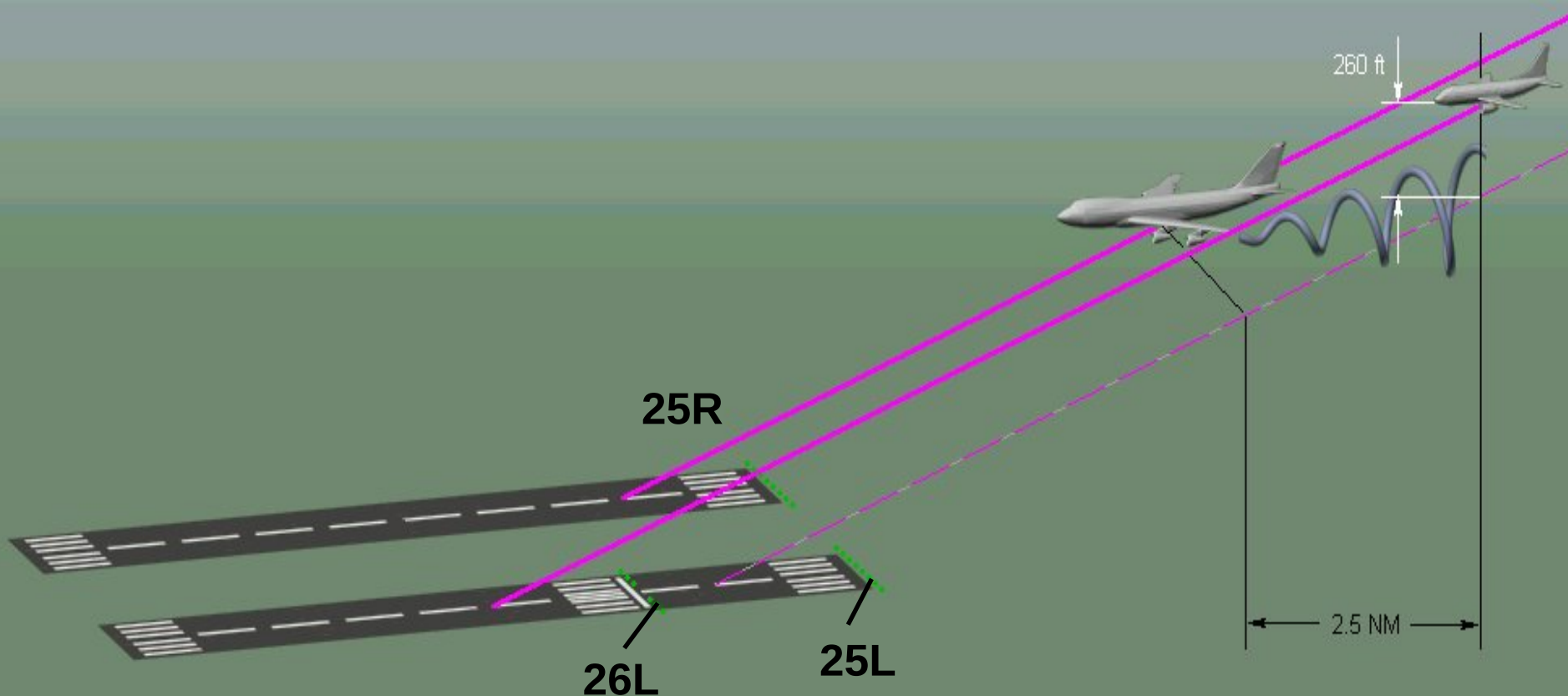
- First trials with acoustic emitters in 2003 still showing technical difficulties
- Start of field trials in spring 2004
- Site acceptance test in III/2004
- First trial phase completed, Results will be presented by Dr. Konopka (DFS)



HALS (High Approach Landing System)

Wake vortex avoidance in case of close parallel runways

Even at the reduced HALS separation of 2,5NM staggered the following aircraft doesn't take a higher risk regarding wake turbulence than at the intrail wake vortex separation of 5NM recommended by ICAO



HALS (High Approach Landing System)

