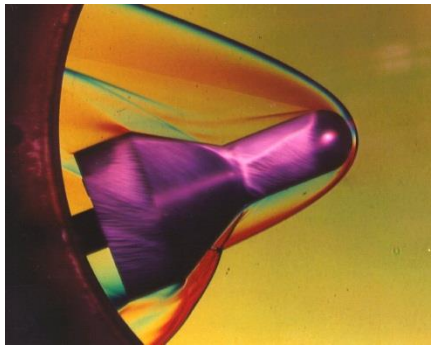
CNS/ATM:
Airborne (Cockpit)
Ground-based (ATC)

TU Delft &
Faculty of Aerospace Engineering

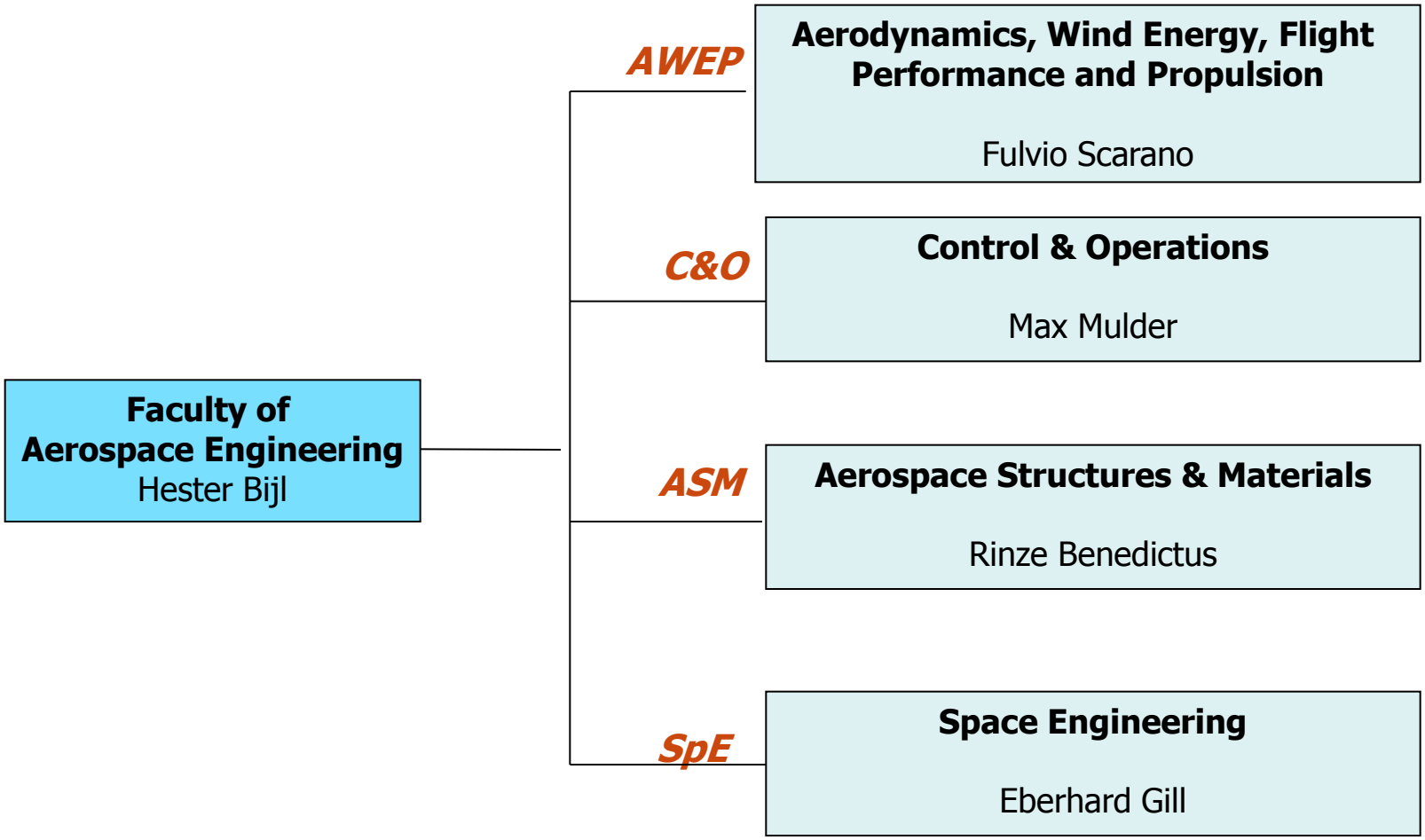


- TU Delft : 19,000 students BSc+MSc
- TU Delft – AE : 2,600 students BSc+MSc

- AE is international faculty, international staff:
  - Fully English taught Bsc, MSc program
- 300 fte faculty staff, 20 full professors

- Research facilities also used in education (incl. BSc):
  - Clean room, Structures, Materials & Chemical labs, Cubesats, Lab aircraft, Flight Simulator, Wind tunnels

Departments of Aerospace Engineering



Organigram C&O Department

- Control and Operations
  - C&O staff
  - Control and Simulation (C&S)
    - CS staff
    - MAVlab
  - Air Transport & Operations (ATO)
    - ATO staff
  - PH-LAB
  - SIMONA





Overview section
Control and Simulation (C&S)

- 3 chairs:
  - Aerospace Human-Machine Systems - Max Mulder
  - Communication, Navigation & Surveillance/Air Traffic Management - Jacco Hoekstra
  - Aerospace Guidance, Navigation & Control - Bob Mulder (Em.)

- 16 fte permanent scientific staff

- Facilities:
  - PH-LAB Laboratory Aircraft
  - Simona flight simulator
  - ATC simulation
  - MAVlab
  - Callibration lab

Control and Simulation

Aerospace Human-Machine Systems

Prof. Max Mulder, Dr. M.M. van Paassen

Research

1. Cybernetic approaches to manual control system design
- model multi-modal pilot perception and control
- haptic interfaces, biodynamics, shared control

2. Cognitive systems engineering to design for situation awareness
- ecological flight deck, ecological air traffic control working positions

Projects

VIDI project "Cybernetic approach to simulator fidelity"; STW "Pilot Task Demand Load"; Cleansky JTI "energy management", EUROCONTROL "separation assurance", NISSAN "steer-by-wire", BOEING "balked landing", ACROSS "reduction of pilot stress"

Collaborations

3ME (Biomech. Eng.), NLR, TNO, LVNL, Max Planck IBC, BOEING, NASA, NISSAN, HONEYWELL, EUROCONTROL, To70, GA Tech, Wright State

Control and Simulation

Communication, Navigation, Surveillance / Air Traffic Mgt

Prof. Jacco Hoekstra

Research

1. Foundations of ATM research
- data mining to study traffic flow dynamics
- common open tools, scenarios and metrics in ATM

2. Exploitation of potential benefits of ASAS/ADS-B/CNS
- concepts and systems prototypes development and validation
- improved trajectory prediction techniques or e.g. CD&R

3. Safety of growing general aviation
- improved CNS/ATM devices for today and future GA

4. Mature UAV systems and applications
- pioneer use cases and prototype systems development
- integration into current and future ATM environments

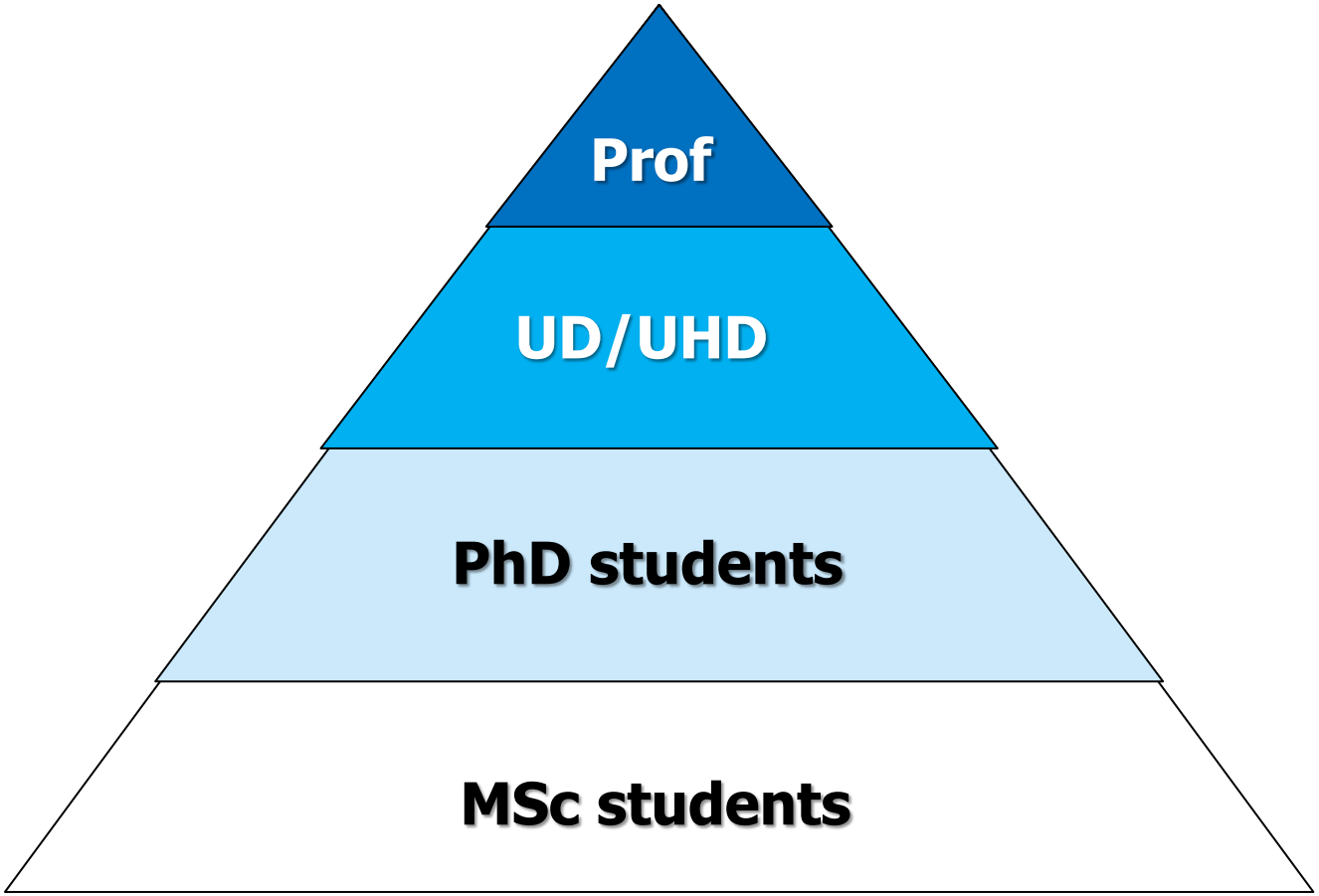
Projects

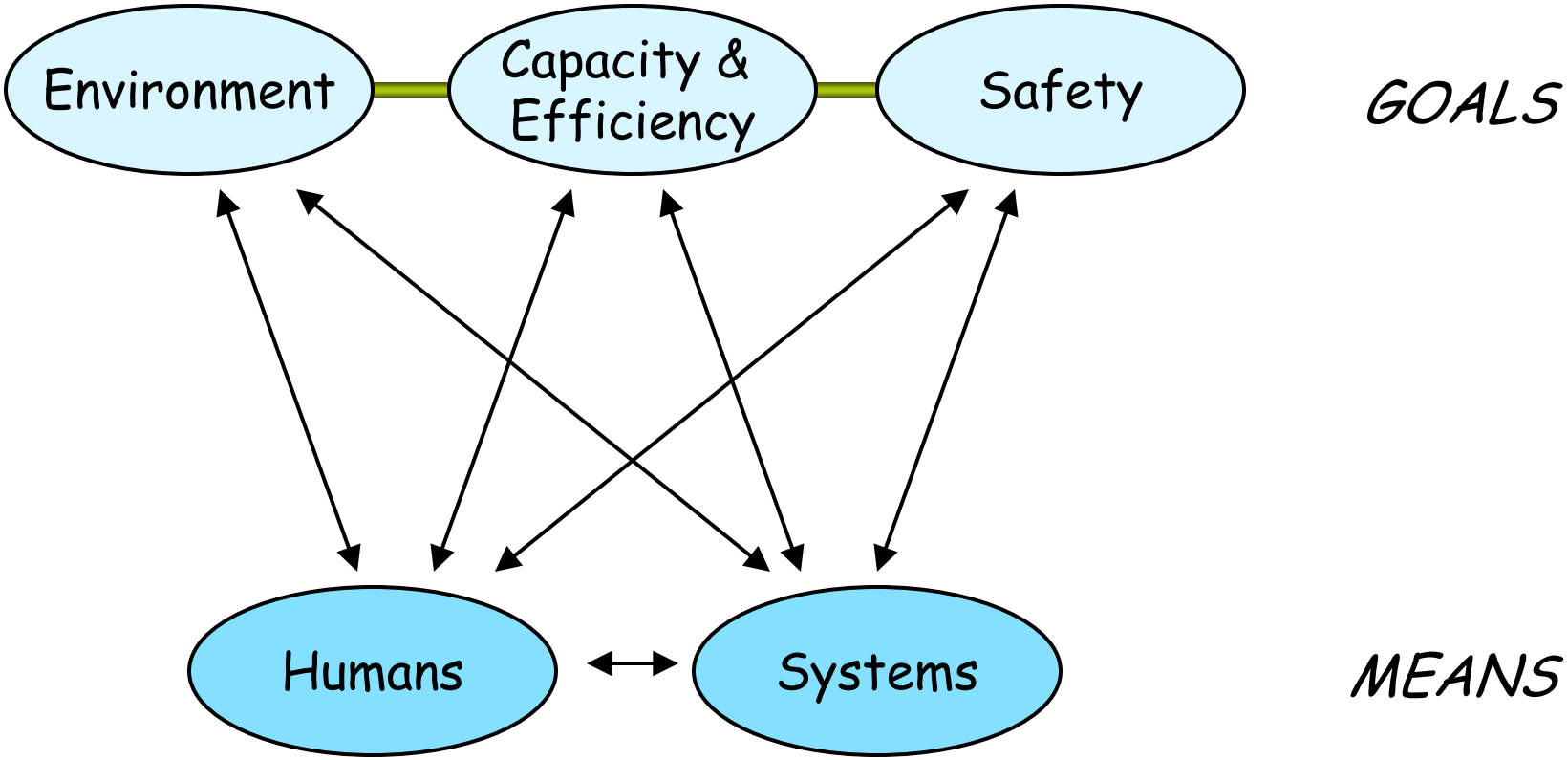
METROPOLIS, Future traffic scenarios, SELFLY, GA radar, UAV sense & avoid

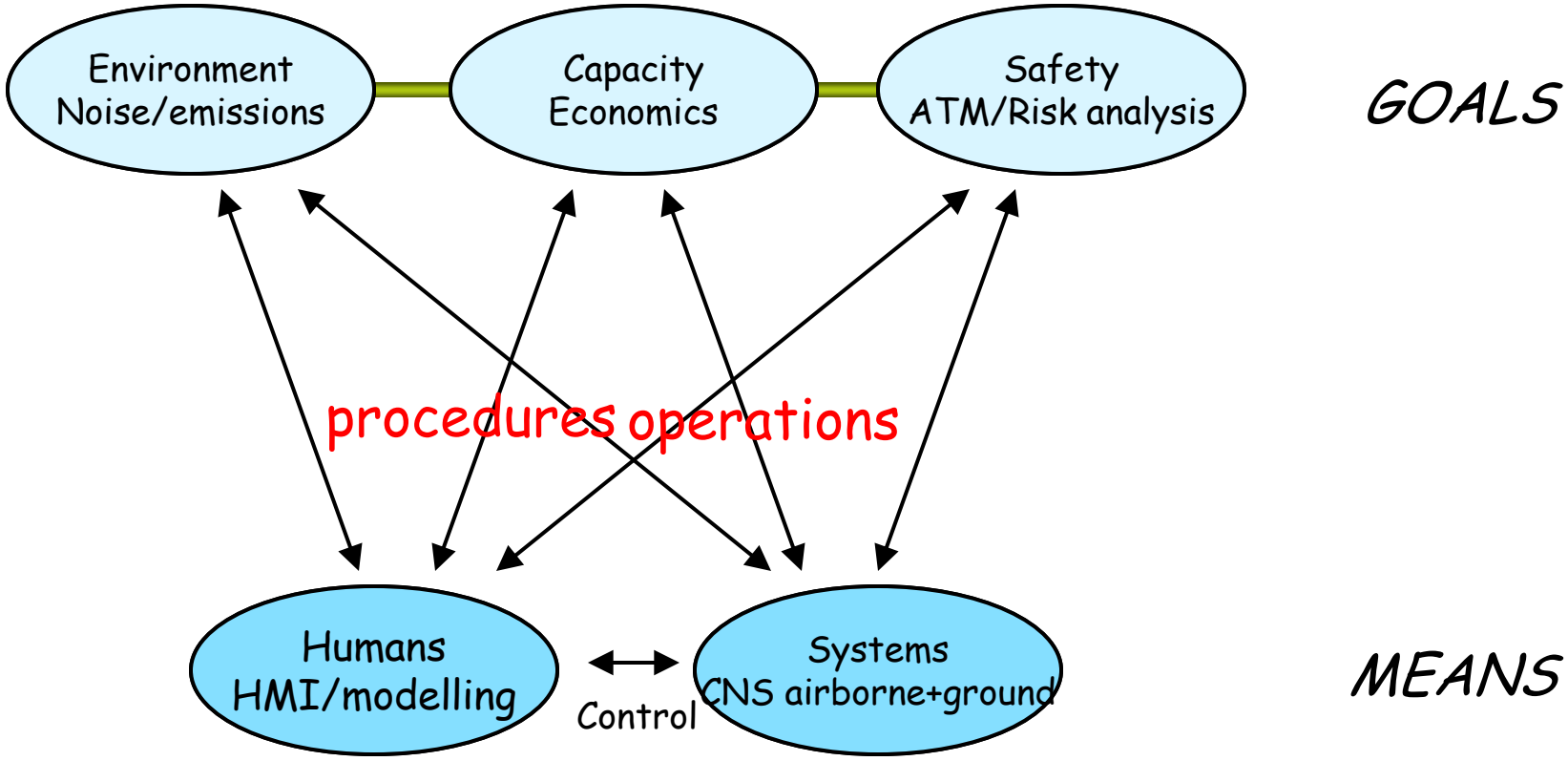
Collaborations

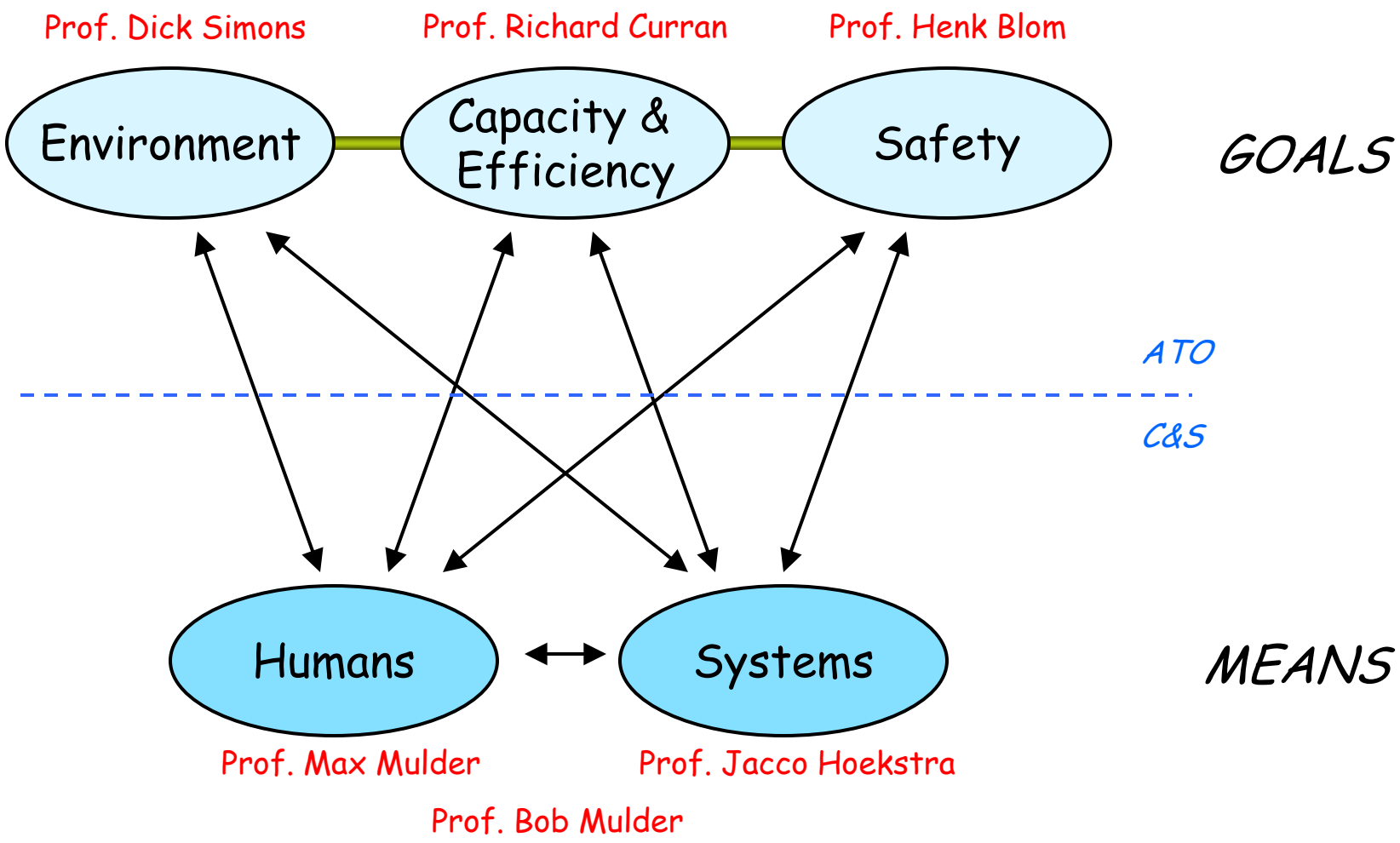
NLR, DLR, LVNL, EUROCONTROL, To70, ENAC, NASA LaRC/Ames, NTSB

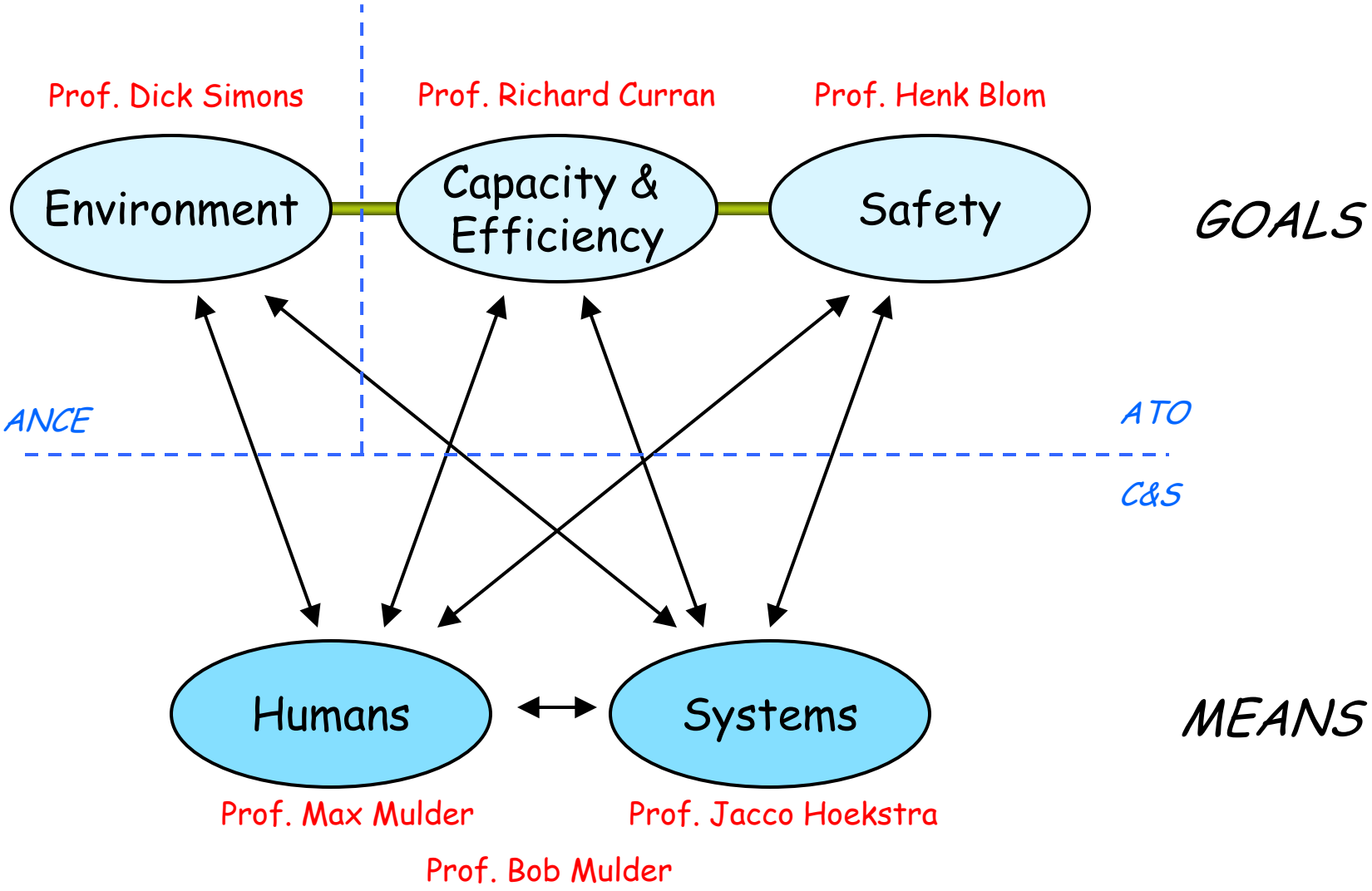
Organisatie van een leerstoel: onderzoek in de pyramide




