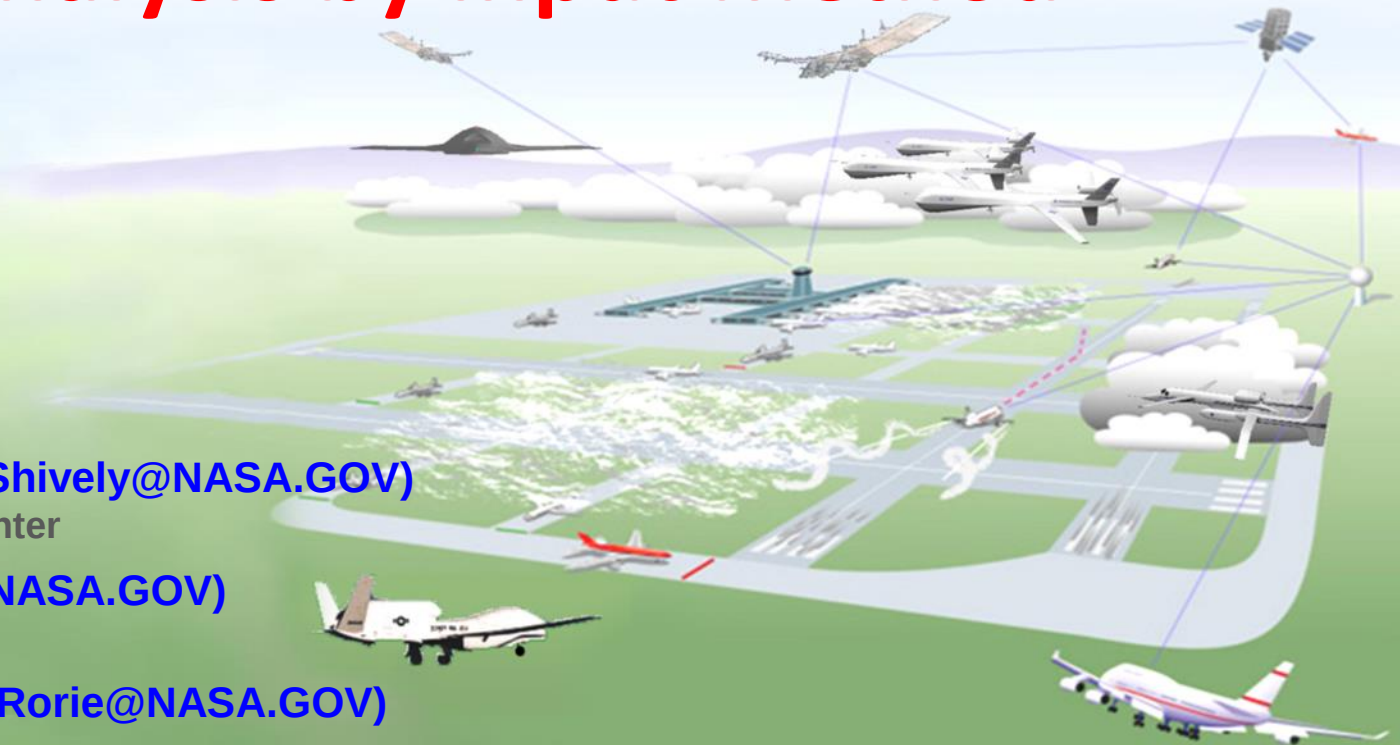




National Aeronautics and Space Administration



UAS Integration into the NAS: HSI Full Mission Simulation Analysis by Input Method



Jay Shively (Robert.J.Shively@NASA.GOV)
NASA Ames Research Center

Lisa Fern (Lisa.Fern@NASA.GOV)
The Ohio State University

Conrad Rorie (Conrad.Rorie@NASA.GOV)
San Jose State University



Initial Method Analysis

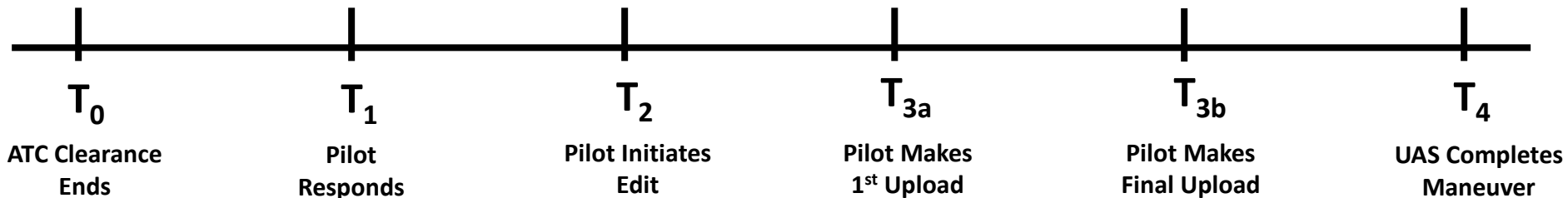


- All **FILTERED** data analyzed by Input Method Type and maneuver type *separately* for 476 completed maneuvers
 - Filtered data excludes all maneuvers $> 90^\circ$ horizontal and/or 1000ft vertical
- By method breakdown:
 - 1) Steering Window = 195
 - 2) Autopilot = 87
 - 3) Waypoint = 95
 - 4) Manual = 99
- By maneuver breakdown:
 - 1) Vertical = 74
 - 2) Direct To = 49
 - 3) Lateral = 238
 - 4) Own Nav = 115



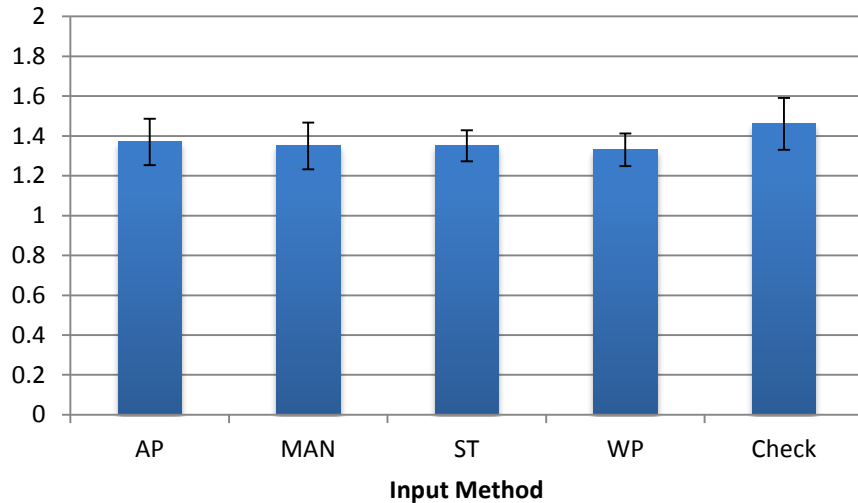
Preliminary Metrics

Metric	Calculation	Description
Verbal Response Time	$T_1 - T_0$	Time it took for pilots to respond verbally to ATC advisories and clearances
Initial Response Time	$T_2 - T_0$	Time it took for pilots to initiate edits in response to ATC clearances
Initial Edit Time (1st Upload)	$T_{3a} - T_2$	Time it took pilots to upload their first edit from the moment they began editing
Total Edit Time (Final Upload)	$T_{3b} - T_2$	Time it took pilots to upload their final edit from the moment they began editing
Aircraft Response Time	$T_{3a} - T_0$	Time it took for the aircraft to begin maneuvering from ATC clearance
Aircraft Maneuver Time	$T_4 - T_{3a}$	Time it took the UAS to complete its maneuver once the maneuver began
Compliance Time	$T_4 - T_0$	Time it took the UAS operator to complete <i>all</i> stages of ATC-Pilot interaction

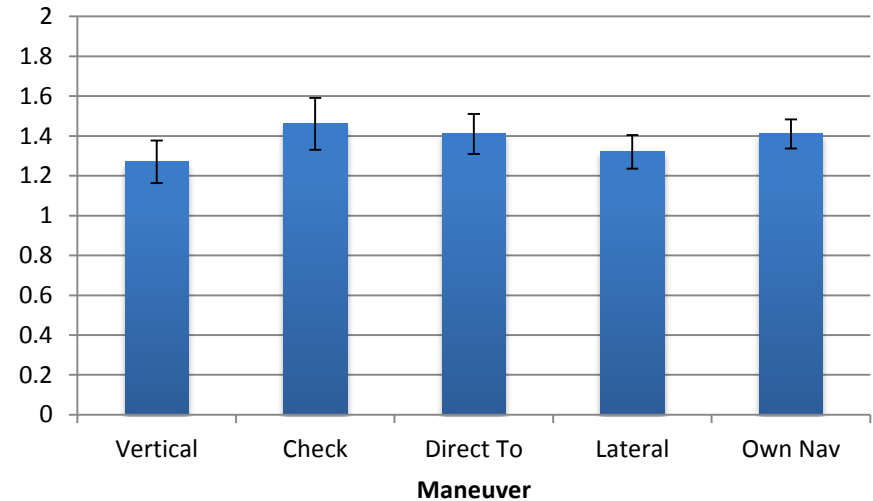




Verbal Response Time ($T_1 - T_0$)



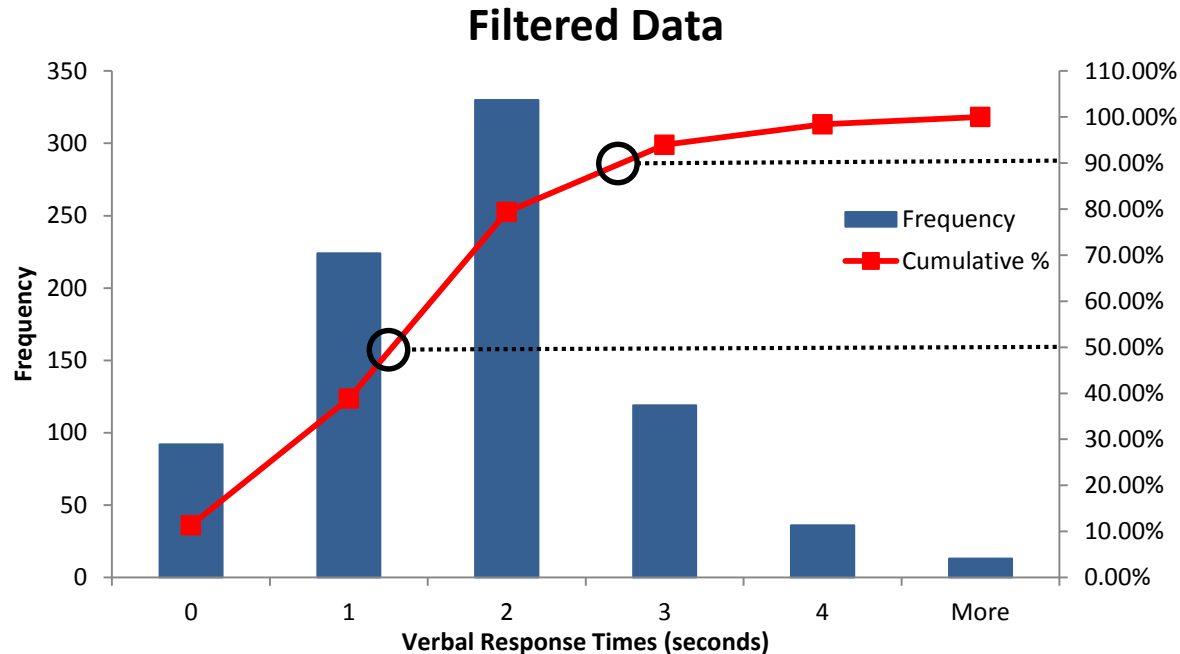
- Check = verbal check for traffic advisory; no input
- There were no significant differences across input method type on verbal response time ($p > .05$)
- Pilots replied to a total of 250 advisories & 540 clearances
 - Autopilot = 1.37 sec
 - Manual = 1.35 sec
 - Steering = 1.35 sec
 - Waypoint = 1.33 sec
 - Check = 1.46
 - Grand Mean = 1.37 sec



- There were no significant differences across maneuver type on verbal response time ($p > .05$)
- Pilots replied to a total of 250 advisories & 540 clearances
 - Vertical = 1.27 sec
 - Check = 1.46 sec
 - Direct To = 1.41 sec
 - Lateral = 1.32 sec
 - Own Nav = 1.41 sec
 - Grand Mean = 1.38 sec



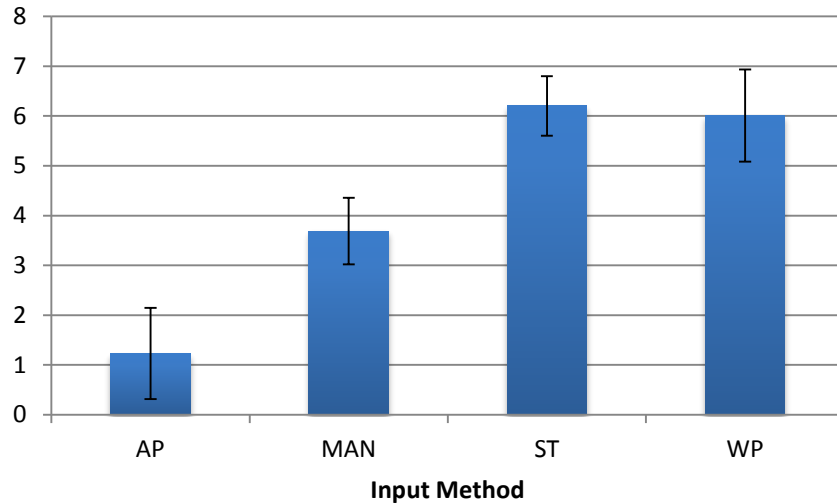
Verbal Response Time ($T_1 - T_0$)



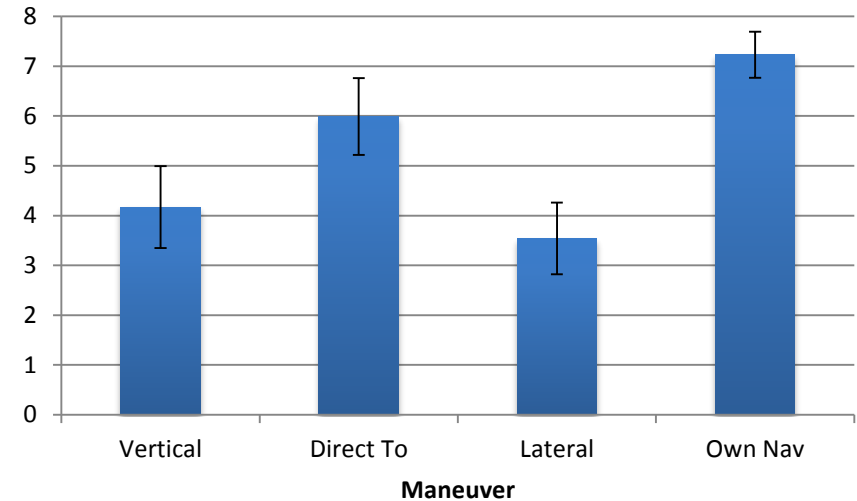
- Distribution:
 - 50% of participants replied 2 seconds or sooner following the controller's clearance
 - 90% of participants replied 3 seconds or sooner following the controller's clearance



Initial Response Time ($T_2 - T_0$)



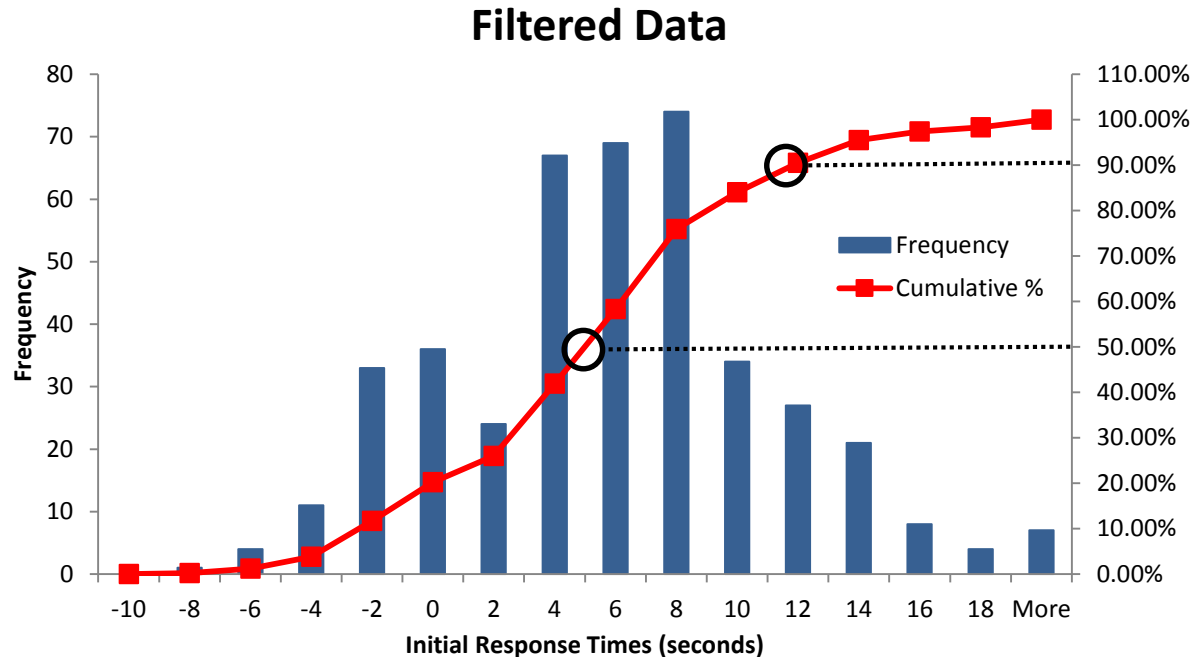
- Autopilot resulted in significantly shorter Initial Response Times than the Steering and Waypoint ($p < .01$)
- Manual was significantly shorter than Steering ($p < .01$)
- Pilots initiated a total of 420 edits in response to ATC clearances
 - Autopilot = 1.23 sec
 - Manual = 3.69 sec
 - Steering = 6.20 sec
 - Waypoint = 6.01 sec
 - Grand Mean = 4.28 sec



