

Simulator Evaluations for US Airways A320 Flight 1549 Accident, Ditching in Hudson River, 1/15/09 (NTSB # DCA09MA026)

Devices: Airbus A320 Full Motion and S22 Engineering simulators, Toulouse, France

Participants: NTSB

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Objectives:

1. To allow the NTSB Operations/Human Performance Group to familiarize themselves with the A320 cockpit, instrument displays, controls, systems, and normal takeoff/landing and emergency procedures.
2. To identify and evaluate the operational and airplane performance implications of the various options available to a flight crew following the loss of thrust on both engines. This will apply to the context of US Airways Flight 1549 and other relevant options.
3. To evaluate the A320 ENG DUAL FAILURE checklists/procedures.
4. To evaluate the operational feasibility of achieving minimum vertical speed at touchdown.

Overview:

Four airline transport pilot members of the operational factors/human performance group, three of whom was type-rated on the A320, and one of whom was an A320-rated Airbus test pilot, participated in an observational study at the Airbus Training Center in Toulouse, France, on April 14-16, 2009. The simulators used for the observations were an S22 engineering test simulator and a S31 motion-based training simulator (see next section).

The purpose of the simulations were to identify and evaluate the various options available to the flight crew of US Airways Flight 1549 following the bird strike (e.g., land at an airport or land on the Hudson River) and to determine the implications of each of those options. Additionally, the group expanded beyond the context of Flight 1549 in order to understand the implications of a dual engine failure in which the aircraft is in the EMER ELEC mode (no green or yellow hydraulics). Finally, the group evaluated the checklists and procedures made available to flight crews, as well as the operational feasibility of achieving minimum vertical speed at touchdown.

Each pilot was fully briefed on the maneuver before it was attempted. The autopilot was off for all tests. Flight scenarios were flown from zero groundspeed on the takeoff runway 4 in LGA, from a pre-programmed point shortly before the bird-strike and loss of thrust, and from 1500' above the river on approach to landing.

Initial conditions duplicated as closely as possible those of the accident flight. They were programmed into the simulator (winds, temp, altimeter, weight and balance). The profile flown duplicated as closely as possible the accident profile (airplane position, thrust setting, altitude at beginning of turns, thrust reduction and clean-up altitudes, speeds, and altitude/speed combination) up until the time of bird ingestion and dual engine failure. Following the failure, pilots followed the US Airways QRH ENG DUAL FAILURE checklist and relied on their training and experience to complete the test conditions. An observer was present to document observations, times, etc. Data from the S22 engineering simulator was recorded electronically for later review and analysis. In addition, the runs flown in the S31 motion-based simulator were recorded with a video camera mounted so as to approximate the point of view of an observer in the jumpseat.

At the completion of each condition, the pilot flying was asked to rate the difficulty of the landing on a scale of 1-7 (1 being very easy, 7 being very difficult) and to provide any comments about observations made during the scenario. In addition, one A320 test pilot and one A320 type-rated pilot completed the Cooper Harper Rating Scale at the end of each condition they performed.

Simulators:

The S31 motion-based simulator used for the evaluations was originally manufactured by CAE and delivered to US Airways. It was brought to Toulouse in the 2R34 configuration, and updated in 2008 to the 2U9B configuration. This update included installation of the HUD, and update to FADEC software. The simulator was identified globally within Airbus as 138B, and locally as simulator S31.

The S22 engineering simulator was originally installed to support the A320 iron-bird, which exists today in the same building. It was a non-motion-based simulator, with a portable visual system that moves on frictionless pads to support other simulators nearby. The S22 had been used to support system and flight control development, and to investigate safety-related events.

Tasks and Conditions:

Task 1: Perform a normal landing under the following conditions.

Configuration: Weight = 142,200 lbs.
 Landing flaps = CONF 3
 Airport elevation = 21 ft.
 Altimeter Setting = 30.25" Hg
 Outside Air Temperature = M6° C (approx. 21°F)
 Wind = 360° (true) @ 8 kts.
 Runway heading = 040° (magnetic)
 Nominal Final Approach Speed (VAPP) = 136 kts (for 142,200 lb)
 Nominal Landing Reference Speed (VREF) = 131 kts (for 142,200 lb)

All conditions began at 1000' or 1500' on approach to runway 4 at LGA.

Condition #	Airport	Runway	Flaps	Simulator
1.1	LGA	4	CONF 3	S31/Motion
1.2	LGA	4	CONF 3	S22/Fixed

Task 2: Determine physics/ability to return to an airport after a bird strike and dual engine failure.

Configuration: Weight = 151,600 lbs.
 Takeoff flaps = CONF 2
 Airport elevation = 21 ft.
 Altimeter Setting = 30.25" Hg
 Outside Air Temperature = M6° C (approx. 21°F)
 Wind = 340° (true) @ 13 kts.
 Runway heading = 040° (magnetic)
 Nominal Takeoff Decision Speed (V_1) = 140 kts (for 151,600 lb)
 Nominal Rotation Speed (V_R) = 145 kts (for 151,600 lb)

At least one condition was flown from takeoff on RWY 4 at LGA. Subsequent conditions were flown at a starting point just prior to the bird strike, a starting point around 2700' when the airplane was in a clean configuration. A pilot in the right cockpit seat was at the controls and a pilot in the left seat made the appropriate callouts prior to the bird strike. For the scenario(s) beginning from zero groundspeed, the flight had a normal departure on runway 4 and made a left turn to 360 beginning at 400'. Thrust reduction to climb detent began at about 1500' and flap retraction began at 2000'¹ (select Flaps1 at 2000', select Flaps0 at 2600'). The pilot followed flight director guidance as closely as possible for repeatability. At 3060', the flight crew experienced a bird strike and dual engine failure. The dual engine failure in the S22 simulator was simulated by reducing engine 1 to idle and seizing/failing engine 2.

For all conditions, except 2.2c and 2.3c, the left seat pilot immediately followed procedures to assume control of the airplane, alerted ATC, made an immediate turn to an airport and attempted a landing. The right seat pilot performed the QRH for ENG DUAL FAILURE and other duties assigned by the pilot flying. In these scenarios, the turn towards the airport following the bird strike was immediate in order to determine, from an aerodynamic point of view, whether the airplane had the performance to glide to a runway from the bird strike location. The immediate turn does not reflect or account for real-world considerations such as the time delay required to recognize the bird strike, and decide on a course of action. These factors are considered in Conditions 2.2c and 2.3c by incorporating a 35-second delay prior to the turn towards the airport.

For scenario 2.2c (2.3c was not performed), the left seat pilot verbalized and moved the ignition switch to IGN/START, pushed the APU Master button to ON, pushed the APU start button to ON, and assumed control of the aircraft. The right seat pilot performed the US Airways QRH ENG DUAL FAILURE checklist and other duties assigned by the pilot flying. When left seat pilot informed ATC of the emergency, s/he was instructed to make a left turn to heading 220. Thirty-five (35) seconds after the bird strike, the pilot flying was told to attempt to land at an airport based on the condition.

Condition #	Airport	Runway	Timing	Turn	Flaps	Simulator
2.1	LGA	22	Immediate	Right	Available/Pilot's discretion	S31/Motion
2.1a	LGA	22	Immediate	Right	Available/Pilot's discretion	S22/Fixed
2.1b [†]	LGA	22	Immediate	Right	Flaps 3/Slats only [^]	S22/Fixed
2.2	LGA	13	Immediate	Left	Available/Pilot's discretion	S31/Motion
2.2a	LGA	13	Immediate	Left	Available/Pilot's discretion	S22/Fixed
2.2b [†]	LGA	13	Immediate	Left	Flaps 3/Slats only [^]	S22/Fixed
2.2c [†]	LGA	13	35 seconds	Left	Available/Pilot's discretion	S22/Fixed
2.3	TEB	19/24	Immediate	Left	Available/Pilot's discretion	S31/Motion
2.3a	TEB	19/24	Immediate	Left	Available/Pilot's discretion	S22/Fixed
2.3b [§]	TEB	19/24	Immediate	Left	Flaps3/Slats only [^]	S22/Fixed
2.3c [§]	TEB	19/24	35 seconds	Right	Available/Pilot's discretion	S22/Fixed

Note: Conditions 2.1, 2.2 and 2.3 performed only once with a different pilot in each condition to provide them with the physical/motion-based cues associated with an immediate turn to an airport; [†] Condition performed only if Condition 2.1a is successful; [†] Condition performed only if Condition 2.2a is successful; [§] Condition performed only if Condition 2.3a is successful; [^] Condition assumes EMER ELEC with APU started

¹ All altitudes corrected to standard altitude + 292'

Task 3. Attempt ditching on river after a bird strike and dual engine failure.

Configuration: Same as Task 2

All conditions started at a predetermined location of 1500' above the Hudson River and 200 knots which closely replicates the location and airspeed of the accident flight. The left seat pilot was at control when the simulator was 'released' and the right seat pilot performed the US Airways QRH ENG DUAL FAILURE checklist and other duties as assigned by the pilot flying. The left seat pilot attempted to land on the river following guidance in the QRH ("touchdown with approximately 11 degrees of pitch and minimum vertical speed").