Environment
Capacity & Efficiency
Safety
GOALS
Humans
Systems
MEANS


Environment
Noise/emissions
Capacity
Economics
Safety
ATM/Risk analysis
GOALS
procedures operations
Humans
HMI/modelling
Control
Systems
CNS airborne+ground
MEANS


Prof. Dick Simons
Prof. Richard Curran
Prof. Henk Blom
Environment
Capacity & Efficiency
Safety
GOALS
ATO
C&S
Humans
Systems
MEANS
Prof. Max Mulder
Prof. Jacco Hoekstra
Prof. Bob Mulder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Systems
MEANS
Prof. Max Mulder
Prof. Jacco Hoekstra
Prof. Bob Mulder


CNS / ATM
Communication, Navigation, Surveillance
Air Traffic Management
"The art of sensing & avoiding traffic, terrain & weather"
"Expedite Traffic Flow in safe & efficient manner"

Trend in research topics over time

Route

Position

State

Air Traffic Management

NASA FF En-Route

PHARE

NASA FF Arrival & Approach

ASAS dev

Avionics

DL HMI

FANSTIC

4D NAV

Off-line
Sim
Flight Test

HUD

MFF

Flight Control System

FMS

INTENT

EFMS AP/ATS modes

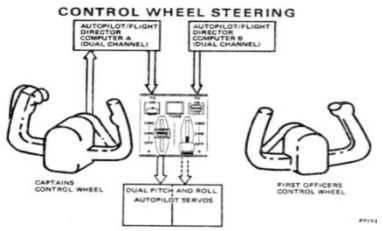
Garteur HQ

CDTI

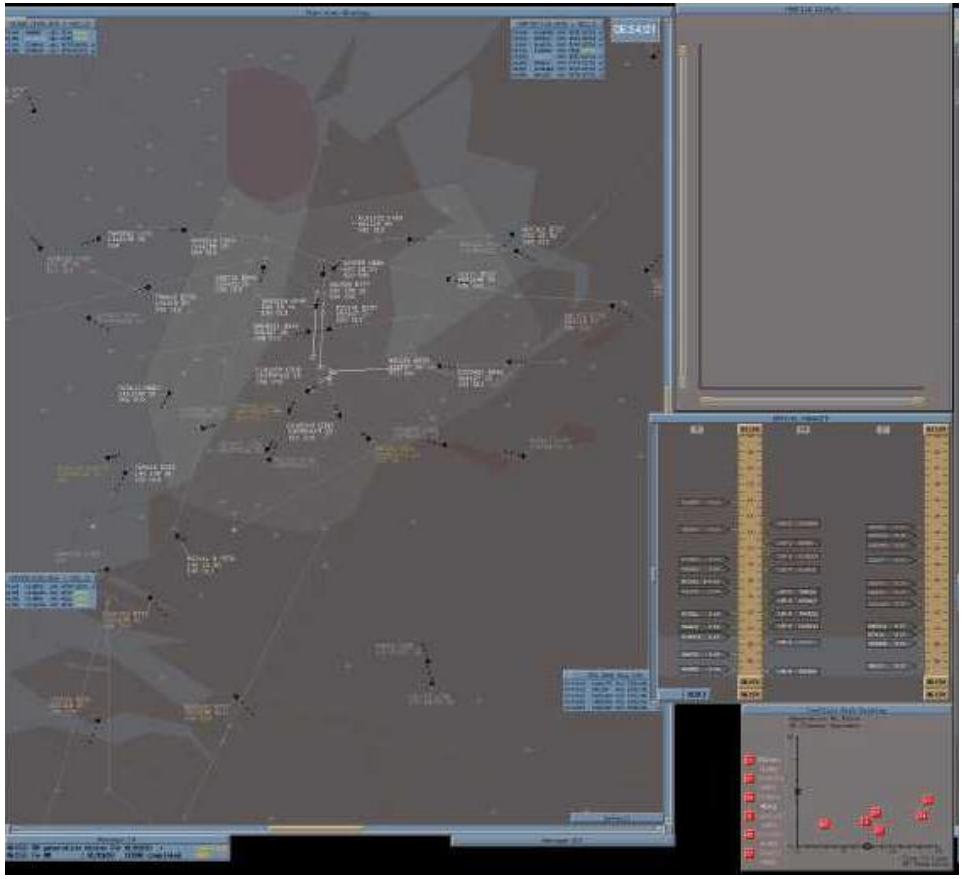
ADFCS-2

ASAS concepts
& gaming effects

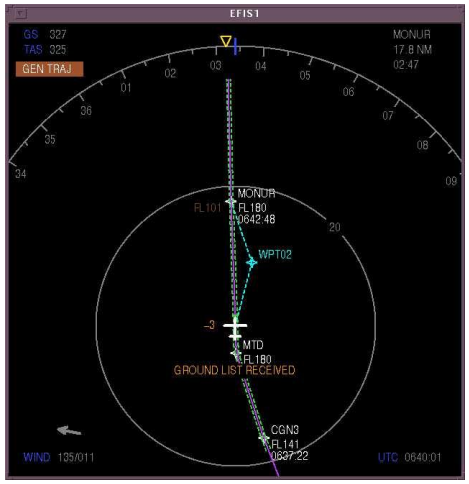
Flight Simulation



Start of my ATM work: PHARE research

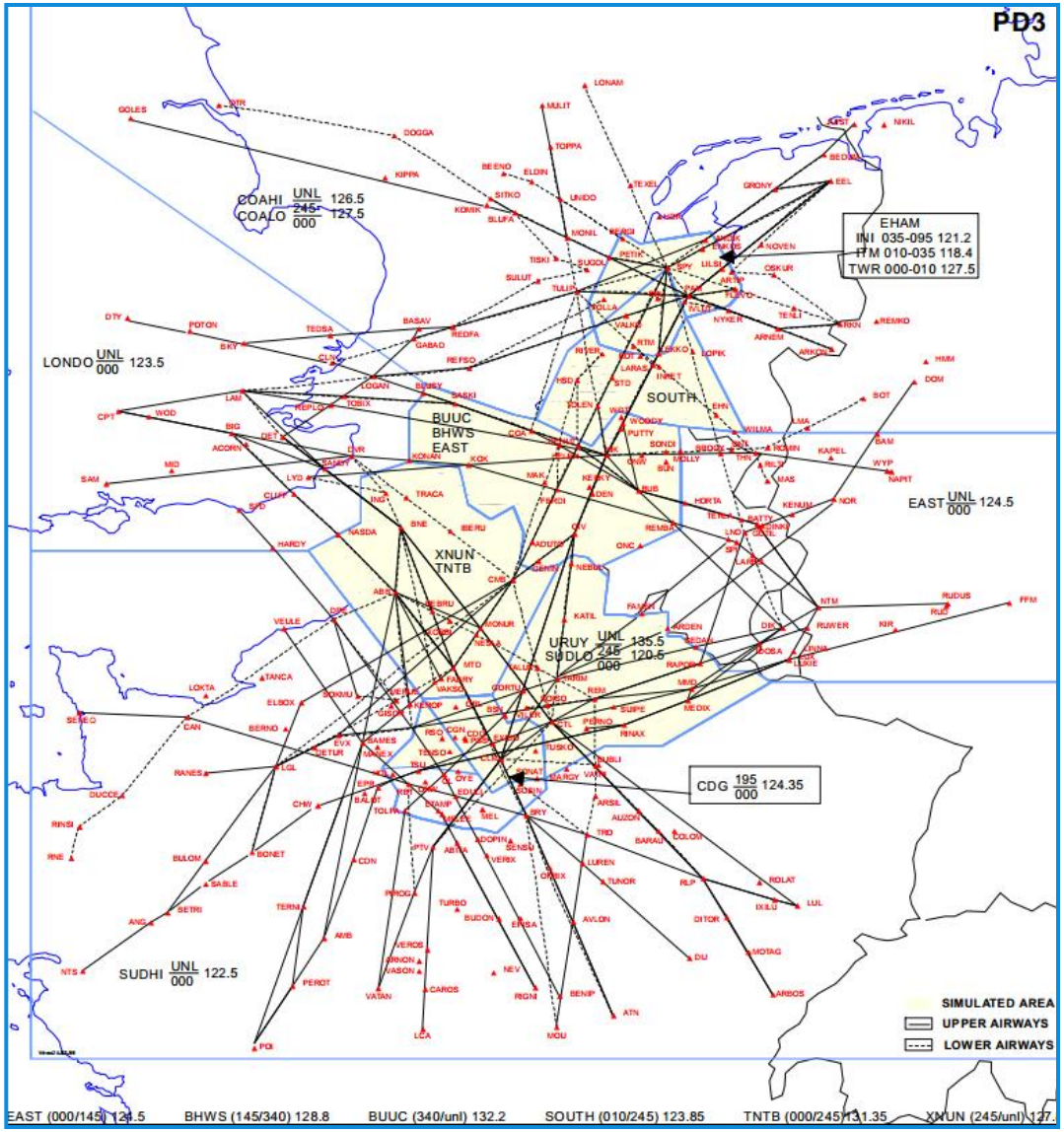


- Conflict free 4D trajectory (HIPS, TEPS, CRD)
- Negotiated safe 4D bubble
- Special FMS: EFMS

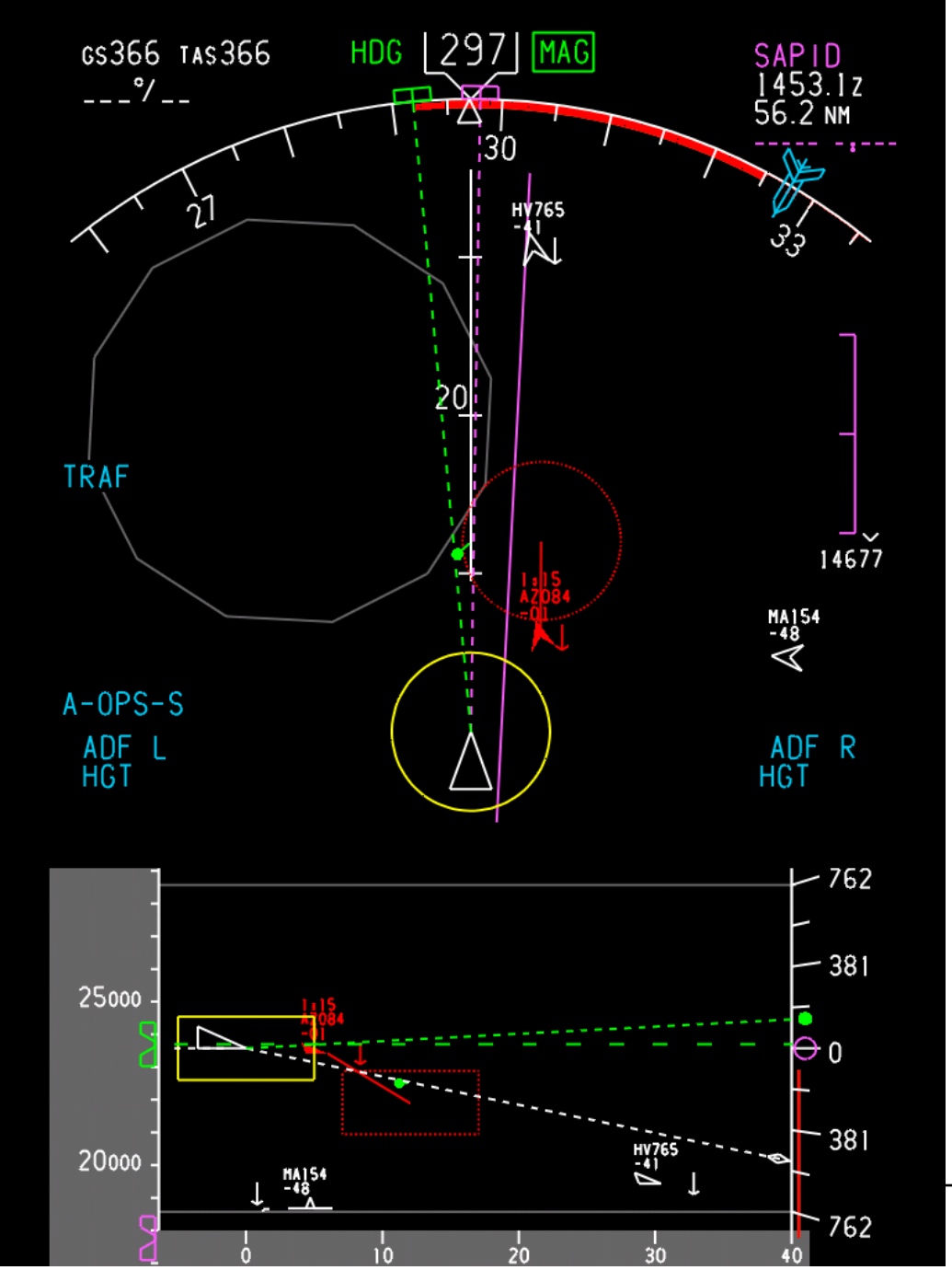


1989 – 1999 PHARE project
Testing the EFMS in the simulator

PD/3 trials

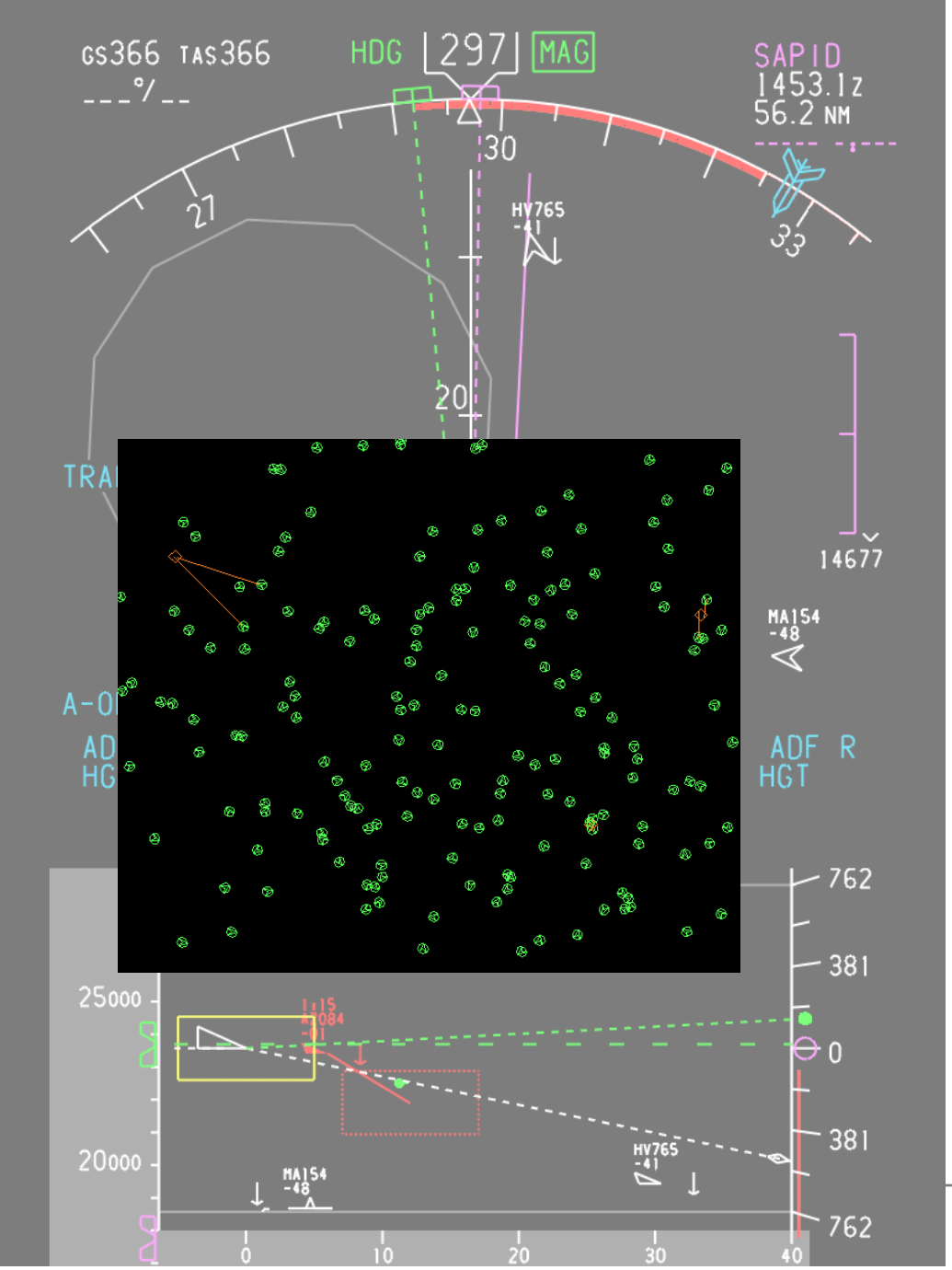


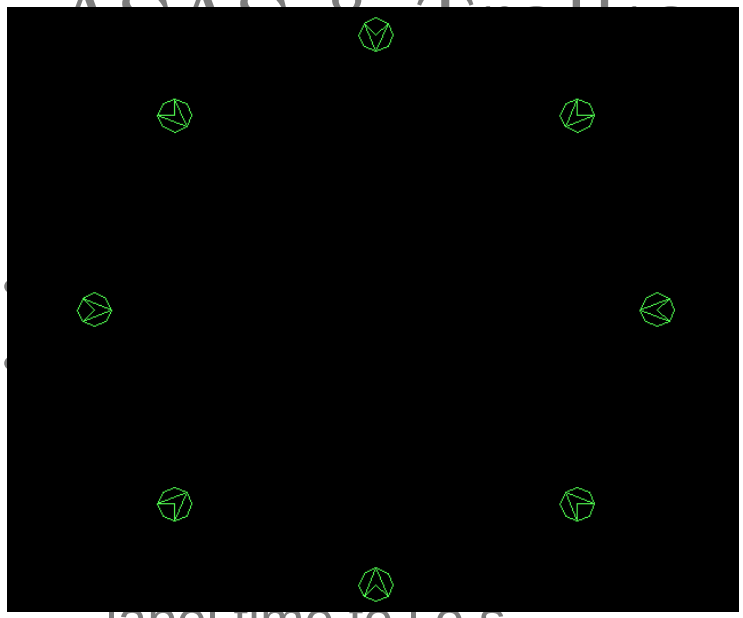
http://www.eurocontrol.int/phare/public/standard_page/PD3.html

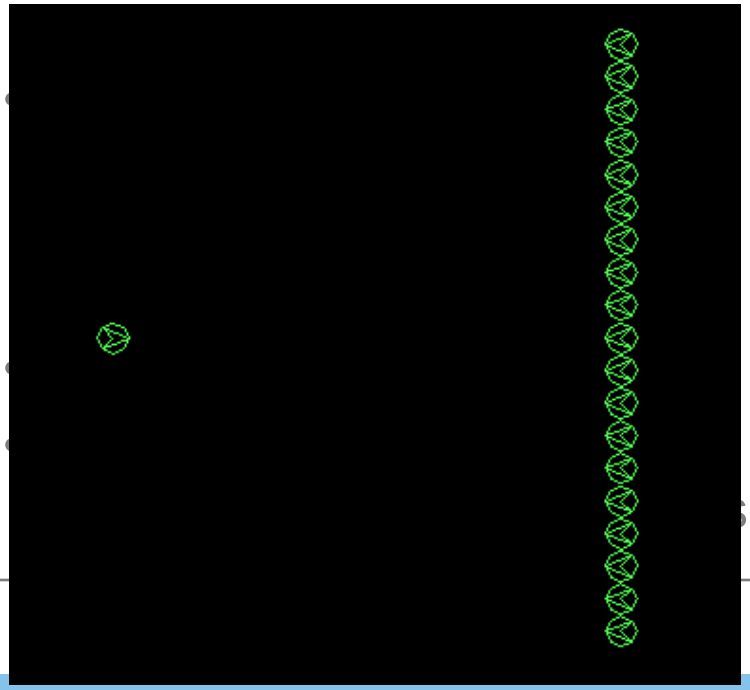


ASAS & Traffic display

- ASAS: 5nm, 5 min, 1000 ft
- Conflict symbology
  - red circle & track
  - yellow circle own zone
  - traffic symbol always
  - label time to l.o.s.
- Resolution symbology
  - horizontal
  - vertical
- Predictive ASAS
- If conflict =>
  first check vertical reso!


GS366 TAS366
HDG 297 MAG
SAPID
1453.1z
56.2 NM
30
27
33
HV765
-41
20
14677
MA154
-48
ADF R
HGT
762
381
0
381
762
25000
20000
0
10
20
30
40





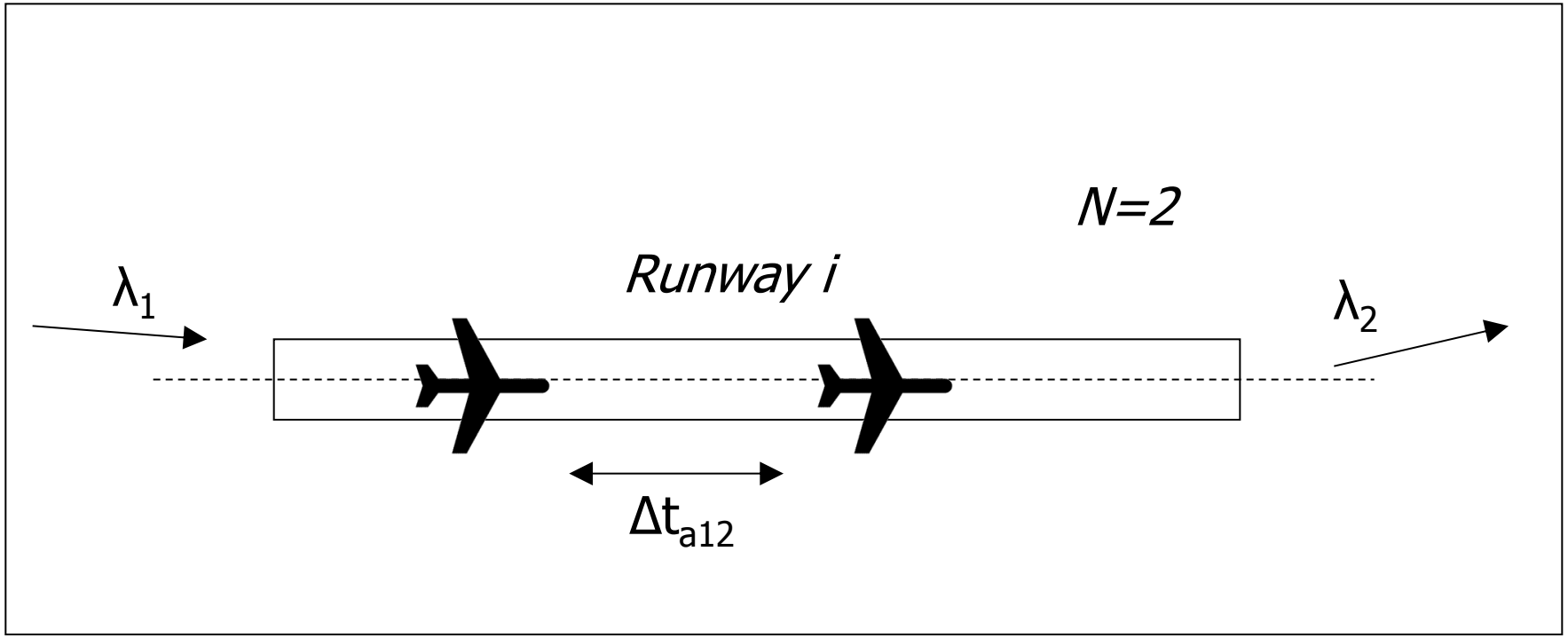
Flight tests: Mediterranean Free Flight (MFF)

- ASAS packages I - III
- Safety analysis
- Air-ground human-in-the-loop simulations
- Multiple ac flight tests of all applications

ATM papers reviewing

“ The AFM-2 is the preferred option for the OPCS when AFDRS is not available in the ACCS. In all scenarios the I-IAA was higher with ARRS switched on.”