- Vertical maneuvers had significantly shorter response times than Own Nav ($p < .01$)
- Lateral maneuvers had significantly shorter response times than Direct To and Own Nav ($p < .05$)
- Direct To maneuvers were significantly shorter than
- Pilots initiated a total of 420 edits in response to ATC clearances
 - Vertical = 4.17 sec
 - Direct To = 5.99 sec
 - Lateral = 3.54 sec
 - Own Nav = 7.23 sec
 - Grand Mean = 5.23 sec



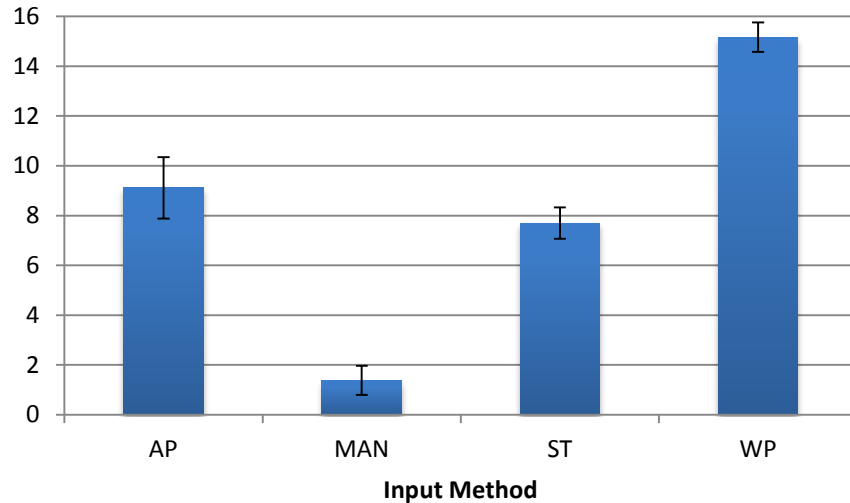
Initial Response Time ($T_2 - T_0$)



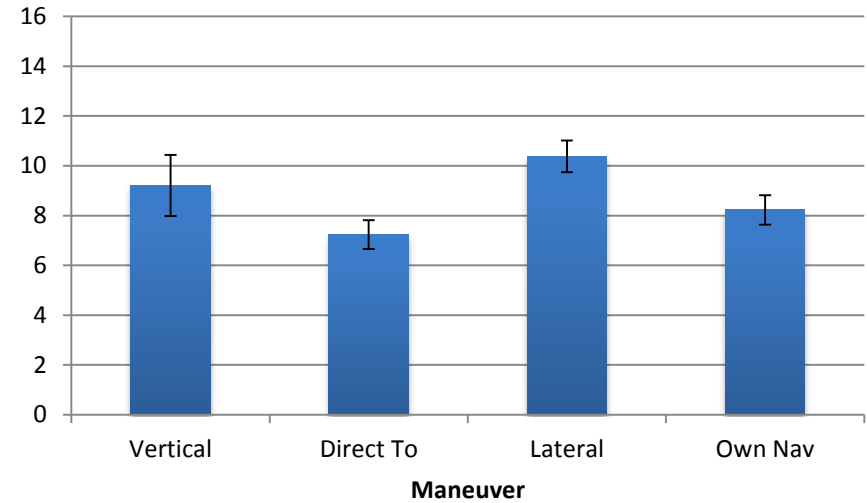
- Distribution:
 - 50% of participants started their edit 5 seconds or sooner following the controller's clearance
 - 90% of participants started their edit at 12 seconds or sooner following the controller's clearance



Initial Edit Time ($T_{3a} - T_2$)



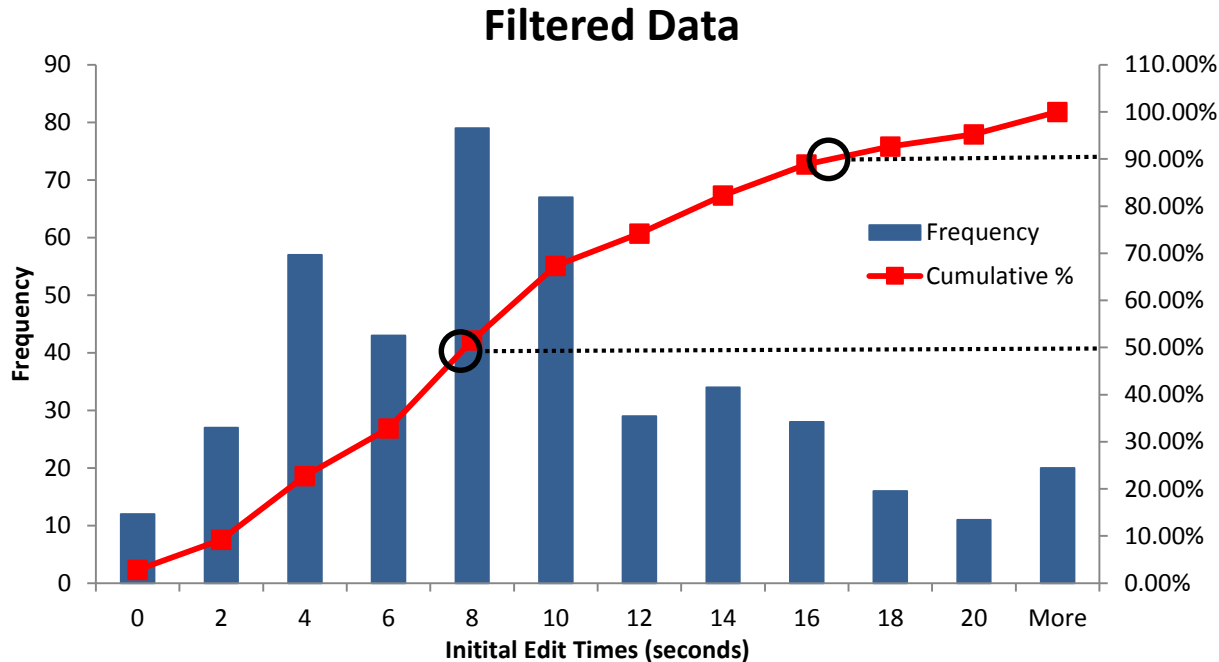
- Manual was significantly shorter than all three other input methods ($p < .001$)
- Waypoint had significantly longer initial edit times than all three other input methods ($p < .01$)
- Pilots successfully uploaded a total of 423 edits
 - Autopilot = 9.11 sec
 - Manual = 1.38 sec
 - Steering = 7.70 sec
 - Waypoint = 15.17 sec
 - Grand Mean = 8.34 sec



- There were no significant differences in initial edit time across maneuver types ($p > .05$)
- Pilots successfully uploaded a total of 423 edits
 - Vertical = 8.21 sec
 - Direct To = 7.24 sec
 - Lateral = 10.38 sec
 - Own Nav = 8.23 sec
 - Grand Mean = 8.77 sec



Initial Edit Time ($T_{3a} - T_2$)

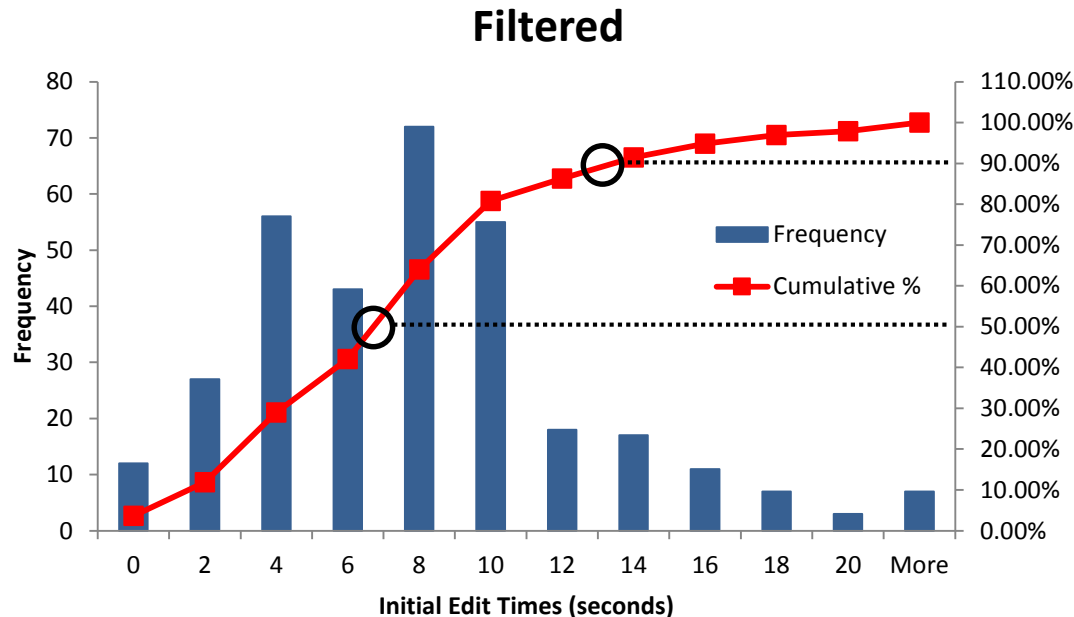


- Distribution:
 - 50% of participants uploaded their *initial* edit 8 seconds or sooner following the start of their edit
 - 90% of participants uploaded their *initial* edit 17 seconds or sooner following the start of their edit



Initial Edit Time ($T_{3a} - T_2$)

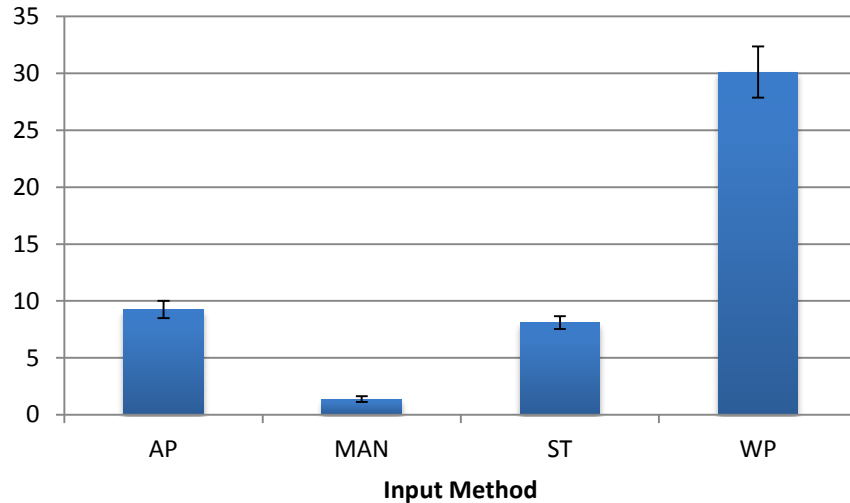
NO WP
INCLUDED



- Distribution:
 - 50% of participants uploaded their *initial* edit 7 seconds or sooner following the start of their edit
 - 90% of participants uploaded their *initial* edit 13 seconds or sooner following the start of their edit



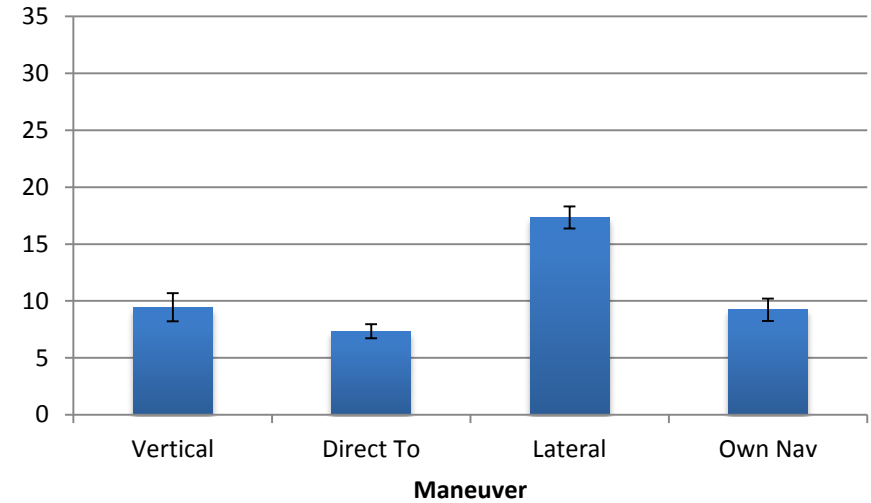
Total Edit Time ($T_{3b} - T_2$)



- Manual was significantly shorter than all three other input methods ($p < .001$)
- Waypoint had significantly longer total edit times than all three other input methods ($p < .001$)
- Pilots successfully completed a total of 423 edits
 - Autopilot = 9.25 sec
 - Manual = 1.38 sec
 - Steering = 8.09 sec
 - Waypoint = 30.12 sec
 - Grand Mean = 12.21 sec

Initial Edit Times

- Autopilot = 9.11 sec
- Manual = 1.38 sec
- Steering = 7.70 sec
- Waypoint = 15.17 sec
- Grand Mean = 8.34 sec



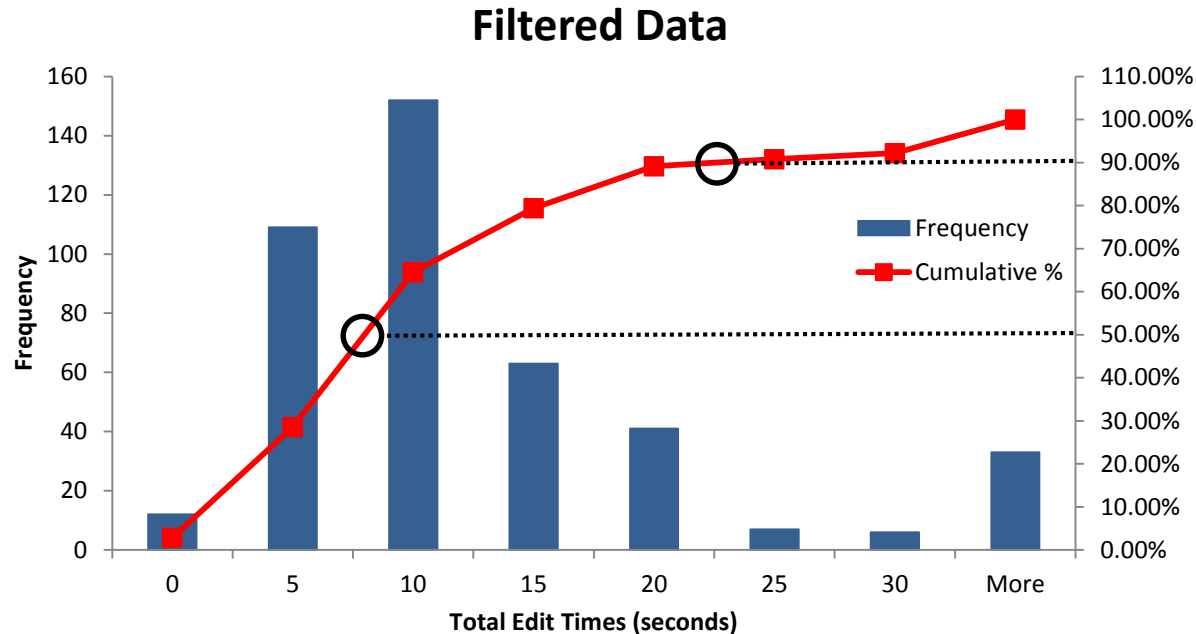
- Lateral maneuvers had significant longer final edit times than all three other maneuver types ($p < .01$)
- Pilots successfully completed a total of 423 edits
 - Vertical = 9.44 sec
 - Direct To = 7.34 sec
 - Lateral = 17.33 sec
 - Own Nav = 9.22 sec
 - Grand Mean = 10.84 sec

