
# Initial Evaluation of NextGen Air/Ground Operations with Ground-Based Automated Separation Assurance

**Thomas Prevot, Jeffrey Homola,**
**Joey Mercer, Matt Mainini and Christopher Cabrall**

**San Jose State University /NASA Ames Research Center**

**8th US/Europe ATM R&D Seminar**
**June, 2009**

# Outline

- Summary
- Problem
- Approach
- Method
- Results
- Conclusions

*Flight Deck Display Research Lab*

*Airspace Operations Lab*

# Summary

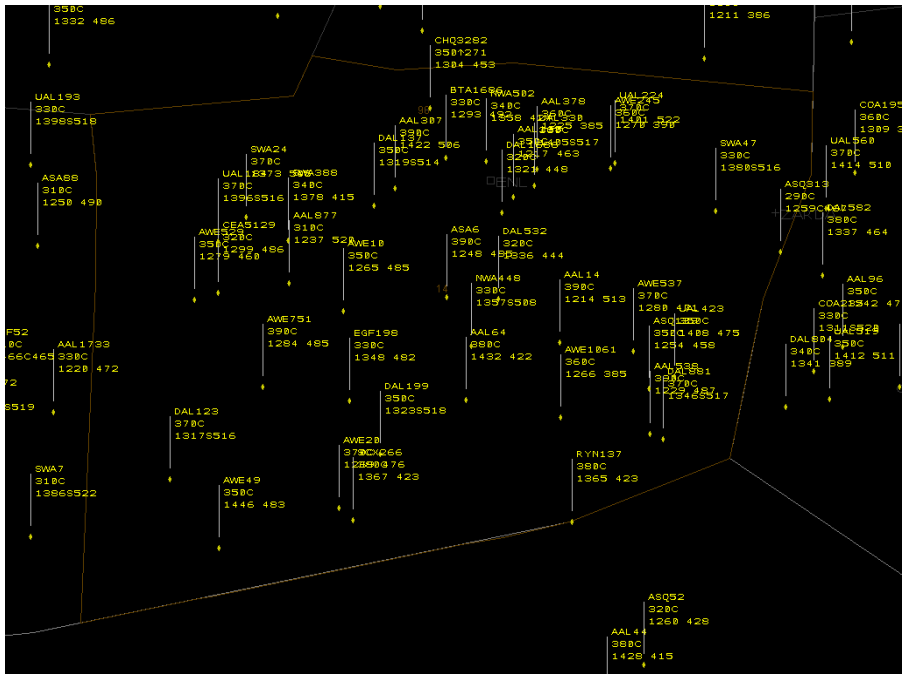
- Objective of the study
  - To Investigate how controllers and pilots handle nominal and off-nominal situations when separation assurance is automated

Main Points

- Ground-based automated separation assurance is a generally sound concept
- Trajectory-based conflict detection and resolution automation integrated with data link is the key enabler
- Flight crew preferences can be accommodated, but air and ground systems need to be compatible
- Future research is required to address human/automation interaction issues particular with regard to near-term conflict prevention
- Aircraft should always be on predictable trajectories

# Problem

NextGen envisions up to three times today's en route capacity and greater routing flexibility for airspace users



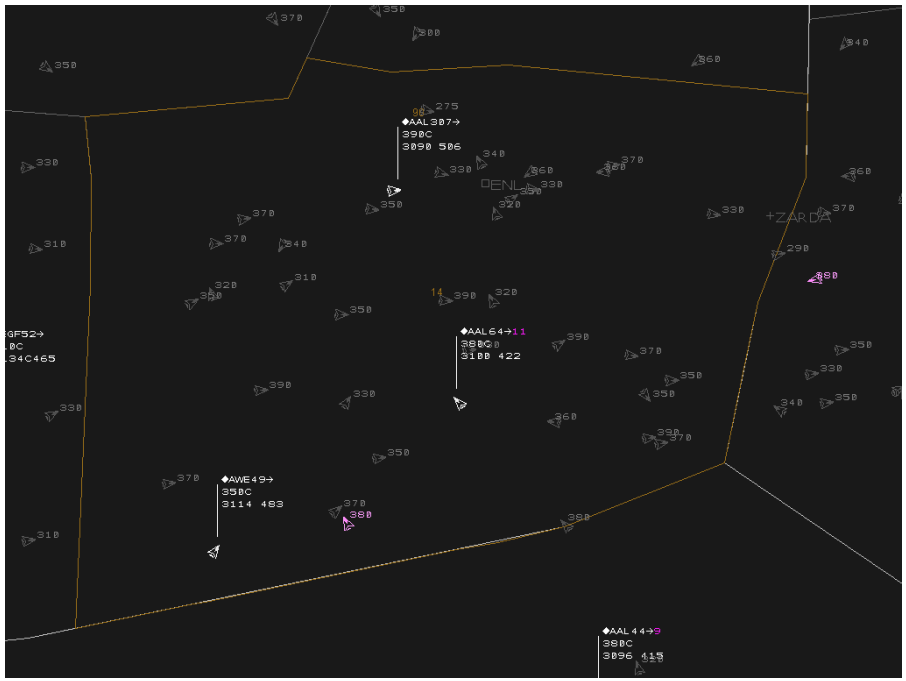

*Current day display at three times today's density (3x)*

but …

- cognitive resources of air traffic controllers are limited
- conventional clearance-based separation assurance is impossible for unstructured high density airspace

# Approach

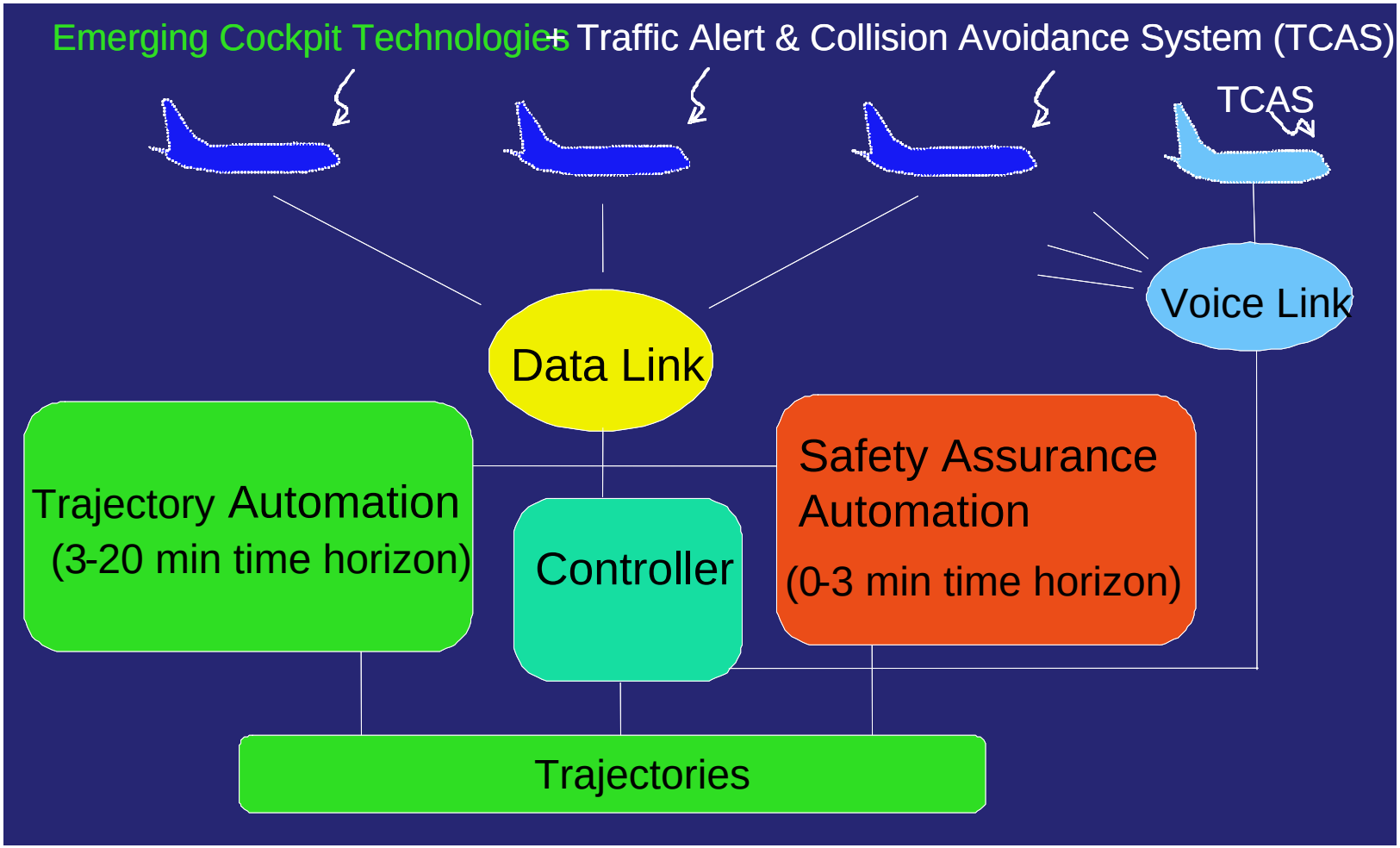
Ground-Based Automated Separation Assurance