Description

- The following MEDIUM-type aircraft flies behind a HEAVY-type aircraft on a displaced threshold using the new landing path, which is by 290 ft (90 m) higher than that of the leading a/c
- The MEDIUM-type aircraft flying the displaced higher flight path is at any time above the generated wake vortex of the HEAVY-type predecessor
- This fact allows a reduction of the wake vortex separation for HEAVY-MEDIUM staggered combinations from 5 NM to 2,5 NM even for CAT I IMC weather conditions
- HALS is at the time being the only wake vortex avoidance technology verified by a Safety Assessment of the DFS

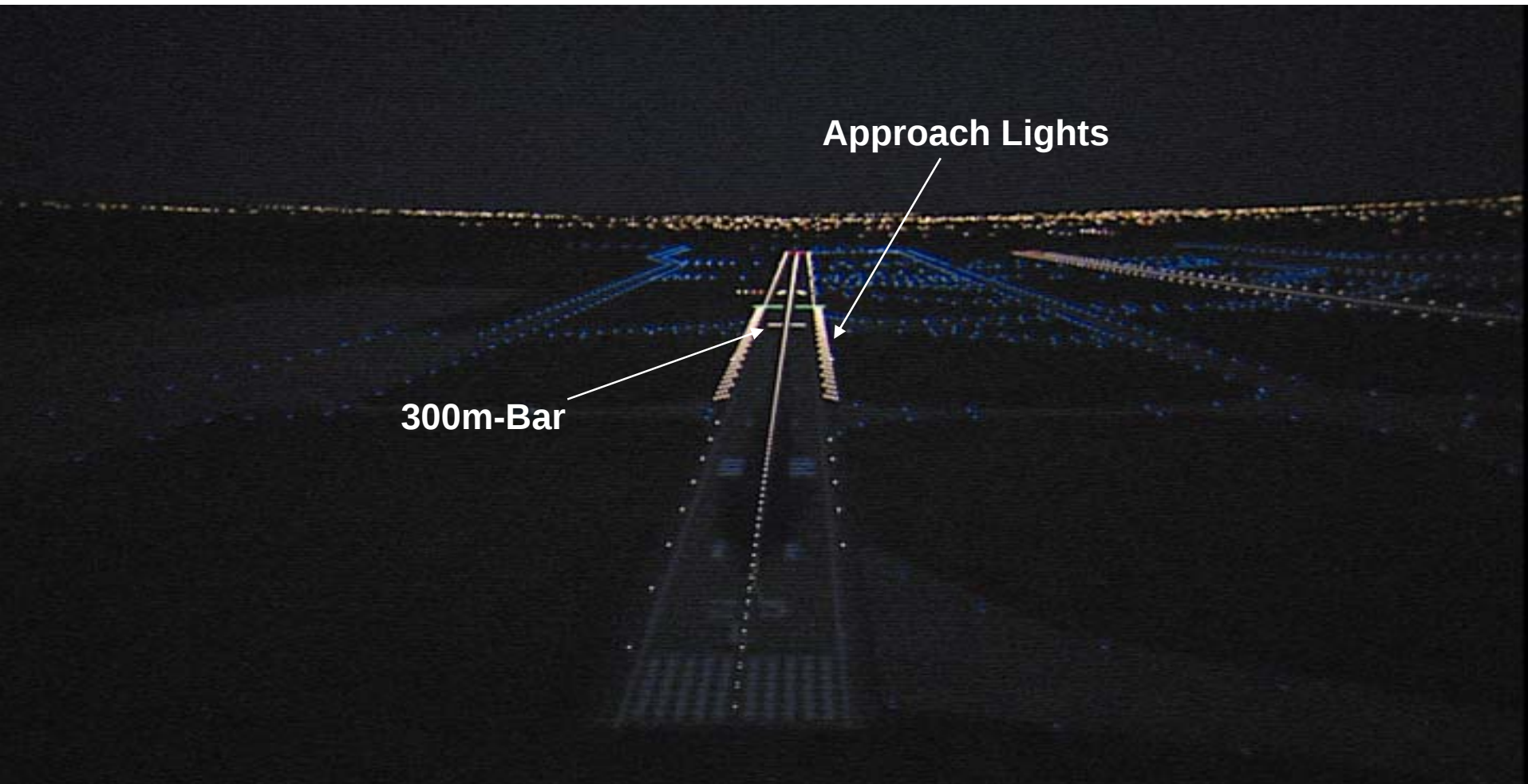
HALS (High Approach Landing System)

