



Cognitive Workload and Visual Attention Analyses of the Air Traffic Control Tower Flight Data Manager (TFDM) Prototype Demonstration*

Kiran Lokhande & Hayley J. Davison Reynolds

MIT Lincoln Laboratory

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MIT Lincoln Laboratory



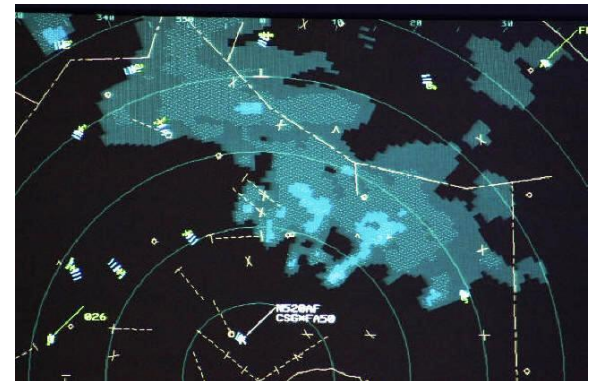
Motivation

- **Multiple display technologies currently used at major US airports:**
 - Paper flight strips
 - ASDE-X (Airport Surface Detection Equipment, Model X)
 - RACD (Remote Arts Control Display)
 - IDS (Integrated Display System)
 - etc.

- **Desired from NextGen ATC tower:**
 - System integration
 - Increased efficiency
 - Decision support tools
 - Automation
 - Safety & cost reduction



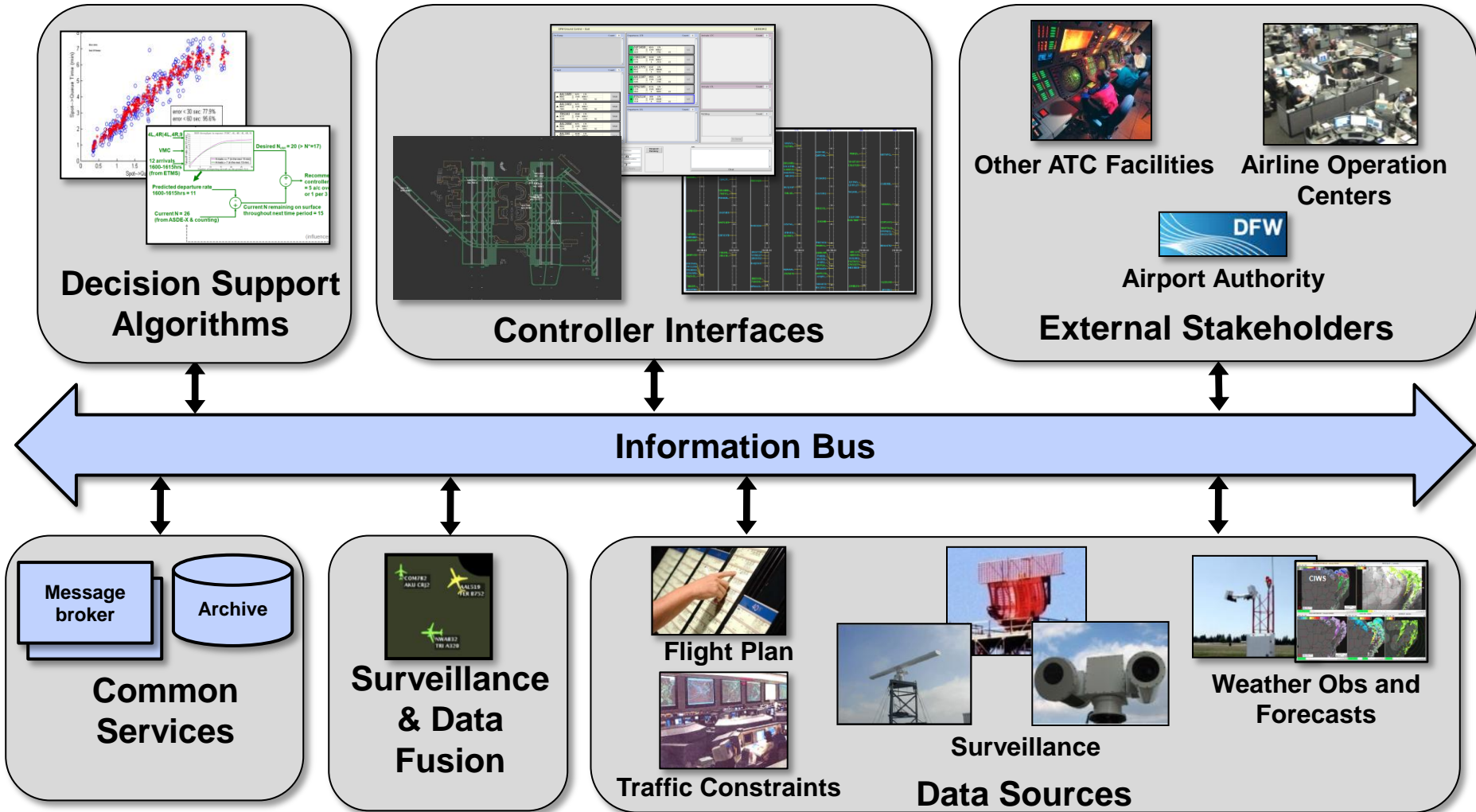
ASDE-X Display



RACD Display

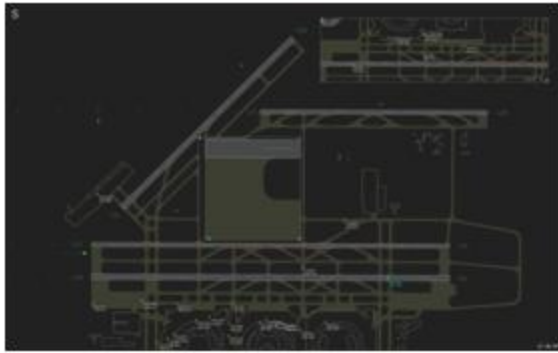


Tower Flight Data Manager Prototype



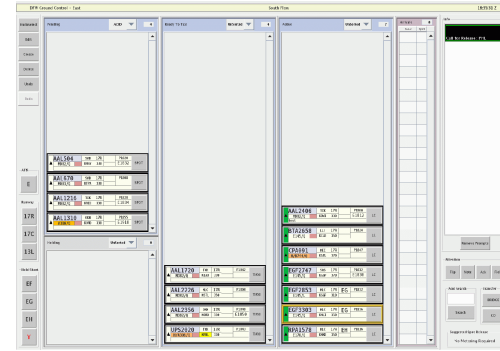


Tower Flight Data Management (TFDM) Human Machine Interfaces



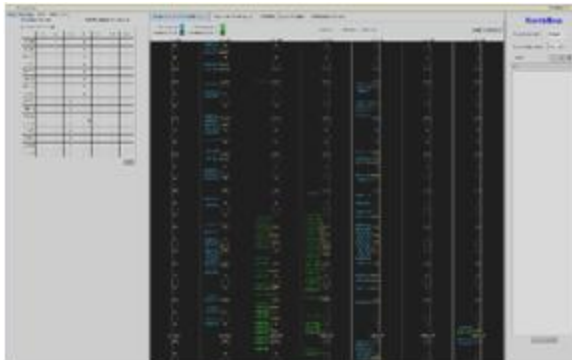
Tower Information Display System (TIDS)

Ground and air surveillance data



Flight Data Manager (FDM)