Condition #	Heading	Speed*	Flaps	Simulator
3.1	Left to 220	Green Dot	Flaps 2	S31/Motion
3.2	Left to 220	Green Dot	Flaps 2	S22/Fixed
3.3	Left to 220	Green Dot	Flaps 3	S22/Fixed
3.4	Left to 220	Green Dot	Flaps 3/Slats only [^]	S22/Fixed

^{*} Condition 3.1 will "recreate" the accident flight; [‡] Per the QRH, pilots will maintain green dot speed until configuring for landing at which time they will assume F speed on the speed tape; [^] Condition assumes EMER ELEC with APU started.

Pilot Ratings and Comments:

All participant pilots were asked to provide subjective difficulty ratings on a number of criteria (see below) at the completion of each condition in the S22 simulator. Ratings were provided on a scale of 1 to 7, with 1 being "very easy," 2 being "moderately easy," 3 being "slightly easy," 4 being "neither difficult nor easy", 5 being "slightly difficult", 6 being "moderately difficult", and 7 being "very difficult".

In addition, one A320 test pilot and one A320 type-rated pilot completed the Cooper-Harper Rating Scale for the below criteria at the completion of each condition they performed in the S22 simulator.

The following criteria will be rated:

- For landing at an airport:
 - Maintaining desired descent slope
 - Maintaining desired airspeed (green dot/F speed)
 - Configuring the airplane for landing
 - Achieving desired touchdown point
 - Completing a successful landing (minimal vertical touchdown speed, desired pitch, stopping prior to end of runway, and maintaining centerline)

- For landing on river:
 - Maintaining desired descent slope
 - Maintaining desired airspeed (green dot/F speed)
 - Configuring the airplane for landing
 - Completing a successful landing (minimal vertical touchdown speed and desired pitch)

In addition to the above ratings, an observer captured comments made by pilots relating to each condition, including the steps completed in the QRH, and the amount of time it took for the APU to start.

Data Recording:

An electronic record of the airplane state as defined by the parameters below was recorded for each scenario, and a means of identifying each scenario in the recorded file was provided. Parameters include but are not limited to altitude, airspeed, heading, angle of bank, indicated vertical speed, actual descent rate, attitude, and longitude/latitude coordinates. The identification used was time of day.

Test Log

A written test log was kept for each simulation run #, condition #, date/time, occupants of left and right seats, difficulty ratings for the left seat pilot and last item completed in the QRH by the right seat pilot. Pilot comments following each run were also included. See Table 1.

Electronic Data Files

An electronic recording of each simulation run was made. A run # or other means of identifying the recorded data with the runs noted in the run log were included in the electronic file. Parameters recorded are listed below.

List of Simulator Parameters Recorded:

- Gross weight
- Wind direction
- Wind speed
- Temps (H)
- Gear position up/down
- Air brakes lever
- Auto-thrust active/non-active
- Auto-thrust engaged/non-engaged
- Auto pilot on/off
- Normal law on/off
- Direct law on/off
- Alternate law on/off
- Ground law on/off
- High AoA protection law on/off
- AoA floor on/off
- Associated speed to stall warning from FAC1
- Associated speed to AoA protection from FAC1
- Associated speed to maximum AoA from FAC1
- Maximum operating speed protection on/off
- Maximum Mach speed protection on/off
- Corrected AoA from ADC1
- Pitch captain side stick deflection
- Pitch first officer side stick deflection
- Roll captain side stick deflection
- Roll first officer side stick deflection
- Left elevator deflection
- Right elevator deflection
- Trim horizontal stabilizer deflection
- Flap deflection
- Pedal deflection
- Rudder deflection
- Left spoiler 3 deflection
- Right spoiler 3 deflection
- Rudder limiter position
- Flight path angle from Adirs1
- Height from radio-altimeter 1
- N1 from engine 1 (left engine)
- N1 from engine 2 (right engine)
- Vertical load factor at A/C CG location (from flight mechanics model)
- Vertical load factor at IRS1 location (from IRS model)
- Filtered body pitch rate from IRS1
- Slat deflection
- Filtered pitch angle from ADIRU1
- Engine 1 throttle Lever Angle
- Calibrated airspeed from ELAC1
- Calibrated airspeed from ADR1
- Lowest speed from FAC1
- True airspeed from ADR1
- Vertical speed at A/C CG location (from flight mechanics model)
- Vertical speed at IRS1 location (from IRS model)

- SEC1 fault signal
- SEC2 fault signal
- SEC3 fault signal
- ELAC1 fault signal
- ELAC2 fault signal
- Blue hydraulic fault signal from ELAC1
- Green hydraulic fault signal from ELAC1
- Yellow hydraulic fault signal from ELAC1
- Double pressurization on elevators on/off
- Lift dumper extension on/off
- Engine 1 reverse deployed/non-deployed
- Engine 1 reverse activated/non-activated
- Longitudinal A/C centre of gravity location
- Lateral A/C centre of gravity location
- Altitude from ADC1
- Estimated air sideslip angle from ELAC1
- Target air sideslip angle from ELAC1
- Air sideslip angle from flight mechanics model
- Yaw damper feedback from FAC1
- Yaw damper feedback from FAC2
- Rudder trim actuator position from FAC1
- Lateral load factor at A/C CG location (from flight mechanics model)
- Body roll rate from flight mechanics model
- Filtered roll angle from ADIRS1
- True heading from ADIRS1
- Body yaw rate from flight mechanics model
- Net thrust differential between eng1 and eng2
- Lowest speed from FAC2
- Angle of attack from ELAC1
- Value of maximum AoA from ELAC2
- Value of AoA protection from ELAC2
- Ground speed from flight mechanics model

Results – Simulator Evaluations:

To accommodate the most efficient use of simulator time, the starting point of runs varied slightly from the proposed plan. Details of each run are outlined in Table 1. Additionally, flight path angles for each run and subjective pilot ratings are depicted graphically in Figures 1-3. Finally, plots were made which depict airspeed, altitude, pitch angle, normal load factors, flight path angle and vertical speed (see Appendix 1).

Task 1: Perform a normal landing under the following conditions.

All pilots were able to achieve a successful landing in both the S31 and S22 simulators (see Table 1). Flight path angle at touchdown ranged from -0.8 degrees to -1.3 degrees (see Figure 1).

Task 2: Determine physics/ability to return to an airport after a bird strike and dual engine failure.

A total of 20 runs were performed in the S22 simulator in which pilots attempted to return to LGA runways 13 or 22, or attempted to land at TEB runway 19. Five of 20 runs (25%) were discarded due to poor data or simulator malfunctions, leaving 15 runs for analysis (6 runs to LGA runway 22, 7 runs to LGA runway 13, and 2 runs to TEB runway 19). Eight of 15 runs (53%) made successful landings. The 8 successful runs were made following an immediate turn to an airport after the bird strike. See Table 1 for details of each run.

Specifically, six runs were made to return to LGA runway 22 immediately following the bird strike. Of those six, two (33%) resulted in a successful runway landing – one using flaps at the pilot's discretion (condition 2.1a; one additional attempt was unsuccessful) and one using slats only (condition 2.1b; four additional attempts were unsuccessful). Due to inadequate successful landing attempts following an immediate turn after the bird strike, attempts to land at LGA runway 22 after a 35 second delay (condition 2.1c) were not performed.

Additionally, pilots attempted to land at LGA on runway 13. All four pilots successfully landed (100%) on LGA runway 13 following an immediate left turn to the airport following the bird strike (condition 2.2a). Two runs were attempted in which the pilot was required to use slats only on landing on runway 13

(condition 2.2b). One landing (50%) was successful and one landing was not successful, requiring the pilot to ditch in the waters adjacent to LGA. The one attempt to return to LGA runway 13 following a 35 second delay (condition 2.2c) was not successful. No additional attempts were made to return to LGA runway 13.