Project review

Milestones of the project

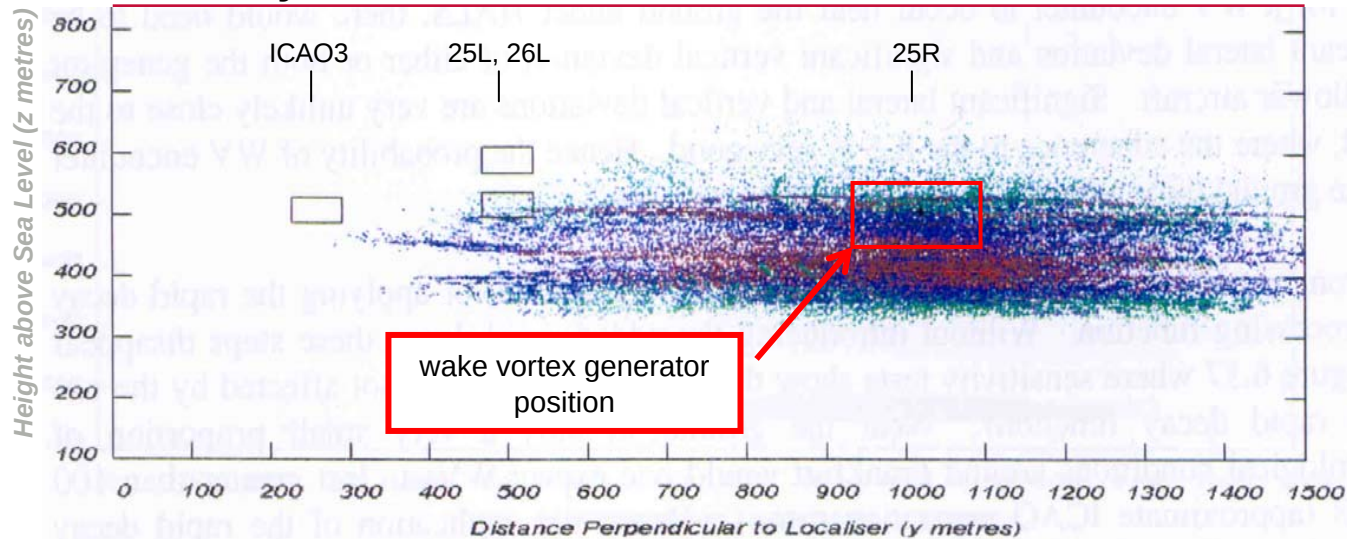
- 09.07.1997: testing of various approach lighting system designs in Lufthansa full flight simulators
- 20.05.1999: Operational trial approval by the appropriate authority (HMWL)
- 21.09.1999: Start of the operational trial stage I (no wake vortex separation reduction for Heavy-Medium, VMC weather conditions)
- 23. Juni 2001: Start of the operational trial stage II (reduced wake vortex separation for Heavy-Medium – up to 2,5 NM, limited visibility conditions – up to 2400 m)
- Operational trial stage II finished at 30.04.2004
- Project partners apply for the regular operations approval by the authorities