Electronic processing and distribution of flight data



Supervisor (SUP) Display

Flight sequencing and scheduling support

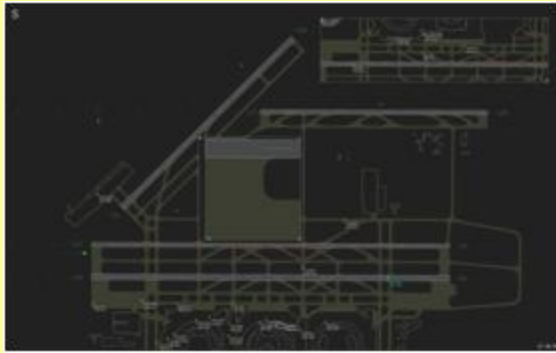


Scanning COHU Camera

Fixed and tracking camera views for surveillance

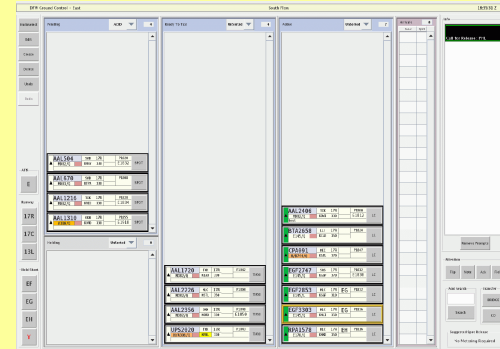


Tower Flight Data Management (TFDM) Human Machine Interfaces Analyzed in Study



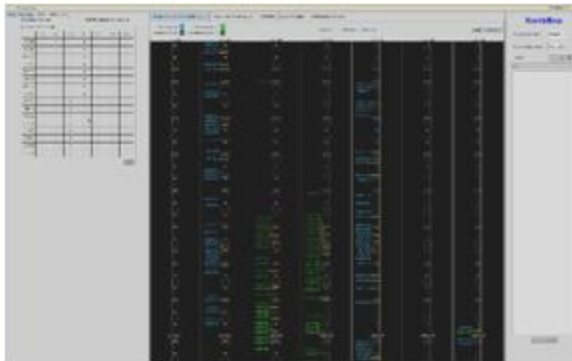
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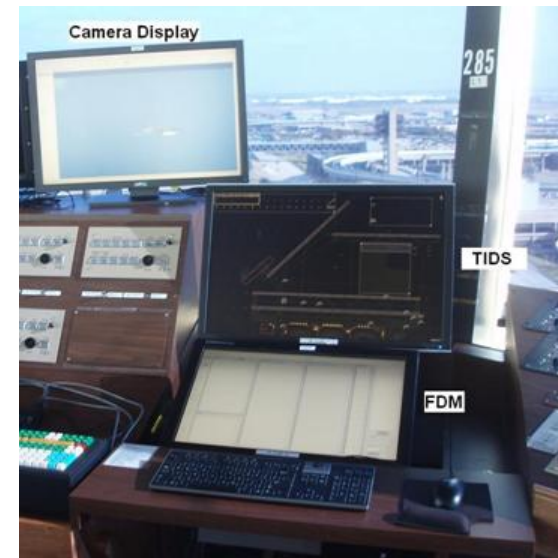
TFDM Testing at Dallas-Fort Worth (DFW)

- **DFW-1: 8/24-9/3 in 2010, focus was on surveillance validation and initial user feedback on interfaces**
- **DFW-2: 4/26-5/5 in 2011, focus on incorporation of decision support tools and camera usage**



Center tower and East tower locations at DFW

- **Participants:**
 - Each day 2 controllers switched off between Ground Control (GC) and Local Control (LC) positions
 - Total: 12 ground, 12 local
- **Shadow operation of East Tower**
- **Data collected:**
 - Human performance data (audio, video)
 - Questionnaires (*not reported here*)
 - Technical performance data (*not reported here*)



TFDM system at DFW airport



Human Performance Data

- **Video/audio of participants and East Tower Controllers (ETC) was compiled into one seamless video playback system**

Measurements

- **Verbal Command Analysis**
 - **Verbal control commands**
Participant vs. ETC (control group)
 - **Gap time & response rate**
Causes of longest gap times
- **Visual Dwell Analysis**
 - **Manual gaze evaluation**
 - **Individual dwell time & total dwell time**
Causes of longest dwells

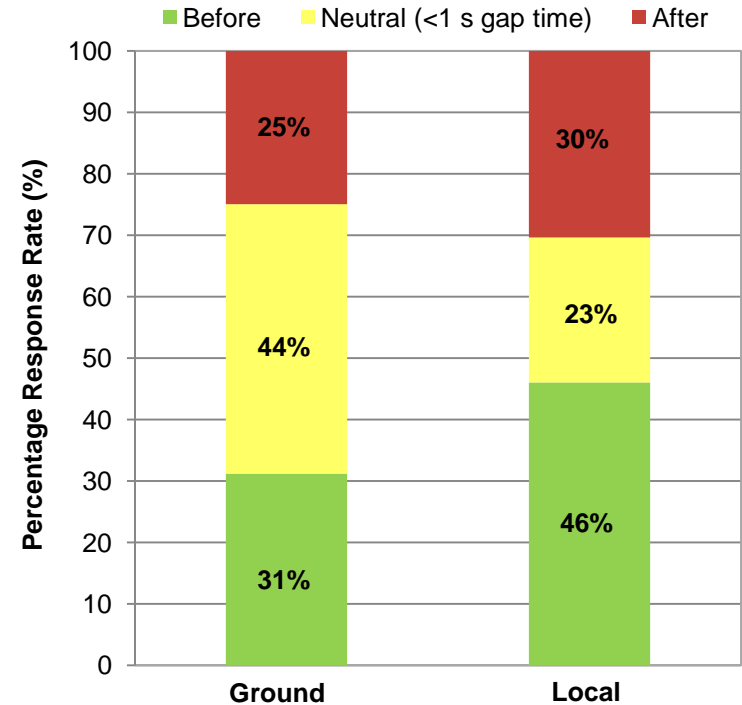


Video playback system for data analysis



Verbal Command Analysis Results

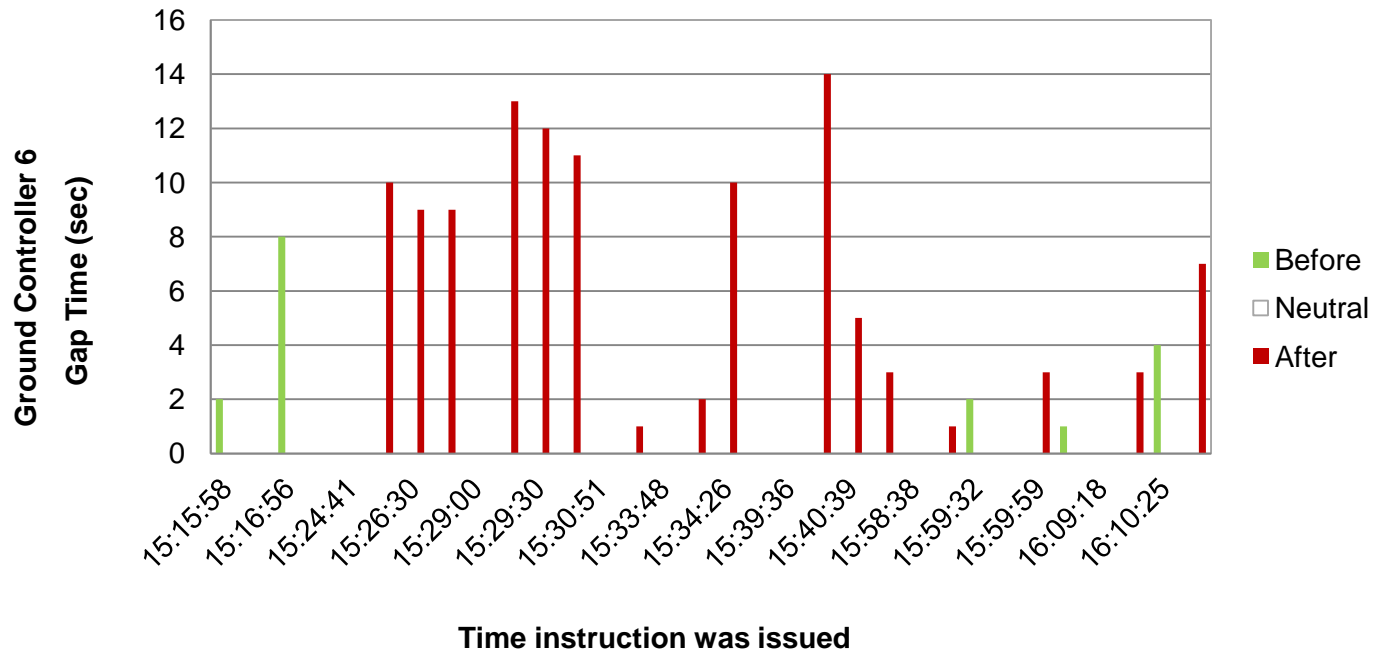
- **Appx. 72% of the time, GC and LC issued instructions before or within one second (neutral to) ETCs**
- **LC issued commands first more frequently than GC, $t(9) = 3.30$, $p < 0.01$**
- **Discarded from analyses:**
 - Interacting with an observer
 - Incongruous operational strategy (2% of GC cases, 10% of LC cases)
- **When issuing commands after ETC, participant controllers appeared to be distracted by operating the TFDM display**





