

National Aeronautics and Space Administration



Flight Deck Surface Trajectory- based Operations (STBO): Results of Piloted Simulations and Implications for Concepts of Operation (ConOps)

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NextGen Flight Deck Taxi Clearance Compliance



Problem

1. Current-day flight deck operations are not able to support:
 - NextGen Arrival - Anticipated throughput generated by NextGen concepts such as M&S, VCSPA, etc.
 - NextGen Departure - Predictability required for NextGen concepts.
(re: IADS RTT ConOps 4-12-10)
2. Must work ATC concepts in parallel with flight deck concepts or be vulnerable to risk of developing concepts to which pilots cannot comply.
(i.e., IADS RTT Doc: "OV-6c NEXTGEN 2018 Scenario 07 - Peak Departures v0.1 4-13-2009")

Research Needs

- Develop/assess Surface Traffic Mgmt. Systems / Flight Deck ConOps variants
- Determine technologies/procedures for pilots to conduct NextGen taxi operations
- Assess compliance and pilot workload under NextGen IADS operations
- Define and conduct RTT IADS RTP efforts

Approach

Iterative Pilot-in-the-loop Simulations

- ConOps Definition / refinement
- Pilot compliance
- Pilot info. requirements
- Pilot acceptance



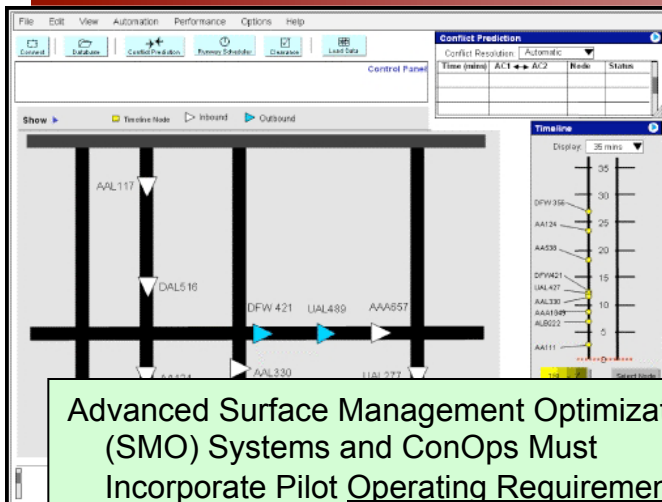
Impact

- ConOps Development
- SMS Algorithm/Parameters Development
- Flight Deck System Requirements
- Robust systems (e.g., off-nominals)

Progress

- Multiple simulations
- Defined ConOps options
- Eliminated specific candidate ConOps options

Pilot requirements for Surface Trajectory Based Operations (STBO) clearances



Problem: Integrating Surface Management Optimization (SMO) STBO clearances with flight deck information requirements

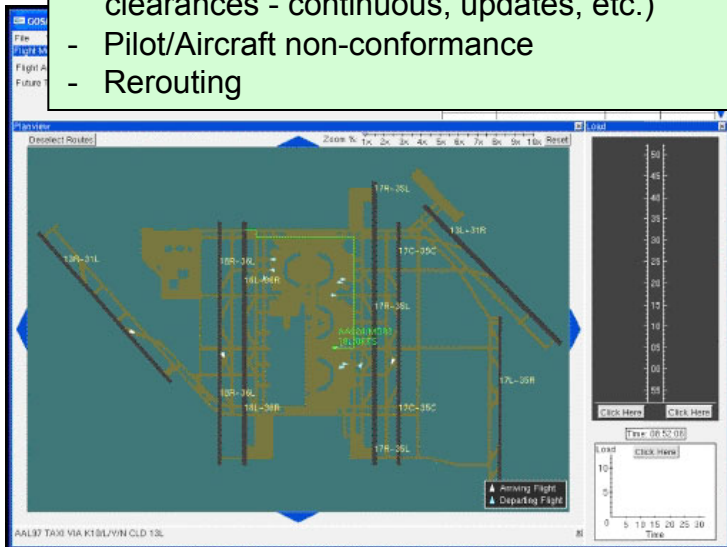
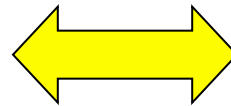


Advanced Surface Management Optimization (SMO) Systems and ConOps Must Incorporate Pilot Operating Requirements

- Ability to comply with speed requests
- Variance of route and time conformance
- Conceptual development (e.g., form of taxi clearances - continuous, updates, etc.)
- Pilot/Aircraft non-conformance
- Rerouting

Human Factors Pilot-in-the-loop Studies to Determine Pilot Operating Requirements

- Speed conformance
- Route and time conformance
- Conceptual (ConOps) development
- Pilot workload, Situation awareness (SA)
- Safety impacts due to time pressure



STBO Flight Deck Issues

STBO Concepts

- Progressive taxi/route updates
- Continuous-coupled STBO clearances
- Endpoint-only STBO Clearances (push-back, departure queue)

STBO Taxi Clearance Formats

- Flight Deck speed & time displays
- Bandwidth of error-nulling (i.e., continuous vs. non-continuous checkpoint error)
- ATC STBO Clearance: Speed, Time

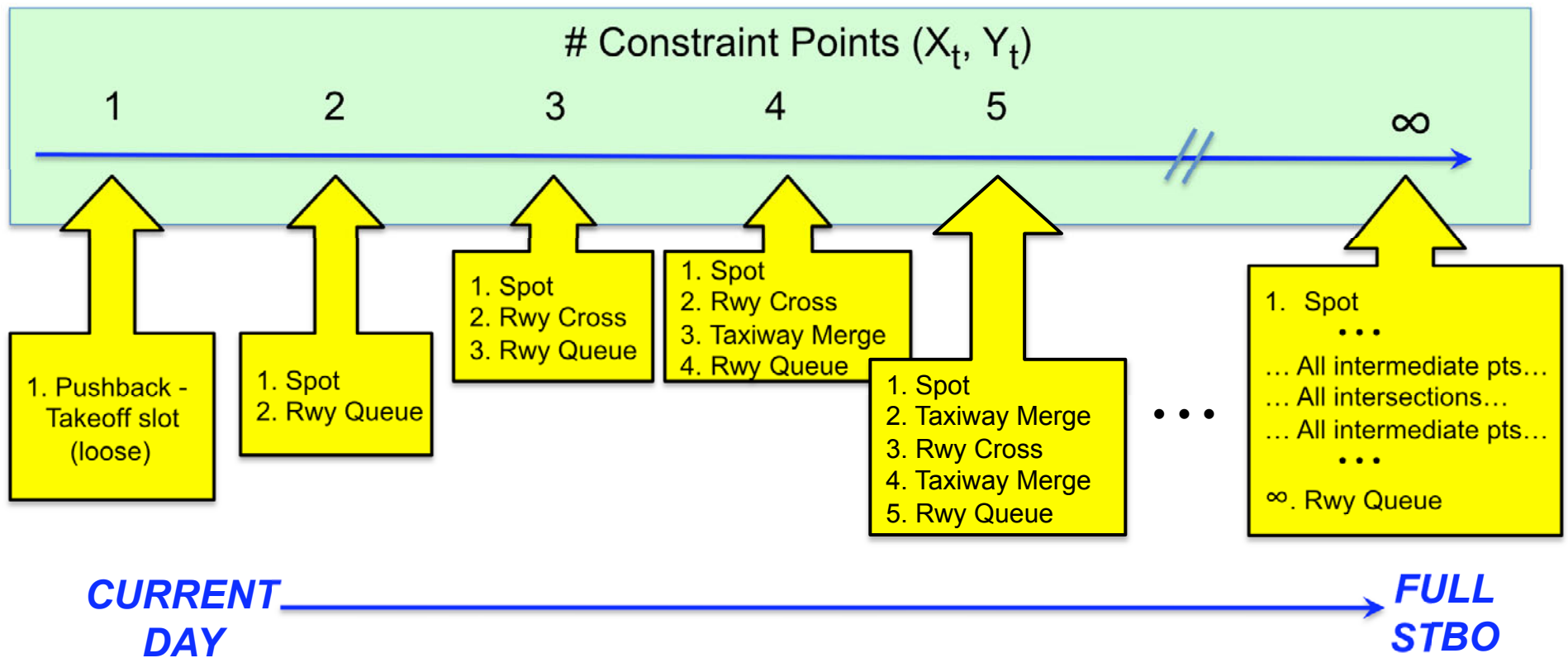
Pilot Performance Metrics

- Variance of speed, time-of-arrival error
- SA, workload, safety impacts

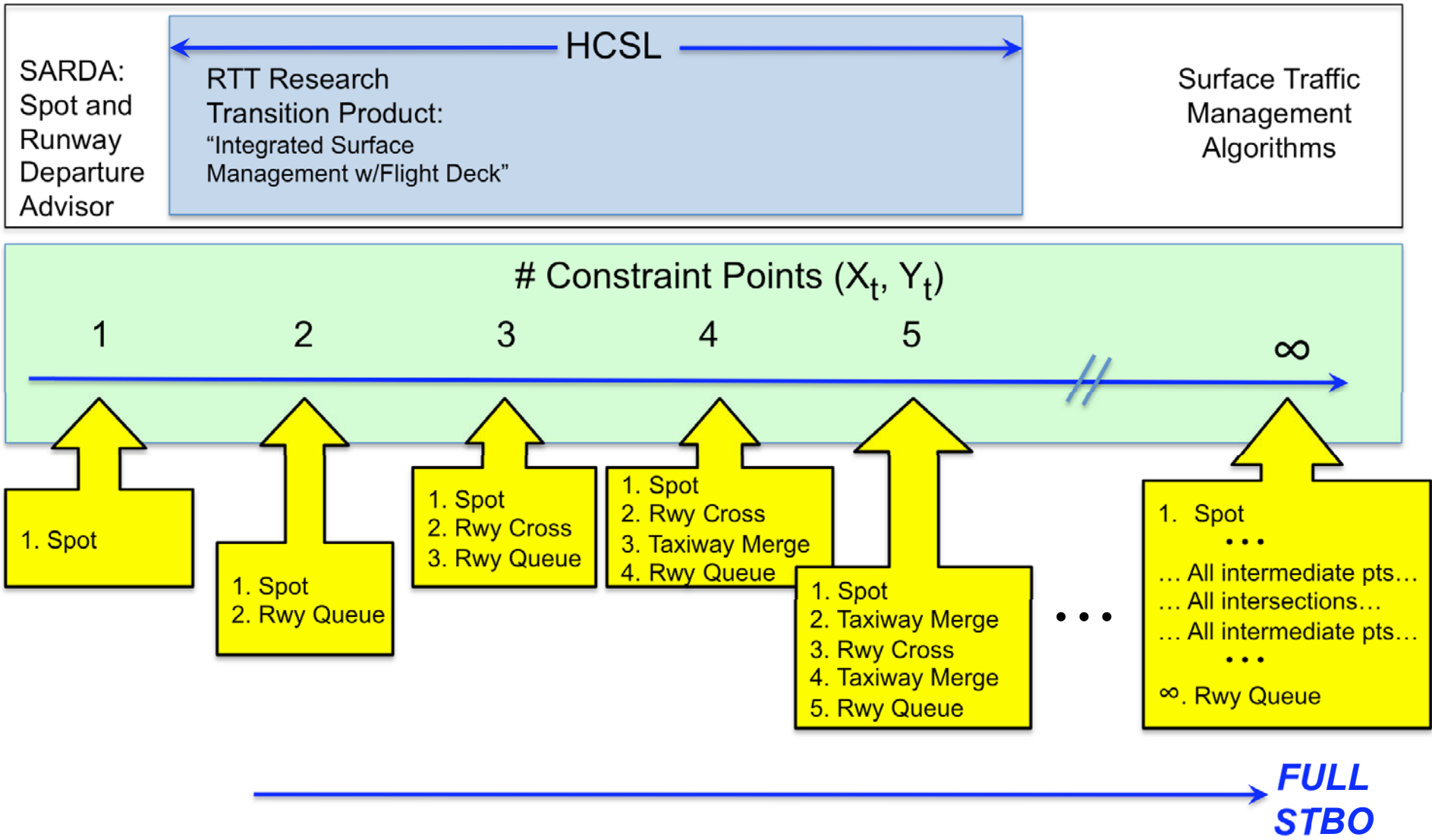
NextGen Taxi / Surface Trajectory-Based Operations (STBO)

Surface Trajectory-Based Operations (STBO) inherently different than In-Air TBO

- In-Air: More constrained – due to aircraft inertia, min/max speeds, in-trail separations.
 - More predictable, much more likely to have fully defined trajectories: $X(t)$, $Y(t)$
- Taxi: Not constrained – aircraft start, stop, wait, merge into queues, no min. separation
 - Less predictable, more variants on defining STBO than in-air TBO



