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Virtual Block Control and Separation Bubble Alerting

Advanced Tools and Procedures for ATC in Low Visibility Conditions

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- **Detailed Concept Description**
- **Simulation Platform**
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Background

- **Eurocontrol Airport Operations Programme (APR)**
 - Capacity, safety and efficiency improvements
 - Use of automation under low visibility conditions
- **A-SMGCS Procedures in Visibility Condition Three**
 - Feasibility study incorporating results of stakeholder interviews and workshops
 - Project discussed several procedural options
- **A-SMGCS Virtual Blocks and Separation Bubbles**
 - Study evaluated candidate concepts
 - Performed initial validation of prototype implementation

Candidate Concepts

- **Parallel Pushback (PP)**
 - requires close co-ordination between platform operators, airlines and tower
- **Convoy Operation (CO)**
 - requires pilots to safely follow an aircraft on taxiways
- **Multiple Line-up (ML)**
 - requires pilots to see aircraft lined up in front
- **Virtual Block Control (VB)**
 - requires pilots to visually indentify holding positions
- **Separation Bubbles (SB)**
 - requires solid algorithm detecting all potential conflicts without creating nuisance



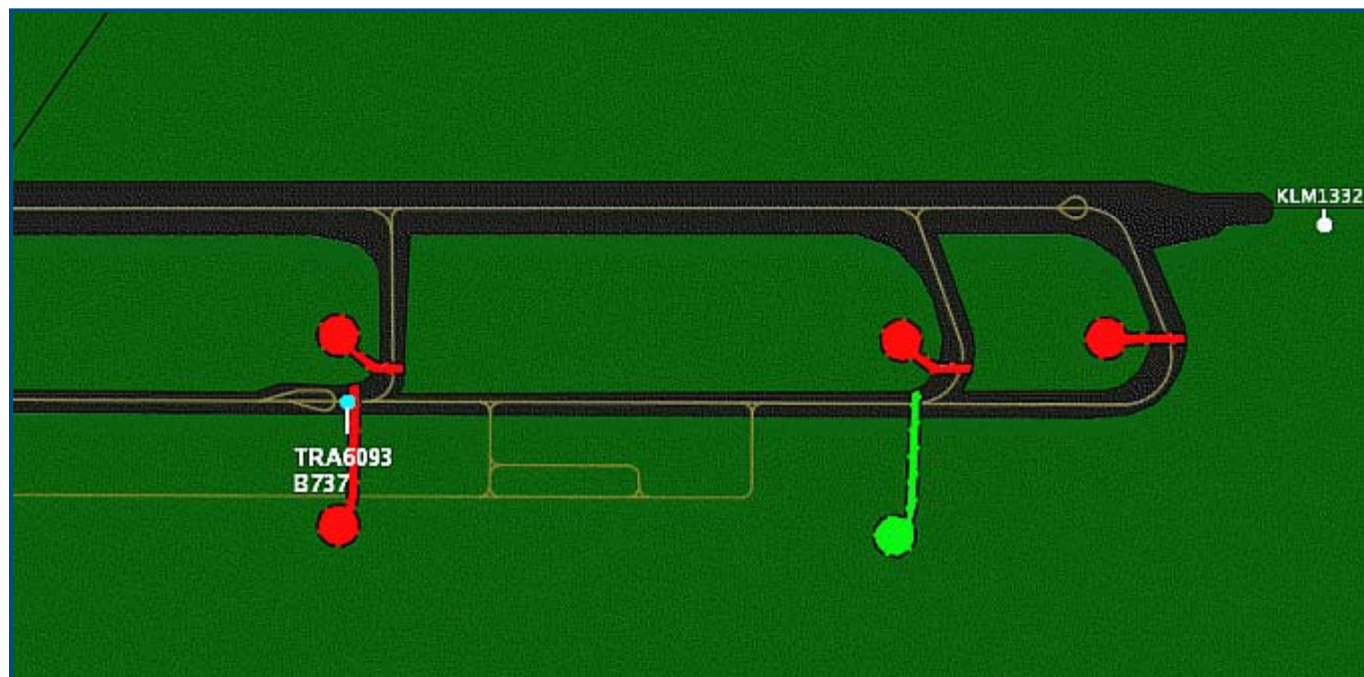
Selection Process - Results

- **Two concept groups: PP/CO/ML versus VB/SB**
 - PP/CO/ML
 - Advantages regarding cost/development
 - Uncertainty regarding roles and responsibilities
 - Safety concerns:
 - co-ordination problems on the apron
 - following aircraft in convoy operations
 - distance between line-up positions
 - Virtual Block Control and Separation Bubble Alerting
 - Intuitive procedures (block control)
 - Minimal infrastructure changes (markings for pre-determined holding positions)
 - Additional safety net

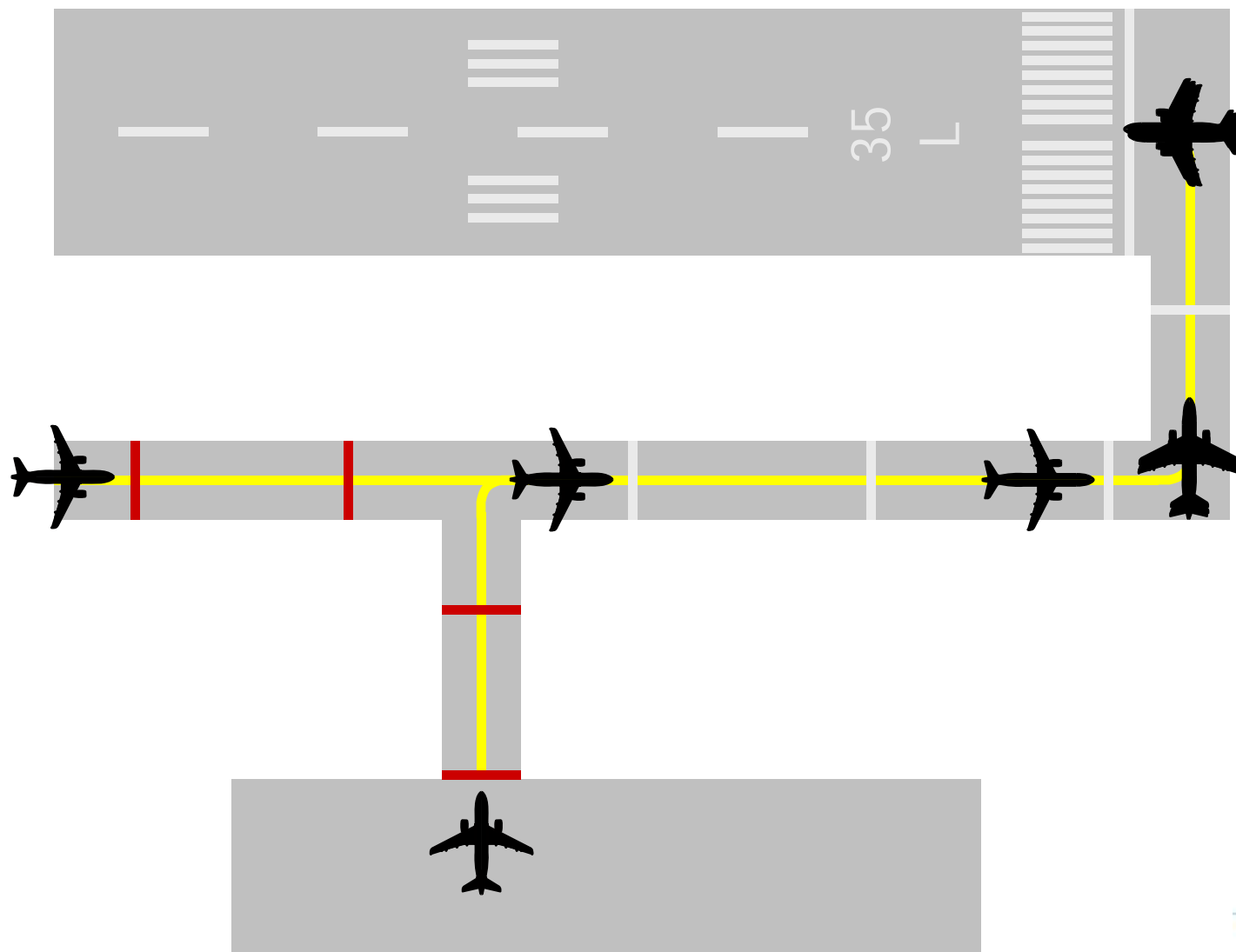
Selection Process - Recommendations

- **VB/SB is preferred concept combination**
- **Additional considerations:**
 - Testing HMI solutions (prototypes)
 - Development of SB algorithm:
 - Longitudinal and lateral spacing
 - Dynamic placing of stop bars (watch dog)
 - Use as control tool or safety net
 - Study pilot reactions in flight simulator
 - Workload issues
 - Safety assessment
 - Develop guidelines for further concept work