Gap Time Charts

- Gap time plots created to investigate causes of high gap times for purposes of prototype design improvement

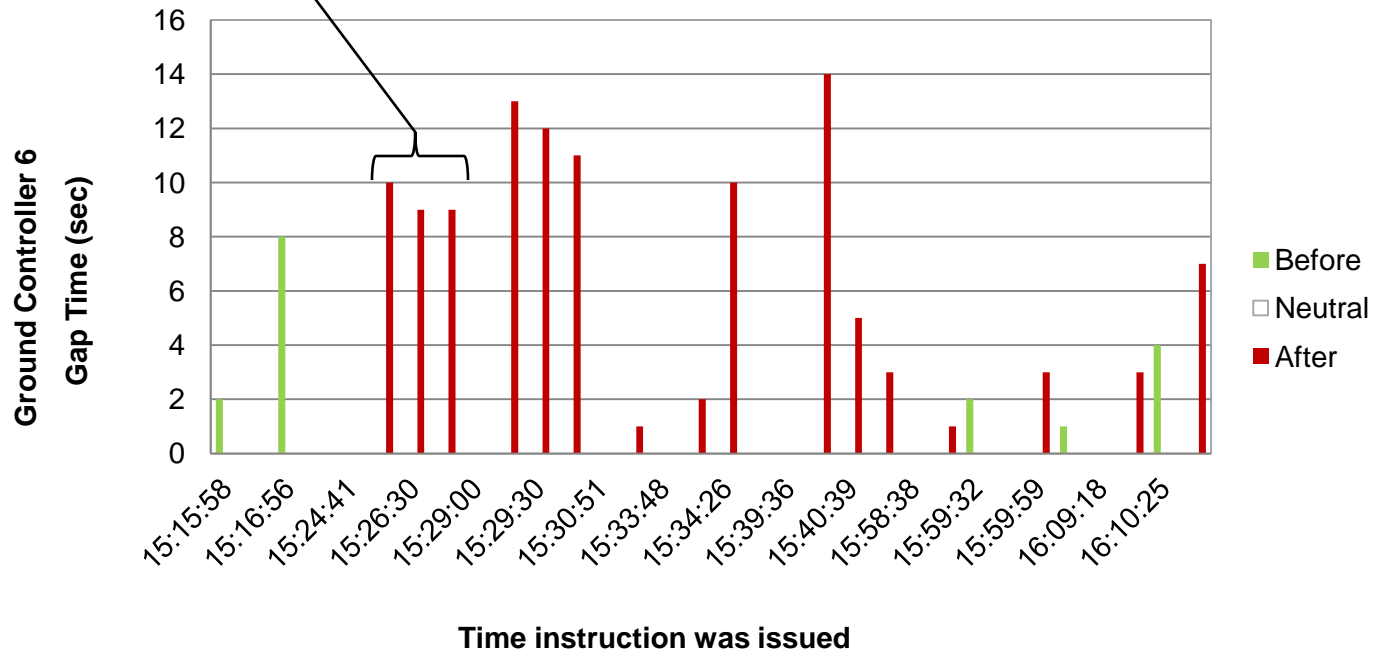




Gap Time Charts

- Gap time plots created to investigate causes of high gap times for purposes of prototype design improvement