Initial Edit Times

- Vertical = 8.21 sec
- Direct To = 7.24 sec
- Lateral = 10.38 sec
- Own Nav = 8.23 sec
- Grand Mean = 8.77 sec



Total Edit Time ($T_{3b} - T_2$)

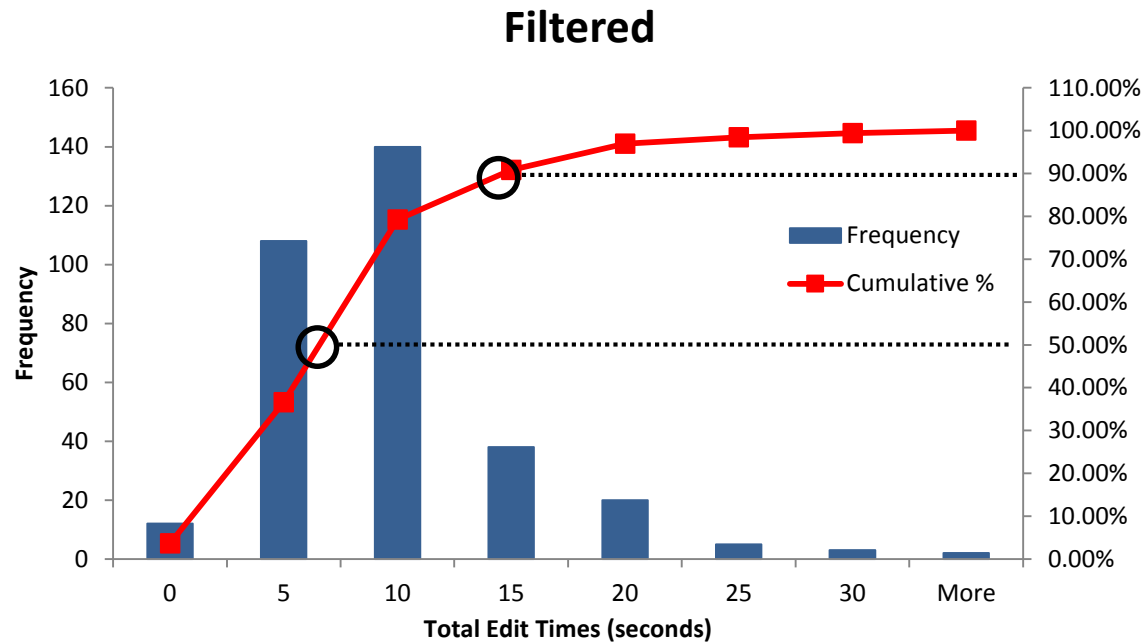


- Distribution:
 - 50% of participants uploaded their *final* edit 8 seconds or sooner following the start of their edit
 - 90% of participants uploaded their *final* edit 23 seconds or sooner following the start of their edit



Total Edit Time ($T_{3b} - T_2$)

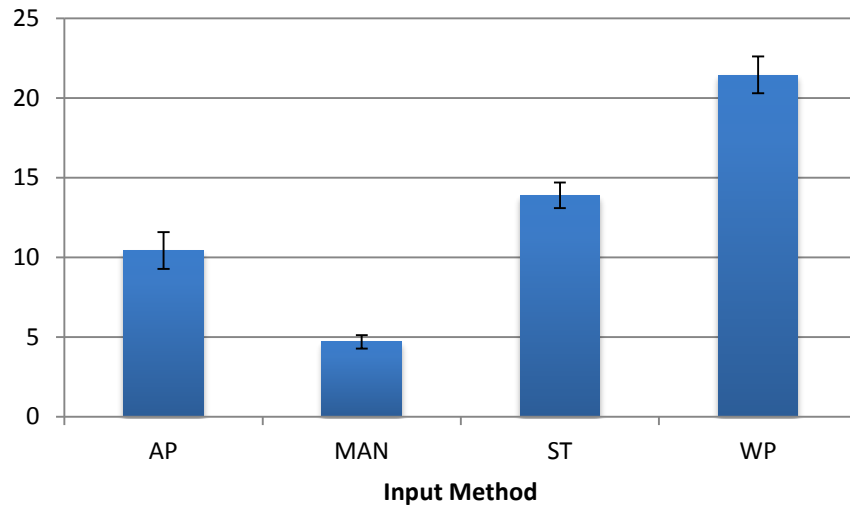
NO WP
INCLUDED



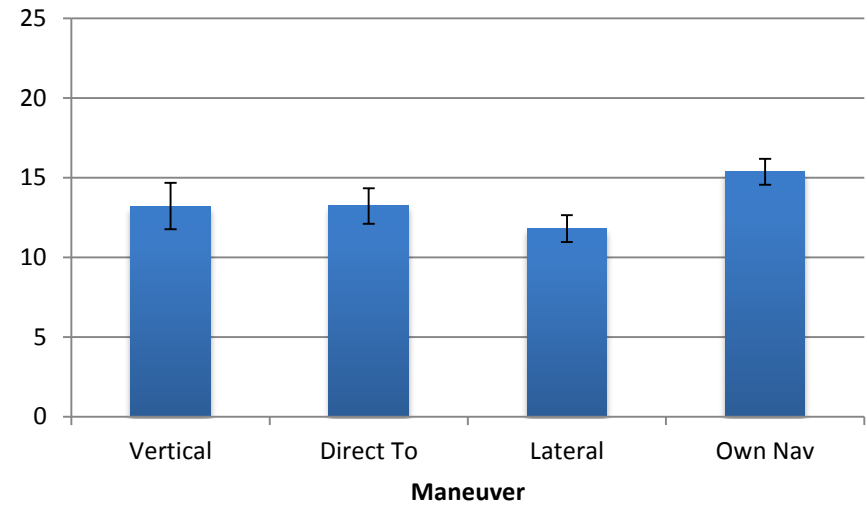
- Distribution:
 - 50% of participants uploaded their *final* edit 7 seconds or sooner following the start of their edit
 - 90% of participants uploaded their *final* edit 15 seconds or sooner following the start of their edit



Aircraft Response Time ($T_{3a} - T_0$)



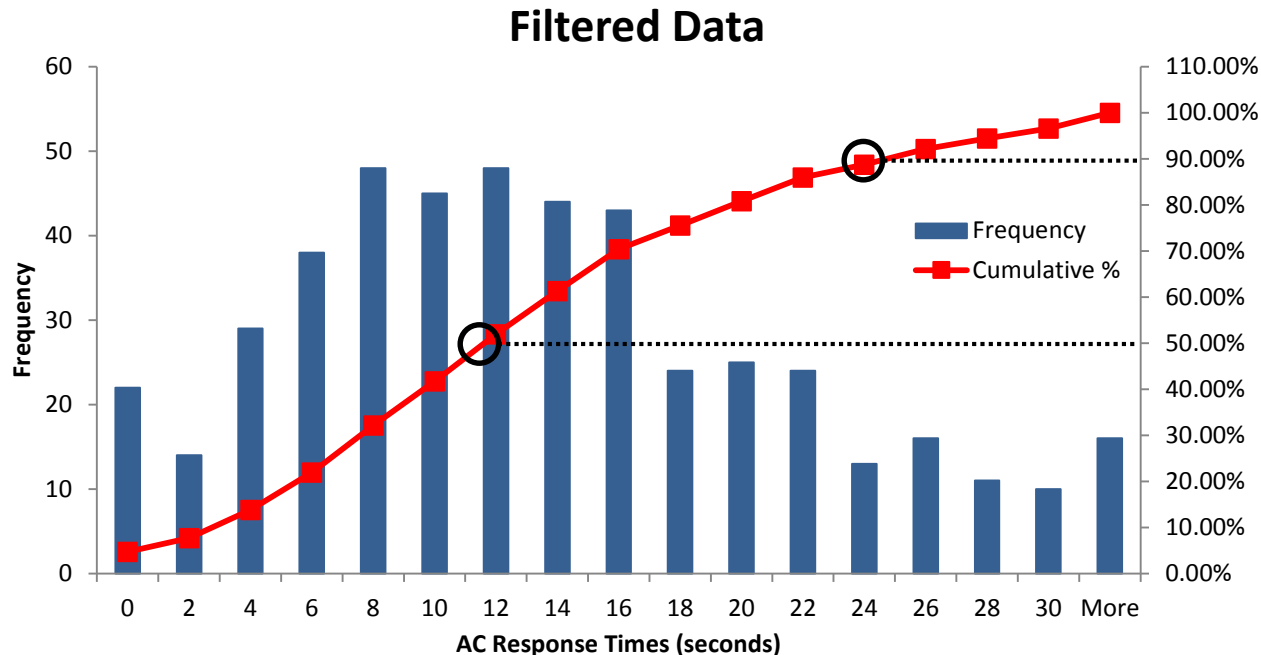
- All differences between Input Method were significant ($p < .01$).
- Manual had significantly shorter RTs than all three other input methods ($p < .01$)
- Waypoint had significantly longer RTs than all three other input methods ($p < .001$)
- AP was significantly quicker than ST ($p < .01$)
- Pilots responded to a total of 470 clearances
 - Autopilot = 10.43 sec
 - Manual = 4.70 sec
 - Steering = 13.89 sec
 - Waypoint = 21.46 sec
 - Grand Mean = 12.62 sec



- There were no significant differences in aircraft response time between maneuver types
- Pilots responded to a total of 470 clearances
 - Vertical = 13.92 sec
 - Direct To = 13.23 sec
 - Lateral = 11.81 sec
 - Own Nav = 15.38 sec
 - Grand Mean = 13.41 sec



Aircraft Response Time ($T_{3a} - T_0$)



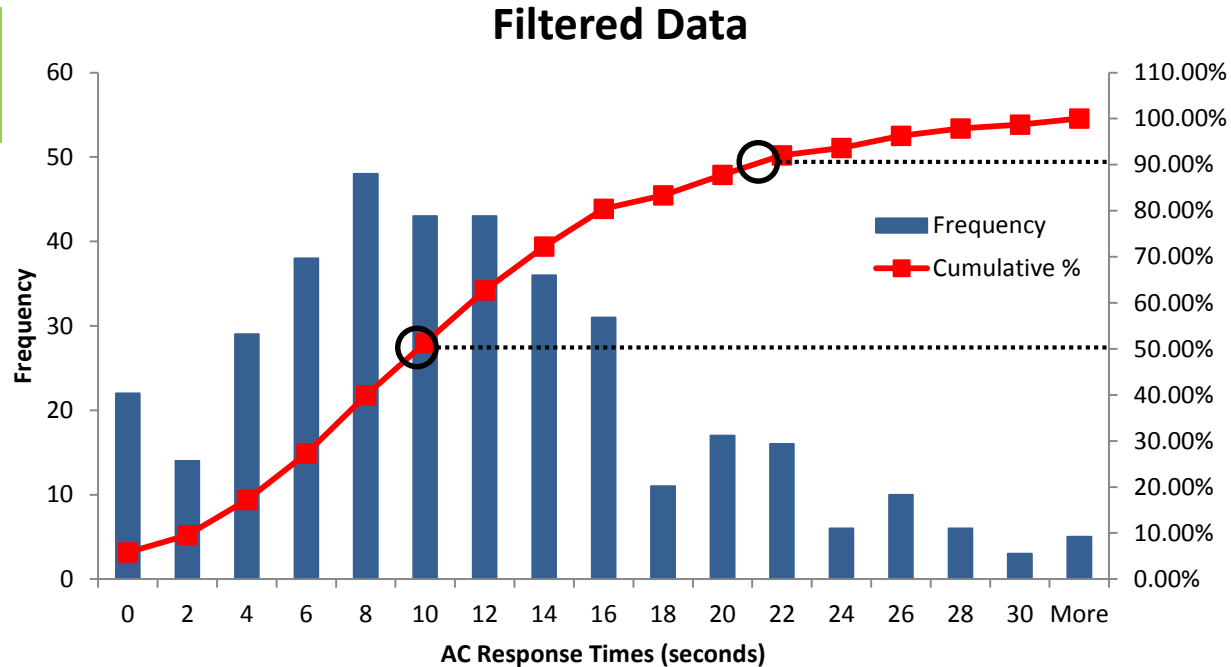
- Distribution:
 - 50% of participants started the AC maneuver within 12 seconds of the controller's clearance
 - 90% of participants started the AC maneuver within 24 seconds of the controller's clearance upload



Aircraft Response Time ($T_{3a} - T_0$)



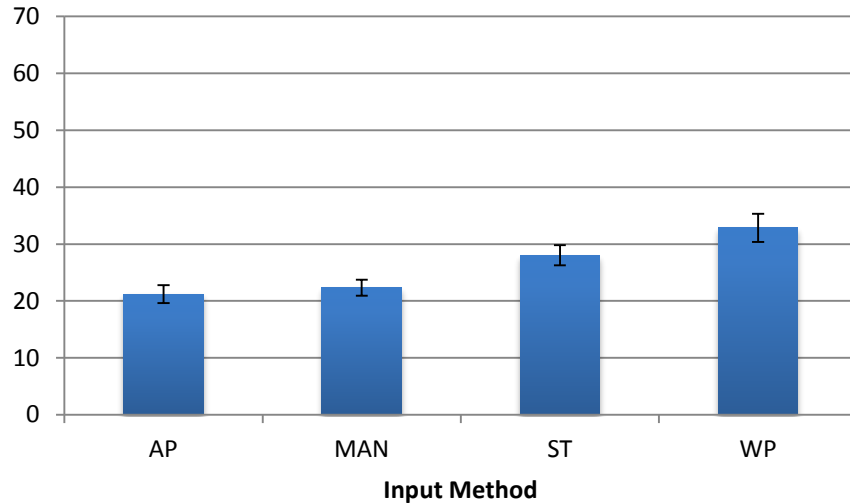
NO WP
INCLUDED



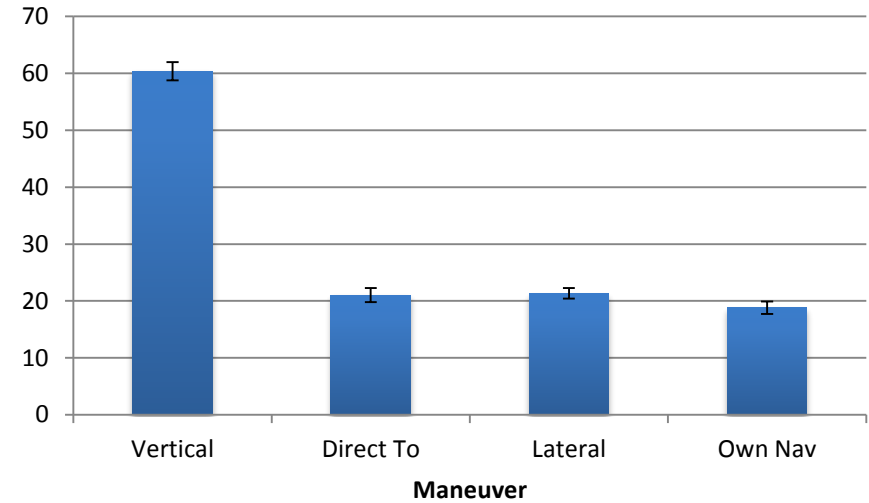
- Distribution:
 - 50% of participants started the AC maneuver within 10 seconds of the controller's clearance
 - 90% of participants started the AC maneuver within 21 seconds of the controller's clearance upload



Aircraft Maneuver Time ($T_4 - T_{3a}$)