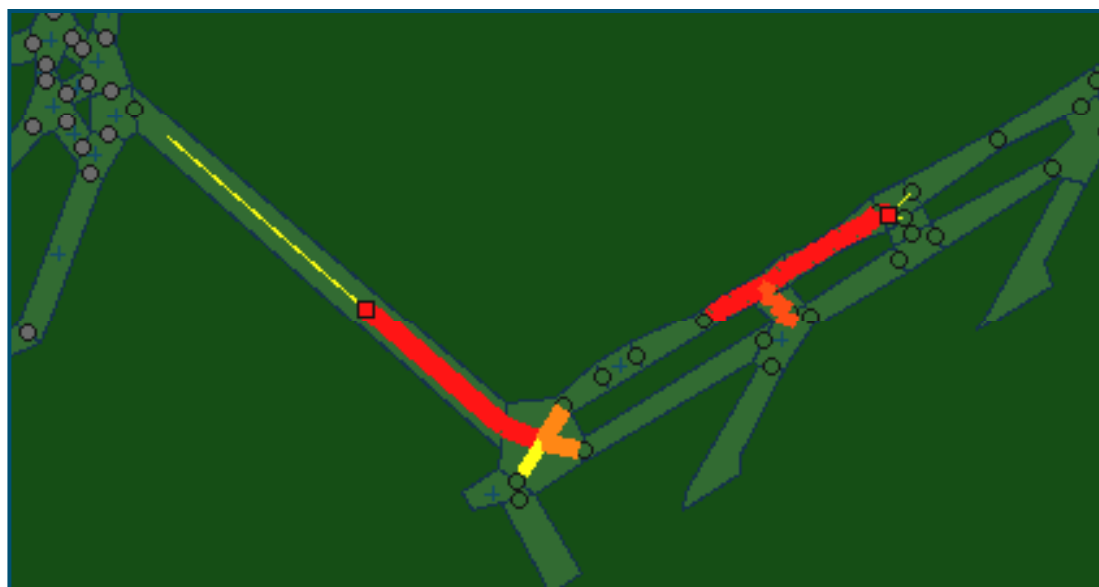
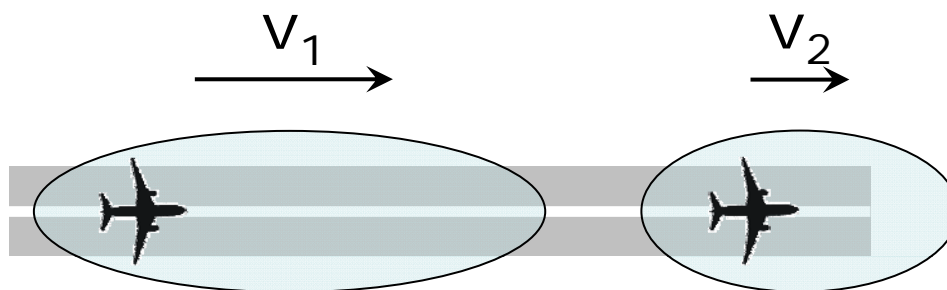
Virtual Block Control



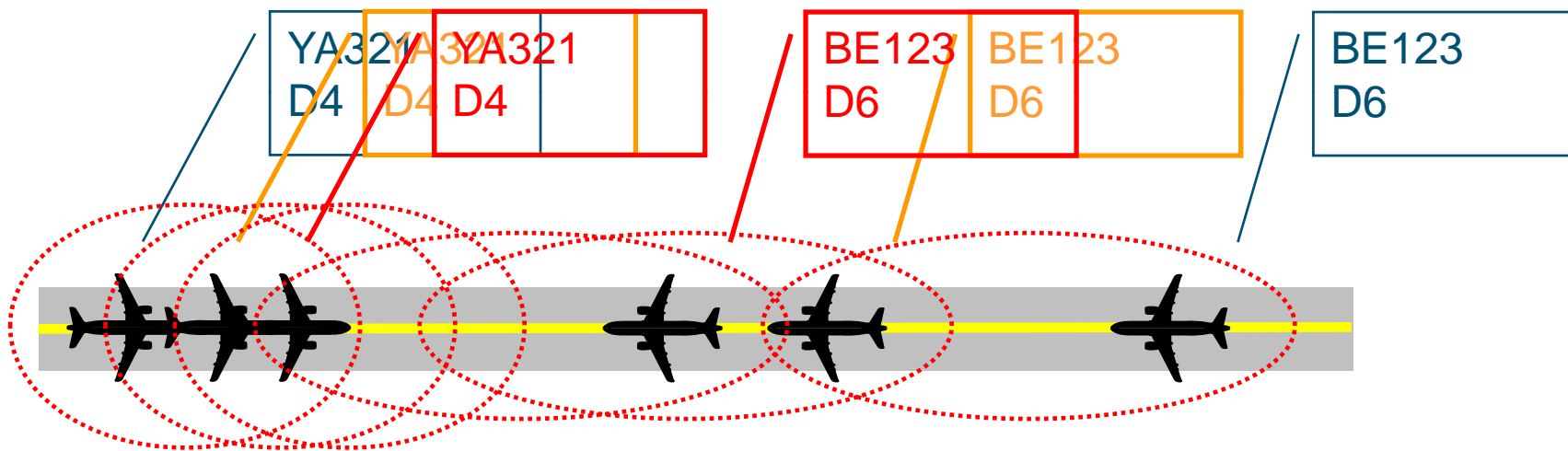
Block Control (Procedural Control)



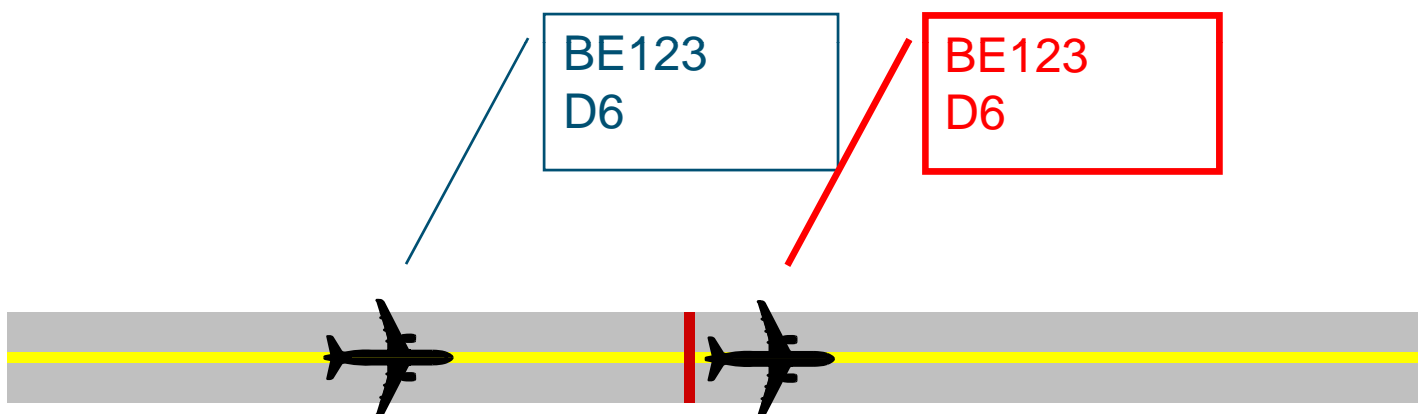
Separation Bubble (TWY Conflict Monitoring)



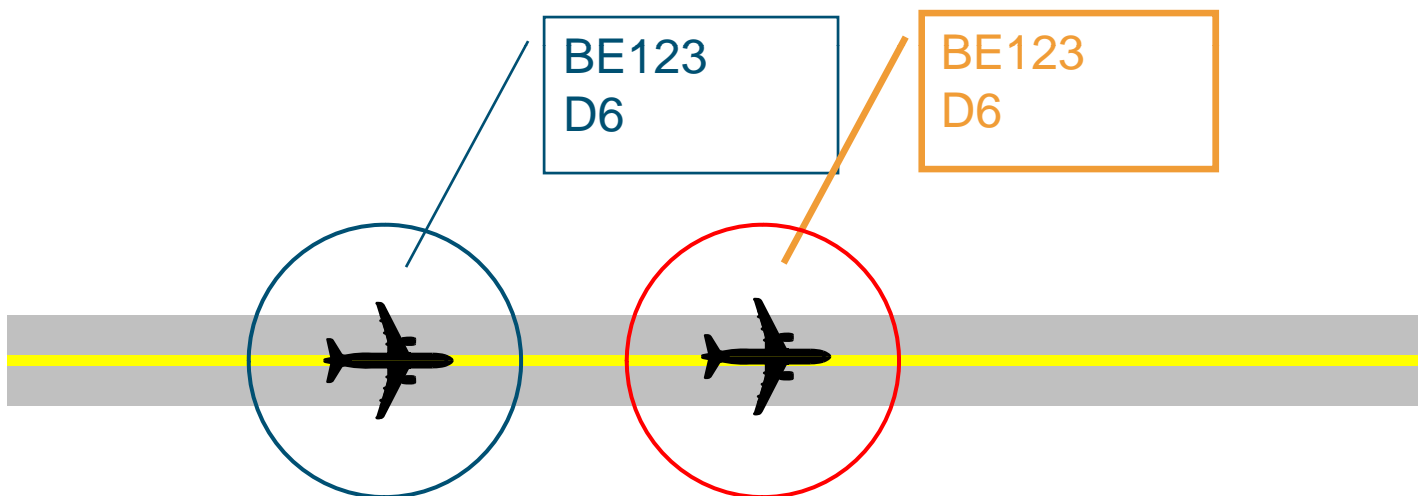
Separation Bubble (TWY Conflict Monitoring)