Highlighting & editing flight strip on FDM



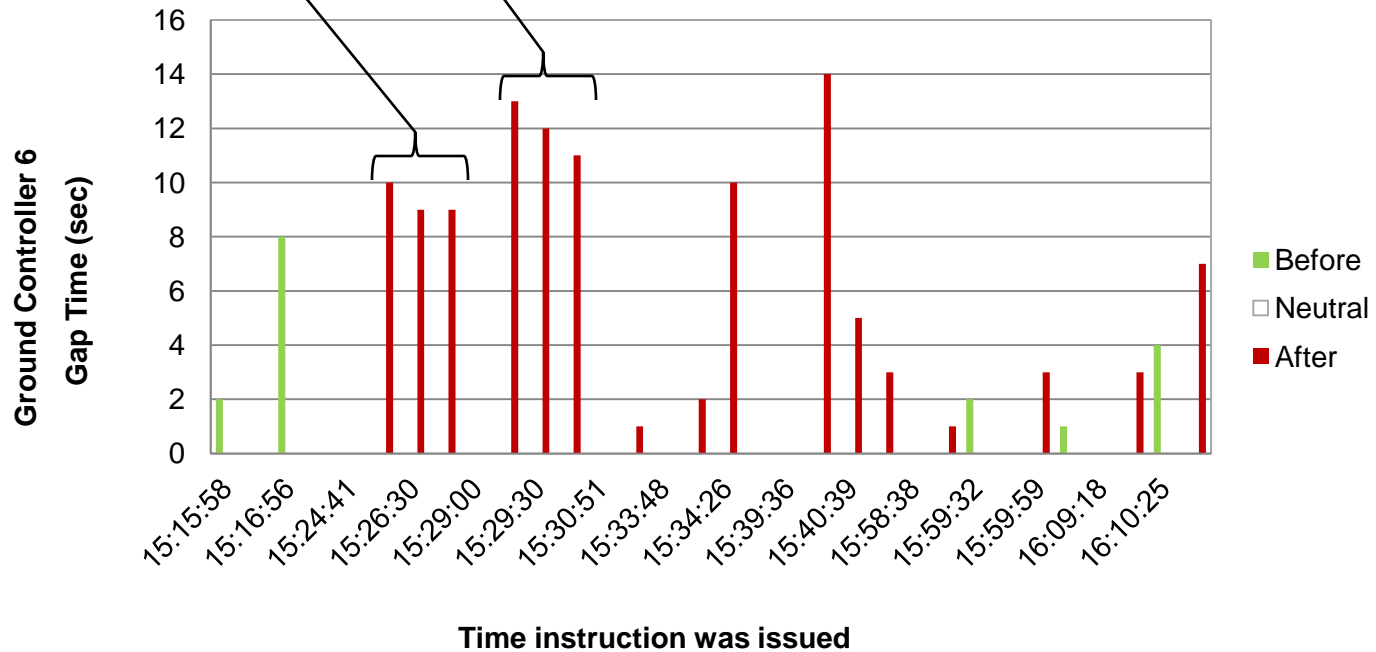


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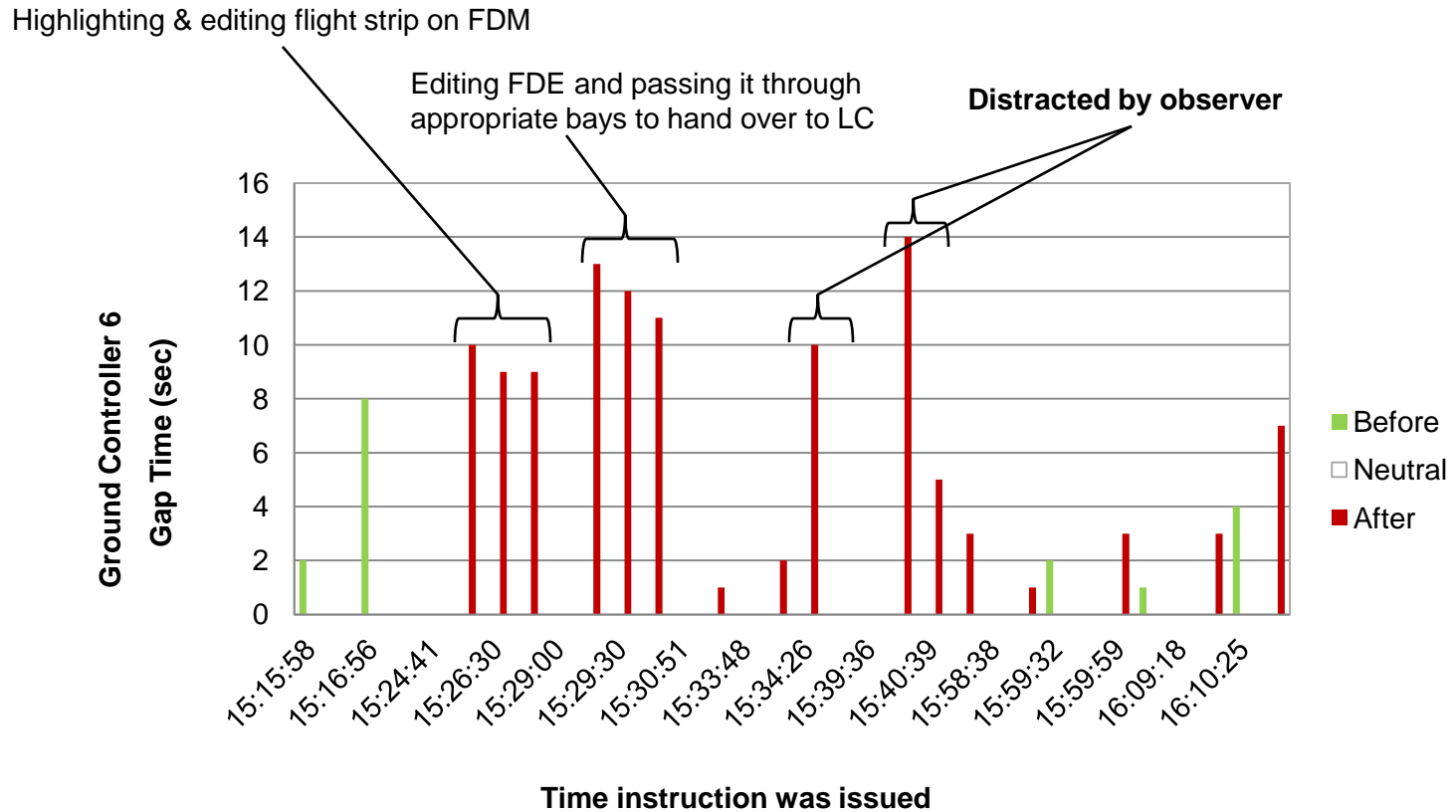
Editing FDE and passing it through appropriate bays to hand over to LC

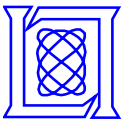




Gap Time Charts

- Gap time plots created to investigate causes of high gap times for purposes of prototype design improvement





Design Implications of Verbal Command Analysis

- **Specific issues found:**
 - **FDM field highlighting feature / FDM text changes**
 - **Confusion when transferring electronic flight strips to different controllers**
 - **ATIS code change**

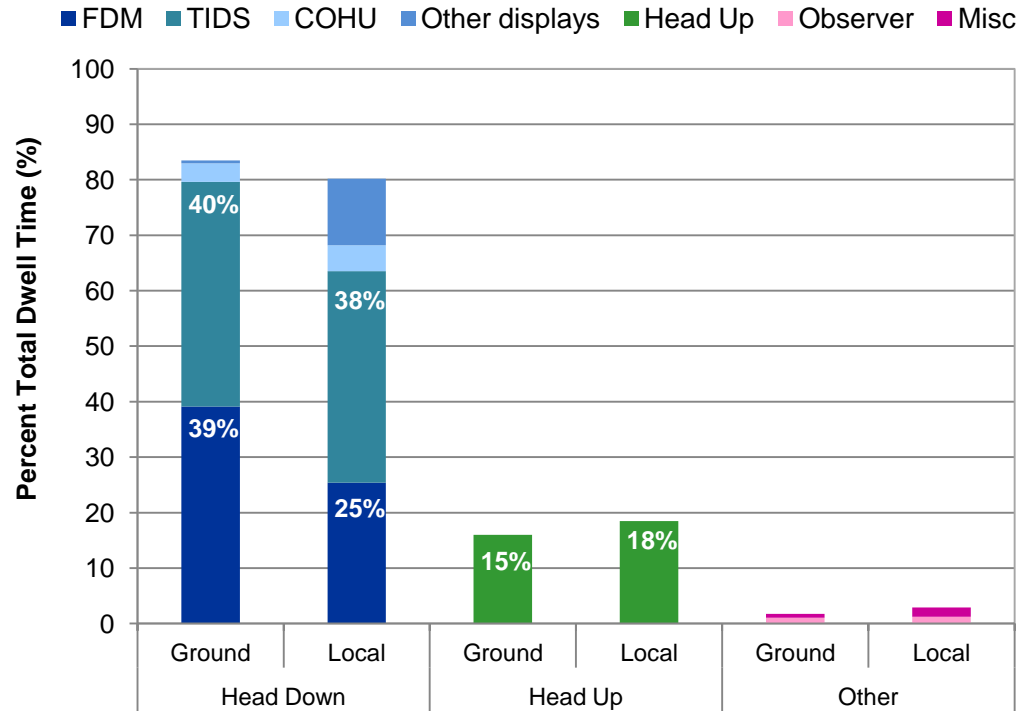
	Ground Control (# of instances)	Local Control (# of instances)
Issued command after hearing ETC	7	12
Interacting with flight strip: Moving flight strip	7	2
Interacting with flight strip: Editing flight strip	4	1
Looking for flight strip	10	2
Using Search to find flight strip	2	0
Looked at RACD	0	3
FDE not sent in time by GC	N/A	3
Tracking flight on TIDS	1	2
TOTAL (all gap times over 3 sec)	54	37

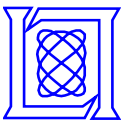


Visual Dwell Analysis Results

Percent Total Dwell Time

- More time spent head-down ($M = 81.9$, $SD = 12.8$) than head-up ($M = 17.2$, $SD = 12.4$), $t(43) = 17.12$, $p < .001$
- More time looking head-up out the window over “Other” dwell areas ($M = 2.3$, $SD = 1.9$), $t(43) = -7.87$, $p < .001$





Design Implications of Visual Dwell Analysis

FDM



- **Ground Control**
 - Forgetting to update FDE
 - Searching for flight strip
 - Editing flight strip
- **Local Control**
 - Confusion over flight strip not sent over to local control

TIDS



- **Viewing/Monitoring**
- **Using Picture in Picture camera view inside TIDS**

	# of dwells over 15 sec		% of dwells over 15 sec	
	Ground (#)	Local (#)	Ground (%)	Local (%)
FDM	104	28	52	26.2
TIDS	81	56	40.5	52.3
Up	12	8	6	7.5
COHU	3	5	1.5	4.7
RACD	0	8	0	7.5
Misc	0	2	0	1.9
Total	200	107	100	100



