



Dedicated to innovation in aerospace



National Technology Project OUTCAST



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The Dutch and UAS?

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

quantity of **alcohol**

Dutch treat

Ebenezer **Scrooge**

Dutch

alcoholic Scrooge?



In fact... the Dutch have a balanced view on getting the pilot out of the aircraft

Presentation Summary

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

1. Strategic conflict management	Flight Rules, Mission Planning etc...			
	Airspace Classification (<u>simplified</u>)			
	Segregated airspace	Non segregated airspace		
		Controlled	Uncontrolled	
	Transponder equipped	Transponder equipped	Not Transp. equipped	
2. Separation Provision	n/a	ATC	pilot	pilot
3. Collision Avoidance	n/a	pilot	pilot	pilot

S&A solution more challenging

The question is not **“Can I fly, yes or no?”**, but
“Where do I want to fly, and what do I need for that?”

Sense & Avoid

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

Sense and Avoid Process

Iterative process – with both aircraft responsible

1. Detect Traffic

Observe

2. Track & Assess Conflict

Orient

- *Conflict?*
- *Constant bearing in straight flight*

3. Select Manoeuvre

Decide

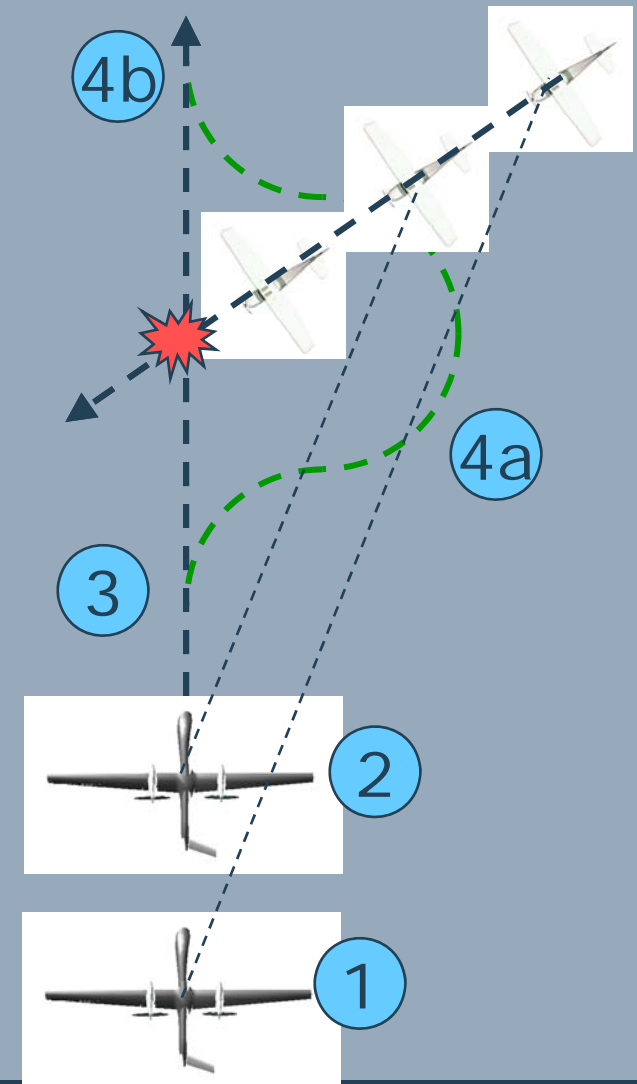
- *Manoeuvre options?*
- *Compatible with manned aircraft operations and TCAS*
- *UAS may have right of way!*

4. Execute Manoeuvre

Act

- *(a) until 'clear of conflict'*
- *(b) after 'clear of conflict'*
- *UAS Climb and Turn Performance?*

OODA loop



NTP OUTCAST

2010 Vision with a Pragmatic Approach

MALE UAVs safely operating as OAT outside segregated airspace in 2010 under 'peacetime conditions'