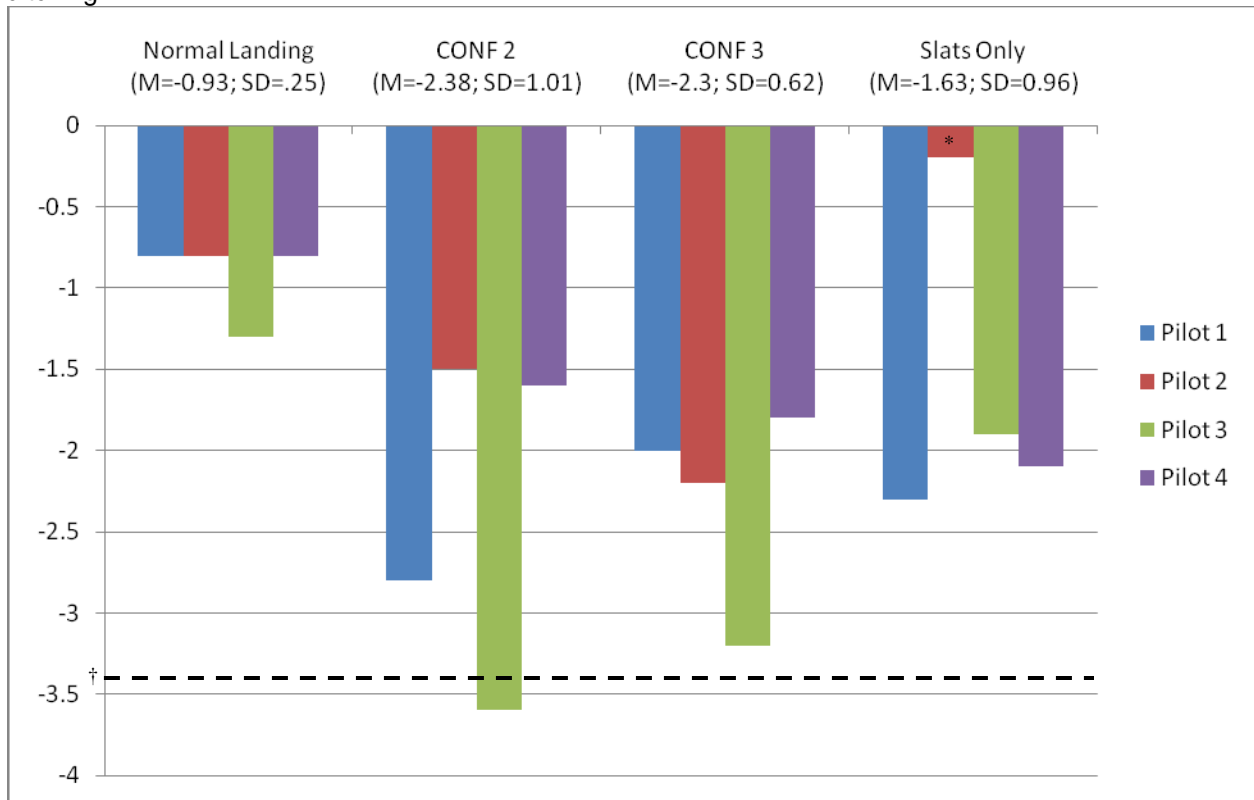
Finally, two runs were attempted to determine the ability of the airplane to land at TEB runway 19 immediately after the bird strike. In both runs, pilots were able to use flaps at their discretion (condition 2.3a). One attempt (50%) was successful and one attempt was unsuccessful. Due to inadequate successful landing attempts following an immediate turn, conditions 2.3b and 2.3c were not attempted.

Task 3. Attempt ditching on river after a bird strike and dual engine failure.

A total of 16 runs were performed in the S22 simulator in which pilots attempted to ditch the airplane, of which two were discarded due to poor data. Each of the four pilots attempted a landing under each of the three conditions – using CONF 2 (condition 3.2), using CONF 3 (condition 3.3) and using CONF 3/Slats only (condition 3.4). The flight path angles of each of these runs are presented in Figure 1. See Table 1 for details of each run.

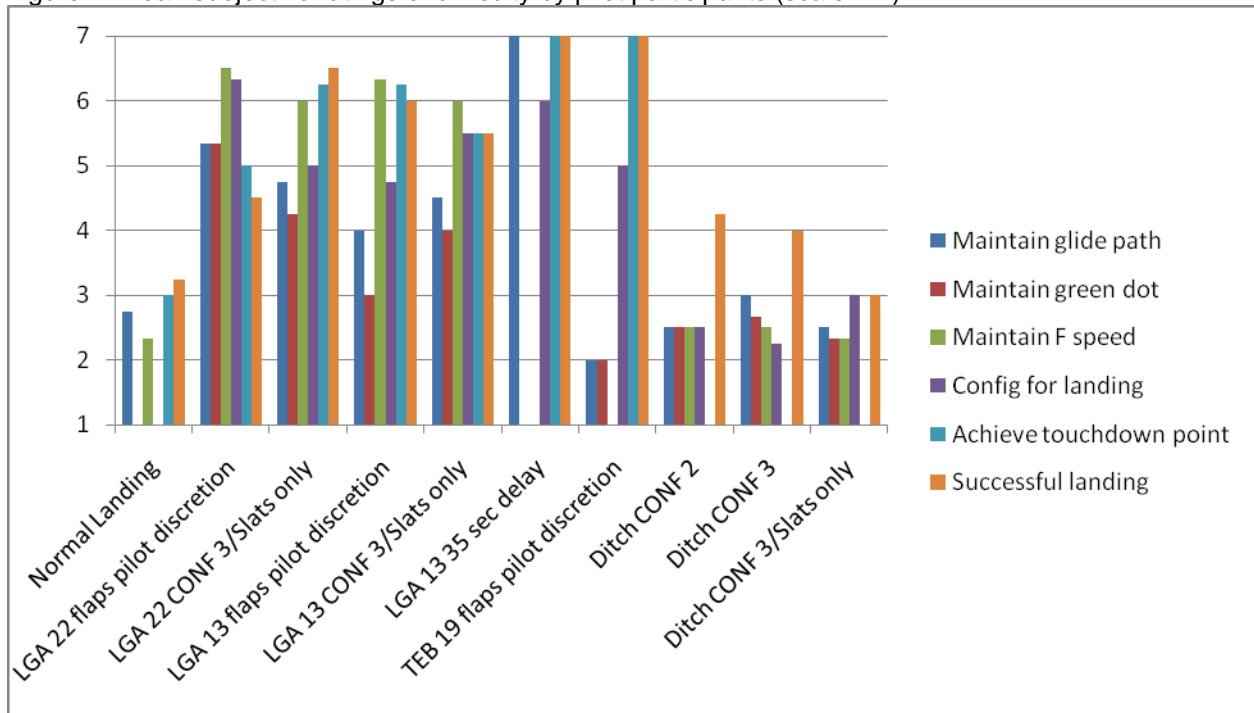
In addition, two runs were attempted in which the pilot flying was instructed to fly within the flight envelope protection range (i.e., alpha protection) to understand the impact of such conditions on the flight path angle. The flight path angles at touchdown for the landings were -6.5 and -6.3 degrees.

Figure 1. Flight path angles (in degrees) for a normal landing and different airplane configurations for ditching



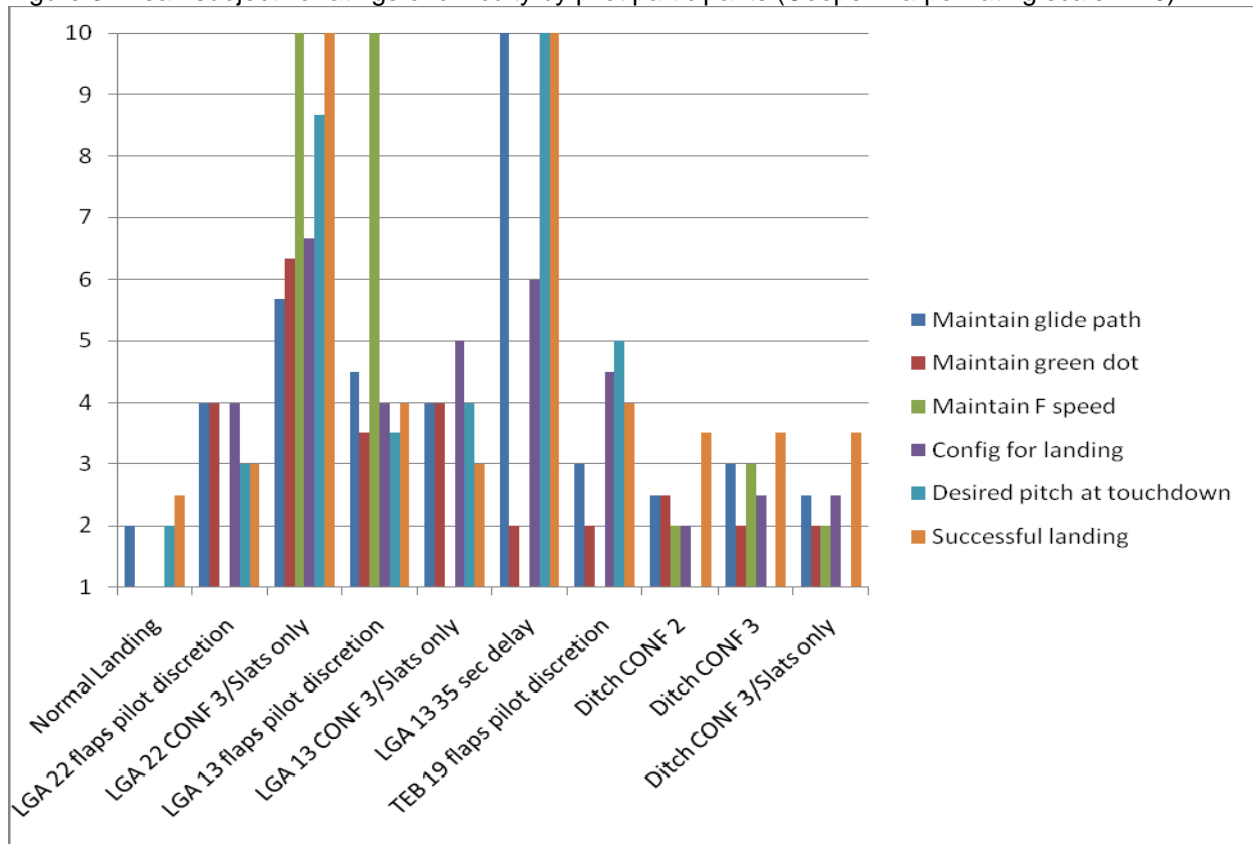
Note: M=mean; SD=standard deviation. Flight path angle calculated by “ $\tan^{-1}(\text{vertical speed} / \text{ground speed})$ ”;
 * Different landing technique flown to attempt to achieve lowest vertical descent rate possible at touchdown; † Flight path angle (-3.4 degrees) of flight 1549