Conclusion

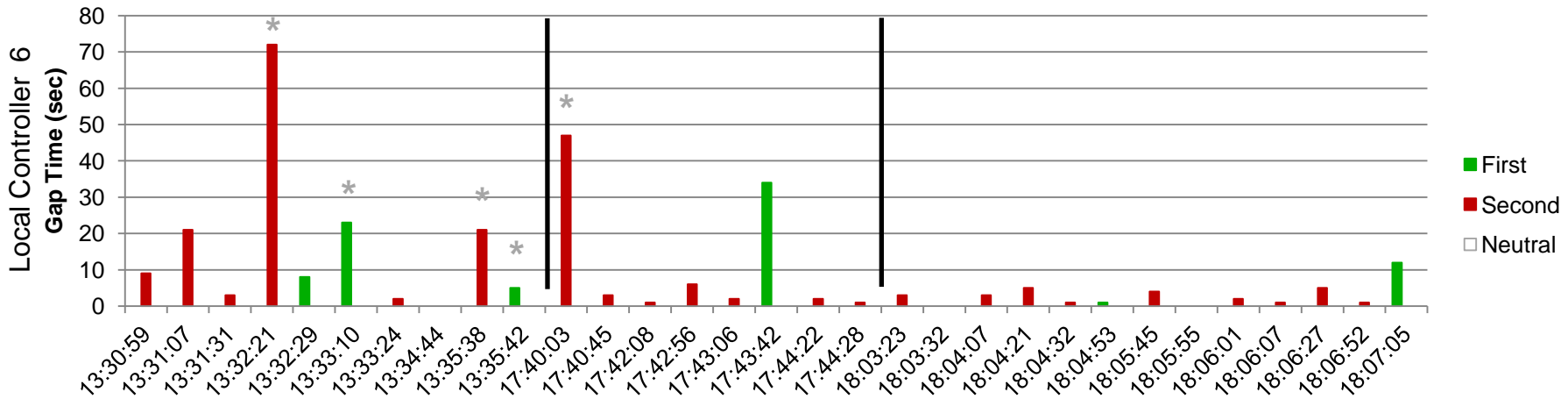
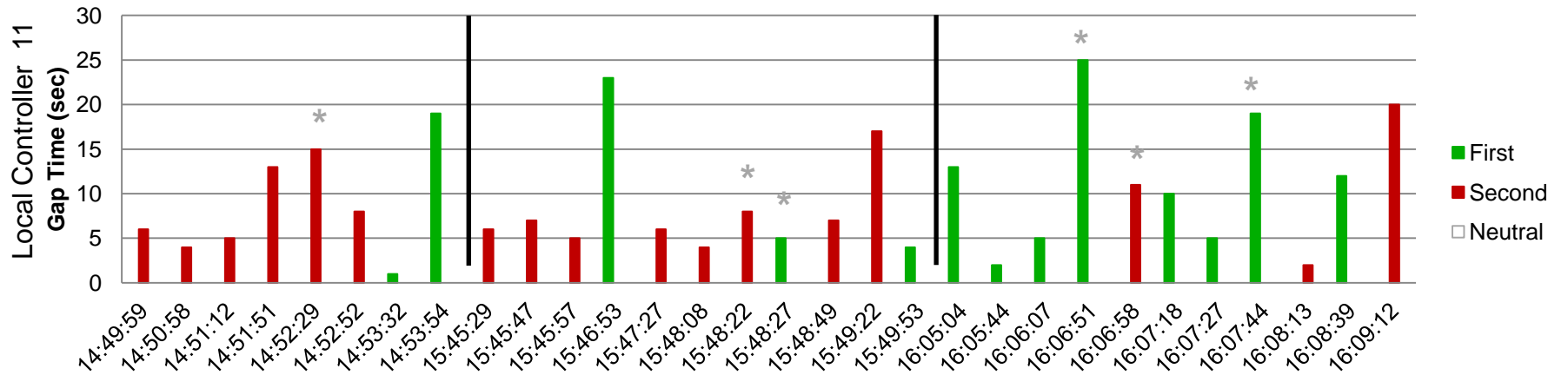
- Development of a quantified and non-intrusive behavioral measure of workload and gross visual attention in a field environment
- TFDM features requiring significant focused attention and resulting in spikes in workload identified for improvement

Issues Discovered Through:	Verbal Instructions	Visual Attention
Manually searching for flight strips on FDM	X	X
Editing & updating flight strips	X	X
Moving flight strips	X	
Difficulty using "Search" function	X	
Tracking flight on TIDS		X
Forgetting to update a flight strip		X
Slow when using FDM keyboard		X
Adjusting TIDS camera view		X
Inconclusive cause	X	X



Additional Gap Time Plots

* Asterisk indicates difference in operational strategy

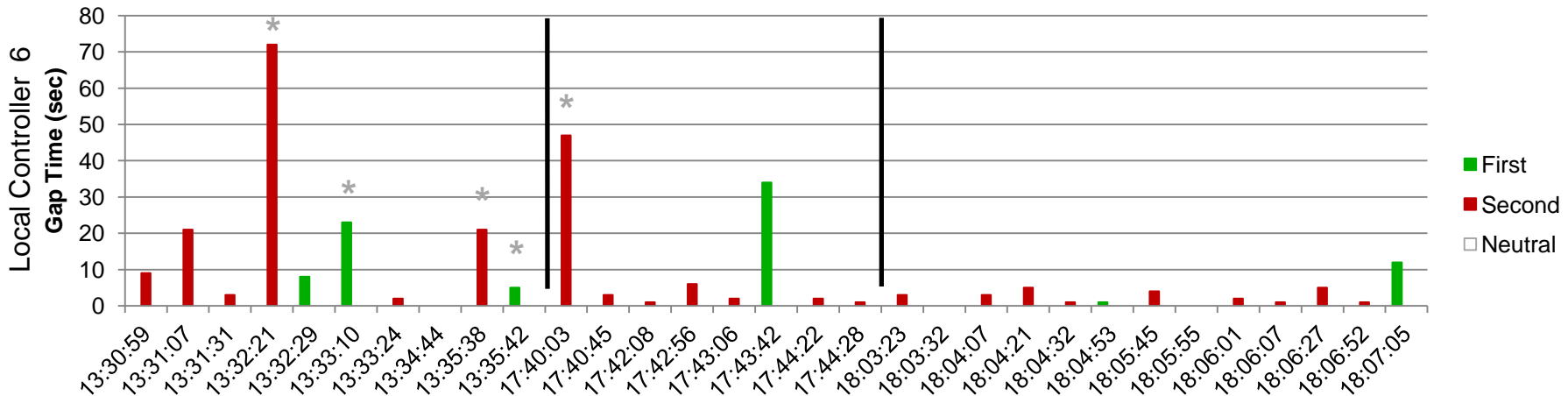
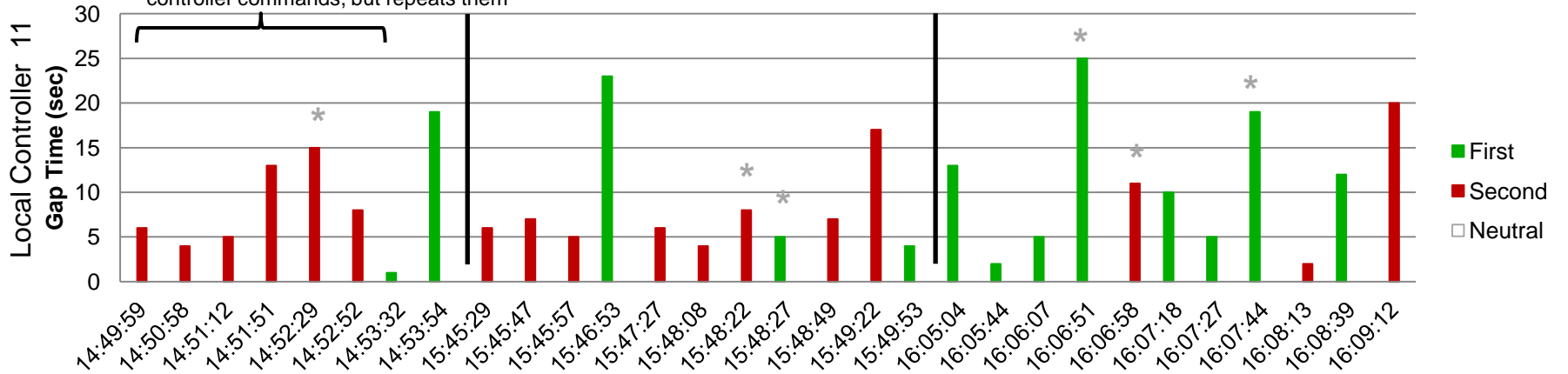