2010 ATM system

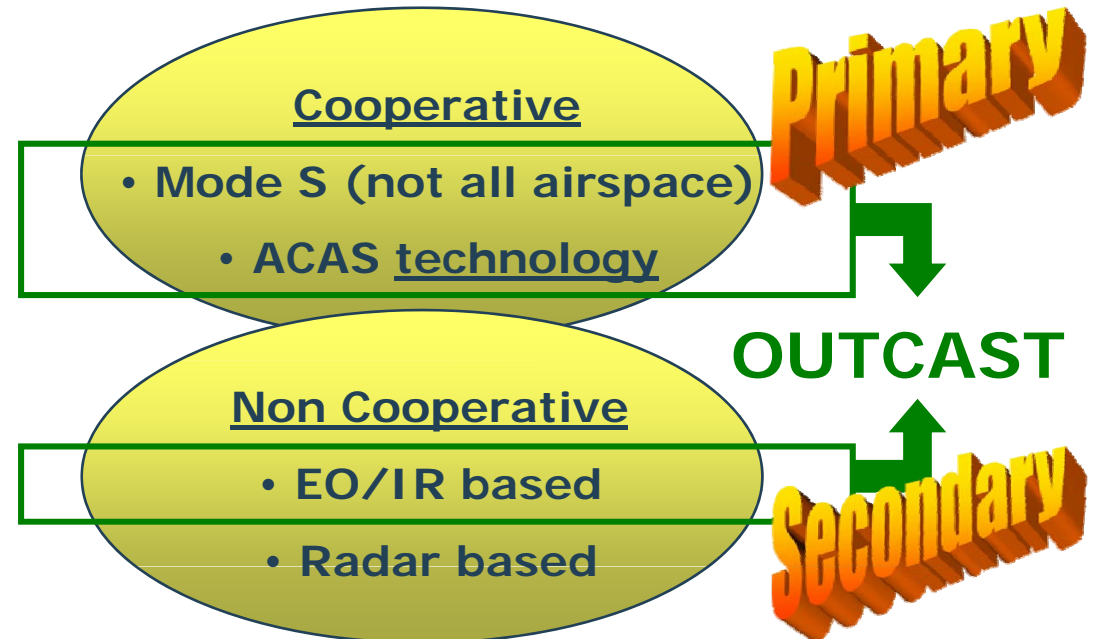
no major changes

No major changes

- Airspace classes
- Flight rules
- ATC services
- detect and avoid

2010 Detect & Avoid Equipment

widely available and mandated?



