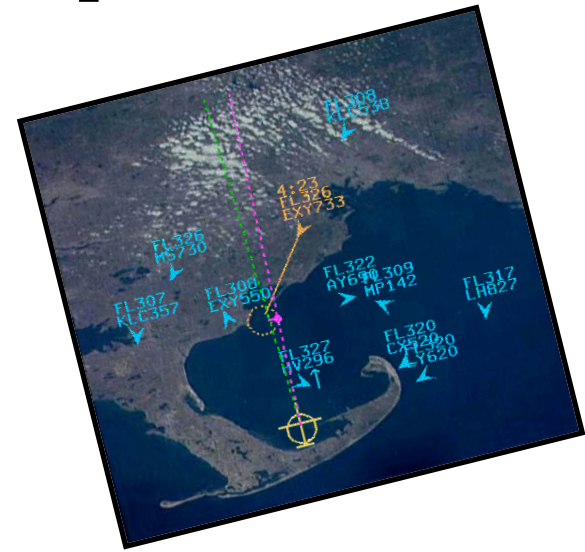


Overview Airborne Separation Assurance: Issues and research questions



4th International Conference on Research in Air Transportation — ICRAT 2010

June 01-04, 2010 — Budapest, Hungary

Outline

- Pioneering age: research on feasibility question
- Research age: research questions
- Implementation: evolution vs. revolution

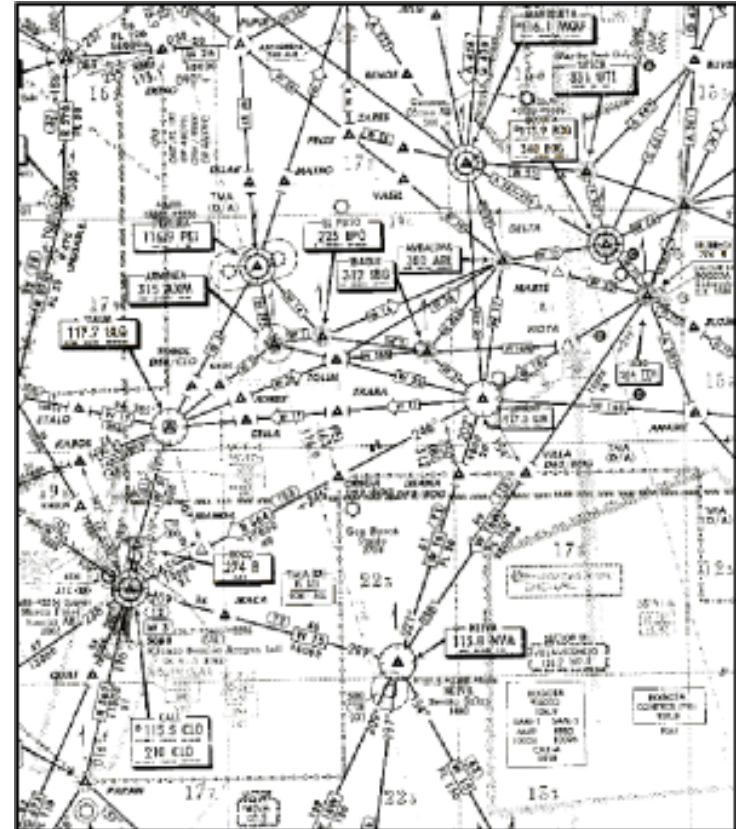
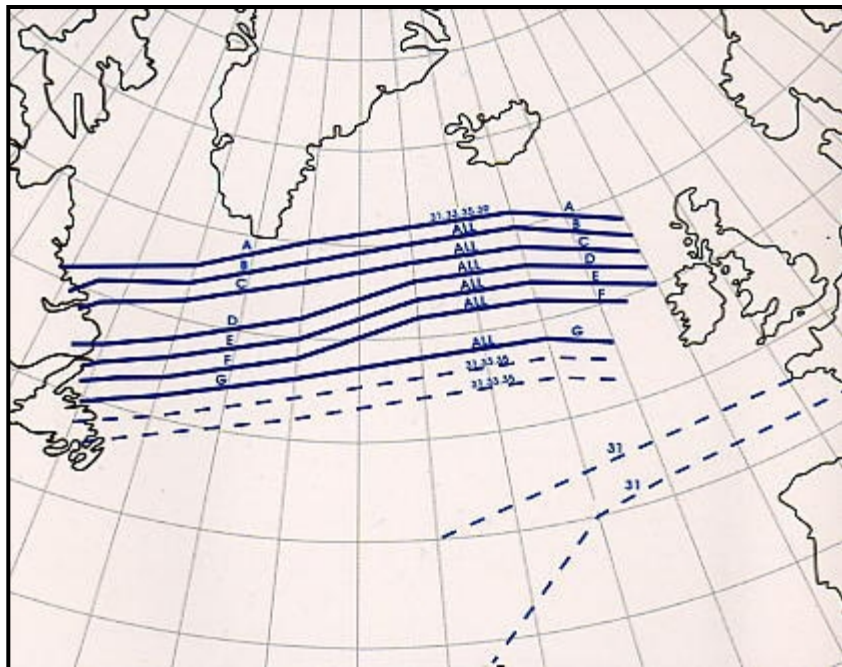
Pioneering age

- Is it feasible to safely make a conceptual design of Free Flight with airborne separation assurance?

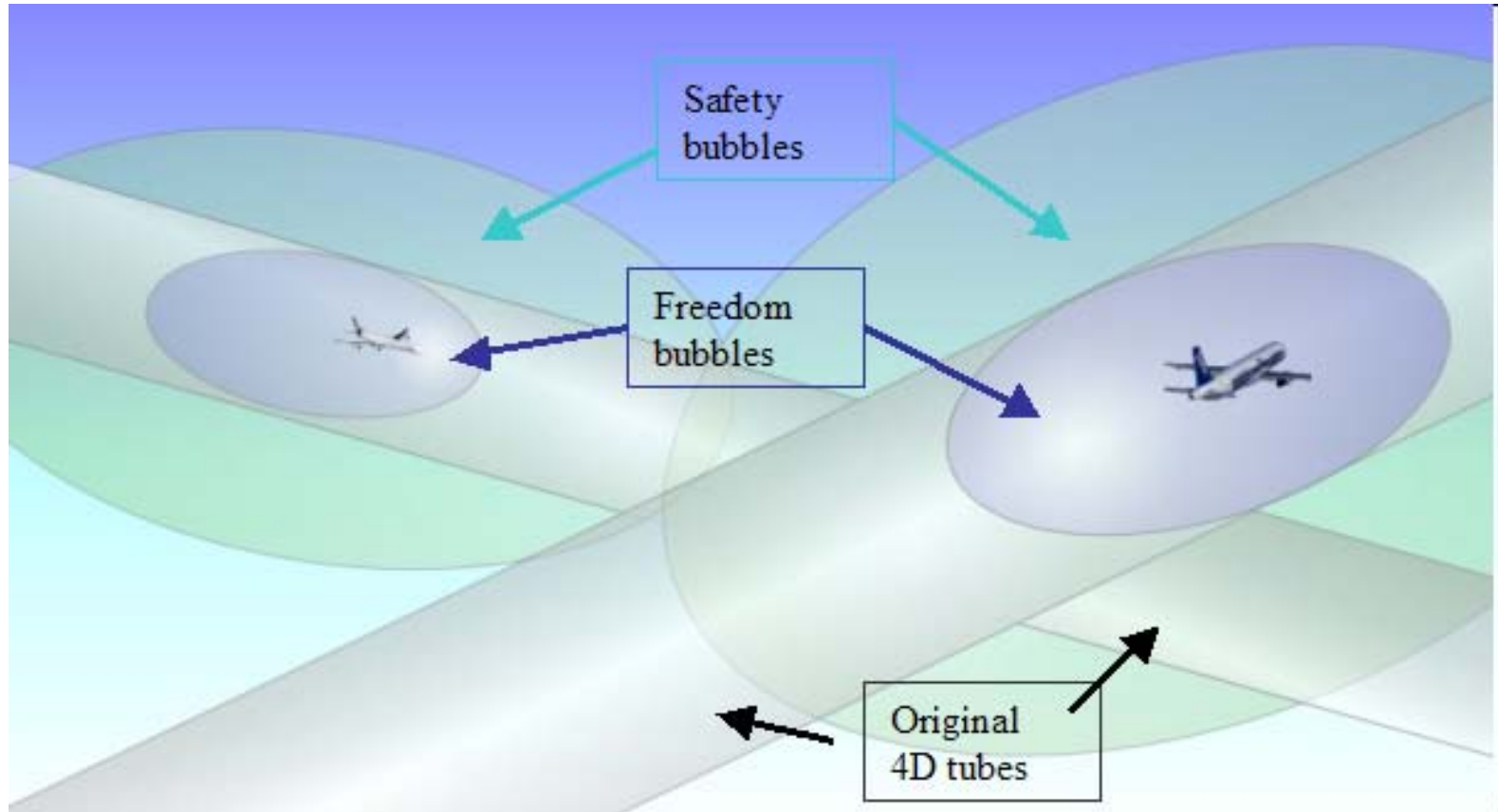


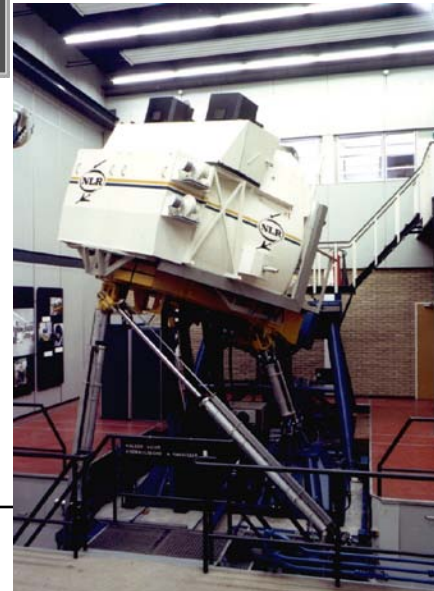
What is Free Flight?