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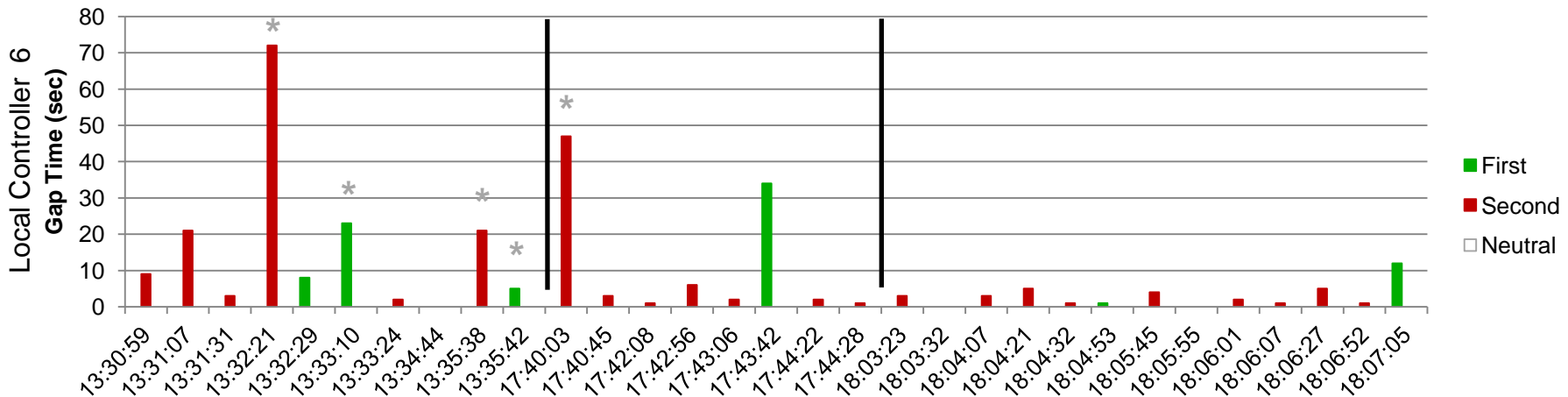
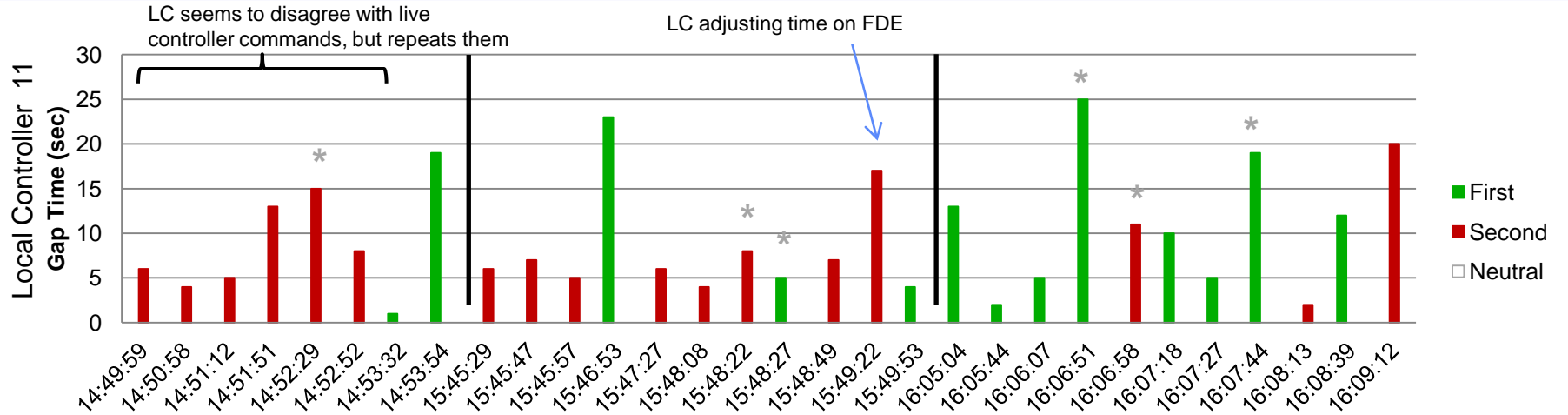
LC seems to disagree with live controller commands, but repeats them





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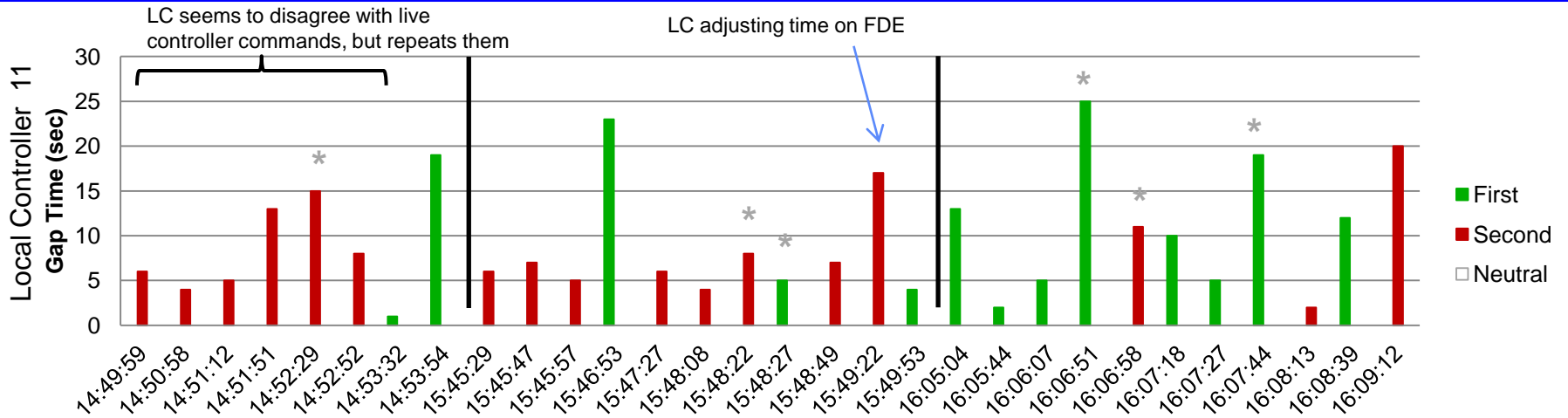
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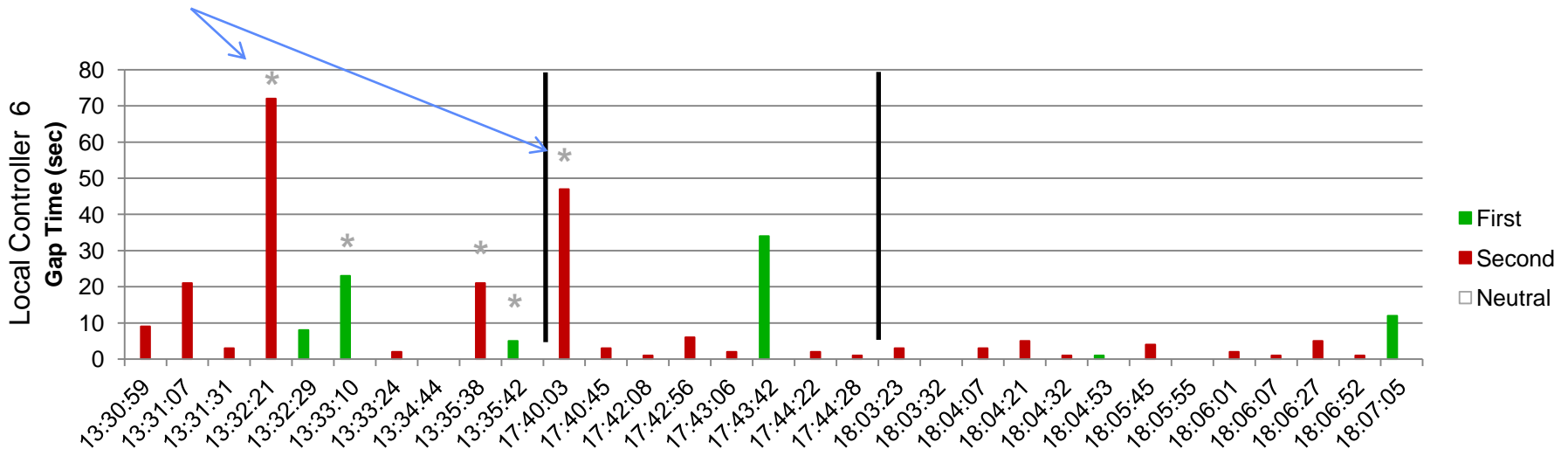