NTP OUTCAST

Project Definition

Customer

- NLD MoD / Defence R&D

Objective

- 'short-term' solution for Sense & Avoid ~2010

Project Duration

- April 2004 – 2007

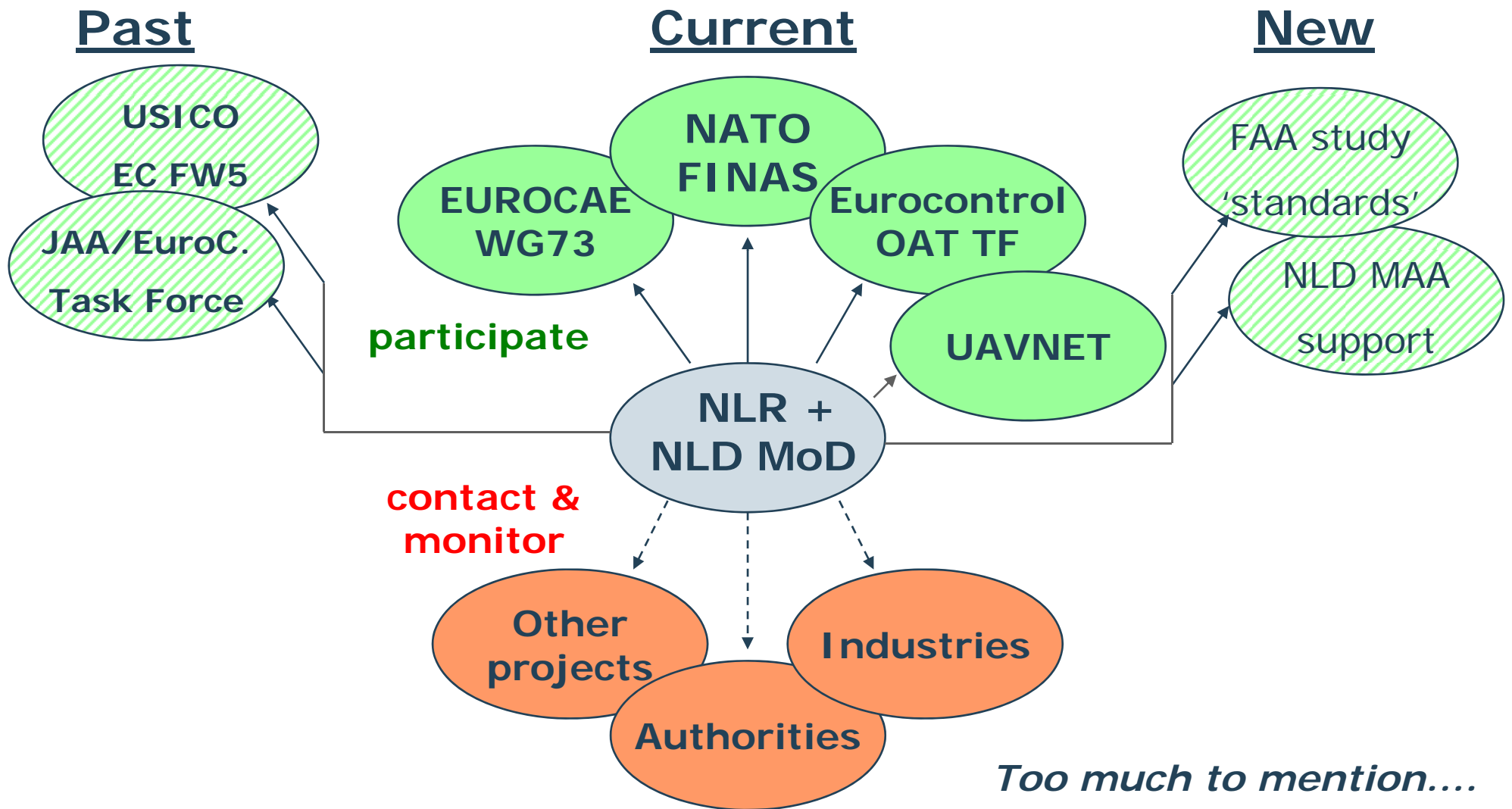
Phasing

1. Requirements Capture
2. Demonstrator Development
3. Flight Test
4. Analysis & Report



NTP OUTCAST

“Work National, Think Global”



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

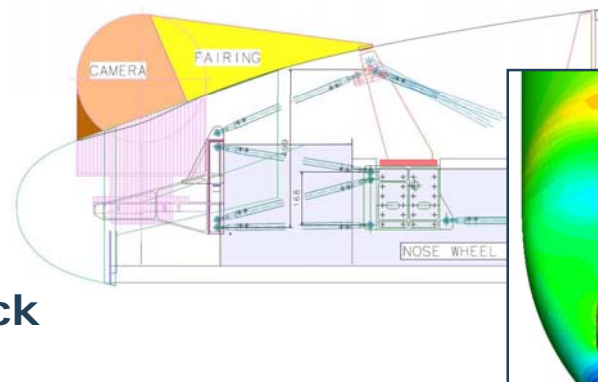


Demonstrator Development by NLR

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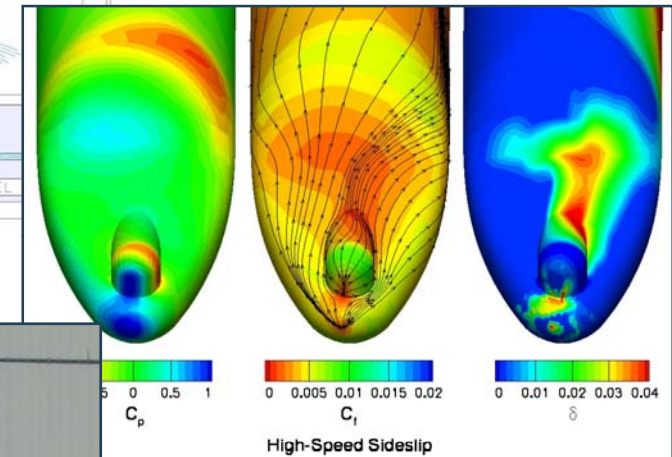
EO/IR Camera