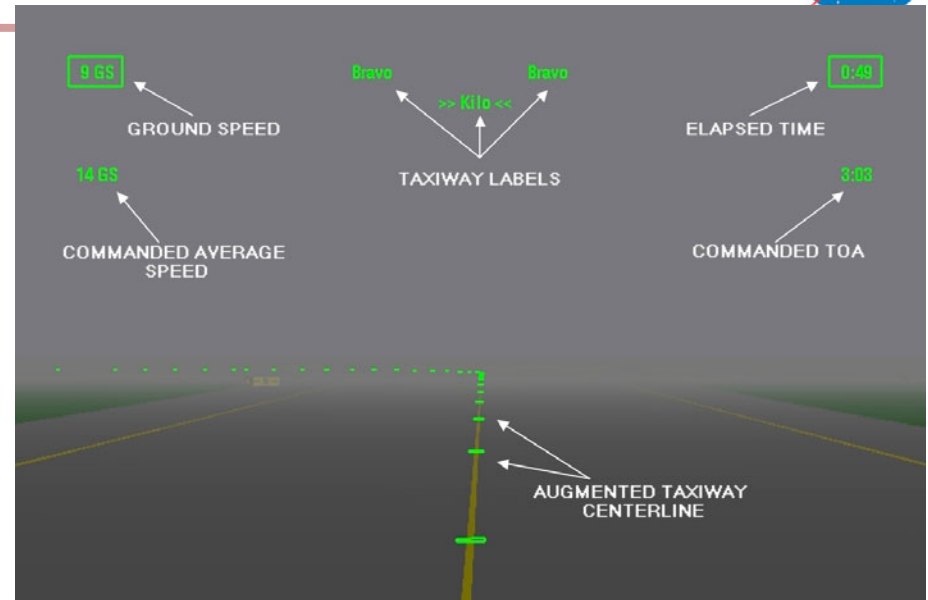
NextGen Taxi / Surface Trajectory-Based Operations (STBO)





Simulation and Results

Pilot requirements for 4-D taxi clearances



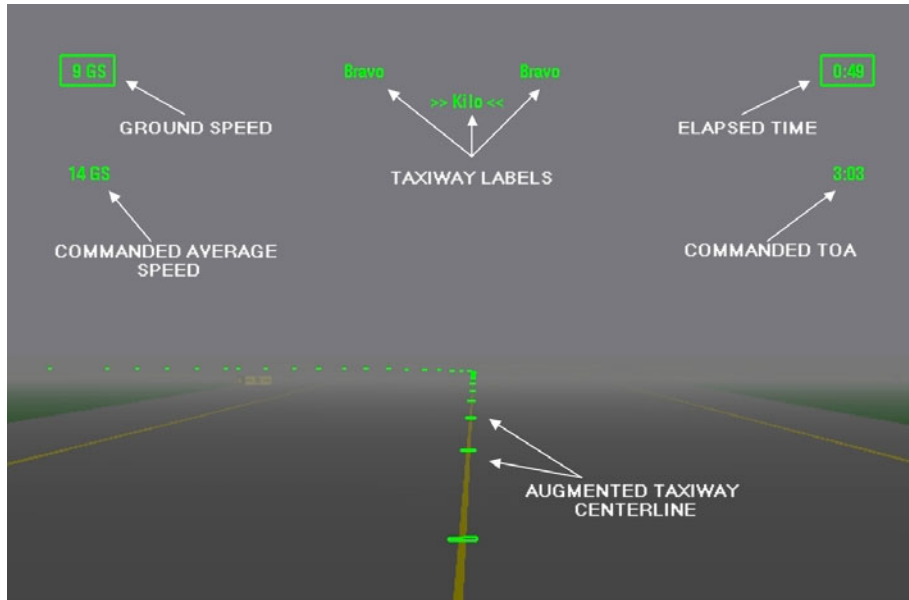
Speed/Time Format (in green)

Initial Baseline 4-D Taxi Navigation Study

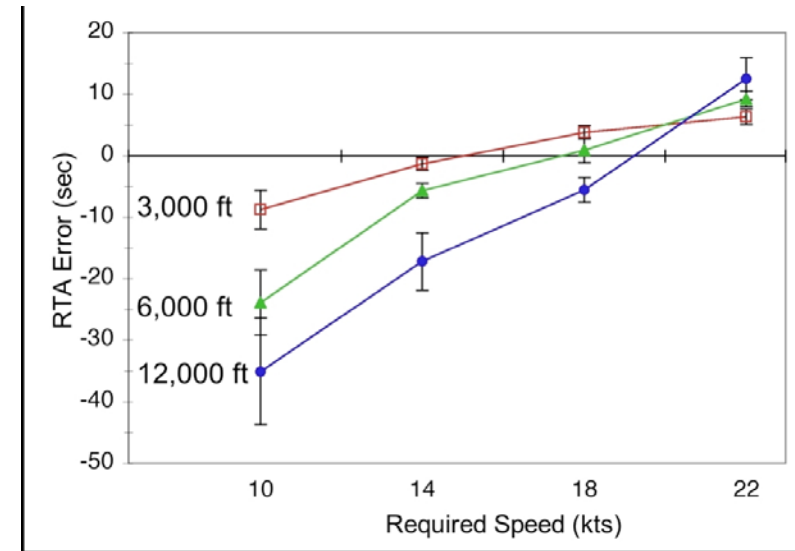
(Williams, Hooey & Foyle, 2006, Proc. AIAA)

- 18 Current Captains
- Minimal display information (baseline study)
- 4-D Taxi Clearance Formats
 - Speed: Commanded average route speed + Current speed
 - Time: Commanded time to RWY + Elapsed time
 - Both: All

Pilot requirements for 4-D taxi clearances



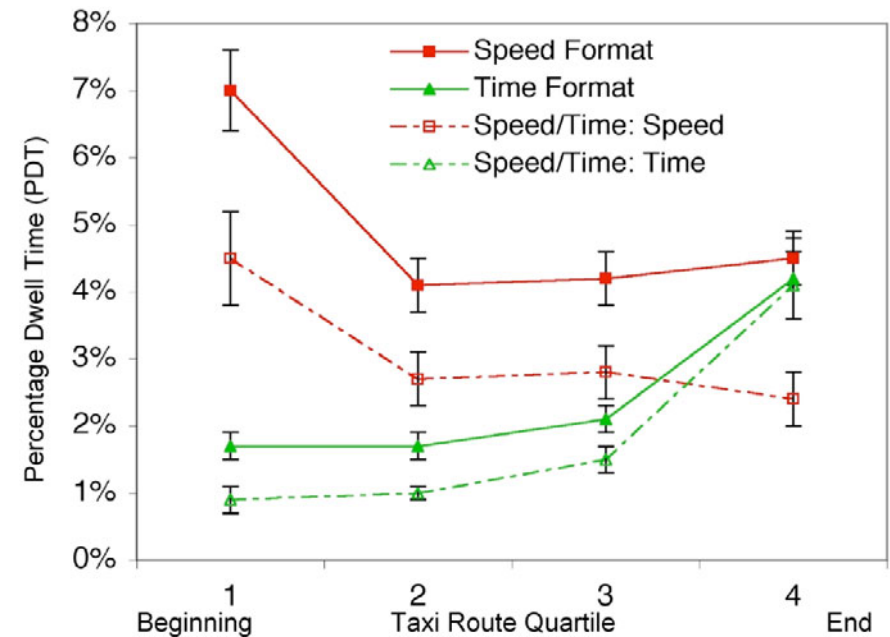
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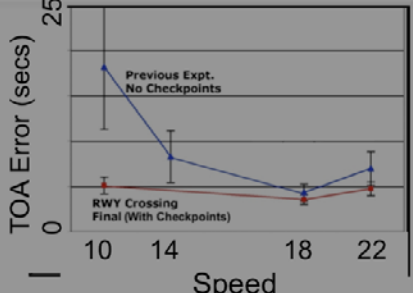
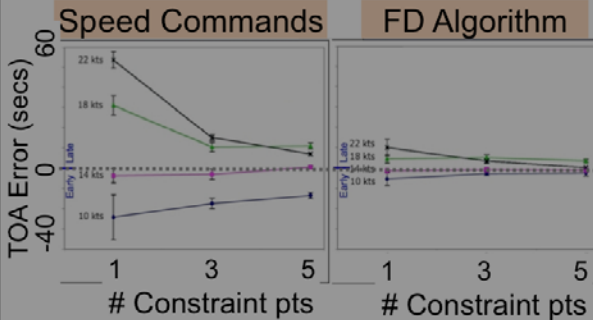
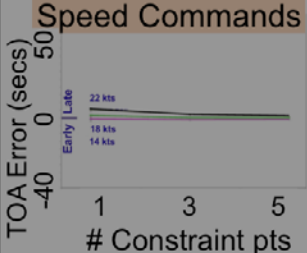
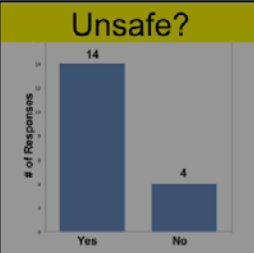
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 - Both: All
- Results
 - Less error with Both (Time and Speed together) formatted clearances
 - Eyetracking usage - speed used early in route, then switch to using time information



HCSL Completed NextGen Taxi Sims

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Simulation and Results

Pilot requirements for 4-D taxi clearances

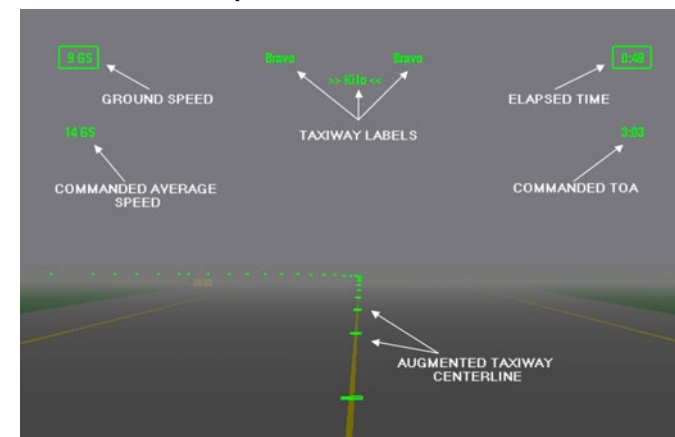
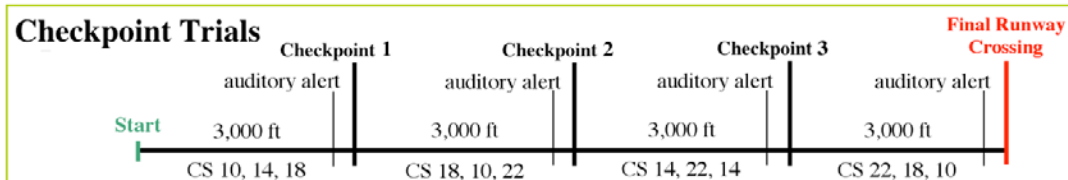
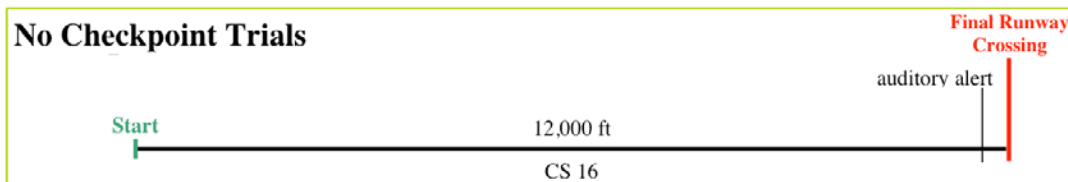


Initial Baseline 4-D Taxi Navigation Study (Expt #1) *(Williams, Hooey & Foyle, 2006, Proc. AIAA)*

- Less error with Both (Time and Speed together) formatted clearances
- Eyetracking usage - speed used early in route, then switch to using time information

Baseline 4-D Taxi Navigation - Updating/adjusting 4-D taxi clearances study (Expt #2)

- Scenario: ATC Taxi clearance - Segmented ATC clearances w/ "time checkpoints" due to:
 - 1) changing conditions; or
 - 2) imperfect aircraft Time of arrival (TOA) compliance at checkpoints
- 17 Current Commercial Transport Captains
- Minimal display information (follow-on to first baseline study)
- 4-D Taxi Clearance Format:
 - Both: Commanded average SPEED + TIME to runway crossing (plus current readout)
- 6 experimental trials: 3 w/checkpoints & 3 no checkpoints
- Time checkpoints on EMM (white bars) & auditory tone 75 ft before checkpoint