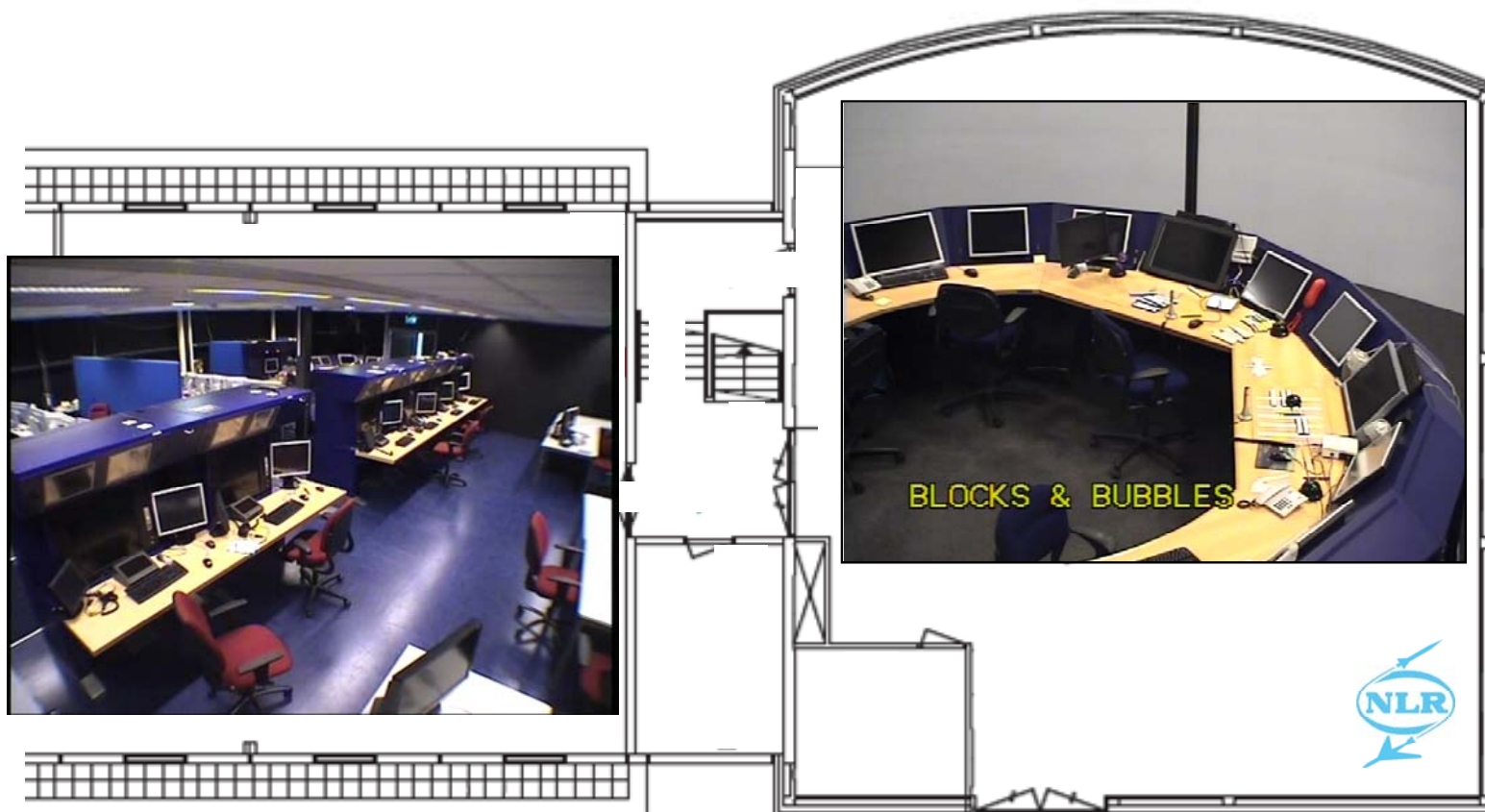
(Virtual) Stop Bar Violation



Watch Dog (Dynamic Virtual Stop Bar)



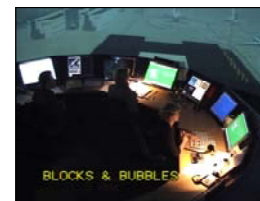
Simulation Environment



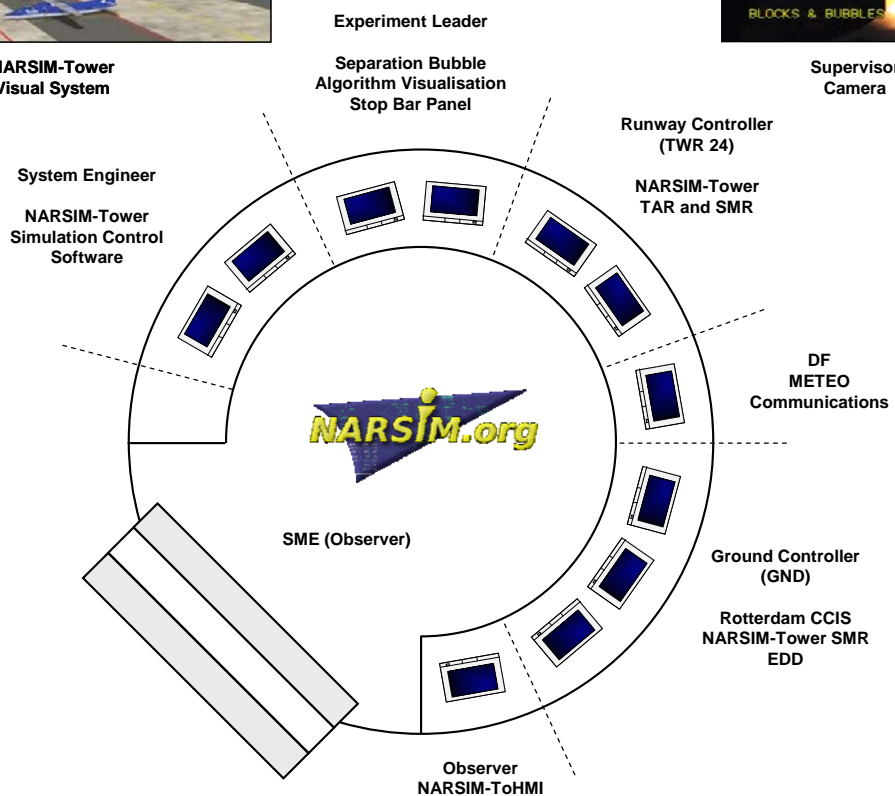
Simulation Environment (Control Room)



**NARSIM-Tower
Visual System**



**Supervisor
Camera**



Simulation Environment (Experiment Leader)



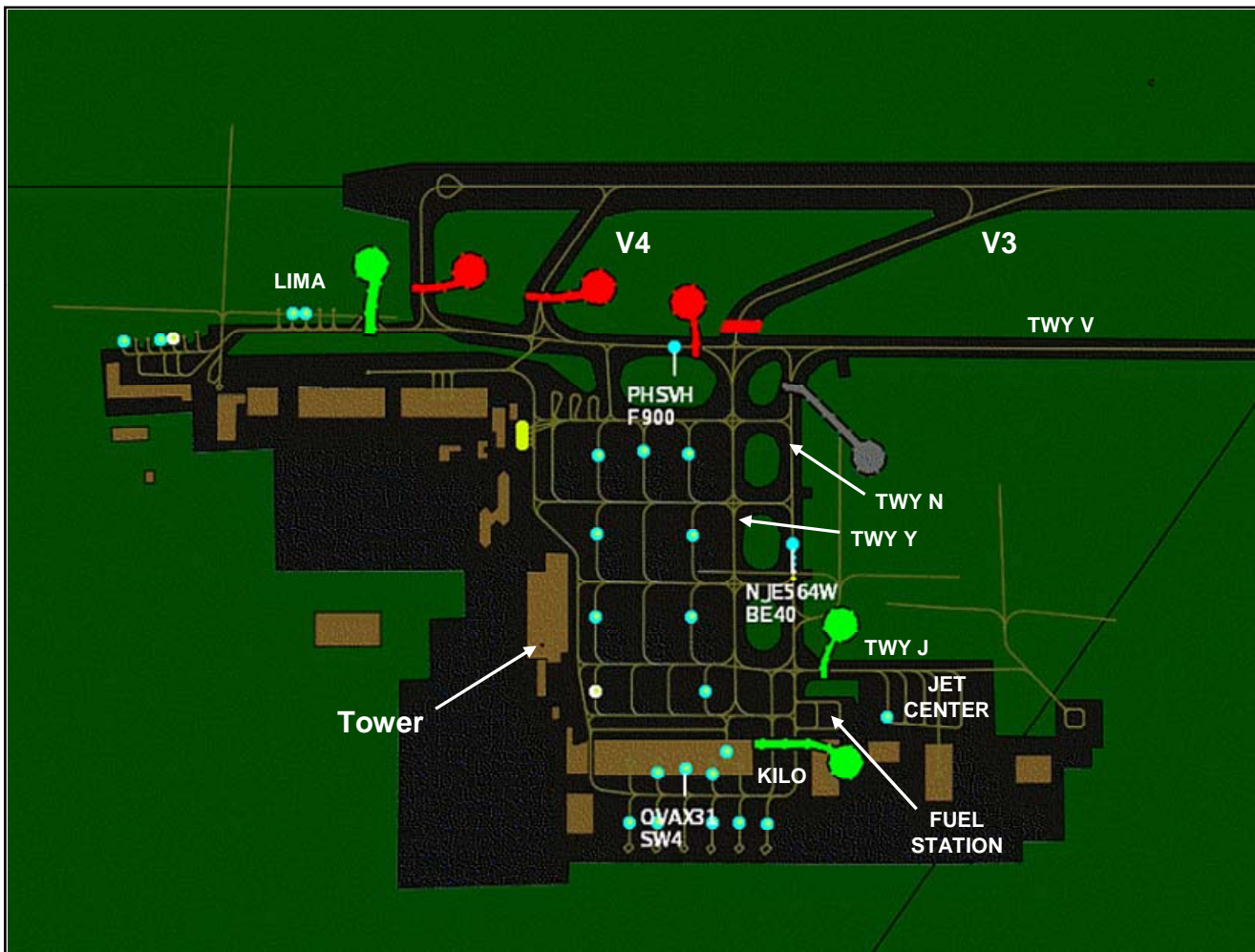
Simulation Environment (Tower Controller)