- 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

Intruder aircraft

Pilatus PC7
(~ general aviation)



Fokker 50
(~ transport a/c)



F-16
(~ fighter)



Roaming Flights

Variety of Air Traffic Encountered (Examples)

C4I PWND STOW MENU
 AZ -033
 EL 017
 001 12:19:15:019
 CCD

 NAR
 FULL

 OFST
 ADJ OFST
 VID SEL IN3
 12:19:14 general aviation

C4I PWND STOW MENU
 AZ -019
 EL 008
 001 12:53:20:579
 CCD

 NAR
 FULL

 OFST
 VID SEL IN3
 12:53:19 airliner

C4I PWND STOW MENU
 AZ 105
 EL 000
 001 08:17:11:773
 CCD

 NAR
 FULL

 VID SEL IN3
 08:17:11 helicopter

C4I PWND STOW MENU
 AZ -098
 EL -005
 001 12:37:11:904
 CCD

 NAR
 FULL

 VID SEL IN3
 12:37:10 gliders

Project Results

S&A Requirements

- ▶ Equivalent Safety
- ▶ Sensor Coverage
- ▶ Separation Minima
- ▶ Level of Automation

OUTCAST System Performance

- ▶ Detect
- ▶ Track
- ▶ Situational Awareness
- ▶ Conflict Resolution



**“However beautiful the strategy,
you should occasionally look at the
results”**

Sir Winston Churchill



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

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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?

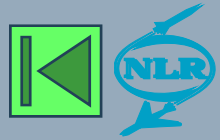


*Hard questions will be
sensed and avoided!*



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The Equivalent Level of Safety... ... does it exist?



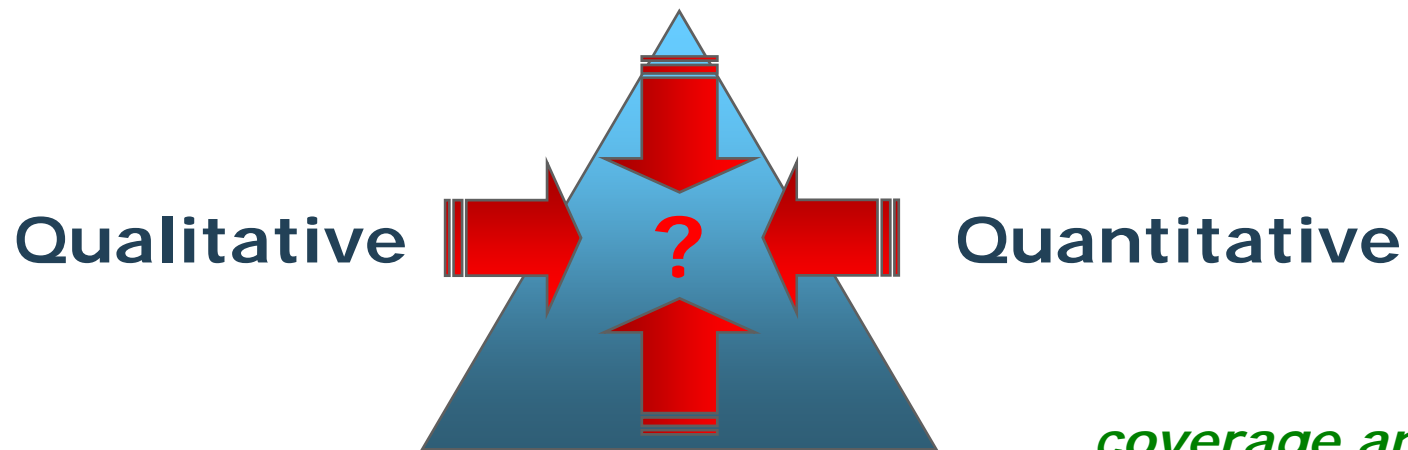
Not well defined in manned aviation!