***Experimental display at three times today's density (3x)***

- the *automation* manages the separation
- the *operators* manage the automation, provide additional services and make decisions

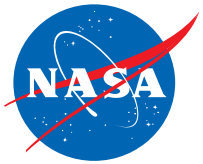
# Approach (Technical)




**Ground-based automated separation assurance**

**Based on the ”Advanced Airspace Concept “ (Erzberger, McNally)**

# Human-in-the Loop Evaluation of Ground-Based Automated Separation Assurance




- Levels of Automation for Trajectory-based Separation Assurance
  *Prevot, Homola and Mercer, ATIO 2008*
- Pilot perspective of automated conflict resolutions
  *Johnson et al., ATIO 2008*
- Feasibility of Mixed Equipage
  *Kopardekar et al., ATM 2009*
- **Air/Ground Operations with Off-Nominal Events**

# Objective and Method

Objective:

Investigate how controllers and pilots handle off-nominal situations when separation assurance is automated

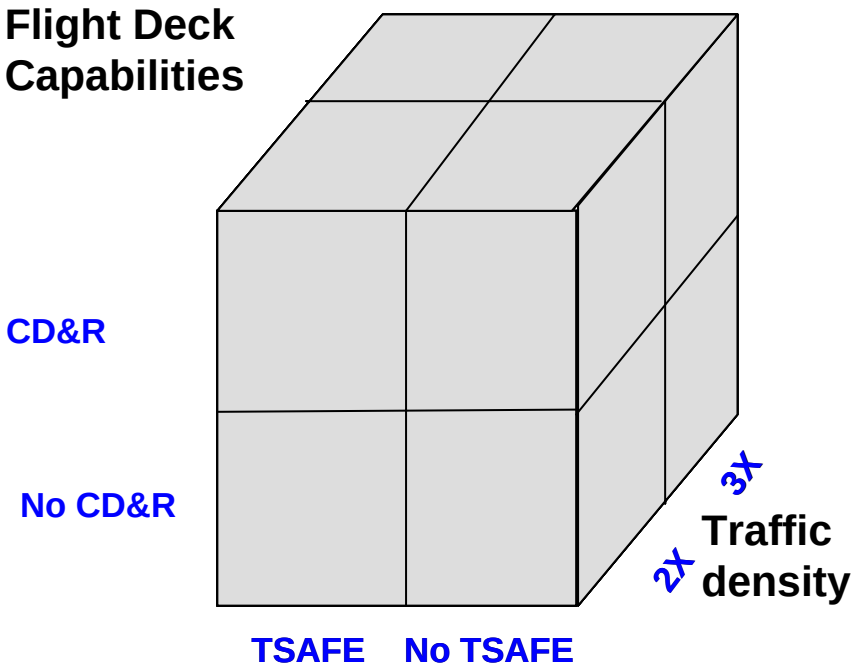
Method:

Part-task study with integrated air/ground operations

- 6 controllers (3 current, 3 retired), 20 pilots
- 24 runs per controller, each 30 minutes
- 3 scripted events every 10 minutes
- Independent variables:
  - Traffic density (2x, 3x)
  - Near-term conflict avoidance mode (TSAFE/No TSAFE)
  - Flight Deck Equipage (CD&R, No CD&R)


**Example: High climb rate of BTA779 causes 3 near-term conflicts (TSAFE issues left turn)**

# Experimental Design




**Ground-based safety assurance automation**

**Three scripted "off-nominal" events every 10 minutes**

- Loss of data link communication
- Medical Emergency
- Loss of cabin pressure
- Early descent
- Late descent
- unexpected turn
- expected turn, but aircraft straight
- climb rate too low
- climb rate too high

- Pilot rejects trajectory uplink
- Pilot modifies trajectory uplink
- Pilot requests trajectory change

# Roles and Responsibilities

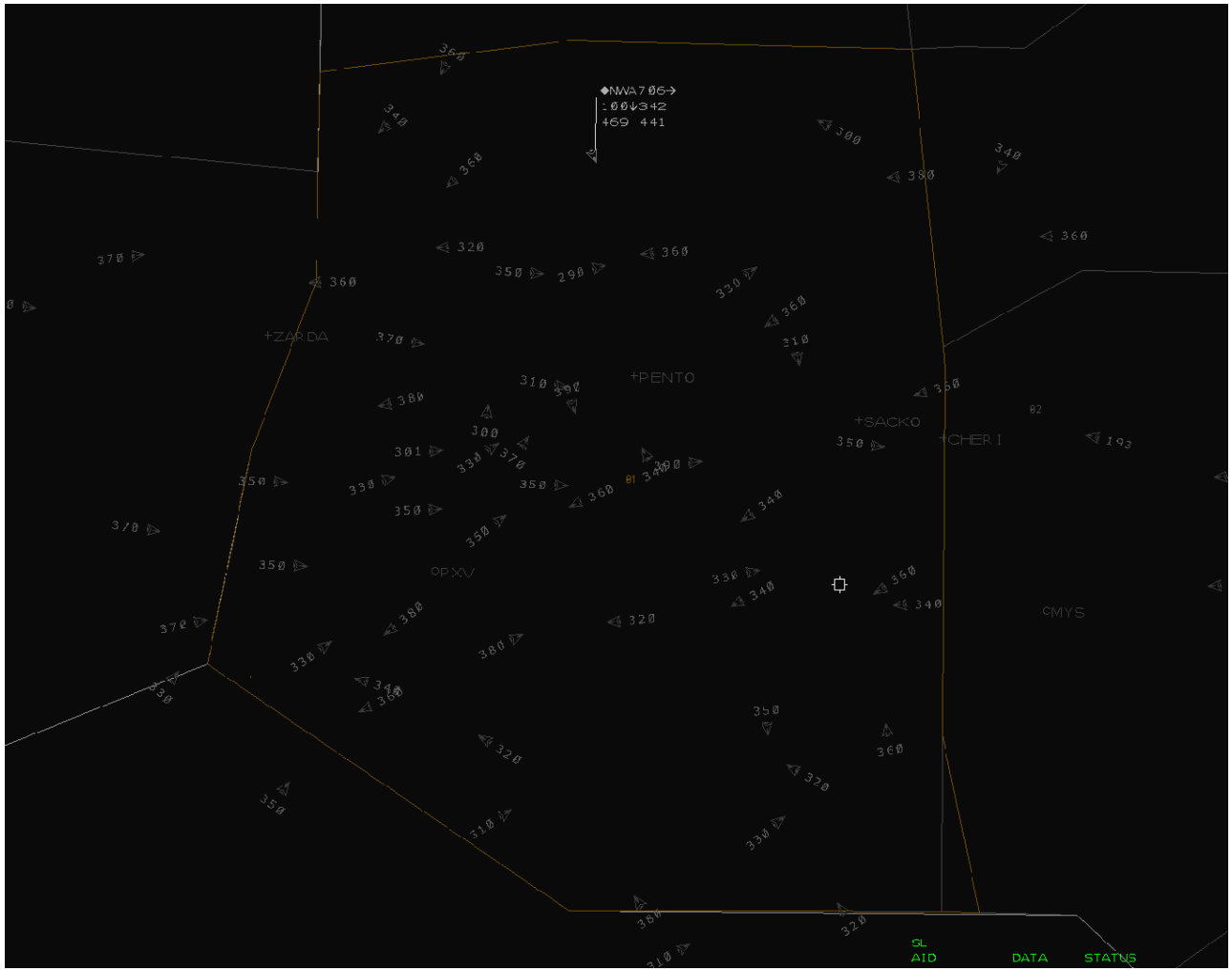
**Trajectory-based operations** (3 to 15 minute to Loss of Separation)