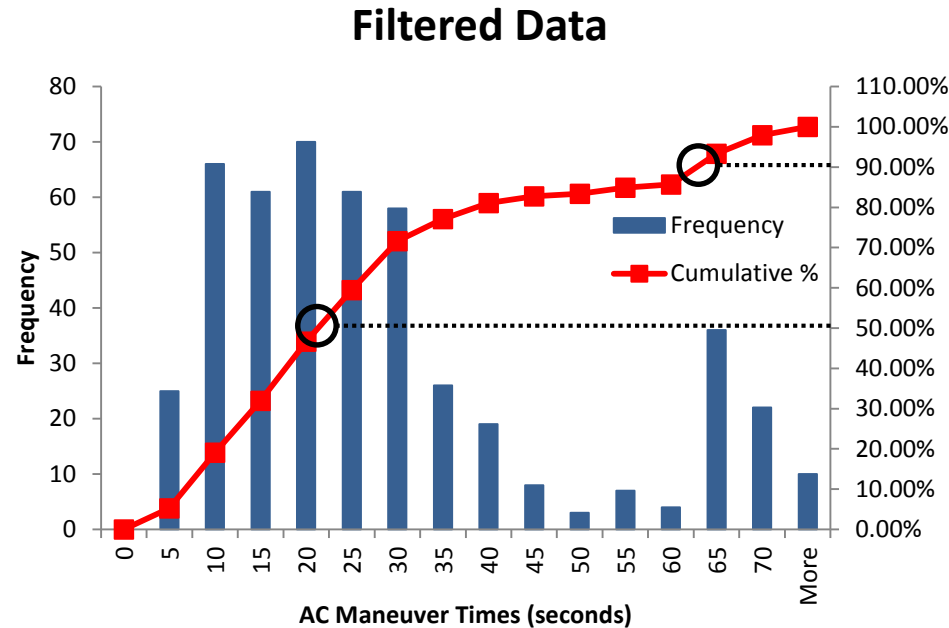
- Autopilot had significantly shorter maneuver times than Steering and WP ($p < .05$)
- Manual had significantly shorter maneuver times than WP ($p < .05$)
- Pilots successfully completed a total of 476 maneuvers
 - Autopilot = 21.19 sec
 - Manual = 22.31 sec
 - Steering = 28.03 sec
 - Waypoint = 32.84 sec
 - Grand Mean = 26.09 sec



- Vertical maneuvers had significantly longer aircraft maneuver times than all other maneuver types ($p < .001$)
- Pilots successfully completed a total of 476 maneuvers
 - Vertical = 60.37 sec
 - Direct To = 21.04 sec
 - Lateral = 21.35 sec
 - Own Nav = 18.80 sec
 - Grand Mean = 30.41 sec



Aircraft Maneuver Time ($T_4 - T_{3a}$)



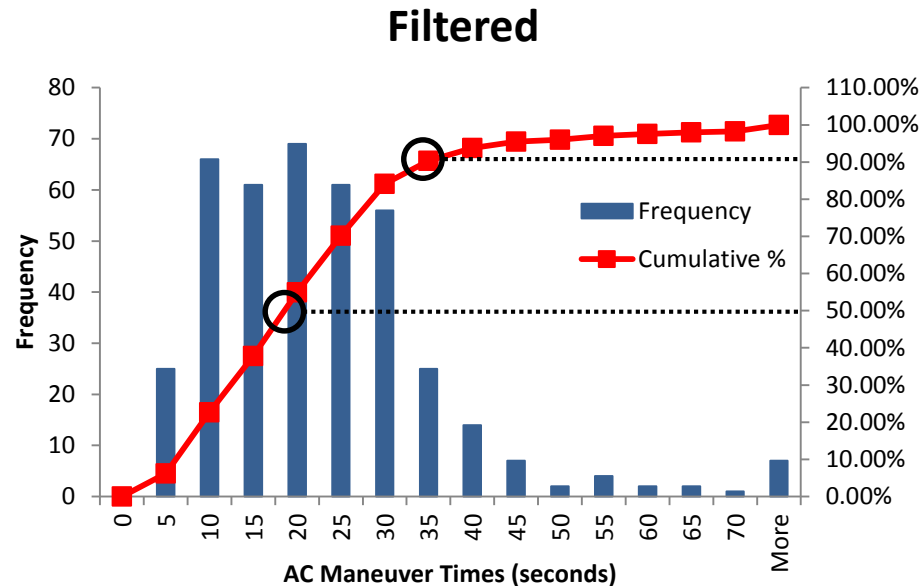
- Distribution:
 - 50% of participants completed their maneuver 22 seconds or sooner following their initial upload
 - 90% of participants completed their maneuver 62 seconds or sooner following their initial upload



Aircraft Maneuver Time ($T_4 - T_{3a}$)



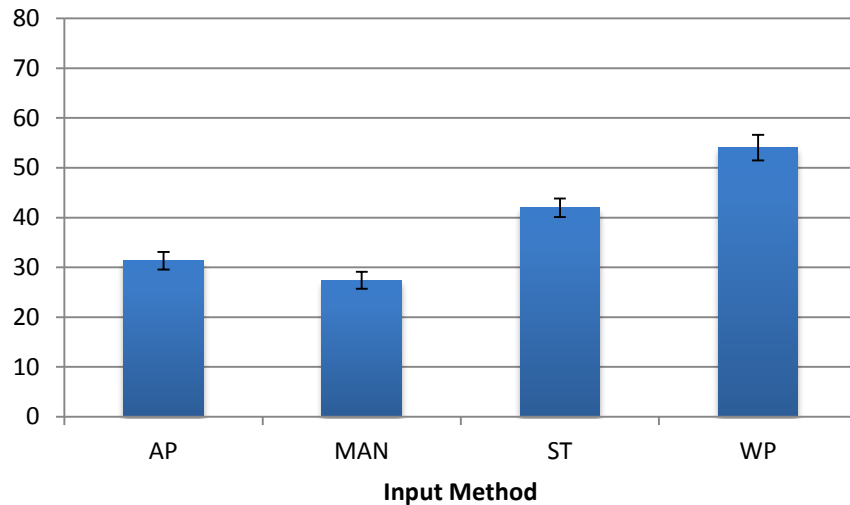
NO VERTICAL
MANEUVERS
INCLUDED



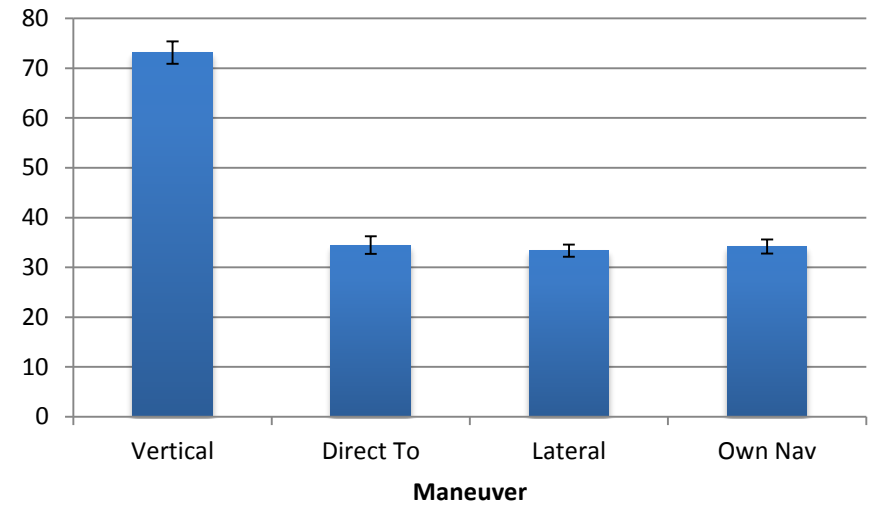
- Distribution:
 - 50% of participants completed their maneuver 18 seconds or sooner following their initial upload
 - 90% of participants completed their maneuver 35 seconds or sooner following their initial upload



Compliance Time ($T_4 - T_0$)



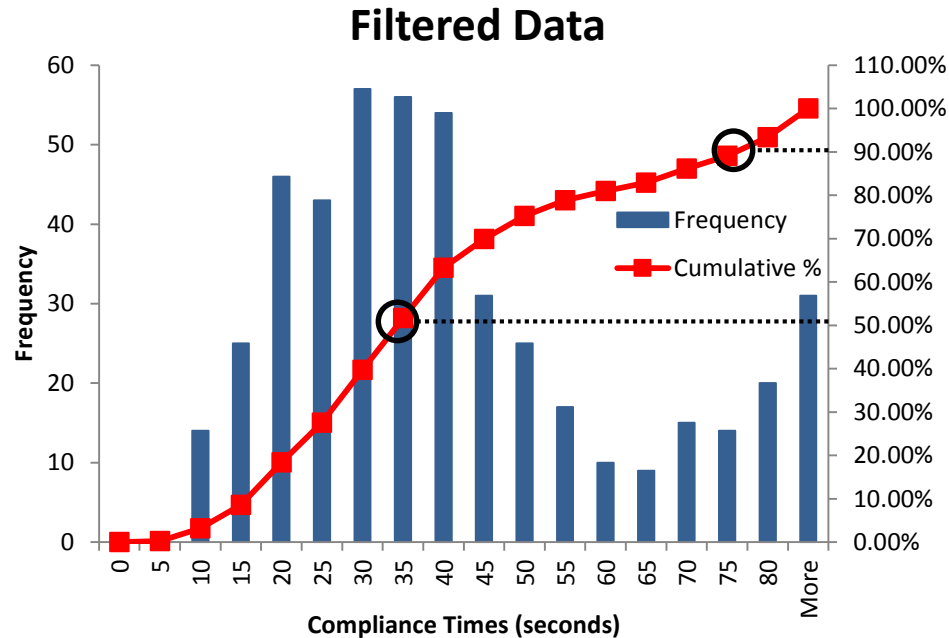
- Autopilot and Manual had significantly shorter compliance times than Steering and Waypoint ($p < .01$)
- Steering had significantly shorter compliance times than Waypoint ($p < .05$)
- There was no significant difference between Autopilot and Manual
- Pilots successfully completed a total of 468 clearances
 - Autopilot = 31.33 sec
 - Manual = 27.40 sec
 - Steering = 41.97 sec
 - Waypoint = 54.04 sec
 - Grand Mean = 38.69 sec



- Vertical maneuvers had significantly longer aircraft compliance times than all other maneuver types ($p < .001$)
- Pilots successfully completed a total of 468 clearances
 - Vertical = 73.12 sec
 - Direct To = 34.46 sec
 - Lateral = 33.36 sec
 - Own Nav = 34.20 sec
 - Grand Mean = 43.78 sec



Compliance Time ($T_4 - T_0$)



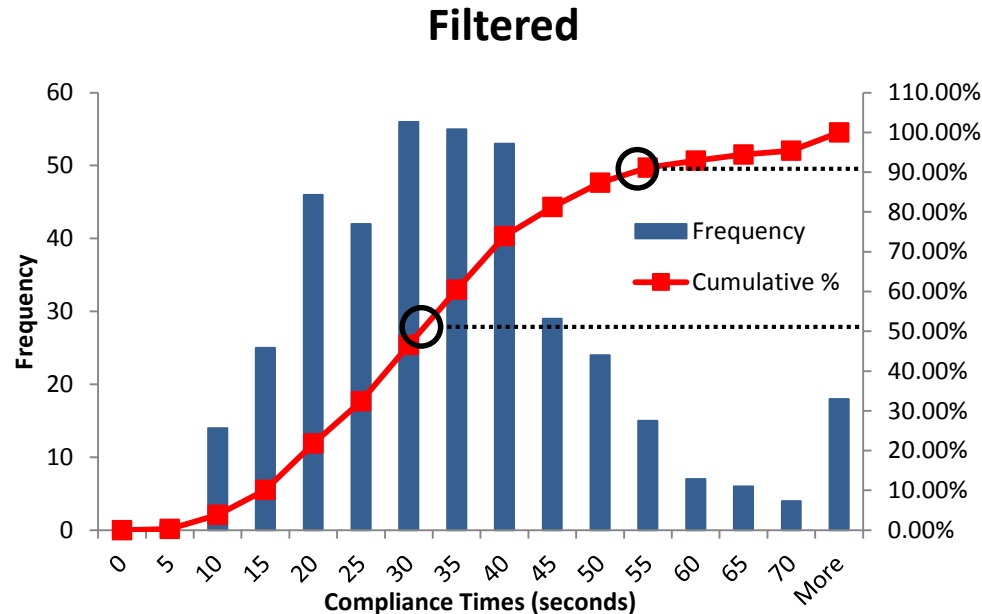
- Distribution:
 - 50% of participants completed their maneuver 35 seconds or sooner following the controller's clearance
 - 90% of participants completed their maneuver 75 seconds or sooner following the controller's clearance



Compliance Time ($T_4 - T_0$)



**NO VERTICAL
MANEUVERS
INCLUDED**



- Distribution:
 - 50% of participants completed their maneuver 32 seconds or sooner following the controller's clearance
 - 90% of participants completed their maneuver 54 seconds or sooner following the controller's clearance



Initial Method X Maneuver Analysis



- Descriptive statistics for all data by Input Method and Maneuver Type
- Select **FILTERED** data subset analyzed by Input Method and Maneuver Type
 - Filtered data excludes all maneuvers > 900 horizontal and/or 1000ft vertical
 - Maneuver types with less than half of pilots employing an input method *for each metric* were removed from analysis
 - Analysis not done for Own NAV and Direct TO (not enough data for input methods other than Steering window)
- *Maneuver by Method for 583 completed maneuvers*
 - 1) Vertical = 74
 - 9 Autopilot (12%)
 - 11 Manual (15%)
 - 46 Steering Window (62%)
 - 8 Waypoint (11%)
 - 2) Direct To = 49
 - 1 Autopilot (2%)
 - 3 Manual (6%)
 - 43 Steering Window (88%)
 - 2 Waypoint (4%)
 - 3) Lateral = 238
 - 76 Autopilot (32%)
 - 83 Manual (35%)
 - 0 Steering Window (0%)
 - 79 Waypoint (33%)
 - 4) Own Nav = 115
 - 1 Autopilot (1%)
 - 2 Manual (2%)
 - 106 Steering Window (92%)
 - 6 Waypoint (5%)
- *Maneuver by Method for 295 completed maneuvers (51% of filtered data)*
 - 1) Lateral = 238
 - 76 Autopilot (32%)
 - 83 Manual (35%)
 - 79 Waypoint (33%)



Initial Method Analysis

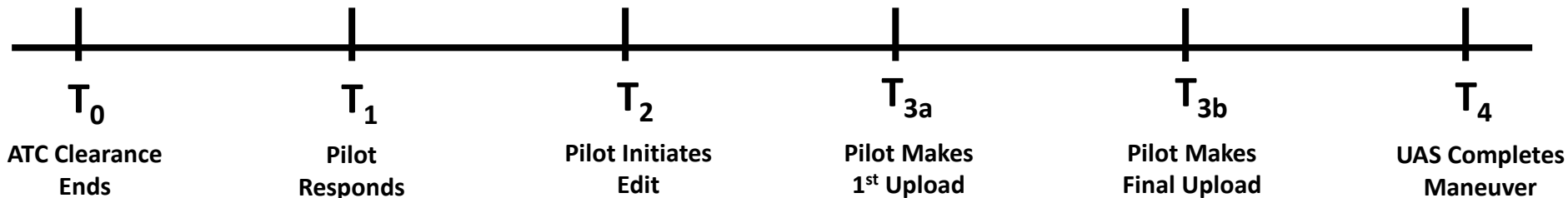
- Descriptive statistics for Method by Maneuver

TOTAL MANEUVERS BY METHOD					
	Vertical	Direct To	Lateral	Own NAV	TOTAL
Autopilot	9 (2%)	1 (.2%)	76 (16%)	1 (.2%)	87 (18%)
Manual	11 (2%)	3 (.6%)	83 (17%)	2 (.4%)	99 (21%)
Steering	46 (10%)	43 (9%)	0 (0%)	106 (22%)	195 (41%)
Waypoint	8 (2%)	2 (.4%)	79 (17%)	6 (1%)	95 (20%)
TOTAL	74 (16%)	49 (10%)	238 (44%)	115 (22%)	476



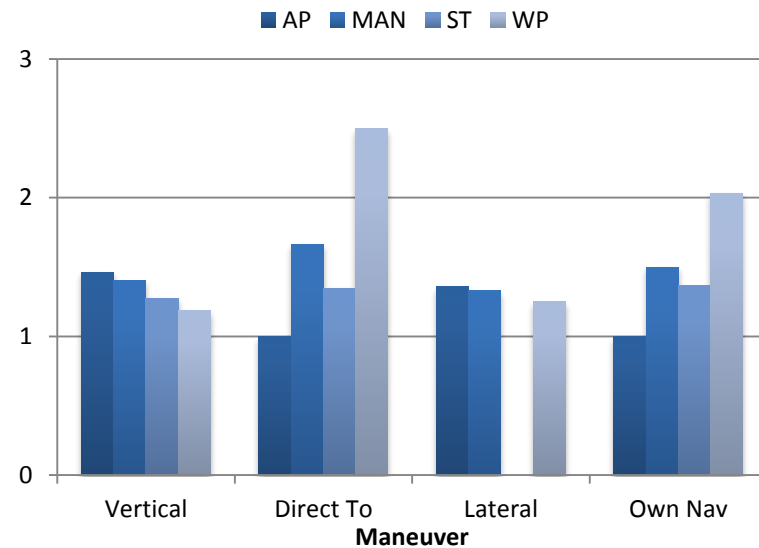
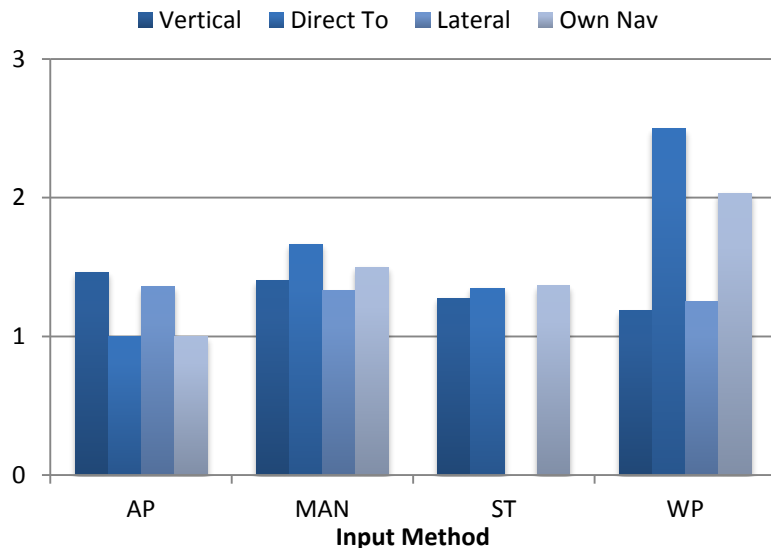
Preliminary Metrics