- Today's “unfree flight”



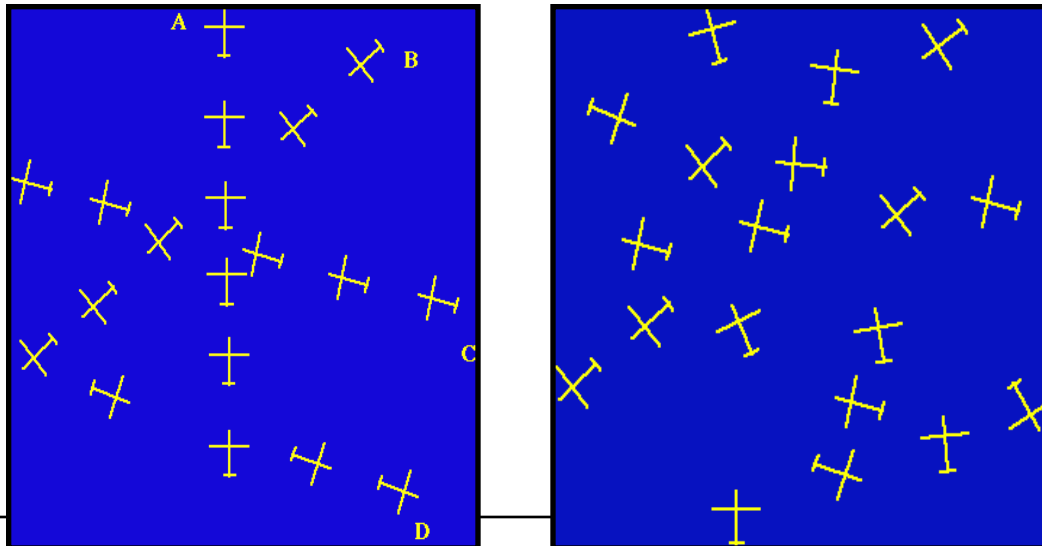
More centralised control: 4D bubbles





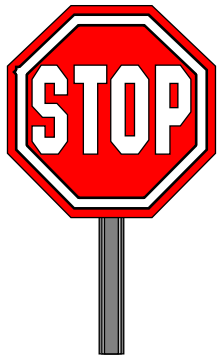
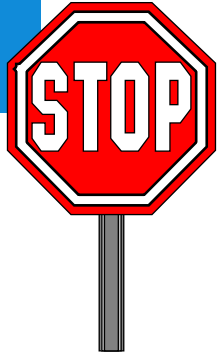
Why Free Flight?

- Self-optimisation
 - Horizontally
 - Direct routes
 - Optimal economic speed
 - Vertically
 - Optimal altitude cruise climb
- En-route: Airborne Separation Assurance (no ground ATC)



Free Flight decentralisation of ATC

- “Free Flight leads to a dangerous jungle with a centrally coordinating element like ATC”
- “Pilots do not have the time, training, and mental capacity to play air traffic controller on top of flying the aircraft”



‘Vrij vliegen is sneller en veiliger’

Onderzoeker bepleit chaos in luchtruim

AMSTERDAM • RICHARD MOOYMAN

Schaf de luchtverkeersleiding af en laat piloten op eigen houtje via de kortste route naar hun bestemming vliegen. Dit is volgens onderzoeker J. Hoekstra van het Nationaal Lucht- en Ruimtevaartlaboratorium(NLR)

middelste van 43 minuten.

Volgens het plan van het NLR worden vliegtuigen uitgerust met apparatuur waarmee de bemanning zelf alle andere toestellen in de wijde omtrek kan waarnemen. De gezagvoerder is dan verkeersleider voor zijn eigen toestel. Koerst hij op een

De capaciteit van het luchtruim neemt fors toe als de vliegbanen op grote hoogte worden afgeschaft. De overbelaste vliegroutes in het versnipperde Europese luchtruim zijn nu een van de belangrijkste oorzaken van de toenemende vertragingen. Luchtvaartmaat-

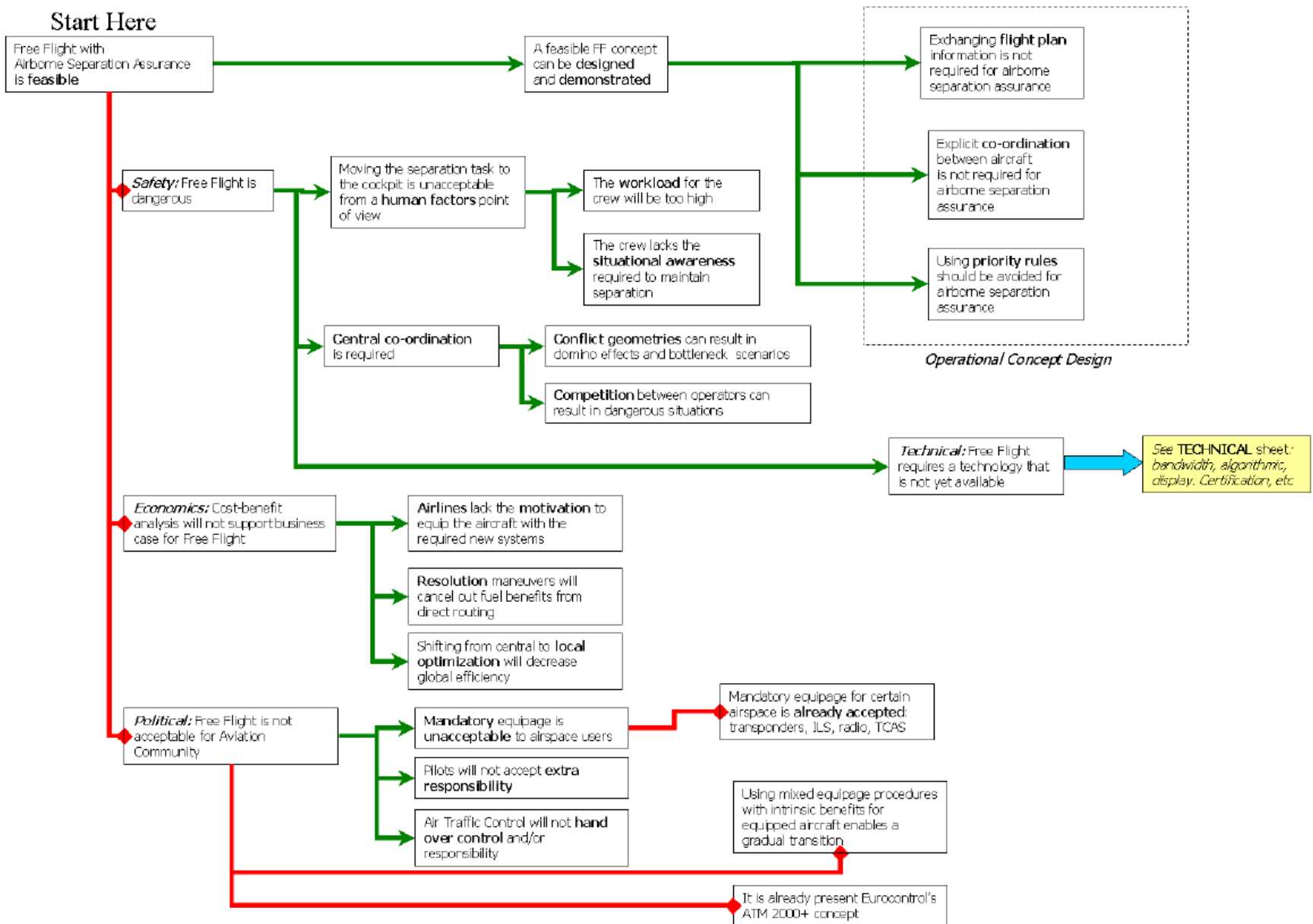
over de verkeersregels in de lucht. Verkeersleidingscentra moeten bevoegdheden inleveren en vliegtuigen dienen met speciale apparatuur te worden uitgerust. Overigens blijven verkeersleiders wel nodig om het starten en landen te begeleiden.

Het NLR kwam onlangs al in

“Research Scientist argues for more Chaos in Airspace”

