In-flight Evaluation of Avionic Systems

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Outline

- Introduction
- Examples of in-flight avionics evaluations
- In flight evaluation of a NESLIE back-up air data system
  - Objectives
  - Accommodation
  - Flight Test Operation
  - Flight Test Analysis and Result
- Conclusion
Where and what is NLR?

www.nlr.nl
How do we test avionics in flight?

NLR Research aircraft
### Cessna Citation
**NLR / TUD Research aircraft**

- **MTOW**: 14,600 lbs
- **Max Payload**: 3,100 lbs
- **Max Altitude**: 43,000 ft
- **Max Speed (Sea level)**: 262 KIAS
- **Max Endurance**: 5 hours
- **Max number cabin seats**: 8
- **P&W JT15D-4 jet engines**
- **EFIS**
- **FMS**
- **RVSM**
Cessna Citation
NLR / TUD Research aircraft

RESEARCH FACILITIES

- Dedicated electrical power system
- Hard points (200 kg)
- External mounting structure
- Side mounted fairing with optical window
- Modified escape hatch
- Nose boom (α and β vanes, 5-hole probe)
- High accuracy positioning system
- Data acquisition system
Fairchild Metro
NLR Research Aircraft

- **MTOW**: 12,500 lbs
- **Max Payload**: 3,000 lbs
- **Max Altitude**: 25,000 ft
- **Max Speed (sea level)**: 248 KIAS
- **Max Endurance**: 5 hours
- **Max number cabin seats**: 6
- **Garrett TPE-331 Turboprop engines**
- **Pax door and large cargo door**
Fairchild Metro
NLR Research Aircraft

RESEARCH FACILITIES

- Dedicated electrical power
- Hard points (160 kg)
- External mounting structure
- Optical window bottom fuselage (60X60 cm)
- Nose boom (α and β VANES, 5-Hole probe)
- High accuracy positioning systems
- Data acquisition system
Flight Test @ NLR

- Aerodynamics
- Atmosphere
- Avionics
- Air Traffic Management
- Flight test methods
- System tests
- Flight inspection
- Airborne Remote Sensing
NLR Flight Test Organisation
Flight Test Preparation

Request For Test (RFT)

Preliminary Risk Assessment

AGREEMENT FOR TEST

SAFETY REVIEW
ROUTINE/LOW: Peers
HIGH: Safety Board

Draft Test Plan

NLR - Dedicated to innovation in aerospace
Examples of in-flight Avionics and Avionic concept evaluations

- Wake vortex and turbulence detection
- Future ATM concepts validation
- Data links
- UAVs in civil airspace: Project Outcast
- Evaluation of prototype commercial products such as an IMU, GPS receiver, weather radar, etc.
Wake vortex and turbulence detection

- S-Wake / Awiator
- I-WAKE
- Delicat

 Forward-looking LiDAR sensor
Wake vortex detection

I-WAKE modification/certification
I-Wake project
Future ATM concepts validation

• Free flight
• Continuous Descend Approach
• GNSS for aviation
GNSS for aviation

Is it ready for the application?
Nice Trials

- 1st time to fly approach on EGNOS (ESTB) guidance
- Procedure flyability was demonstrated
- Assessment of TSE in terms of NSE and FTE

NLR - Dedicated to innovation in aerospace
Data links

- VDL-4 ADS-B
- Eurocontrol Link2000
UAVs in civil airspace: Project Outcast

- See-and-avoid in civil airspace
- IR and visible cameras
- “Ground” operator on board
OUTCAST project
NESLIE project

- **Type**
  - European Commission 6th Framework project

- **Budget**
  - 1 M€ NLR / 6 M€ total

- **Duration**
  - 2006 – 2009

- **Composition**
  - Among partners are
    - Thales
    - Airbus
    - Dassault
    - EADS
Objectives

- **NESLIE = NEw Standby Lidar InstrumEnt**
- **Overall objective**
  - Airspeed measurement LiDAR
  - Airspeed measurement Pitot-static
  - Reduction probability of common failures
  - Improvement Flight Safety