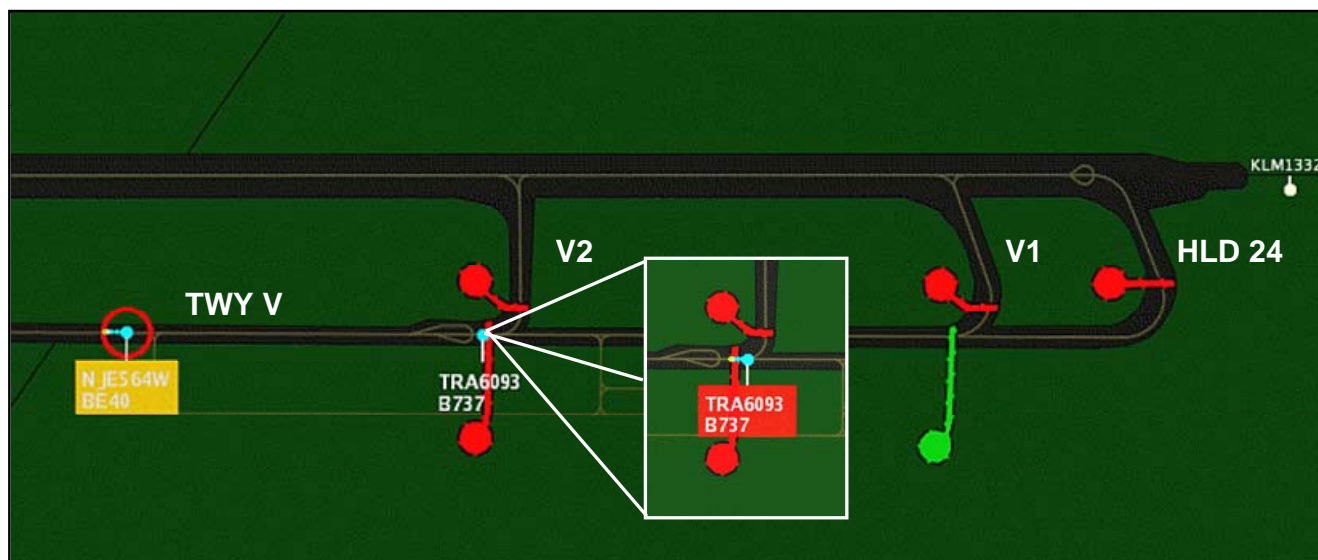
Simulation Environment (Pseudo-pilots)



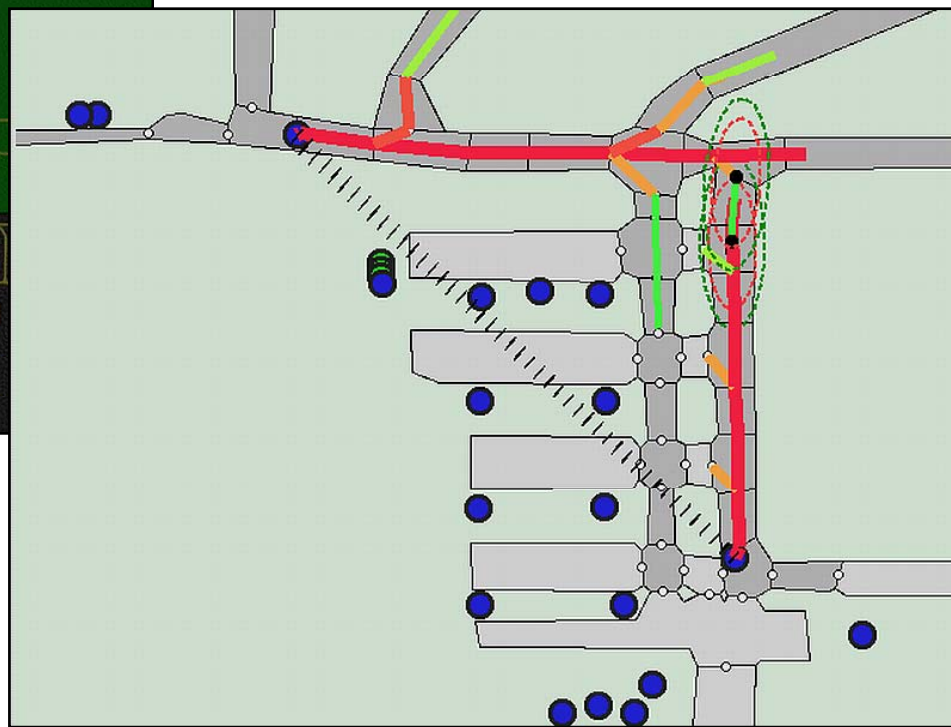
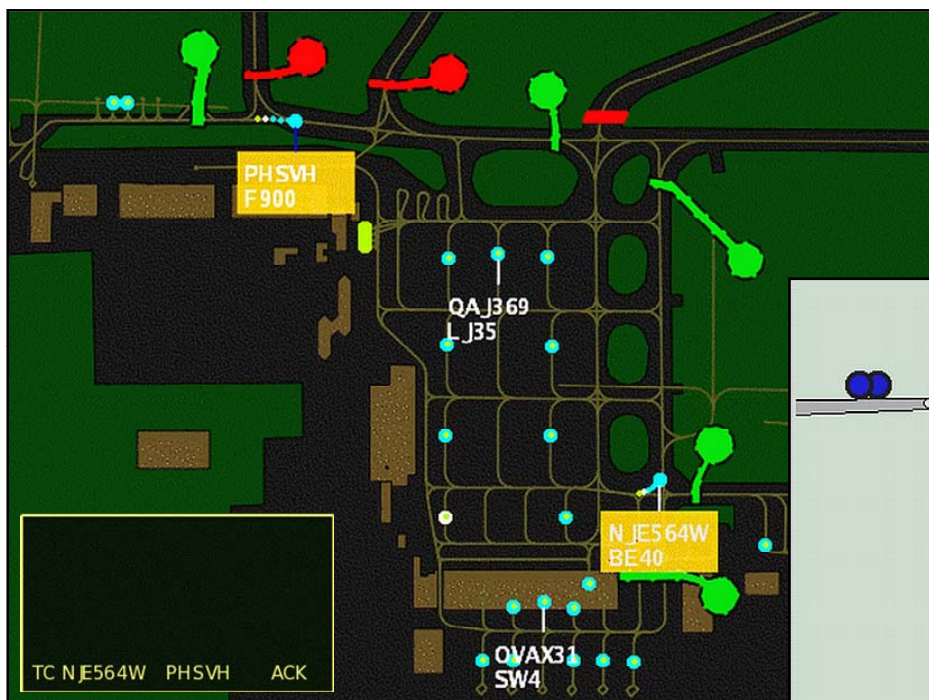
SMR Screen (Apron)



SMR Screen (Watch Dog/Stop Bar Violation)



SMR Screen (Separation Bubble Alert)



- **Settings**

- Look ahead: 35s
- p threshold: 0.5
- Hysteresis: 0.9-1.2

Evaluation Exercises

- **Evaluation Scenarios**

- Each tool in isolation (virtual stop bars and watch dog functionality is considered a single tool)
- Combined operation
- Performed in order to investigate procedural aspects (how the tools are used most effectively)

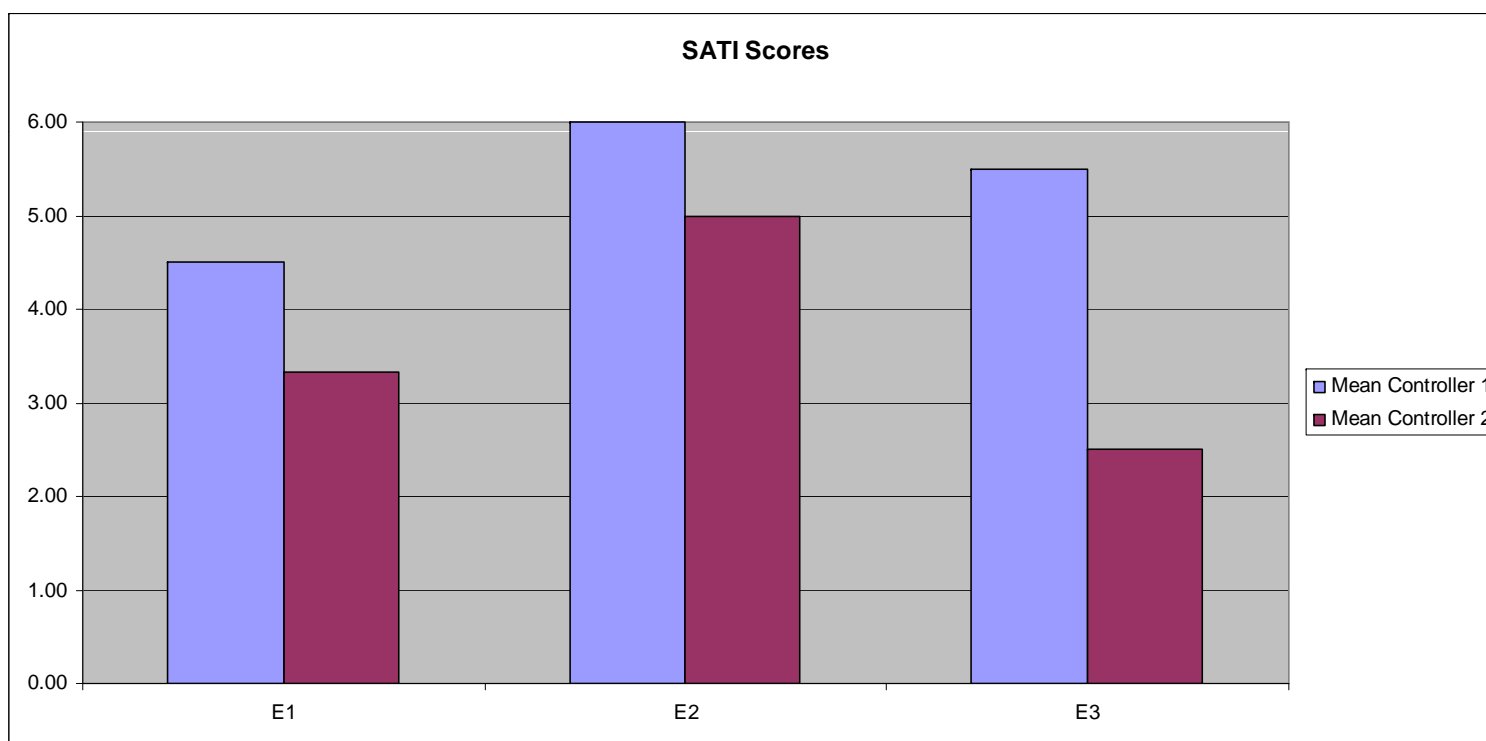
- **E1: Separation Bubbles**

- **E2: Virtual Block Control and Watch Dog**

- **E3: Combination of tools**

Automation Trust (SATI)