Figure 2. Mean subjective ratings of difficulty by pilot participants (scale 1-7)



Note: no rating indicates that pilot participants found the criteria not applicable for a run or data was missing

Figure 3. Mean subjective ratings of difficulty by pilot participants (Cooper-Harper rating scale 1-10)



Note: no rating indicates that pilot participants found the criteria not applicable for a run or data was missing

Results – Observations:

In addition to the simulator evaluations, an observation was also made in the full motion simulator of the Airbus dual engine failure training, as well as an observation of the accident scenario using the Airbus QRH ENG DUAL FAILURE checklist.

Dual engine failure training

Two participant pilots were provided with instruction on a dual engine failure by an Airbus flight instructor. The exercise began at flight level (FL) 350 in which both engines failed. The right seat pilot was the pilot flying and immediately after the failure the left seat pilot took over the controls. The right seat pilot performed the Airbus QRH ENG DUAL FAILURE checklist. The instructor guided the pilots through the checklist and procedures. One engine restarted at FL 190 and the exercise ended. Observations revealed how emergency situations can lead to minor errors when performing the checklist. Specifically, the right seat pilot lost his place in the checklist after looking away from the checklist; and the right seat pilot only cycled the master switches on and off one time. The latter observation revealed a confusion point in the checklist for the pilot. The Airbus checklist (as well as the US Airways checklist) stated that “Unassisted start attempts can be repeated until successful, or until APU bleed is available.” The discussion surrounding this statement indicated that “can be repeated” did not imply that it “should” be repeated as would be appropriate in the scenario.

Use of Airbus QRH ENG DUAL FAILURE checklist during simulated accident scenario

In the accident scenario, the flight crew of flight 1549 were able to perform the checklist to the point of cycling the engine master switches off and then on one time. To understand how improvements could be made to the checklist, two Airbus instructors flew the accident scenario in the full motion simulator and used the Airbus QRH ENG DUAL FAILURE checklist to determine how far the pilots could get in the checklist before landing on the river. The instructors were able to switch on the APU bleed and cycled the engine master switches off and on two times (once before the APU bleed started and one time after). At that point, the instructors skipped the remaining relight checklist items and performed the ditching checklist for engines without power.

Additional observations made of the pilots were the pilot flying was about 10-15 knots below green dot. The pilot flying indicated that he went to his instinct of what attitude the airplane should be at rather than airspeed. At 1700' above ground level (agl), the crew extended flaps 1. The pilot flying indicated that he did this because he knew the airplane was below green dot and he wanted time and to increase the stall margin. The crew had flaps 3 extended by 200' agl. Statements made by the instructors were "it was hard to find relevant items" in the checklist and "the river is seductive".

Table 1. Simulator Test Run Log

Run #	Cond. #	Date/ Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
1	1.1	4/14/09 09:00:04	Land: 3	Pilot 1						Pilot 2			<u>Start point:</u> 1500' on approach <u>Observations:</u> $V_{LS} = 139$; successful landing
2	2.1	4/14/09 09:11:32	T/O: 2 Land: 2	Pilot 1						Pilot 2			<u>Start point:</u> takeoff from runway 4 at LGA <u>Observations:</u> Terry programming FMS – DCA as destination to have departure guidance. LGA VOR on NAV page for reference for right turn to runway 22; Not immediate turn, turned on APU; Not on green dot during portions of flight. Will try again, maintaining green dot; Crash just short of runway; Takes some time to reset simulator after crash. Issue with getting simulator gear doors to close. <u>Comments:</u> “Maybe called for flaps too early”; “Altitude over water is difficult to judge”; “Once lights were in sight, I went below green dot”; “Natural tendency to pull up”
3	2.1	4/14/09 09:46:25	T/O: 2 Land: 2	Pilot 1						Pilot 2			<u>Start point:</u> takeoff from runway 4 at LGA <u>Observations:</u> Will try to take a “snapshot” just before bird strike so as to return to this point easily next time; Immediate turn with no immediate APU start, try to maintain green dot; Did not use spoilers. Snapshot position: 4050.9N 0735.2 W; Alt 3160. Per Airbus, simulator does not compensate for temperature, so true vs. indicated may not be accurate here; Made back to runway, but overrun. <u>Comments:</u> “Configured too early last time”; “Didn’t realize I was high until last few seconds”
4	1.1	4/14/09 10:08	Land: 3	Pilot 3						Pilot 2			<u>Start point:</u> 1500' on approach <u>Observations:</u> Pilot 3 asks for VASI lights to be turned on; stopped on runway <u>Comments:</u> “Lights hard to see”; “Hard to distinguish runway from taxiway in visuals”.

Run #	Cond. #	Date/ Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
5	2.2	4/14/09 10:12:09		Pilot 3						Pilot 2			<u>Start point:</u> takeoff from runway 4 at LGA <u>Observations:</u> TOGA locked at takeoff; Pilot 2 flies takeoff; Something happened with thrust (alpha floor protection activated) – got engines back, energy profile off; crashed short of runway; Run no good
6	2.2	4/14/09 10:18	Land: full	Pilot 3						Pilot 2			<u>Start point:</u> snapshot at 3160' just before bird strike <u>Instructions:</u> Pilot 3 instructed to make an immediate turn, no immediate APU start <u>Observations:</u> Pilot 3 did not use spoilers; Stopped just before end of runway overrun area <u>Comments:</u> "Without runway lights it was hard to find"; "Felt too fast for getting things out"; Pilot 2 "pointed out runway which helped"
7	3.1	4/14/09 12:25	Land: 2	Pilot 3						Pilot 2			<u>Start point:</u> snapshot at 3160' just before bird strike <u>Observations:</u> Gear was out at beginning of run so run stopped.
8	3.1	4/14/09 12:27	Land: 2	Pilot 3						Pilot 2	Master on/off		<u>Start point:</u> snapshot at 3160' just before bird strike <u>Observations:</u> Pilot 2 canceled warning; Ditching flaps 2, pitch 11, rate of descent very gradual; stopped on runway <u>Comments:</u> "I hugged the right side of the Hudson like crew did"; "Held green dot until low which gave me more time"
9	1.1	4/14/09 12:41	Land: 3	Pilot 4						Pilot 2			<u>Start point:</u> 1500' on approach <u>Observations:</u> Run stopped
10	1.1	4/14/09 12:46	Land: 3	Pilot 4						Pilot 2	N/A		<u>Start point:</u> 1500' on approach <u>Observations:</u> stopped on runway

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
11	2.2	4/14/09 12:51	T/O: 2 Land:	Pilot 4						Pilot 2	Master on/off		<u>Start point:</u> takeoff from runway 4 at LGA <u>Instructions:</u> Pilot 4 instructed after bird strike, start ignition, start APU, assume control then turn 15 seconds (after bird strike). <u>Observations:</u> Very low on turn to final and final approach, overshoot turn to runway but made runway and stopped well short of end. <u>Comments:</u> "A crew would never turn that soon"
12	1.2	4/14/09 14:38	Land: 3	Pilot 1	2 2	G:x;F:x G:1;F:1	NA NA	2 2	1 2	Pilot 2	NA	-0.8	<u>Start point:</u> 1000' on final approach to runway 4 <u>Comments:</u> "Floated a little with CONF 3"
13	2.2a	4/14/09 14:51	Land: 2	Pilot 1						Pilot 2			<u>Start point:</u> snapshot at 3160' just before bird strike <u>Observations:</u> Had to set altitude from 2800 ft to 3060 ft indicated; QNH: 1024; Crash short of runway. <u>Comments:</u> "Runway very hard to see"; "Aimed for wrong runway"
14	2.2a	4/14/09 14:57	Land: 2	Pilot 1						Pilot 2			<u>Start point:</u> snapshot at 3160' just before bird strike <u>Observations:</u> Repeat, put LGA at top of NAV to find airport; Not valid starting point and ended up 700' above runway; For next run, will build a waypoint to aim for (4050.8863 N 7352.5653 W); This same as previous bird strike; something else must have been wrong with this run.
15	2.2a	4/14/09 15:13	Land: 2	Pilot 1	4 5	G:3;F:10 G:3;F:7	5 6	5 6	5 6	Pilot 2	Cycled 1 off/on Used FAC		<u>Start point:</u> bird strike: 4050.8863N: 07352.5653W <u>Observations:</u> No APU; Put in ILS info; Landed left of center line but stopped before end of runway <u>Comments:</u> "Shooting for first 1/3 of runway"; "Difficult to judge altitude to configure at because of visuals"

