Time, Speed, Spacing Methods for Flow Management

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Outline

- Background
- Simulation
- Experiment
- Sample video
- Sample results

Time, Speed, Spacing

- Time, Speed, Spacing encompasses methods for executing Time-Based Management
- Time-Based Management is a major component of NextGen

	Clock Time	Relative Spacing
Ground-calculated Speed	Ground Interval Management – Spacing & Terminal Sequencing and Spacing	Automated Terminal Proximity Alert
Flight Deck-calculated Speed	Time of Arrival Control	Advanced Interval Management

Clock Time

- Clock Time – deliver aircraft to a fixed point at a fixed time based on a schedule

- Ground Interval Management – Spacing (GIM-S)
  - Cruise and descent speeds
  - Controller relays to flight crew for implementation
- Terminal Sequencing and Spacing (TSAS)
  - Terminal area metering
  - Controller relays to flight crew for implementation

- Time of Arrival Control (TOAC)
  - Also known as Required Time of Arrival (RTA)
  - Flight Management System adjusts speed
  - Controller instructs flight crew to cross a point at the given time
  - Limited human interaction

Relative Spacing

- Relative Spacing– deliver aircraft to a fixed time at a time relative to leading aircraft

- Automated Terminal Proximity Alert (ATPA)
  - Provides controllers with visual information for relative spacing
  - No speed guidance is provided
- Europe is investigating a GIM-S-like tool based on relative spacing

- (Advanced) Interval Management (A-IM)
  - For this work there is no material difference between Interval Management and Advanced Interval Management
  - Flight Deck Automation provides speeds to achieve or maintain spacing relative to another aircraft
  - Controller instructs flight crew to cross a point with a given spacing relative to a target aircraft
  - Only one communication from controller to flight crew needed

Simulation Environment

- Airspace and Traffic Operations Simulation (ATOS)
  - Simulation Manager (Sim-Man)
    - Controls the operation of each simulation component – launch, time-sync, termination
    - Issues CPDLC messages scripted in the scenario
  - TBO-TIGAR
    - Gathers and displays state data from all aircraft in the simulation
    - Issues conditional CPDLC messages (i.e., sequencing a waypoint)
  - Aircraft Simulation for Traffic Operations Research (ASTOR)
    - Simulation of individual aircraft
    - Contains performance model, pilot model, CPDLC, FMS, cockpit displays