HALS (High Approach Landing System) Approach Lighting System



HALS (High Approach Landing System) DFS Safety Assessment findings

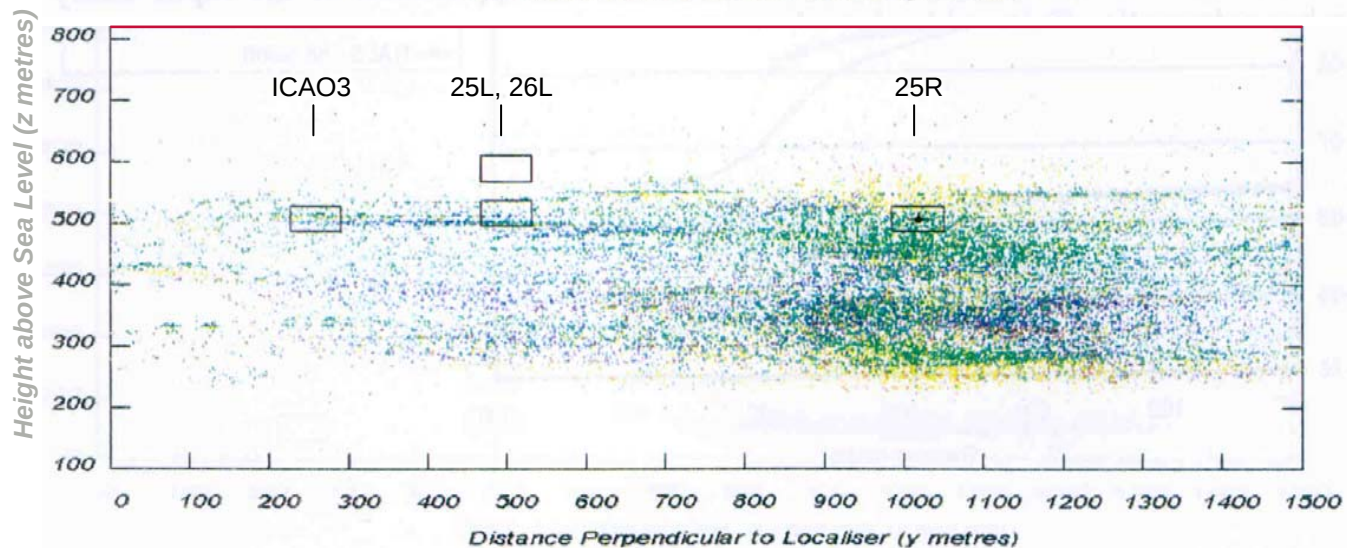
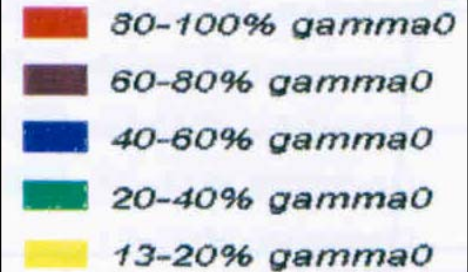
HALS Safety Assessment - Medium behind HEAVY



Outer Marker

2,5 NM separation

vortex intensity



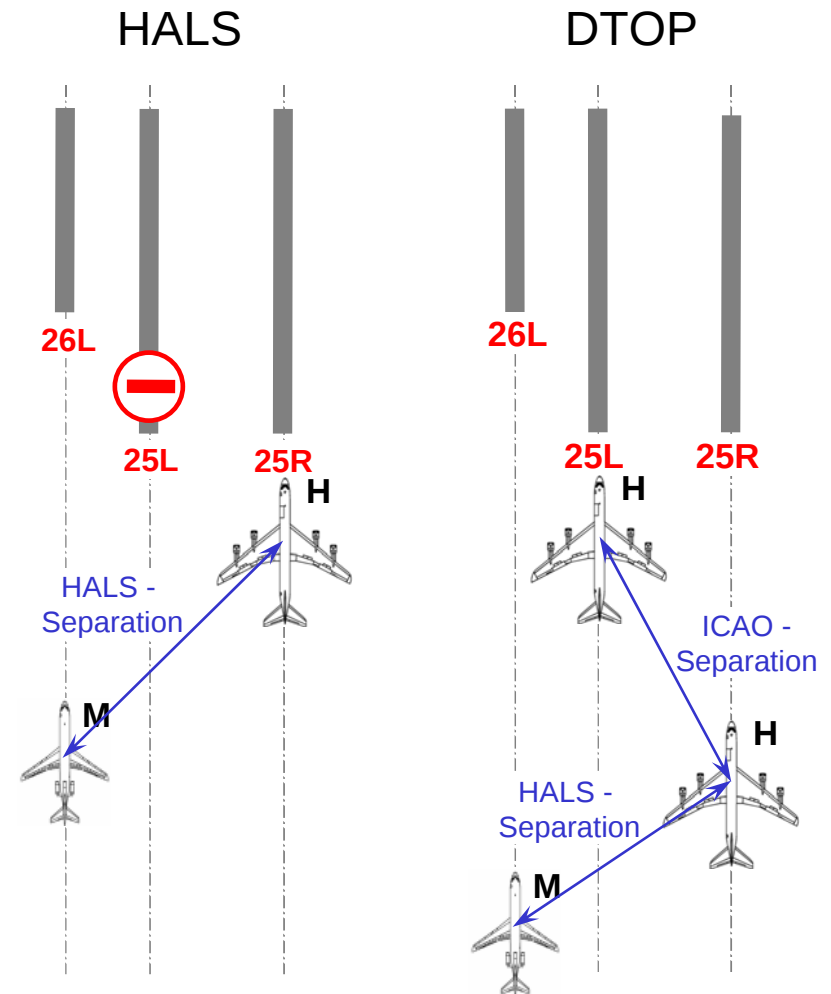
5 NM separation

DTOP (Dual Threshold Operation)