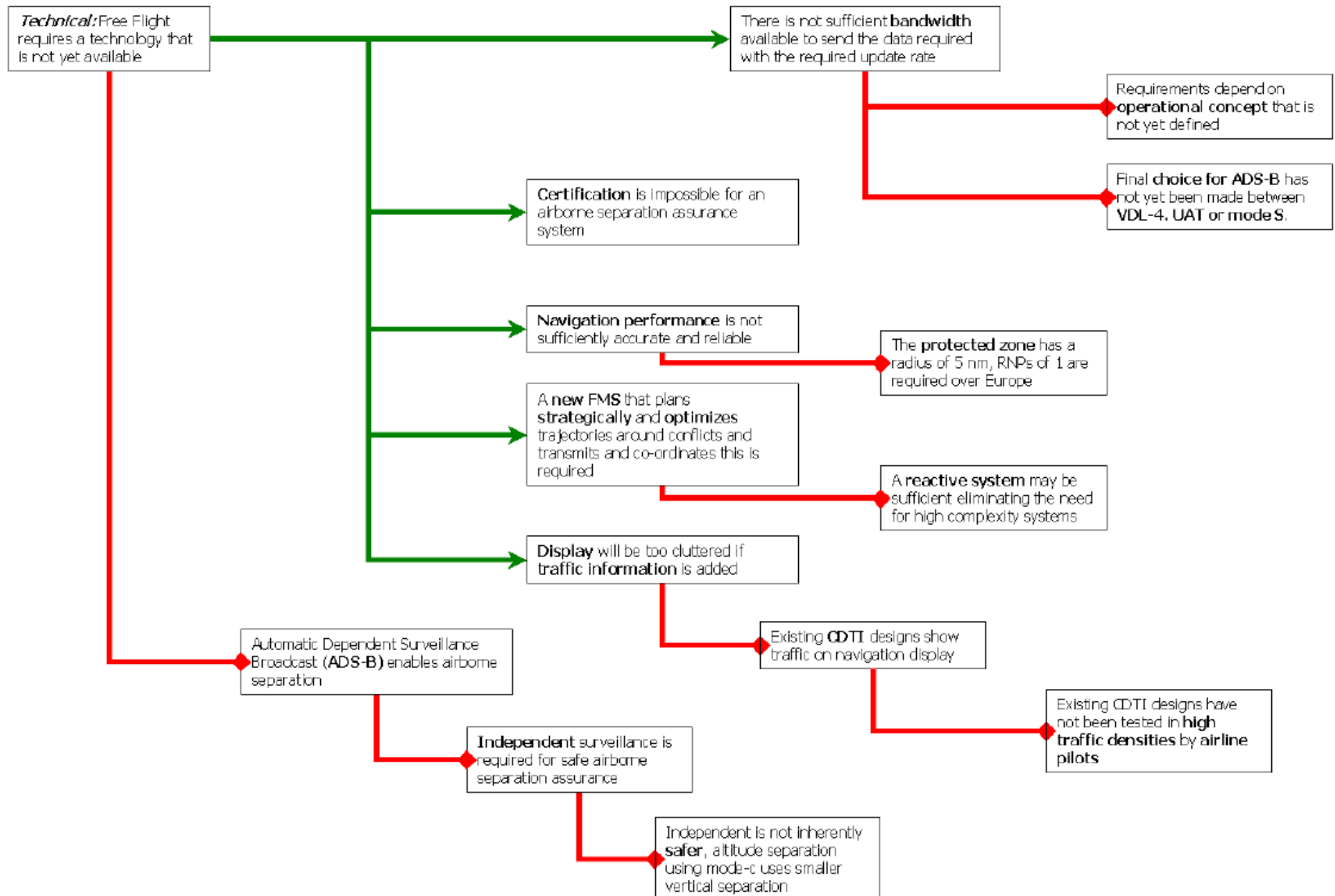
Hypothesis tree

Start Here



Hypothesis tree sub-tree (branch)

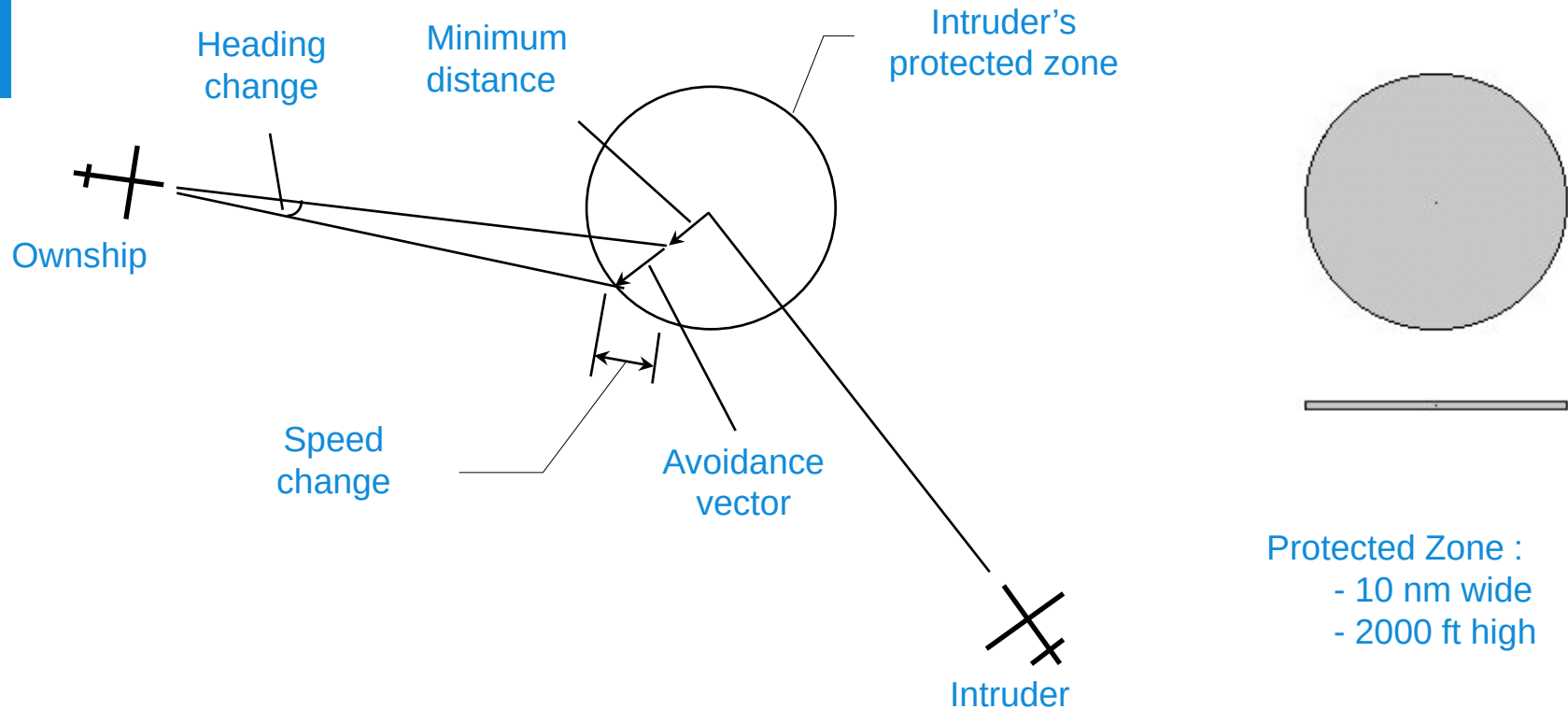
Technical



Three *simultaneous* tracks

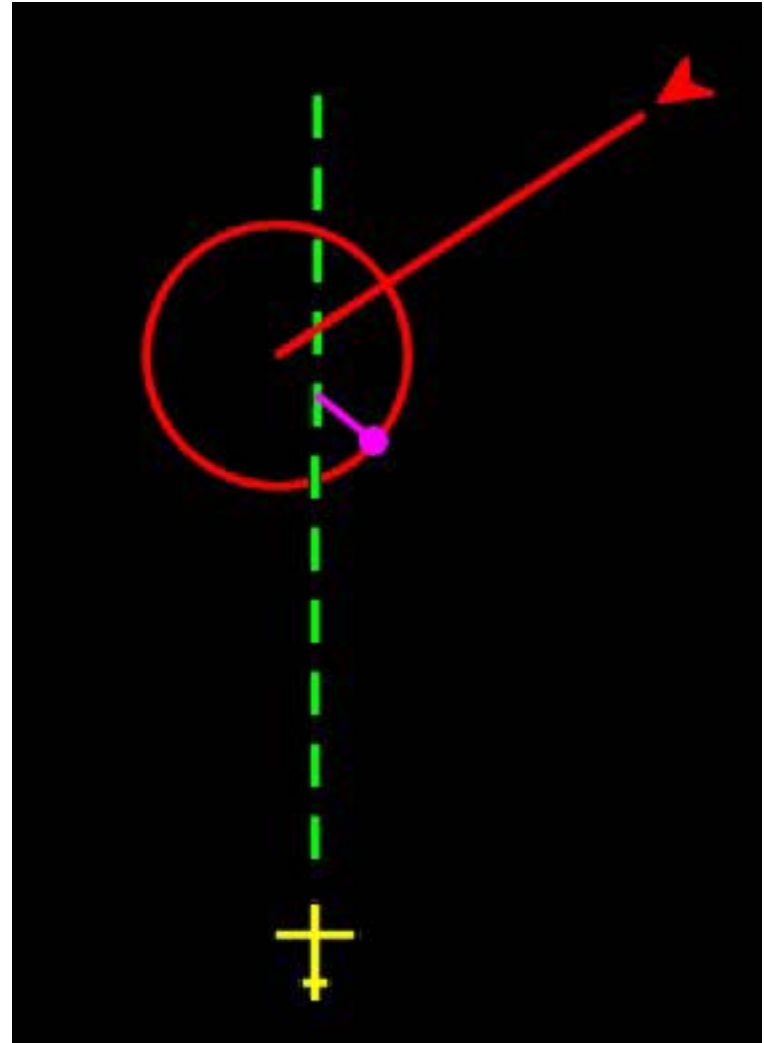
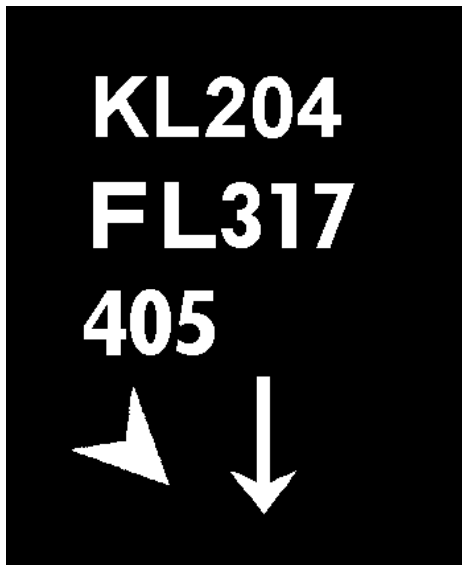
- Analysis (many different tools, a.o. TMX still used by NASA, Raytheon, NLR)
- Off-line simulation (on desktop computers with traffic simulators)
- On-line simulation (human in the loop, research flight simulator)