Pilot requirements for 4-D taxi clearances

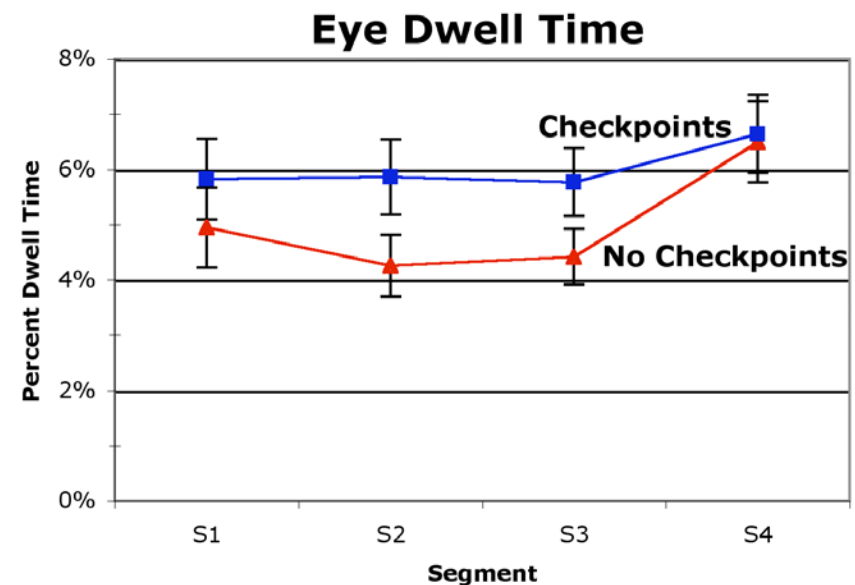
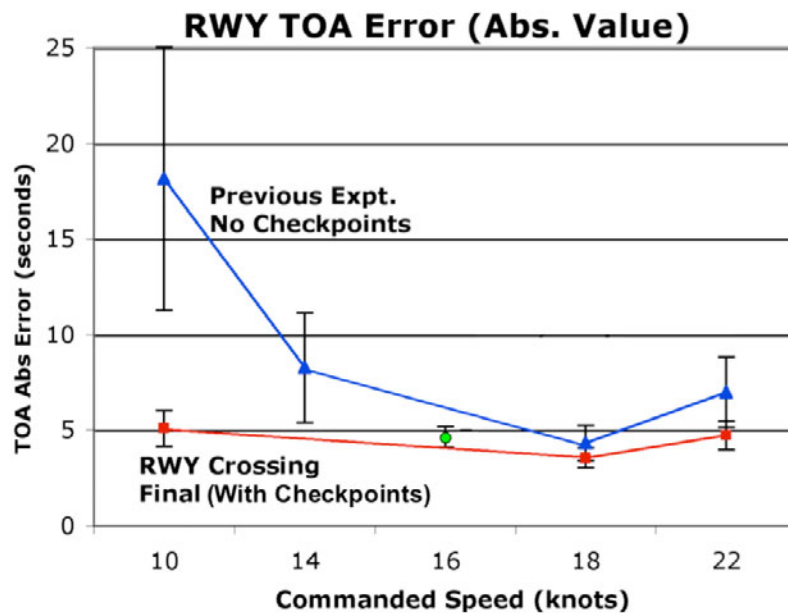


TOA Absolute Error (Left panel)

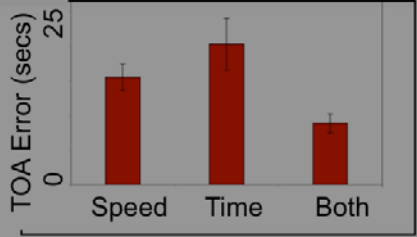
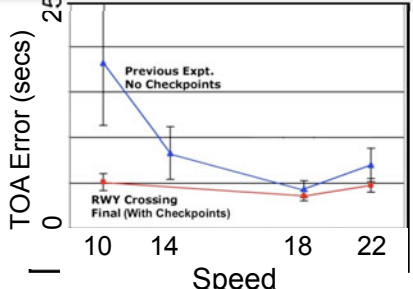
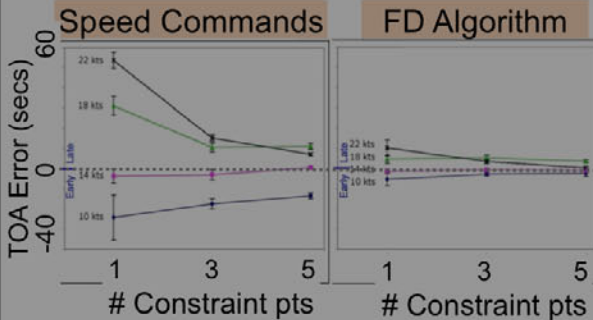
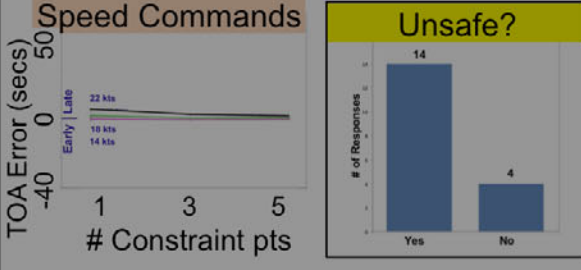
- For slower commanded taxi speeds, time checkpoints improve Runway (Time of Arrival) TOA accuracy

Eye Dwell Time (Right panel)

- Overall, pilots looked at display information more during checkpoint trials than non-checkpoint trials (24% vs 20% of trial)
- Middle-of-route checkpoints (Segments S2 & S3) --> more visual attention (% Dwell Time) on display
 - Pilots received new updated checkpoint information 4 times as often
 - Visual workload increased
 - Possible traffic awareness issues



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Simulation and Results

AP.2.S.09 - "NextGen Time-based Taxi Clearances" Pilot-in-the-loop simulation



Experiment Goal

Characterize the distribution of pilots' Time of Arrival (TOA) performance to inform the development of Surface Traffic Management (STM) algorithms.

Compare three STM system concepts (# traffic flow points; within-subjects factor):

- 1) One single traffic flow point to ensure on-time arrival at the destination runway;
- 2) Occasional (three) traffic flow points to enable traffic sequencing at important intersections and
- 3) Frequent (five) traffic flow points to enable dynamic system re-optimizations and very close coordination

Compare two NextGen Time-based Taxi Ops implementations (Between-subjects factor):

- 1) Speed Clearances: Current-day Avionics without Speed Error Nulling
- 2) Speed & Time (Checkpoint) Clearances: Advanced Avionics with Speed Error Nulling

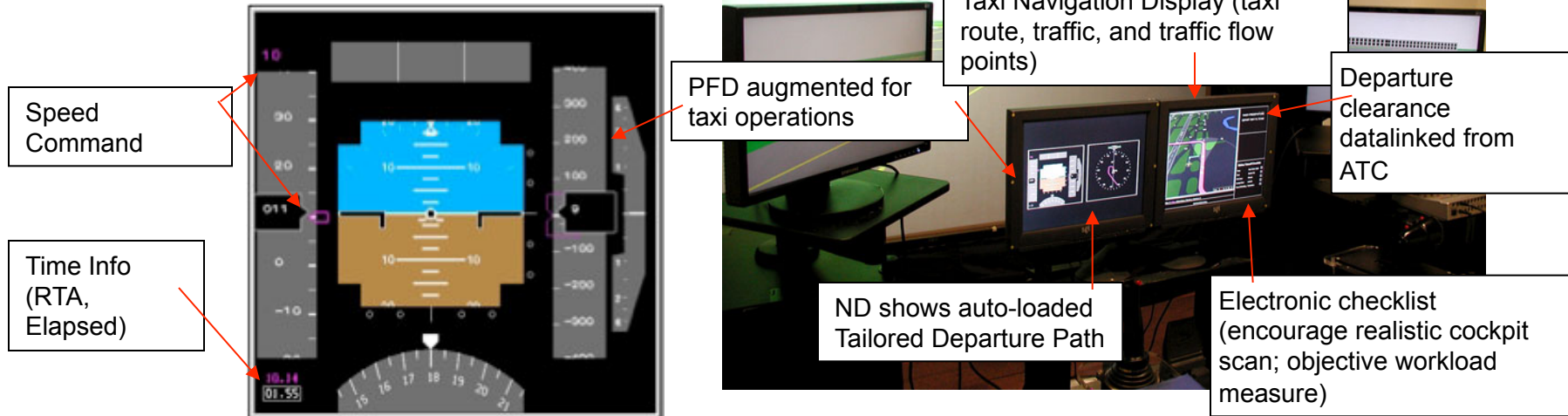
Experiment Overview

16 Pilots (Commercial Transport, CA & FO)

32 departure taxi trials ('spot' to runway)

Medium-fidelity simulator; DFW airport

Questionnaires; SME debriefs



Time of Arrival Error

Speed Effect:

- Slow speeds (10 kts): A/C early
- Fast speeds (18, 22 kts): A/C late
- 14 kts (negligible error)

Traffic Flow Point Effect:

- TOA error larger for 1 traffic flow point than for 3 and 5

Next-Gen Implementation Effect:

- TOA Error larger for "no error nulling"
- Reduced spread of TOA Error distribution with "error nulling"

Workload

- Error-nulling avionics increased time to verify/accept departure clearance (~ 1 sec for nominal clearance; 12 sec for off-nominal clearance with error)
- 2-3 speed/checkpoint updates recommended by pilots
- 5 updates viewed as too many for:
 - Error nulling: 88%; 7 of 8
 - No Error nulling: 0%; 0 of 6($p < .001$, Performance/workload trade-off)

Structured Interview Results

Safety: "eyes in" vs "eyes out"

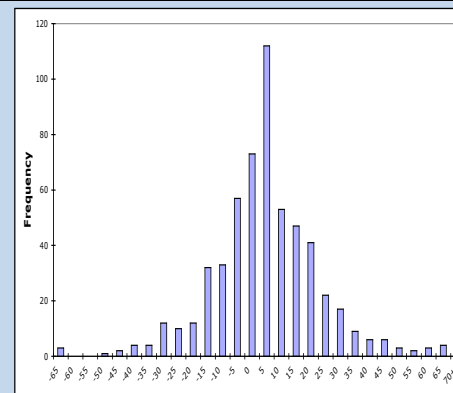
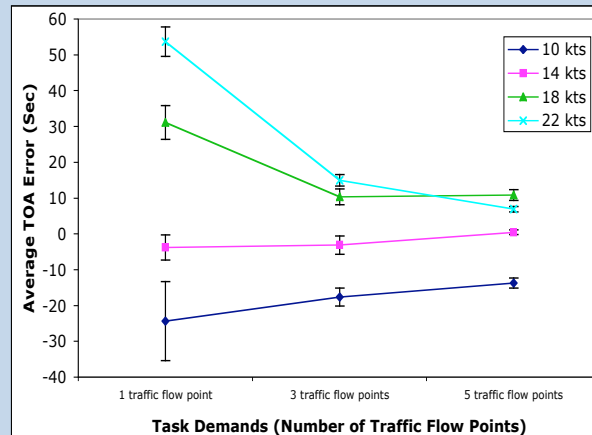
NextGen Implementation:

- PFD appropriate and intuitive
- Taxi navigation display should show traffic and taxi hold instructions
- Increased cockpit coordination (i.e., "callouts" for speed & traffic)

AP.2.S.09: "NextGen Time-based Taxi Clearances" Pilot-in-the-loop simulation

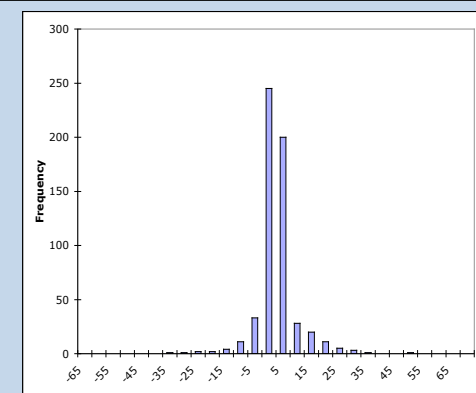
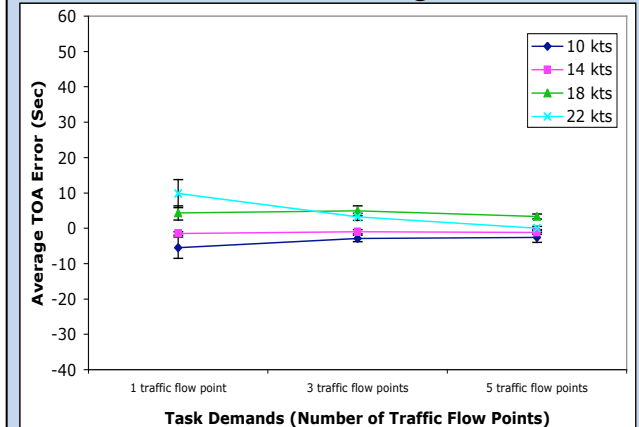


Next-Gen Implementation: Speed Clearance / No Error Nulling



Distribution of TOA Errors

Next-Gen Implementation: Speed & Time Clearances / Error Nulling



Distribution of TOA Errors

Average TOA Error = Actual TOA - Commanded TOA
Positive Error = Aircraft was late / too slow
Negative Error = Aircraft was early / too fast
(plotted with +/- 1 standard error)