Description

- The concept and design of HALS/DTOP was generally developed for operating the two landing thresholds simultaneously
- HALS is one of the possible ways to use the second displaced landing threshold on the runway. HALS allows the optimal exploitation of a higher flight path for wake vortex separation reduction
- Within the DTOP concept the both regular and displaced thresholds on the southern runway 25L/07R are used simultaneously

Operation mode



DTOP (Dual Threshold Operation)

Potentials of dual threshold operations

- Reduction of the wake vortex separation for staggered Heavy-Medium approaches compared to the regular operation
 - Higher operational flexibility compared to HALS:
The availability of the conventional threshold 25L allows Heavy-type aircraft to apply staggered approaches
The flexible usage of the three available landing thresholds leads to benefits for the outbound traffic
 - Compared to HALS there are no separation losses when starting/finishing DTOP operations as observed during HALS operational trials
- ➡ DTOP conjoins wake vortex separation benefits of HALS with the operational flexibility of the conventional operations

DTOP (Dual Threshold Operation)

Milestones of the project

- DTOP test flights in June 2003 for the purpose of visual assessment of both approach lighting systems on the southern runway (regular and HALS) operating simultaneously
- The HALS/DTOP experts board positively evaluated the visual impression gained during DTOP test flights and promoted further DTOP development
- The dual thresholds project is developed within the scope of the aeronautical research programm of the German government LUFO III since 2004
- In summer 2004 Fraport AG and its LUFO III project partners successfully conducted a full flight simulator study for the evaluation of the pilot taskload during DTOP approaches. The DTOP taskload situation does not significantly exceed the taskload value for ICAO standard ILS approaches