En-route: 'flight traffic rules



“Implicit coordination”
Small manoeuvres

Prototype procedure & cockpit systems

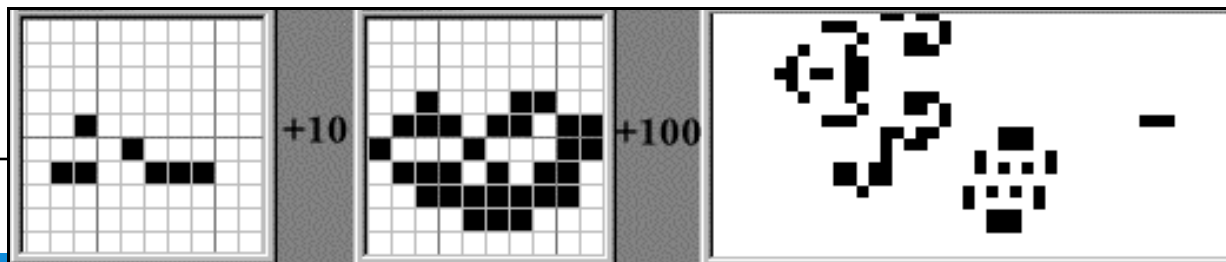
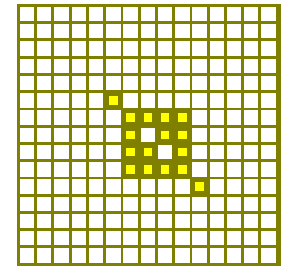
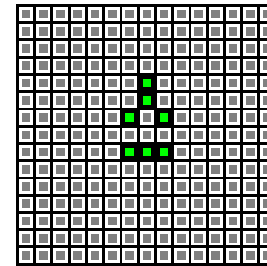
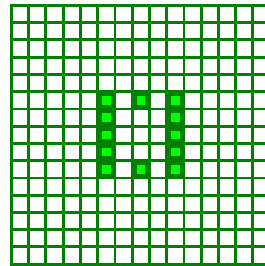
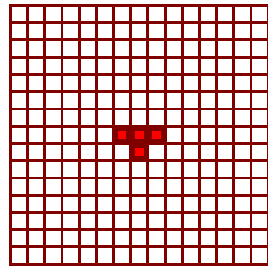
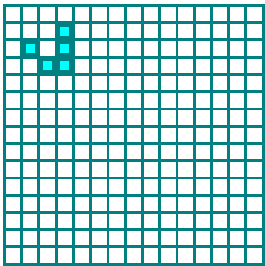


'Emergence' problem of Free Flight: Compare with Conway's Game of Life

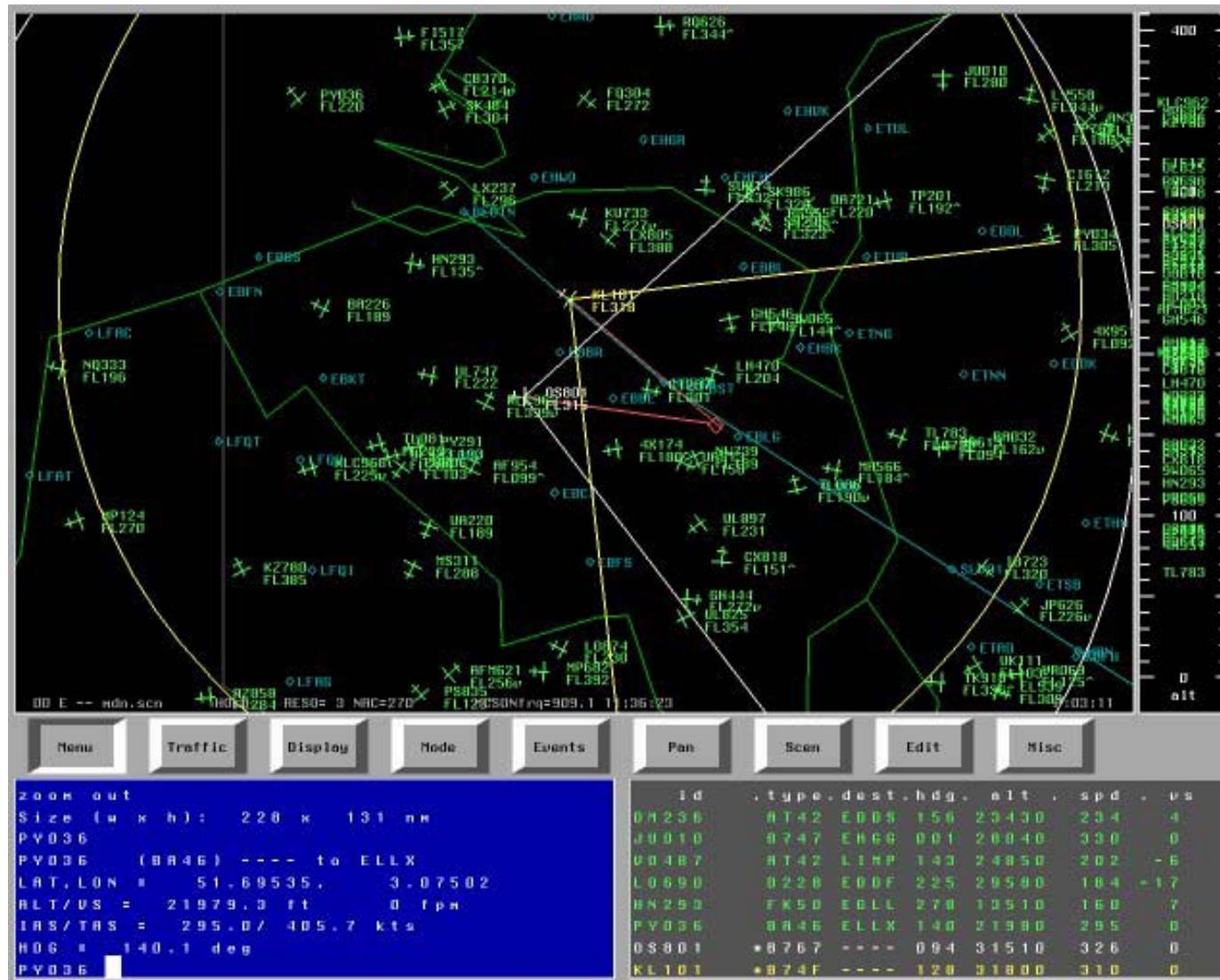
- **Micro-level: simple rule, If sum cells around cell**

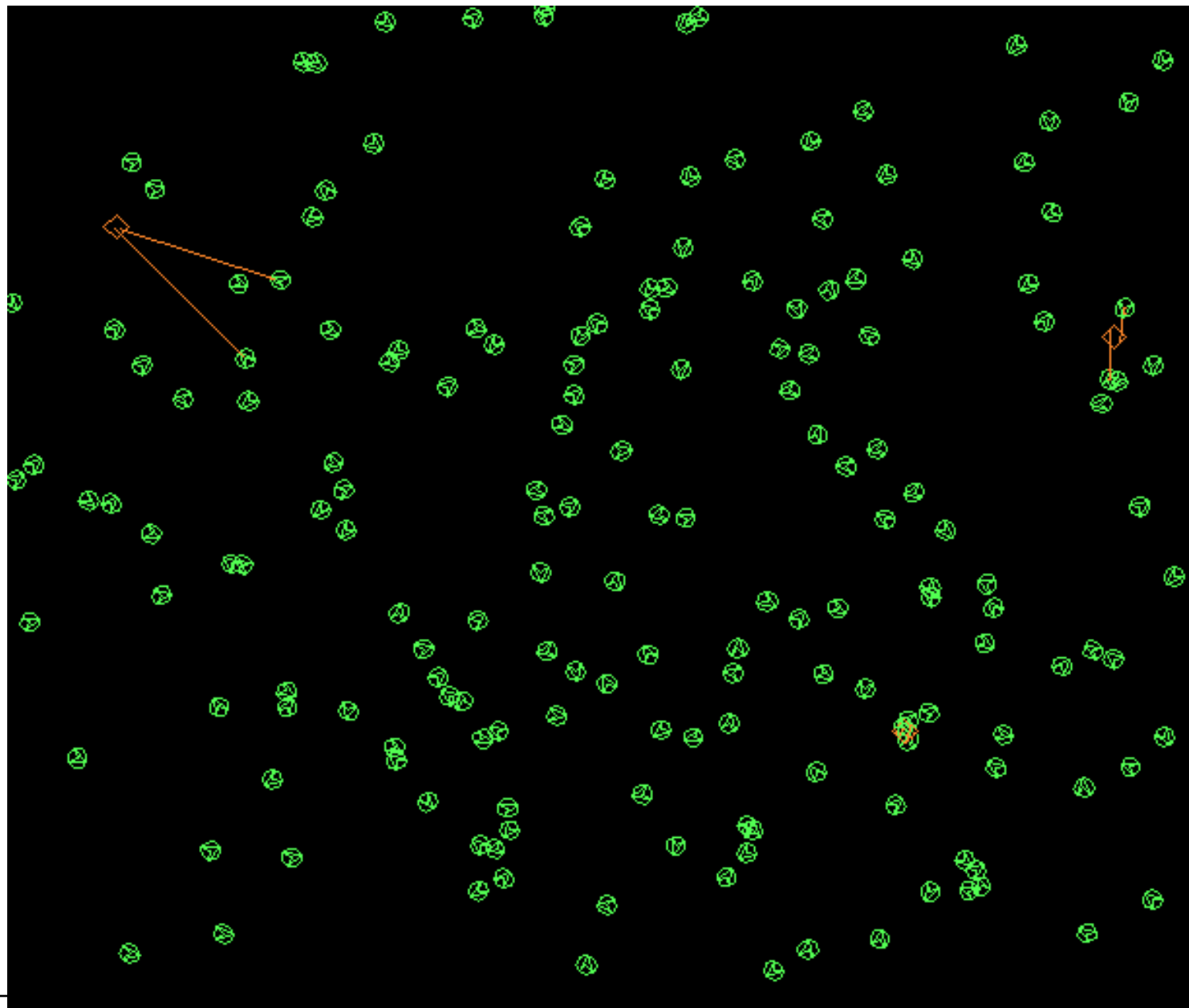
0,1	= cell 'dies'
2	= cell 'survives'
3	= 'birth'
4-8	= cell 'dies'