1. The ground automation detects and resolves conflicts automatically and sends new trajectories to the aircraft without controller involvement
2. The flight crews execute ATC trajectories if acceptable
3. Flight crews can downlink new trajectories. If conflict free the ground automation will uplink approval. If not, it will present the request to the controller for review.
4. The controller monitors and makes decision on flight crew requests

**Tactical safety assurance** (<3 minutes to Loss of Separation)

1. The automation is responsible for conflict detection.
2. Short-term conflict resolution is a primary independent variable:
   - *No TSAFE*: the controller issues a verbal clearance without the automation
   - *TSAFE*: the automation proposes and issues a maneuver resolution automatically
3. Flight crews will receive a *verbal instruction or a data link message* with the resolution maneuver and are expected to comply with it quickly.

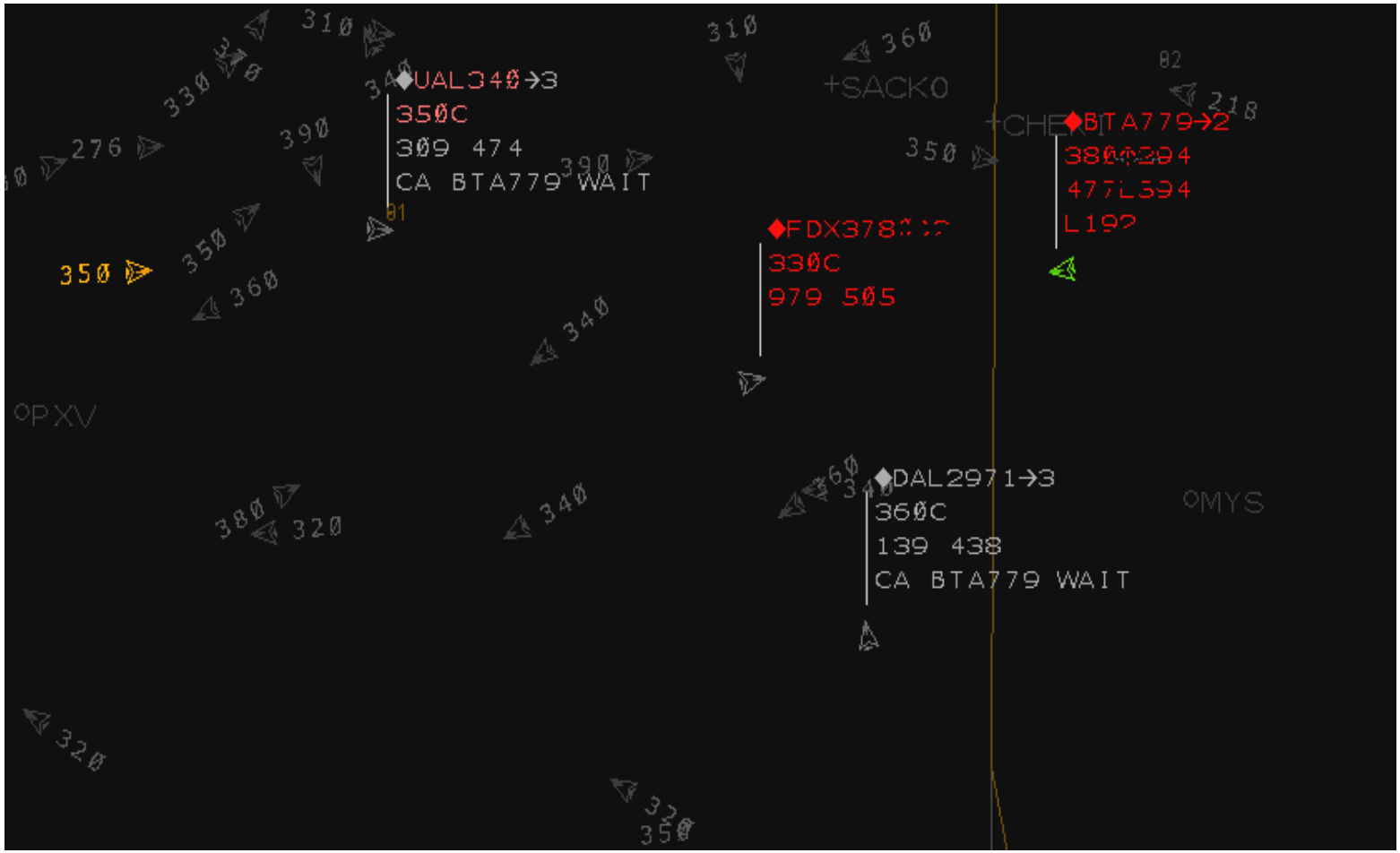
# Example (1/5)




**The automation manages the trajectories for all aircraft.**

**One flight declares an emergency and the controller handles it**

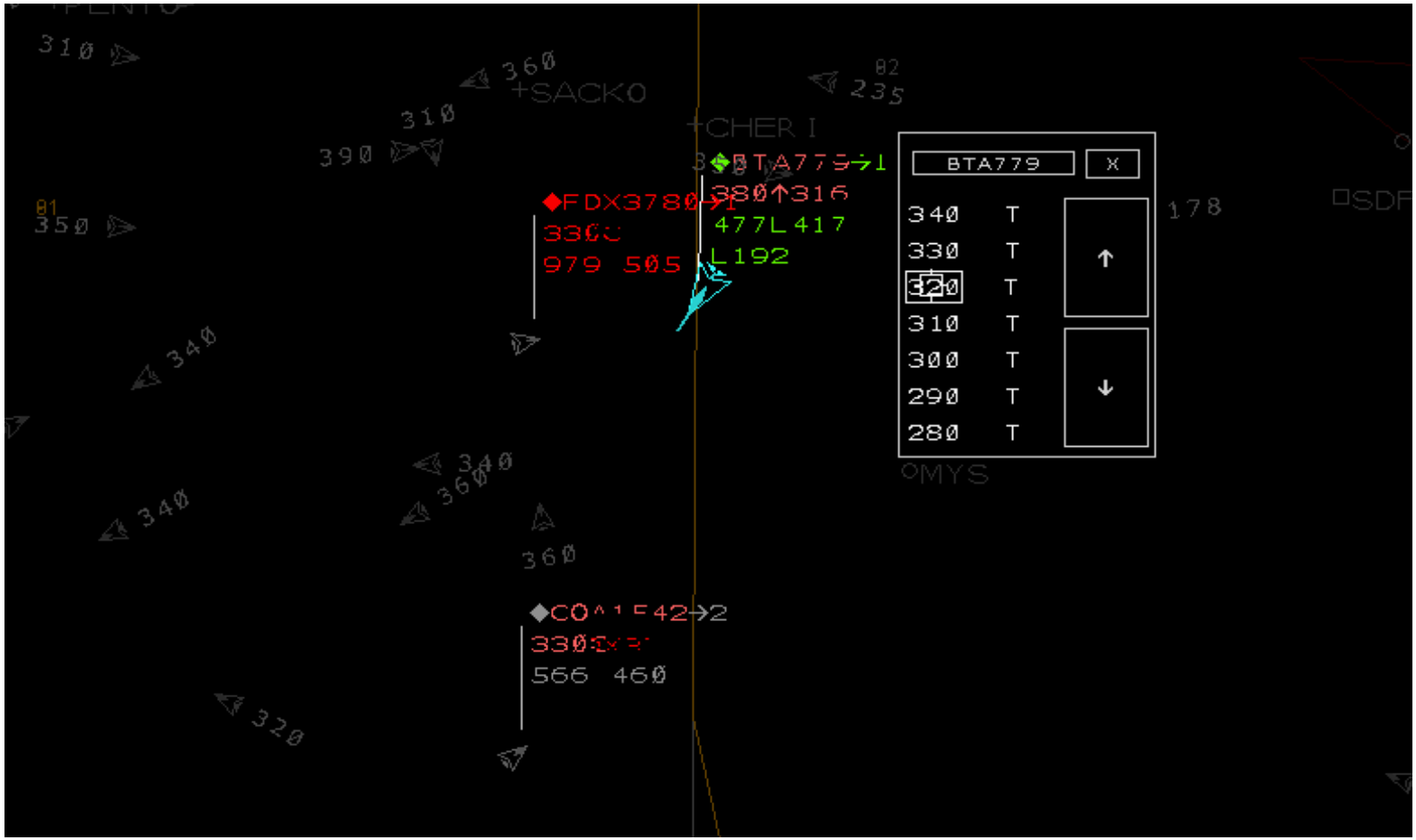
# Example (2/5)