***Real 26L DTOP Approach,
test flight on 09.06.2003***



Lufthansa

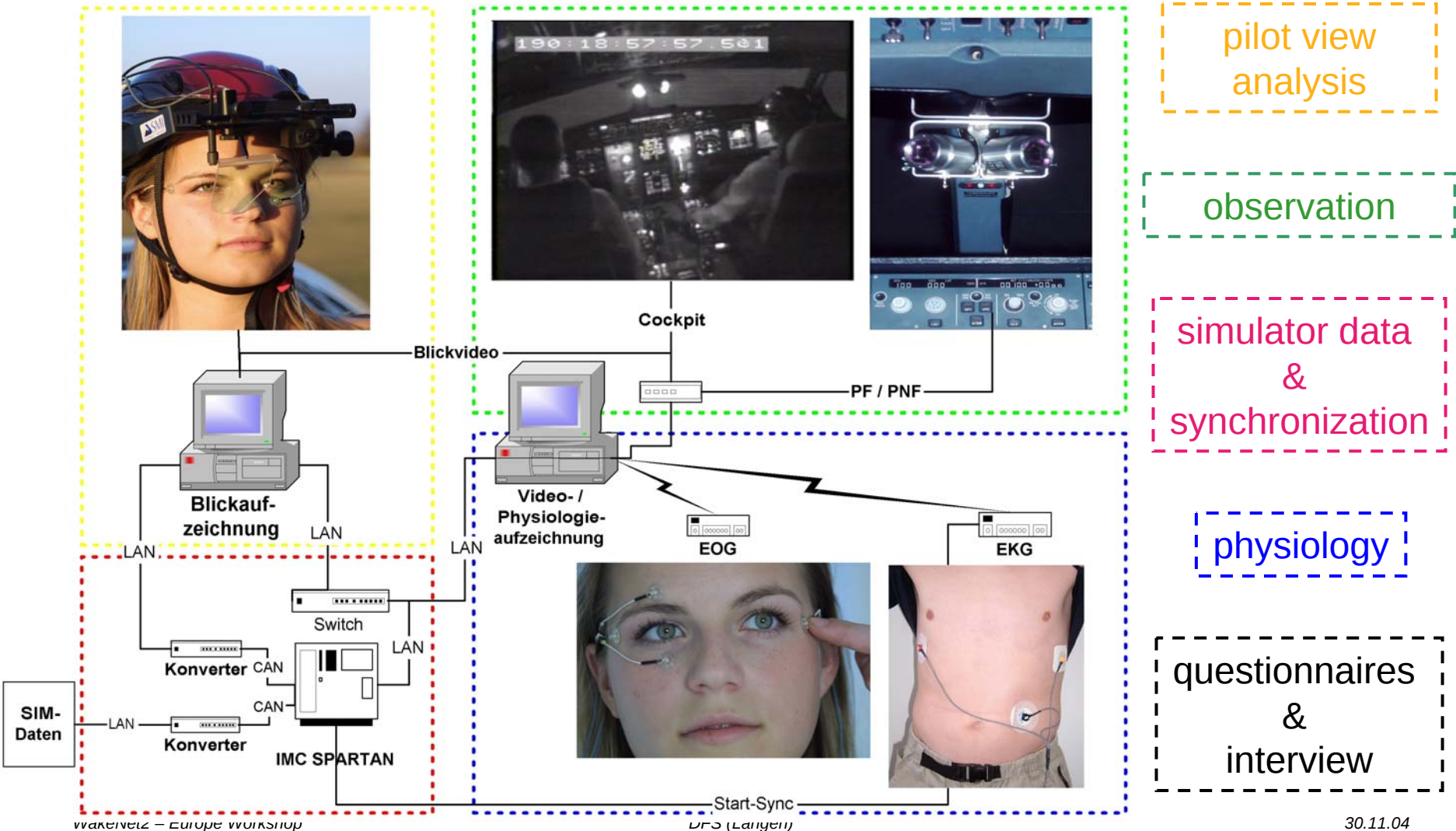


DFS Deutsche Flugsicherung



DTOP (Dual Threshold Operation)

DTOP pilots' taskload study technology

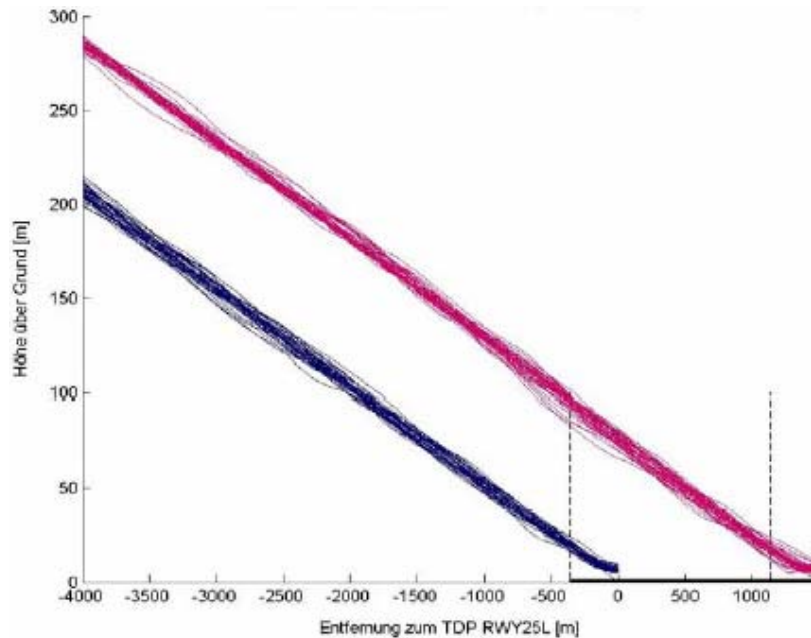


DTOP (Dual Threshold Operation)