Metric	Calculation	Description
Verbal Response Time	$T_1 - T_0$	Time it took for pilots to respond verbally to ATC advisories and clearances
Initial Response Time	$T_2 - T_0$	Time it took for pilots to initiate edits in response to ATC clearances
Initial Edit Time (1 st Upload)	$T_{3a} - T_2$	Time it took pilots to upload their first edit from the moment they began editing
Total Edit Time (Final Upload)	$T_{3b} - T_2$	Time it took pilots to upload their final edit from the moment they began editing
Aircraft Response Time	$T_{3a} - T_0$	Time it took for the aircraft to begin maneuvering from ATC clearance
Aircraft Maneuver Time	$T_4 - T_{3a}$	Time it took the UAS to complete its maneuver once the maneuver began
Compliance Time	$T_4 - T_0$	Time it took the UAS operator to complete <i>all</i> stages of ATC-Pilot interaction





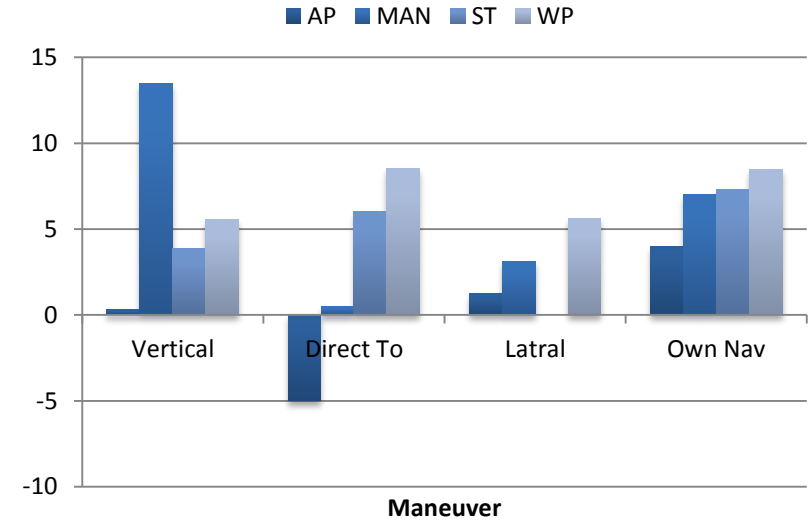
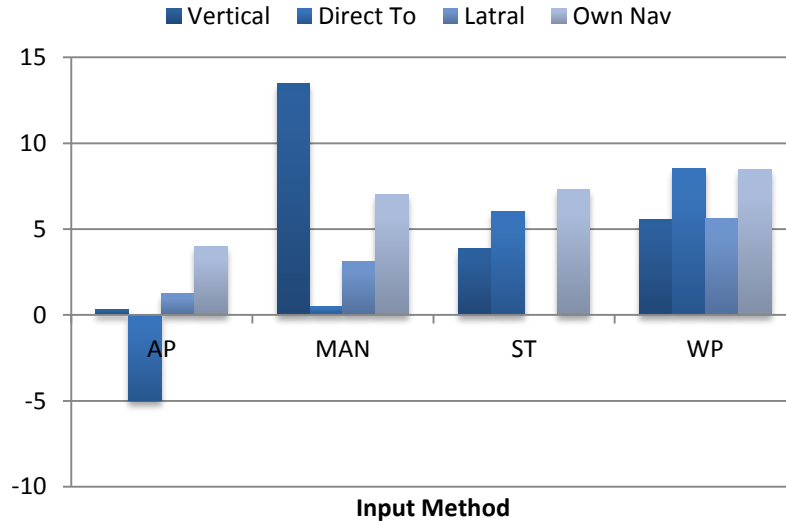
Verbal Response Time ($T_1 - T_0$)



	Autopilot				Manual				Steering			Waypoint			
	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Own Nav	Vertical	Direct	Lateral	Own Nav
MEAN	1.46	1.00	1.36	1.00	1.40	1.67	1.33	1.50	1.28	1.35	1.37	1.19	2.50	1.25	2.03
Count	13	1	83	1	15	3	93	4	54	45	119	13	2	85	9
STDEV	0.74		0.51		0.81	0.58	0.47	0.58	0.83	0.29	0.28	0.90	2.12	0.27	0.58
Min	0.00	1.00	0.60	1.00	0.50	1.00	0.63	1.00	0.50	1.00	1.00	0.00	1.00	0.80	1.50
Max	2.00	1.00	2.50	1.00	3.00	2.00	2.25	2.00	3.75	2.00	1.83	2.00	4.00	1.71	3.00



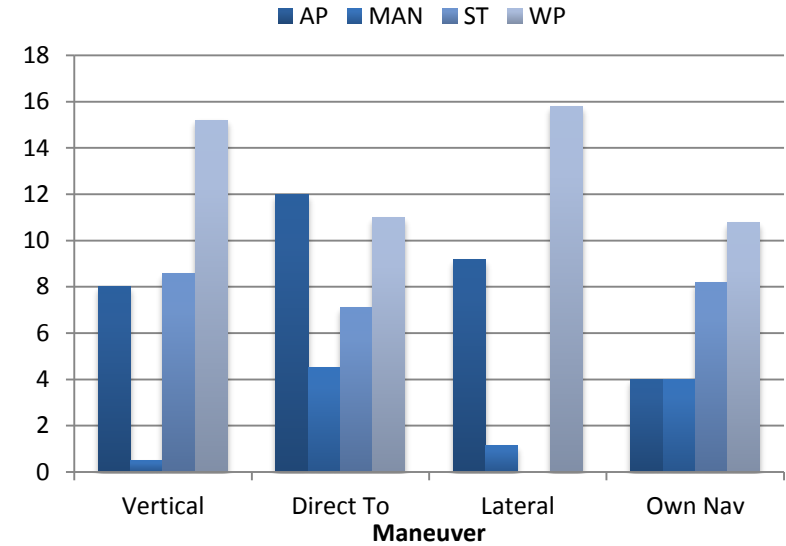
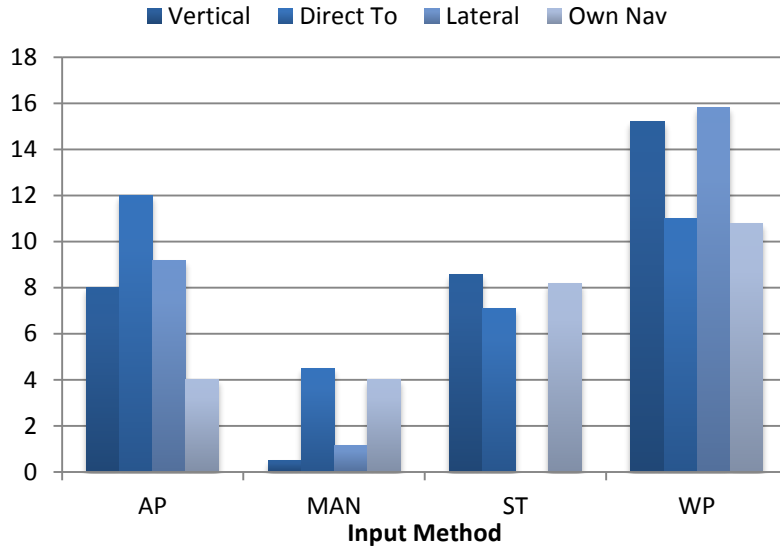
Initial Response Time ($T_2 - T_0$)



	Autopilot				Manual				Steering			Waypoint			
	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Own Nav	Vertical	Direct	Lateral	Own Nav
MEAN	0.31	-5.00	1.23	4.00	13.50	0.50	3.10	7.00	3.84	6.05	7.29	5.54	8.50	5.61	8.44
Count	10	1	75	1	2	2	40	1	46	42	104	7	2	81	6
STDEV	6.65	N/A	3.47	N/A	7.78	3.54	2.34	N/A	4.93	2.85	2.08	2.27	4.95	4.03	2.36
Min	-9.00	-5.00	-4.33	4.00	8.00	-2.00	-2.00	7.00	-6.00	3.00	3.33	2.50	5.00	-1.80	6.33
Max	13.50	-5.00	8.71	4.00	19.00	3.00	6.25	7.00	11.00	12.50	10.67	8.00	12.00	15.00	11.00



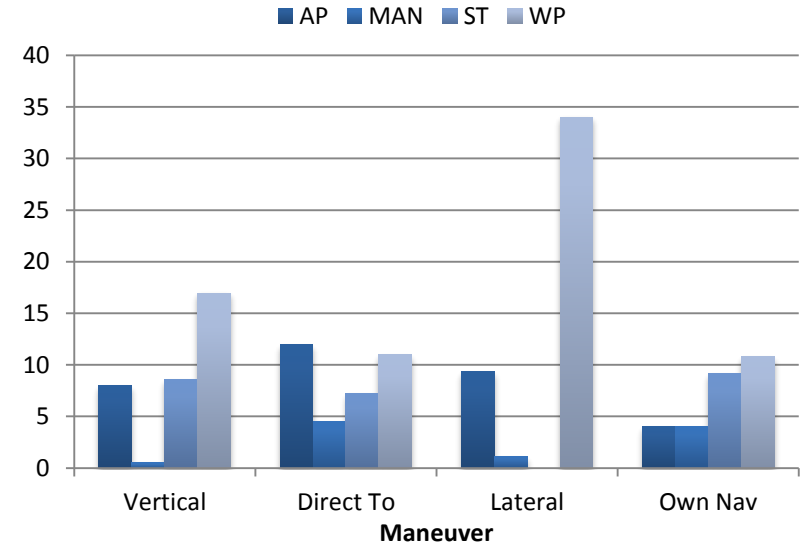
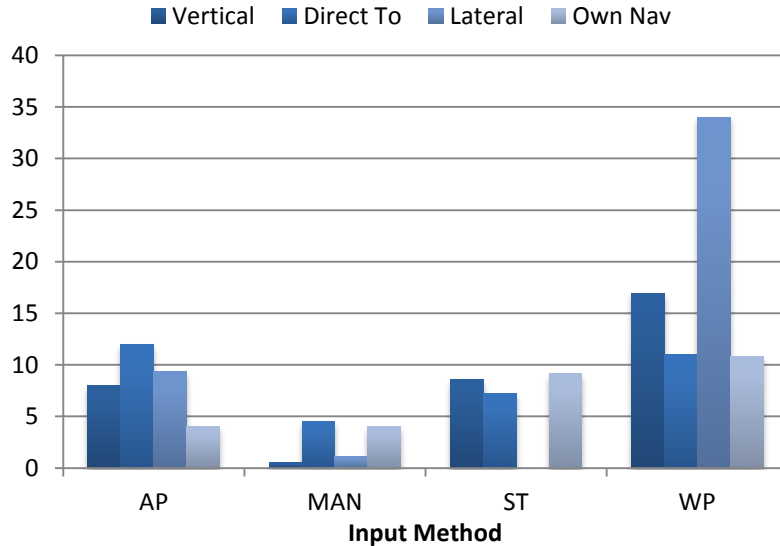
Initial Edit Time ($T_{3a} - T_2$)



	Autopilot				Manual				Steering			Waypoint			
	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Own Nav	Vertical	Direct	Lateral	Own Nav
MEAN	8.00	12.00	9.19	4.00	0.50	4.50	1.15	4.00	8.55	7.11	8.18	15.21	11.00	15.81	10.78
Count	10	1	76	1	2	2	39	1	46	43	107	8	2	79	6
STDEV	3.37	N/A	2.94	N/A	0.71	2.12	0.83	N/A	5.57	2.83	2.22	2.76	5.66	3.26	4.74
Min	3.00	12.00	6.60	4.00	0.00	3.00	0.20	4.00	4.80	3.67	4.33	13.50	7.00	10.75	5.33
Max	12.00	12.00	18.50	4.00	1.00	6.00	3.00	4.00	23.50	14.00	10.91	19.33	15.00	23.00	14.00



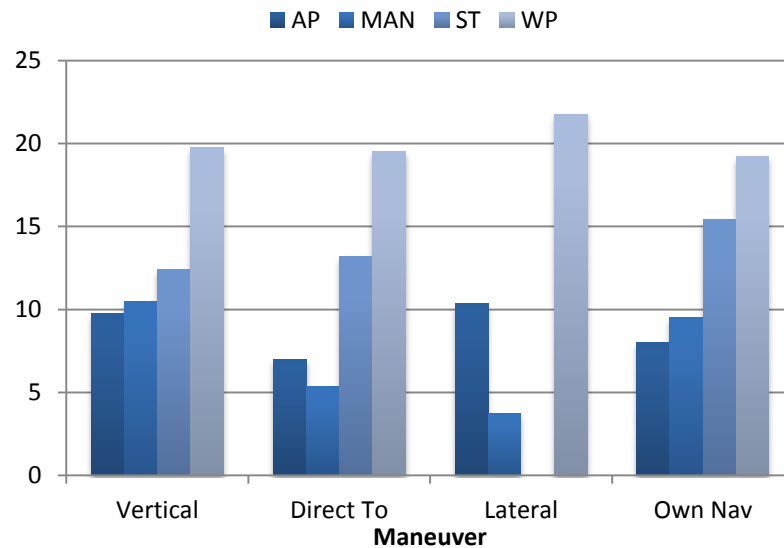
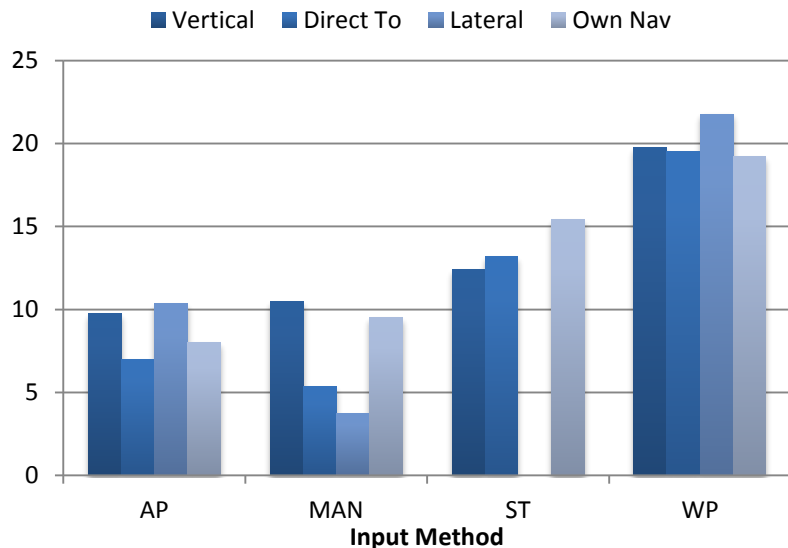
Total Edit Time ($T_{3b} - T_2$)



	Autopilot				Manual				Steering			Waypoint			
	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Own Nav	Vertical	Direct	Lateral	Own Nav
MEAN	8.00	12.00	9.34	4.00	0.50	4.50	1.15	4.00	8.55	7.23	9.16	16.96	11.00	34.02	10.78
Count	10	1	76	1	2	2	39	1	46	43	107	8	2	79	6
STDEV	3.37	N/A	2.91	N/A	0.71	2.12	0.83	N/A	5.57	2.94	3.77	3.45	5.66	11.77	4.74
Min	3.00	12.00	6.60	4.00	0.00	3.00	0.20	4.00	4.80	3.67	4.33	14.00	7.00	14.00	5.33
Max	12.00	12.00	18.50	4.00	1.00	6.00	3.00	4.00	23.50	14.00	20.00	20.50	15.00	63.00	14.00