ATM papers reviewing



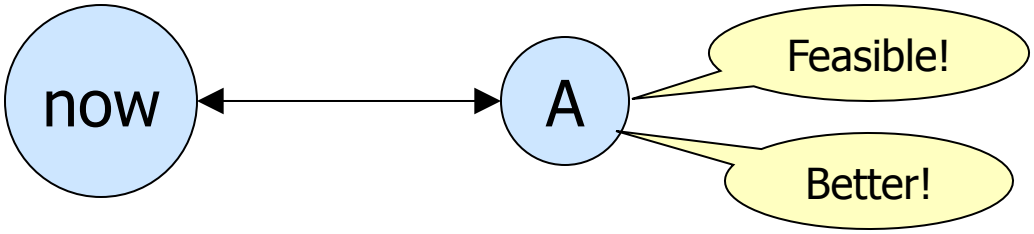
Imagine a physics paper…

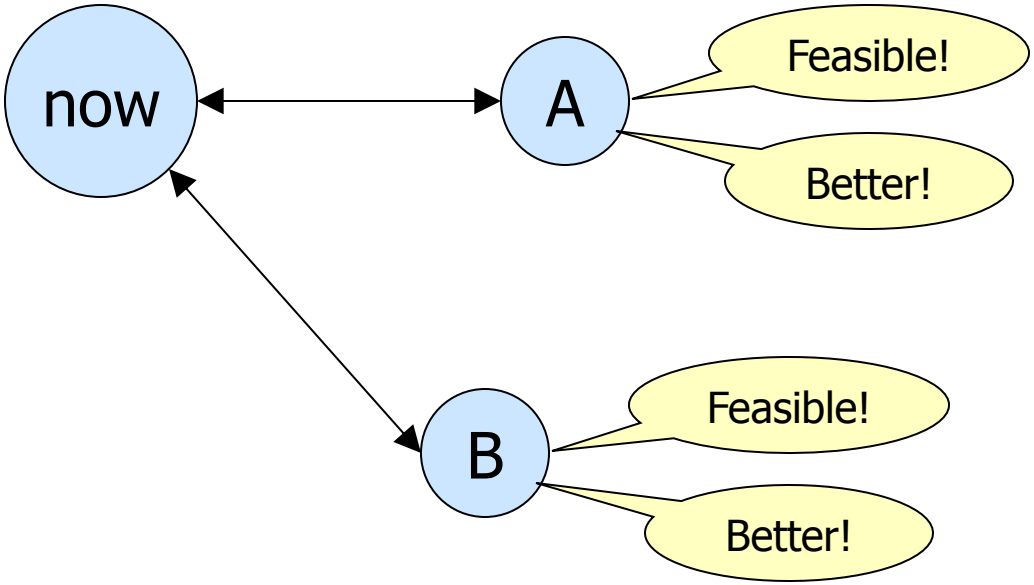
Assume we have a certain volume of gas in a container. This gas has many molecules. All molecules hit the walls with different speeds. This causes a force on the walls of the container perpendicular to the surface. This total normal force on the wall of the container divided by the surface area of the container we call the pressure with symbol *p*.

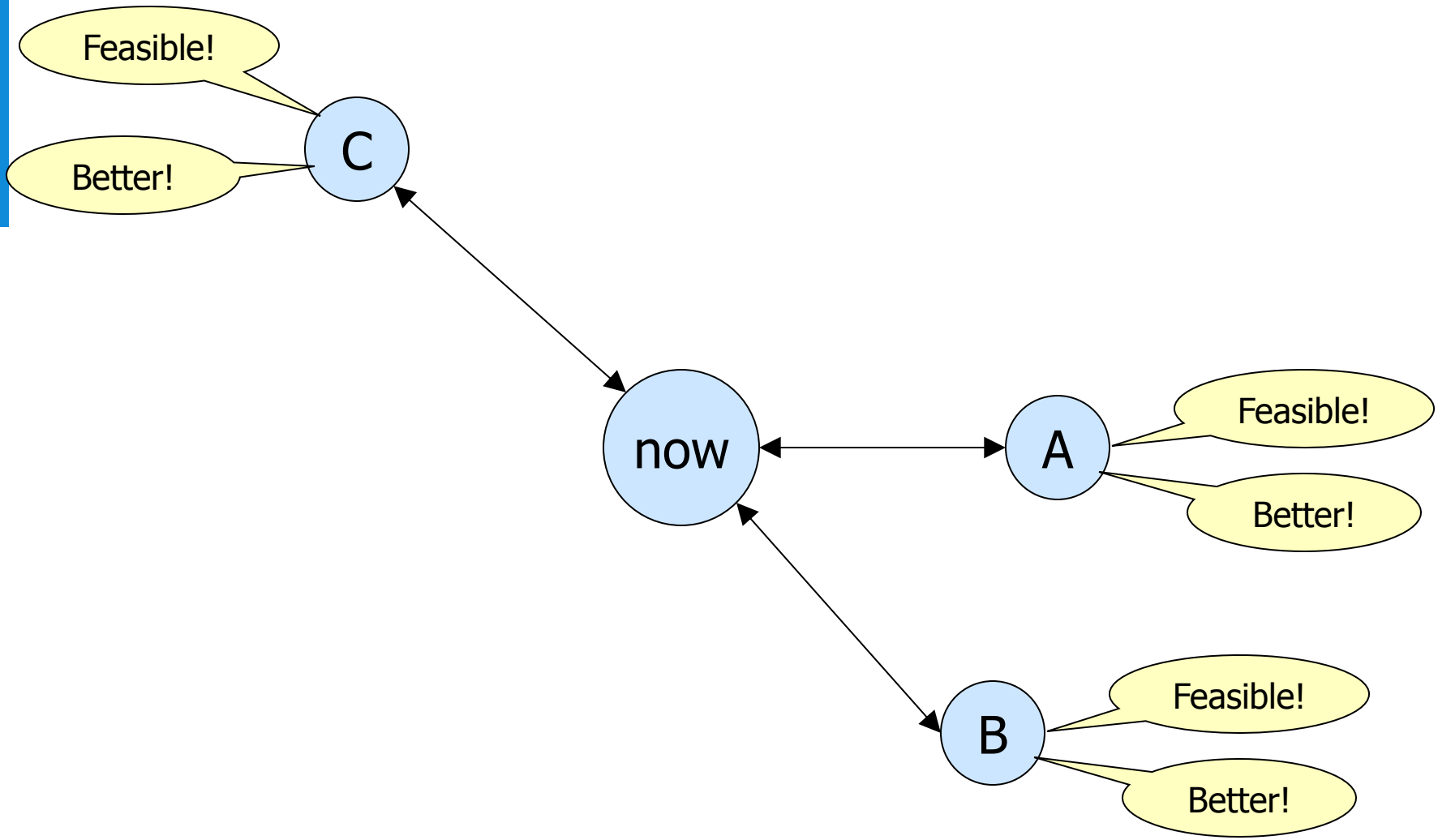
$$p = \frac{\text{force}}{\text{area}}$$

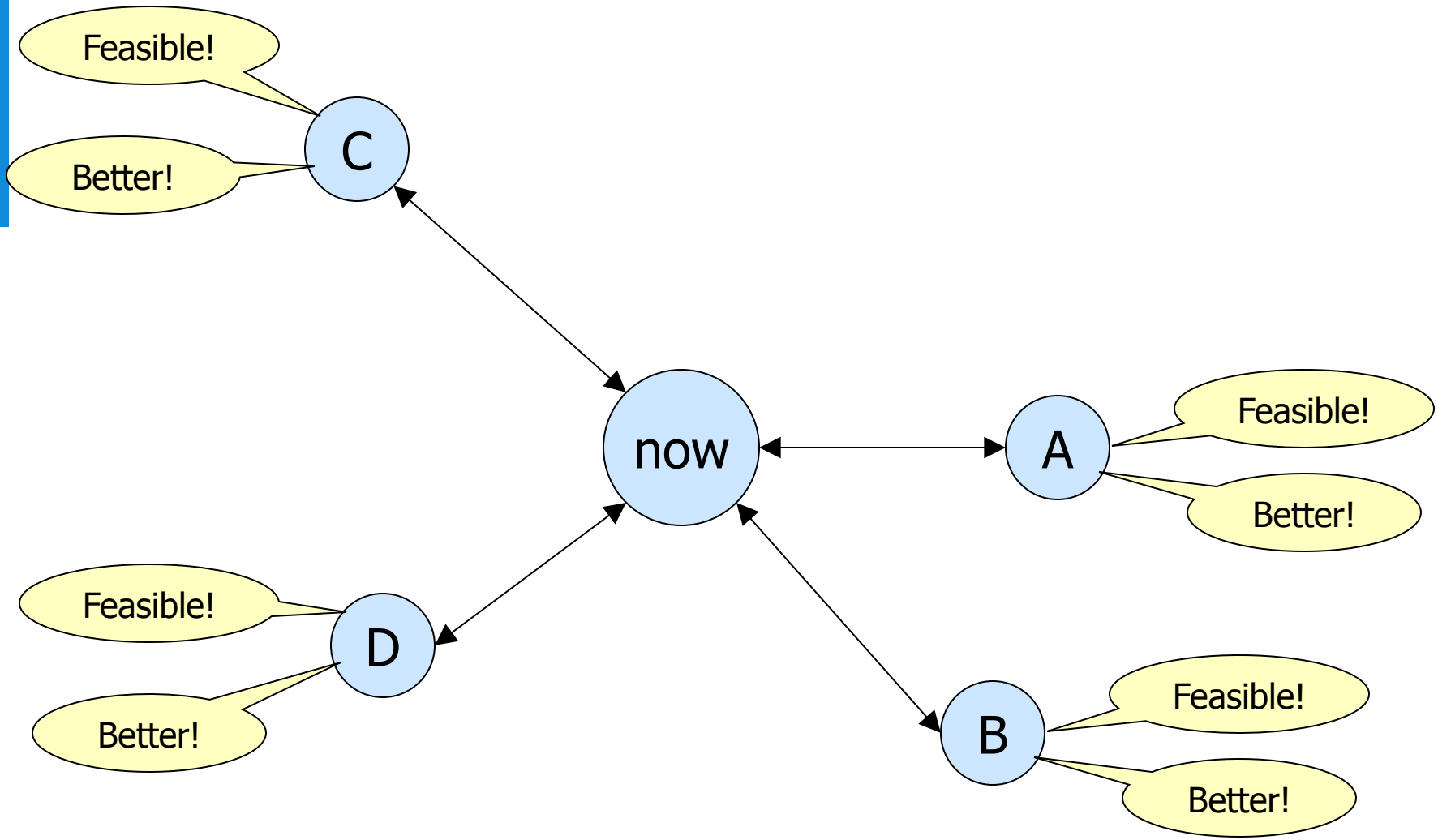
The amount of gas in terms of mass per volume we call density with the symbol ρ (rho). The kinetic energy of the molecules……

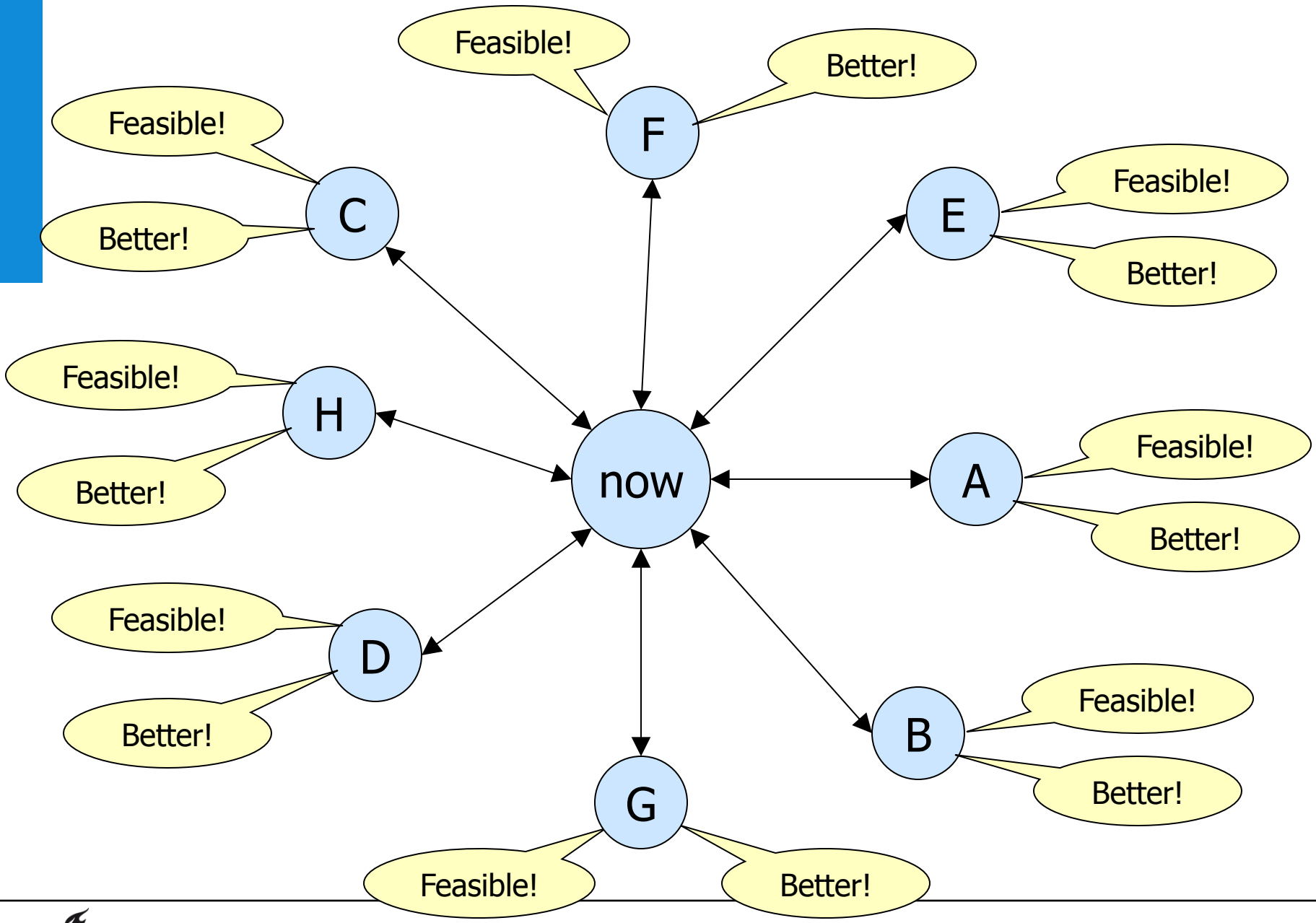
Current status of ATM Science



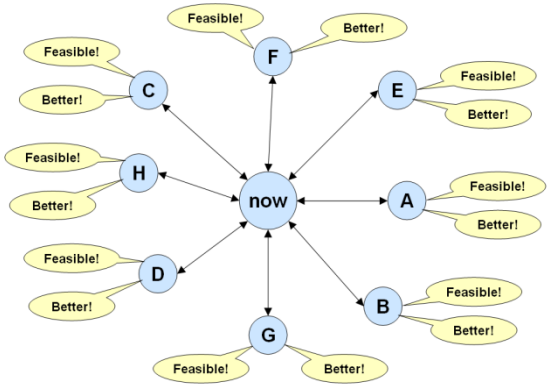

now
A
Feasible!
Better!
B
Feasible!
Better!


Feasible!
Better!
C
now
A
Feasible!
Better!
B
Feasible!
Better!


Feasible!
C
Better!
now
A
Feasible!
Better!
Feasible!
D
Better!
B
Feasible!
Better!


Feasible!
Better!
F
Feasible!
Better!
C
Feasible!
Better!
E
Feasible!
Better!
Feasible!
Better!
H
now
Feasible!
Better!
A
Feasible!
Better!
Feasible!
Better!
D
Feasible!
Better!
B
Feasible!
Better!
G
Feasible!
Better!

How to compare them?



1. Foundation definition

   - Metrics & definitions, common language
   - Higher level of abstraction

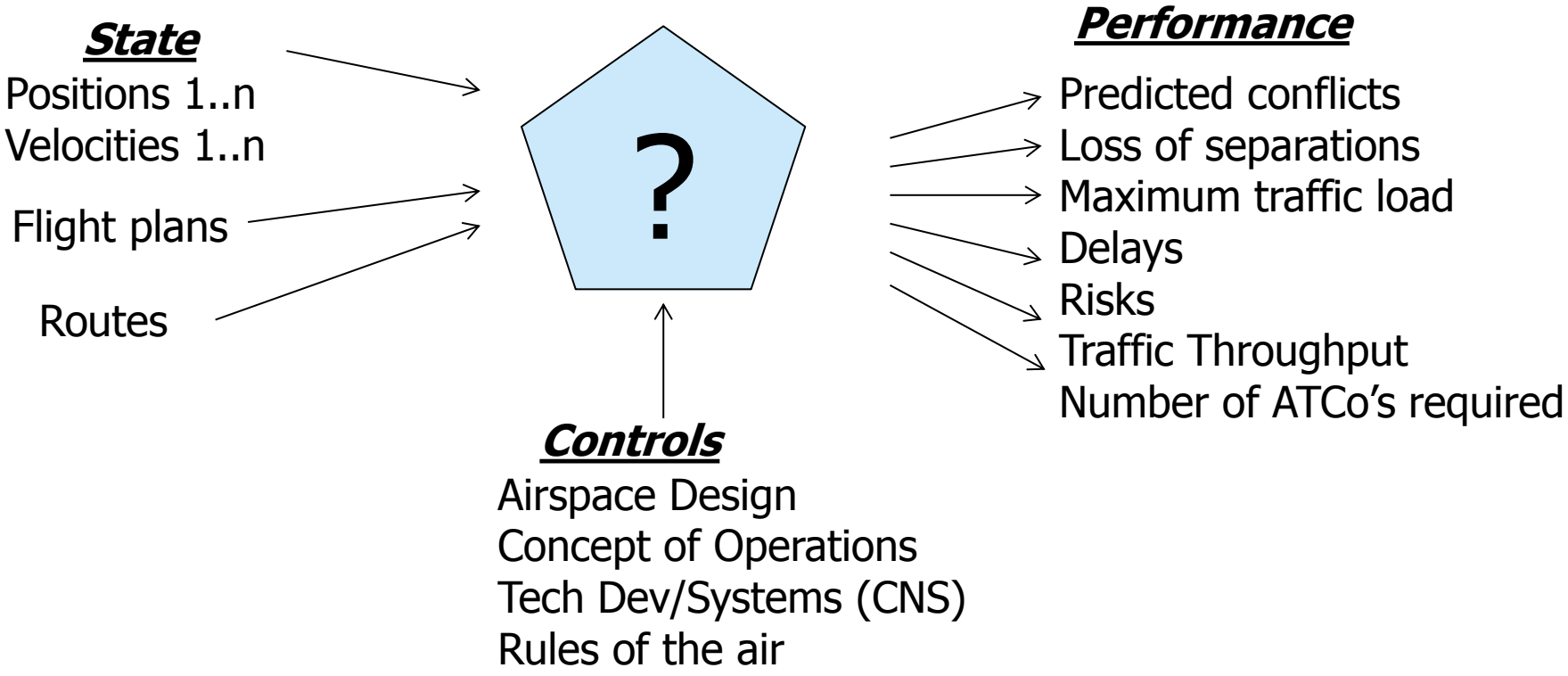
2. Foundation implementation

   - Benchmark scenarios, share results & data
   - Open (source & data) innovation and tools

Enables:

- Advancing by building on each others' research
- (Still) Provide many innovative concepts & tools bottom-up, but now with their rated, validated and comparable performance

Fundamental definitions

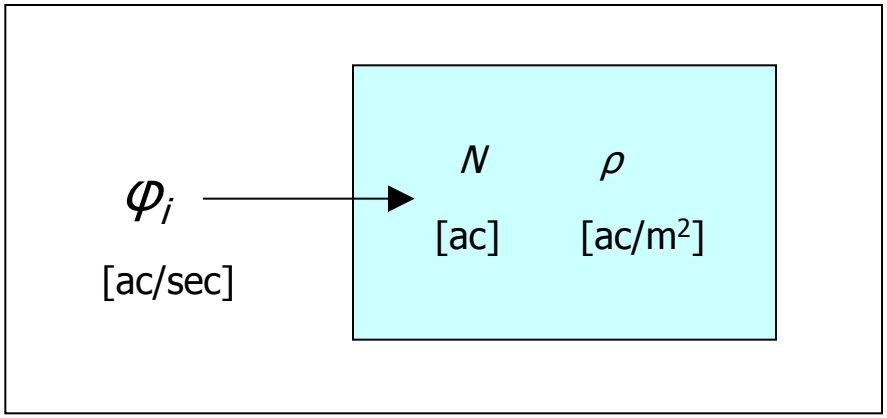


Common Model Based Metrics

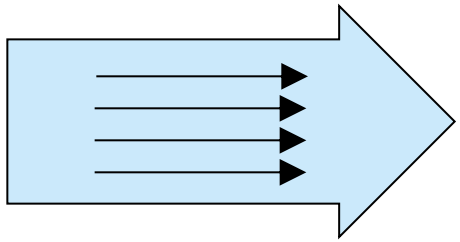
- Goal: A globally accepted general system description of ATM with a level of abstraction that, in a generic way, connects ATM state and ATM control variables with the ATM performance

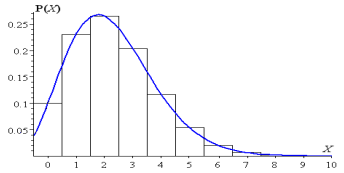
Understand Traffic Flow Dynamics

- Establishing traffic complexity metrics
- Evolution over time of traffic complexity metrics
- Predictive value of traffic complexity metrics
- Improve Traffic Flow Management under uncertanties



Applicable abstraction required





Research Questions Foundation theme

- How can we benchmark and compare different systems & concepts (4D contracts/ASAS, FAB, ADS-B, CDAs, etc.) in an open and transparent way? Which scenarios/tools?
  - Scientific Method: Common Metrics/Scenarios/ etc.
  - Blue Sky Open ATM Sim, Data Mining etc.

- Traffic Flow Dynamics:
  - Dynamic behaviour of traffic complexity, close the control loop
  - Uncertainties: effect on trajectory/traffic flow predictions

- Other fundamental questions like:
  What is the basis of the current separation criteria? How is (or should it be) built up? Are they sufficient?