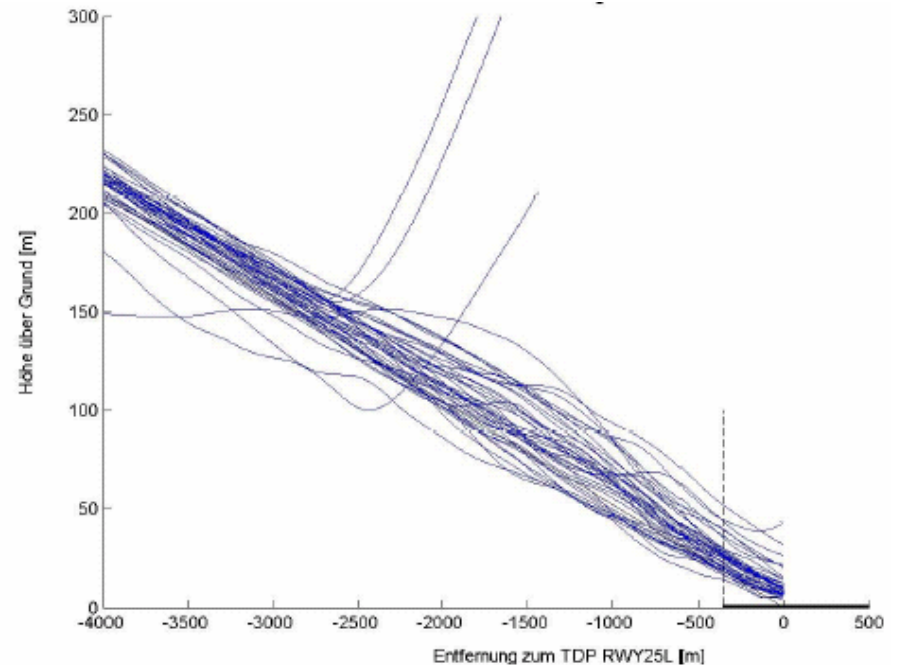
DTOP pilots' taskload study results

vertical GS-deviation for:

- ICAO 25L (blue), good visibility
- DTOP 26L (red), marginal visibility



vertical GS-deviation for ICAO 25L
NDB/DME, marginal visibility



DTOP (Dual Threshold Operation)

Further project actions

- Further DTOP development within the scope of the LUFO III programm
- Real time ATC DTOP simulations – evaluation of the ATC procedures and air traffic controllers' taskload together with DFS
- Enabling the Approach Lighting System for dual threshold operation
- DTOP trial operation
- DTOP regular operation

Precision Approach Monitoring (PAM)

Background:

- Trials conducted in 1998 together with DFS at FAA Technical Center, Atlantic City, showed significant benefits for Frankfurt runway configuration by usage of high update rate radar
- Assessment of e-scan PRM-type radar evolved potential problems:
 - High RF load due to all-call-Mode A/C-interrogation
 - Large obstacle free areas around radar required
 - High investment necessary
- Positive experience with surface surveillance by multilateration supported interest in wide area application of this technology

PAM – Potential Approach Procedures

ATS – Along Track Separation (intended by Fraport)

Procedure:

- Closely spaced parallel runways with spacing below 1035 m
- Approach without No Transgression Zone (NTZ) with a reduced diagonal separation of down to 1,5 NM

Advantage:

- Possible for all visual conditions down to ILS minima

Disadvantage:

- Procedure is not yet in operation and certified at any airport

ATS (Along Track Separation)