- **Macro-level: complex patterns**

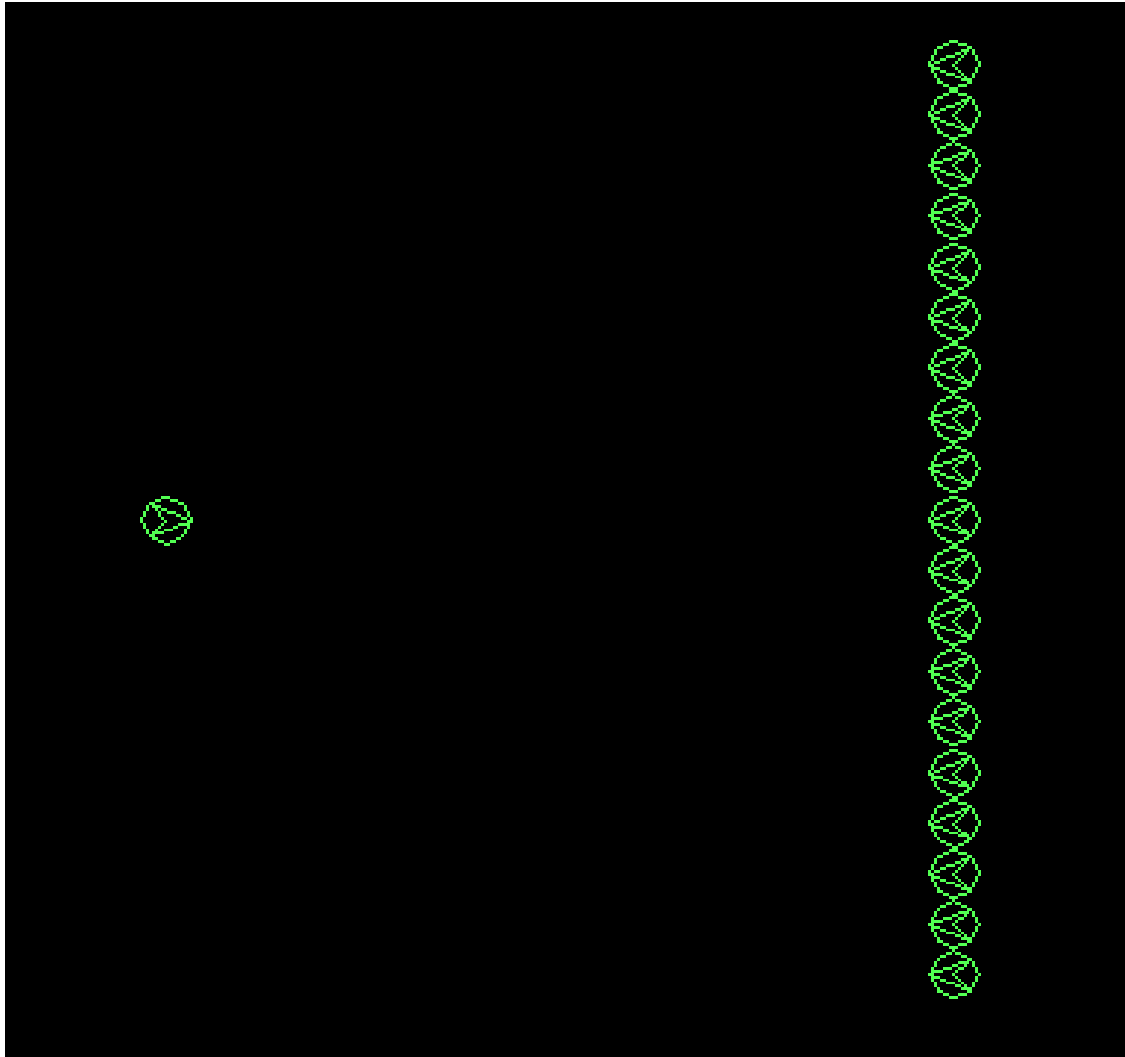


Offline simulation - Traffic Manager

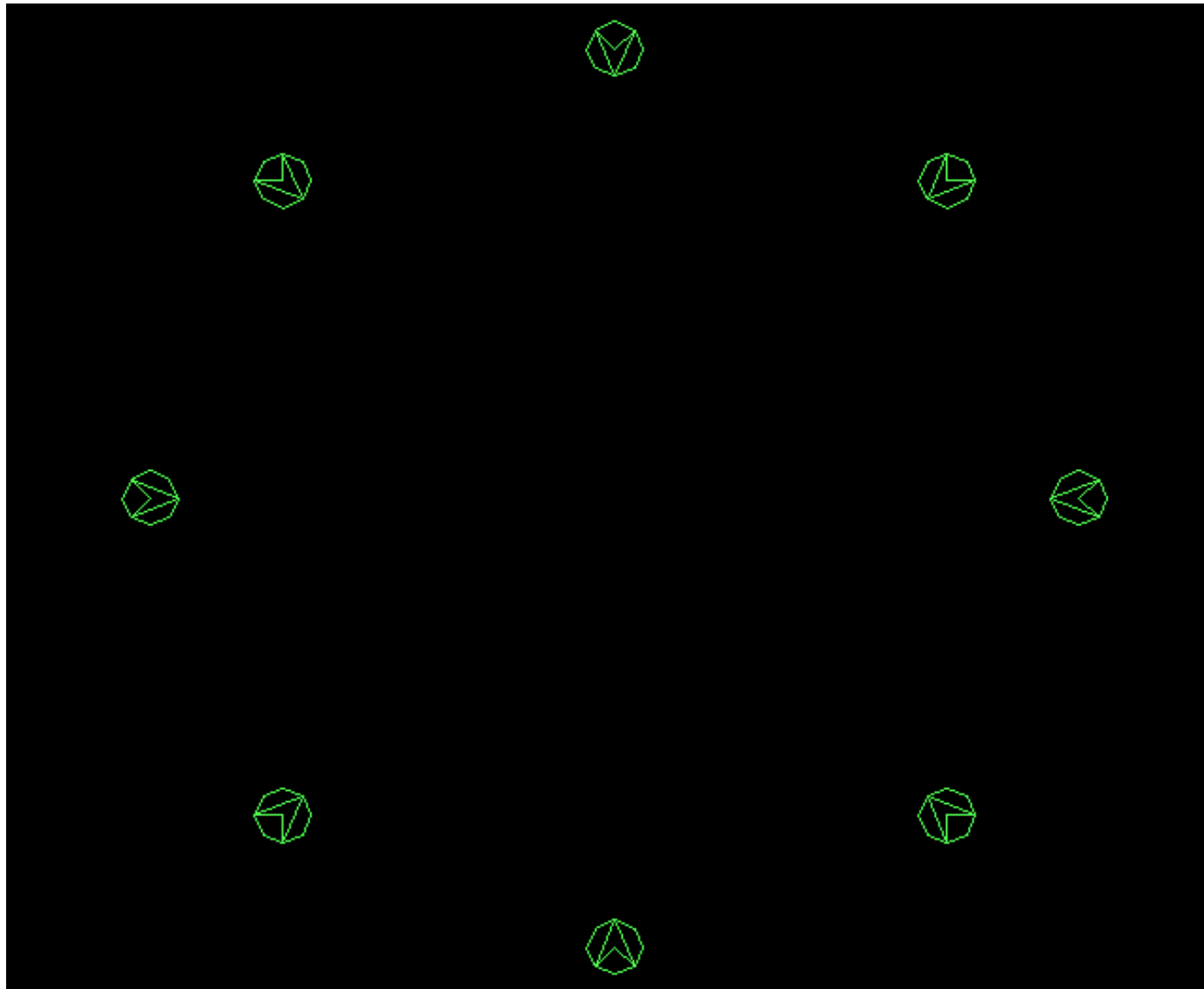




The wall



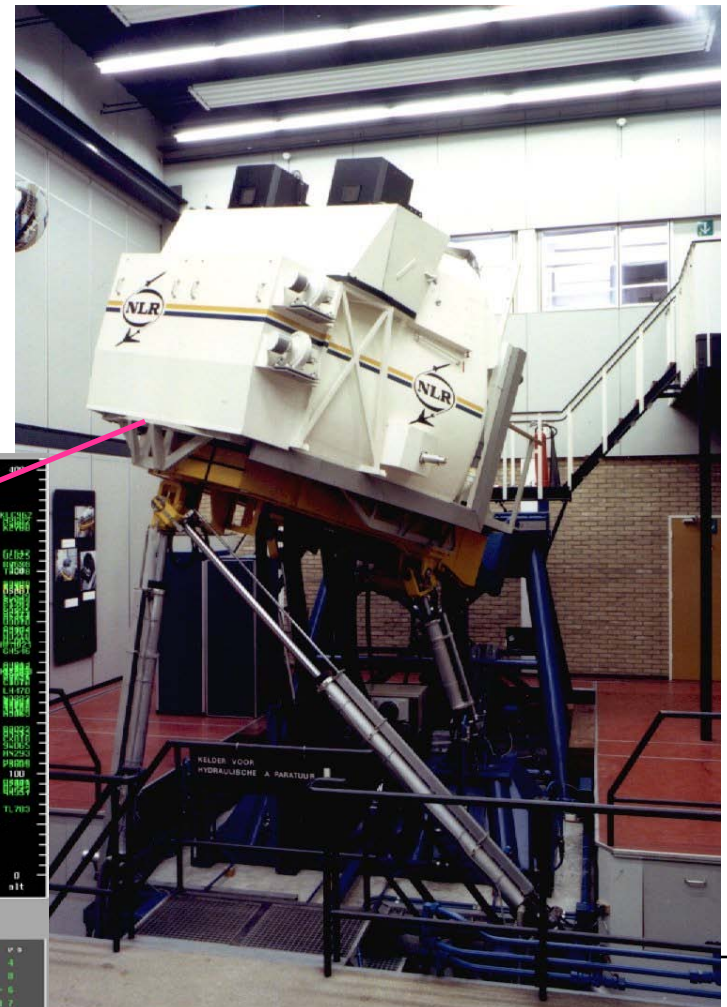
Circular conflict (“superconflict $n=8$ ”)