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
16	2.1b	4/14/09 15:30	Land: 2 (slats)	Pilot 1	6 6	G:8;F:10 G:6;F:7	5 5	6 6	10 7	Pilot 2	Cycled 1 off but not on FAC		<u>Start point:</u> bird strike <u>Observations:</u> Intended 2.1a, ended up being 2.1b.; true EMER ELEC condition because RAT did not deploy; simulator switched to alternate law which resulted in a stall warning; Made runway but couldn't stop before end; did brakes not work because RAT not deployed and no hydraulics? <u>Comments:</u> "Easy to hold green dot until I looked outside"; "Standing on brakes but little effect"
17	2.1a	4/14/09 15:46	Land: 2	Pilot 1	4 5	G:4;F:NA G:5;F:NA	4 6	3 3	3 2	Pilot 2	Cycled 1 and 2 off/on		<u>Start point:</u> bird strike <u>Instructions:</u> Pilot 2 instructed to start APU right away to be sure don't get into EMER ELEC. Also started ignition <u>Observations:</u> used speed brakes; used trim; Made runway, stopped well before end. <u>Comments:</u> "Hard to judge short final and altitude over water, and when to configure for landing"
18	2.1b	4/14/09 15:57	Land: 2 (slats)	Pilot 1	2 2	G:3;F:NA G:2;F:NA	7 5	10 7	10 7	Pilot 2	Cycled FAC		<u>Start point:</u> bird strike <u>Observations:</u> EMER ELEC condition; no APU or ignition start; way too much energy, touchdown far down runway, and overrun; used speed brake; Pilot 1 didn't remember gear down; Pilot 2 remembered but no hydraulic pressure to get them down and no time for emergency extension by time realized. Not a "quirk" of the simulator, but reflects real-world behavior.
19	2.1a	4/14/09 16:13	Land: 1	Pilot 3	6	G:6;F:7	6	NA	NA	Pilot 1	Cycled 1/2 on/off		<u>Start point:</u> bird strike <u>Observations:</u> LGA preprogrammed; not a successful landing, crashed short. <u>Comments:</u> "Shouldn't have done flaps so early"; "No motion so I thought I was closer"

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
20	2.2a	4/14/09 16:21	Land: 3	Pilot 3	3	G:3;F:6	4	7	NA	Pilot 1	Cycled 1/2 on/off		<u>Start point:</u> bird strike <u>Observations:</u> used speed brake; made runway; funny thing happened in pitch following touchdown (sort of somersault). Much higher here than in motion simulator, and didn't use all flaps. <u>Comments:</u> "hard without motion"; "Didn't like that touchdown was too early"; "Shouldn't have used speed brake"; "Don't like no motion"
21	2.1b	4/14/09 16:32	Land: 1 (slats)	Pilot 3	4	G:3;F:5	4	5	5	Pilot 1	Cycled 1/2 off		<u>Start point:</u> bird strike <u>Observations:</u> Not true EMER ELEC b/c #1 not failed just at idle; Made runway, stopped on runway. <u>Comments:</u> "Simulator hard to fly. Not like simulator, not like airplane"; "Deceleration on runway unrealistic" (even for degraded condition); "Secret is to "configure late.""
22	1.2	4/14/09 16:41	Land: 3	Pilot 3	3	G:NA;F:3	NA	4	5	Pilot 1	NA	-1.3	<u>Start point:</u> bird strike <u>Observations:</u> None
23	1.2	4/14/09 16:56	Land: 3	Pilot 4						Pilot 3			<u>Start point:</u> 1500' on approach to LGA runway 4 <u>Observations:</u> bad configuration so stopped simulator because no glide slope
24	1.2	4/14/09 16:59	Land: 3	Pilot 4	4	G:NA;F:3	NA	5	4	Pilot 3	NA	-0.8	<u>Start point:</u> 1500' on approach to LGA runway 4 <u>Comments:</u> "Unfamiliar with simulator"; "Flies weird"

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
25	2.1a	4/14/09 17:08	Land: 2	Pilot 4	5	G:5;F:6	7	7	7	Pilot 3	Brace call		<u>Start point:</u> bird strike <u>Observations:</u> Flaps 1 ~ 1000 ft; Erroneous stall warnings came on; Hard landing on threshold, Large bounce; validity of run is questionable – asked simulator experts if any concerns before proceeding? Airbus does not think performance was affected, just an indication problem (computer reset). <u>Comments:</u> “Finding airport is difficult”; “Knowing when/where to configure was difficult” “visuals terrible” Question: “were actual flaps achieved?”
26	2.2b	4/14/09 17:28	Land: 3 (slats)	Pilot 4	6	G:6;F:6	7	7	7	Pilot 3	Brace call		<u>Start point:</u> bird strike <u>Observations:</u> APU stopped working so ended up being inadvertent EMER ELEC/2.2b; Overshot runway in turn, touched down near threshold but overran in spite of “stepping on brakes”; Emergency parking brake pulled by Pilot 3 but either no effect or insufficient effect <u>Comments:</u> “Didn’t realize no flaps so that was why I was so high”; EMER ELEC, airplane comes back in alternate law. SPLR?
27	2.2a	4/14/09 17:38	Land:	Pilot 4	4	G:4;F:6	6	7	7	Pilot 3	Cycle 1/2 on/off		<u>Start point:</u> bird strike <u>Observations:</u> Good touchdown, stopped well before end. <u>Comments:</u> “Poor visuals make it difficult to know when to judge “cut” for turn, etc.”; “Guessing to find runway”

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Fit Path Angle	Comments
28	2.2a	4/14/09 17:48	Land: Full	Pilot 2	5 4	G:4;F:NA G:2;F:NA	3 3	2 5	3 5	Pilot 4	Oxygen masks		<p><u>Start point:</u> bird strike</p> <p><u>Observations:</u> Good touchdown, stopped well before end. Pilot 4 armed spoilers before touchdown; used speed brakes 2x on approach; Have to put the airplane on the ground, because don't want to float in flare / extra awareness of energy.</p> <p><u>Comments:</u> "Aimed for a constant slope"; "Couldn't tell where I was"; "Didn't concentrate on green dot and went higher and lower in speed because I was paying attention to other things"; "aimed for first 1/3 of runway"; "Can't tell where you will be in flare"</p>
29	2.1b	4/14/09 17:59	Land: 2 (slats)	Pilot 2	9 7	G:8;F:NA G:6;F:NA	8 6	10 7	10 7	Pilot 4	Oxygen masks		<p><u>Start point:</u> bird strike</p> <p><u>Observations:</u> was not going to make runway, so ditched into water.</p> <p><u>Comments:</u> "A lot more aileron force needed when in EMER ELEC"; "Difficult to maintain green dot"; "Had to use rudder to assist rolling out of turn"</p>
30	2.2b	4/14/09 18:07	Land: 3 (slats)	Pilot 2	4 3	G:4;F:NA G:2;F:NA	5 4	4 4	3 4	Pilot 4	Oxygen masks		<p><u>Start point:</u> bird strike</p> <p><u>Observations:</u> Failure of engine 1 delayed, so dark cockpit delayed. APU fault; Good touchdown, stopped on runway; Plenty of energy.</p> <p><u>Comments:</u> "Couldn't get full configuration (had to manually lower gear)"; "Hit spot I wanted to but required a lot of input to hit slope"; "Had to work harder to get green dot"; "Brakes seemed less effective but still had brakes"; "Was in my touchdown zone"</p>
31	1.2	4/15/09 14:17	Land: 3	Pilot 2						Pilot 3			<p><u>Start point:</u> 1500' on approach to LGA runway 4</p> <p><u>Observations:</u> Flight director not following glideslope; Run stopped</p>