CNS/ATM Research Themes

- **Theme 1: ATM Foundation -** What is foundation of ATM?
  - *Use a.o. common open tool and scenarios to establish this*
  - *Data mining (ADS-B, radar data, Ectl PRC, etc.) to study traffic flow dynamics*

- **Theme 2: Surveillance -** How to exploit benefits of ASAS/ADS-B?
  - *Concept & System prototypes development & validation*
  - *Improved Trajectory Prediction techniques, for CD&R*

- **Theme 3: GA CNS -** How can we improve the safety of growing GA?
  - *Improved CNS/ATM dev & flight test for today and future GA*

- **Theme 4: UAV CNS -** How to mature UAVs systems and applications?
  - *Pioneer use cases and prototype system development, flight tests*
  - *Integration into ATM system*

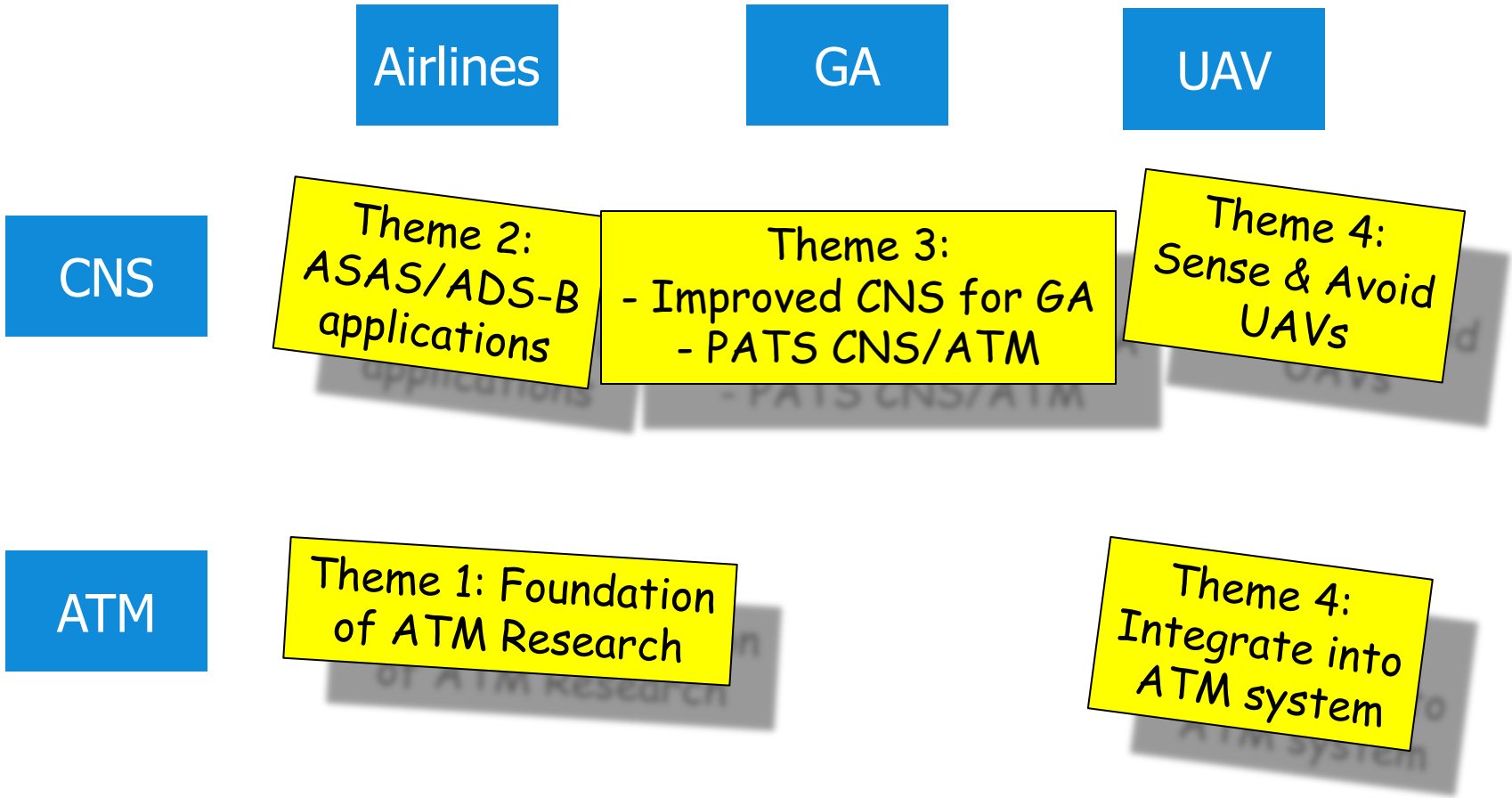
- **Theme 5: Schiphol/NL – Advanced CNS/ATM for a mainport**

Theme 5:
growing new plants in the garden

- Schiphol/NL related topics such as:
  - CDO's
  - Exploring Bird Radar Advisory tool @ Schiphol with Robin Radar
- New ideas:
  - ……
  - …….
  - Following meetings/brainstorms with staff members
- Any new topics arising from opportunities with partners or programmes

CNS/ATM

Communication, Navigation, Surveillance/Air Traffic Management



Current PhDs at CNS/ATM chair

Theme 1: Foundation

- Emmanuel Sunil – Relation Airspace Structure & Capacity
- Julia Rudnyk – Medium Term Conflict Detection
- Edu Gallo – Trajectory Prediction
- <open> - Trajectory Generation in 4D problem space
- <open> - Open Source/Open Data ATM Validation Tools (BlueSky/Ahmed)

Theme 2: ADS-B

- Junzi Sun – ADS-B model parameter estimation

Theme 3: GA

- Jerom Maas – Modelling GA Radar based Avionics Suite
- Ronald van Gent – GA Sense & Avoid/ EVFR Radar

Theme 4: UAVs

- Yazdi Ibrahim Jenie – UAV Sense & Avoid
- Lodewijk Sikkel – APRA/PID, Sense & Avoid + robust controller
- Ewout Smeur – Delphi Sensing

Theme 5: Schiphol related

- Isabel Metz – Deterministic Effects of Bird Radar for ATC

Current MSc-Students

- Ted Verbraak - Quality assessment of ADS-B data
- Mazin Inaad- ADS-B analysis of CDO's at Schiphol
- Thijs Gloudemans - Flight envelope modeling from ADS-B historical data
- Thom Langejan- ADS-B uncertainty and CD&R
- Martijn Tra -Airspace structure and conflict probability
- Pieter Danneels - New Complexity Metric for Traffic Scenarios
- Alexander Vanwelsenaere - Departure info of secondary airports for XMAN
- Kevin Lamers - Delfly Obstacle Avoidance
- Daphne Rein-Weston - 4D planning using graph search methods
- Marc van Horssen – LHR concept op Schiphol

Projects per theme

Theme 1: Foundation

BlueSky

Ahmed

Airspace Structure vs. Capacity

(Metropolis+follow-up)

Traffic Predictability

Medium term Conflict Detection

Pop-up flights and E-AMAN

Theme 2: ADS-B applications

ADS-B data for a/c performance models

ADS-B Raw Quality analysis

ADS-B models for ASAS

ASAS algorithm comparison

Theme 3: General Aviation

Air-to-air radar for GA for ATSAW

Radar based avionics suite

Theme 4: UAV

Micro-UAVs sense & Avoid

Theme 5: Schiphol Related

Upstream Delay absorption

Bird radar for ATC

Continuous Descent Approach Effects

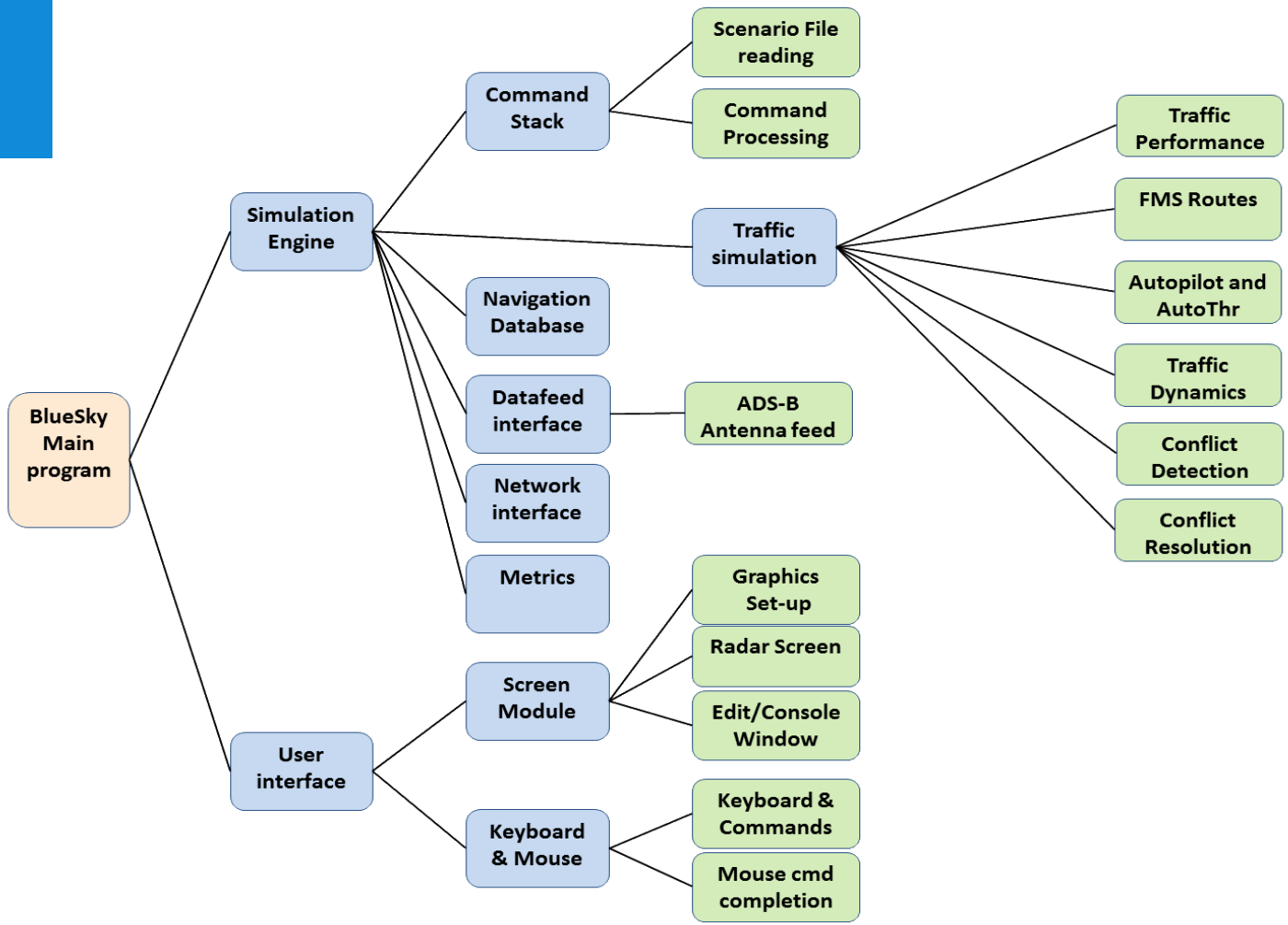
BlueSky Project

Theme 1: Foundation

One enabler: Open ATM simulator

- ATM simulator developed in readable, open source, multi-platform language (Python)
- Using publicly available data for a/c perform
- Downloadable for free with benchmark scer
  third party software
- Open Development like Wikipedia, TUD/ASI
- Focus on Europe and US
- Establish user base among universities using ASDA . Also coop with A1-One, Eurocontrol, FAA, NASA etc.
- Build working prototype first, start community bottom-up

BlueSky Open ATM Sim



TrafScript: generic scenario language

```
CRE acid,type,lat,lon,hdg,alt,spd
ALT acid,alt/FL
SPD acid,CAS/Mach
ADDWPT acid,navaid/latlon[,alt,spd,afterwp,rta]
HDG acid,hdg
LEFT acid, hdg
RIGHT acid, hdg
DEST acid,apt/latlon
ORIG acid, apt/latlon
DEL
MOVE acid,latlon
POS acid
MCRE n, */type,*/alt,*/spd,*/dest
```

Point and click

acid,latlon, navaid,apt, hdg

CRE ?

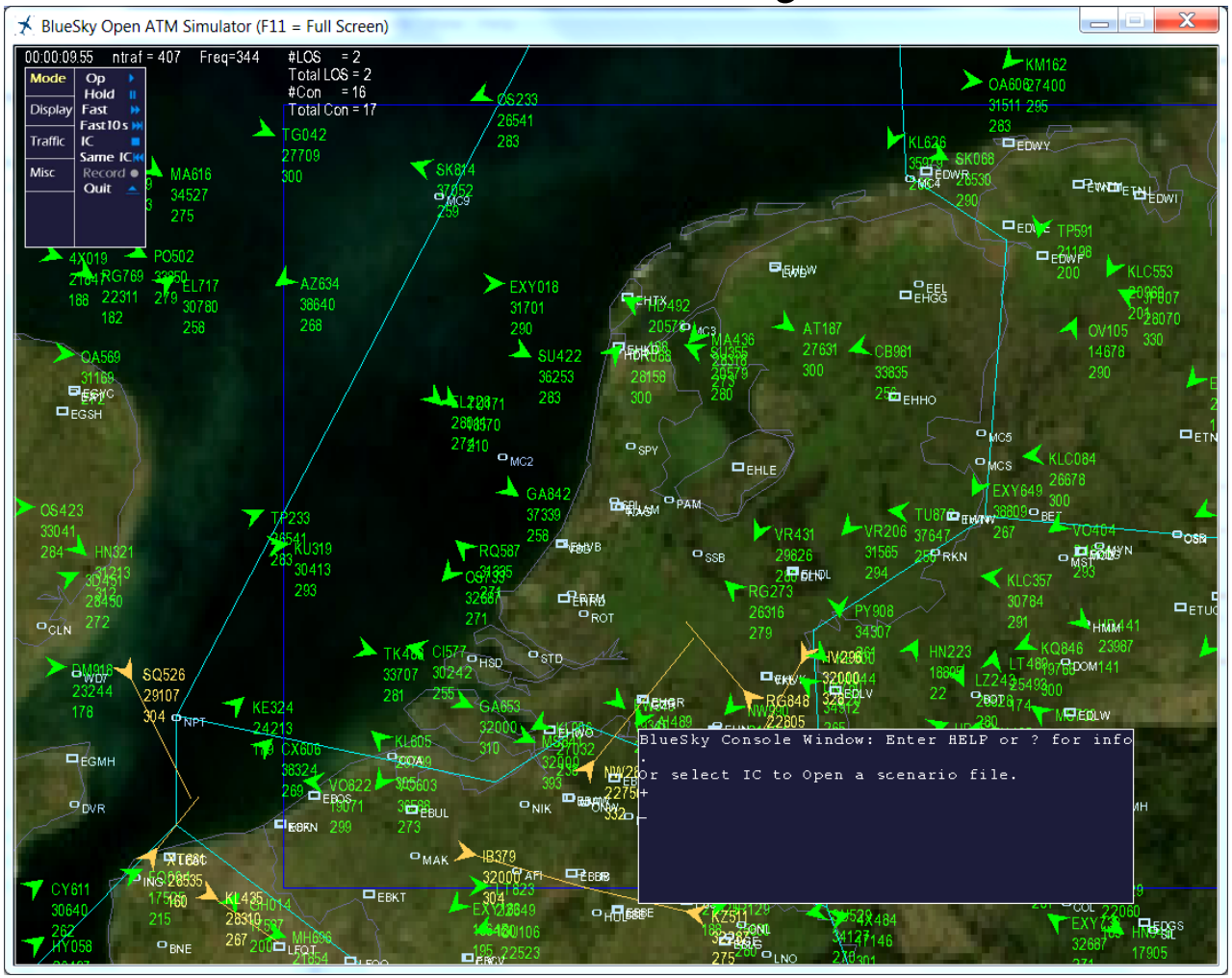
CRE acid,type,lat,lon,hdg,alt,spd

> CRE KL204,B744,52,4, 90 FL120 250
> KL204 ORIG LFPG
> KL204 HDG 270
> ALT KL204 FL070
> KL204 ALT 4000
> KL204 SPD 200
> KL204 DEST EHAM
> KL204 ADDWPT SPY
> PAN EHAM

example.scn scenario file (plain text file)

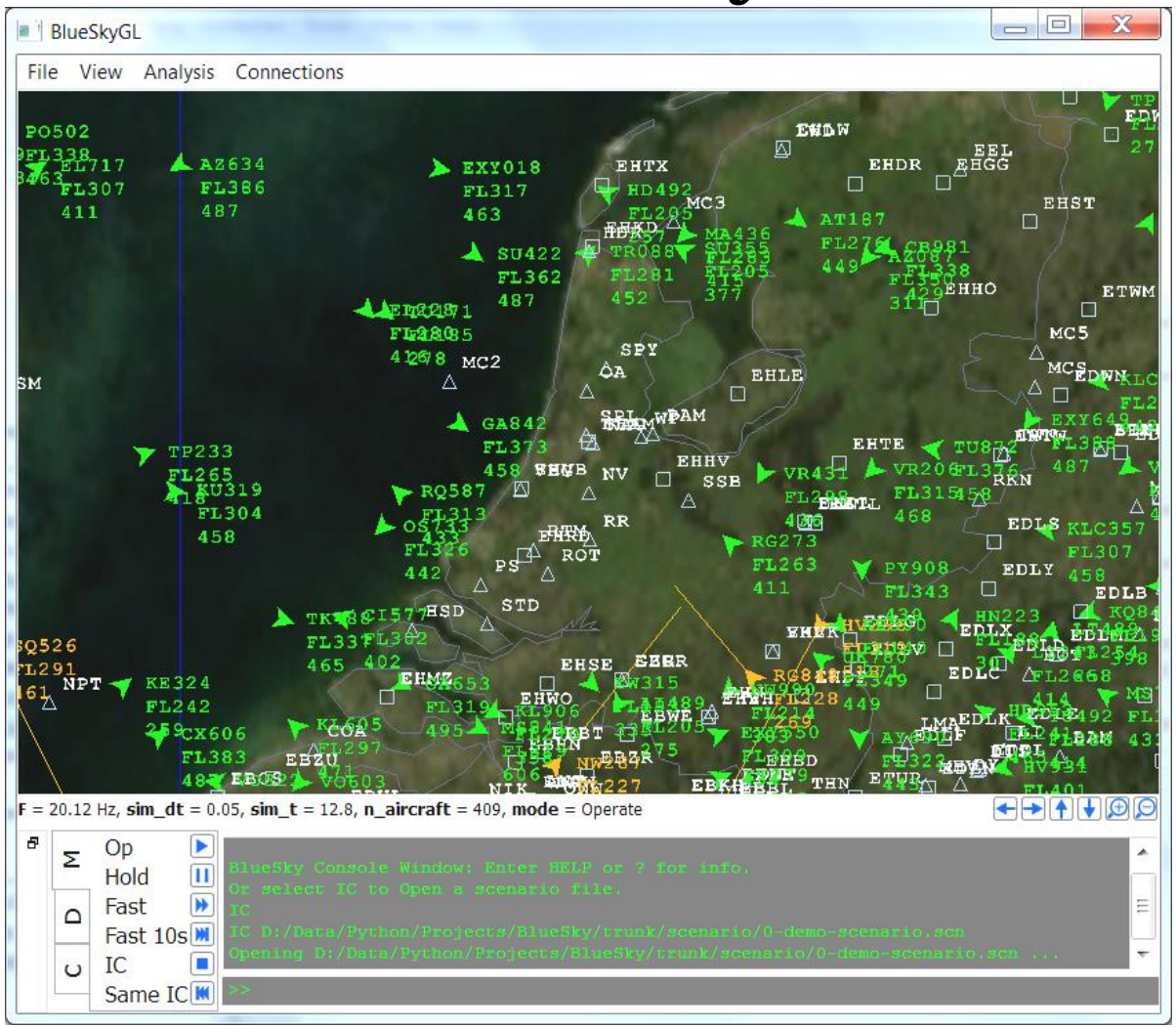
```
00:00:00.00>CRE KL204,B738,N52'18'58,E4'46"47,180,FL120,300
00:00:00.00>KL204 ORIG EHAM
00:00:00.00>KL204 DEST LEMD
00:00:00.00>ADDWPT KL204,LEKKO,10000,250
00:00:00.00>ADDWPT KL204,WOODY,,0.55
00:00:00.00>ADDWPT KL204,CIV,,0.84
00:00:10.00>CRE MP205,B744,52.0123,4.000 , 270,10000, 250
# Martinair plane
00:00:20.00>MP205 HDG 300
00:00:20.00>MP205 SPD 280;MP205 ALT FL70
00:00:30.00>HDG MP205,270
```

BlueSky



Classic, single thread version

BlueSky



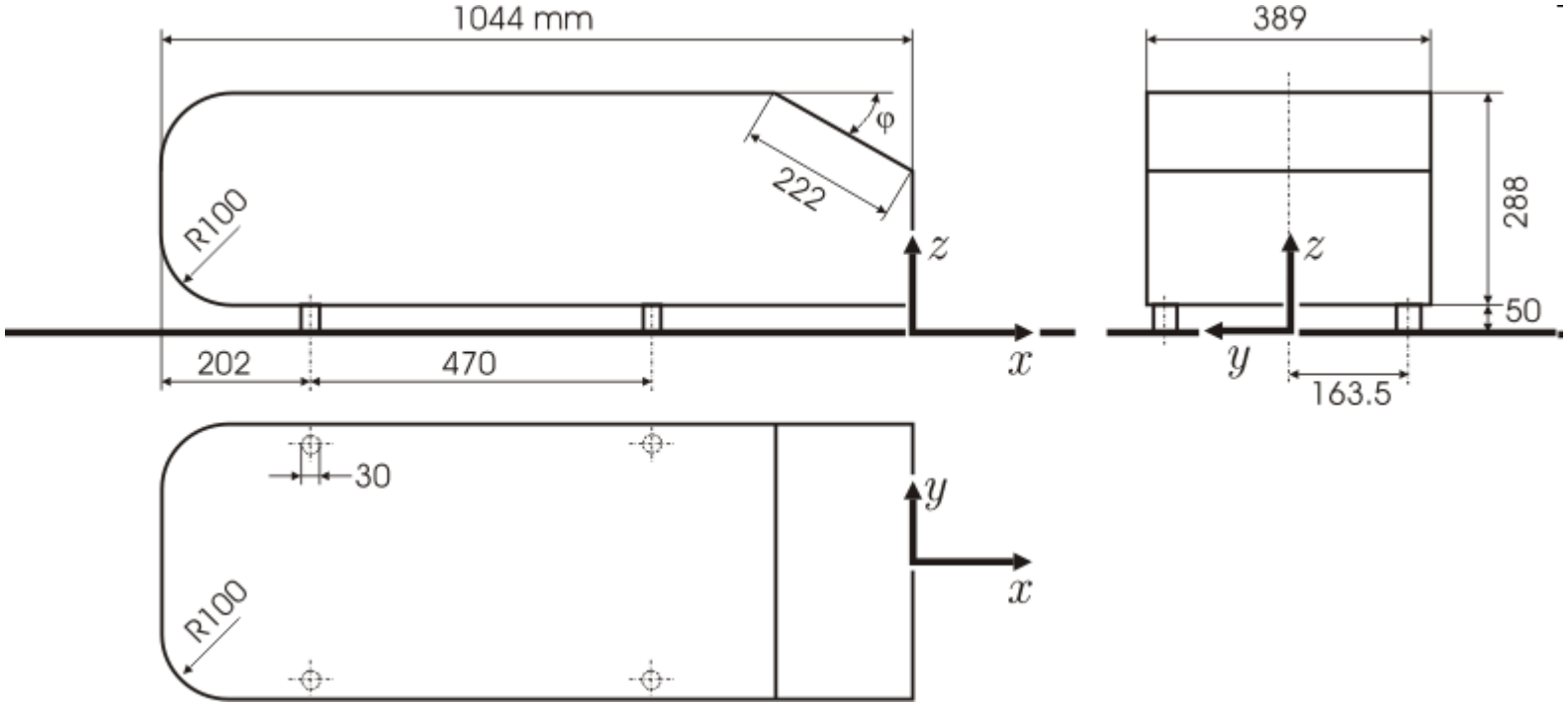
Multi-threaded, OpenGL thread version (based on Qt)

Ahmed Project

Theme 1: Foundation

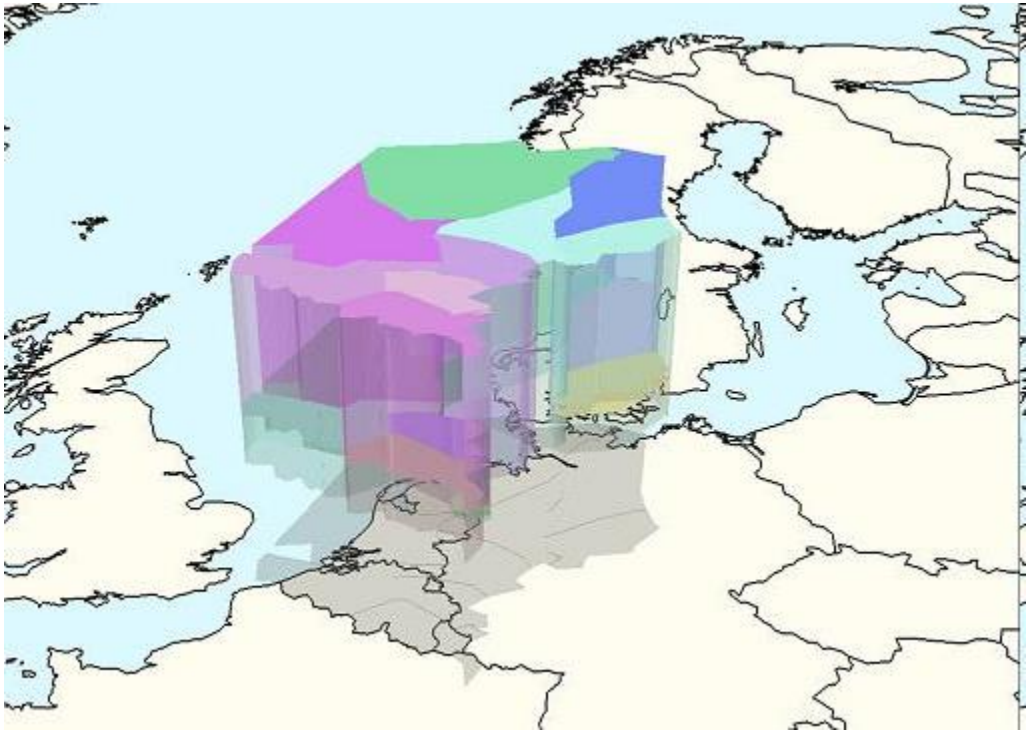
Proposal: Ahmed body

- "Ahmed body" needed, like in wind-tunnel testing of road vehicles



Ahmed body for Air Traffic Management

- "Ahmed body" needed: standard sector, could be imaginary or real day of busy traffic of Europe for which all data is available



"Sector X"

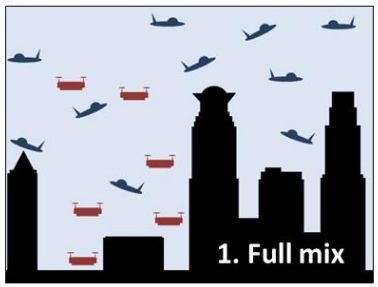
Some days in Europe in 2020

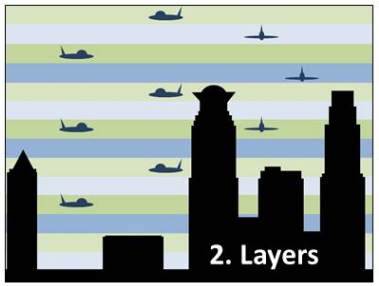
Metropolis Project: Airspace Structure vs. Capacity

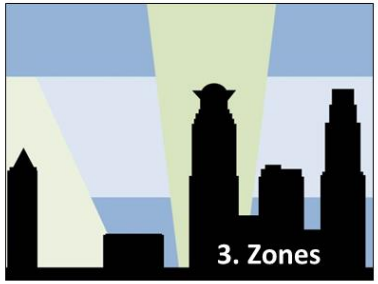
Theme 1: Foundation

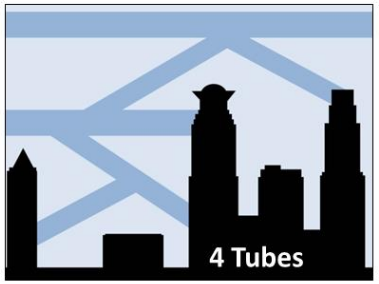
Metropolis: study extreme densities of PAV and UAVs

- What if personal air transport technology & UAVs really does take off and results in a massive amount of flying vehicles?
- Extreme densities: Structured airspace design or spread the traffic?