- *What is it?*
- *How do we achieve it?*
- *How do we prove it?*



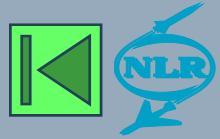
⇒ Acceptable level of safety

'do no harm' safety case ↔ **Top down** ↔ *collision risk 10^{-x} / hour*



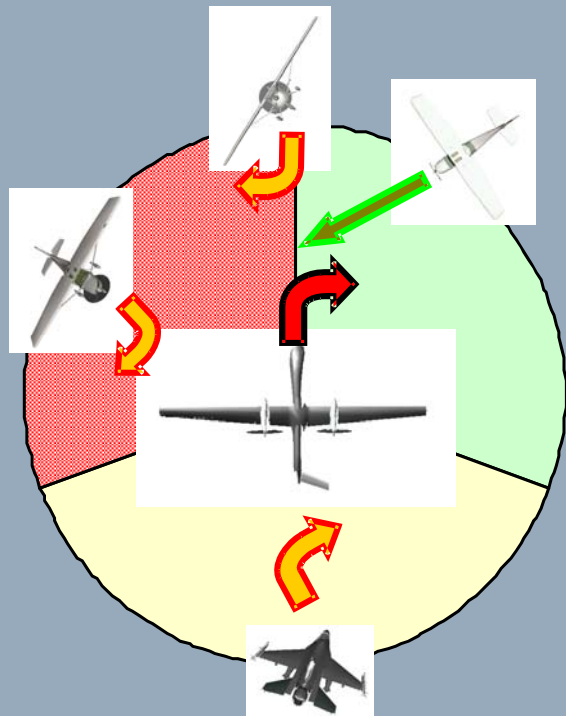
'do no harm' safety case ↔ **Bottom up** ↔ *coverage angles, separation minima etc*

OUTCAST Sense and Avoid Requirements Coverage



Azimuth: $\pm 110^\circ$

Elevation: $(\pm 15^\circ \text{ initial})$
 $\pm 20^\circ \text{ final proposal}$

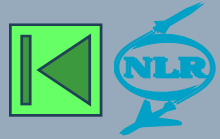


ICAO Right of way rules



OUTCAST Sense and Avoid Requirements

Separation Minima



ATC responsible for separation

Use ATC separation minima

Required for UAS:

- *Transponder, VHF Comms,*
- *UAS pilot supervision*

UAV pilot responsible for separation

No equivalent in manned aviation!

NATO FINAS Proposal:

- *0.5 Nm horizontal*
- *500 ft vertical*

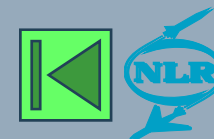
Feedback from OUTCAST flight tests

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

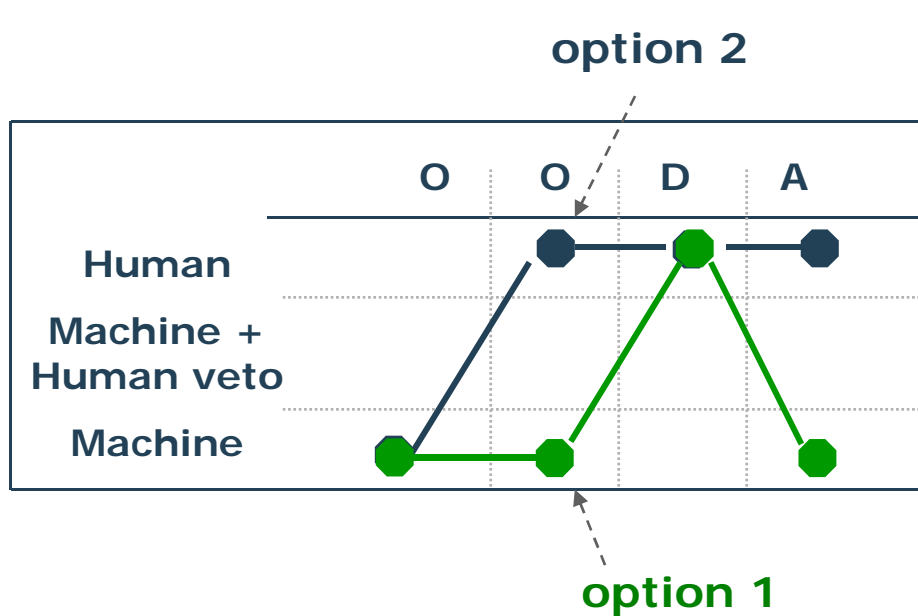
How are such numbers going to be (mis)used by industry?