- Different controller opinions on separation bubbles (are reflected in result for combination)



E1: Separation Bubbles

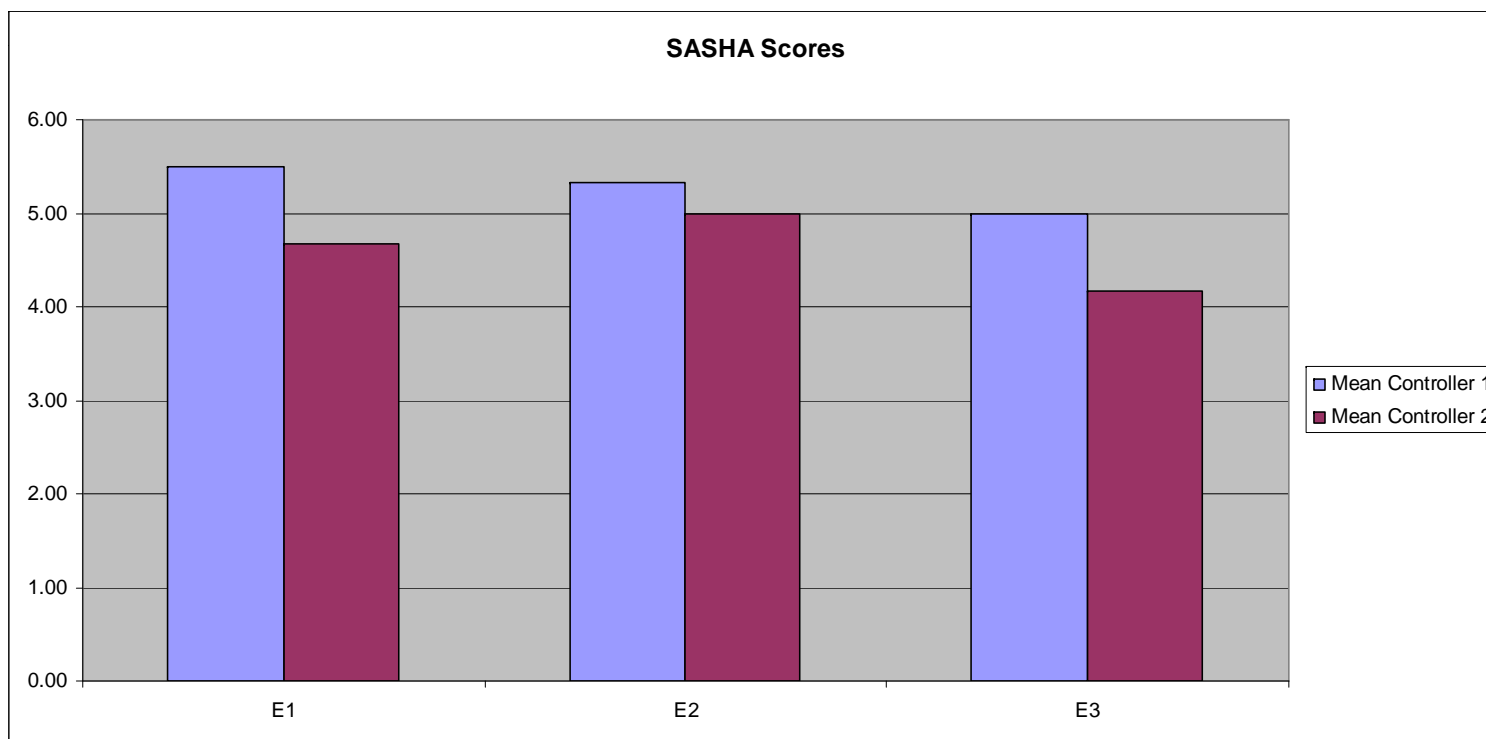
E2: Virtual Block Control and Watch Dog

E3: Combination of tools



Situation Awareness (SASHA)

- Combination of tools leads to small loss in situation awareness (however, this was the first time that procedures for the combination of tools were assessed)



