Research Grant
Creating wake vortex awareness for pilots and controllers
- Progress Meeting -

December 2009
Summary of Activities
Timeline

• Kick-Off in Braunschweig – 20.06.2008
• Progress Meeting at ECTL – 07.11.2008
  – discussion of achieved results, future deliverables
  – presentation at the ECTL Scientific Seminar
• Presentation of concept at WakeNet3-Europe 1st Workshop – 08.01.2009
• Progress Meeting in Braunschweig – 30.06.2009
• papers submitted, accepted and presented at:
  • CEAS 2009 in Manchester – 26.-29.10.2009
  • DASC 2009 in Orlando – 25.-29.10.2009
  • INO Workshop in Bretigny – 01.-03.12.2009
• Progress Meeting in Bretigny – 02.12.2009
Activities of last period - publications

- papers and presentations
  - DASC 2009 (Digital Avionics and Systems Conference)
    - **Collaboration of Wake Vortex Models and Sensors in Modern Avionic Systems**
      - published in conference proceedings and IEEE Library
      - current status: editorial reviewed
  - CEAS 2009 (European Air and Space Conference)
    - **Wake Vortex Prediction and Detection Utilising Advanced Fusion Filter Technologies**
      - published in conference proceedings, peer reviewed publication in *Journal of Royal Aeronautical Society* under discussion
  - 8th INO Workshop
    - **Surveillance Systems On-Board Aircraft: Predicting, Detecting and Tracking Wake Vortices**
      - peer reviewed by workshop committee, published on EUROCONTROL website
Activities of last period – publications (cntd.)

- accepted abstract for next year:
  - ICAS 2010 (September 2010, Nice)
    - topic: use of WV models and sensors in fused system
    - peer reviewed full paper, oral presentation
Activities of last period – presentations, others

- attendance to conferences
  - Global WakeNet, November 2009
  - Onboard Wake Vortex Warning Systems – Developments for the long-term
- link to Russian wake vortex research
  - visit to GosNIIAS,
  - gather information on Russian WV models and “Vortex Vision System”
  - coordinated with EUROCONTROL
Progress in software development and implementation
Simulation for specific error types

- advantage of simulated Lidar data:
  - controlled, repeatable error behaviour
  - known uncertainties
  - detailed investigation of new system possible
Optimisation of filter parameters

state (WV trajectory error, circulation error)

state transition (error random walk)

error/uncertainty-feedback

measurement uncertainty

process uncertainty

Covariance (analogous to uncertainty bound in current models, but decreased by measurement)

Measurement-Update

\[ K_k = P_k^{-1} H^T (H P_k^{-1} H^T + R_k)^{-1} \]

\[ \hat{x}_k = \hat{x}_k^- + K_k (z_k - H \hat{x}_k^-) \]

\[ P_k = (I - K_k H) P_k^- \]

measured quantities (WV circulation, position)

state transition (error random walk)
Error state closed loop – extension of error state

\[ \Gamma_{\text{prediction},k}^+ = \Gamma_{\text{prediction},k}^- - \Delta \Gamma_k^+ \]
\[ y_{\text{prediction},k}^+ = y_{\text{prediction},k}^- - \Delta y_k^+ \]
\[ z_{\text{prediction},k}^+ = z_{\text{prediction},k}^- - \Delta z_k^+ \]
\[ v_k^+ = v_k^- - \Delta v_k^+ \]
Error state closed loop - results

- simulation with constant errors
Further work

- derivation of model equation for system dynamic matrix (full state ODE)
- Status of PVM?
  - license?
  - best way: use of error state
    ➔ independent of used prediction model
    ➔ use general equations within full state (like published D2P equations); e.g. from published Wake4D description
- detail work on error state and optimisation
- benchmarking
  - definition of benchmarking
    • a priori or a posteriori residuals?
- further analysis of provided databases