OUTCAST Sense and Avoid Requirements

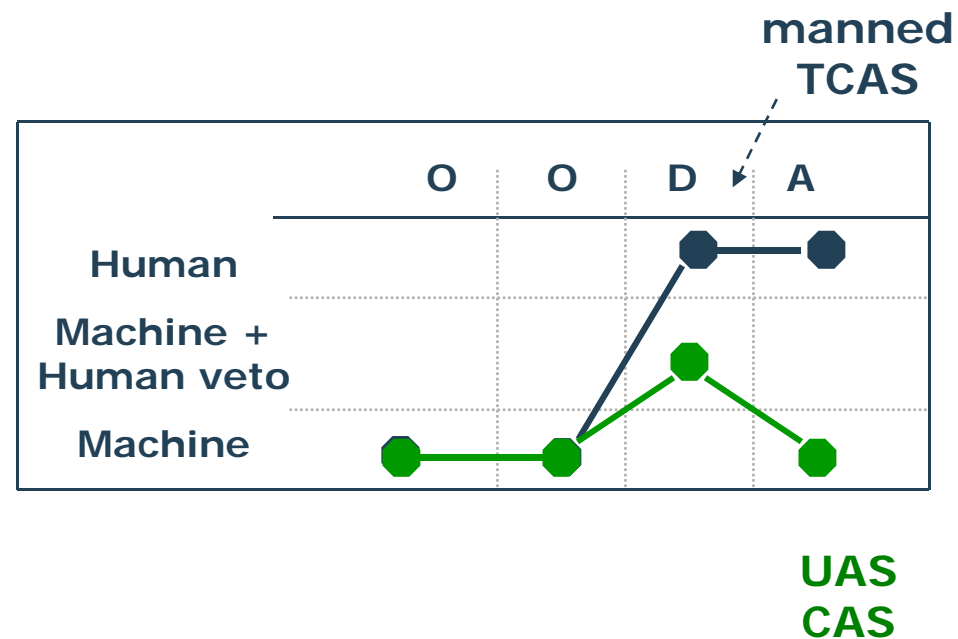
Level of Automation



Self-separation function



Collision Avoidance function



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

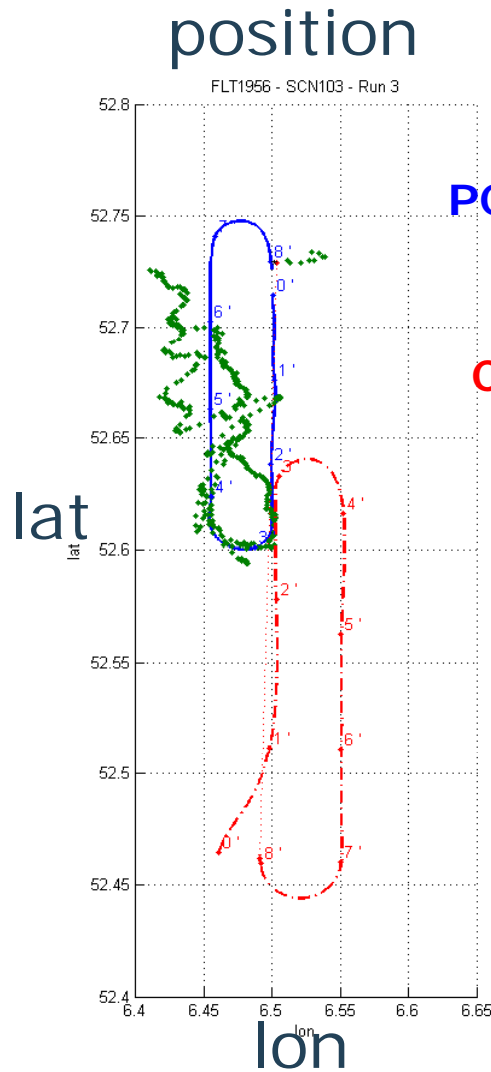
Distance Approx. 16 Nm (30 km)