ASTOR

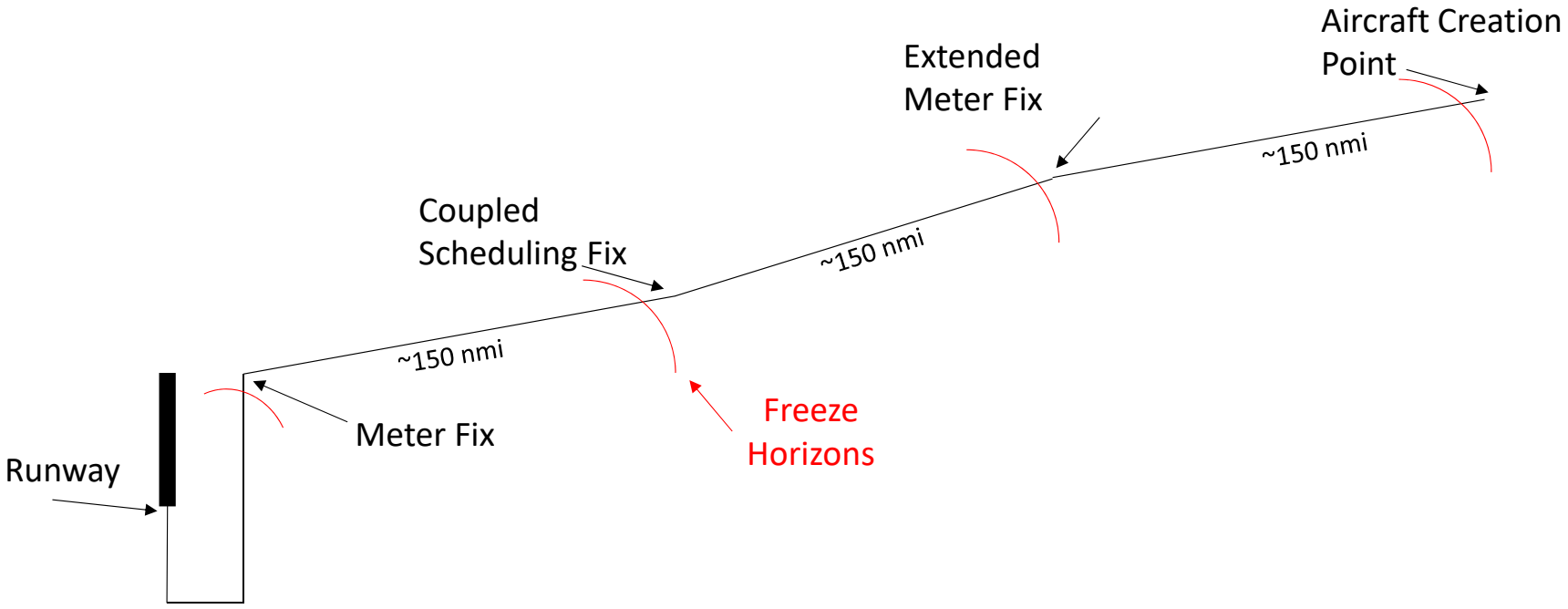

EFIS Control Panel (EFISCP)
Mode Control Panel (MCP)
Multi-Function CDU (MCDU)
EICAS & Multi-Function Display (MFD)
Display Select Panel (DSP)
Primary Flight Display (PFD)
Navigation Display (ND)
Radio Tuning Panel (RTP)
Transponder Control Panel (XCP)
Throttle Control Stand Panel
Simulation Status Panel

Experiment Design

- Purpose for study
  - Investigate the interactions between multiple speed control methods
  - Compare different NASA LaRC Air Traffic Operations Laboratory (ATOL) batch experiment platforms

- Control Methods
  - Ground-based Interval Management – Spacing Speed Advisories (GIM-S)