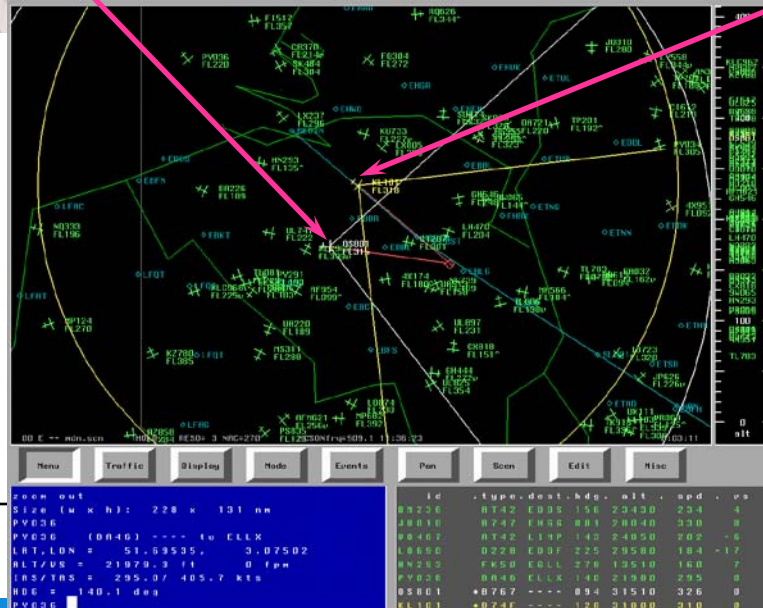
Simulation configuration on-line



Flight simulator

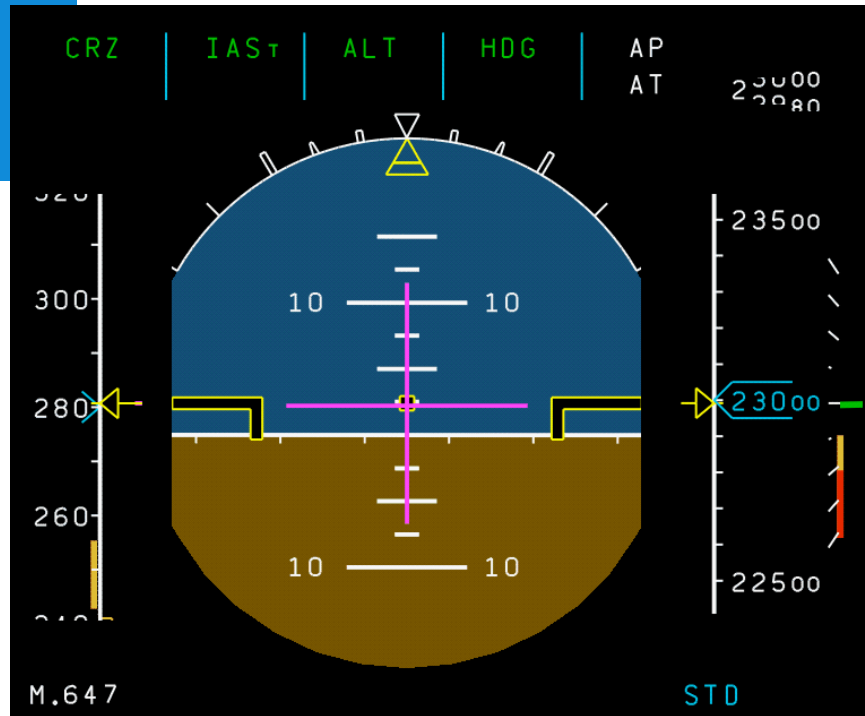


Desktop
simulation



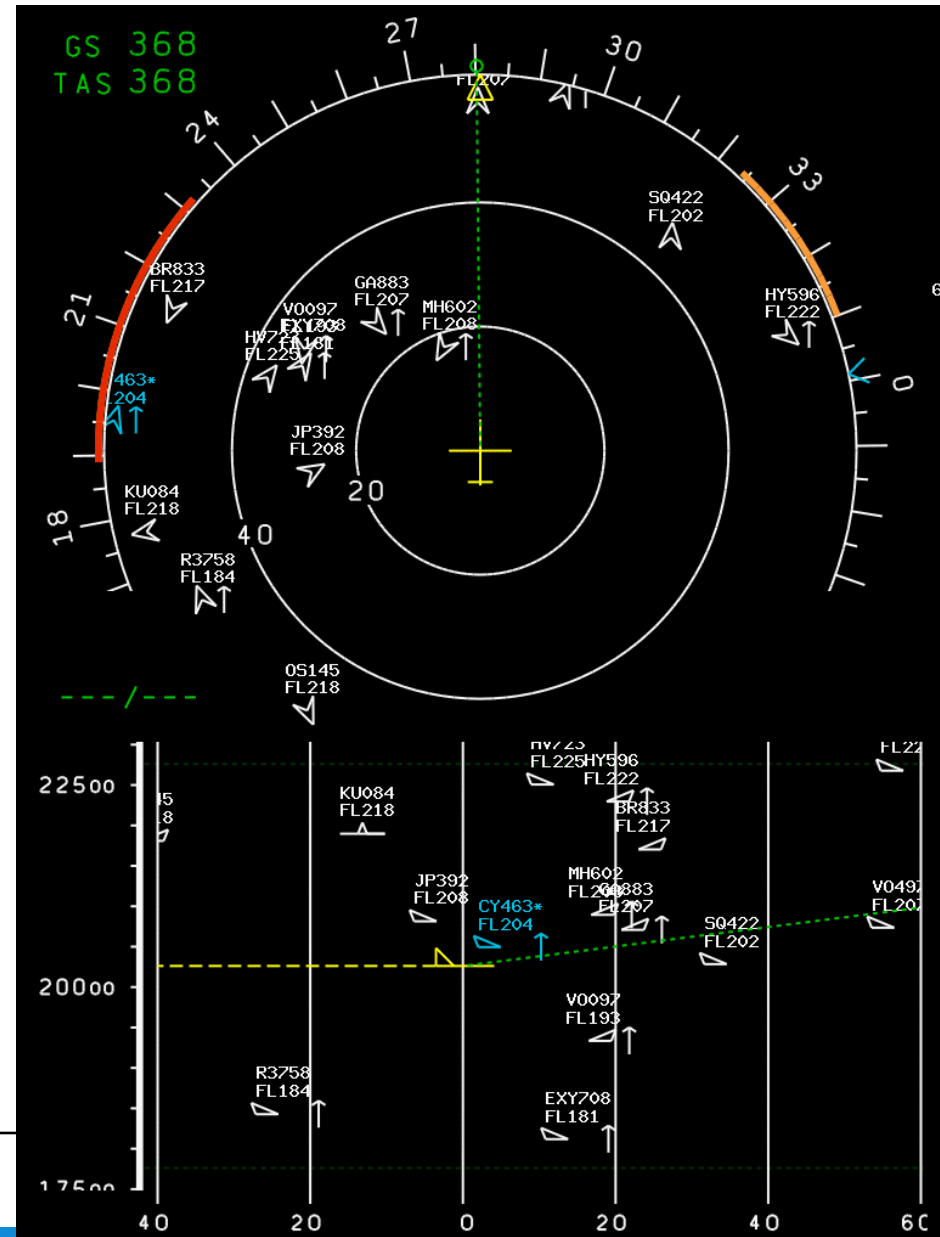
Traffic
Manager
TU Delft

Predictive ASAS



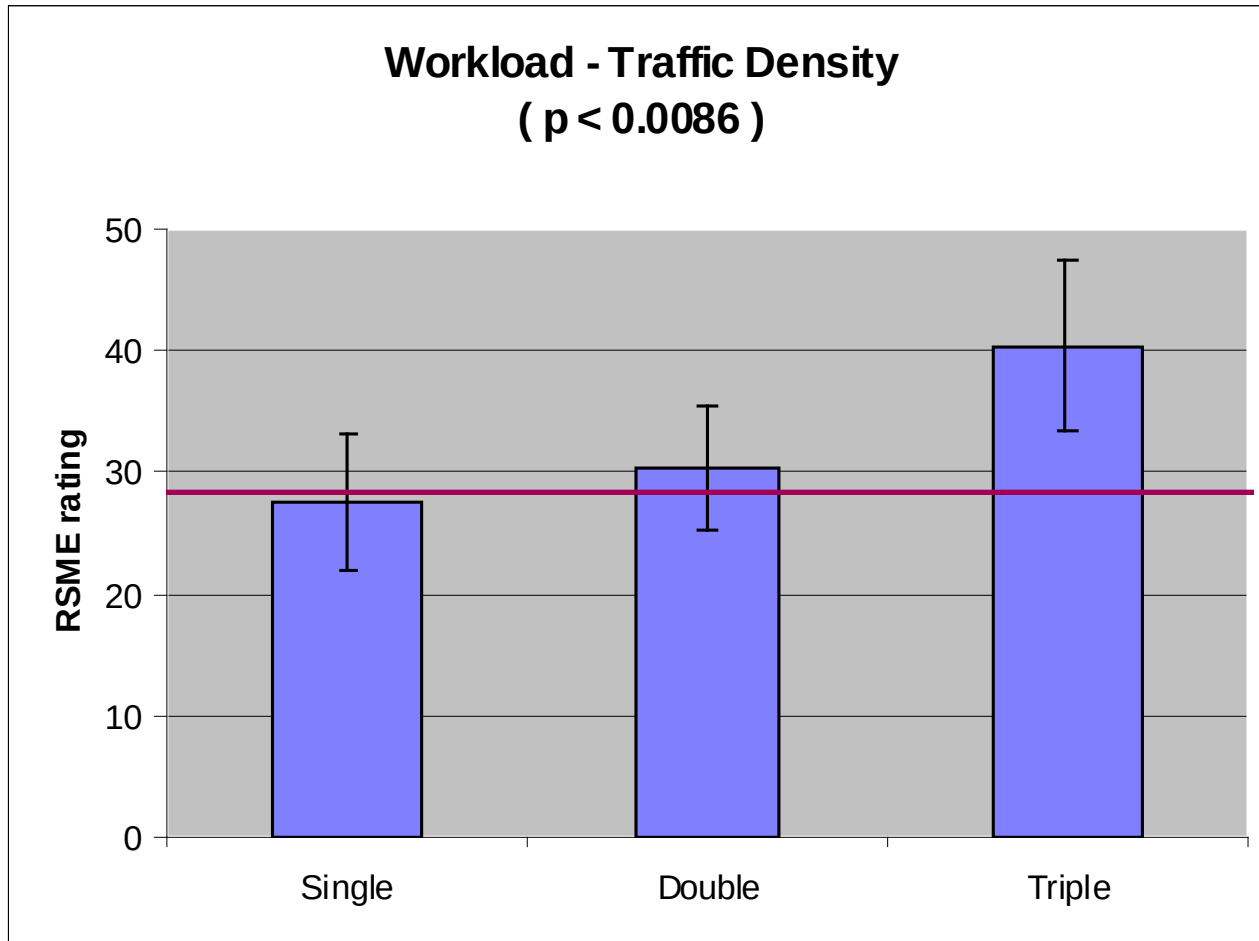
Algorithms for “ Don’t go” indications:

- **Track**
- **Vertical speed**
- **Speed**



Human-in-the-Loop experiment 97

Results



Task comparison

Controlled vs. Free Flight

Fly

Navigate

Communicate with ATC

Controlled Flight

Fly

Navigate

Separation

Free Flight

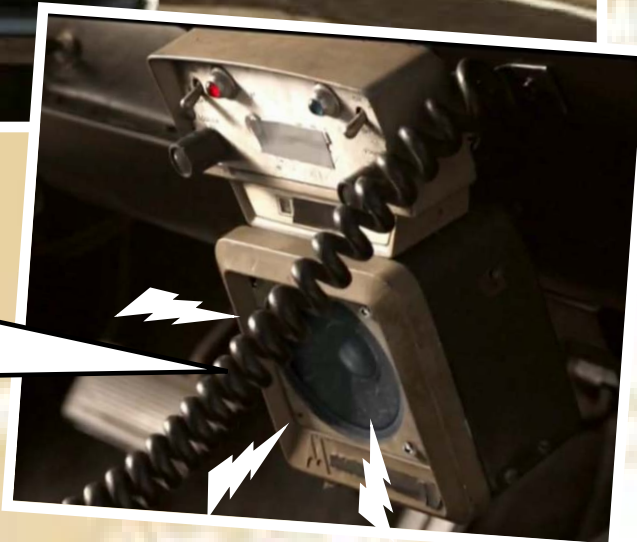
This is Free Flight



This is today's Controlled Flight



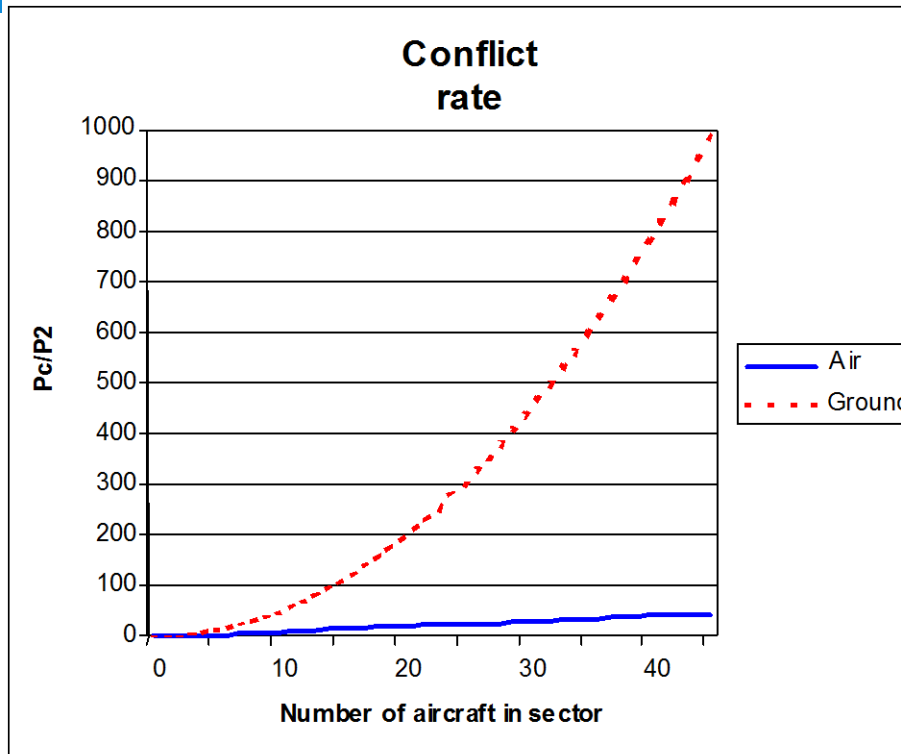
*Accelerate to 100 mph,
move one lane left!*



Please de-conflict....



Fundamental, mathematical reason to de-centralise



$$p_{c_g} = \frac{1}{2} N(N-1) p_2$$

$$p_{c_a} = (N-1) p_2$$