**High climb rate of BTA779 causes 3 near-term conflicts**

**TSAFE automation recommends left turn**

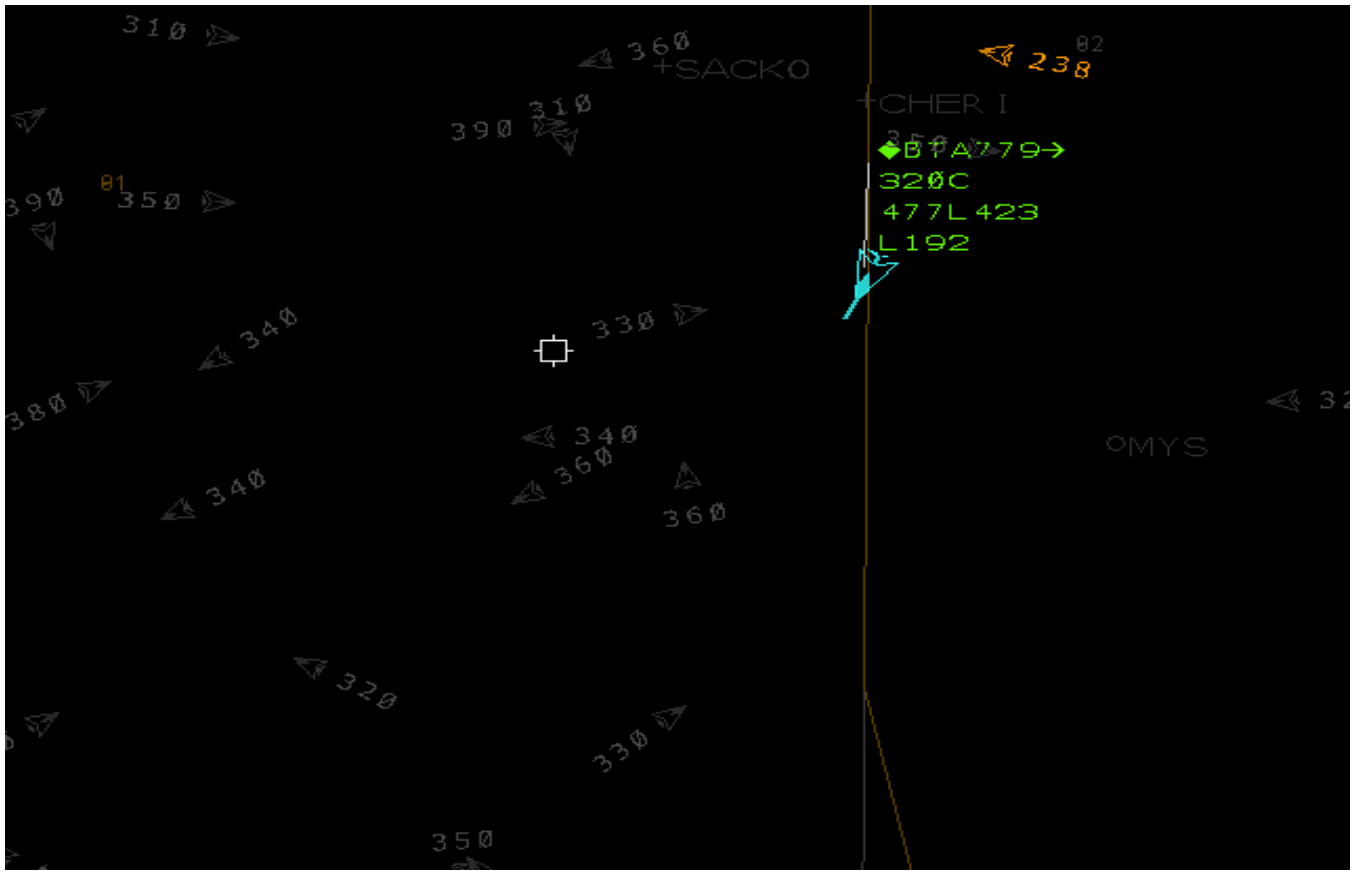
# Example (3/5)




**TSAFE issues left turn**

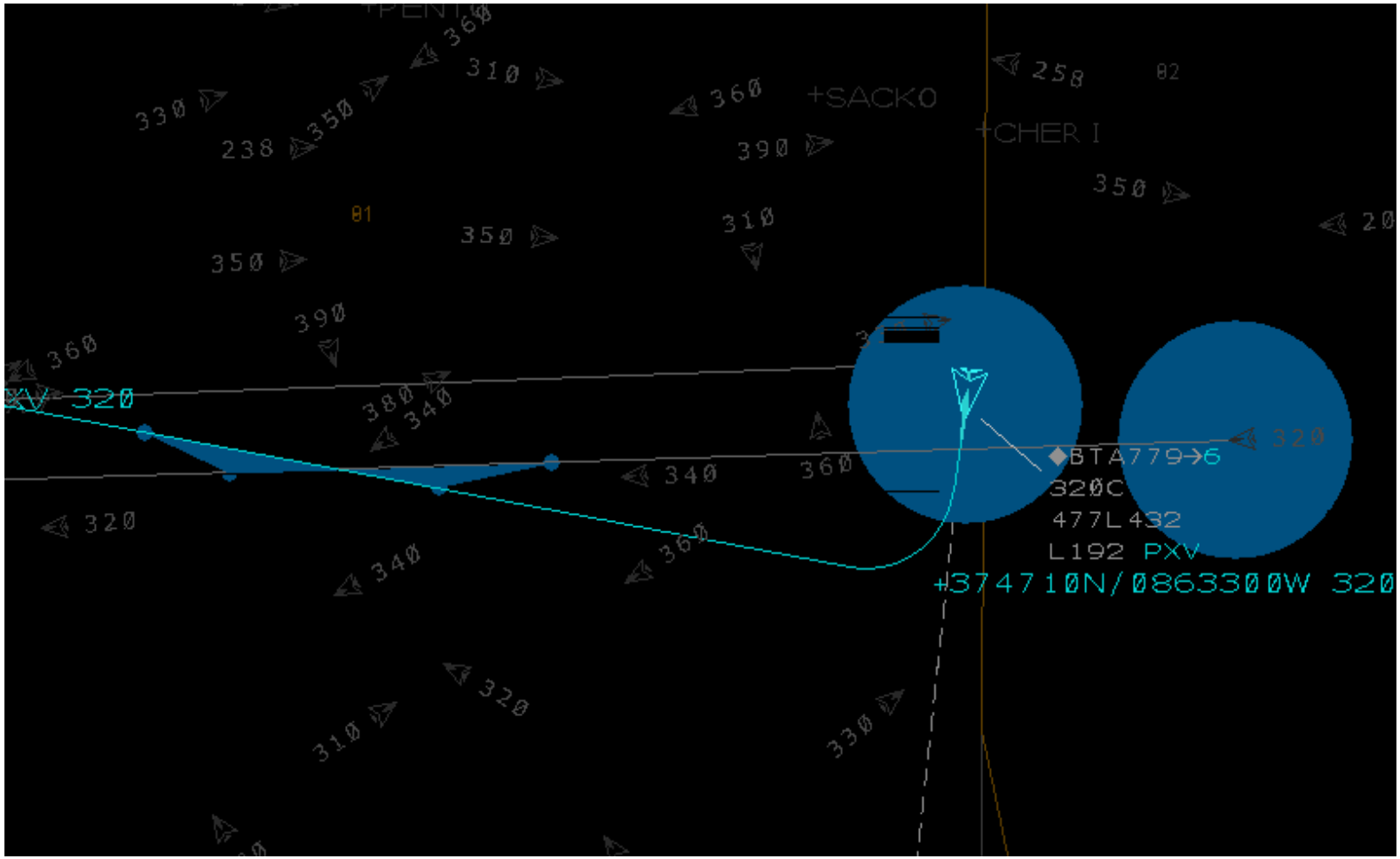
**Controller issues stop altitude verbally**