  - Time Of Arrival Control (TOAC)
  - Advanced – Interval Management (A-IM)

Schematic of Control Points



Experiment Control Method Combinations

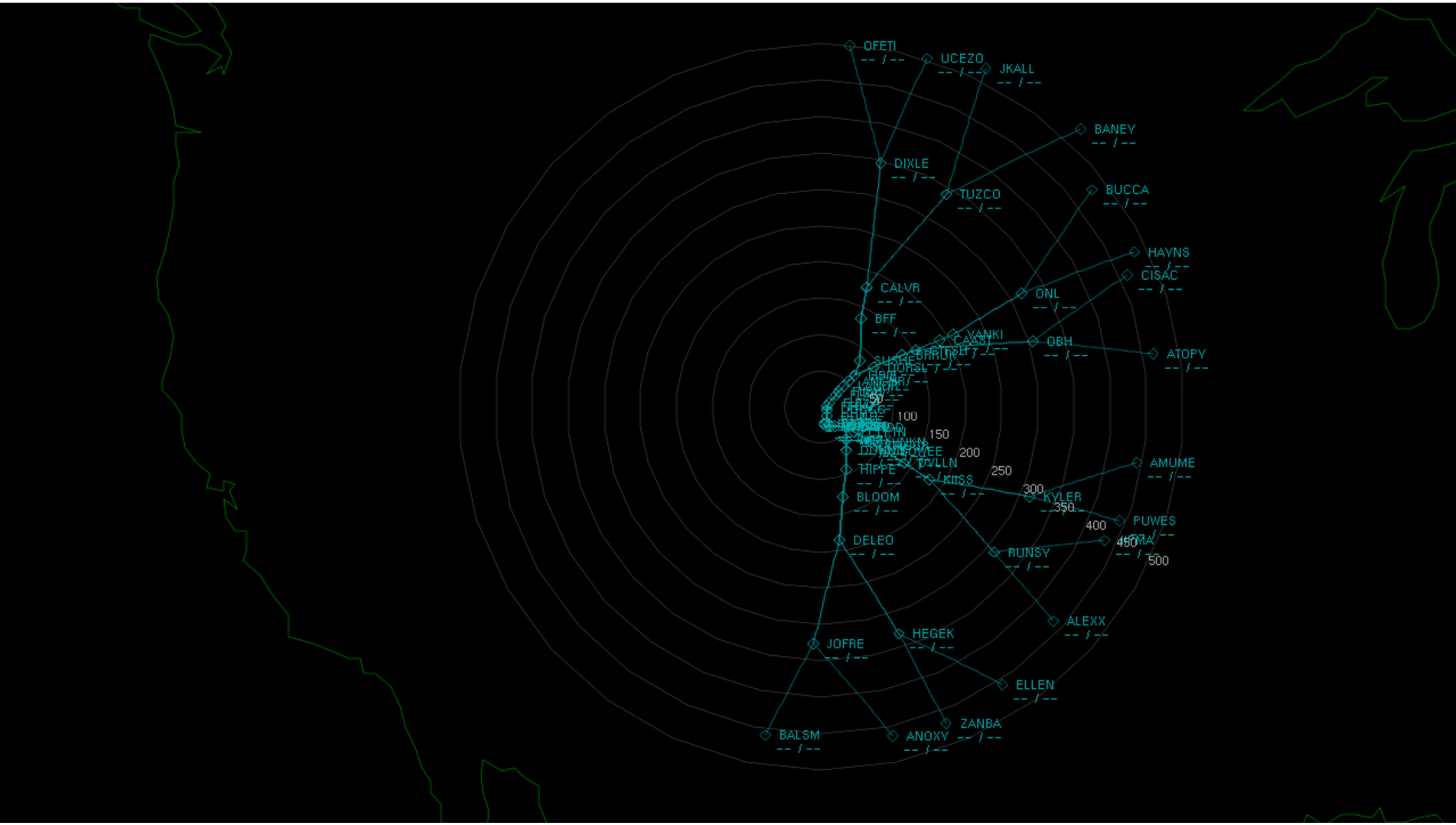
Flight segment Control method(point)	Creation to Extended Metering	Extended Metering to Coupled Scheduling	Coupled Scheduling to Metering	Metering to Runway
	GIM-S (EM)	GIM-S (CS)	GIM-S (M)	A-IM (R)
	GIM-S (EM)	GIM-S (CS)	A-IM (M)	A-IM (R)
	GIM-S (EM)	TOAC (CS)	A-IM (M)	A-IM (R)
	TOAC (EM)	TOAC (CS)	TOAC (M)	A-IM (R)
	GIM-S (EM)	TOAC (CS)	TOAC (M)	A-IM (R)
	GIM-S (EM)	A-IM (CS)	A-IM (M)	A-IM (R)
	A-IM (EM)	A-IM (CS)	A-IM (M)	A-IM (R)