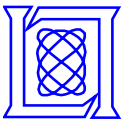
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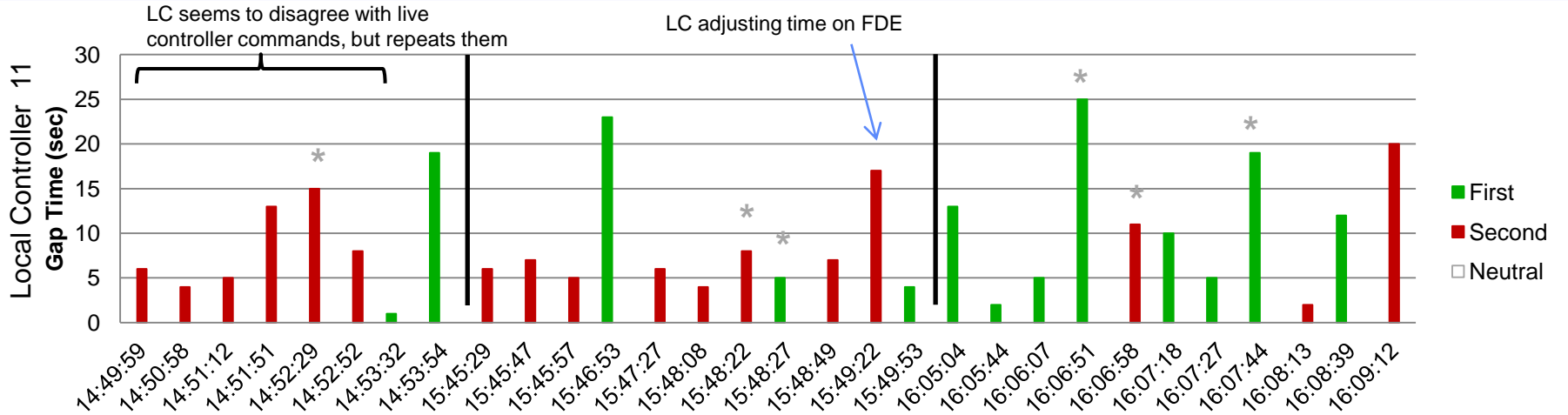
Large gaps due to difference in operational strategy





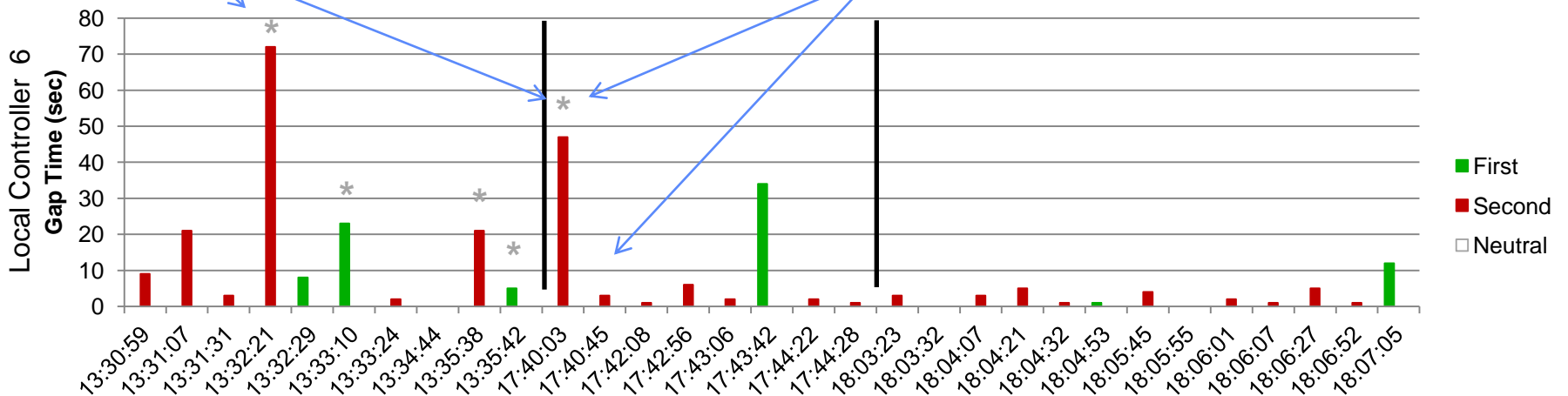
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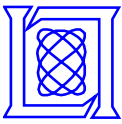
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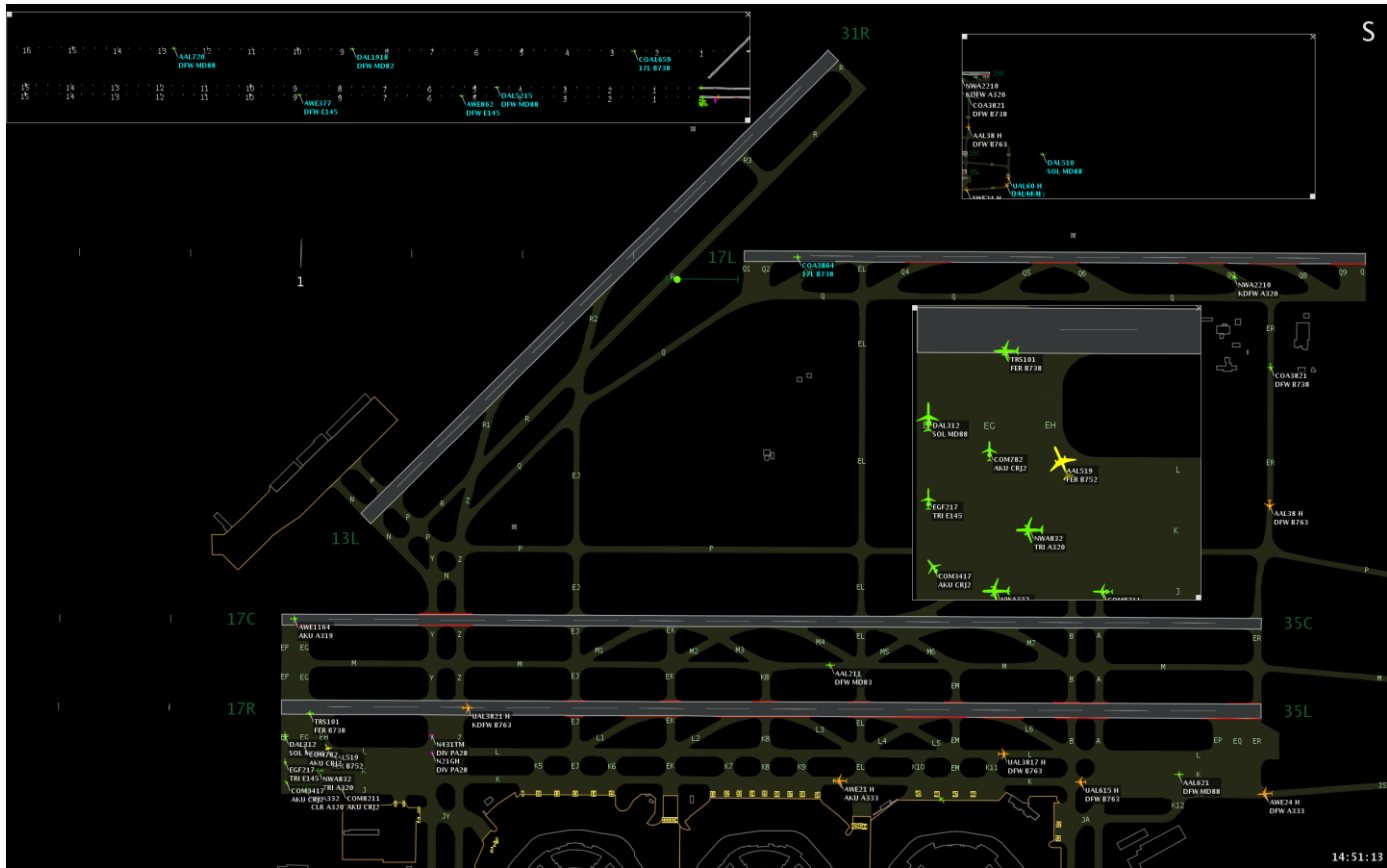
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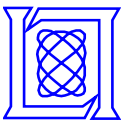
LC busy moving FDEs around to appropriate bays