# Example (4/5)




**Aircraft is off-trajectory**

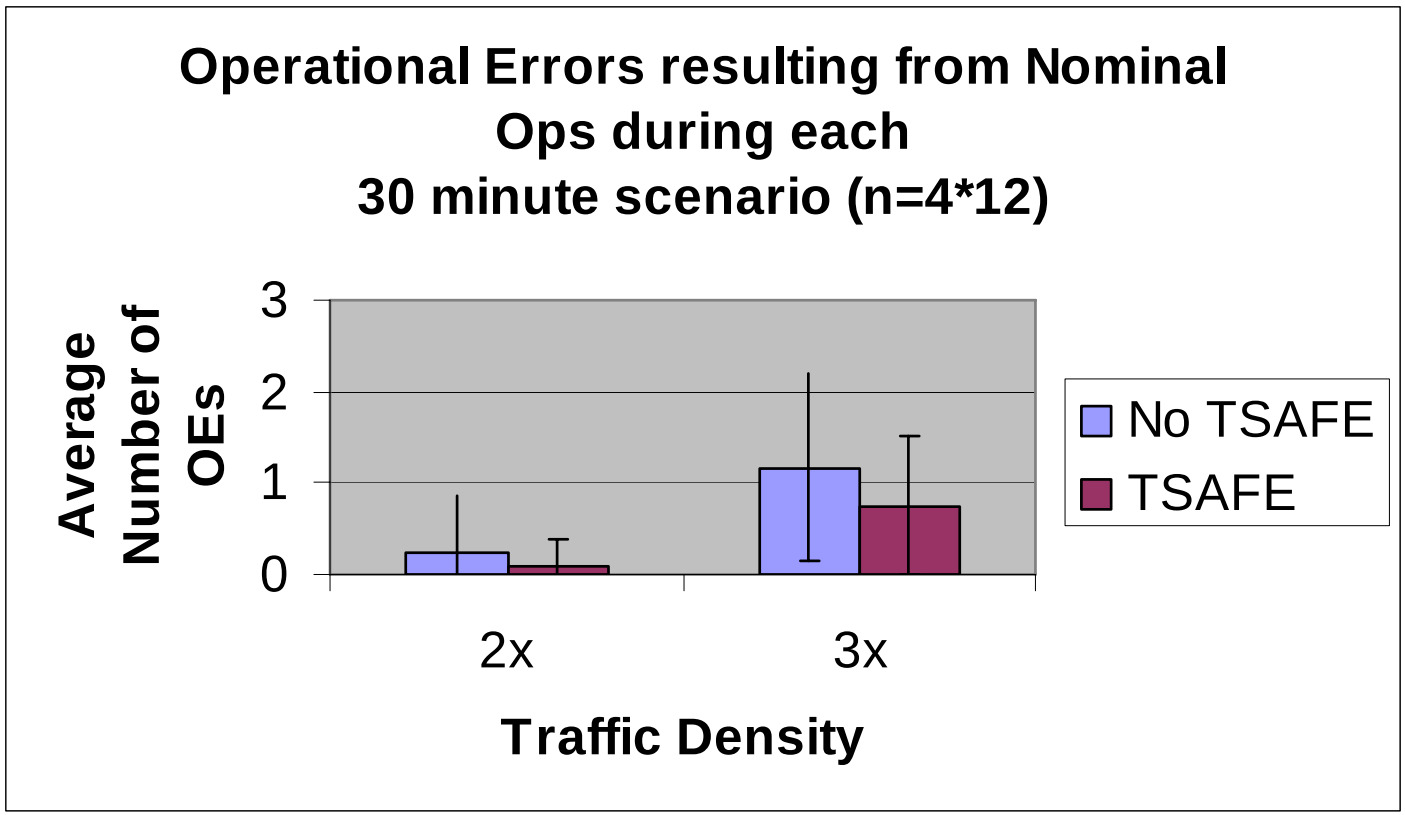
# Example (5/5)




**Controller plans trajectory that will get aircraft back to its original route**


320
360
290
350
330
360
DA
370
+PENTO
310
300
310
360
380
+SACKO
390
287
330
340
350
330
390
350
01
350
360
340
OPXV
330
360
340
340
380
320
380
330
340
360
360