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
32	1.2	4/15/09 14:18	Land: 3	Pilot 2	2 2	NA NA	NA NA	2 1	3 2	Pilot 3	NA	-0.8	<u>Start point:</u> 1500' on approach to LGA runway 4 <u>Observations:</u> Pilot 2 didn't realize ground touch and airplane skipped
33	2.2c	4/15/09 14:31		Pilot 2						Pilot 3			<u>Start point:</u> bird strike: 4050.8863N: 07352.5653W <u>Observations:</u> no delay before turn- redoing run
34	2.2c	4/15/09 14:32		Pilot 2						Pilot 3			<u>Start point:</u> bird strike: 4050.8863N: 07352.5653W <u>Observations:</u> 5 miles away at 1000 ft. altitude, TL aborted attempt for LGA 13 and headed for water; Numerous bells and stall warnings; Airplane went to direct law (stabilizer jam) for unknown reasons; Going to fly takeoff from runway to sort it out.
35	2.2c	4/15/09 14:43		Pilot 2						Pilot 3			<u>Start point:</u> takeoff from runway 4 at LGA <u>Instructions:</u> Fly direct to GESE (bird strike coordinates) where failure will occur, Pilot 2 take control turn to runway 13; will be given heading to 220 15 sec after bird strike (per FDR data indicating start of turn). <u>Observations:</u> At 230 knots at time of bird strike (too much energy). Target ~ 218 knots; Winds not correct at start, corrected during run. Next will start w/ correct winds; Had stabilizer jam again.
36	2.2c	4/15/09 14:50	Land:	Pilot 2	10 7	G:2;F:NA G:1;F:NA	6 6	10 7	10 7	Pilot 3	Engine off (stopped checklist)		<u>Start point:</u> takeoff from runway 4 at LGA <u>Observations:</u> Speed ~ 200 knots (low) at bird strike; Hard landing just short of threshold; Landing gear extended late; 3:02 time from bird strike to LGA <u>Comments:</u> "landing gear wouldn't have matter due to close proximity to runway)

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
37	2.3a	4/15/09 15:02	Land: 2	Pilot 2	3 2	G:2;F:NA G:2;F:NA	4 4	NA NA	NA NA	Pilot 3	Engine off; waiting for timing of 30 secs		<u>Start point:</u> takeoff from runway 4 at LGA <u>Observations:</u> Speed ~123 knots at bird strike; Malfunction w / simulator @ 500 ft; lost pitch trim but looks like there was energy to get to TEB; Seeing runway and lining up with it might be hard; LC was helping find TEB; TEB about 7 miles from LGA? <u>Comments:</u> "Other pilots on immediate turn have made TEB"; "A little close and high"
		4/15/09		Pilot 2									Timed APU start. Result = 1:06:91
38	3.2	4/15/09 15:20	Land: 2	Pilot 2						Pilot 4			<u>Start point:</u> 1500' feet over the Hudson at 200 knots. <u>Observations:</u> APU on for these scenarios; Gear down at start of run, raised during run; Master warning before touchdown (gear?); Gear down from start so will redo run
39	3.2	4/15/09 15:24	Land: 2	Pilot 2	3 2	G:3;F:2 G:2;F:2	2 1	NA NA	3 6	Pilot 4	Ditching	-1.5	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Pitch 10-11 speed 128 knots; Pilot 2 scans between radar alt, pitch, and outside view to achieve target pitch attitude and descent rate at touchdown; Master warning going off. <u>Comments:</u> "Didn't use green dot but got speeds I wanted"; "Went to flaps based on checklist; Pilot 2 asked pilot 4 for ditching checklist"; "Water difficult to land on; look and PDF and outside"; "Went up and down from 5' to 10"; "F speed verbalized; had to sneak up on it and then nail it"; "Gave a 6 rating on landing b/c difficult task to fly pitch attitude"

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
40	3.3	4/15/09 15:31	Land: 3	Pilot 2	3 3	G:2;F:3 G:2;F:2	3 2	NA NA	4 6	Pilot 4	Ditching	-2.2	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Pitch at 11 / 700 ft/min sink, airspeed 123/124 knots; Ballooning when flaps go to 2 is a mild deficiency in maintaining glide slope; Pitched up and down <u>Comments:</u> "Couldn't feel balloon"; "No green dot flown"; "Not pitch I wanted but no seat of pants feel"
41	3.4	4/15/09 15:42	Land: 3 (slats)	Pilot 2	3 2	G:2;F:NA G:2;F:NA	3 5	NA NA	5 6	Pilot 4	Ditching	-0.2	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Start with APU on and fail engine after release to obtain blue hydraulics only; Speed = 150, pitch above 10 deg. <u>Comments:</u> "F speed in red; no speed guidance"; "Got down over water, checked alt then tried to maintain a constant pitch picture. Was hard to vary pitch to hold picture."; "Trying to find what pitch works"
42	3.3	4/15/09 16:06	Land: 3	Pilot 1	3 2	G:NA;F:3 G:NA;F:2	2 2	NA NA	3 3	Pilot 4	Ditching	-2.0	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Pitch was 5 but Pilot 1 thought was higher. <u>Comments:</u> Green dot: "went below and called for flaps"; Pitch: "thought I was where I wanted to be" but maybe not.
43	3.4	4/15/09 16:12	Land: 3 (slats)	Pilot 1						Pilot 4	Ditching		<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Loss of pitch control during run. Blue hydraulics at zero - have to manually deploy the RAT.
44	3.4	4/15/09 16:16	Land: 2 (slats)	Pilot 1	2 2	G:NA;F:2 G:NA;F:2	2 3	NA NA	2 2	Pilot 4	Ditching	-2.3	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> RAT deployed after engine failure. Pitch = 11; Pilot 1 tried to achieve target pitch at touchdown and was successful. <u>Comments:</u> "Held speeds I wanted as configured but not green dot"; "Never achieved F speed but was slowing to what I wanted"; "didn't get to full back stick".

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
45	3.2	4/15/09 16:21	Land: 2	Pilot 1	2 2	G:2;F:2 G:2;F:2	2 3	NA NA	4 5	Pilot 4	Ditching	-2.8	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Comments:</u> "Almost at full back stick, floating at around 20-30 ft, 700 ft/min at impact"; "Trouble judging height above water, achieved pitch above water and then floated, a little harder controlling pitch"; "Was not at green dot but at speeds I wanted"
46	3.4	4/15/09 16:29	Land: 3 (slats)	Pilot 4	3	G:3;F:3	2	NA	2	Pilot 1	Ditching	-2.1	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Simulator was going to alternate law/got stall warning, but this shouldn't affect performance. <u>Comments:</u> "Not trying to maintain green dot"
47	3.3	4/15/09 16:33	Land: 3	Pilot 4	3	G:3;F:3	3	NA	3	Pilot 1	Ditching	-1.8	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Pitch = 6 <u>Comments:</u> "I was low on speed tape so tried to hold what I had"
48	3.2	4/15/09 16:36	Land: 2	Pilot 4	2	G:3;F:3	3	NA	3	Pilot 1	Ditching	-1.6	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Alternate law/got stall warning; Ballooned at 10'; Full back stick, pitch 9, low descent rate. <u>Comments:</u> "Easier to land CONF 2 because steadier, more time to prepare for it"; "Better visibility over nose as well".
49	3.2	4/15/09 16:41	Land: 2	Pilot 3	4	G:3;F:3	3	NA	6	Pilot 1	Ditching	-3.6	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Pitch 6 <u>Comments:</u> "Trying hard to keep pitch at 11 but had too much speed, bleeding off took longer than I thought"
50	3.4	4/15/09 16:46	Land: 3 (slats)	Pilot 3	3	G:2;F:2	2	NA	2	Pilot 1	Ditching	-1.9	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Pitch 10; Alternate law/got stall warning <u>Comments:</u> "Seemed more controllable"
51	3.3	4/15/09 16:48	Land: 3	Pilot 3	4	G:3;F:3	2	NA	4	Pilot 1	Ditching	-3.2	<u>Start point:</u> 1500' feet over the Hudson at 200 knots <u>Observations:</u> Pitch 9; Ballooned slightly at 40' and held altitude <u>Comments:</u> "Pitch control harder than conf 2; had almost full back stick; was trying to hold 11 degrees; noticed burble when went from 1 to 2"

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
52	3.2 Alpha prot	4/15/09 16:55	Land: 2	Pilot 3						Pilot 1		-6.5	<p><u>Start point:</u> bird strike: 4050.8863N: 07352.5653W</p> <p><u>Instructions:</u> Deliberately fly slow in Alpha Prot to see if "SPEED SPEED SPEED" warning activates.</p> <p><u>Observations:</u> Got SPEED SPEED SPEED warning near bottom of VLS bar (before Alpha Prot).</p> <p><u>Comments:</u> "Felt very controllable, slow, pitch is much different because no airspeed to lower nose"; "Only had slight pitch at end"; "I looked ahead to make sure I was where I wanted to be"</p>
53	3.2 Alpha prot	4/15/09 17:00	Land: 2	Pilot 3						Pilot 1		-6.3	<p><u>Start point:</u> bird strike: 4050.8863N: 07352.5653W</p> <p><u>Instructions:</u> Repeat previous run but get into alpha prot in clean configuration</p> <p><u>Observations:</u> No SPEED warning in clean (as designed); High descent rate at touchdown; No altitude callouts - Did SPEED warning override altitude calls?; No pitch at touchdown</p>
54	2.3a	4/15/09 17:11	Land: Full	Pilot 2	3 2	G:2;F:NA G:2;F:NA	5 6	5 7	4 7	Pilot 3			<p><u>Start point:</u> takeoff from runway 4 at LGA</p> <p><u>Observations:</u> Matched bird strike conditions well; Alternate law at some point; Made runway; stopped on runway. Configuring has to be "played perfectly" to make it; Stopped 9.6 NM (nautical miles) from LGA runway 4 threshold to check TEB location in simulator; Simulator said 8.7 NM from TEB to GESE, 4.8 NM from LGA runway 04 to GESE, and 8 NM TEB to LGA?</p> <p><u>Comments:</u> "If delay the first lap a little longer, can have a little higher final but not by much."; "Descent slope good until end"; "Didn't hold green dot long"</p>