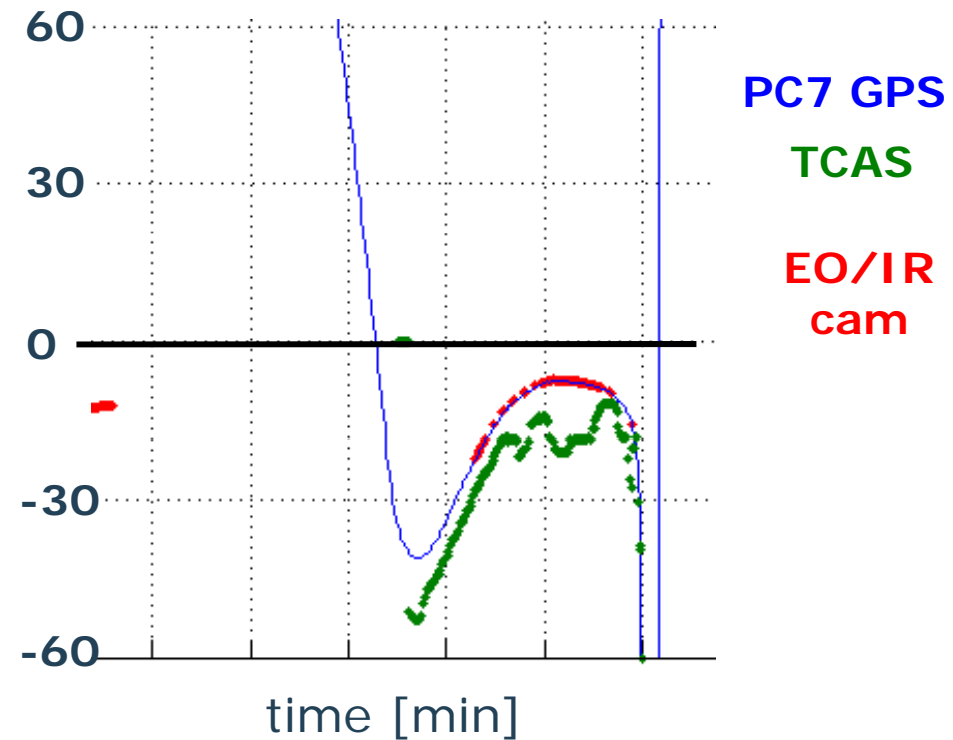
'Pilot Visual' at 6 Nm (11 km)

Tracking Performance - Example

PC7 head-on, TCAS versus GPS and camera



bearing to PC7 [deg]

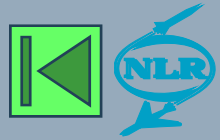


Note:

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

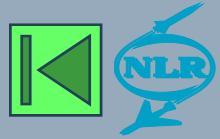
Further study Recommended

- Human Machine Interface
- UAS crew training requirements



Situational Awareness – Traffic Display

Potential for Improvement Identified

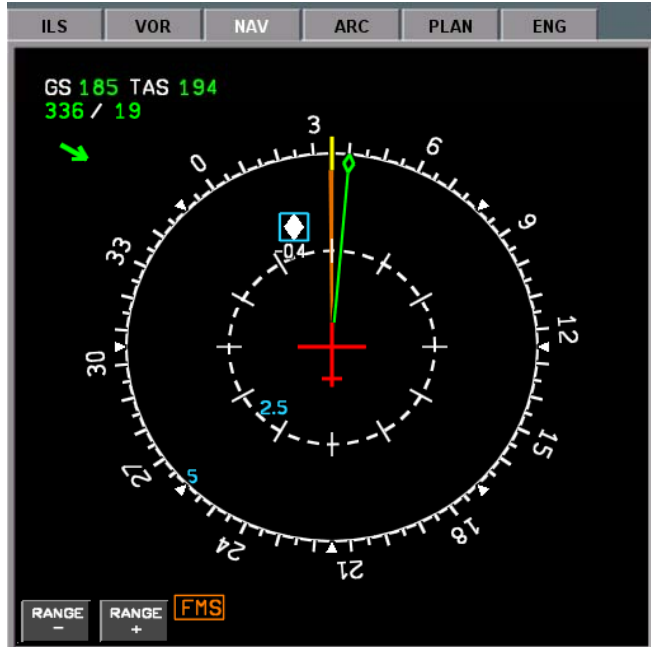


Better information on other traffic by data fusion

- 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