National Technology Project OUTCAST

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Since the 17th century rivalry with the English, the Dutch have a bad name

Dutch roll - An uncomfortable, undesirable type of aircraft motion

Dutch courage - False courage, based on large quantity of alcohol

Dutch treat - Everyone pays for himself, Dutch are like Ebenezer Scrooge

Dutch UAS? - Undesirable Alcoholic Scrooge?

In fact… the Dutch have a balanced view on getting the pilot out of the aircraft
Sense and Avoid

- Essential for UAS airspace integration
- S&A is more than ‘the last ditch’ collision avoidance

National Technology Project OUTCAST

- Vision: integrate UAS as OAT into airspace in 2010-2012
- ‘2010’ hybrid S&A concept demonstrator developed

Airborne surveillance of SSR transponders + Optical & Infrared Sensors

- Evaluated in 33 test flights on NLR’s (manned) Cessna Citation

Results

- Definition of S&A Requirements ("Equivalent Safety?")
- OUTCAST concept promising for ‘workable’ and pragmatic solution
**ICAO Conflict Management**

*A Layered Safety Concept*

<table>
<thead>
<tr>
<th>1. Strategic conflict management</th>
<th>Flight Rules, Mission Planning etc...</th>
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<tr>
<td></td>
<td>Airspace Classification <em>(simplified)</em></td>
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<td>S&amp;A solution more challenging</td>
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<td>3. Collision Avoidance</td>
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The question is not “Can I fly, yes or no?”, but “Where do I want to fly, and what do I need for that?”

**S&A Solution: Technology + common sense operational ATM Procedures**

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**Sense & Avoid**
Sense and Avoid Process

**Iterative process – with both aircraft responsible**

1. **Detect Traffic**
   - **Observe**

2. **Track & Assess Conflict**
   - **Conflict?**
     - Constant bearing in straight flight
   - **Orient**

3. **Select Manoeuvre**
   - **Decide**
     - Manoeuvre options?
     - Compatible with manned aircraft operations and TCAS
     - UAS may have right of way!

4. **Execute Manoeuvre**
   - **Act**
     - (a) until ‘clear of conflict’
     - (b) after ‘clear of conflict’
     - UAS Climb and Turn Performance?

**OODA loop**

*NLR - Dedicated to innovation in aerospace*
MALE UAVs safely operating as OAT outside segregated airspace in 2010 under ‘peacetime conditions’

2010 ATM system
no major changes
- No major changes
  - Airspace classes
  - Flight rules
  - ATC services
  - detect and avoid

2010 Detect & Avoid Equipment
widely available and mandated?
- Cooperative
  - Mode S (not all airspace)
  - ACAS technology
- Non Cooperative
  - EO/IR based
  - Radar based

NTP OUTCAST
2010 Vision with a Pragmatic Approach
NTP OUTCAST

Project Definition

Customer
- NLD MoD / Defence R&D

Objective
- ‘short-term’ solution for Sense & Avoid ~2010

Project Duration
- April 2004 – 2007

Phasing
1. Requirements Capture ✓
2. Demonstrator Development ✓
3. Flight Test ✓
4. Analysis & Report
Past
USICO
EC FW5
JAA/EuroC.
Task Force

Current
NATO
FINAS
EUROCAE
WG73
participate
Eurocontrol
OAT TF
UAVNET

New
FAA study
‘standards’
NLD MAA
support

Contact &
monitor

Other projects
Industries
Authorities

Too much to mention....
Demonstrator Development by NLR

From Design until Certification in NLR Cessna Citation II

TCAS (as available on Citation)
- known bearing inaccuracy; but within ACAS MOPS
- Read out ARINC data between TCAS computer and display

UAV crew consoles
- Focus on traffic avoidance
- Goal: to enable effective flight testing
- HMI NOT (yet) optimised

HMI (Human-Machine Interface)
Demonstrator Development by NLR
From Design until Certification in NLR Cessna Citation II

EO/IR Camera
- Structures integration (60kg)
- Fairing to reduce aero. impact

FAR Certification Compliance Check
- Structures analysis
- Aero/CFD analysis
- Stability and Control
- taxi tests and flight tests

Certification by NLD CAA
- Supplemental Type Certificate
Flight Tests  
*November 2006 & March-April 2007*