Results inform STM Algorithm Development

Departure clearance operations under NextGen surface operations conditions



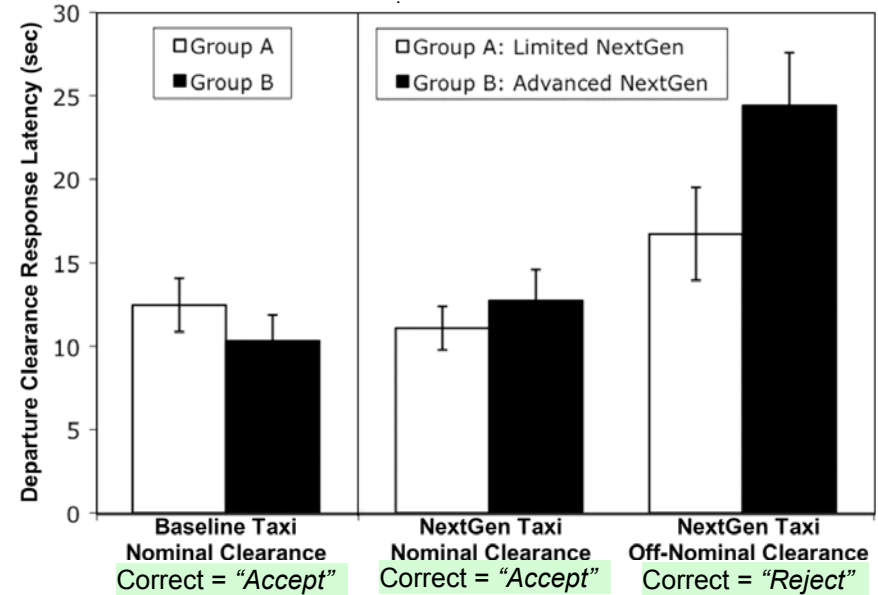
Compared to “current-day” baseline taxi,
Advanced NextGen (error-nulling avionics) had longer latencies to:

- Correctly accept correct clearances
- Correctly reject incorrect clearances

Compared to Limited NextGen (speed commands only),
Advanced NextGen (error-nulling avionics) had longer latencies to:

- Correctly reject incorrect clearances

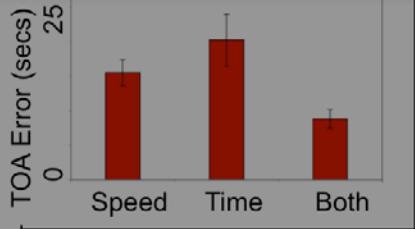
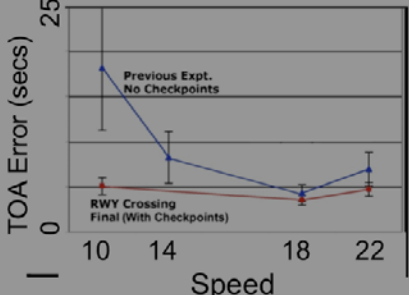
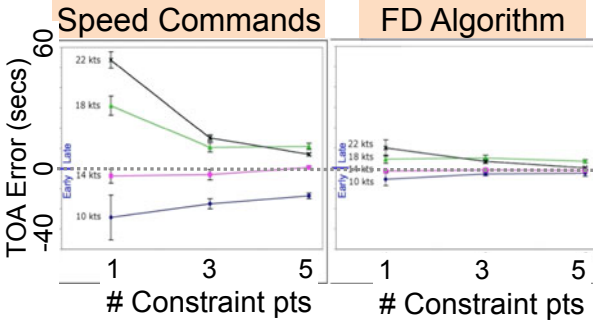
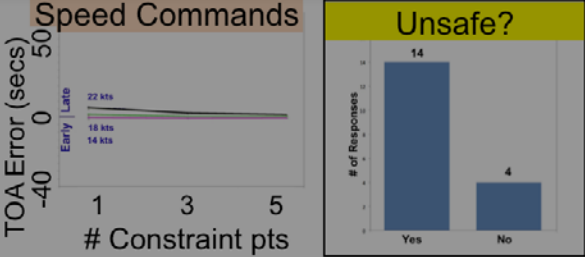
May be indicative of increased workload in Advanced NextGen implementation



Structured Interview Results

- Datalinked direct upload (vs. manual FMS loading): Potential flightdeck workload savings
- "Tailored Departures / Unique Dynamic RNAV/RNP Departures": Clear advantages for system efficiency (re: Wx, winds, traffic) and individual aircraft efficiency (e.g., flight time, fuel savings)
- Need for verification of route (e.g., "NA227-123456), especially vs. SIDs implementations
- Issues:
 - How does flightdeck "back up" tailored departure routes in case of equipment failure, FMS dumping route, etc. (vs. Current SIDs with hard copy, FULL route information)
 - How does crew do pre-departure route briefing? (vs. Current SIDs with heading based turns, speeds, etc.)

HCSL Completed NextGen Taxi Sims

Evaluated	Results	Findings	ConOps Implications															
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Simulation and Results

Milestone AP.2.S.11

Assess System Performance of Varying Options for 4D Taxi Clearance Information to Provide a Scientific Basis for Future Systems Requirements for Mature Surface Automation and Arrival/Departure Seamless Airspace Transition



ConOps: “ATC Voice Taxi Clearances with Speed Commands”

Pilots: 18 commercial transport Captains (current or recent retirees)

Scenario: DFW Taxi out to take off – Ramp parking spot to runway through take-off roll (up to 80 kts)

Concept Scope

Trajectory-Based Surface Operations

Taxi out operations with:

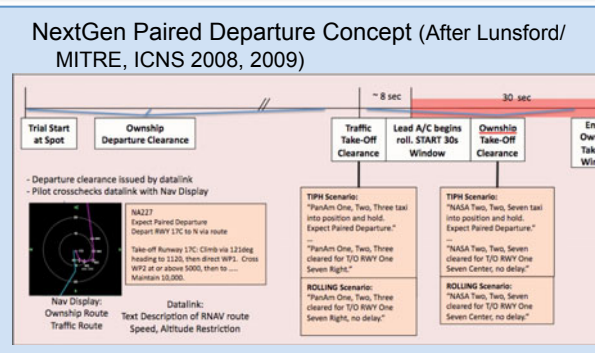
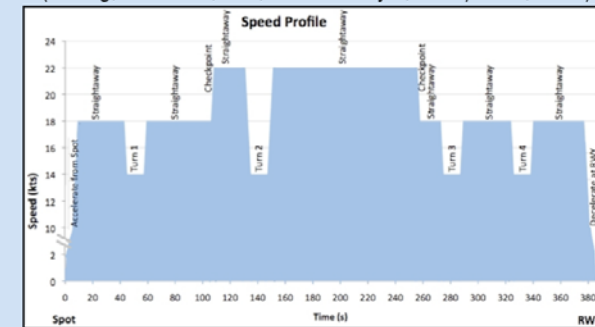
- ATC voice speed commands
- Pilots required speed range compliance of +/- 1.5 kts
- Pilot acceleration profile control requirement
- Pilot crosscheck of dynamic RNAV routes datalinked to cockpit (waypoints/crossing restrictions)

NextGen Paired Departures

- Closely spaced parallel paired departures - (MITRE/ Lunsford; ICNS 2008, 2009)
- Ownship informed of paired departure via datalink, paired aircraft’s route depicted on Navigation Display



A/C dynamics: 2 kts/sec spool up/down; 14 kts turns; Max. acceleration of: 0.25g long.; 0.15g lateral (Cheng, Sweriduk, Yeh, Andre & Foyle; AIAA) GNC, 2008)



Milestone AP.2.S.11

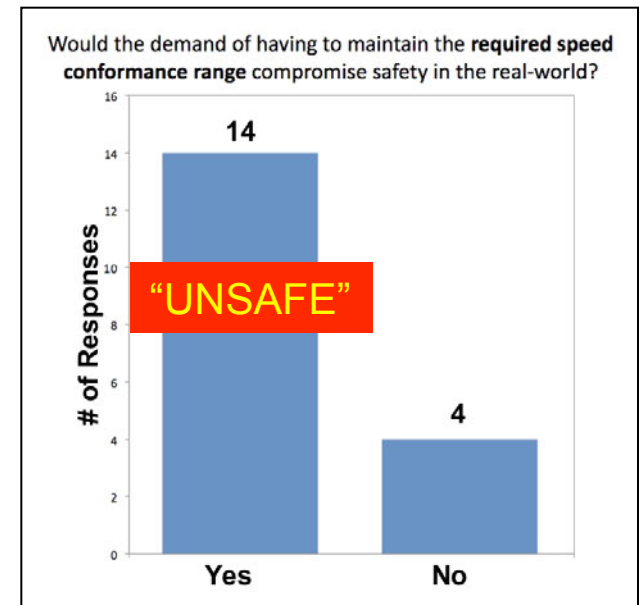
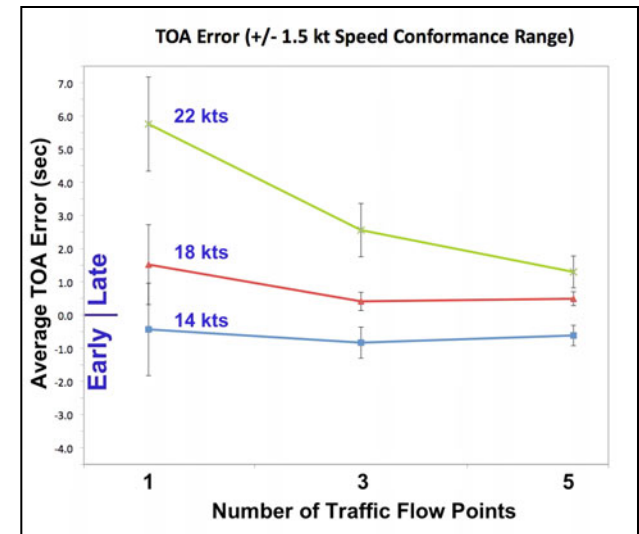
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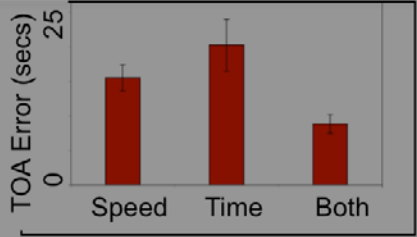
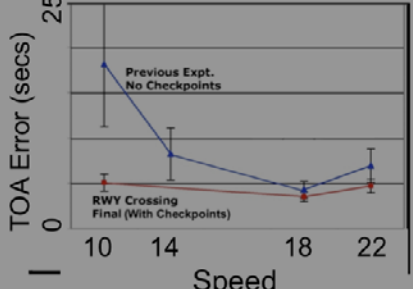
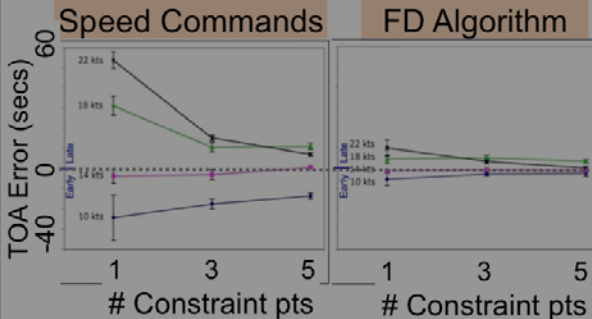
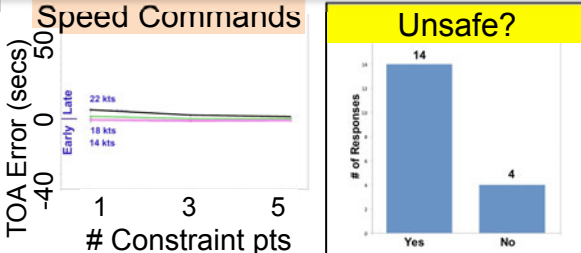
- Time of Arrival (TOA) Error to traffic flow points is improved compared to previous study (40-60 secs TOA error, Foyle et al, 2009) - because of defined aircraft acceleration and speed range requirements ...**BUT**...
- Workload and safety level were **unacceptable**
- Likely due to increased requirements of taxi task (Acceleration profile, speed range requirement)
 - 14 of 18 pilots responded that speed conformance range restriction would compromise safety ($p = .018$)
 - Rated more difficult than current actual taxi operations ($p = .042$)
 - Eyes-in time 18-24% compared to 8% baseline
 - Responded that they were “frequently” focused on the PFD speed tape when needed to attend to the taxiway

IMPACT

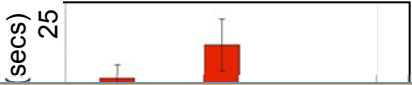

- ConOps of ATC providing taxi clearances with speed (via ATC DST) is not workable
- Need for RTA in taxi clearance; flight deck displays



HCSL Completed NextGen Taxi Sims

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HCSL Completed NextGen Taxi Sims

Evaluated	Results	Findings	ConOps Implications
<p>Taxi <u>information</u> needed time, bc (18 CAs)</p>		<p>• Need both Speed (A/C</p>	<p>• Need FD displays clearance B mfg.</p>
<p>Intermed <u>checkp</u> speed+ (18 CAs)</p>			<p>As in taxi Develop.</p>
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Conclusion: What do we know re: ConOps?