Run #	Cond. #	Date/Time	Flap Setting	Left Seat	Diff. 1	Diff. 2a/b	Diff. 3	Diff. 4	Diff. 5	Right Seat	QRH Complete	Flt Path Angle	Comments
55	n/a	4/15/09 17:26		Pilot 2						Pilot 5			<u>Start point:</u> takeoff from runway 4 at LGA <u>Observations:</u> Pilot 5 to feel differences in stick forces between normal law and alternate law. Pilot 5 flies takeoff and normal approach and landing. Comments: "in Alpha Prot, very difficult to hold aft stick, almost had to use two hands"

Note: Shaded areas indicate successful runs in S22 simulator; Video camera running for all runs on 4/14/09

Diff. 1: Maintaining glide path; Diff. 2a/b: Maintaining airspeed (a: green dot; b: F speed); Diff. 3: Configuring airplane for landing; Diff. 4: Achieving touchdown point; Diff. 5: Successful landing (for ditching scenarios, asked if achieved desired pitch at touchdown)

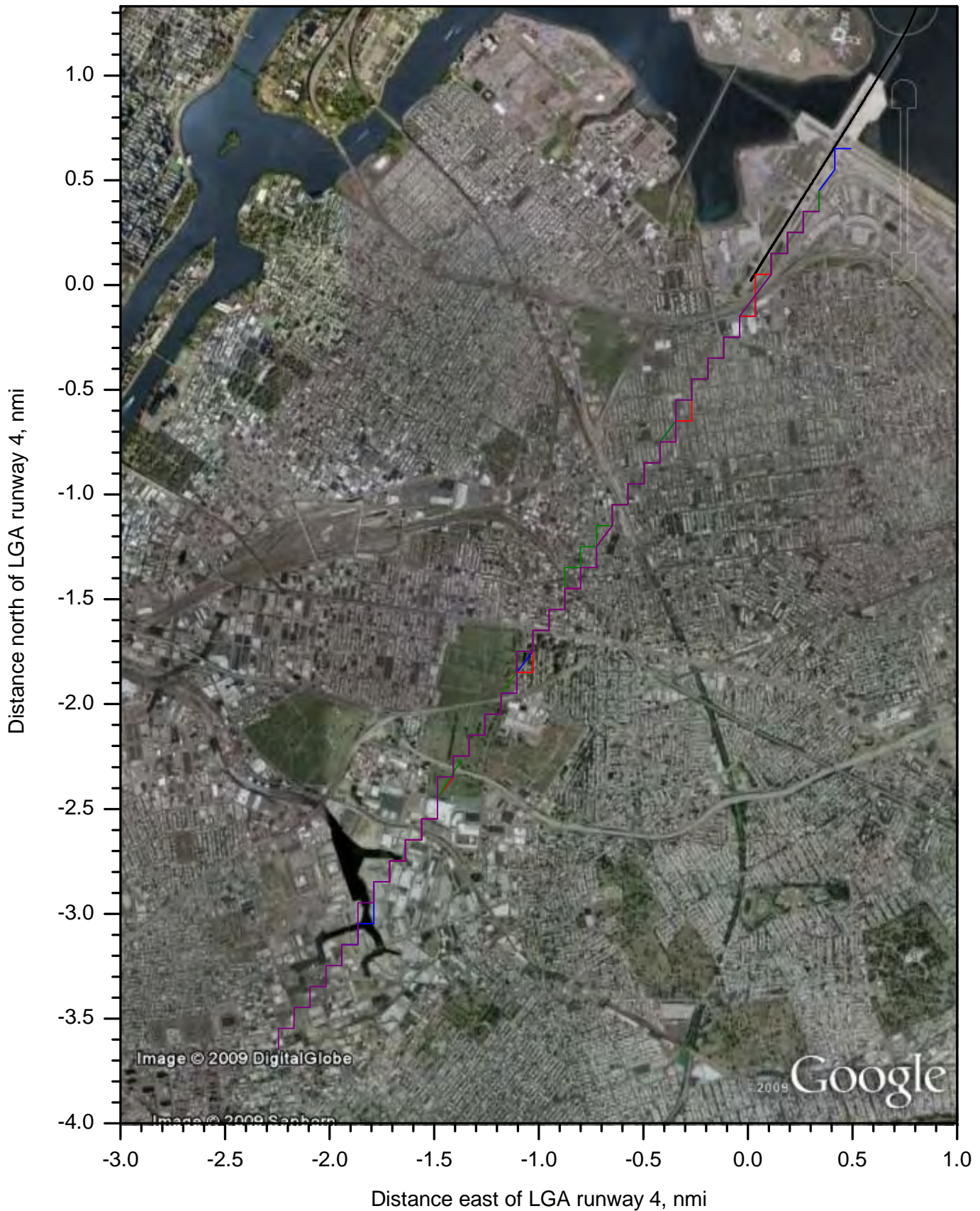
* Cooper-Harper Rating Scale values

Flight path angle was calculated using $\alpha - \theta$ (deg), and was only calculated for useable ditching and normal landing runs.