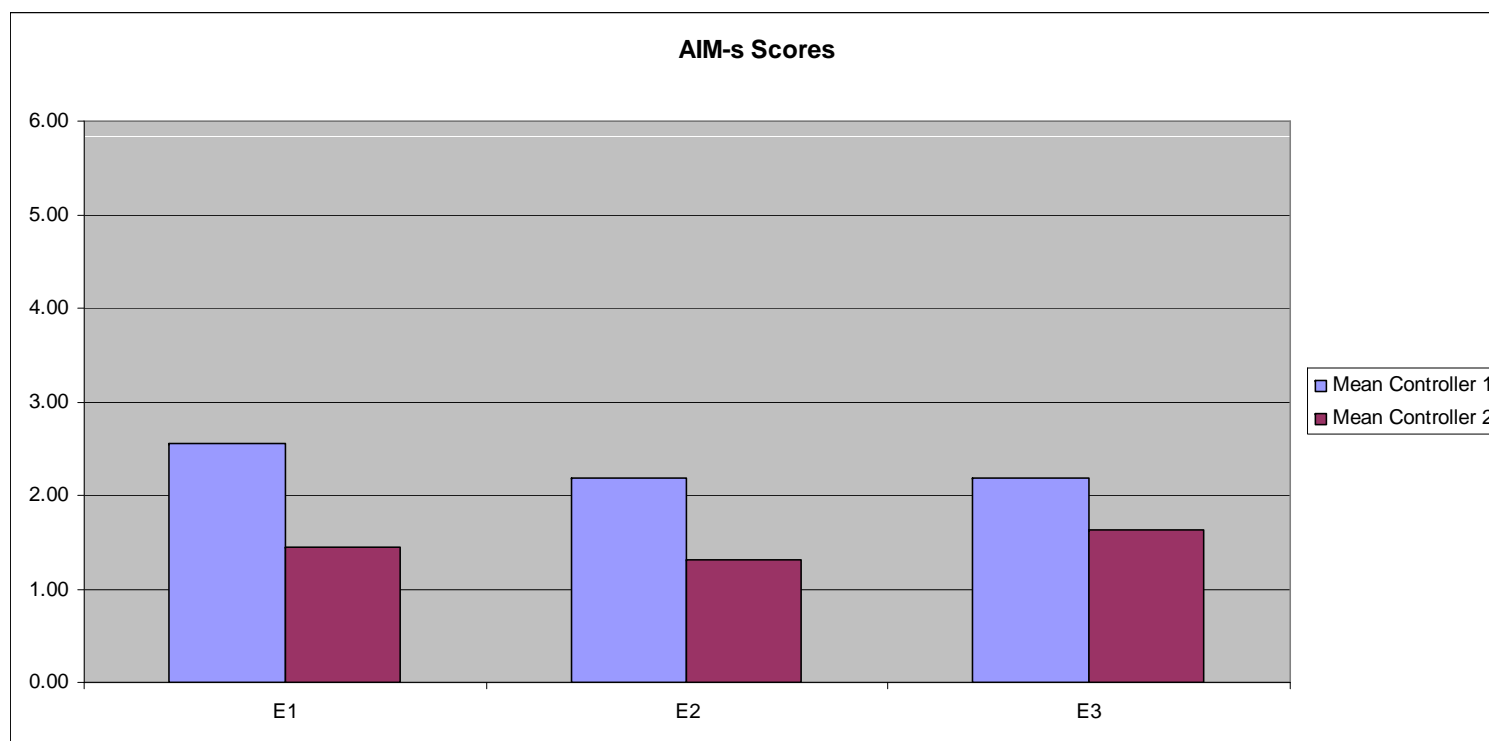
E1: Separation Bubbles

E2: Virtual Block Control and Watch Dog

E3: Combination of tools

Impact of Automation on Mental Workload

- Slightly higher workload when separation bubbles are involved



E1: Separation Bubbles

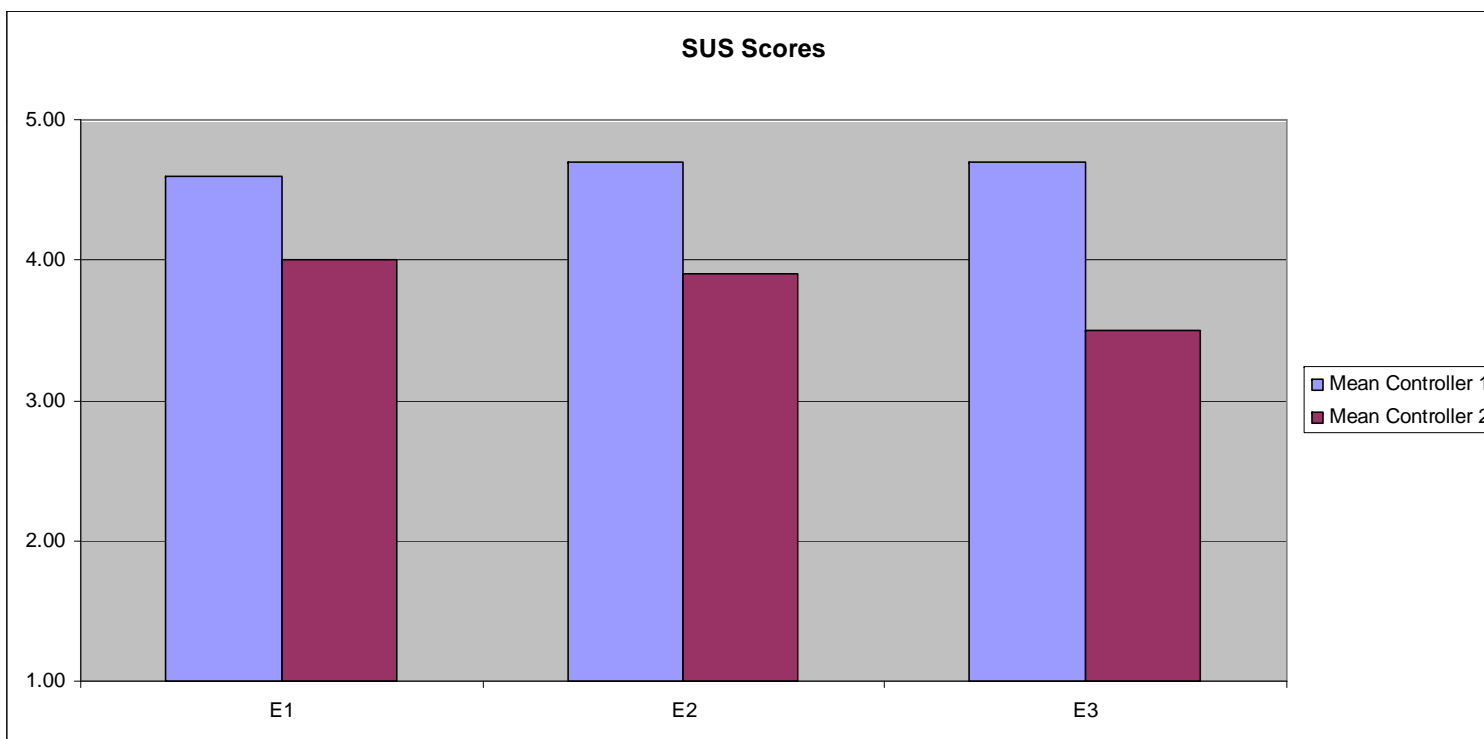
E2: Virtual Block Control and Watch Dog

E3: Combination of tools



System Usability

- Comparable results with small disadvantage for combination of tools



E1: Separation Bubbles

E2: Virtual Block Control and Watch Dog

E3: Combination of tools



Controller Interviews and Debriefing

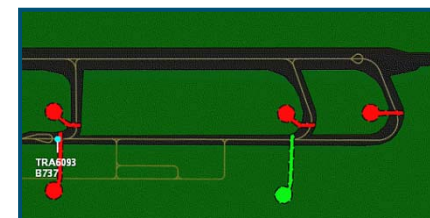
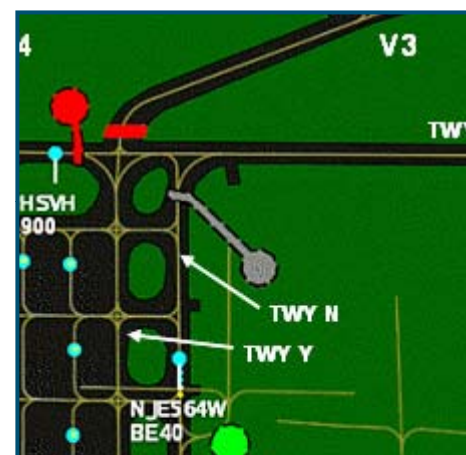
- Interviews and debriefing revealed that
 - Separation bubbles used in isolation are less effective than virtual blocks as regards trust, situation awareness and mental workload
 - Virtual blocks used in isolation are very effective as regards trust, situation awareness and mental workload when used procedural
 - Combination of tools is deemed necessary when higher throughput is to be achieved (deviate from procedural control with virtual blocks and use separation bubbles as safety net when aircraft are taxiing somewhat closer within one virtual block)
 - When used with current EHRD (good visibility) operations, separation bubbles result in too many alerts (even though the alerts are considered valid)
 - Use of watch dog as dynamic block on taxiways without a clearance limit is considered a safety risk (in case of R/T failure)



Conclusions

- **Combination of tools should be used**

- Virtual blocks offer controllers a more structured and safe working approach under low visibility
- Separation bubbles should be used as extra safety net when procedural control with virtual blocks is gradually lifted to allow for more throughput
- Watch dog should only be used on the apron or after a stop bar violation
- Current EHRD (good visibility) operations should change under low visibility (exit via V4 instead of V3, when exiting via V3 do not hold at virtual stop bar N)
- Separation bubble tool needs to be slightly tuned (considering too many alerts at line-up)
- Making tools dependent of each other could pose a safety risk



Validation Exercises (Baseline)

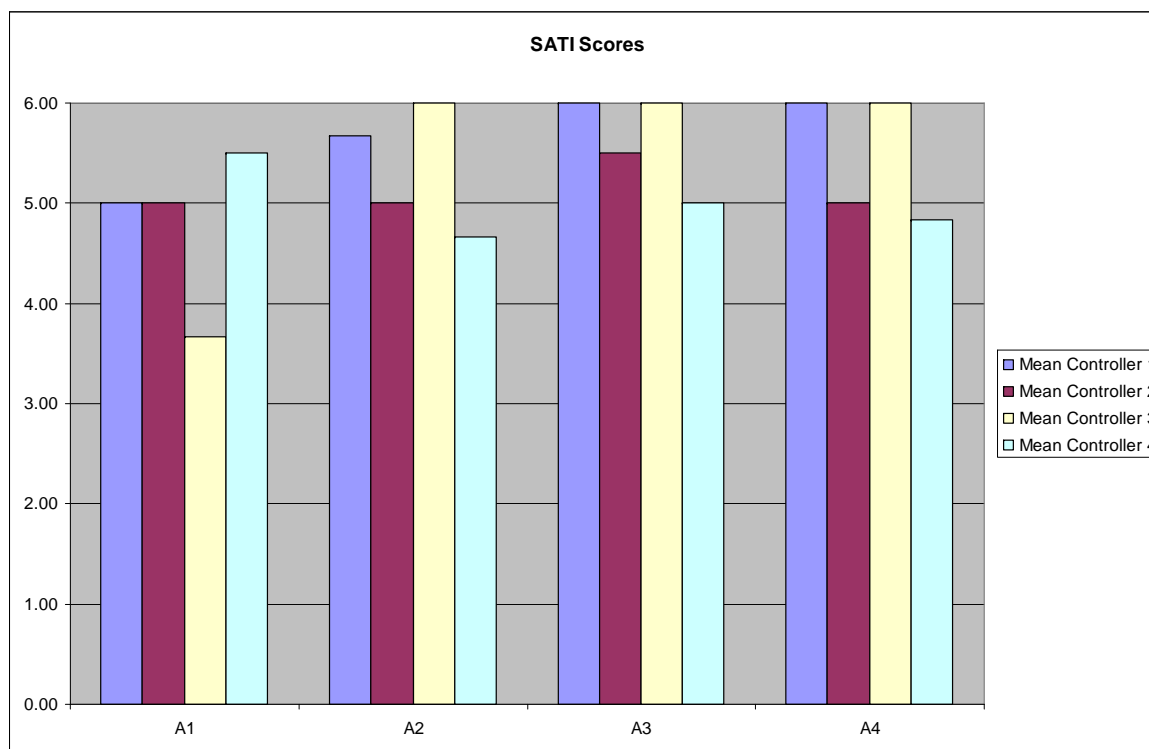
- **Baseline Scenario**
 - Current EHRD low visibility operations (i.e. without virtual block control and separation bubble tools but with radar screen)
 - Baseline will lead to certain amount of departure delay (no co-ordination with start-up simulated)
- **B1:**
follow ICAO regulation
(procedural control, i.e. one aircraft moves at a time, radar not used for control)
- **B2:**
do follow own intuition
(work as efficient and safe as deemed necessary, use radar for control)

Validation Exercises (Advanced)

- **Advanced Scenarios**
 - Simulations with tool combination are performed several times to get good indication of achievable capacity and efficiency
- **A1 to A4:
different traffic scenarios
with same amount of traffic
(30 aircraft per hour, inbound plus outbound)**

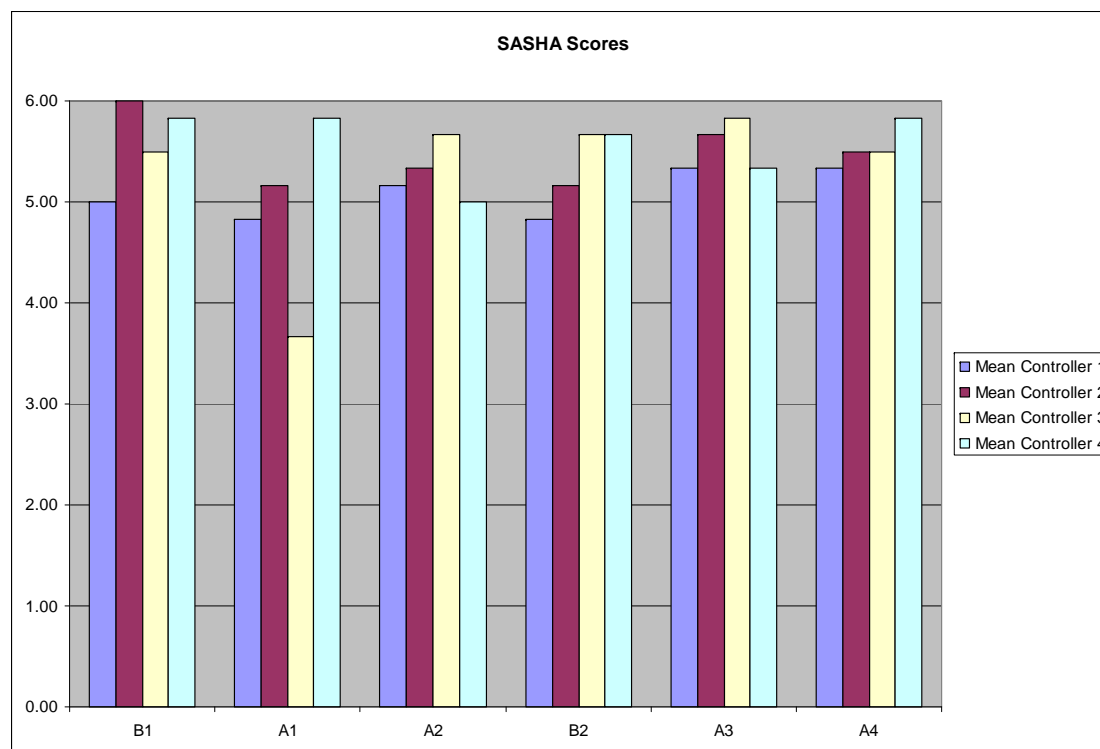
Automation Trust (SATI)