Sufficiently feasible to continue

- But there were many shortcuts:
 - Implicit coordination, with state-based CD&R, no priority at certain high densities in the cruise phase with a given display and alerting system seems feasible
- Next question: what is best solution in the interest of safety, capacity and acceptability?

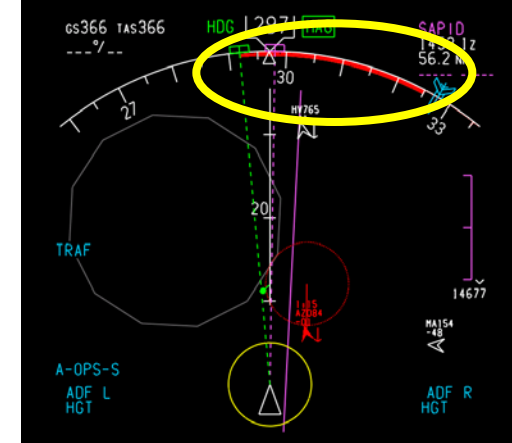
Research age: To do list

- Conflict prevention
 - Dynamic density/flow management
 - Traffic awareness HMI
- Conflict detection:
 - Lookahead-time
 - Level of Intent information
 - Protected zone dimensions
- Conflict Resolution:
 - Priority or co-operative maneuvering
 - Multi-aircraft conflicts: sequential or summing? Priority solving?
- Flight phase: only cruise or also lower?
- Mixed equipage
- Partial delegation of responsibility (operations)? Role air-ground.
- Which Human-Machine Interface? Level of automation?