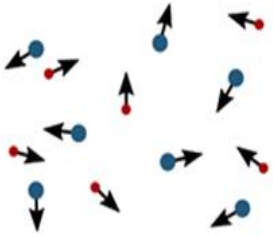
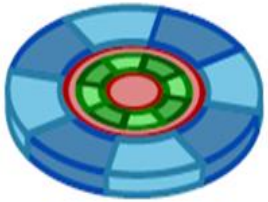
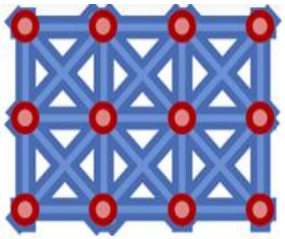




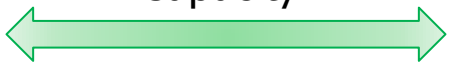
The Effect of Airspace Structure on Capacity

Goal

Four Concepts of Increasing Airspace Structure

Full Mix	Layers	Zones	Tubes
			
0 Constraints	**1 Constraint** • Altitude	**2 Constraints** • X Position • Y Position	**4 Constraints** • X Position • Y Position • Altitude • Speed

Capacity?

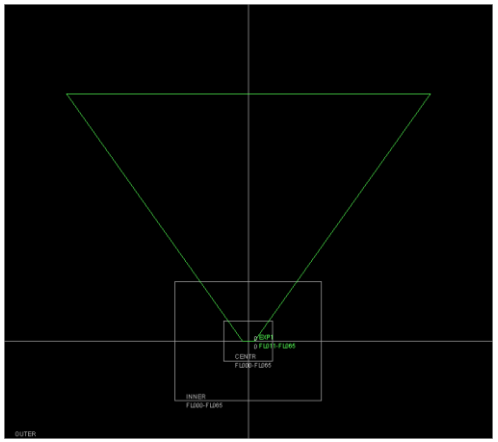


Researcher: Emmanuel Sunil
Supervisors: Jacco Hoekstra
Joost Ellerbroek

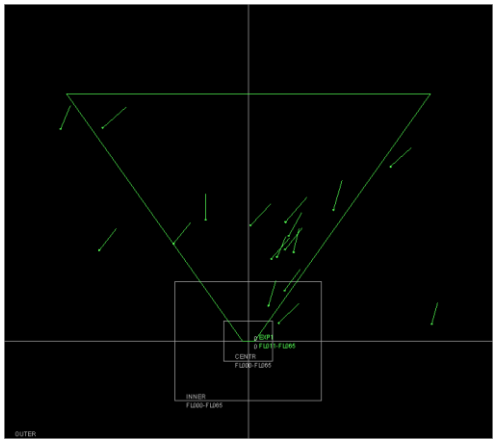
The Effect of Airspace Structure on Capacity