- 1) Surface Traffic Management System ← Sim data (TOA error, variability) of taxi speed, route length, # constraint points
- 2) ATC Clearance: Recommend $1 \leq \#$ intersection constraint points ≤ 4
- 3) ATC Clearance: Time (RTAs) necessary but not sufficient
- 4) ATC Clearance/Flight Deck: Taxi clearances with speed not safe/workable with current-day flight deck
- 5) Flight Deck: Need flight-deck display (avionics/EFB) capability

Next Steps: HCSL NextGen Taxi Sims

Conclusion: What do we know re: ConOps?

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Overall Research Objectives

Expand ConOps to address:

- Flight Deck Avionics/EFBs
- Traffic management

Specific Plan

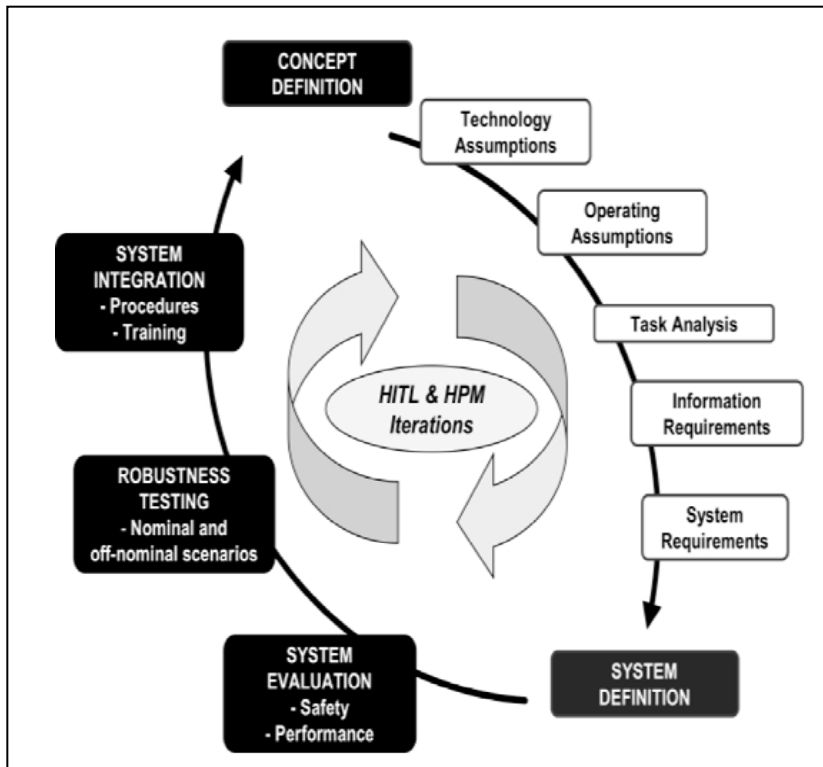
- FY11 Simulations
 - Sim #1 – Timing/format parameters for Data Comm vs. Voice trades for taxi re-routing
 - Sim #2 - Initial look at RTT RTP “Integrated Surface Management w/ Flight Deck”
 - a) Evaluate Flight Deck Display concepts x Traffic Flow concepts
 - b) Increase scenario complexity (traffic conditions, ATC-revised Rwy RTAs)
- FY12 sims – Advanced flight deck concepts to enable SMO re-optimizations
- FY13 – SMS / Flight Deck Integration sims
 - a) Evaluate Flight Deck concept elements (# Constraint Points + Flightdeck + Traffic) defined in previous sims with actual SMS algorithms (informed by sims)
- FY14-15 sims – Develop RTT RTP “Integrated Surface Management w/ Flight Deck”



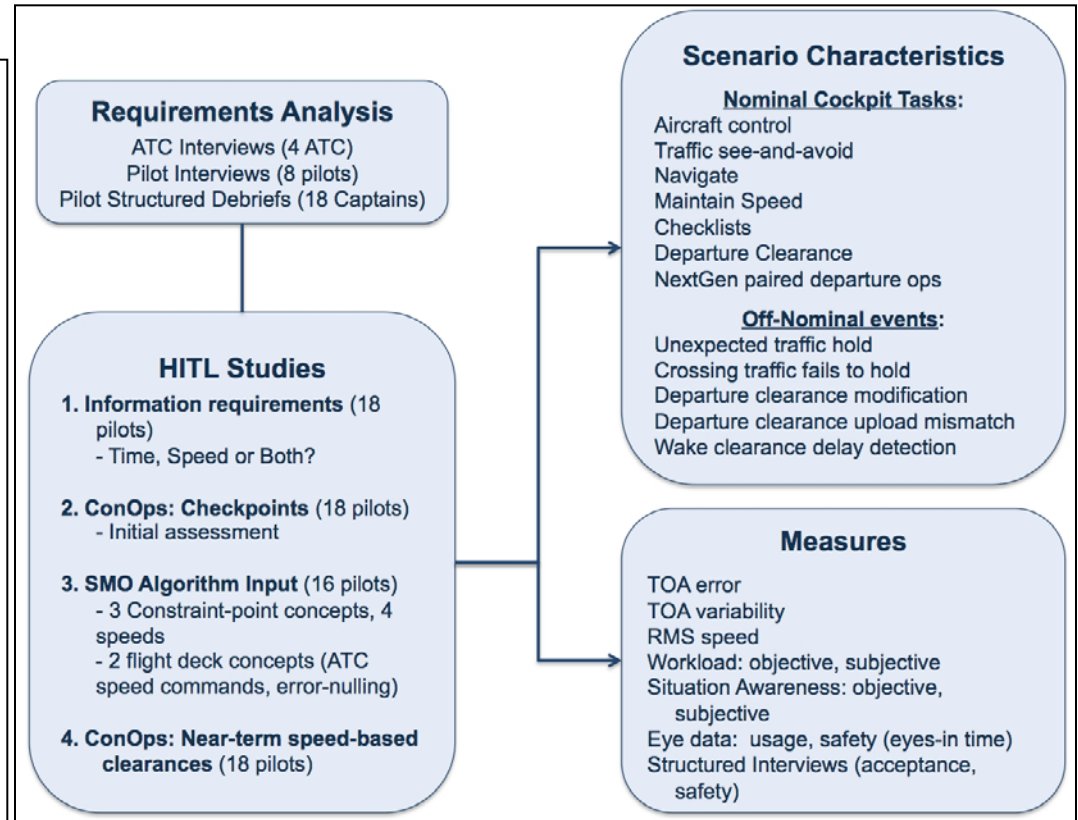
Backup Slides



Research Approach



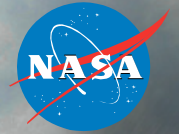
Human-centered design and evaluation process
(from Foyle & Hoey, 2008)



**NextGen Pilot Taxi Operations
HITL Research Approach**

Off-nominal Methodology Papers:

- Foyle & Hoey (2003). ISAP Conference.
- Newman & Foyle (2003). ISAP Conference.
- Foyle, Newman & Hoey (2005). NATO Conference.



Flight Deck Surface Trajectory-based Operations (STBO): Results of Piloted Simulations and Implications for Concepts of Operation (ConOps)

David C. Foyle, NASA Ames Research Center
Becky L. Hoey, Deborah L. Bakowski San Jose State University

Airspace Systems Program
2011 Technical Interchange Meeting
March 28–31 2011
San Diego, CA
www.nasa.gov



Research Focus: Pilot requirements for Surface Trajectory Based Operations (STBO) clearances



Objective

STBO to enable NextGen flight deck operations to support:

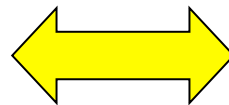
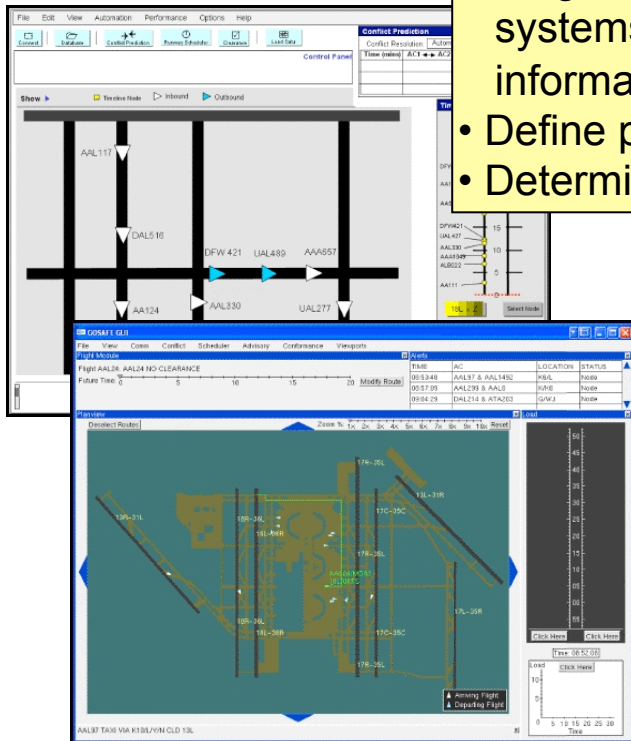
- NextGen Arrival - Anticipated throughput generated by NextGen concepts such as M&S, VCSPA, etc.
- NextGen Departure - Predictability required for NextGen concepts (e.g., Rwy; Merge; Flow) (ref: IADS RTT ConOps 4-12-10)

Must work ATC concepts in parallel with flight deck concepts

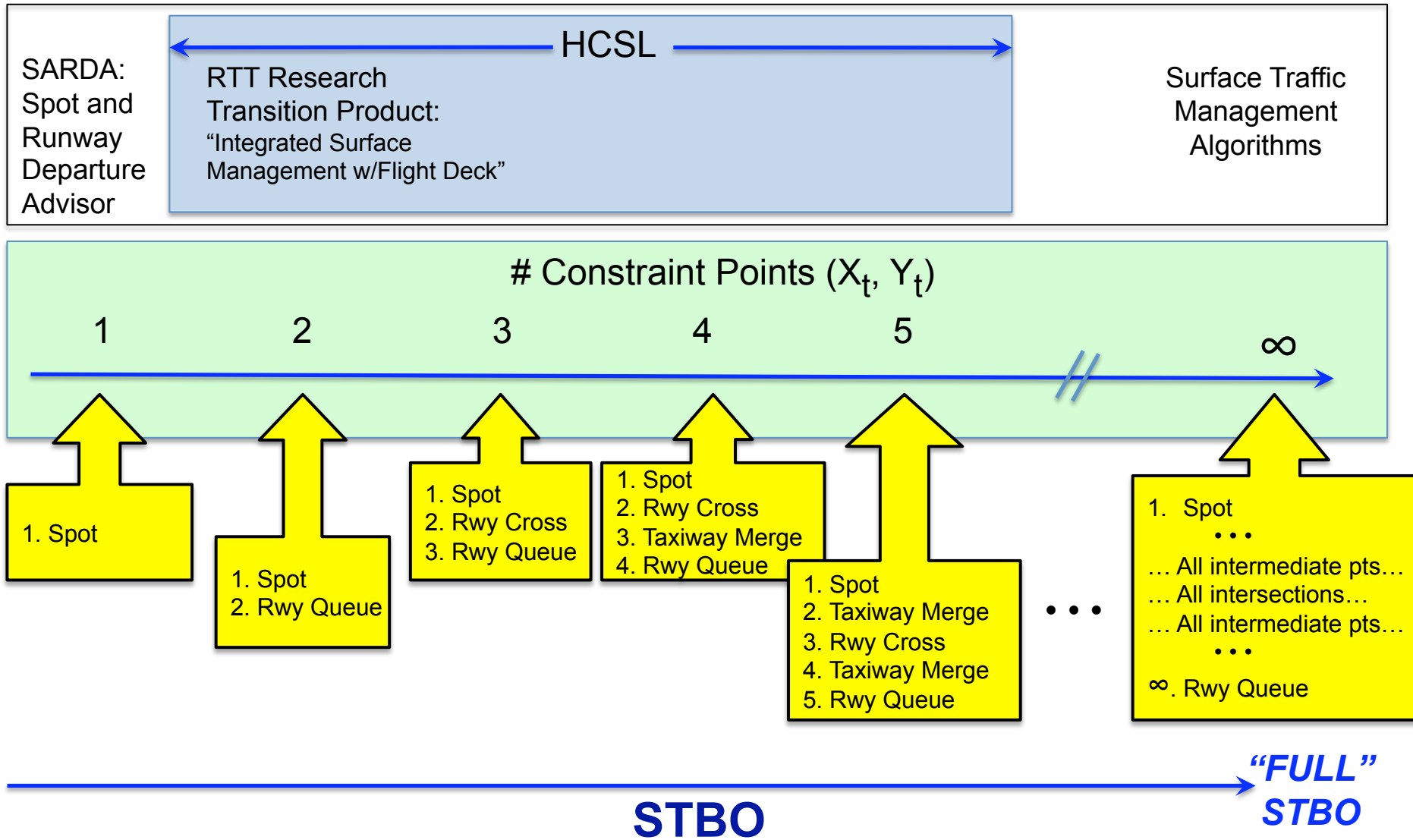
- Otherwise, vulnerability to risk of developing concepts to which pilots cannot comply (ref: IADS RTT Doc: "OV-6c NEXTGEN 2018 Scenario07 / Peak Departures v0.1 4-13-2009")