# Results: Operational Errors (Nominal Operations)

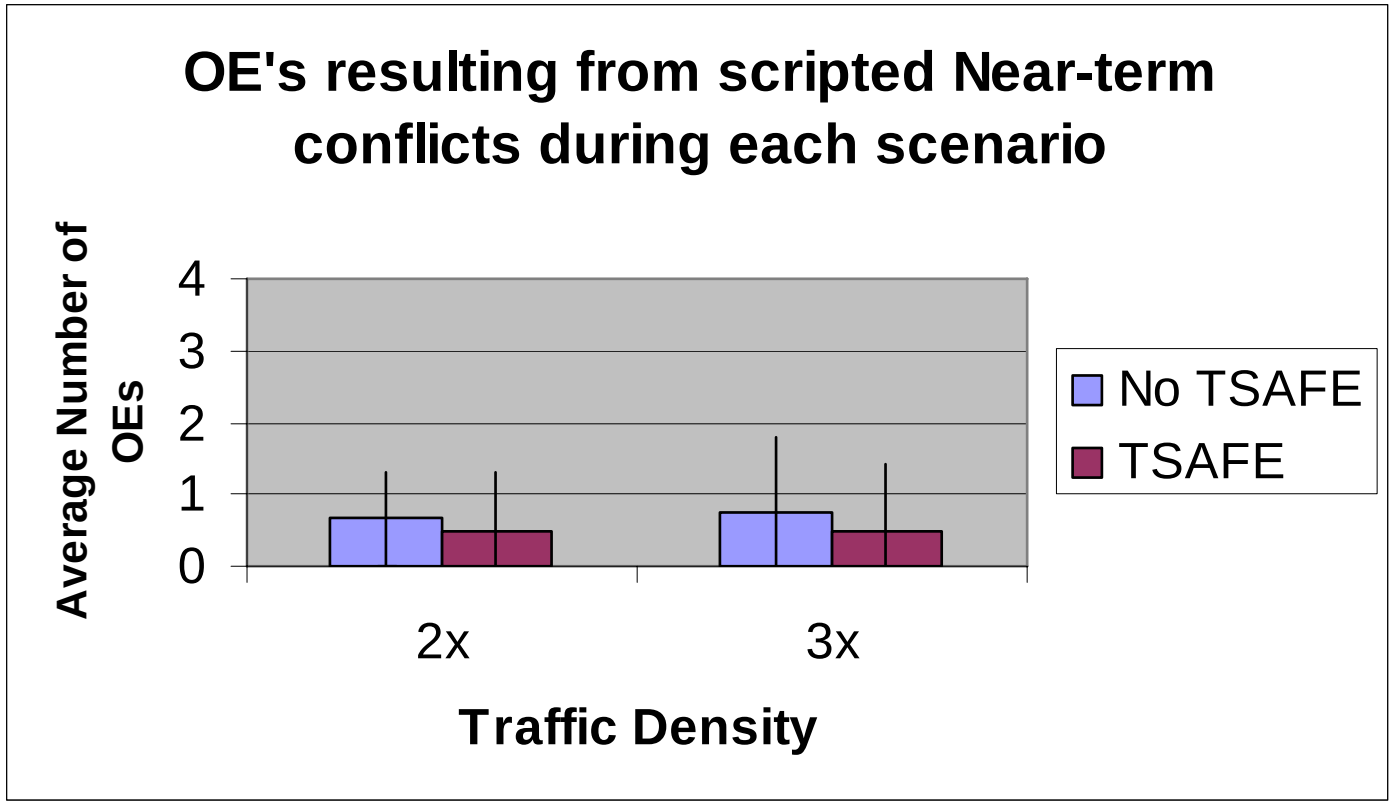



**Average number of conflicts:** **2x: 32/ 30 min**

**3x: 67/ 30 min**

**Significant effect of traffic density for total number of operational errors and conflict resolution rate**

# Results: Operational Errors (Off-Nominal Operations)

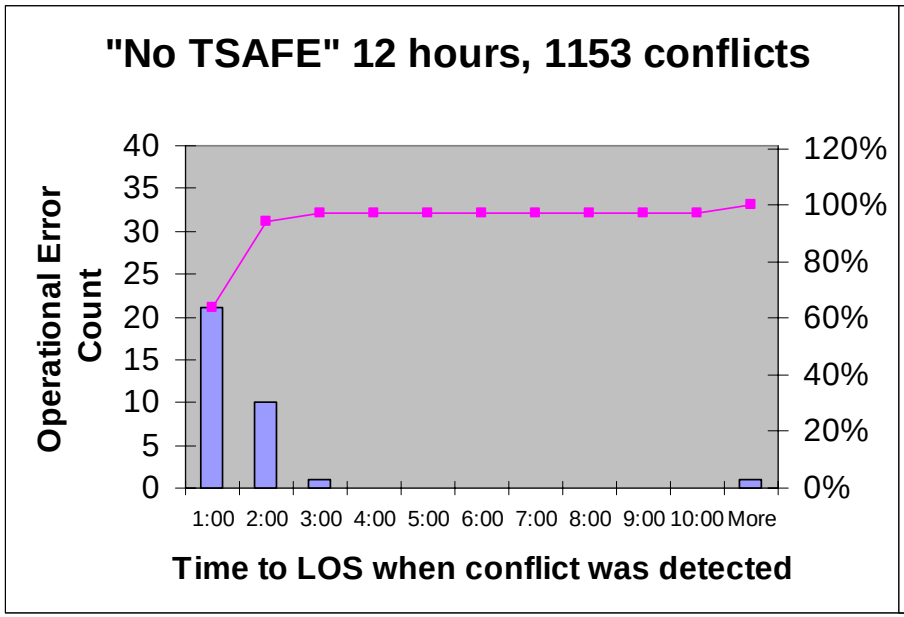


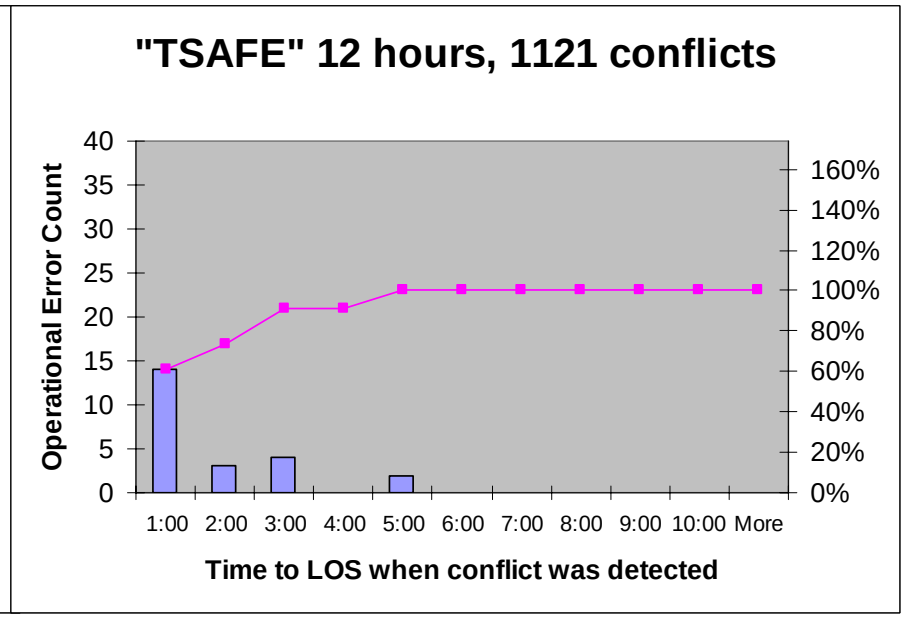

**Average number of conflicts:** **2x: 2.25/30 min**

**3x: 2.25/30 min**

**No effect of traffic density on total number of operational errors and conflict resolution rate**

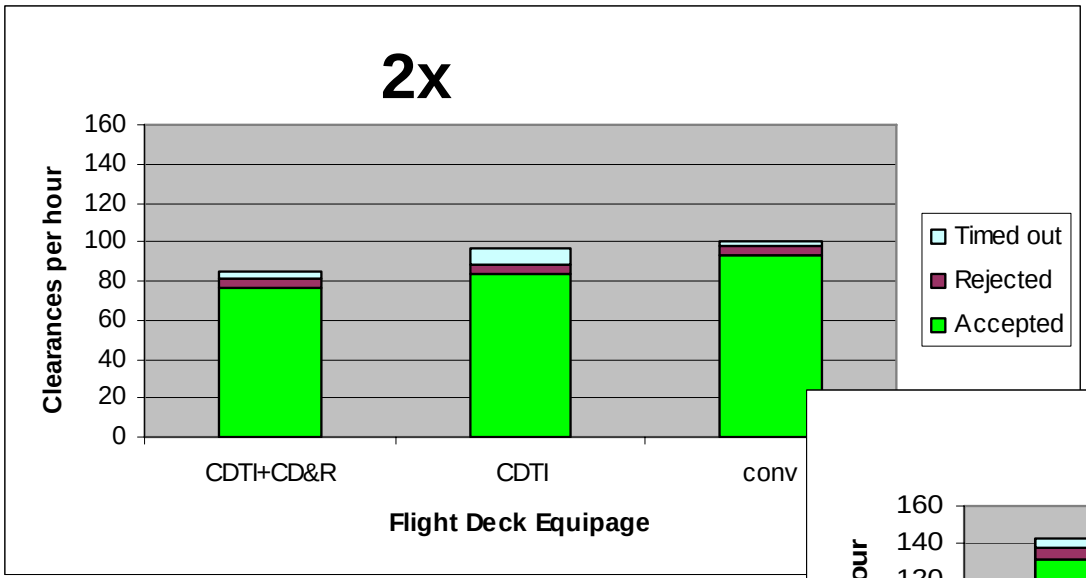
# Results: Operational Error Analysis

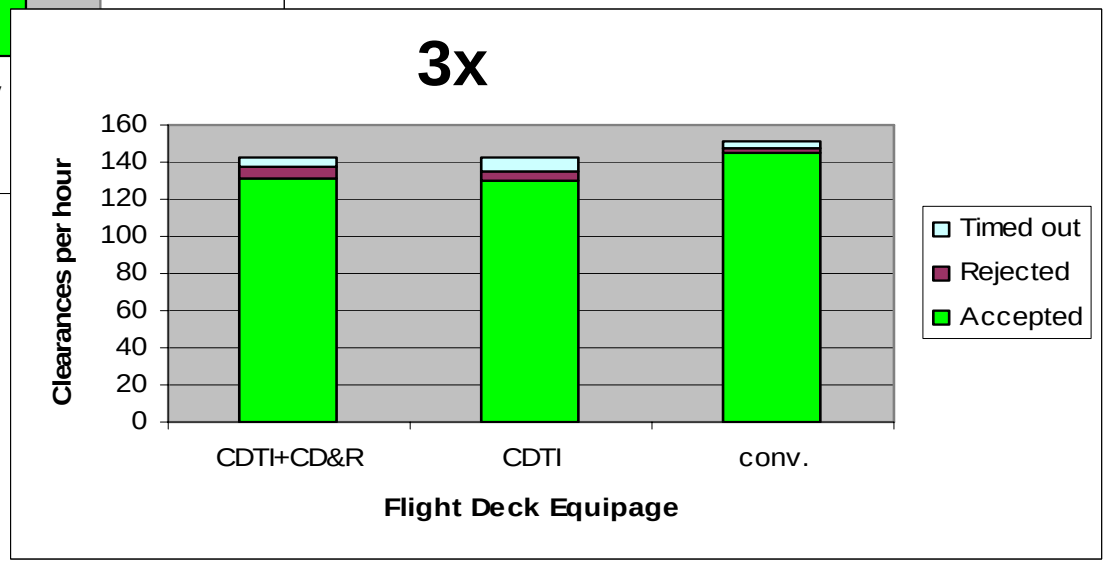



**Operational Errors were almost always associated with a late conflict detection**

# Results: Ground Side Initiated Uplinked Trajectory Clearances

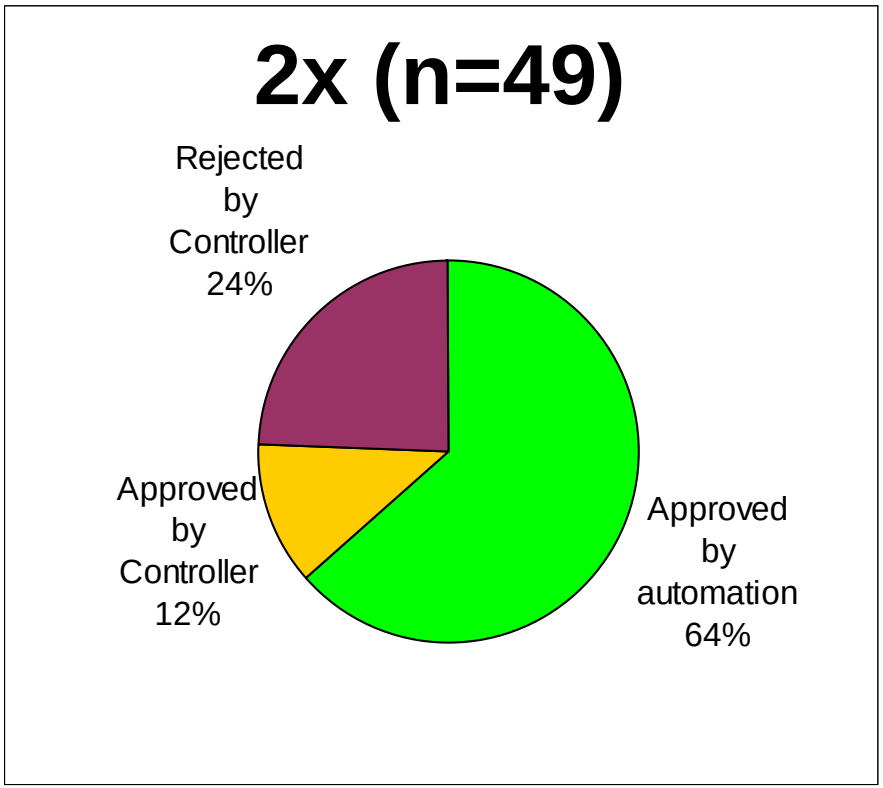