- Trust seems to increase with time (learning curve)
- Range: 4.8 (A1) to 5.6 (A3) Overall mean: 5.3



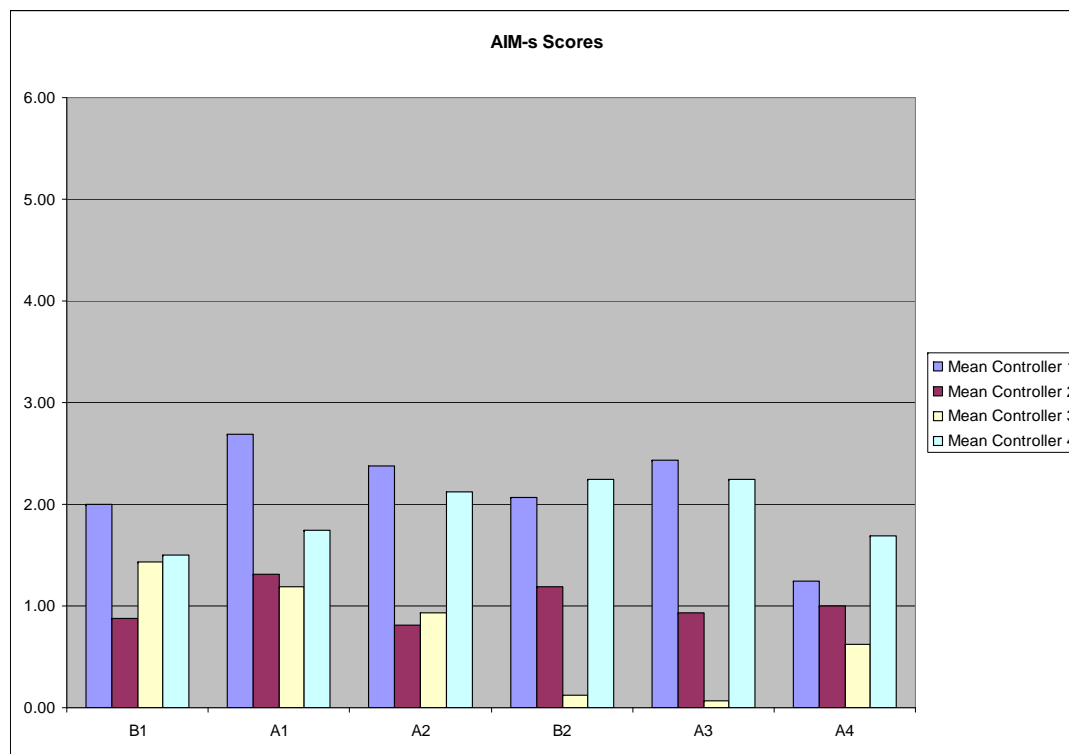
Situation Awareness (SASHA)

- Situation awareness seems to stabilise with time
- Range: 4.9 (A1) to 5.6 (B1) Overall mean: 5.4



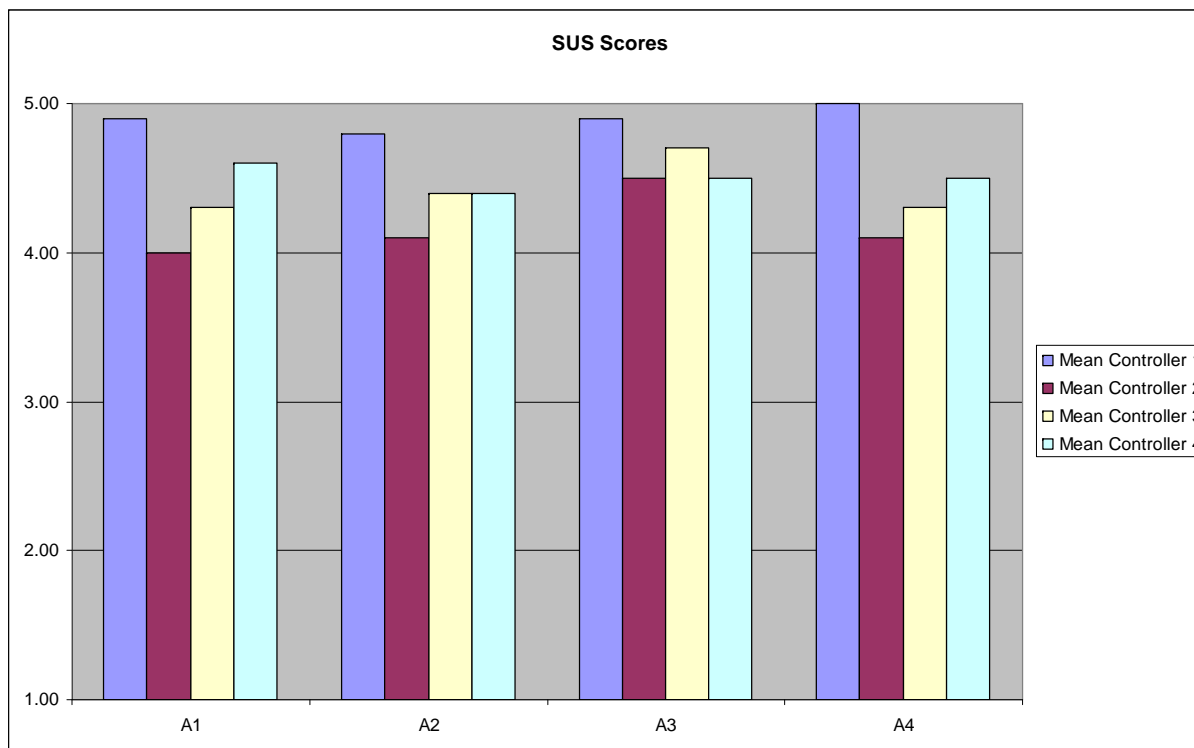
Impact of Automation on Mental Workload

- **Workload seems to decrease with time**
 - Much noise in data (task, traffic, learning curve)
- **Range: 1.1 (A4) to 1.7 (A1) Overall mean: 1.5**



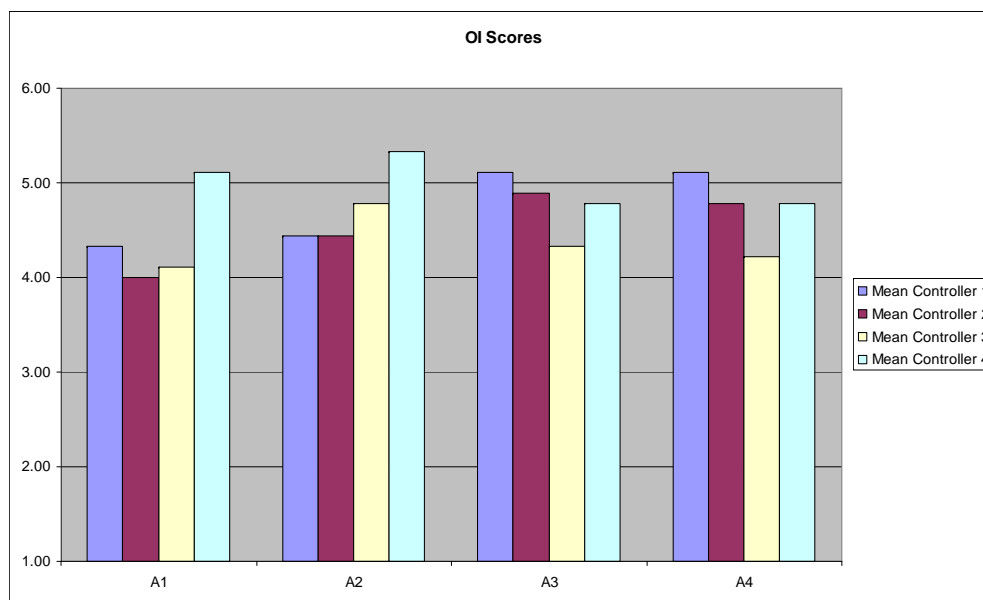
System Usability

- System usability values are steady on a high level
- Range: 4.4 (A2) to 4.7 (A3) Overall mean: 4.5