Goals:

- Integrate Surface Traffic Management (STM) systems' STBO clearances with flight deck information requirements
- Define parameters for flight deck and STM system
- Determine ConOps for STBO



NextGen Taxi / Surface Trajectory-Based Operations (STBO)





Flight Deck Simulations and Results

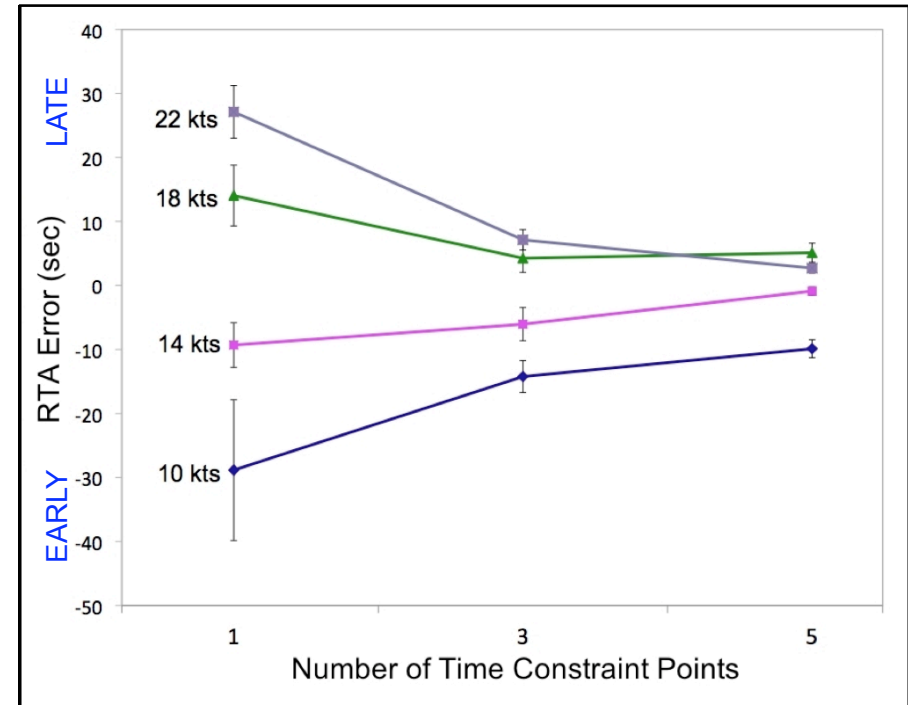
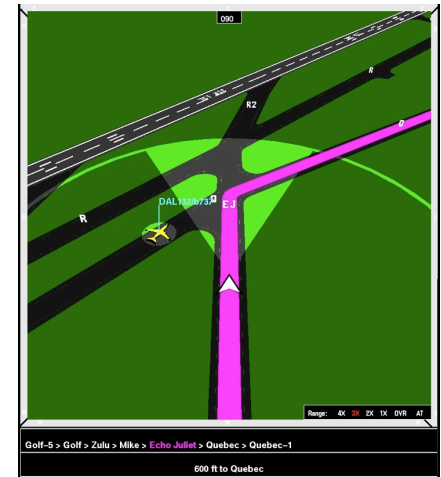
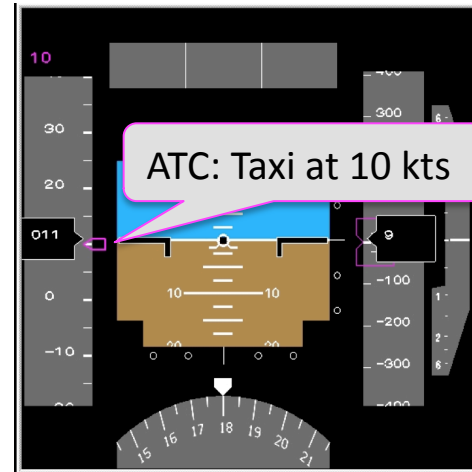
Experiment 1: Commanded Speed – Without Speed Profiles or Conformance



Foyle, Hooley, Kunkle, Schwirzke & Bakowski, 2009, ICNS

Objective: “Minimum Flight Deck Equipage”
ConOps Evaluation

- 1) ATC provides ‘A/C required speed’ in taxi clearance (either automated or ATC Decision Support Tool)
 - 2) Pilots not required to follow specific acceleration/deceleration speed profiles (only “be aggressive”)
- 8 Current or recently retired pilots: 6 CAs; 2 FOs
 - STBO Taxi Clearances – manipulated:
 - **Speed:** Taxi clearance included required speed
 - **# Intermediate Time Constraint Points**
 - Results
 - More RTA error with 1 time constraint point
 - Less RTA error with 3 or 5 time constraint points
 - Slower required speeds → early arrival; Faster required speeds → late arrival



Experiment 1: Commanded Speed – Without Speed Profiles or Conformance



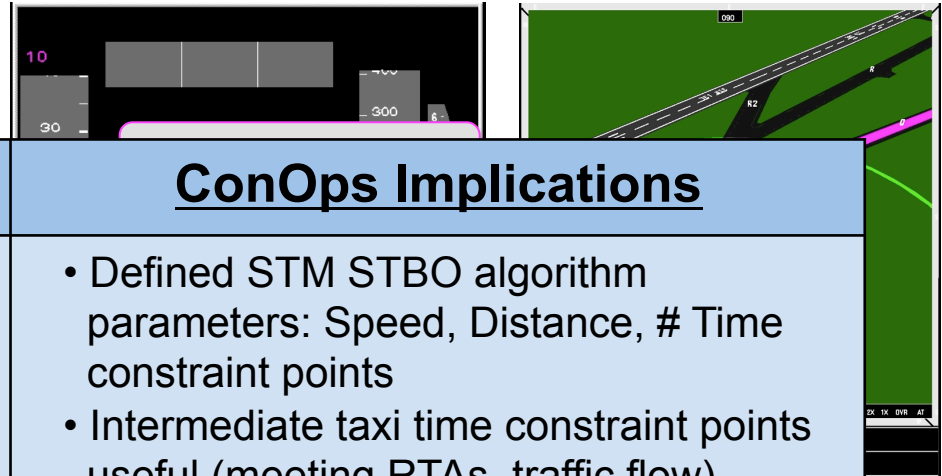
Foyle, Hooley, Kunkle, Schwirzke & Bakowski, 2009, ICNS

Objective: “Minimum Flight Deck Equipage”
ConOps Evaluation

- 1) ATC provides ‘ATC required speed’ in taxi clearance
- 2) Pilot does not comply with ATC required speed → poor RTA conformance

- 8 Cu
- STB
- Sp
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required speeds → late arrival



Findings

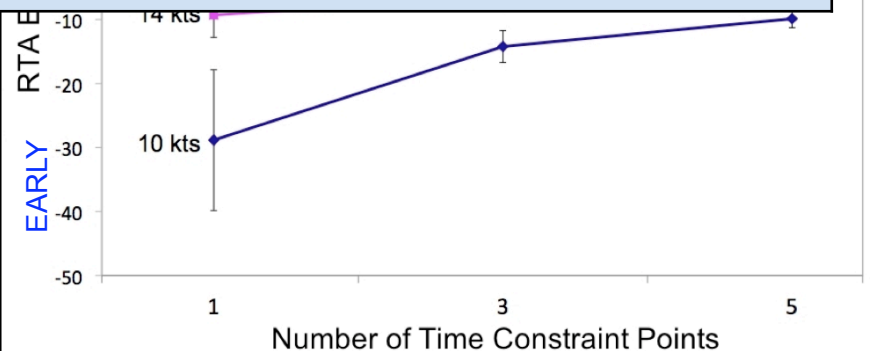
- ATC taxi clearances with speed → poor RTA conformance

ConOps Implications

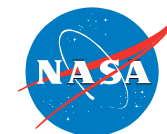
- Defined STM STBO algorithm parameters: Speed, Distance, # Time constraint points
- Intermediate taxi time constraint points useful (meeting RTAs, traffic flow)
- ATC taxi clearances with speed alone may not suffice

Customers:

FAA, avionics/EFB mfg., STM STBO Developers



Experiment 2: Commanded Speed – With Speed Profiles/Conformance Range

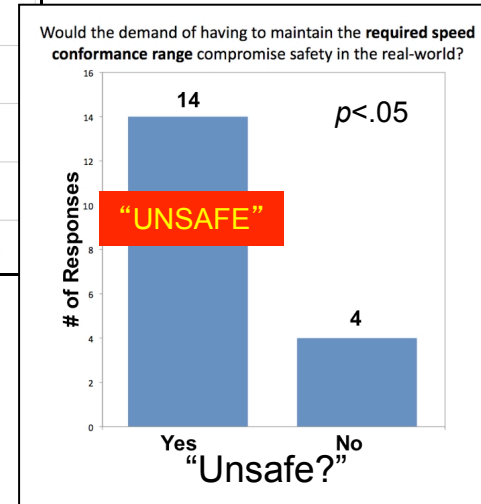
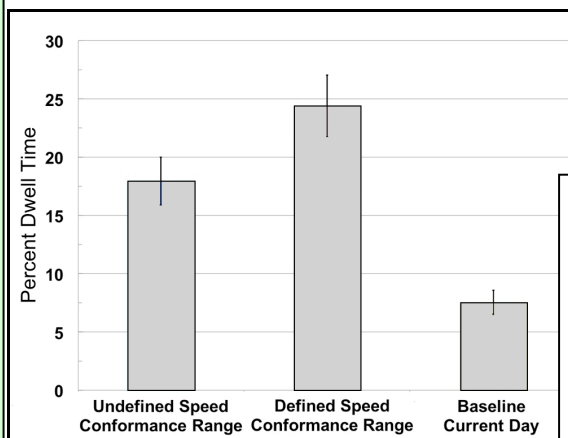
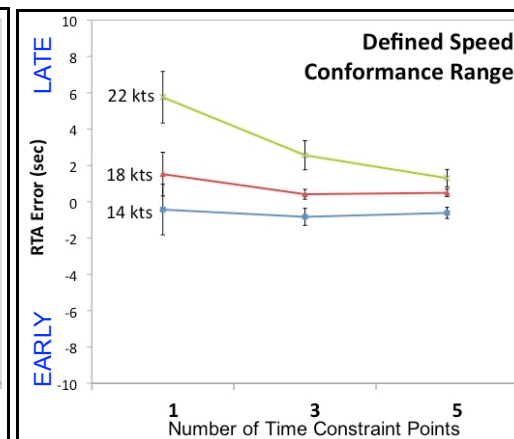
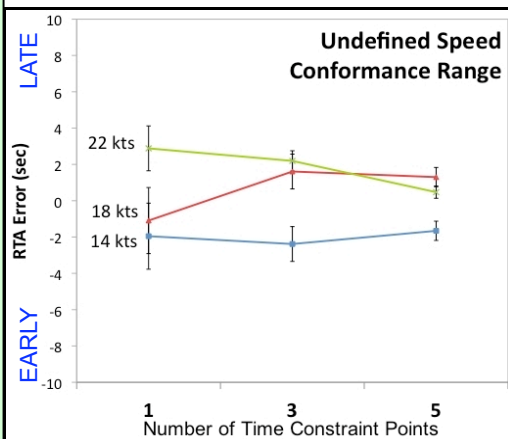


Bakowski, Foyle, Kunkle, Hooley & Jordan, 2011, ISAP

Objective: “Minimum Flight Deck Equipage”
ConOps Evaluation

- 1) ATC provides ‘A/C required speed’ in taxi clearance (either automated or ATC Decision Support Tool)
- 2) Pilots required to follow specific acceleration/ deceleration speed profiles (2 kts/sec accel./ decel.)
- 3) Investigated speed conformance tolerance

- 18 Current/recently retired pilots: 13 CAs; 5 FOs
- STBO Taxi Clearances – manipulated:
 - **Speed:** Taxi clearance included required speed
 - **# Intermediate Time Constraint Points**
 - **Speed Conformance Range:**
Undefined (tested first) / Defined (+/- 1.5 kts);
Current-Day Baseline
- Results
 - Improved RTA error (because of defined aircraft acceleration and speed range requirements
BUT...
 - Visual workload and safety level were **unacceptable**



Experiment 2: Commanded Speed – With Speed Profiles/Conformance Range



Bakowski, Foyle, Kunkle, Hooley & Jordan, 2011, ISAP

Objective: “Minimum Flight Deck Equipage”

ConOps Evaluation

1) ATC provides ‘A/C required speed’ in taxi clearance (either automated or ATC Decision)

Sup

2) Pilots

ATC taxi clearances with speed:

- Poor RTA conformance without speed accel./decel. profiles
- Good RTA conformance with speed accel./decel. profiles, *but*
 - with 2-3x “eyes-in” time
 - viewed as *not safe*

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Current-Day Baseline

▪ Results

- Improved RTA error (because of defined aircraft acceleration and speed range requirements

BUT...