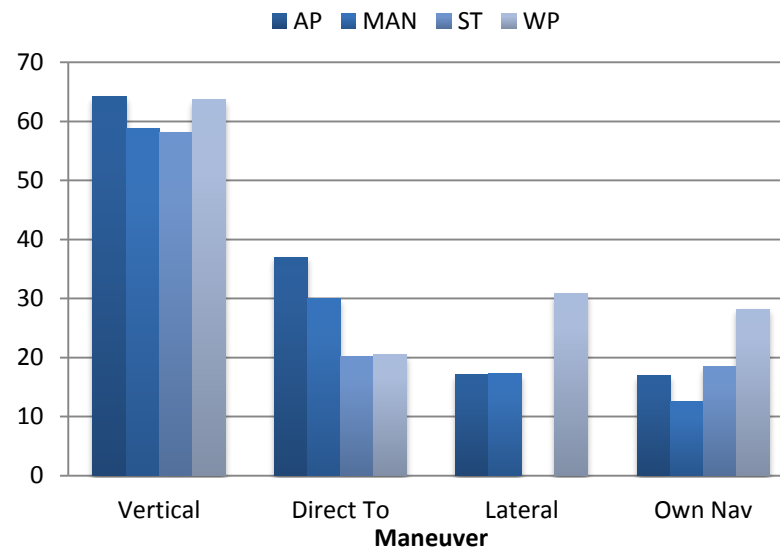
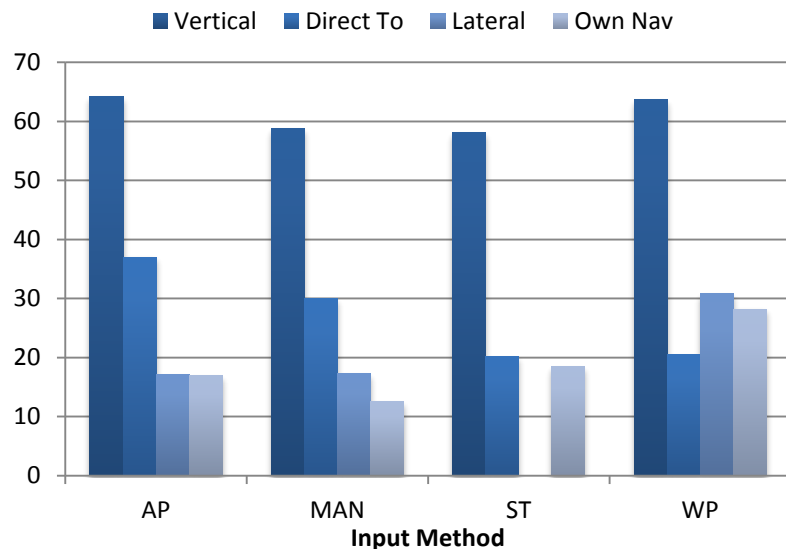
Aircraft Response Time ($T_{3a} - T_0$)



	Autopilot				Manual				Steering			Waypoint			
	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Own Nav	Vertical	Direct	Lateral	Own Nav
MEAN	9.74	7.00	10.37	8.00	10.50	5.33	3.74	9.50	12.39	13.19	15.44	19.75	19.50	21.77	19.22
Count	10	1	75	1	11	3	83	2	46	42	104	7	2	77	6
STDEV	9.55	N/A	4.12	N/A	9.73	1.15	2.32	2.12	8.55	4.50	3.08	4.50	10.61	4.39	6.84
Min	-6.00	7.00	5.33	8.00	2.00	4.00	-1.00	8.00	0.00	8.00	7.67	16.00	12.00	14.40	11.67
Max	25.50	7.00	20.50	8.00	33.00	6.00	7.00	11.00	29.00	22.50	19.08	25.00	27.00	29.00	25.00



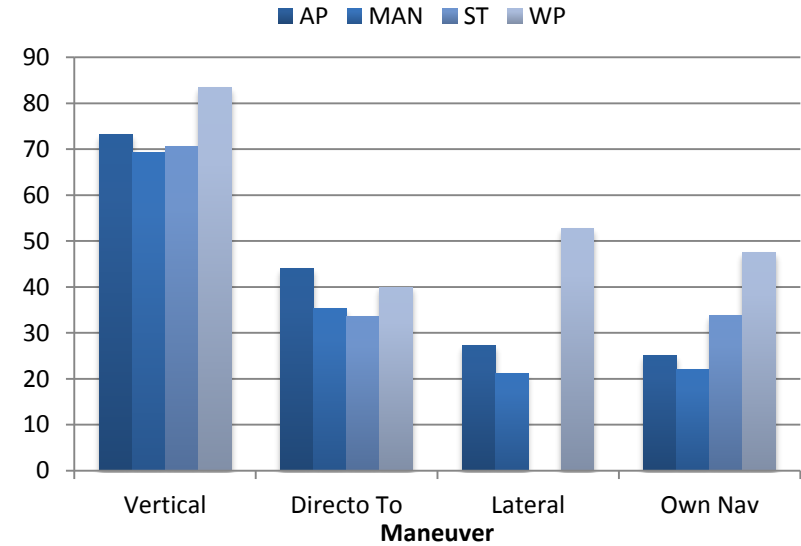
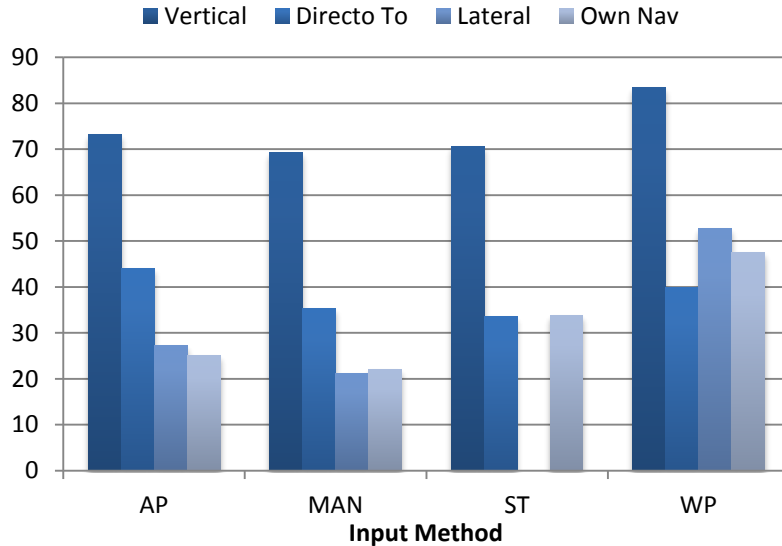
Aircraft Maneuver Time ($T_4 - T_{3a}$)



	Autopilot				Manual				Steering			Waypoint			
	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Own Nav	Vertical	Direct	Lateral	Own Nav
MEAN	64.29	37.00	17.04	17.00	58.72	30.00	17.24	12.50	58.15	20.18	18.44	63.67	20.50	30.75	28.22
Count	9	1	76	1	11	3	83	2	46	43	106	8	2	79	6
STDEV	1.11	N/A	4.13	N/A	32.58	10.00	3.56	13.44	10.15	5.02	4.16	1.41	6.36	9.33	4.30
Min	62.00	37.00	10.11	17.00	16.00	20.00	10.40	3.00	29.00	11.00	13.33	61.67	16.00	19.75	24.67
Max	65.00	37.00	25.40	17.00	114.00	40.00	23.71	22.00	65.50	29.50	29.33	65.00	25.00	56.00	33.00



Compliance Time ($T_4 - T_0$)



	Autopilot				Manual				Steering			Waypoint			
	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Lateral	Own Nav	Vertical	Direct	Own Nav	Vertical	Direct	Lateral	Own Nav
MEAN	73.24	44.00	27.30	25.00	69.22	35.33	21.17	22.00	70.55	33.56	33.81	83.42	40.00	52.69	47.44
Count	9	1	75	1	11	3	82	2	46	42	103	7	2	78	6
STDEV	7.92	N/A	5.34	N/A	37.90	10.07	4.66	15.56	15.31	8.16	5.45	3.40	4.24	10.07	10.84
Min	59.00	44.00	15.44	25.00	23.00	26.00	11.00	11.00	29.00	19.00	21.00	80.00	37.00	39.25	36.33
Max	85.00	44.00	35.80	25.00	147.00	46.00	29.71	33.00	94.50	48.50	46.67	86.67	43.00	80.50	58.00



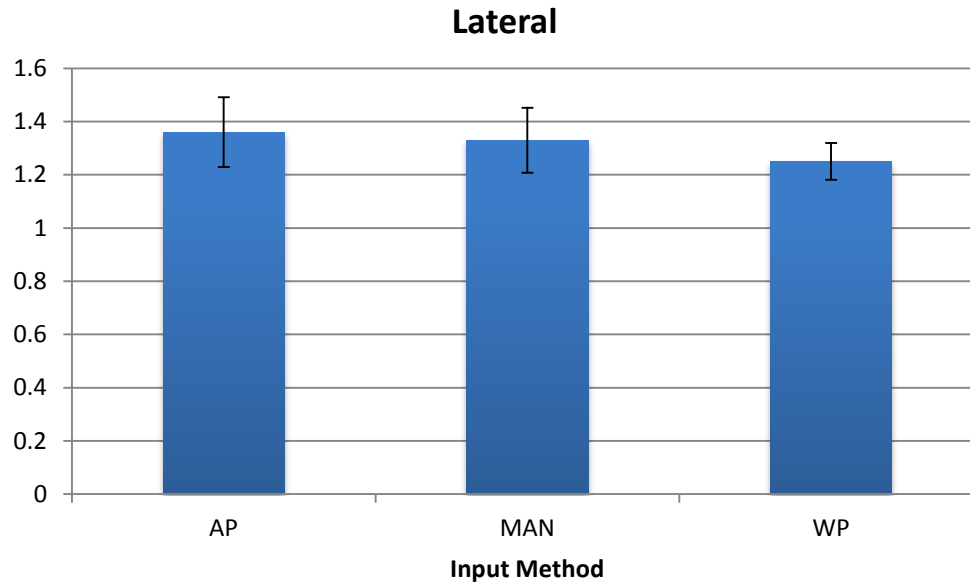
Initial Method X Maneuver Analysis



- ANOVA for Method by Maneuver subset
- *Maneuver* by Method for 295 completed maneuvers (51% of filtered data)
 - 1) Lateral = 238 (100% of all filtered lateral maneuvers)
 - 76 Autopilot (32%)
 - 83 Manual (35%)
 - 79 Waypoint (33%)



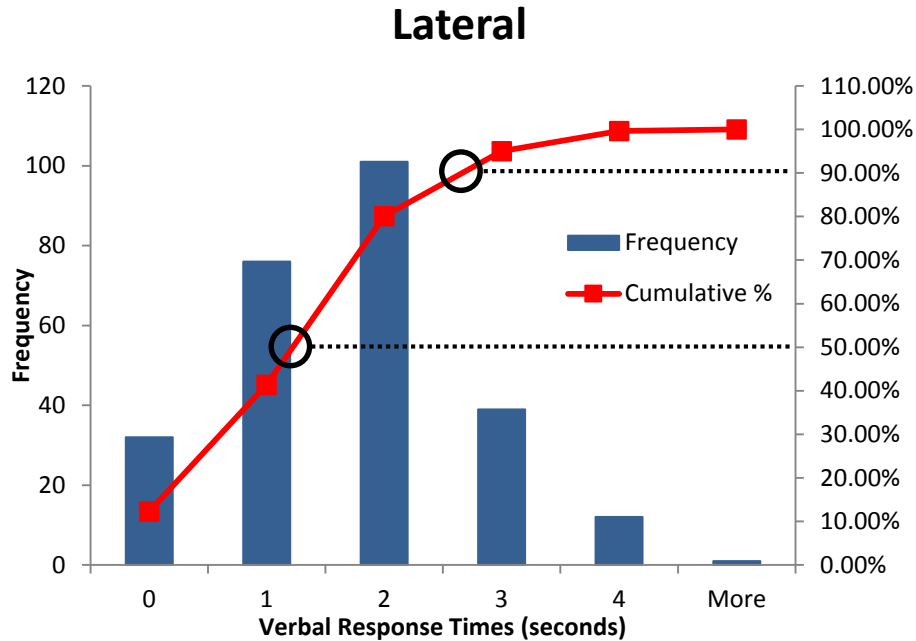
Verbal Response Time ($T_1 - T_0$)



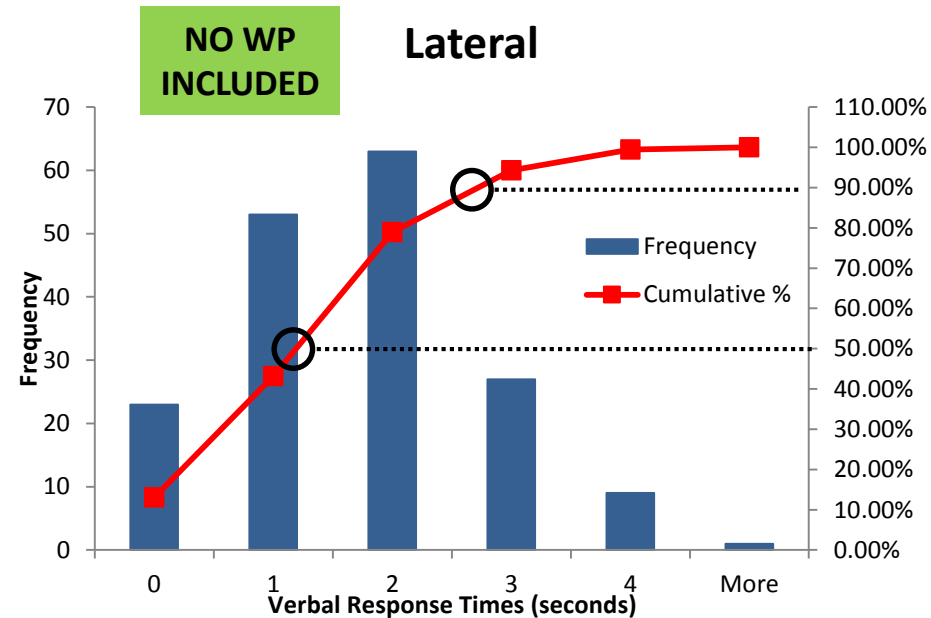
- No significant differences found between method type for lateral maneuvers
- Pilots initiated a total of 261 lateral edits in response to ATC clearances
 - Autopilot = 1.36 sec
 - Manual = 1.33 sec
 - Waypoint = 1.25 sec
 - Grand Mean = 1.31 sec



Verbal Response Time ($T_1 - T_0$)



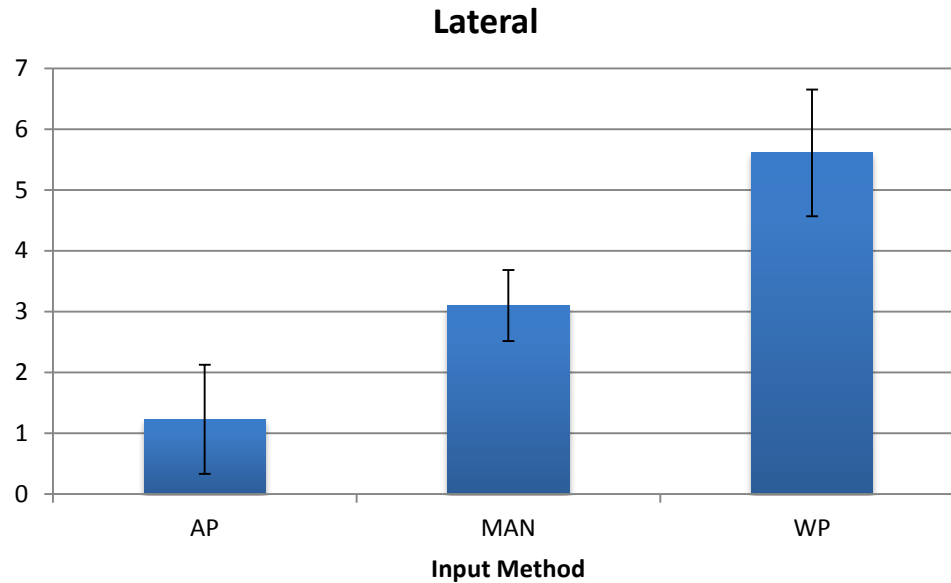
- Distribution:
 - 50% of participants replied 2 seconds or sooner following the controller's clearance
 - 90% of participants replied 3 seconds or sooner following the controller's clearance



- Distribution:
 - 50% of participants replied 2 seconds or sooner following the controller's clearance
 - 90% of participants replied 3 seconds or sooner following the controller's clearance



Initial Response Time ($T_2 - T_0$)