Operational Improvements

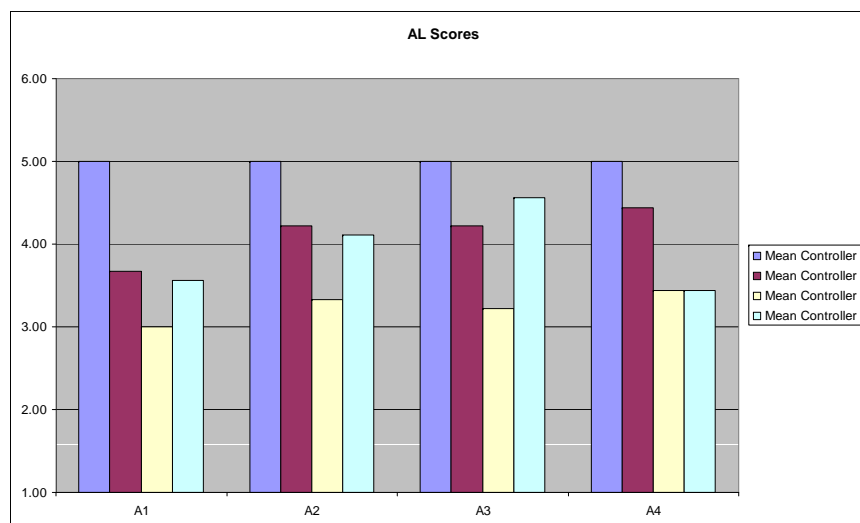
- **Operational Improvements:**
 - Tools do not impair safety: 5.2
 - Tools enable controller to handle more traffic: 4.9
 - Tools do not increase average stop time: 3.9
 - Tools increase traffic throughput: 4.2
 - Tools reduce human error: 5.1



Alerting Tool Assessment

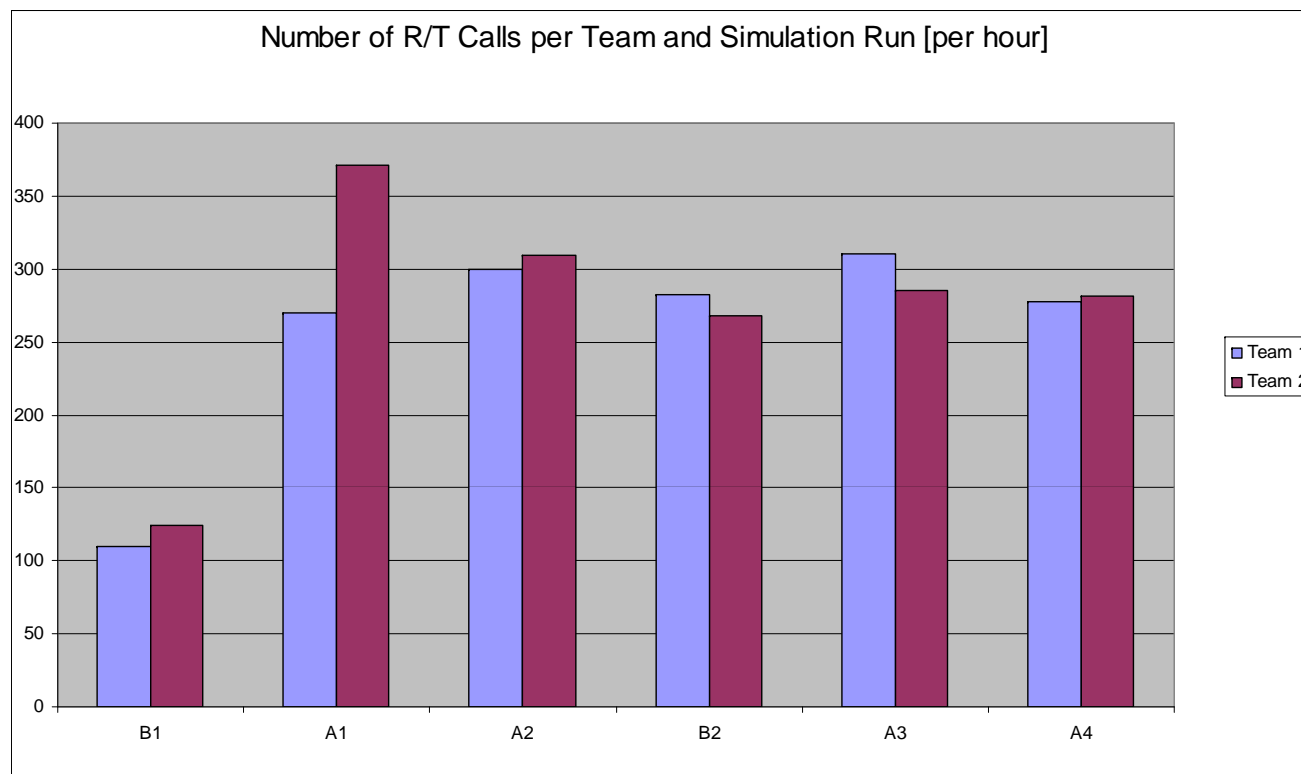
- **Alerting Tools:**

- Tools identify conflicts in time: 4.3
- Presentation of conflict information unambiguous: 4.8
- False alert number sufficiently low: 4.2
- Alerts only on taxiways are useful: 4.9
- Use alerting under better visibility: 3.4
- Two stages of alerts are useful: 2.3



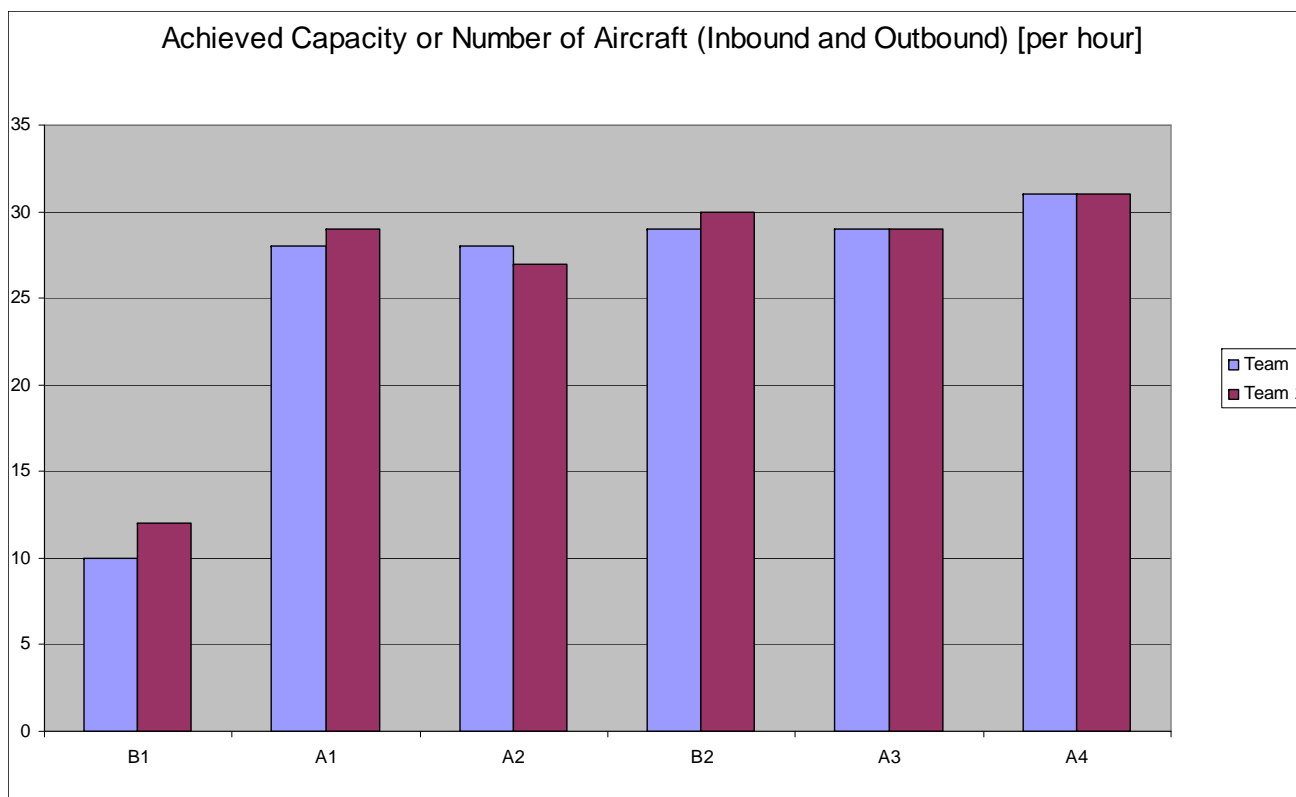
R/T Load Assessment

- **Number of R/T calls on a steady level**
 - B2 level comparable indicating “mental” block control
 - A1 is outlier as controllers had procedural problems



Capacity Assessment

- **Capacity has direct relation to R/T calls**
 - Factor 3 higher than in ICAO baseline
 - Same amount of communication workload per aircraft



Controller Interviews and Debriefing

- **Interviews and debriefing revealed that**
 - Very realistic and stable simulation environment (use of Rotterdam training facilities)
 - Tools lead to more efficiency in low visibility when compared to current procedures (factor 3)
 - Working without tools but making use of SMR information (which is against ICAO recommendation) leads to the same level of throughput, however, at the cost of safety (no alerting) and workload (not confirmed by data though)

Recommendations

- Perform in-depth safety assessment
- Study large and complex airports (e.g. Schiphol)
- Study positioning of virtual stop bars by fast-time simulations (flow and capacity issues, workload)
- Watch dog should only be used after stop bar violations
- Integrate with electronic flight strips (EFS)
- Study pilot situational awareness and visibility issues in cockpit simulations (identification of holding positions)



Conclusions

- **Tools allow to work with more efficiency as compared to current regulation**
- **Tools allow to work more safely and reach the same level of throughput than when bending the rules**
(not working procedural under low visibility conditions and making use of radar for control purposes)
- **Current regulation needs to be improved**
as it is open to interpretation and does not consider the use of safety enhancing control tools
- **Tools are a cost efficient solution and are easy to implement and easy to configure**
(inexpensive and flexible)



Questions