- 33 measurement flights

**Detect & Track:** 75 ‘collisions’ / 3 intruders

**Sit. Awareness & Avoid:** 90 ‘encounters’  
- sometimes collision / sometimes not

**9 flights through regular NL airspace**

- (Too?) good weather conditions
- No significant equipment or aircraft malfunctions
- 170 Gb of flight test data

A very smooth flight test phase
Roaming Flights
 Variety of Air Traffic Encountered (Examples)

general aviation

airliner

helicopter

gliders
Project Results

S&A Requirements
- Equivalent Safety
- Sensor Coverage
- Separation Minima
- Level of Automation

"However beautiful the strategy, you should occasionally look at the results"

Sir Winston Churchill

OUTCAST System Performance
- Detect
- Track
- Situational Awareness
- Conflict Resolution

The USAF has announced budget cut backs...
Preliminary Conclusions & Recommendations

Feedback to working groups on regulations and standards
- Flight Tests are indispensable, also in this part of the process

Recommended System Improvements
- Data Fusion
  - Range altitude from ACAS surveillance, bearing from EO/IR
  - Matching intruders between cooperative and non-coop. sensors

- Find the right balance between Human and Computer
  - Optimise situational awareness
  - Assistance in conflict analysis
  - Assistance in conflict resolution

OUTCAST Concept feasible for state UAS (OAT)
- Provided regulations are in place (stepwise introduction)
- Provided required system improvements are addressed
- In combination with pragmatic procedures

Next Steps
- Discuss with NLD MoD
- In solving the short-term... keep thinking about the long term
Presentation Summary

**Sense and Avoid**

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**Results**

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- OUTCAST concept promising for ‘workable’ and pragmatic solution
Acknowledgements

- RNLAF aircraft
- Military ATC support
- Engineering support for functional integration with Toplite
- All project participants...
- 16 departments in all 3 divisions
- a true multi-disciplinary effort
Questions?

Hard questions will be sensed and avoided!

Dedicated to innovation in aerospace

www.nlr.nl - info@nlr.nl
The Equivalent Level of Safety...  
... does it exist?

Not well defined in manned aviation!
- What is it?
- How do we achieve it?
- How do we prove it?

⇒ Acceptable level of safety

'no harm' safety case ← Top down ← collision risk $10^{-x}$ / hour

Qualitative

'no harm' safety case ← Bottom up ← coverage angles, separation minima etc

Quantitative
OUTCAST Sense and Avoid Requirements

Coverage

Azimuth: +/- 110°

Elevation: (+/- 15° initial)
+/- 20° final proposal

ICAO Right of way rules

Fokker 50 @ az 110°; el -18°
Climbing and triggering TCAS RA
OUTCAST Sense and Avoid Requirements
Separation Minima

ATC responsible for separation
Use ATC separation minima

UAV pilot responsible for separation
No equivalent in manned aviation!

Required for UAS:
- Transponder, VHF Comms,
- UAS pilot supervision

NATO FINAS Proposal:
- 0.5 Nm horizontal
- 500 ft vertical

Feedback from OUTCAST flight tests
- 0.5 Nm horizontal: mismatch with UAS crew / pilot comfort
  - 500 ft vertical: ok for pilots, but triggers TCAS TA/RA

How are such numbers going to be (mis)used by industry?
OUTCAST Sense and Avoid Requirements
Level of Automation

Self-separation function

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Collision Avoidance function

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Option 1

Option 2

manned TCAS

UAS CAS
Example - Fokker 50 head on
Acquisition & Track with EO/IR Camera

Distance Approx. 16 Nm (30 km)

Infrared

Daylight

‘Pilot Visual’ at 6 Nm (11 km)
Tracking Performance - Example
PC7 head-on, TCAS versus GPS and camera

Note:
ADS-B would provide similar tracking performance as the blue GPS plot
Situational Awareness

**Video Monitoring**

*Video provides insight in intruder manoeuvring*
- straight or turning flight

*... but interpretation NOT Trivial*
- Different and less intuitive than manned a/c pilot
- Combine camera angle with ownship attitude

**Further study Recommended**
- Human Machine Interface
- UAS crew training requirements
Better information on other traffic by data fusion

- Better position of intruder AND insight in flight direction of intruder

OUTCAST HMI

(remember: not yet optimised)

clear of conflict?

Example HMI Improvement based on “Free Flight” research

clear of conflict!

HMI Study Recommended