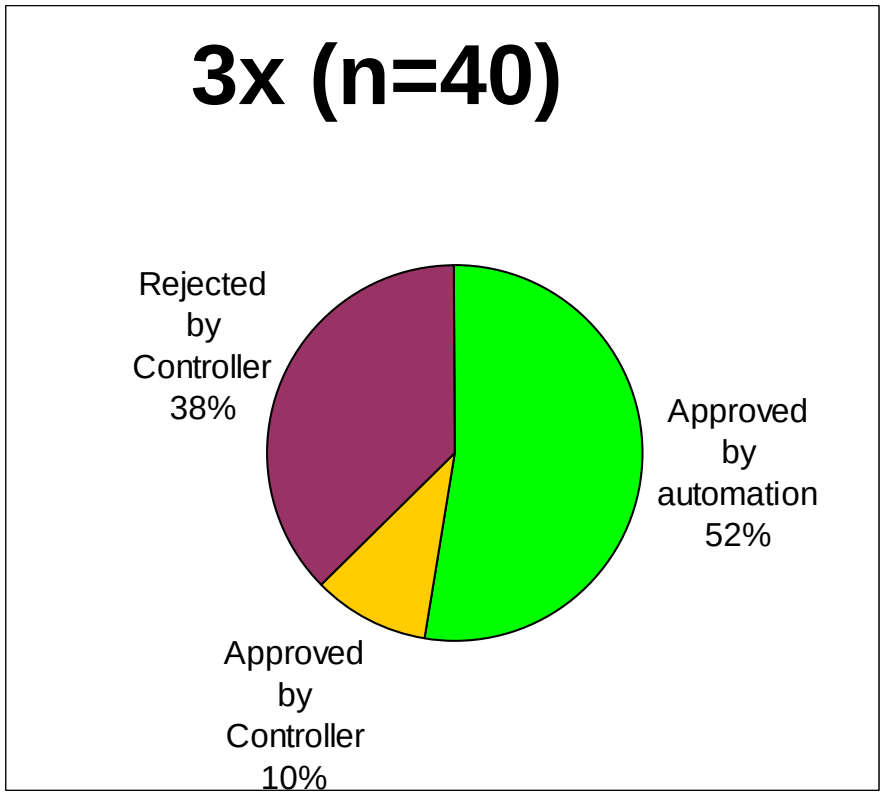




**1873 trajectory changes were sent by the ground-side**

**31 scripted rejections , 43 unscripted rejections (2.3%)**

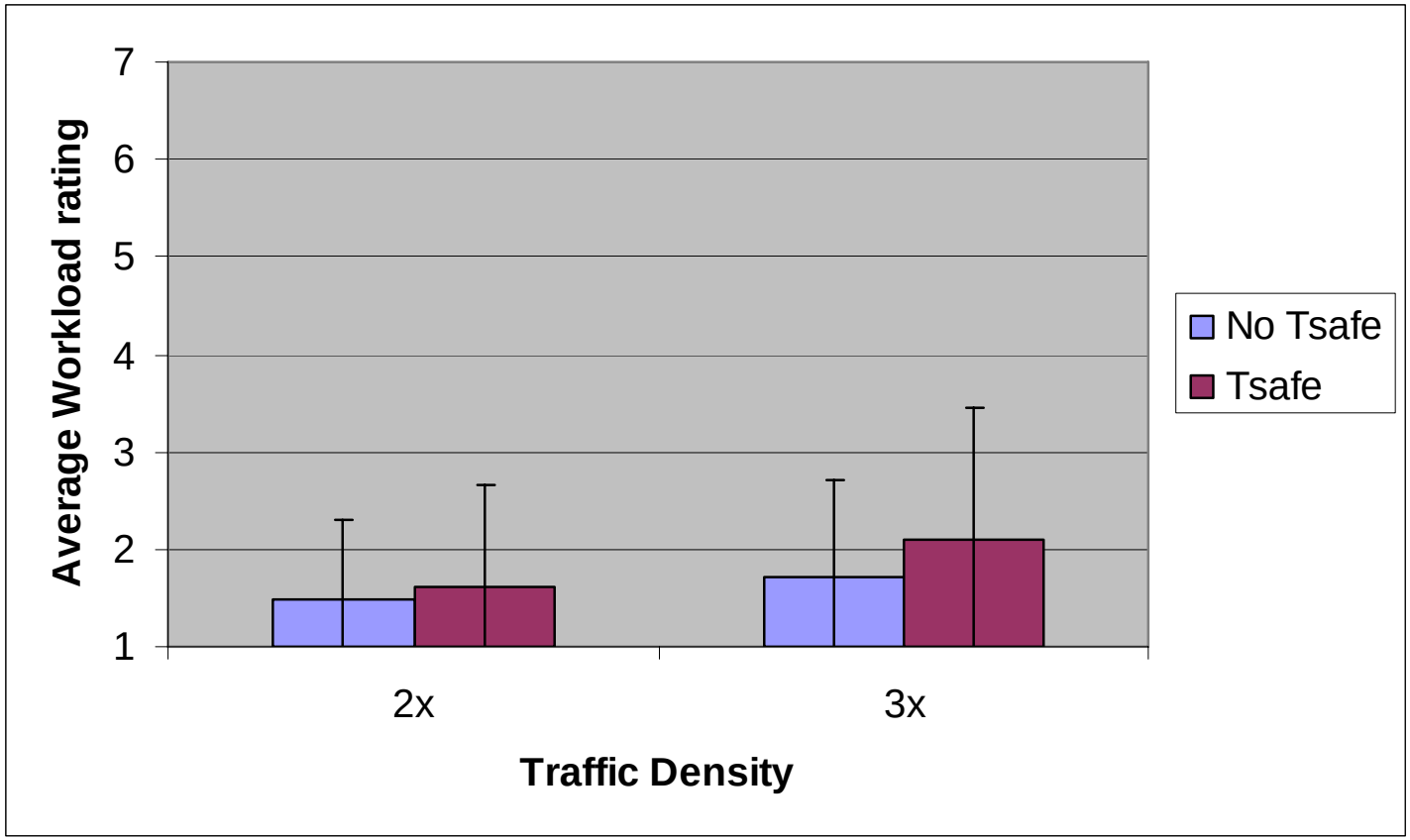
# Results: Flight Crew Initiated Downlinked Trajectory Requests




**ADS-B range limitations and differences in trajectory data and look ahead times resulted in trajectory rejections**

# Results: Controller Workload

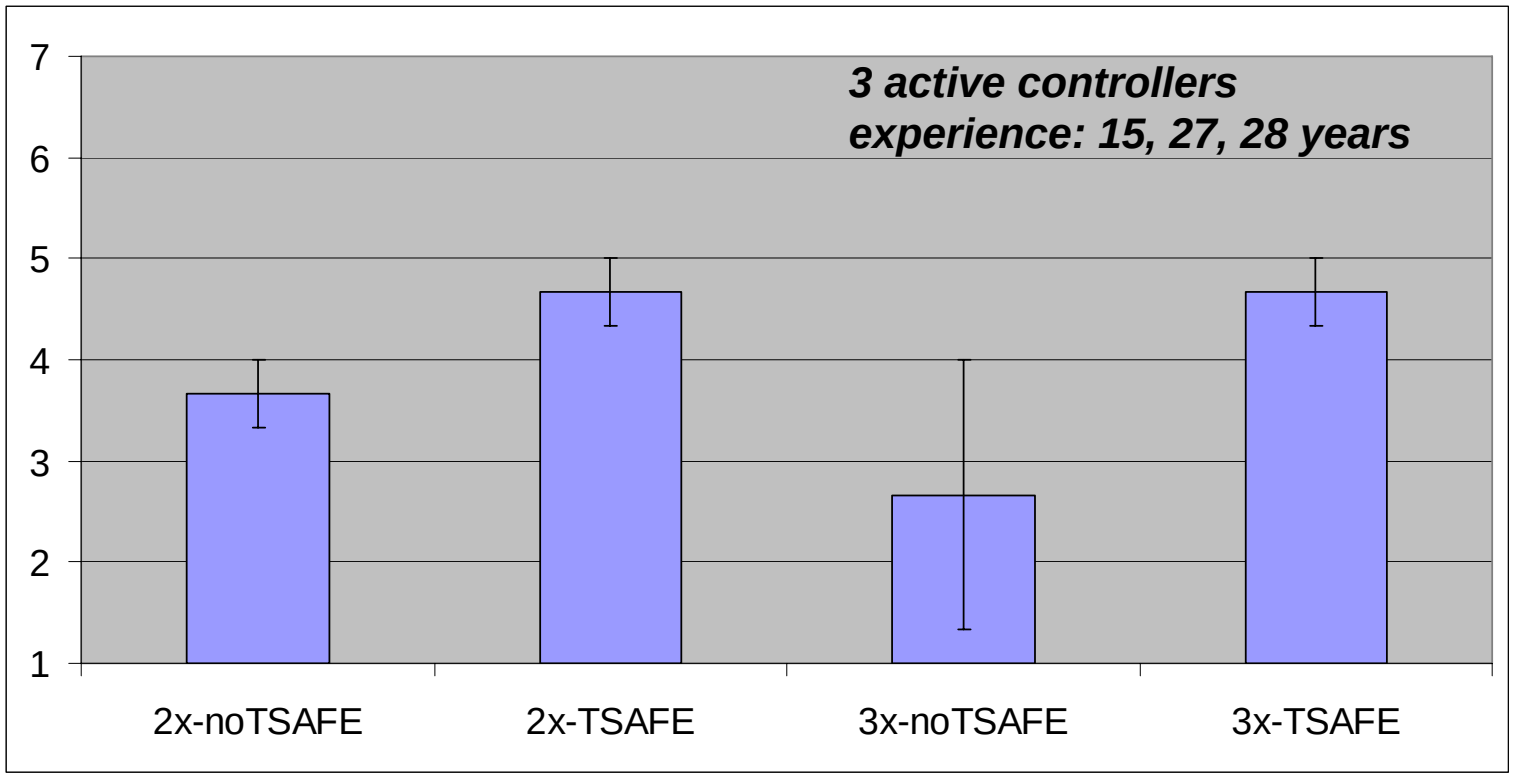



**Controllers reported workload via a button press every 5 minutes during the run on a scale of 1 (very low) to 7 (very high)**

**Controller workload was generally low, but short peaks are not captured very well by this metric**

# Results: Controller Acceptance

**How acceptable/feasible was the overall concept ?**
***1=completely unacceptable, 7=completely acceptable***



# Conclusions

- Ground-based automated separation assurance is a generally sound concept for trajectory-based operations in high density en route airspace
- Trajectory-based conflict detection and resolution automation integrated with data link is the key enabling technology
- Automating nominal operations causes generally low controller workload and opens up resources for controllers and pilots
- Pilot preferences can be accommodated through data link, but air and ground systems need to be compatible
- Future research is required to address human/automation interaction issues particular with regard to near-term conflict prevention
- Aircraft should always be on predictable trajectories