Method: Empirical

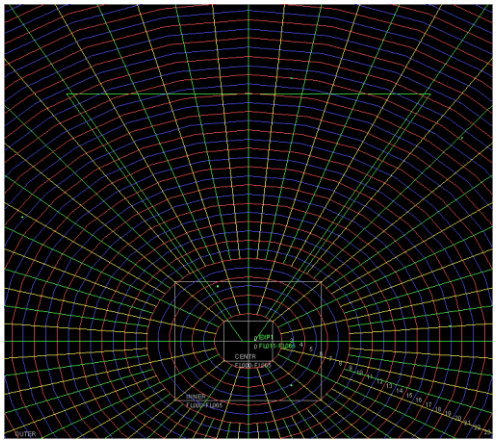
Full Mix



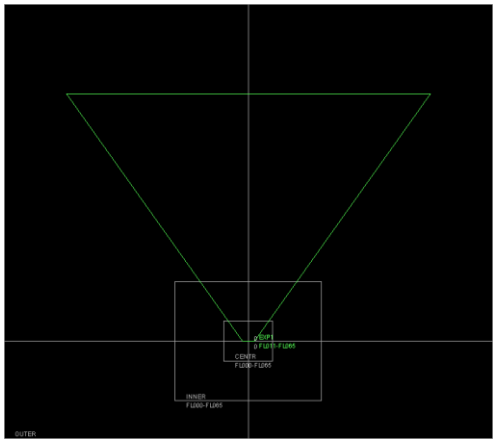
Layers



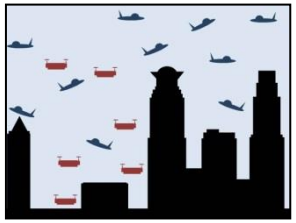
Zones



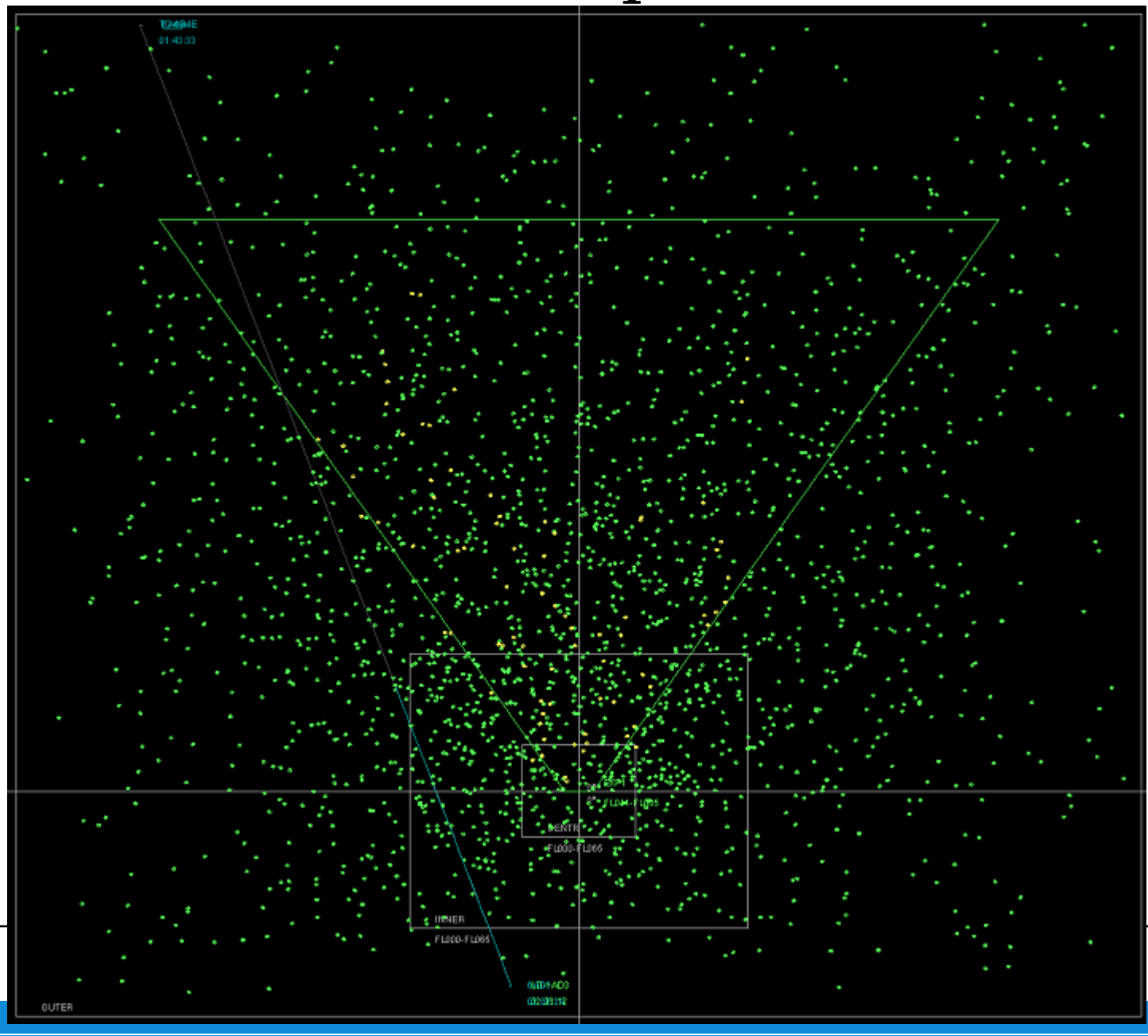
Tubes



First screenshots and impressions

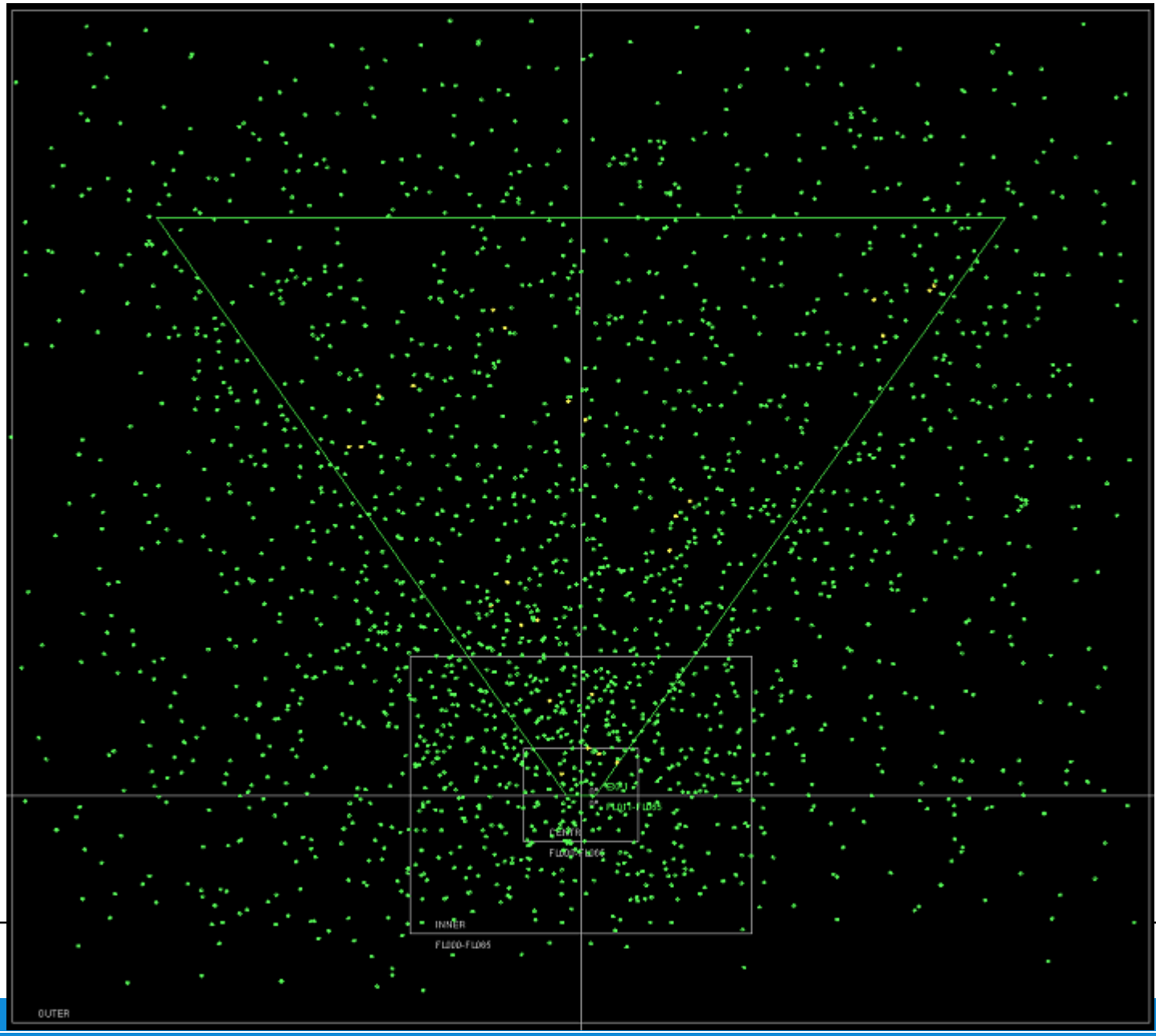


Full Mix



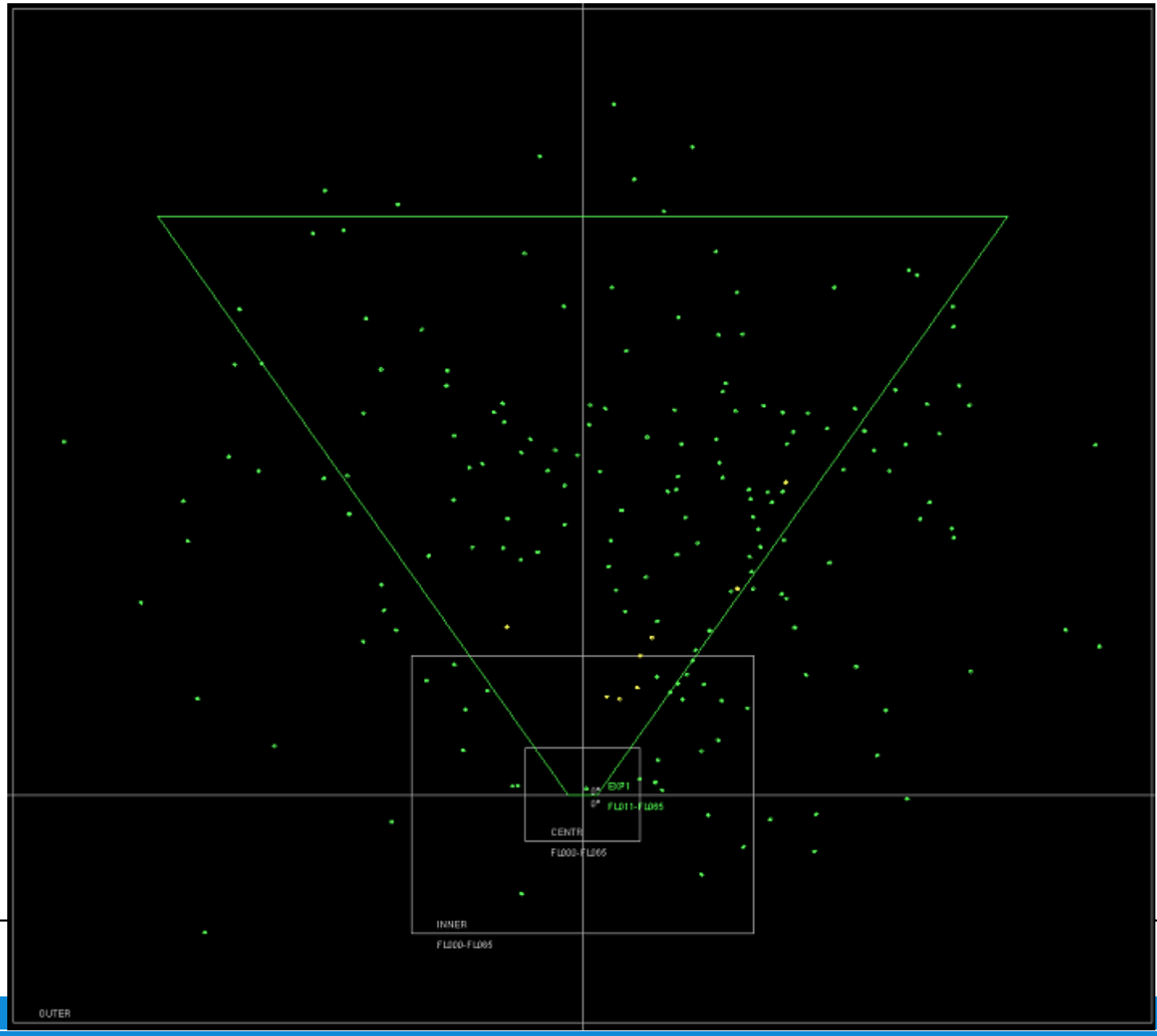
First screenshots and impressions

Layers



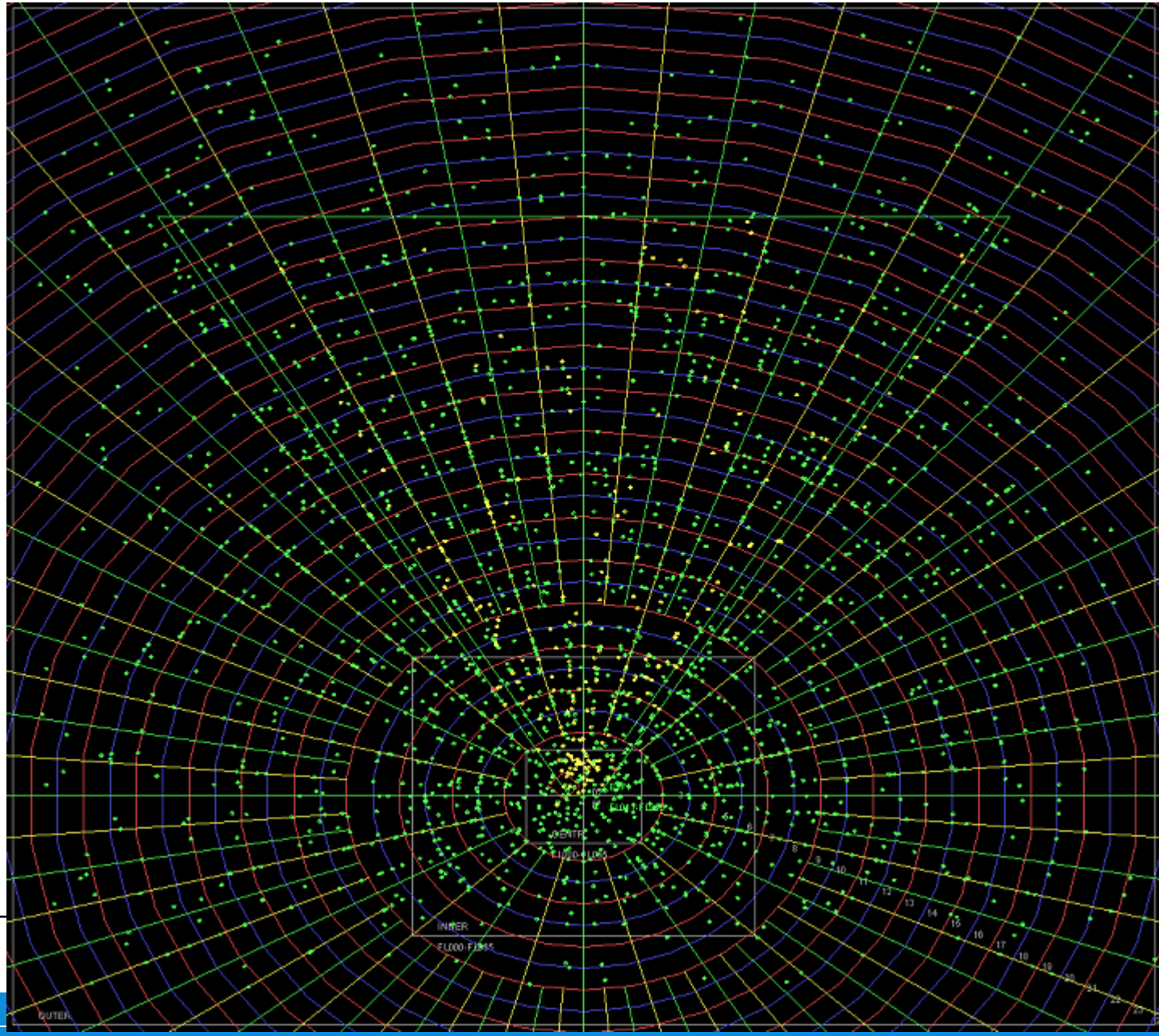
First screenshots and impressions

Layer



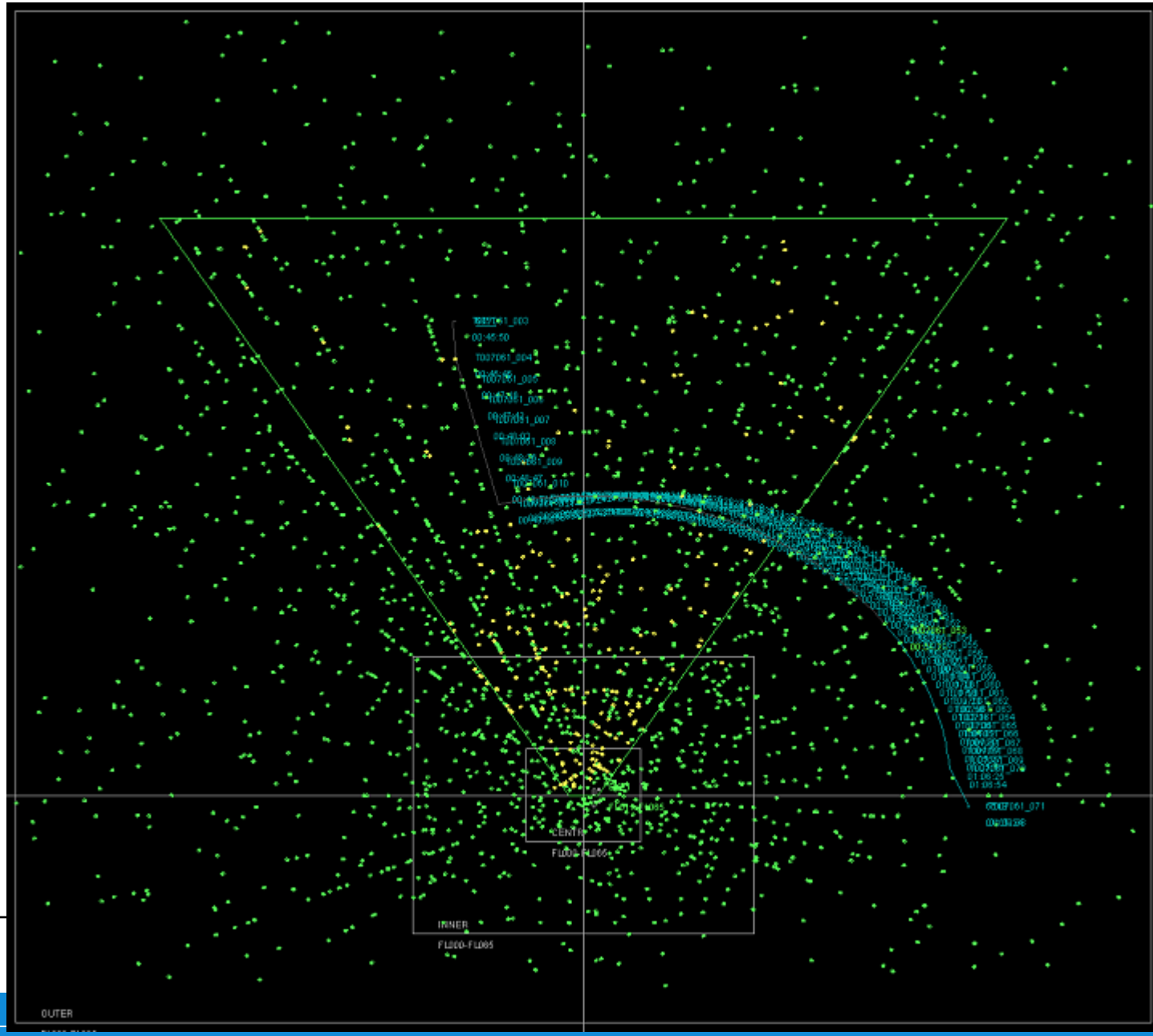
First screenshots and impressions

Zones



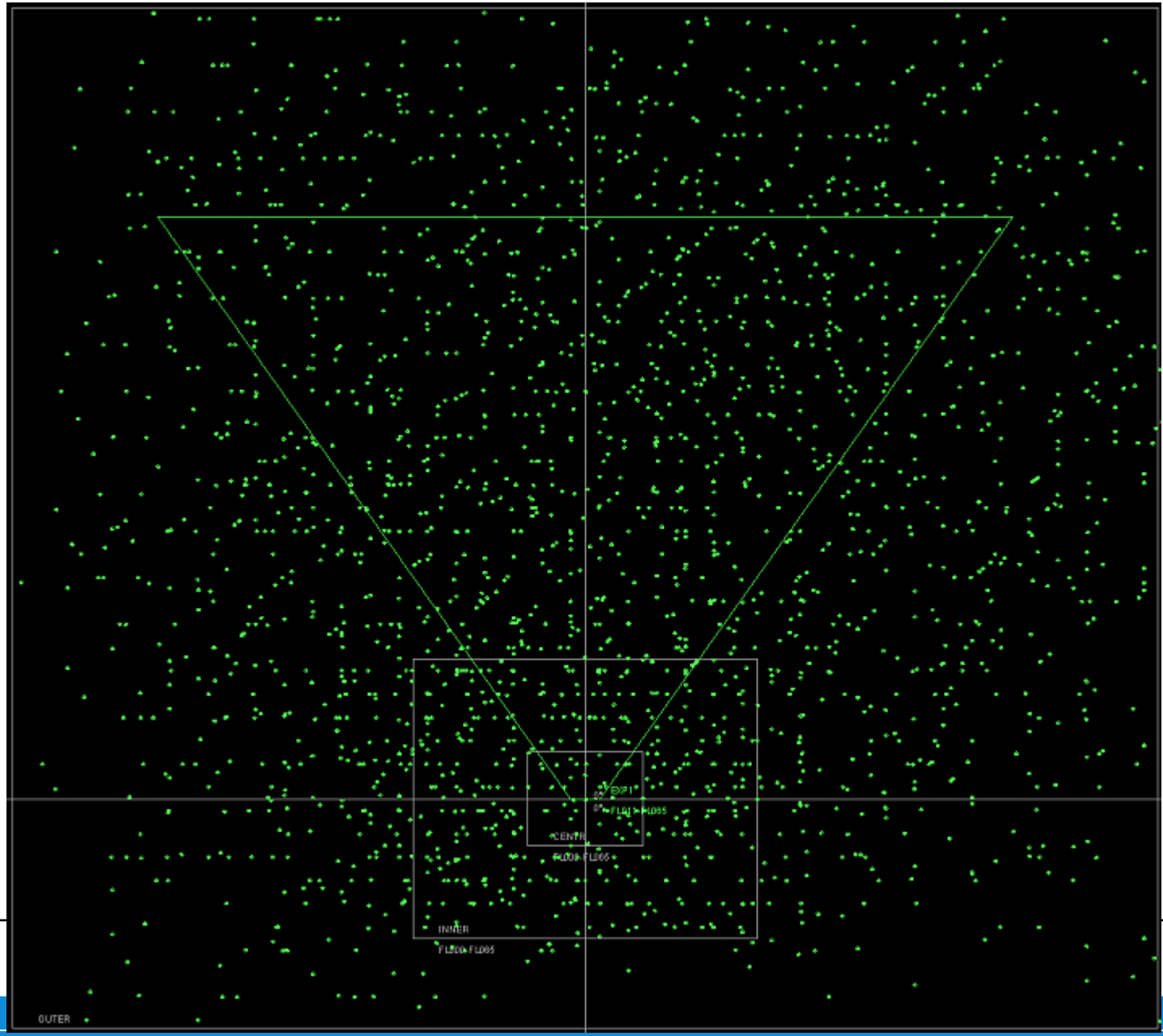
First screenshots and impressions

Zones



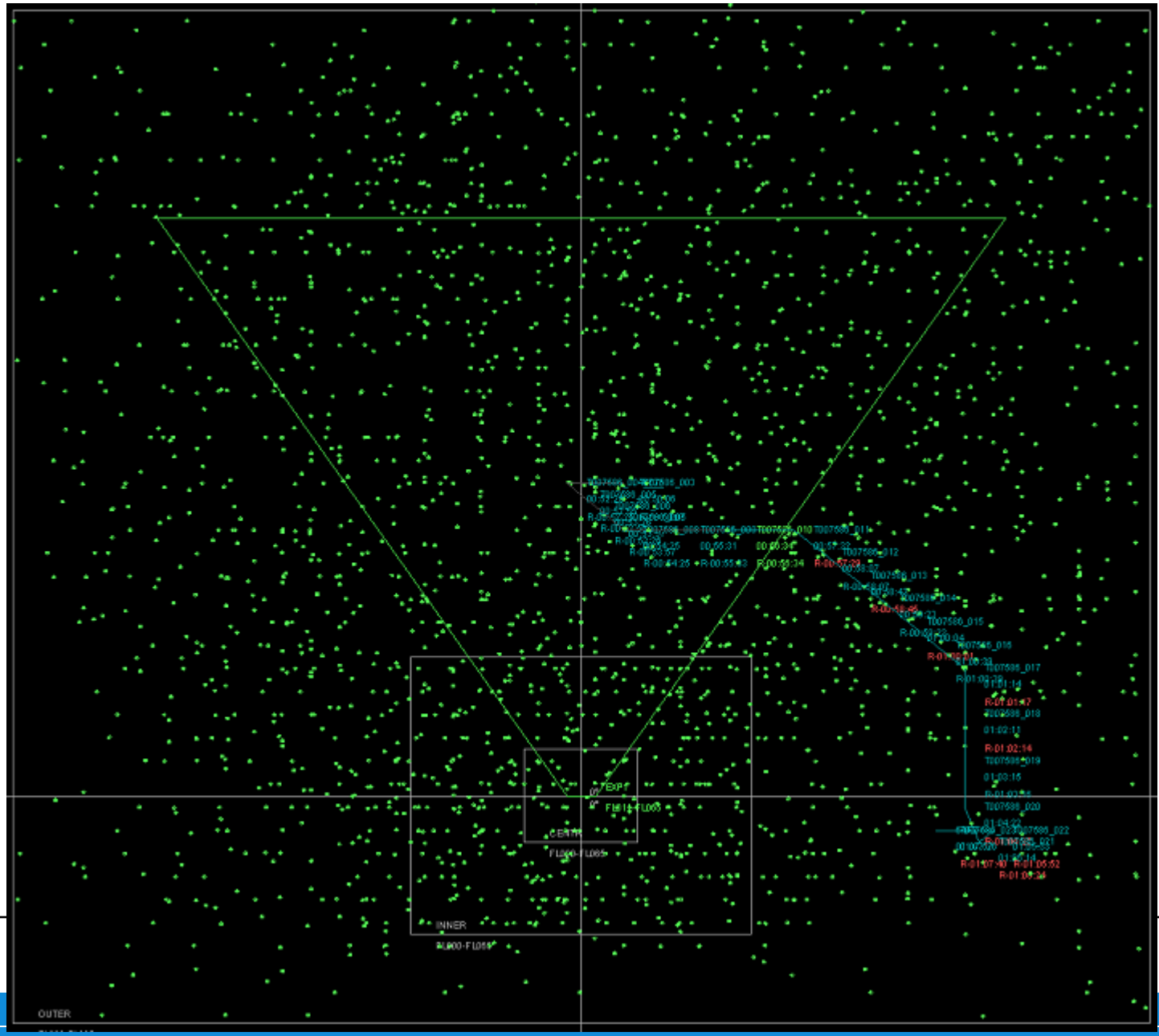
First screenshots and impressions

Tubes

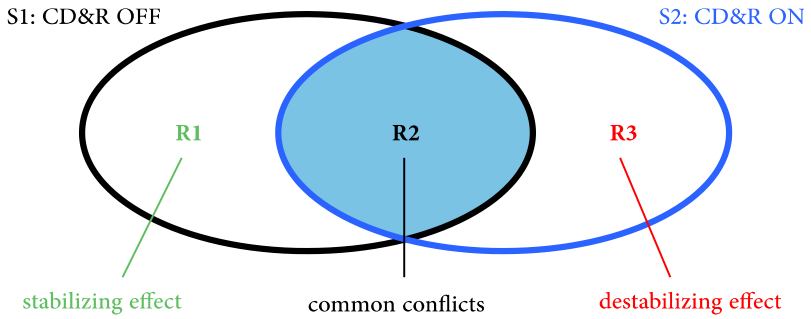


First screenshots and impressions

Tubes



The domino effect parameter



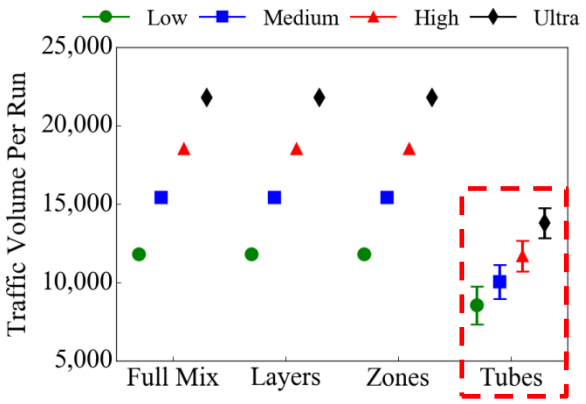
Venn diagram for CD&R conflicts

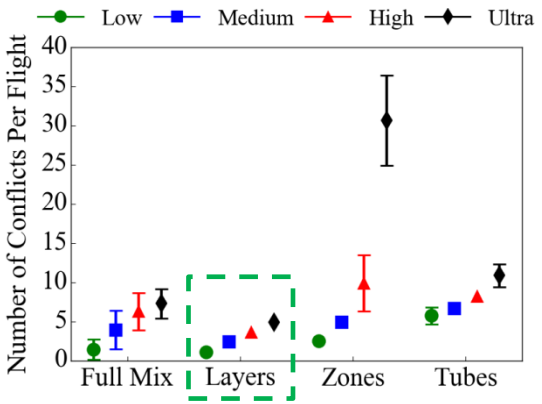
S_1: conflicts that occur with no CD&R
S_2: conflicts that occur with CD&R

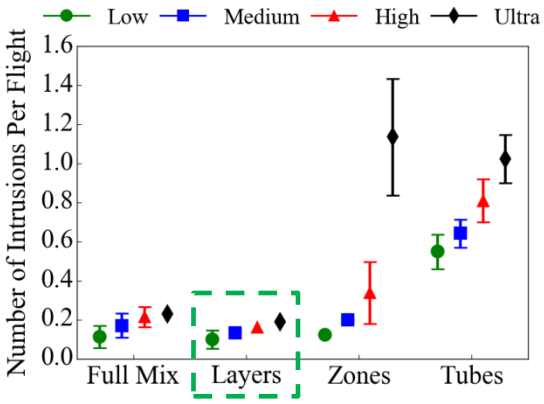
$$DEP = \frac{|R_3| - |R_1|}{|S_1|} = \frac{|S_2| - |S_1|}{|S_1|} = \frac{|S_2|}{|S_1|} - 1$$

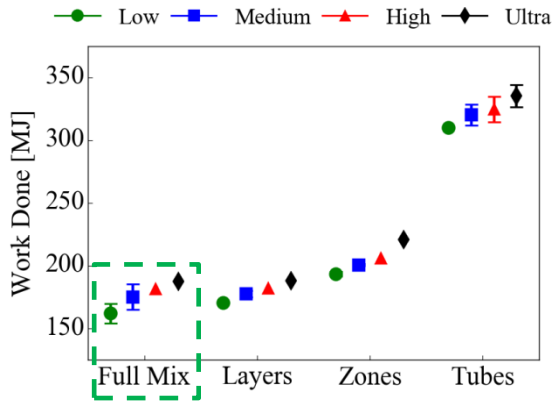
The Effect of Airspace Structure on Capacity

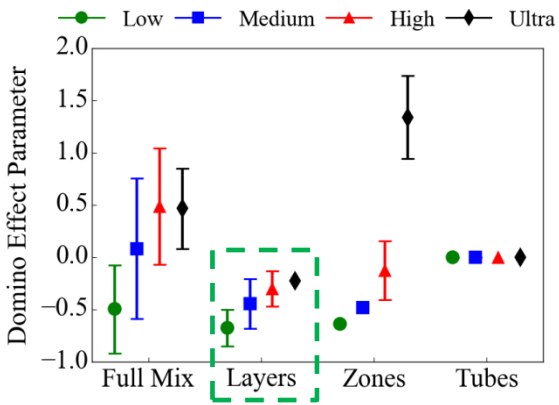
Results

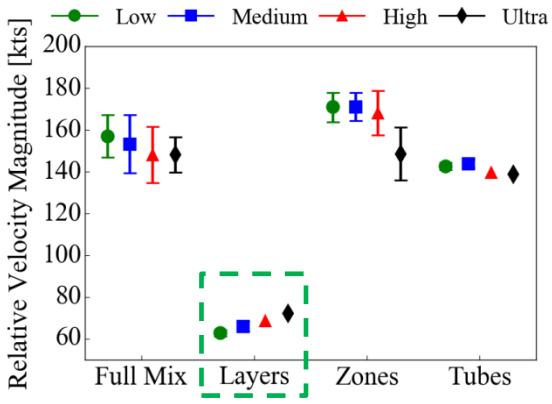












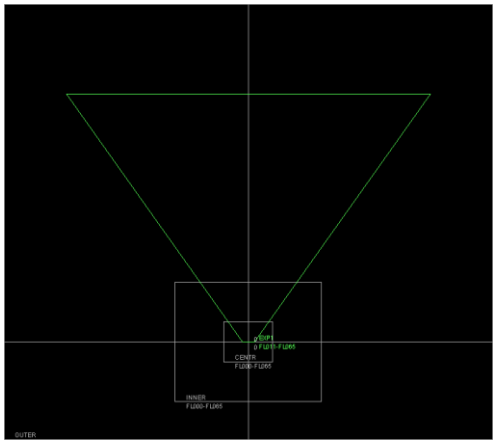
Follow-up Metropolis Project: Explaining the results Airspace Structure vs. Capacity

Theme 1: Foundation

Quantifying the Capacity Benefits of a Layered Airspace Concept

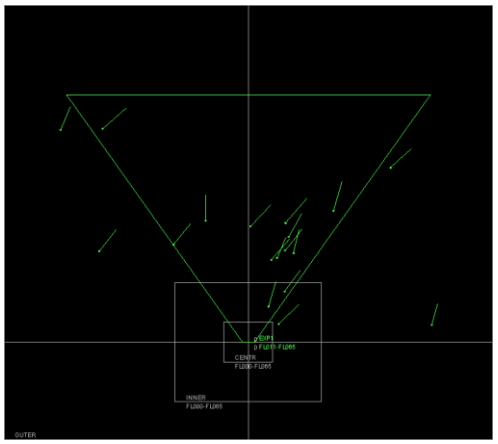
Goal

Full Mix



vs

Layers



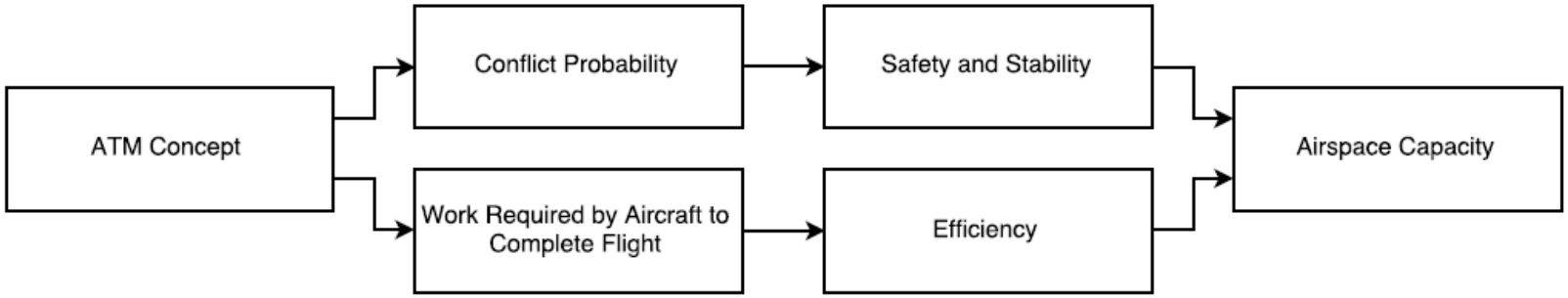
1. To what extent is Layers better than Full Mix?
2. How does the heading range per altitude band affect Layer's capacity?

Researcher: Martijn Tra
Supervisors: Emmanuel Sunil
Jacco Hoekstra
Joost Ellerbroek

Quantifying the Capacity Benefits of a Layered Airspace Concept

MSc student Martijn Tra

Method: Semi-Empirical Approach



Cruising Per Layer:

$$E[N_C] = \left[\frac{N_{SS}(N_{SS}-1)}{2}\right]\left[\frac{D_{sep}V\ T}{A}\right]\left[\frac{2\pi}{\alpha} - \frac{4\pi}{\alpha^2}\sin(\alpha/2)\right]p_0$$

Expected number of conflicts

Airspace Parameters

x

x

Average Relative Velocity of 2 ac

x

Constant/Model term

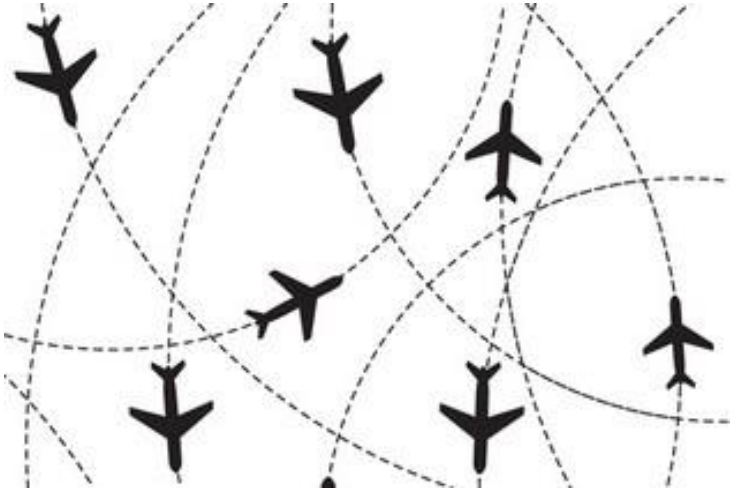
Empirically derived through simulation

Traffic Predictability: Medium Term Conflict Detection

Theme 1: Foundation

Trajectory prediction for Medium Term Conflict Detection

PhD student Julia Rudnyk



Method:

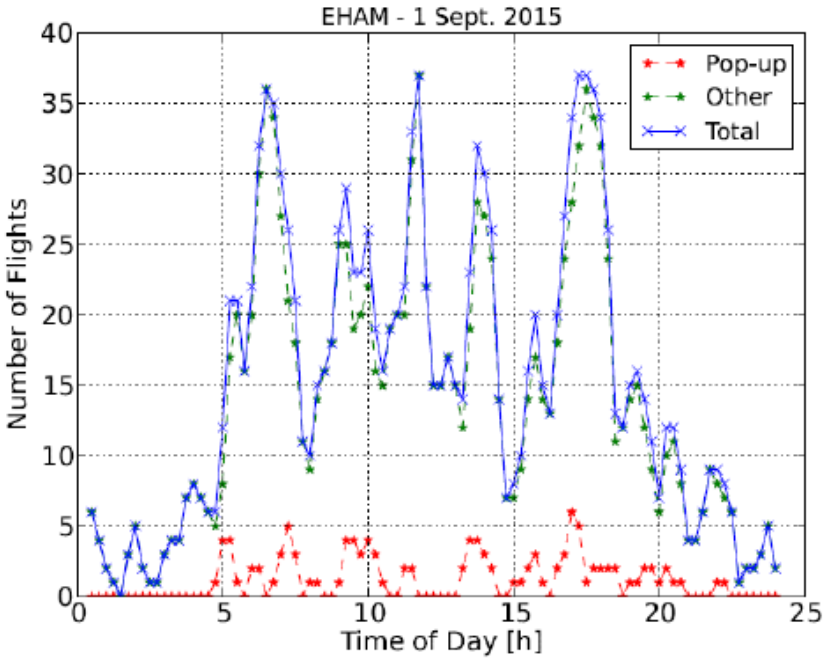
- **Create Trajectory Prediction Tool**
- **Analyse sources of present uncertainties**
- **Predict uncertainty(ies)**
- **Include predicted uncertainty(ies) in Trajectory Prediction Tool**
- **Verify in shadow mode**

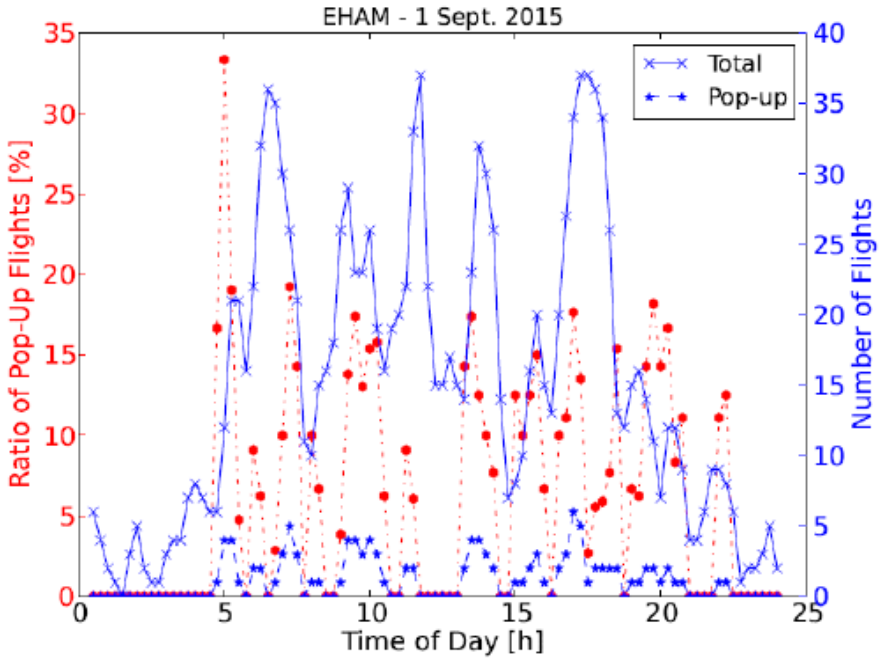
Traffic Predictability: Pop-Up Flights and Cross-border Arrival Management

Theme 1: Foundation

Pop-up Occurrence

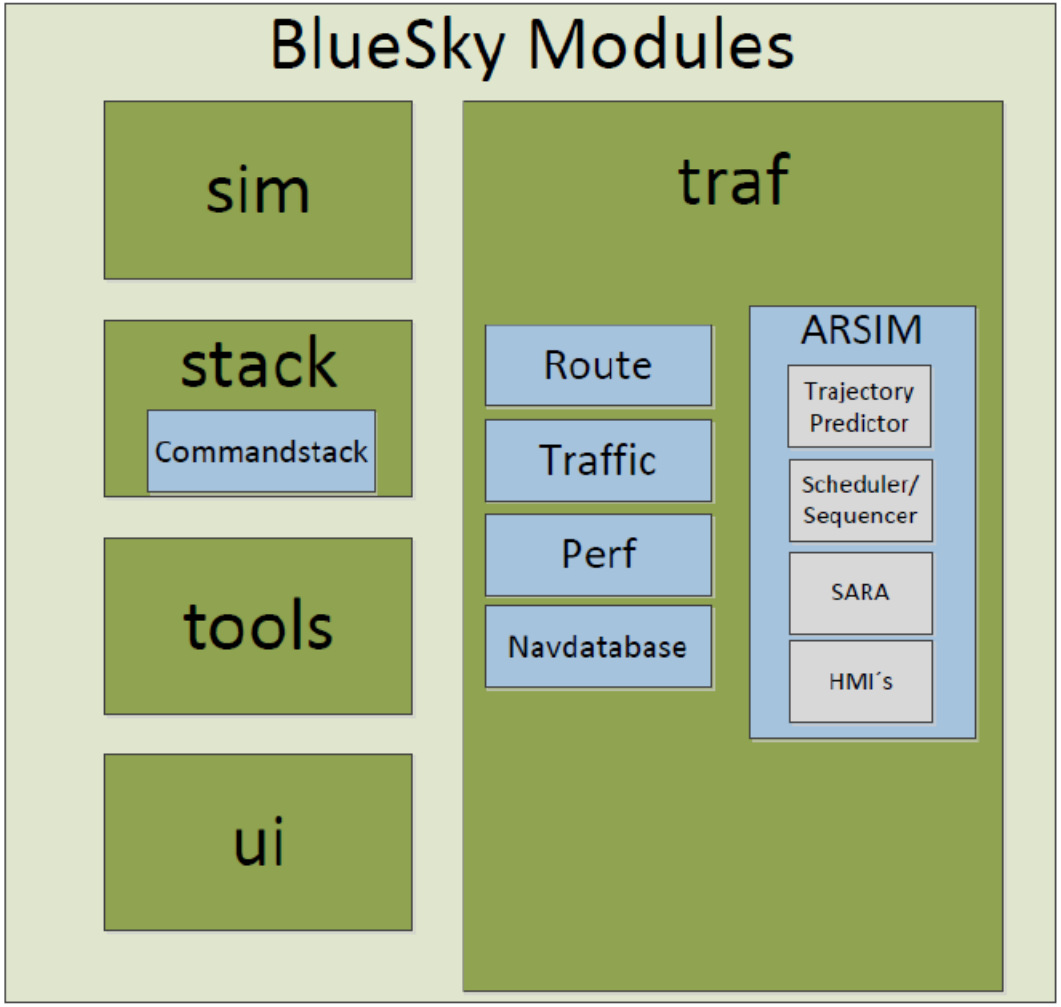
MSc student Alexander van Welsenaere





AMAN Research Simulator (ARSIM)