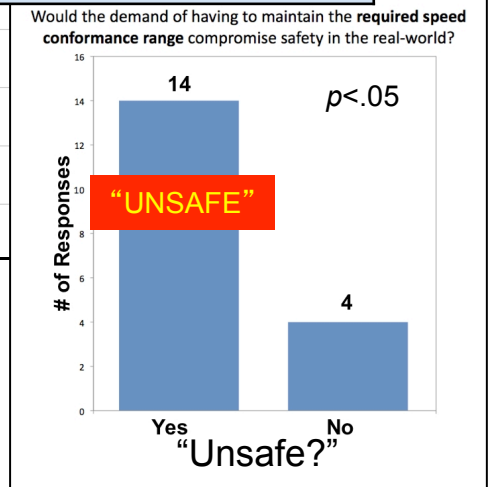
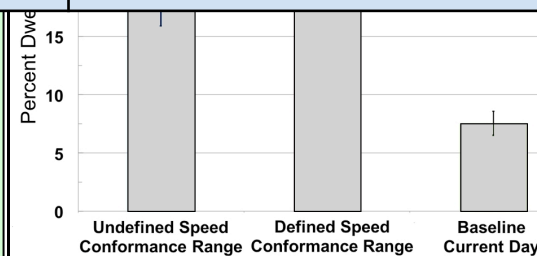
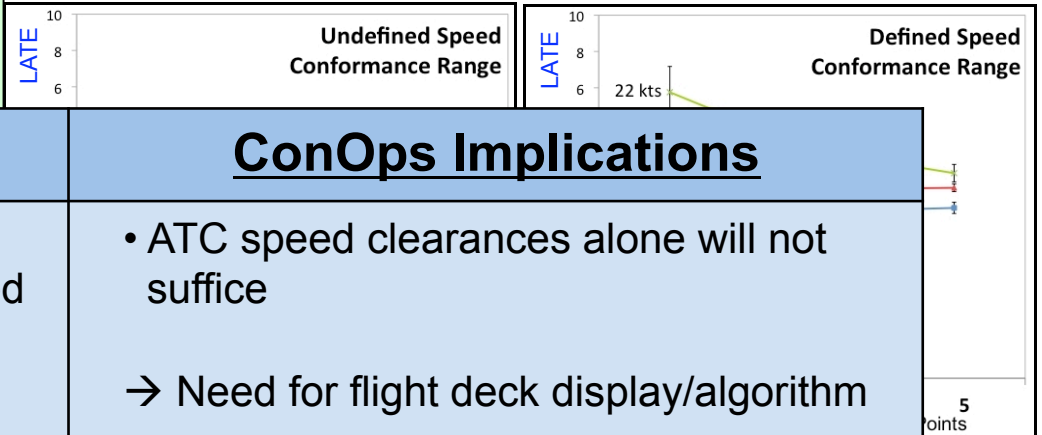
- Visual workload and safety level were ***unacceptable***

Findings

ConOps Implications

- ATC speed clearances alone will not suffice
- Need for flight deck display/algorithm

Customers:
FAA, RTT



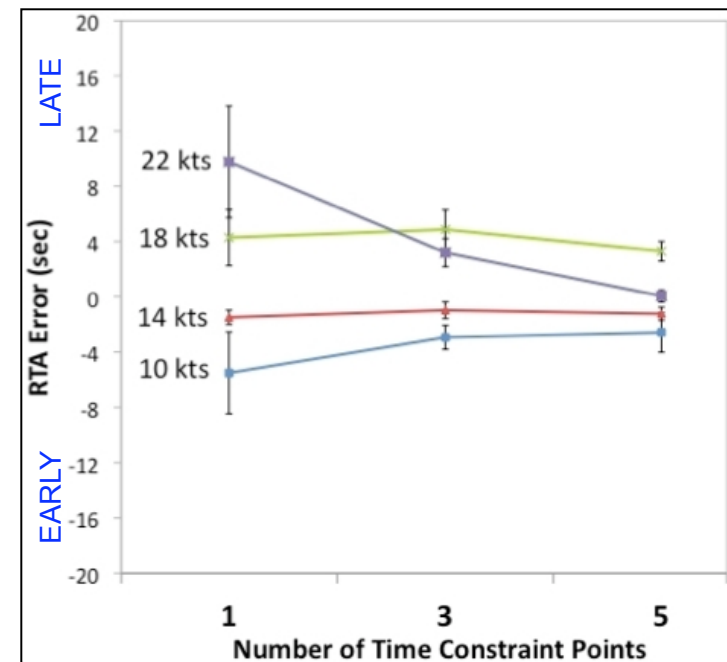
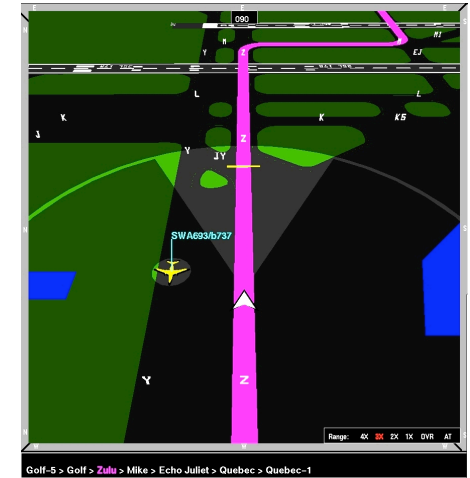
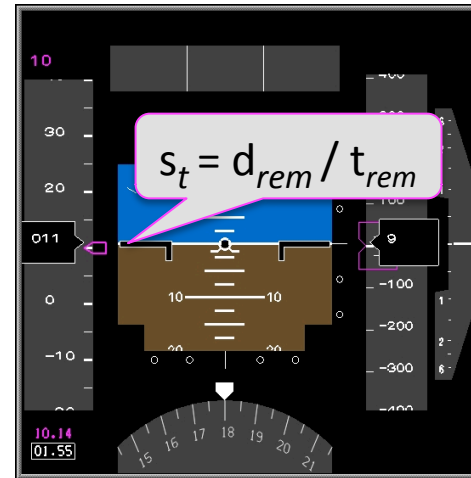
Experiment 3: Error-nulling algorithm/display



Foyle, Hooey, Kunkle, Schwirzke & Bakowski, 2009, ICNS

Objective: “Flight Deck Equipage” ConOps Evaluation

- 1) ATC provides taxi clearance with RTA
- 2) Flight deck equipage (Avionics or EFB, electronic flight bag)
 - 8 Current or recently retired pilots: 7 CAs; 1 FO
 - Displays (PFD; Taxi Nav. Display, TND)
 - **PFD**: RTA time-to-go; Elapsed time;
Algorithm: Speed required to meet RTA
(Enables *strategic* usage)
 - **TND**: Route; Time constraint point
 - STBO Taxi Clearances – manipulated:
 - Speed
 - # Intermediate Time Constraint Points
 - Results
 - Display/algorithm with speed recalculation
→ good RTA conformance



Experiment 3: Error-nulling algorithm/display



Foyle, Hooley, Kunkle, Schwirzke & Bakowski, 2009, ICNS

Objective: "Flight Deck Equipage" ConOps Evaluation

- 1) ATC provides taxi clearance with RTA
- 2) Flight deck equipage (Avionics/EFB)

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Findings

- Flight deck algorithm: Speed recalculation → good RTA conformance

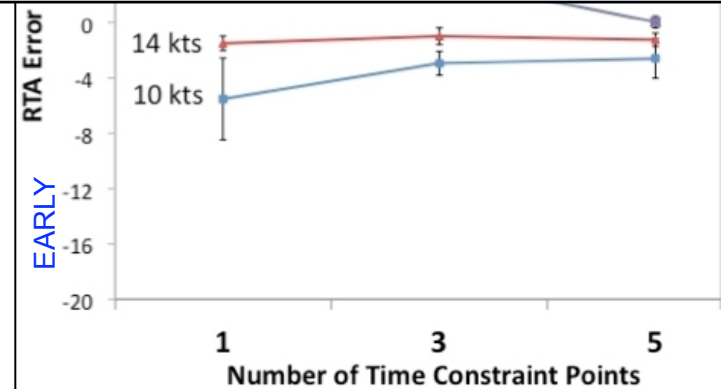
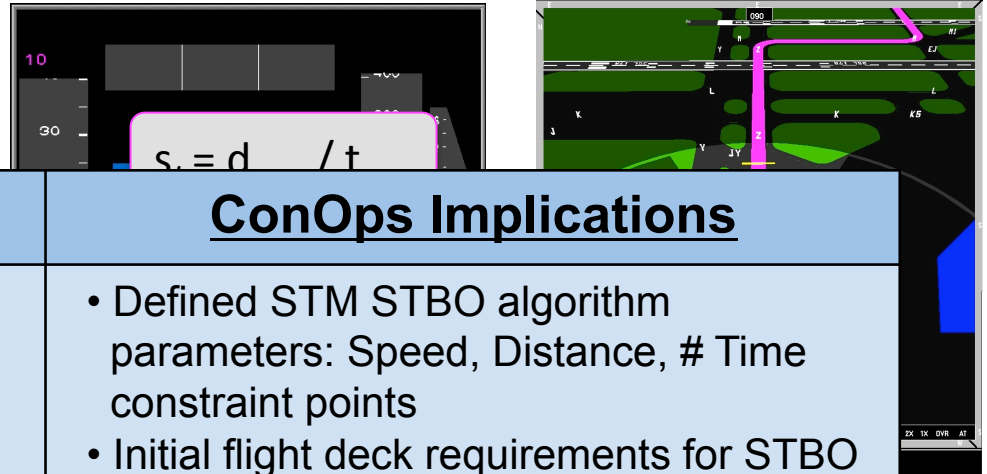
ConOps Implications

- Defined STM STBO algorithm parameters: Speed, Distance, # Time constraint points
- Initial flight deck requirements for STBO ConOps

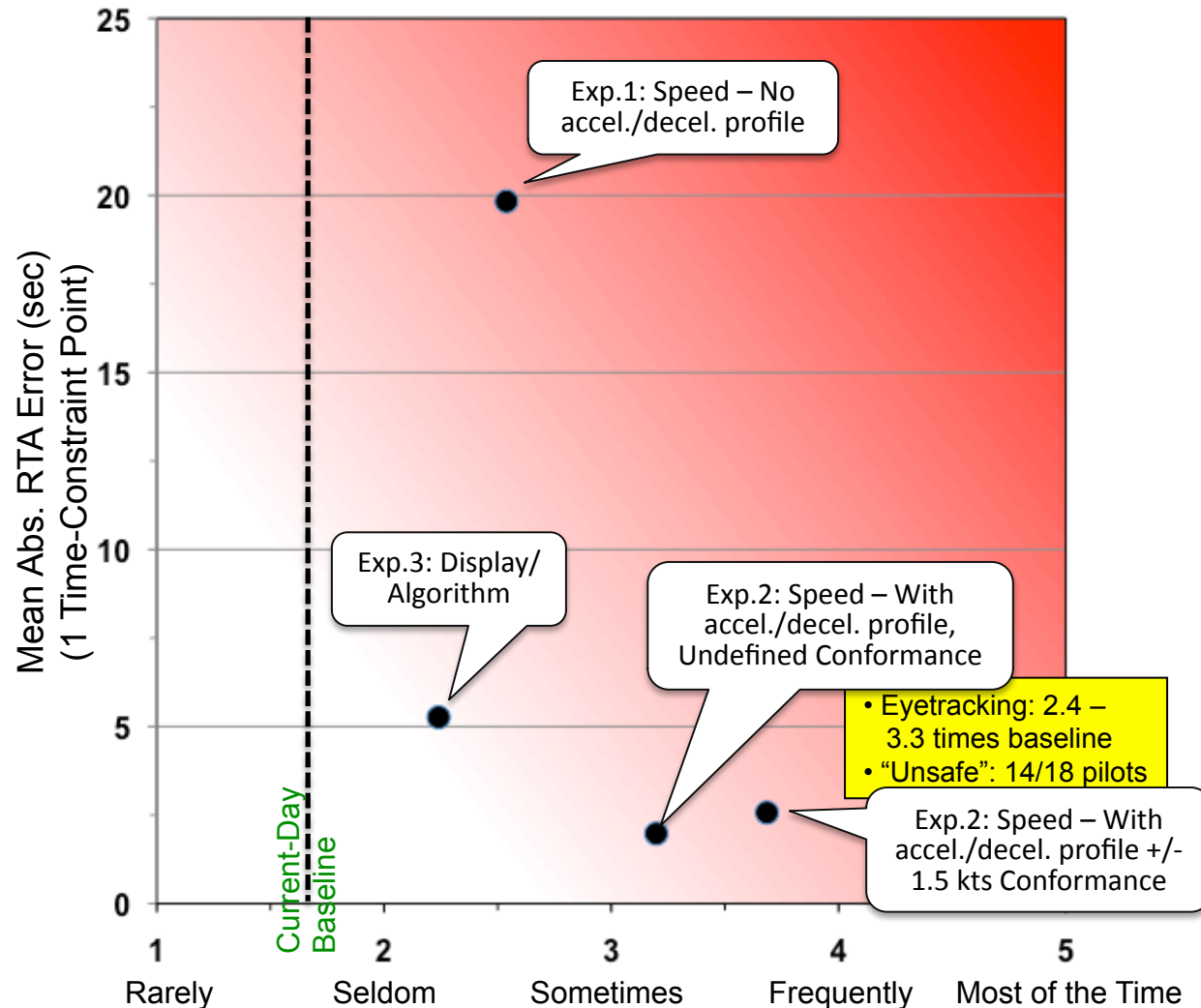
Customers:

FAA, avionics/EFB mfg., STM STBO Developers

→ good RTA conformance



Cross-Studies: Usage/Safety Implications



“How often did you find yourself **focusing on the PFD Speed or Time** display, when you **should have been paying attention to the external taxiway environment?**”

Summary / Overall ConOps Implications



Summary Findings	ConOps Implications
<ul style="list-style-type: none"> • STBO clearances with speed are not viable solution • Taxiing Captain cannot “tightly control/ track” speed, navigate, and maintain separation • Only flight deck algorithm/display condition → Good RTA conformance AND appropriate visual workload / safety <p><i>Caveat:</i> Flight deck algorithm/display -- Needs to allow “strategic operation”, not “tight control/tracking”</p>	<ul style="list-style-type: none"> • Requirement for <i>human-centered*</i> flight deck display/algorithm for STBO <p><u>Customers:</u> FAA, avionics/EFB mfg., STM STBO Developers</p> <div style="border: 1px solid black; padding: 5px;"> <p><i>*Human-centered designed systems (Foyle, 2009):</i></p> <ul style="list-style-type: none"> - Are intuitive and “natural” - Have readily accessible information - Support human capabilities (e.g., perceptual processing) - Mitigate human limitations (e.g., memory) - Have features supported by “human factors design principles trace” - Enable appropriate task usage strategies </div>

Next Steps:

- STBO human-centered flight deck displays
- Operational issues: Datalink coordination between STM system and flight deck
 - Integration with SARDA (Spot and Runway Departure Advisor)



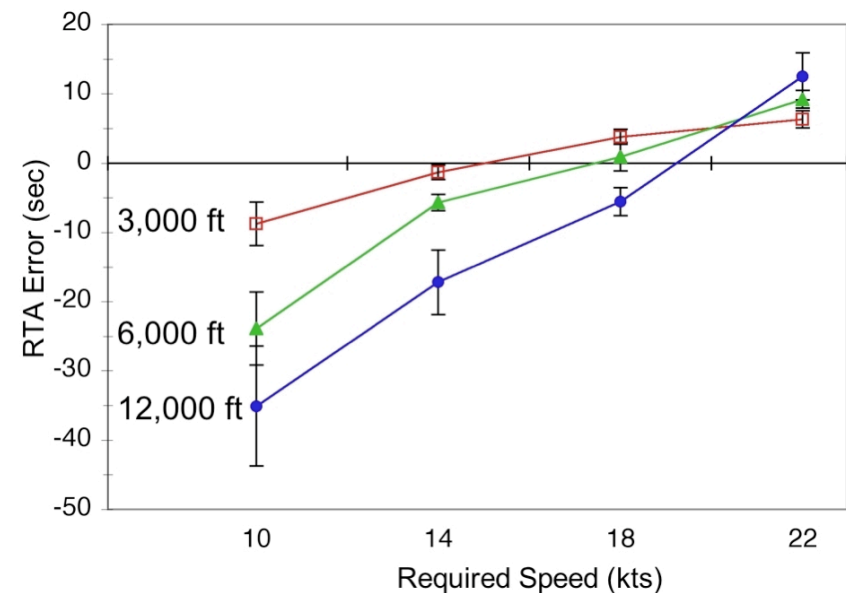
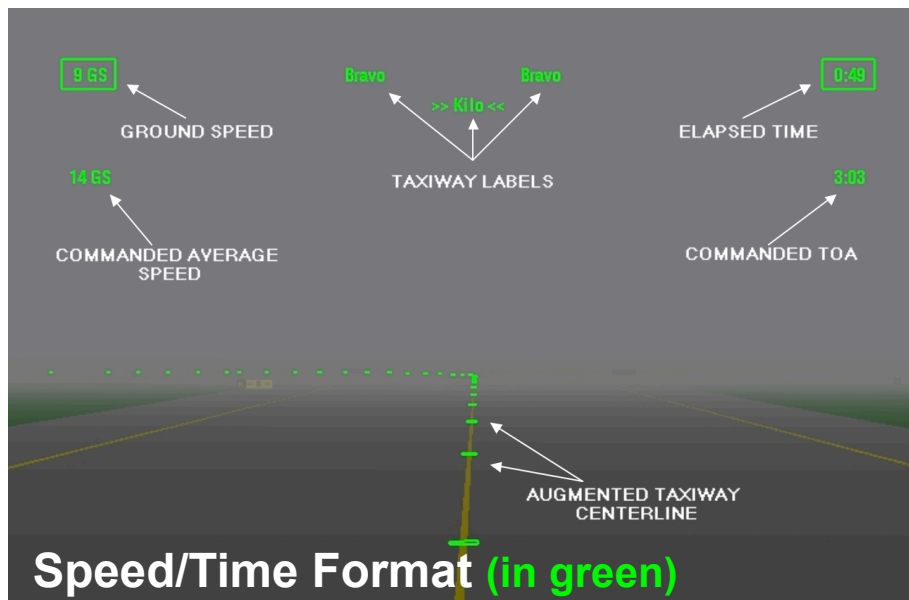
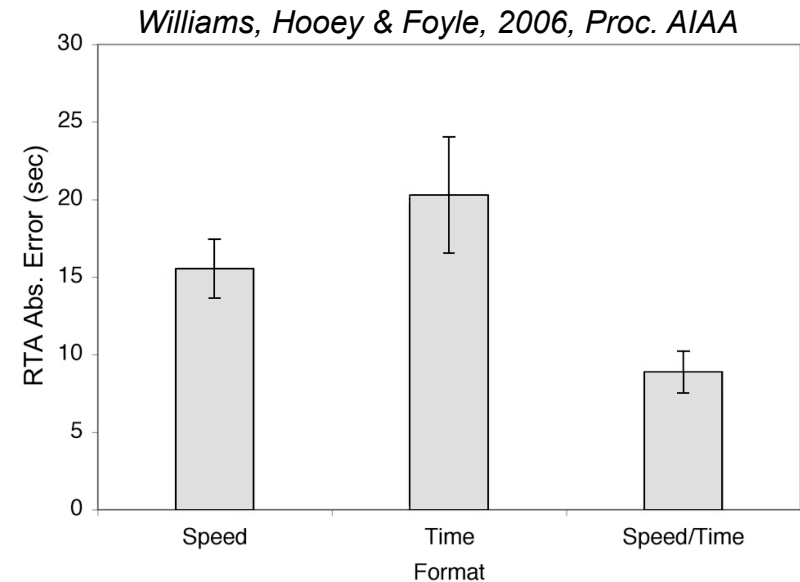
Backup Slides

Preliminary Experiment: Pilot information requirements for STBO taxi clearances



Objective: Initial Baseline 4-D Taxi Navigation Study

- 18 Current Captains
- Minimal display information (baseline study)
- STBO Taxi Clearance Formats
 - **Speed**: Commanded average route speed + Current speed
 - **Time**: Commanded time to RWY + Elapsed time
 - **Both**: All
- Results
 - Less RTA error with Both Time and Speed clearances
 - More RTA error with longer routes
 - Slower speeds → early arrival; Faster speeds → late arrival
 - Eyetracking usage - speed used early in route, then switch to using time information



Preliminary Experiment: Pilot information requirements for STBO taxi clearances



Objective: Initial Baseline 4-D Taxi Navigation Study

- 18 Current Captains
- Minimal display information (baseline study)
- STBO Taxi Clearance Formats
 - **Speed:** Commanded average route speed + Current speed
 - **Time:** Commanded time to RWY + Elapsed time
 - **Both**

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Findings

To accurately meet RTAs:

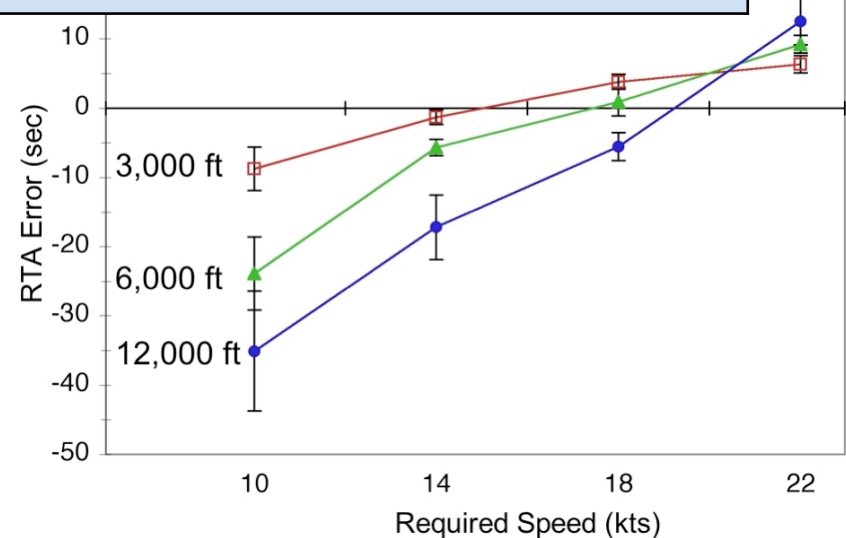
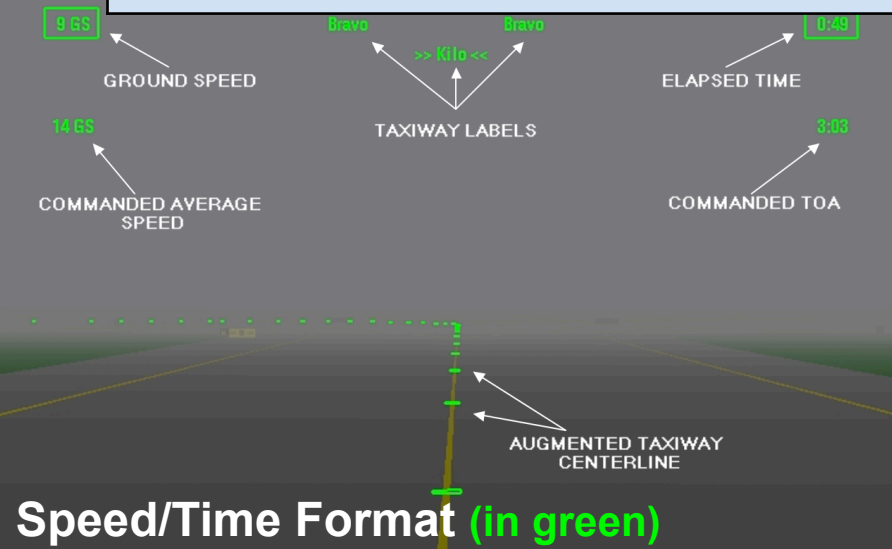
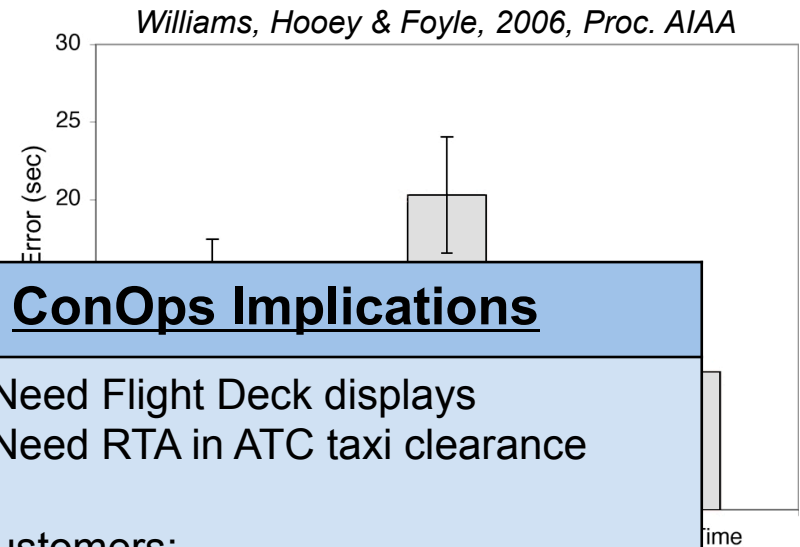
- Need both Speed (A/C control) and Time (RTA) information

ConOps Implications

- Need Flight Deck displays
- Need RTA in ATC taxi clearance

Customers:

FAA, avionics/EFB mfg.



Cross-Studies: Usage/Safety Implications



“How often did you find yourself *focusing on the PFD Speed or Time* display, when you *should have been paying attention to the external taxiway environment?*”