PAM – Project Scope

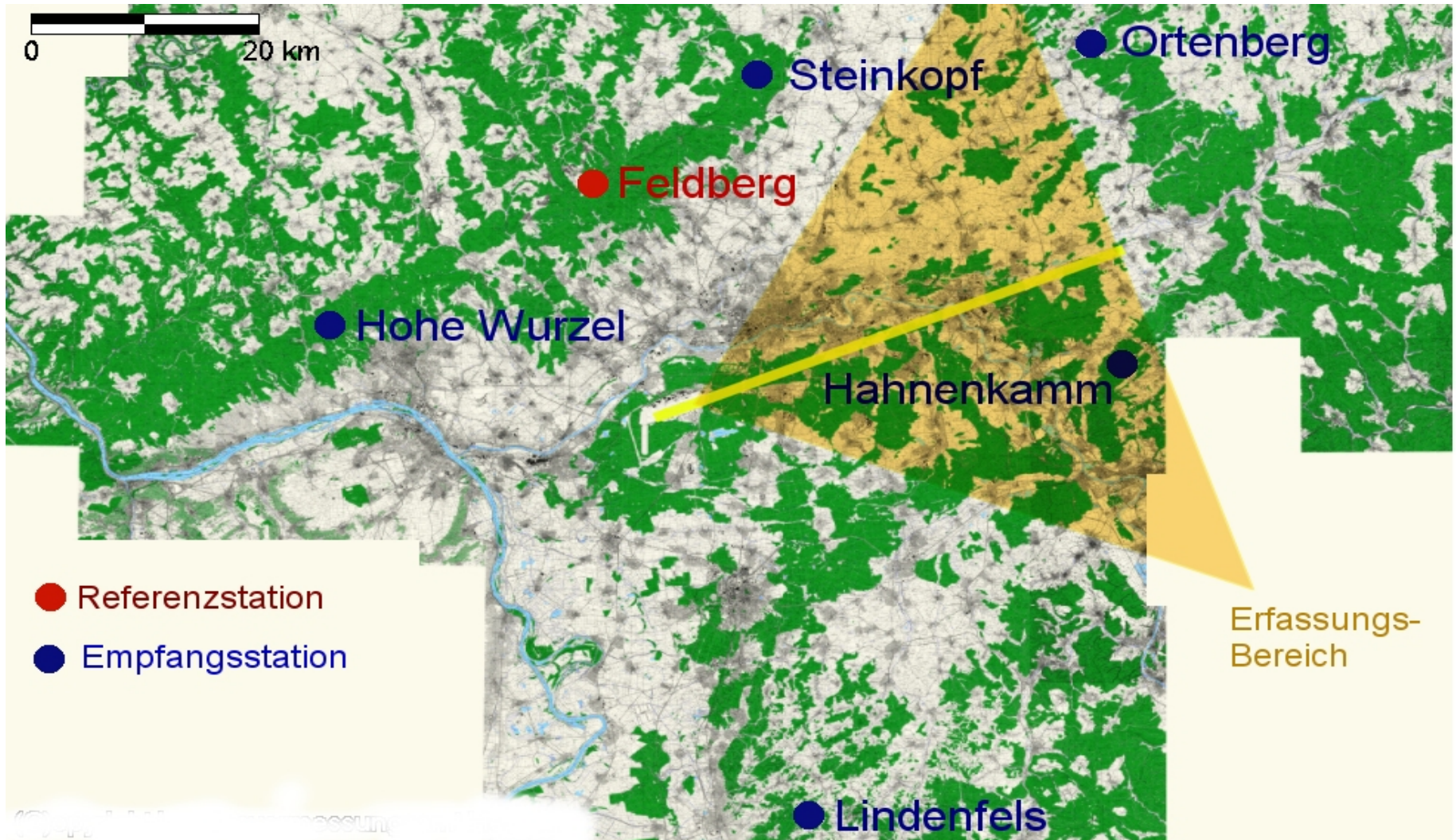
PAM Prototype:

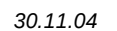
- Project in co-operation with DFS (German ATC) and Lufthansa
- Sensor locations selected for coverage of approach direction 25 with accuracy target of better than 15 m
- Coverage of downwind and 07 approaches with reduced precision expected
- Evaluation of PAM Prototype until end of 2004

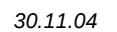
Operational use:

- If prototype evaluation is successful, the integration in existing ATC systems and transfer to operational use is intended by DFS

PAM – Sensor Locations







PAM – Results and Next Steps

Evaluation Phase:

- First test flights have shown that the precision and resolution of PAM is comparable or better than conventional aerodrome surveillance radar
- Senior ATC-controllers have participated in an operational evaluation of the PAM system in combination with the Phoenix-Display
- The judgements of controllers indicate, that higher update rate and accuracy is very beneficial for approach controller's work

Operational use:

- For an operational system, enhancements like more remote stations to fully cover 07-approach and redundant central components are required
- Following a positive decision of DFS, an operational use of complete PAM-system could be achieved by 2006

Conclusions

- In order to cope with the increasing traffic demand, capacity enhancement and punctuality are the ultimate strategic goals for Frankfurt airport
- **Measures to predict the occurrence of wake vortices (WVWS / WTR)** have been evaluated for many years by DFS and Fraport. Results will be presented later today.
 - ⇒ **Further research is required**
- **Measures to avoid wake vortex encounters (HALS)** have been tested successfully at Frankfurt airport. The ongoing development of DTOP will overcome the procedural deficits of HALS
- **Technology to reduce minimum radar separation (PAM)** has also been tested successfully. The decision to install operational system and procedures has not been taken yet

Thank You for Your Attention!