Luchtverkeersleiding Nederland
Air Traffic Control the Netherlands



Dependent Variables

Run simulation with different strategies, different AMAN horizons, Pop-up frequency, runway use, dep info

Experiment to measure:

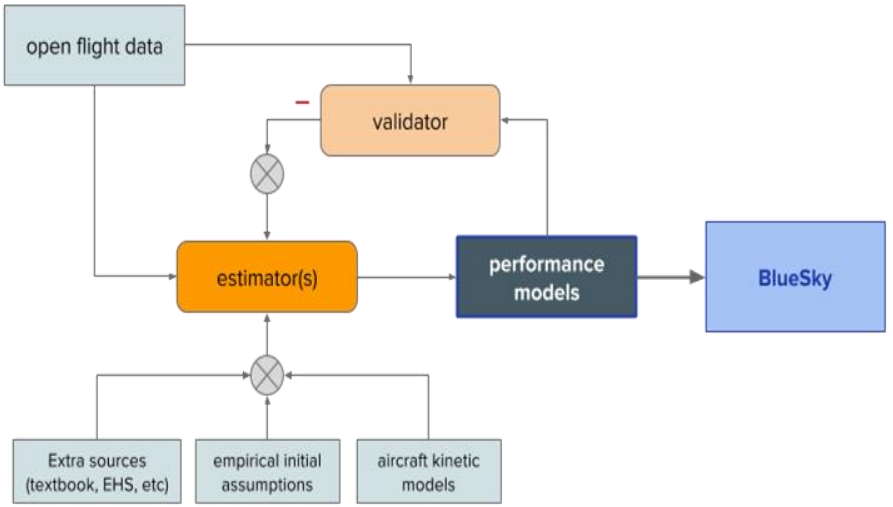
- Sequence Stability
- Advisory Accuracy and Reliability
- Delay
- Delay Cost
- Runway utilisation
- Conflicts

Developing Aircraft Performance Models Using ADS-B Data Mining

Theme 2: ADS-B

Methods

- **Step 1: Collection of open data**
  - [ADS-B] latitude, longitude, altitude, speed and heading, call sign, position integrity, etc
  - [web open data] Aircraft ID, owner, engine, structure parameters
- **Step 2: Data mining**
  - clustering, filtering, and aggregate data features
  - flight data state determination
- **Step 3: APM applications**
  - Flight envelope detection
  - Performance at different flight phases
  - Drag Lift polar estimation
  - Fuel consumption estimation
  - and, more...
- **Step 4: Outputs**
  - BlueSky simulator
  - Independent open source APM library



APM open data estimation process

ADS-B Daily Statistics

- 12 millions of ADS-B message
- 5 millions of positions decoded
- 5.5 millions of velocities decoded
- 5 thousands of flights
- 2.5 GB of data

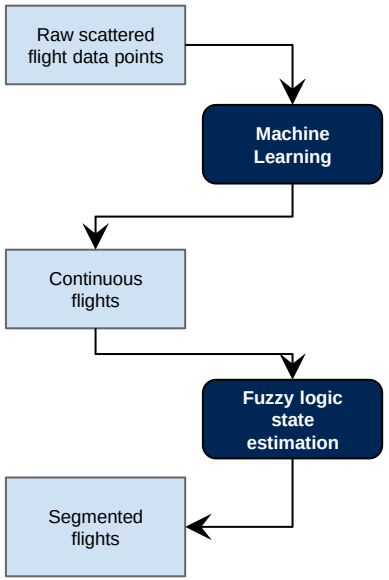
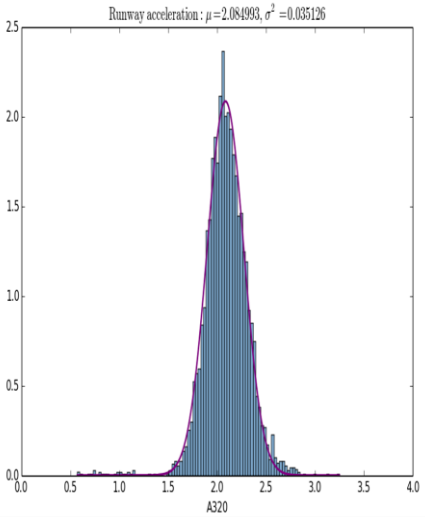


Illustration of big data learning process

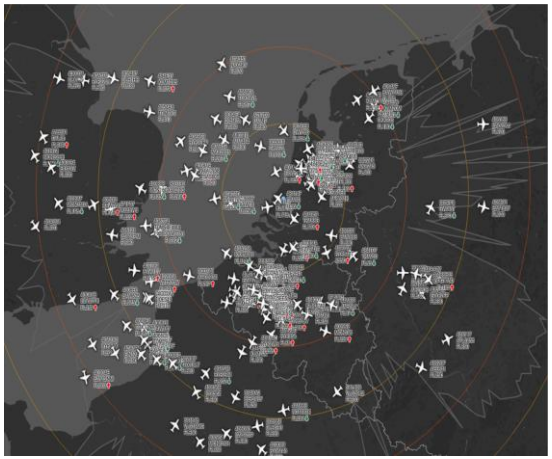
Intermediate Results

Sil

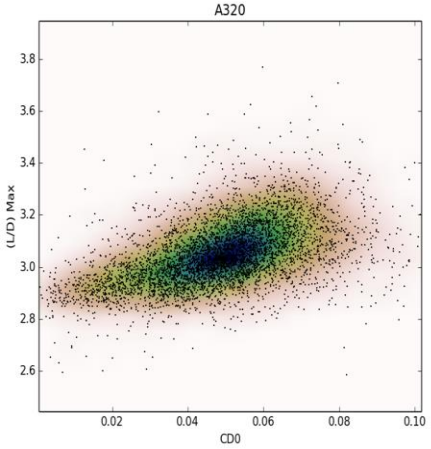
- Open ADS-B data repository
- ADS-B data streaming service
- A set of tools for ADS-B data process and analysis
- Methods for building APM limitation modules (flight envelope) using big data mining
- Aircraft take-off performance
- First approach for Lift-Drag polar analyse
- First approach of Zero Lift Drag Coefficient (CD0) estimation for different commercial aircraft



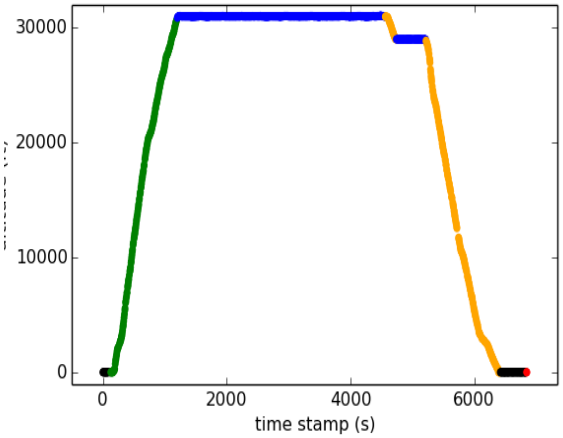
Example of Runway performance of an commercial aircraft type



System for gathering and displaying ADS-B data at TuDelft



Example of CD0 estimation for an commercial aircraft type



Example result from machine learning algorithm for clustering and segmenting ADS-B flight data

ADS-B Raw signal quality

Theme 2: ADS-B

Method

Division in Data quality and Signal quality.

Data quality
ADS-B is compared to track data to determine the latency and the positional accuracy of the GPS measurements

Signal quality
The totality of all ADS-B messages are analyzed on the average update interval (i.e. when an aircraft updates its position) and the integrity/availability (i.e. how many received messages are trustworthy enough to actually be used?)

Performance degradation
It is tried to find correlation between several internal and external factors and the performance of ADS-B.

MSc student Ted Verbraak

TU Delft

First Results

Accuracy

The currently found accuracy is in the order of ~300meters, although this has to undergo some sanity checks.

Update interval

75% of all messages show an update interval of less than 2sec, and 95% of all messages show an update interval of less than 7 sec.

Integrity/Availability

Messages with poor integrity are in *almost* all cases sent by aircraft which send messages only with poor integrity (i.e. aircraft showing good integrity show good integrity performance along the entire flight)

TU Delft

ADS-B surveillance quality

Theme 2: ADS-B

Effect of ADS-B uncertainties and realities on tactical CD&R performance

MSc student Thom Langejan

Different ADS-B realities/uncertainties:

- State accuracy
- Truncation
- Update interval
  - Use “old” information
  - Non synchronous for all aircraft

System related

- Reception probability
  - Range
  - Interference

Situation related

Goal

How do all these **uncertainties** affect tactical CD&R performance?

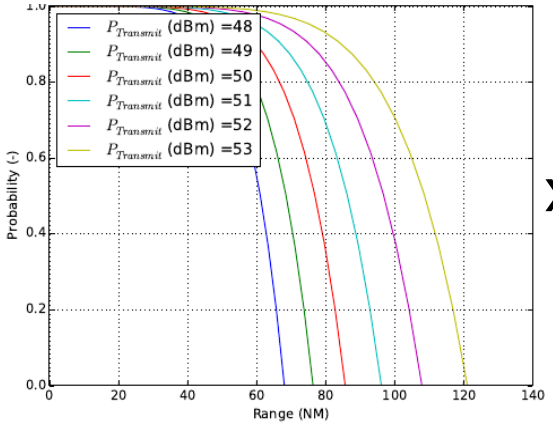
Researcher: Thom Langejan
Supervisors: Emmanuel Sunil
Jacco Hoekstra
Joost Ellerbroek

Effect of ADS-B uncertainties and realities on tactical CD&R performance

MSc student Thom Langejan

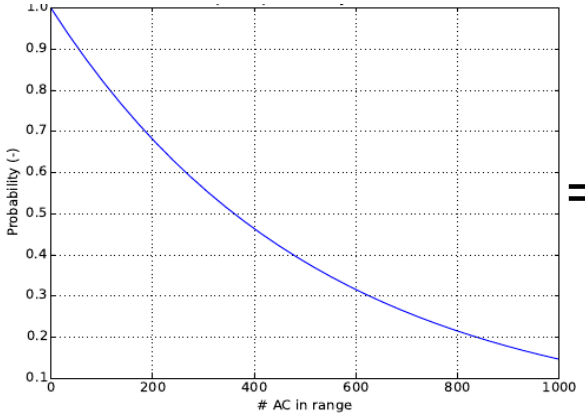
Method: Mathematical ADS-B model

Range



x

Interference



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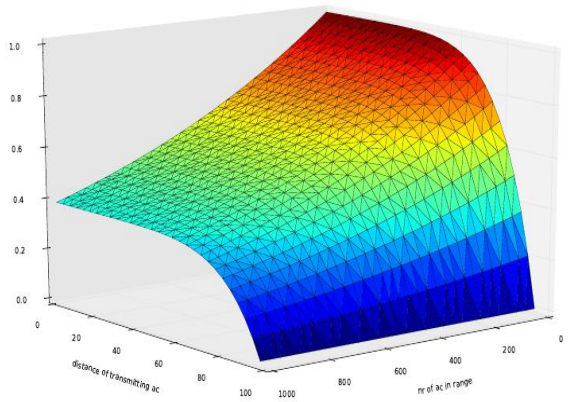
Total Reception Probability



Future Work:

Match model to observations
Use simulation experiments to study the effect ADS-B model on safety metrics

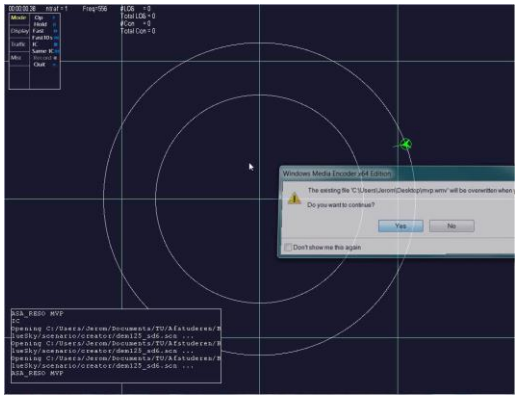
Airborne Separation Assurance Algorithms

Theme 2: ADS-B

Comparison of Tactical Conflict Resolution Methods

Goal + Method

MVP

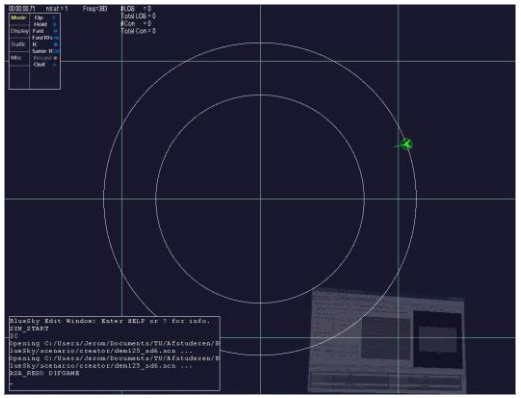


vs

Swarming

vs

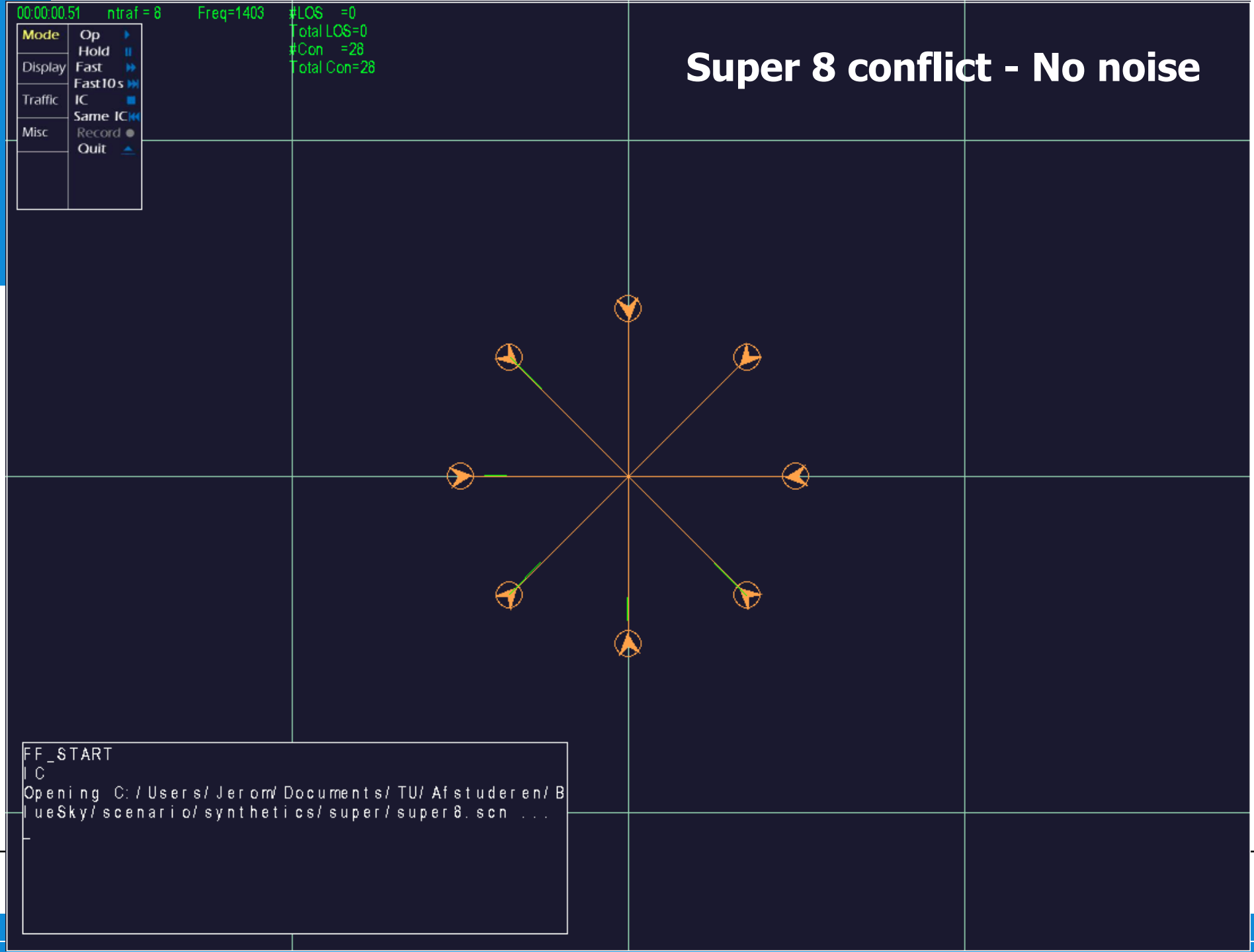
Differential Game



How does the choice of CD&R method affect:

1. Safety
2. Efficiency
3. Stability

Researcher: Jerom Maas
Supervisors: Emmanuel Sunil
Jacco Hoekstra
Joost Ellerbroek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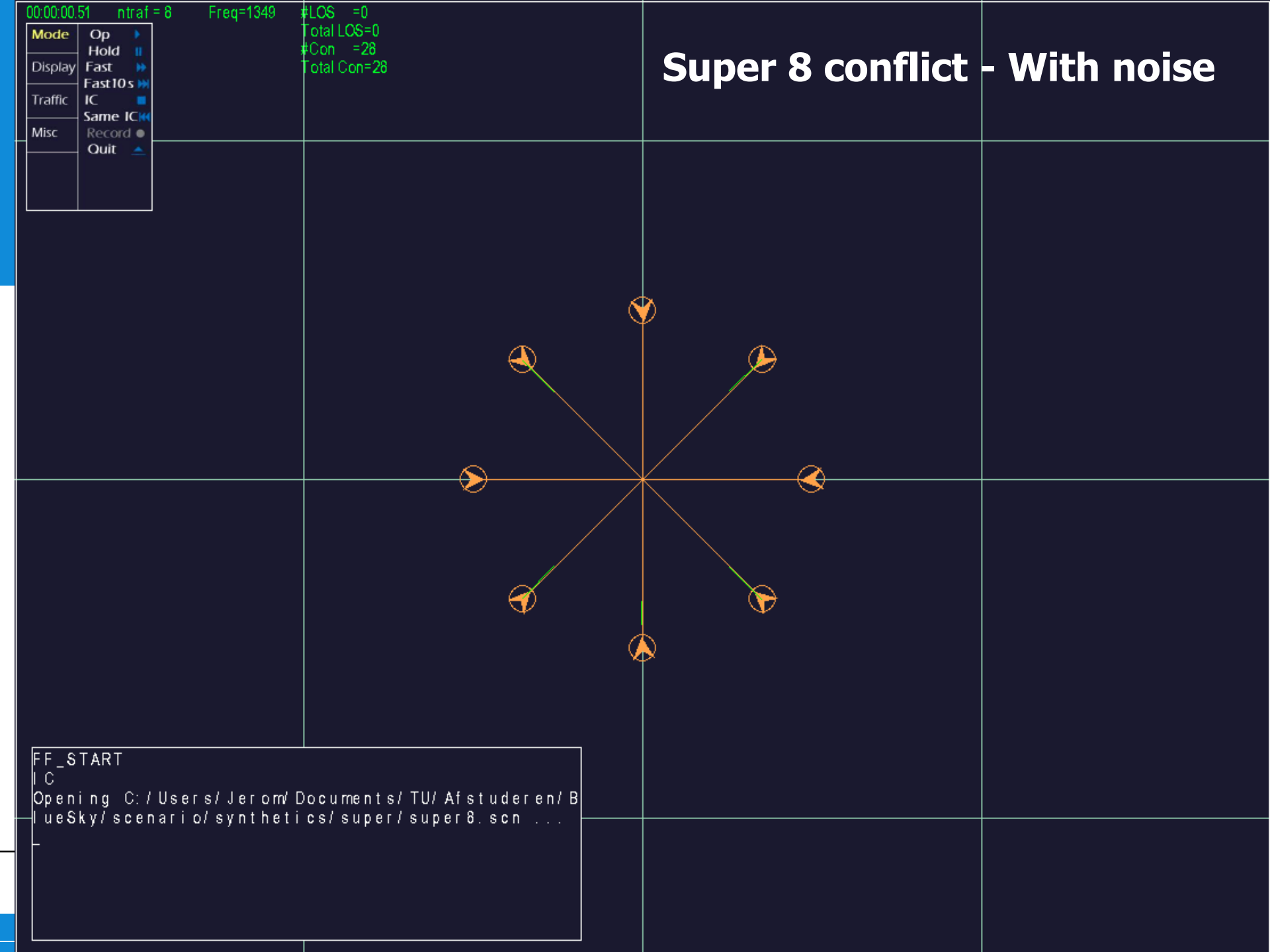
Total LOS=0
#Con =28
Total Con=28
Mode
Op
Hold
Display
Fast
Fast10s
Traffic
IC
Same IC
Misc
Record
Quit
FF_START
IC
Opening C:/Users/Jerom/Documents/TU/Afstuderen/BlueSky/scenario/synthetics/super/super8.scn ...
Super 8 conflict - No noise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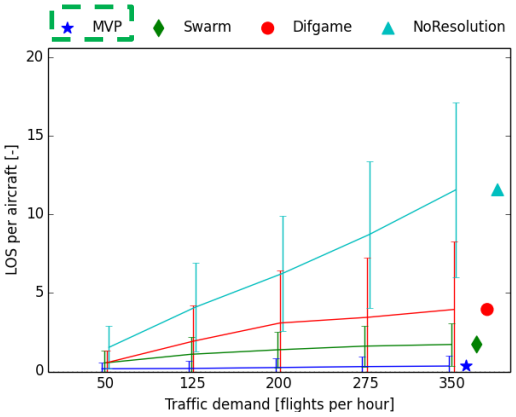
Op
Hold
Display
Fast
Fast10s
Traffic
IC
Same IC
Misc
Record
Quit
Super 8 conflict - With noise
FF_START
IC
Opening C:/Users/Jerom/Documents/TU/Afstuderen/BlueSky/scenario/synthetics/super/super8.scn ...