Experiment Independent Variables

- Control methods (7)
- Traffic data (2 schedules)
  - Arrival schedule (120 second intervals)
  - Route assignment (random assignment to one of 16)
  - Aircraft types (737, 757, 777)
  - Initial Flight Level (300, 320, 340)
  - Initial speeds (three speeds/aircraft type)
- Initial time error (none, error1)
- Wind forecast error (none, error1)

Design of scenarios

- Using Denver International Airport (KDEN)
- Using North arrival runway (Runway 35R)
  - 2 Meter Fixes
  - 4 Coupled Scheduling Fixes
  - 8 Extended Meter Fixes
  - 16 aircraft creation points
- 110 aircraft in the arrival flow
- 120 second nominal arrival interval between aircraft
- ~ 5.5 hour duration per scenario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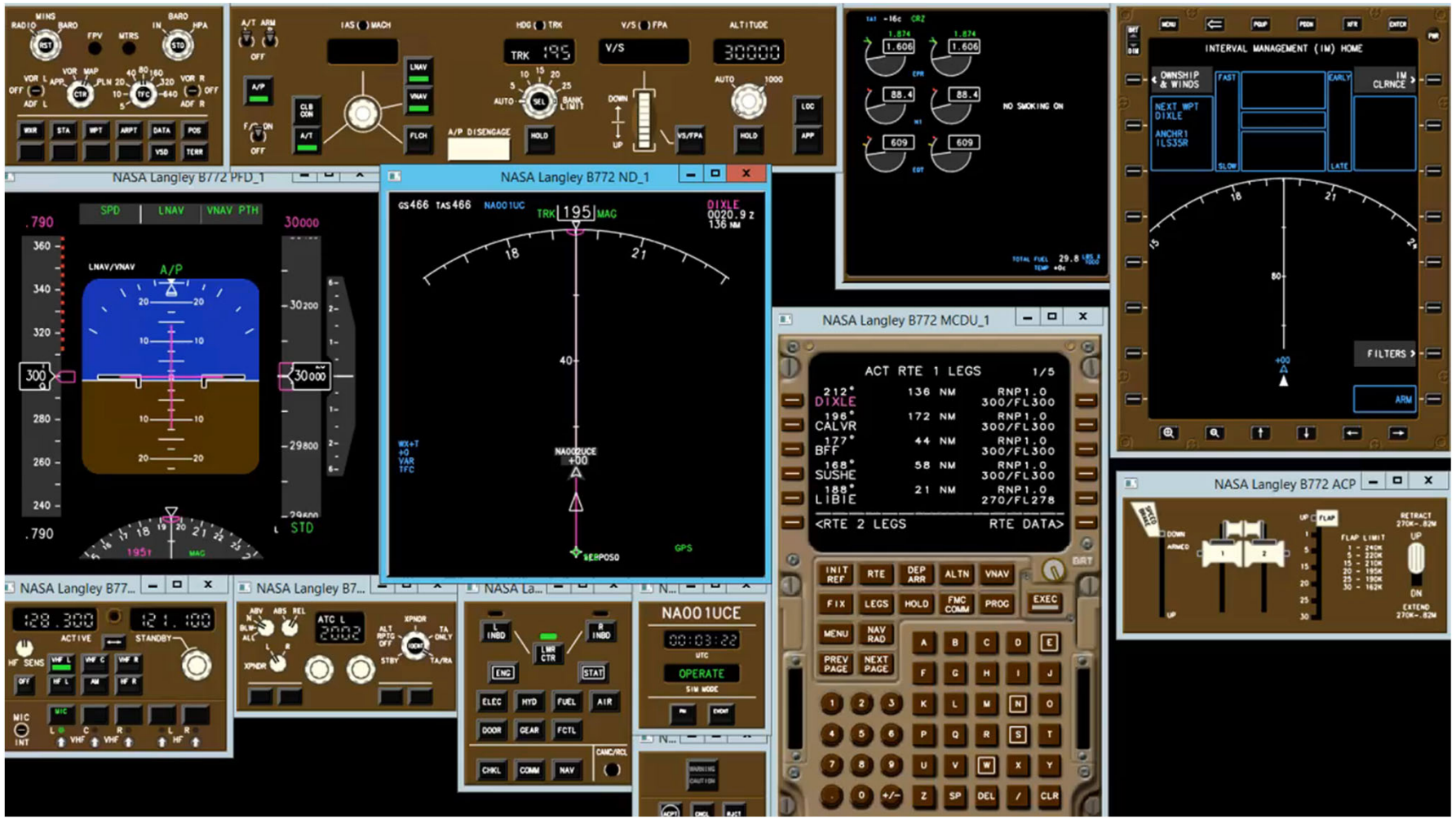
ASTOR simulation



Experiment Dependent Variables

- Inter-aircraft spacing error at control points
- Schedule conformance at control points
- Number of speed commands
- Number of procedural speed commands
- Number of speed increases
- Percent of fuel burn normalized by baseline fuel burn
- Number of potential resequencing events
- Spoiler deployment
- RMS of command CAS and Profile CAS
- RMS of command CAS and actual CAS

Preliminary results: schedule conformance

		Control Method		
		GIM-S	RTA	A-IM
Control Point	Extended Metering	Mean=22.39 SD=13.28 N=218	Mean=-0.04 SD=.93 N=109	N/A
	Coupled Scheduling	Mean=30.59 SD=9.44 N=198	Mean=-.44 SD=1.01 N=109	Mean=53.81 SD=15.70 N=20
	Metering	Mean=31.50 SD=13.02 N=174	Mean=7.52 SD=6.50 N=109	Mean=44.33 SD=20.15 N=44
	Runway	N/A	N/A	Mean=24.73 SD=17.97 N=327+
		Mean=27.83*	Mean=2.35*	Mean=28.43*

* Mean spacing error across all flight segments using respective control method.
+ 3 scenarios, each with 109 aircraft crossing each control point.

Preliminary results: Inter-aircraft spacing

		Control Method		
		GIM-S	RTA	A-IM
Control Point	Extended Metering	Mean=.28 SD=16.43 N=204	Mean=-0.03 SD=1.01 N=102	N/A
	Coupled Scheduling	Mean=-2.52 SD=14.29 N=192	Mean=0.01 SD=1.44 N=106	Mean=23.24 SD=16.06 N=20
	Metering	Mean=-2.99 SD=18.46 N=172	Mean=-0.00 SD=5.08 N=108	Mean=9.53 SD=20.02 N=44
	Runway	N/A	N/A	Mean=-0.13 SD=20.04 N=327+
		Mean=-1.66*	Mean=-0.01*	Mean=2.15*

* Mean spacing error across all flight segments using respective control method.
+ 3 scenarios, each with 109 aircraft crossing each control point.