Tower Information Display System (TIDS)





Flight Data Manager (FDM)

DFW Ground Control - East South Flow 183531 Z

ACID	Class	Level	Mark	Priority	
AA1504	SW	17R	P180	SPOT	
AA1670	SW	17R	P180	SPOT	
AA1216	SW	17R	P180	SPOT	
AA1310	SW	17R	P180	SPOT	
AA12406	TR	17R	P180	LC	
BTA2850	AL	17R	P180	LL	
CPA091	ML	17R	P180	LC	
EGF2747	MS	17R	P180	LC	
EGF2853	ML	17R	EG	P180	LC
EGF3303	ML	17R	EG	P180	LC
HPA1578	ML	17R	EH	P180	LC
AA11720	TR	17R	P180	YAX	
AA12226	ML	17R	P180	YAX	
AA12356	SW	17R	P180	YAX	
UPS2020	TR	17R	P180	YAX	

Ground FDM Display

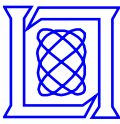
DFW Local Control - East North Flow 164836 Z

ACID	Class	Level	Mark	Priority
TR174				
EGF2478				
EGF2249				
AA1445				
EGF2713	CL	17R	S180	
AA11232	UNITED	17C	P180	
AWE1596	WEL	17R	S180	

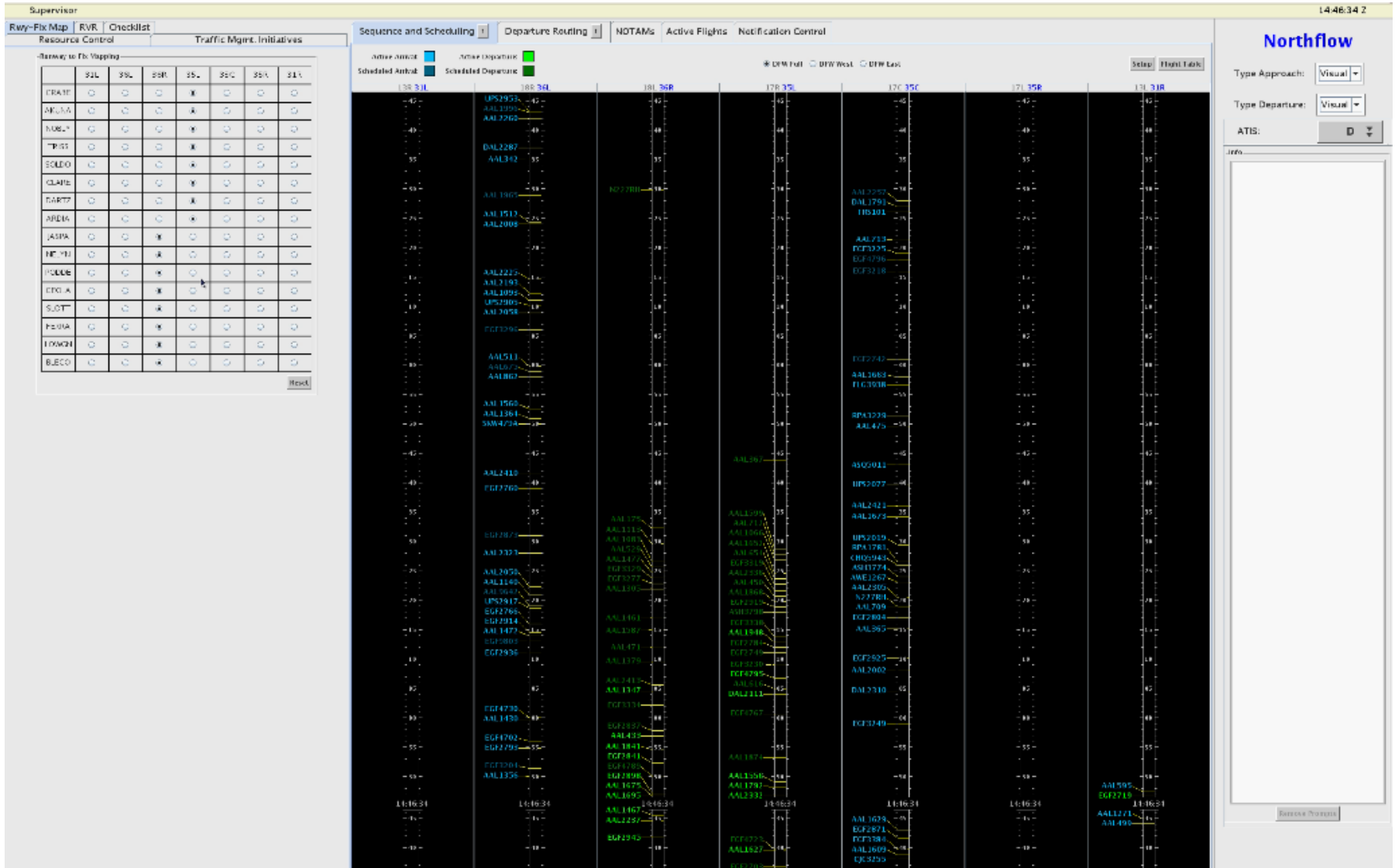
Local FDM Display

▲	AAL1122	TRISS3	17R	EG	P1740	LC	
	B752/Q	B	BOS	38	FRC		E1800
	> SWAP <NRP						

Flight Data Entry (FDE)



Supervisor (SUP) Display





COHU camera