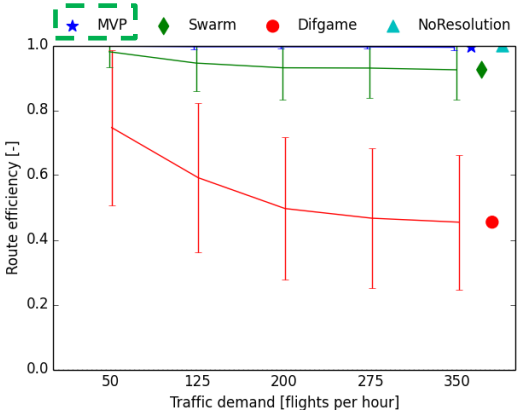
Comparison of Tactical Conflict Resolution Methods

MSc student Jerom Maas

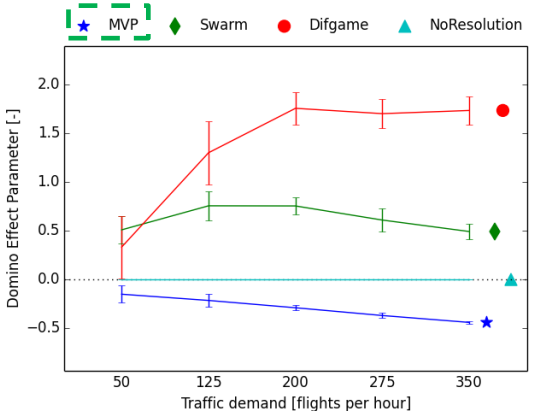
Safety



Efficiency

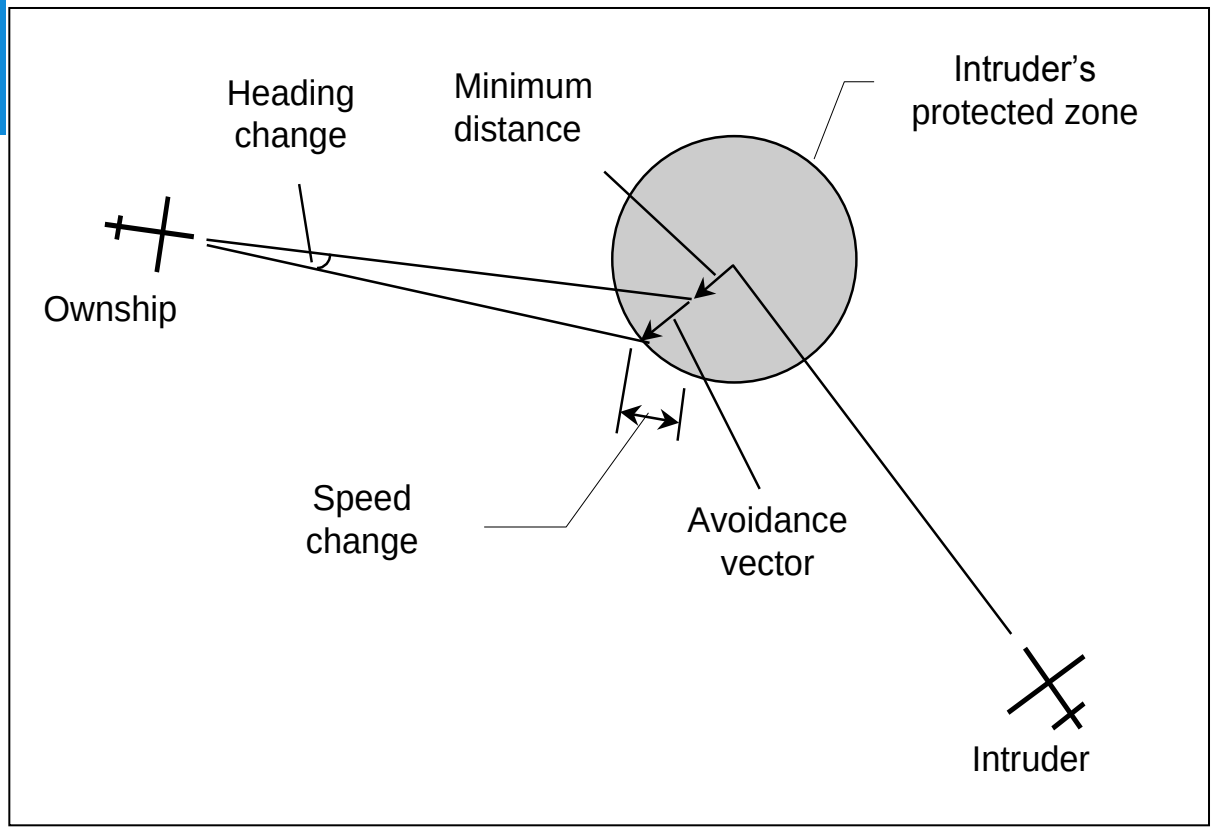


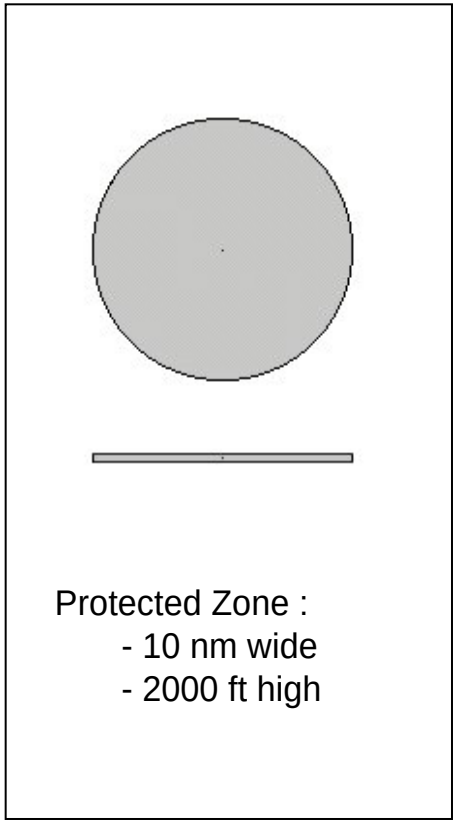
Stability



For all metrics, **MVP** resulted in the best performance (MVP=Velocity Obstacle with implicit coordination)

Traffic rule #1: Implicit coordination = Always increase distance at CPA





Vertical resolution maneuvers are indicative in cruise and some cases during climb & descent

Applicable on Flight plan & state changes

Air-to-air radar for General Aviation

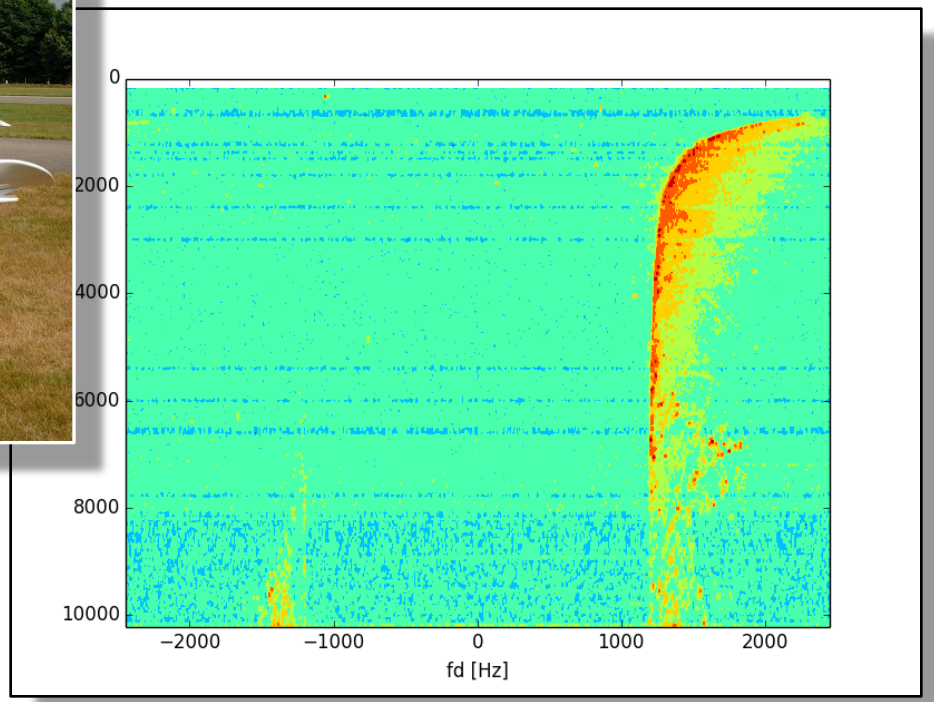
Theme 3: General Aviation

Visual Flight Rules, dangerous?

- Friday October 19th 2007: Collision Fuji FA-200 and Cessna 172R, while in circuit under VFR, killing Ronald Slingerland(46) and Poppe de Lange (70). Transponder was off, following local regulations.

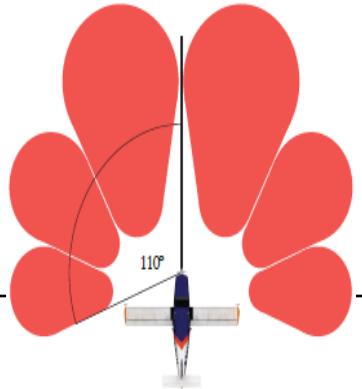
- Study by MIT Lincoln Labs: Chance of visual traffic: 56% if not alerted, 86% if alerted

General Aviation:
Flight tests new CNS equipment



Selfly ED&A - Collision avoidance radar

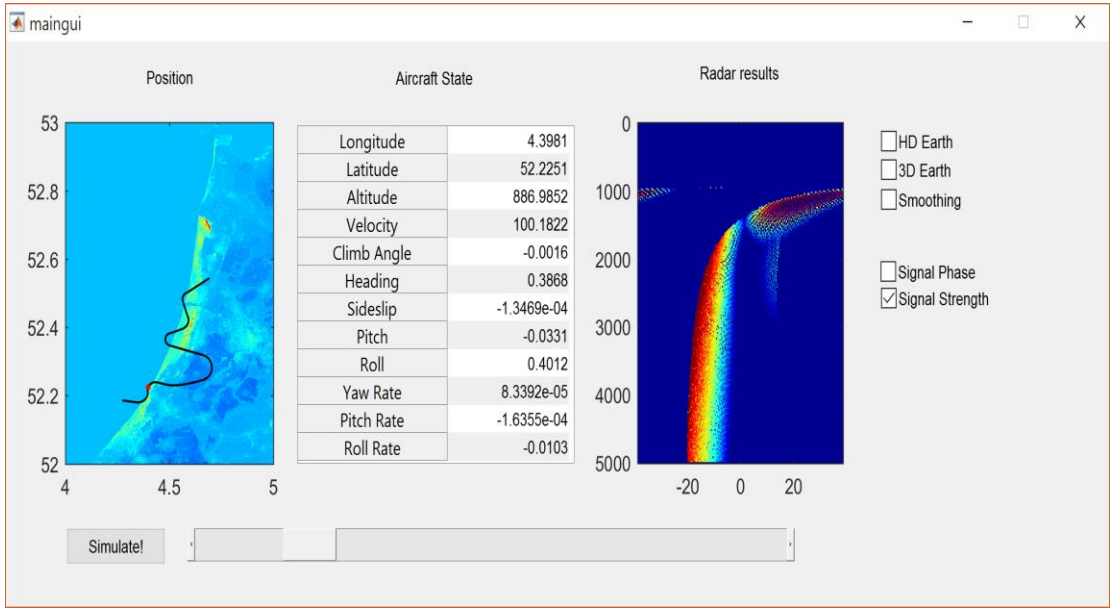
- General aviation
- On-board radar
  - Range
  - Radial velocity
  - Direction
- Electronic VFR
- In all directions



Prototype of the collision avoidance radar

Possible applications

- Attitude determination
- Verification of flight instruments
- Navigation
- Object detection
- Collision alerts
- Weather cell detection



Preliminary simulations of radar data

UAV Sense & Avoid

Theme 4: UAV

Autonomous flight with small MAVs

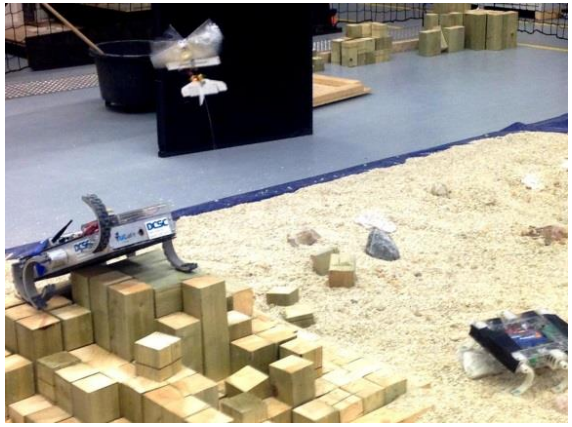
Light weight in the order of tens of grams means few sensors and little processing capabilities.

How to solve:
– Attitude & altitude control
– Obstacle & Vehicle Avoidance
– Outdoor and indoor navigation
– Odor source localization

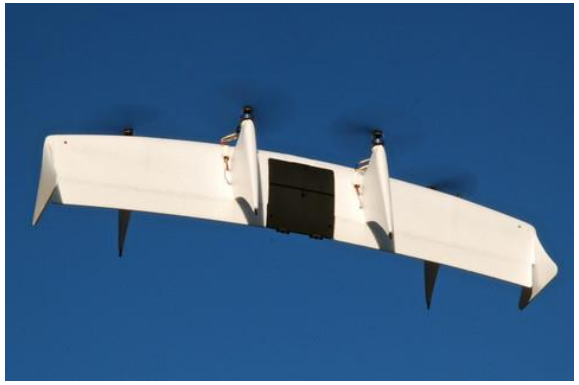
Swarming

Swarms of small, rather primitive, robots can perform complex tasks together.

How to solve:
– Intra-swarm sensing
– Intra-swarm communication
– Decentralized control of large groups of robots



Swarming

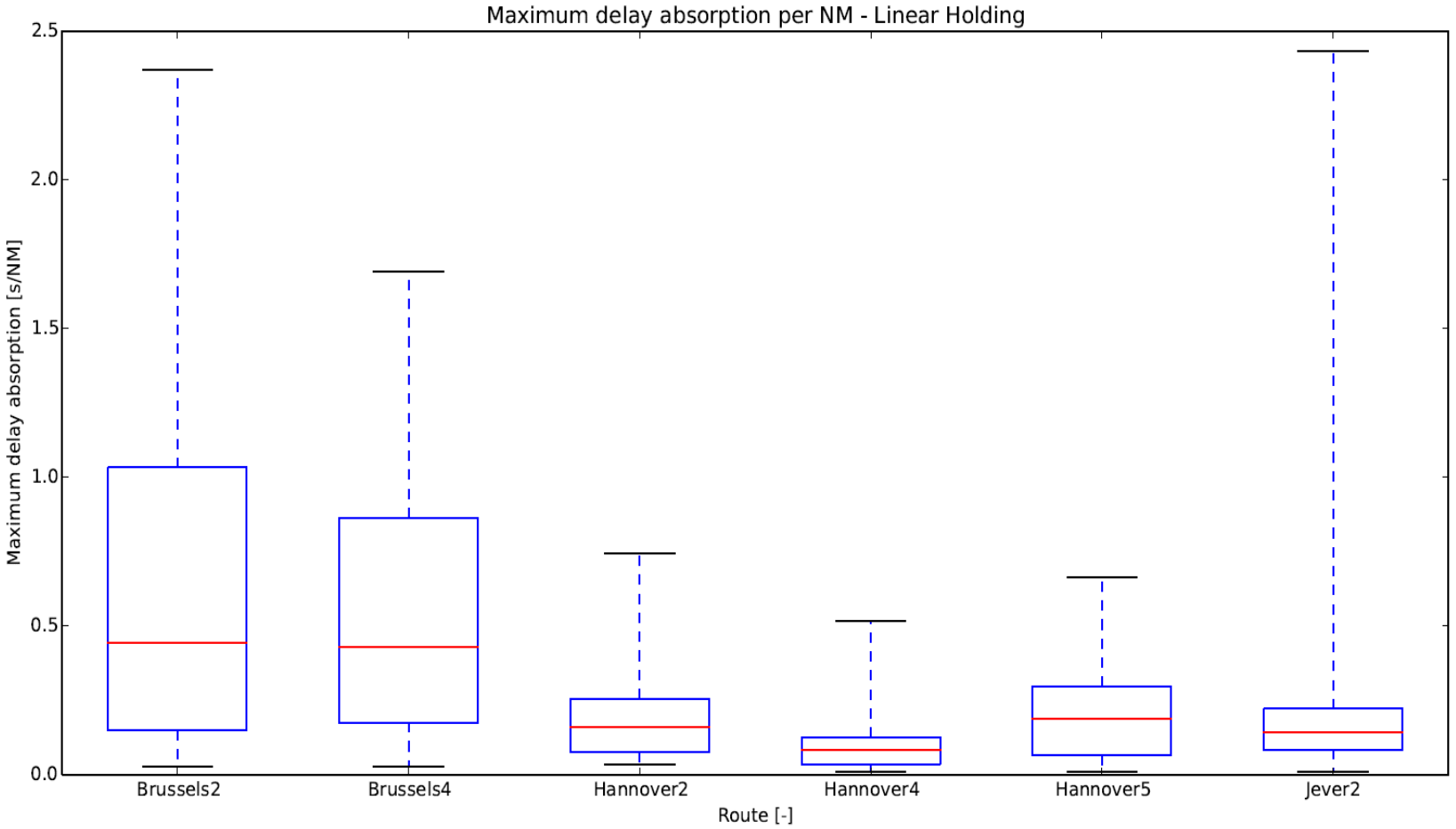


Schiphol related: Upstream Delay-Absorption

Theme 5: Schiphol Related

Luchtverkeersleiding Nederland
Air Traffic Control the Netherlands

MUAC delay absorption for EHAM



Communication required for delay absorption

Luchtverkeersleiding Nederland
Air Traffic Control the Netherlands

	Measure	Total	Jever	Brussels	Hannover
February	Dry	6038	1315	2948	1775
	Linear holding	6063 (+0.4%)	1300 (-1.1%)	2969 (+0.7%)	1794 (+1.1%)
	Dropping	6101 (+1.0%)	1307 (-0.6%)	2986 (+1.3%)	1808 (+1.9%)
	Dry_2	1094	1094	-	-
	Detouring	1087 (-0.6%)	1087 (-0.6%)	-	-
	Turtling	1087 (-0.6%)	1087 (-0.6%)	-	-
August	Dry	8641	1498	4988	2155
	Linear holding	8750 (+1.3%)	1512 (+0.9%)	5079 (+1.8%)	2159 (+0.2%)
	Dropping	8799 (+1.8%)	1525 (+1.8%)	5086 (+2.0%)	2188 (+1.5%)
	Dry_2	1191	1191	-	-
	Detouring	1158 (-2.8%)	1158 (-2.8%)	-	-
	Turtling	1156 (-2.9%)	1156 (-2.9%)	-	-

Total # conflicts in MUAC airspace

		Total	Jever	Brussels	Hannover
February	Dry	2718	450	1556	712
	Linear holding	2684 (-1.1%)	416 (-7.6%)	1559 (+0.2%)	709 (-0.4%)
	Dropping	2702 (-0.4%)	421 (-6.4%)	1569 (+0.8%)	712 (0%)
	Dry_2	401	401		
	Detouring	384 (-4.2%)	384 (-4.2%)		
	Turtling	385 (-4.0%)	385 (-4.0%)		
August	Dry	5534	633	3723	1178
	Linear holding	5573 (+0.7%)	661 (+4.4%)	3828 (+2.8%)	1084 (-8.0%)
	Dropping	5572 (+0.7%)	659 (+4.1%)	3805 (+2.2%)	1101 (-5.9%)
	Dry_2	452	452		
	Detouring	407 (-10.0%)	407 (-10.0%)		
	Turtling	408 (-9.7%)	408 (-9.7%)		

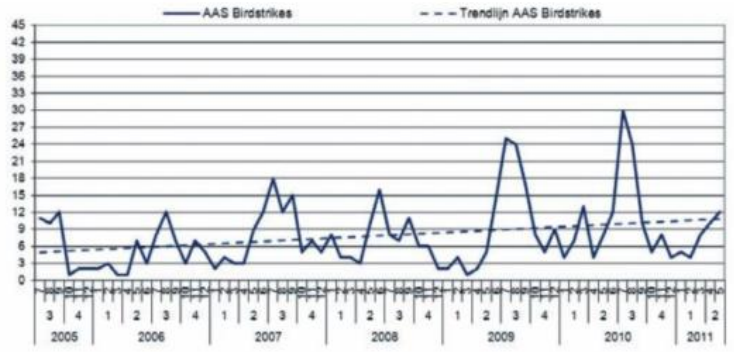
Schiphol related:
Bird-Strike Radar for ATC
PhD student Isabel Metz

Theme 5: Schiphol Related

Motivation

Despite extensive measures for bird control at airports such as

- unattractive airport grounds
- chasing birds away
- reducing of bird populations



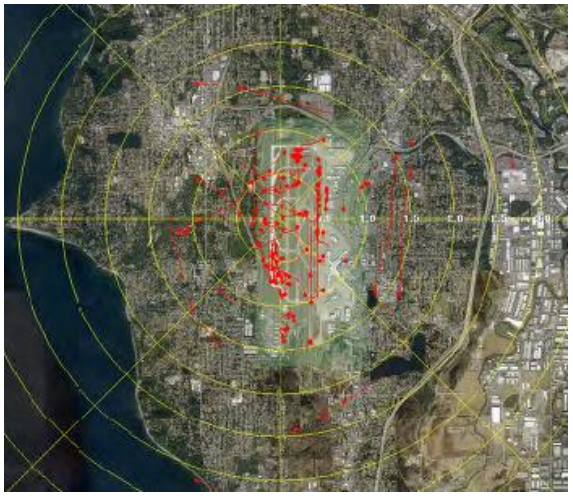
Number of bird strikes at Schiphol during landing below 200 ft and during climb to 500 ft (Source:Beumkes, 2011)

bird strikes so far have caused

- 48 fatal accidents with 261 fatalities and
- 91 hull losses of aircraft since 1912
- costs of approximately one billion euros per year to civil aviation (Maragakis, 2009)

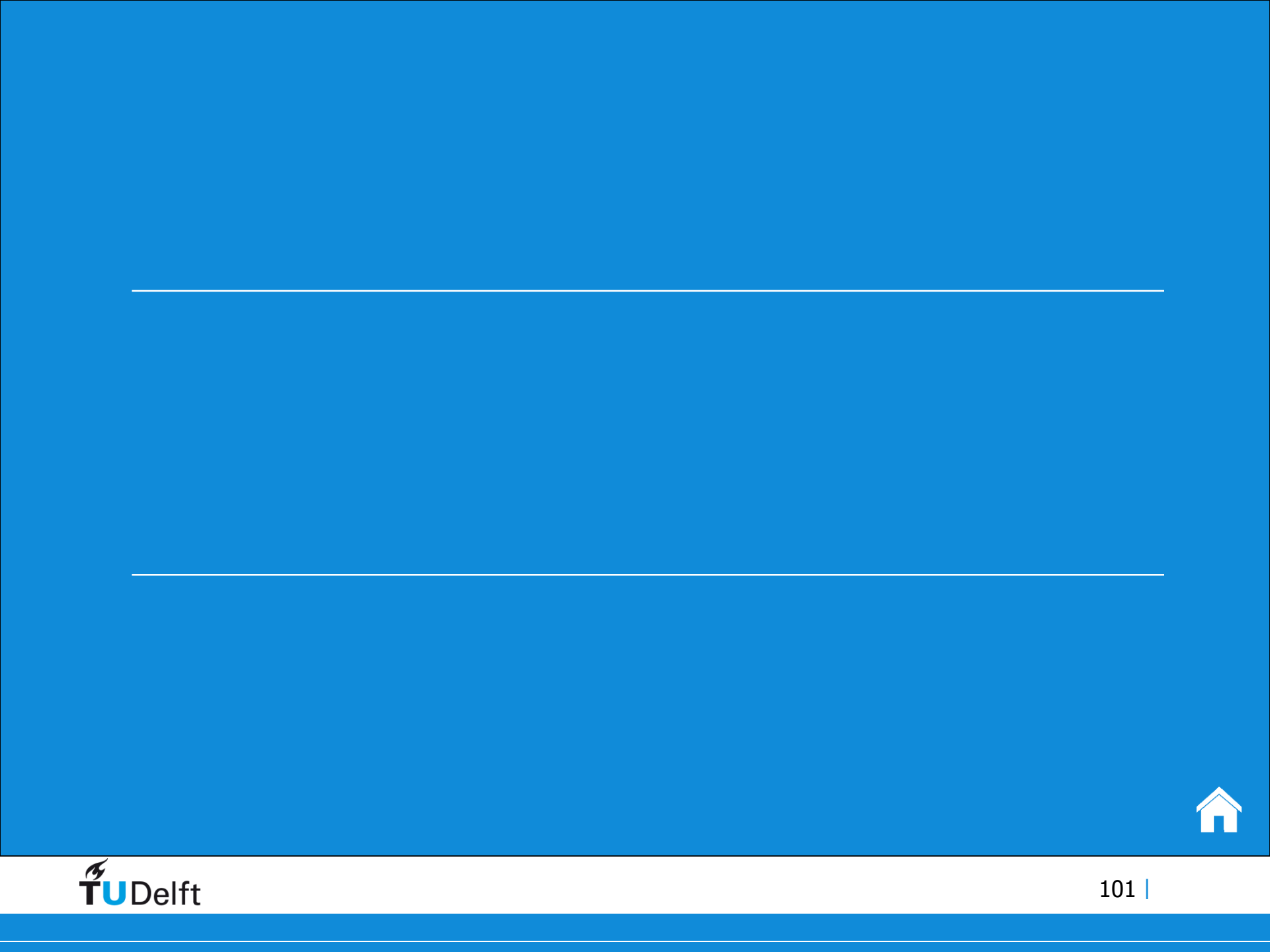
Method
… first steps

- Background information
  - Justification
  - Avian radar technology
  - Bird trajectories
  - Requirements for an ATC alert system
- Model for a simulation environment
  - Airport environment
  - Air traffic
  - Bird traffic
  - Avian radar
  - Operator
- Effects on capacity & safety deterministic or not?



Example Avian Radar Display
(Source: Brand et al., 2011)

M. Brand, G. Key, T. Nohara, and R.Beason. Integration and Validation of Avian Radars (IVAR). Technical Report J
K.E. Beumkes. Emergency landing after bird strike Boeing 737-4B6 , Amsterdam Schiphol Airport 16 June 2010. Techni
The Dutch Safety Board, The Hag
I. Maragakis. Bird population trends and their impact on Aviation safety 1999-2008. Technical report, EA




Questions?