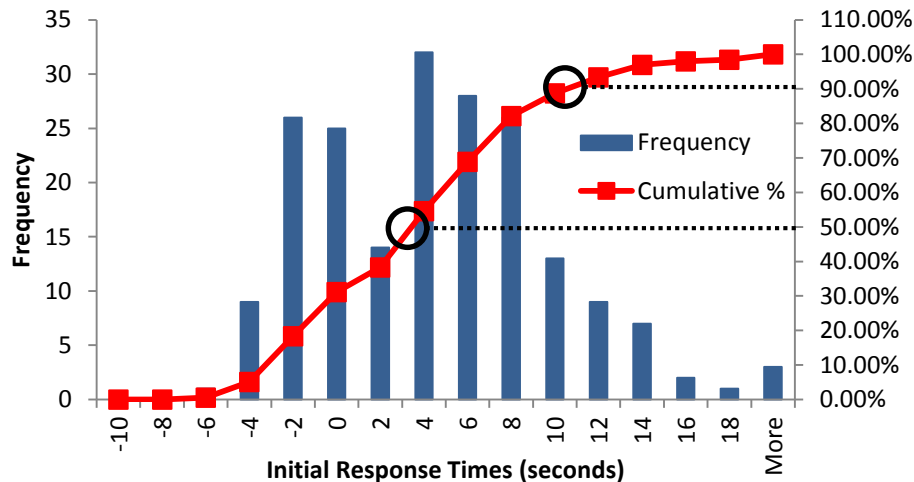
- Autopilot resulted in significantly shorter times than WP ($p < .05$) for lateral maneuvers
- Pilots initiated a total of 196 lateral edits in response to ATC clearances
 - Autopilot = 1.23 sec
 - Manual = 3.10 sec
 - Waypoint = 5.61 sec
 - Grand Mean = 3.31 sec



Initial Response Time ($T_2 - T_0$)



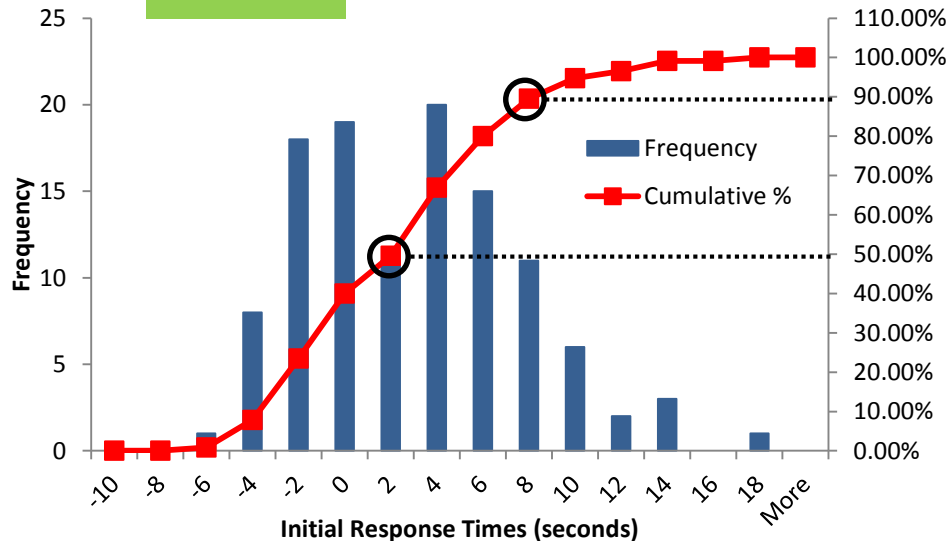
Lateral



- Distribution:
 - 50% of participants started their edit 3 seconds or sooner following the controller's clearance
 - 90% of participants started their edit at 11 seconds or sooner following the controller's clearance

**NO WP
INCLUDED**

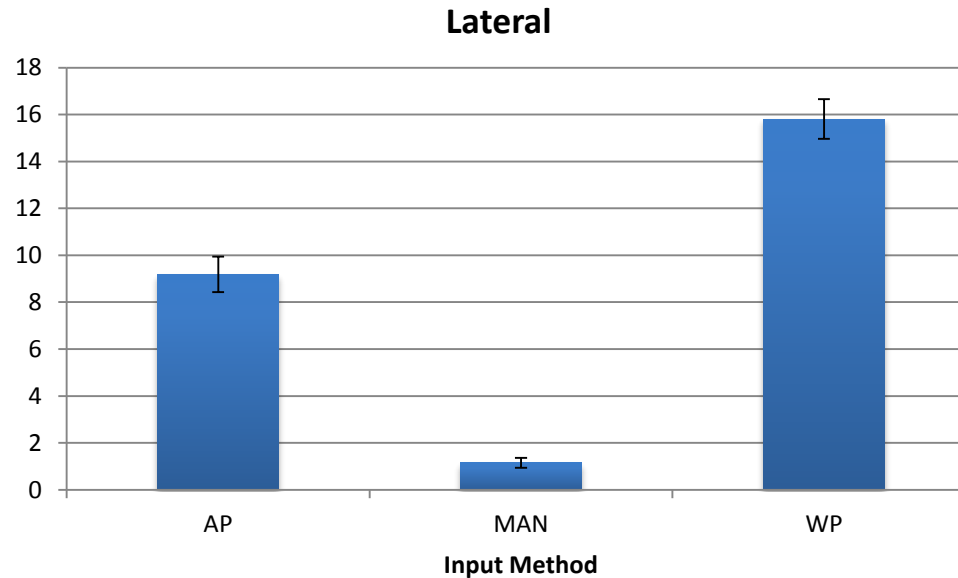
Lateral



- Distribution:
 - 50% of participants started their edit 2 seconds or sooner following the controller's clearance
 - 90% of participants started their edit at 8 seconds or sooner following the controller's clearance



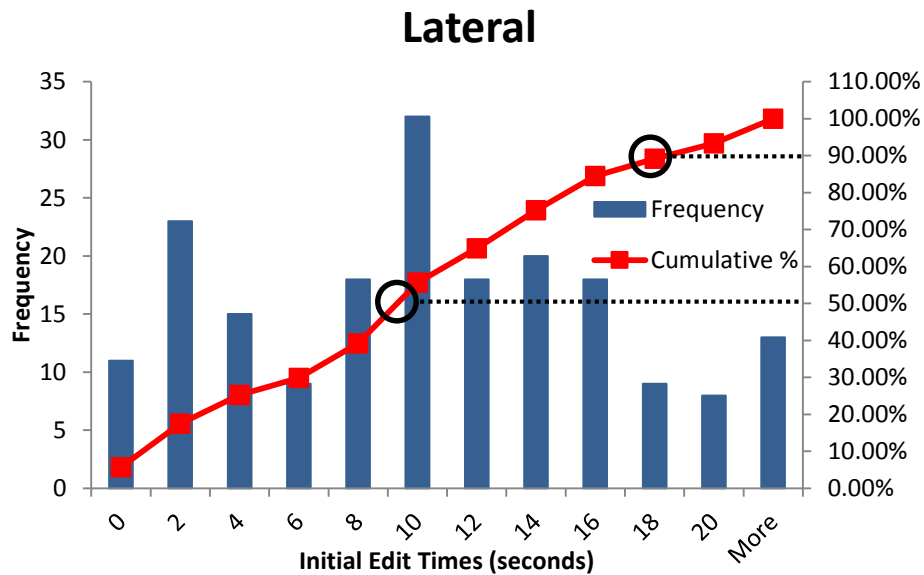
Initial Edit Time ($T_{3a} - T_2$)



- All differences between input methods were significant ($p < .01$) for lateral maneuvers
- Pilots initiated a total of 194 lateral edits in response to ATC clearances
 - Autopilot = 9.18 sec
 - Manual = 1.15 sec
 - Waypoint = 15.81sec
 - Grand Mean = 8.71 sec

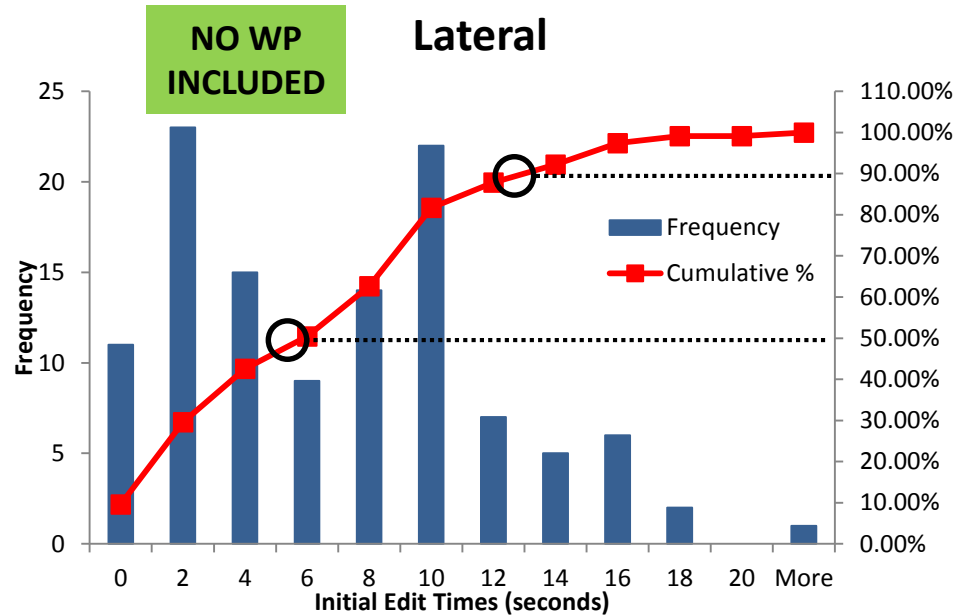


Initial Edit Time ($T_{3a} - T_2$)



- Distribution:

- 50% of participants uploaded their *initial* edit 9 seconds or sooner following the start of their edit
- 90% of participants uploaded their *initial* edit 18 seconds or sooner following the start of their edit

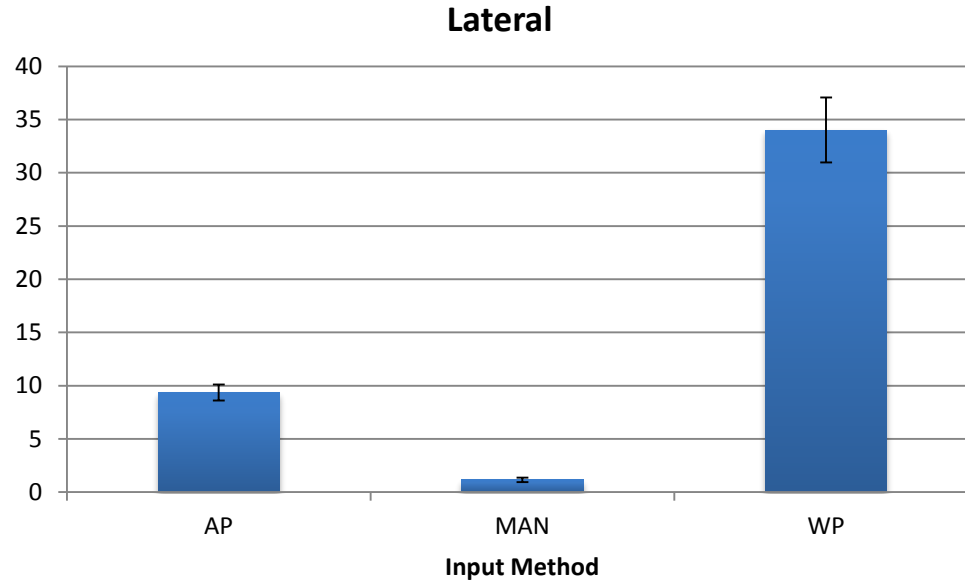


- Distribution:

- 50% of participants uploaded their *initial* edit 6 seconds or sooner following the start of their edit
- 90% of participants uploaded their *initial* edit 13 seconds or sooner following the start of their edit



Total Edit Time ($T_{3b} - T_2$)

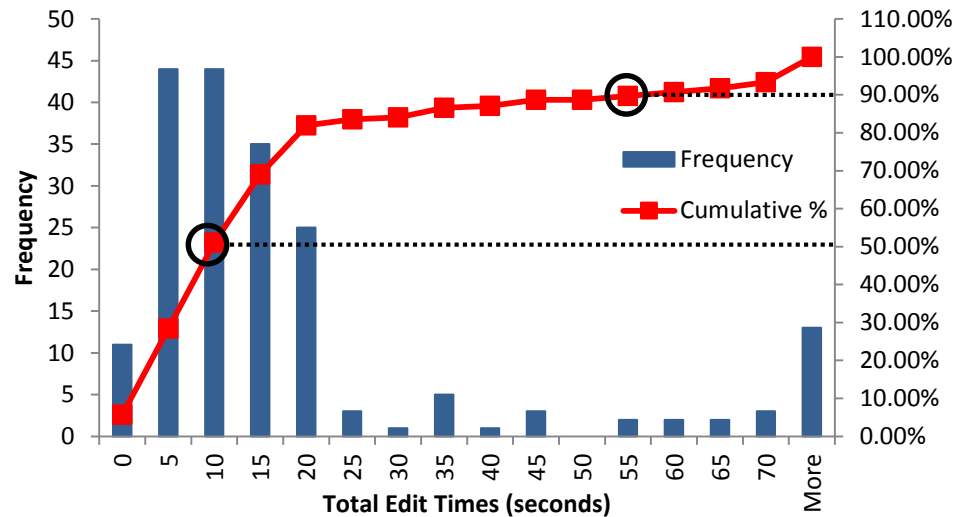


- All differences between input methods were significant ($p < .001$) for lateral maneuvers
- Pilots initiated a total of 194 lateral edits in response to ATC clearances
 - Autopilot = 9.34 sec
 - Manual = 1.15 sec
 - Waypoint = 34.02 sec
 - Grand Mean = 14.84 sec



Total Edit Time ($T_{3b} - T_2$)

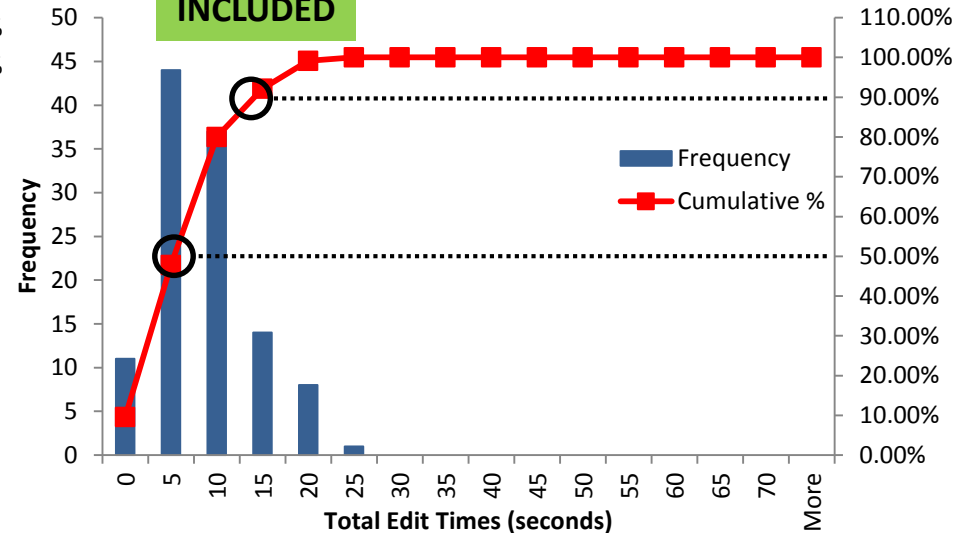
Lateral



- Distribution:
 - 50% of participants uploaded their *final* edit 10 seconds or sooner following the start of their edit
 - 90% of participants uploaded their *final* edit 55 seconds or sooner following the start of their edit