- **Project objective**
  - Evaluation of NESLIE system in flight test campaign
    - system performance with regard to a/c reference
    - influence of atmosphere on backscattered signals
Principle

- **Laser signal**
  1. emitted in airflow
  2. backscattered by particles in atmosphere
  3. received with Doppler shift

- **Doppler shift is measure for true air speed component in direction of beam**
Configuration

- **Configuration laser beams**
  - Four laser beams
  - Focused in small measurement volume (pyramid shape)
  - Four airspeed components > three required

- **Location measurement volume**
  - Just outside fuselage / boundary layer
  - In front of emergency hatch
    - near free-stream conditions
    - as far as possible upstream of wing
Components

- Two avionics boxes
  - Optics
  - Signal processing
- Attached to seat tracks in cabin
- Laser output via glass fibre
Accommodation (1/2)
Accommodation (2/2)
### Test matrix

<table>
<thead>
<tr>
<th>Shakedown</th>
<th>Step climbs to max altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backscattering</td>
<td>Step climbs to max altitude</td>
</tr>
<tr>
<td>measurement</td>
<td>Constant max altitude</td>
</tr>
<tr>
<td>under different</td>
<td>Sea, countryside,</td>
</tr>
<tr>
<td>atmospheric</td>
<td>dense urban area</td>
</tr>
<tr>
<td>conditions</td>
<td>Stable conditions</td>
</tr>
<tr>
<td>Performance</td>
<td>Turbulent conditions</td>
</tr>
<tr>
<td>measurements</td>
<td>Side slips, AOA variations</td>
</tr>
<tr>
<td>(with noseboom)</td>
<td>with flaps</td>
</tr>
<tr>
<td></td>
<td>Rapid speed changes</td>
</tr>
<tr>
<td></td>
<td>Parabolic flights (0-g</td>
</tr>
<tr>
<td></td>
<td>manoeuvres)</td>
</tr>
<tr>
<td>Backup flights</td>
<td>As required</td>
</tr>
</tbody>
</table>
Flight statistics

- Number of test flights: 18
- Accumulated flight test time: 40 hrs
- Flight test period: April – May 2009
- Test area: Netherlands, Northsea & Germany
- Test level: Max FL410
- Test speeds: Max 260 KIAS
- All matrix items covered
Recorded data

- **NESLIE system**
  - Backscatter signal data
  - Airspeed data
  - System data

- **Aircraft**
  - Reference data (AOA, sideslip, airspeed) for which also a noseboom with vanes was used
  - Forward looking video

- **Weather**
  - Several weather products
    - METAR, TAF, SIGWX, UWT, wx balloon profiles, etc.
Content of analysis

- Number of detections
- Consistency of data

**Comparison of Neslie air data and NLR aircraft data**
  - Major question: Is there a one-to-one relation?
    - if yes (within expected accuracy): ok
    - if no: can we find an explanation for differences?

- Signal processing algorithm
Air data comparison (straight & level speed changes)

Calibrations exist

\[ T_{\text{AS calibrated}} = 1.03 \, T_{\text{AS Neslie}} - 11.2 \quad [\text{kt}] \]

\[ A_{\text{OA calibrated}} = 0.64 \, A_{\text{OA Neslie}} - 1.78 \quad [\text{deg}] \]
Air data comparison (parabolic manoeuvres)

How does calibration work for dynamic manoeuvre?
Improved calibration

**Good coherence between aircraft data and NESLIE system data**

$$TAS_{calibrated} = 0.98 \ TAS_{neslie} - 0.014 \frac{dTAS}{dt} - 0.97 \ AAB + 3.4 \ [kt]$$
Follow up project DANIELA

- Follow up project DANIELA
- Now: campaign in Spitsbergen
Conclusions

NESLIE

- An innovative optical backup air data system was developed, built and tested
- The system was integrated in NLR’s Cessna Citation for in-flight evaluation
- The flight test campaign delivered a large quantity of data
- Results are promising, a large step was made towards an avionic system
- Data can be calibrated

- Flight testing avionics in an instrumented, easy-to-modify research aircraft in an experienced flight test organisation is effective and efficient
NESLIE flight test impression