Safety comparison

Conflict Prevention system

Vertical speed



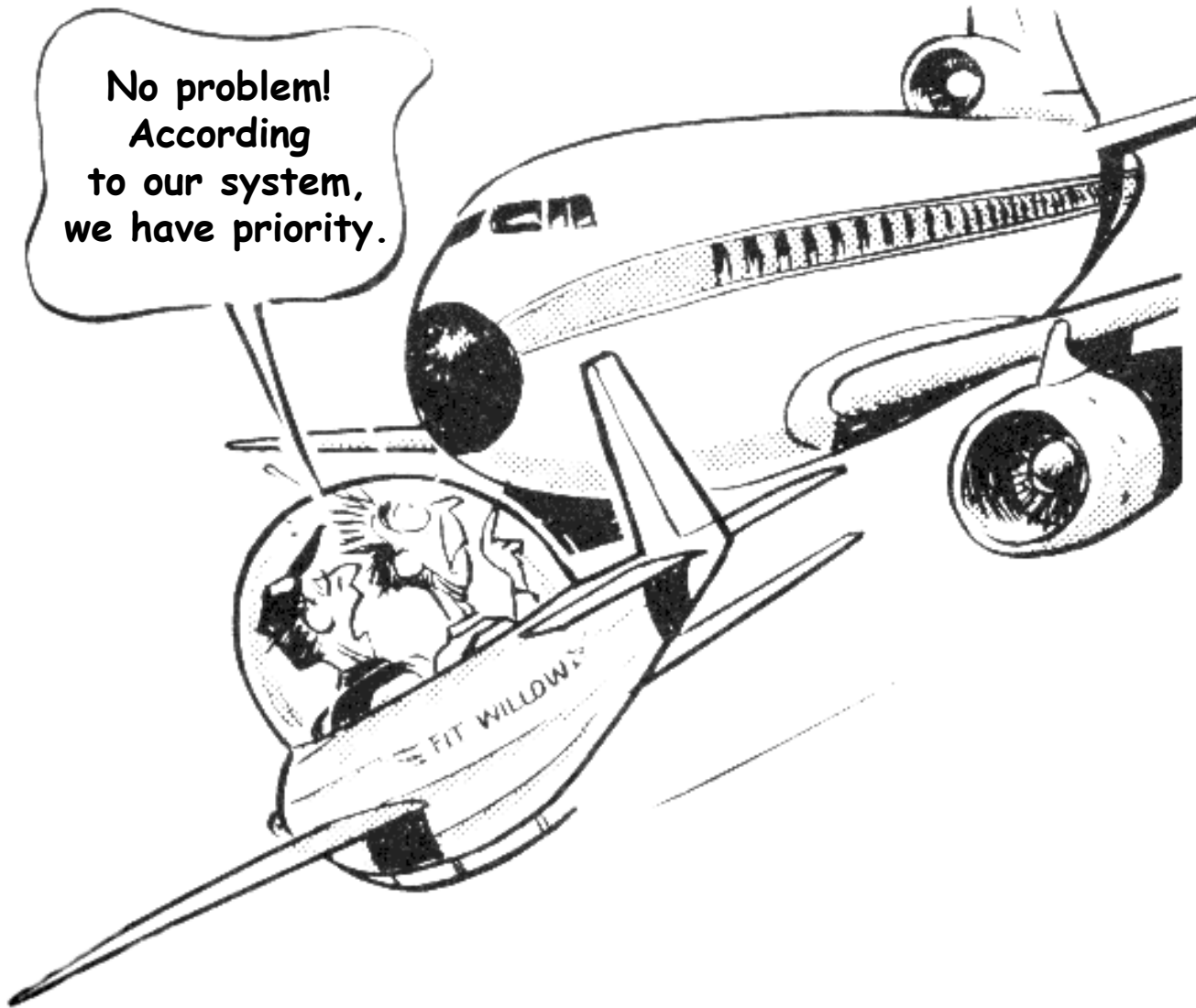
Speed

Heading



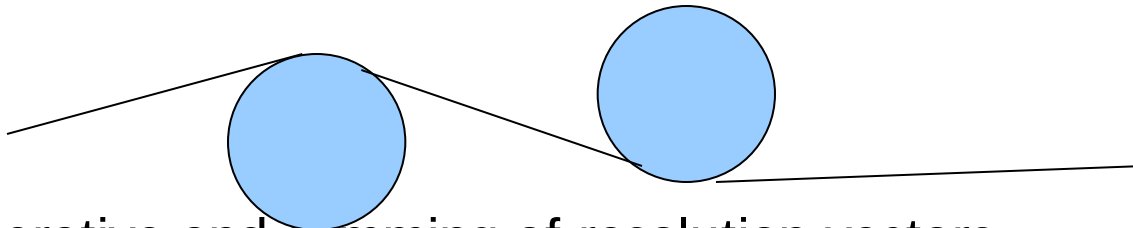
Priority or no priority?

No problem!
According
to our system,
we have priority.

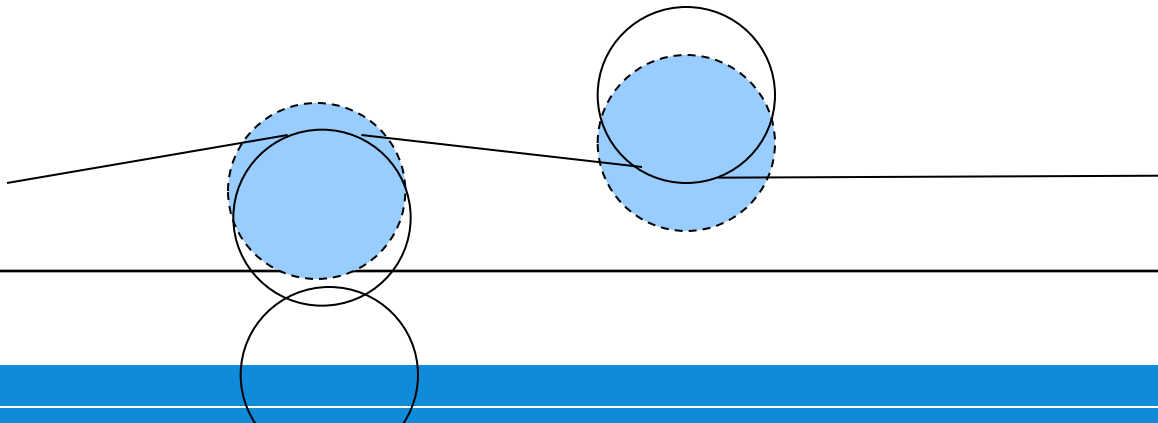


Priority or no priority?

- Priority and sequential solving
 - lower workload
 - less prone to gaming
 - more suitable for flight plan deconfliction



- Cooperative and summing of resolution vectors
 - stability of multiple aircraft conflicts
 - more robust
 - more suitable for basic mode deconfliction

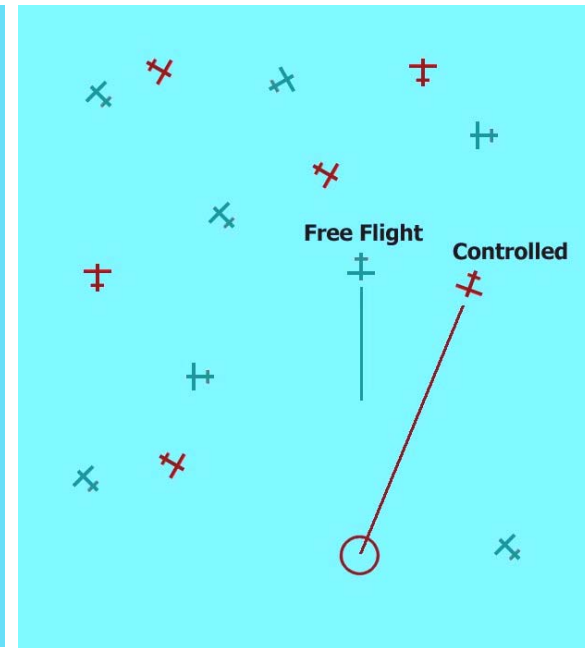


Relation intent/priority

- Levels of intent:
 - None (pure state based)
 - Target values (MCP or FMS current leg)
 - Flight plan (waypoint list)
- Link with priority/negotiation/multi-aircraft effect
- Implementation/safety issues (false alerts vs. missed alerts vs. late alerts)

(see diagrams on flip-over)

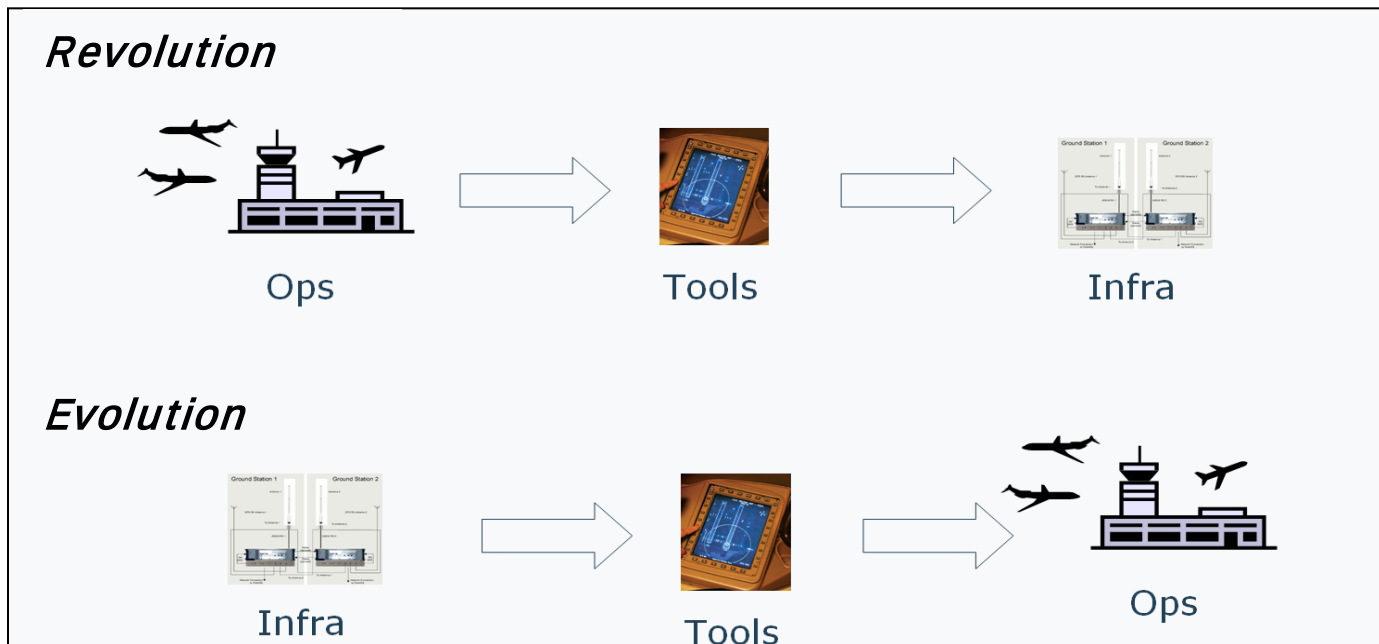
Mixed Equipage



- Segregated airspace or not?
- Mandatory equipage or benefit structure?

Implementation age

- Standardisation
- Evolution vs. revolution



Let's make it safe!