NO WP INCLUDED

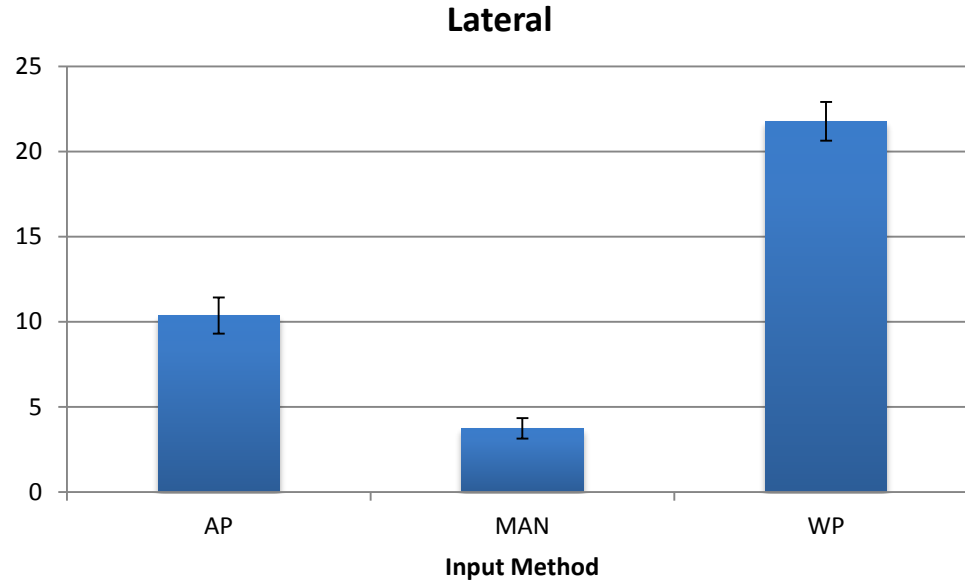
Lateral



- Distribution:
 - 50% of participants uploaded their *final* edit 6 seconds or sooner following the start of their edit
 - 90% of participants uploaded their *final* edit 14 seconds or sooner following the start of their edit



Aircraft Response Time ($T_{3a} - T_0$)



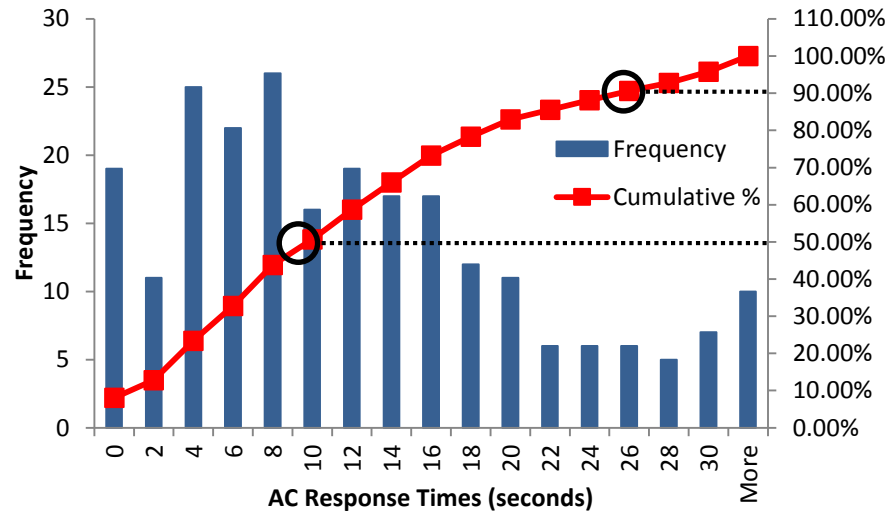
- All differences between input methods were significant ($p < .001$) for lateral maneuvers
- Pilots responded to a total of 235 lateral ATC clearances
 - Autopilot = 10.37 sec
 - Manual = 3.74 sec
 - Waypoint = 21.77 sec
 - Grand Mean = 11.96 sec



Aircraft Response Time ($T_{3a} - T_0$)



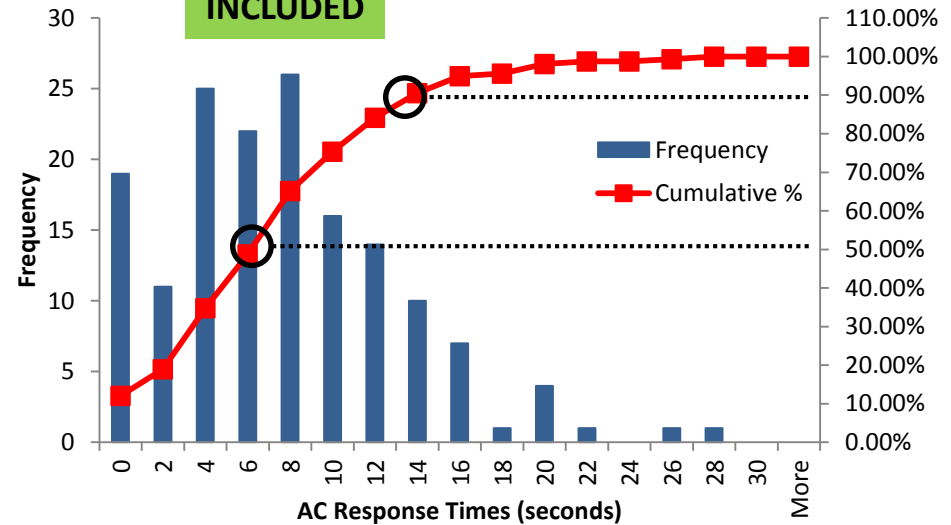
Lateral



- Distribution:
 - 50% of participants started the AC maneuver within 10 seconds of the controller's clearance
 - 90% of participants started the AC maneuver within 26 seconds of the controller's clearance upload

**NO WP
INCLUDED**

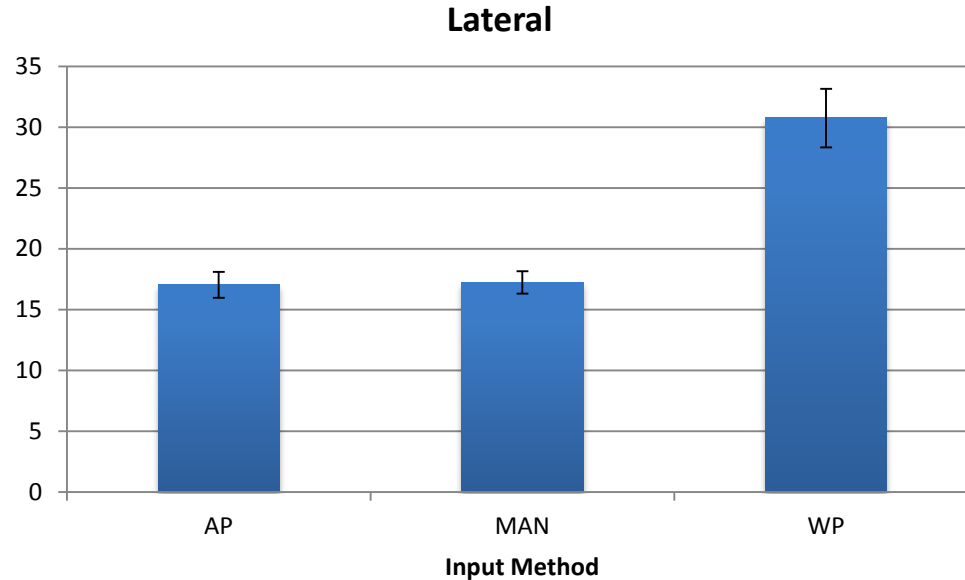
Lateral



- Distribution:
 - 50% of participants started the AC maneuver within 6 seconds of the controller's clearance
 - 90% of participants started the AC maneuver within 14 seconds of the controller's clearance upload



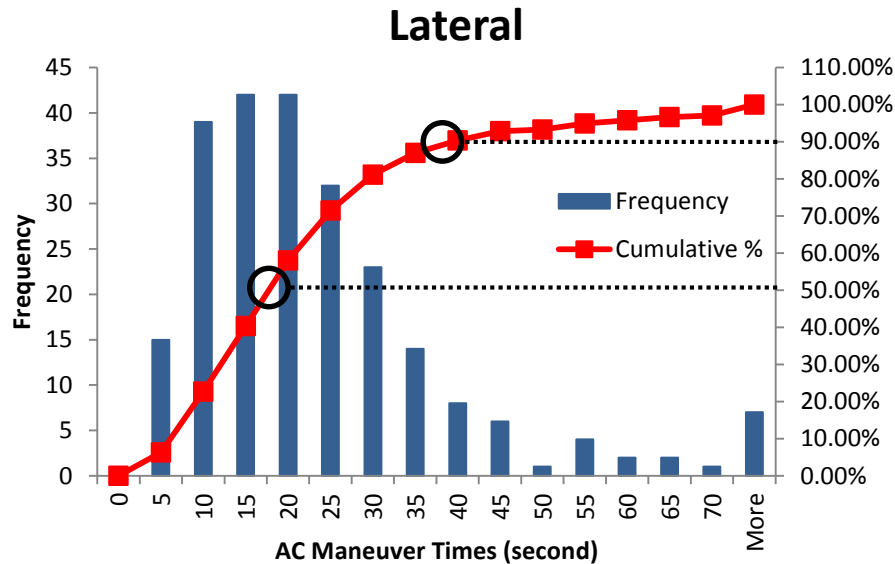
Aircraft Maneuver Time ($T_4 - T_{3a}$)



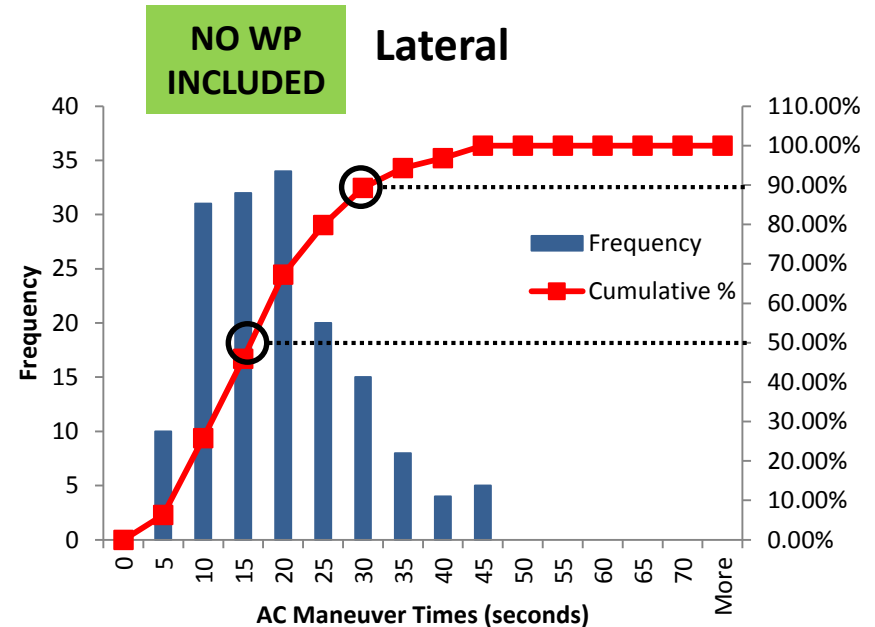
- Maneuver times for AP and MAN were both significantly shorter than WP ($p < .05$) for lateral maneuvers
- Pilots maneuvered for a total of 238 lateral ATC clearances
 - Autopilot = 17.04 sec
 - Manual = 17.24 sec
 - Waypoint = 30.75 sec
 - Grand Mean = 21.68 sec



Aircraft Maneuver Time ($T_4 - T_{3a}$)



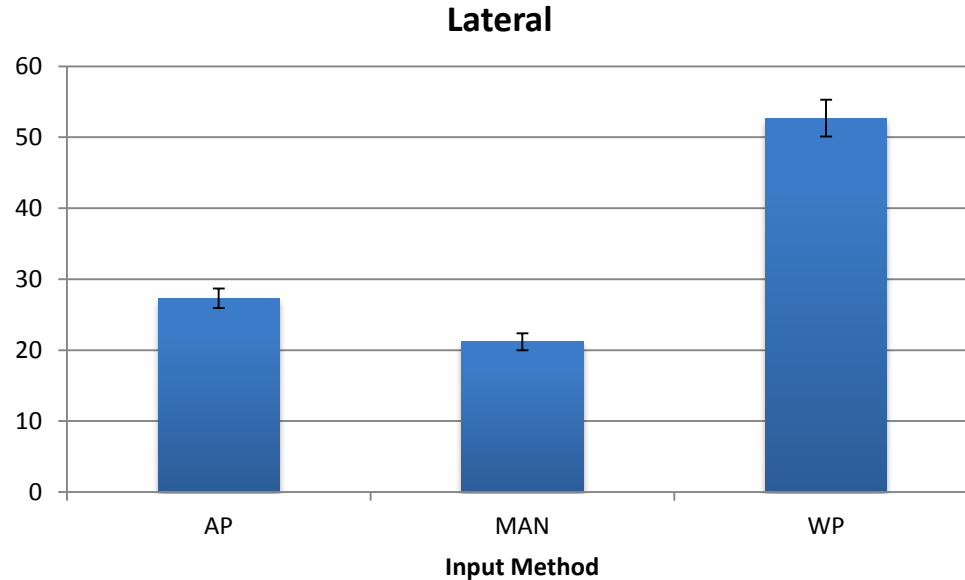
- Distribution:
 - 50% of participants completed their maneuver 18 seconds or sooner following their initial upload
 - 90% of participants completed their maneuver 40 seconds or sooner following their initial upload



- Distribution:
 - 50% of participants completed their maneuver 16 seconds or sooner following their initial upload
 - 90% of participants completed their maneuver 30 seconds or sooner following their initial upload



Compliance Time ($T_4 - T_0$)



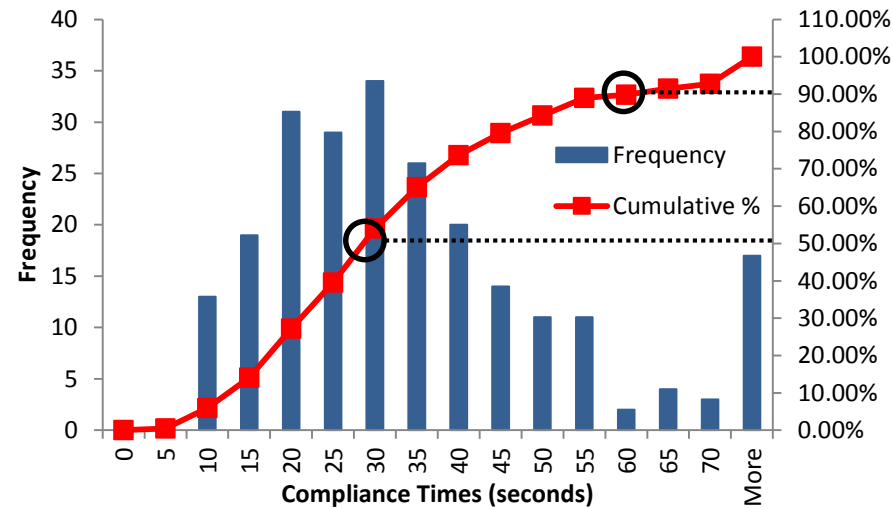
- All compliance time differences between input methods were significant ($p < .01$) for lateral maneuvers
- Pilots complied with a total of 235 lateral ATC clearances
 - Autopilot = 27.30 sec
 - Manual = 21.17 sec
 - Waypoint = 52.69 sec
 - Grand Mean = 33.72 sec



Compliance Time ($T_4 - T_0$)



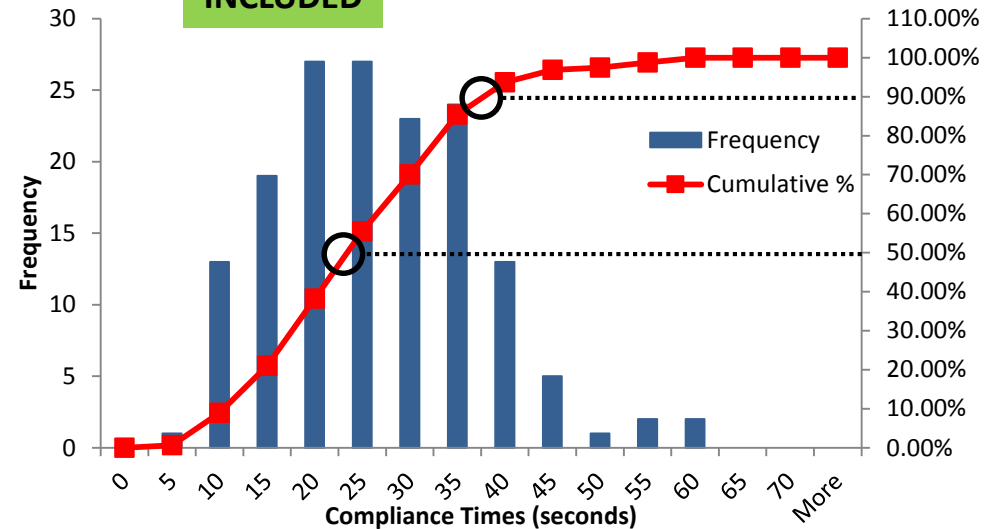
Lateral



- Distribution:
 - 50% of participants completed their maneuver 30 seconds or sooner following the controller's clearance
 - 90% of participants completed their maneuver 60 seconds or sooner following the controller's clearance

NO WP INCLUDED

Lateral



- Distribution:
 - 50% of participants completed their maneuver 24 seconds or sooner following the controller's clearance
 - 90% of participants completed their maneuver 38 seconds or sooner following the controller's clearance