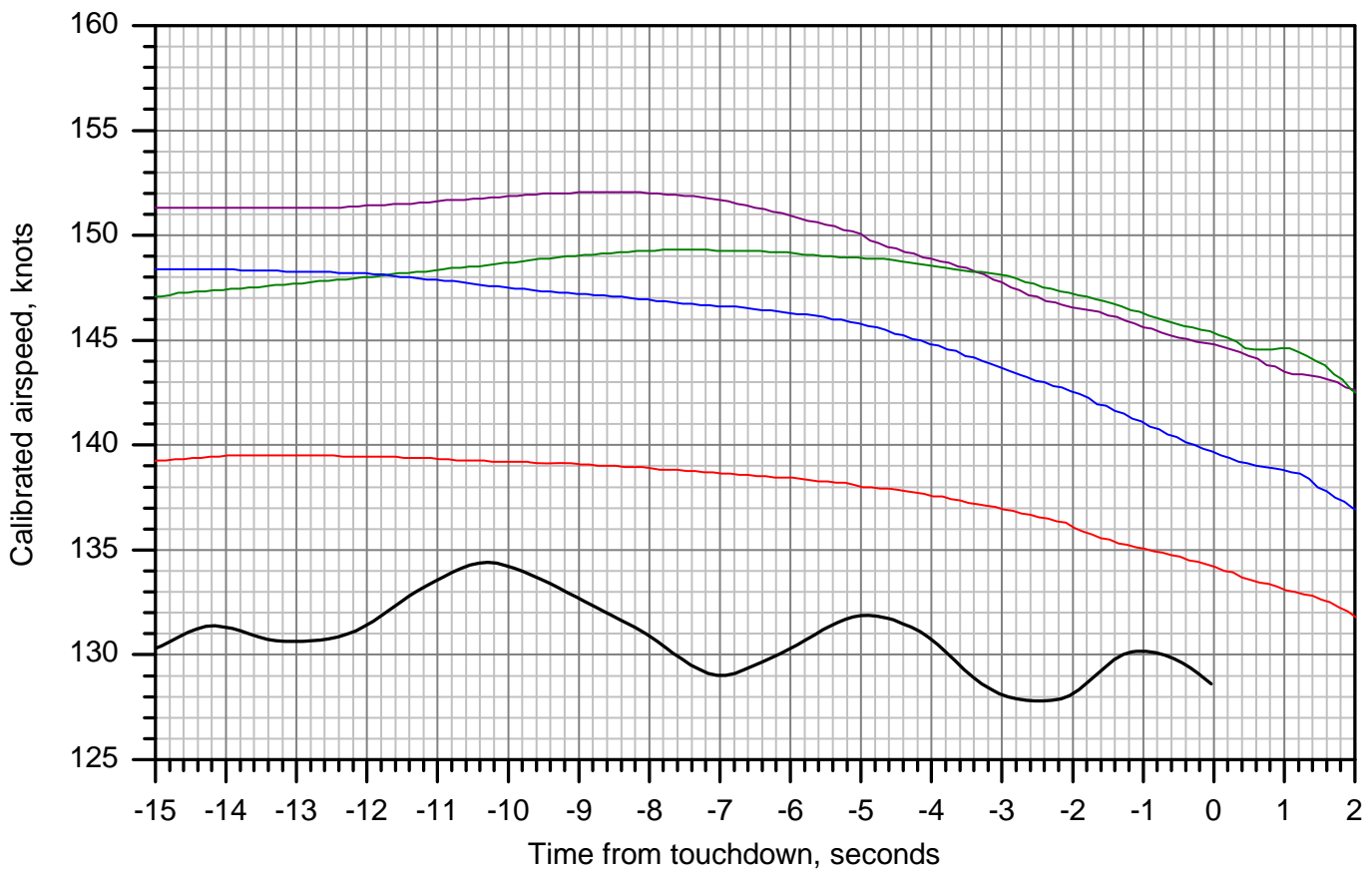
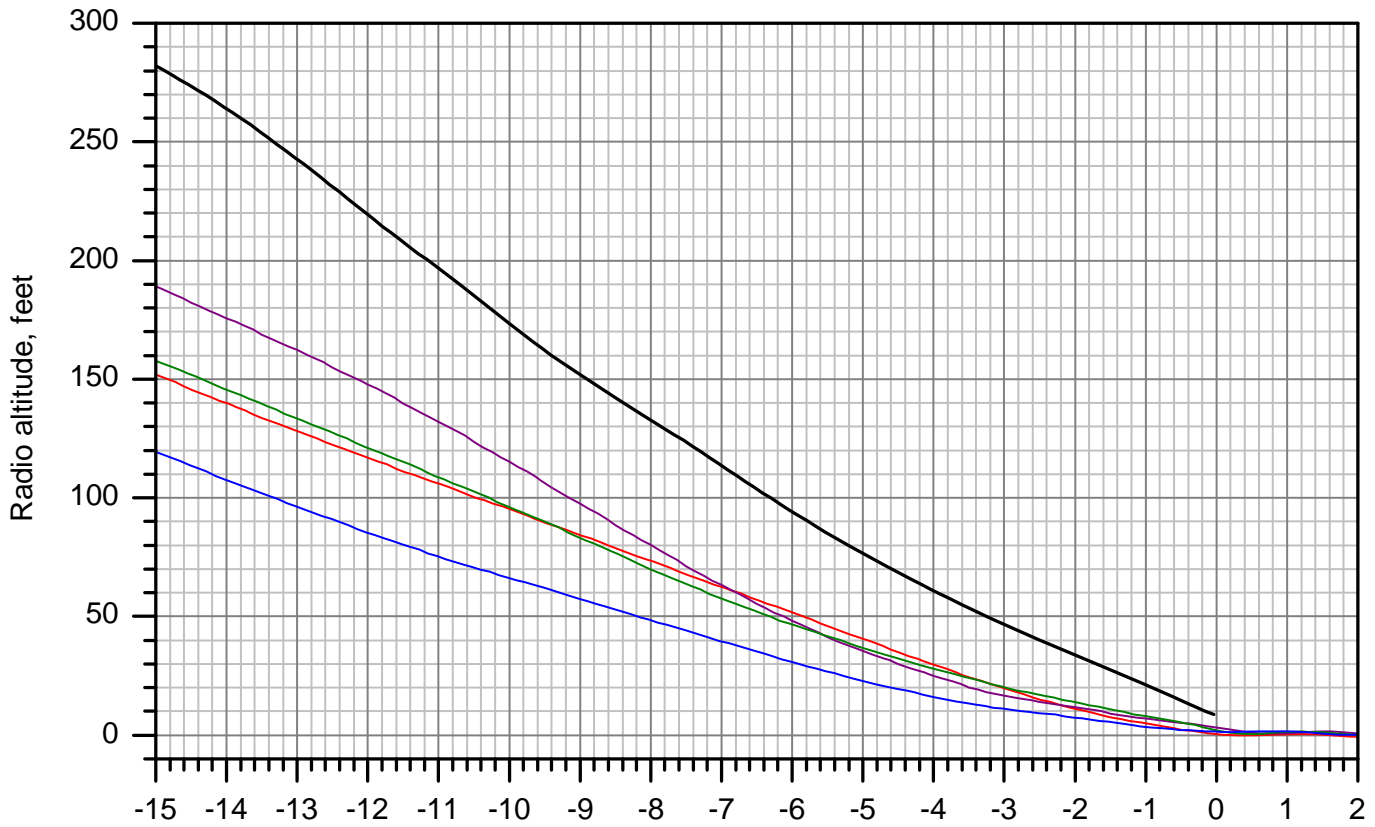
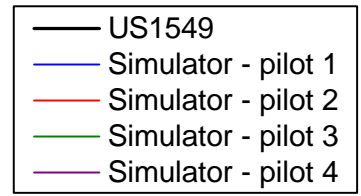
Appendix 1: Simulator Test Run Plots (by type of landing)

Simulation results: normal landing

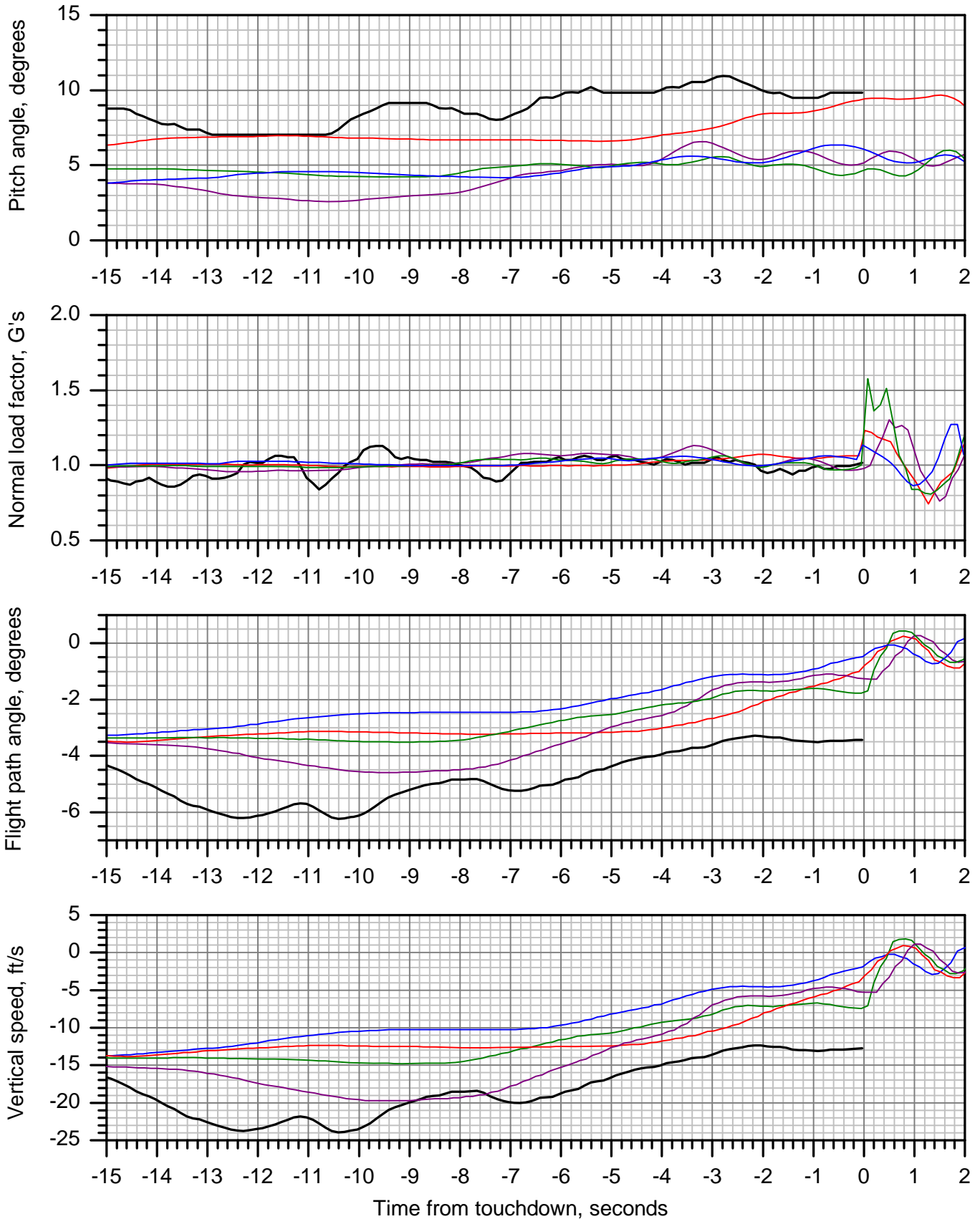
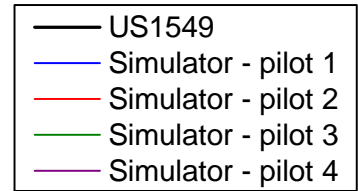
- US1549
- Simulator - pilot 1
- Simulator - pilot 2
- Simulator - pilot 3
- Simulator - pilot 4



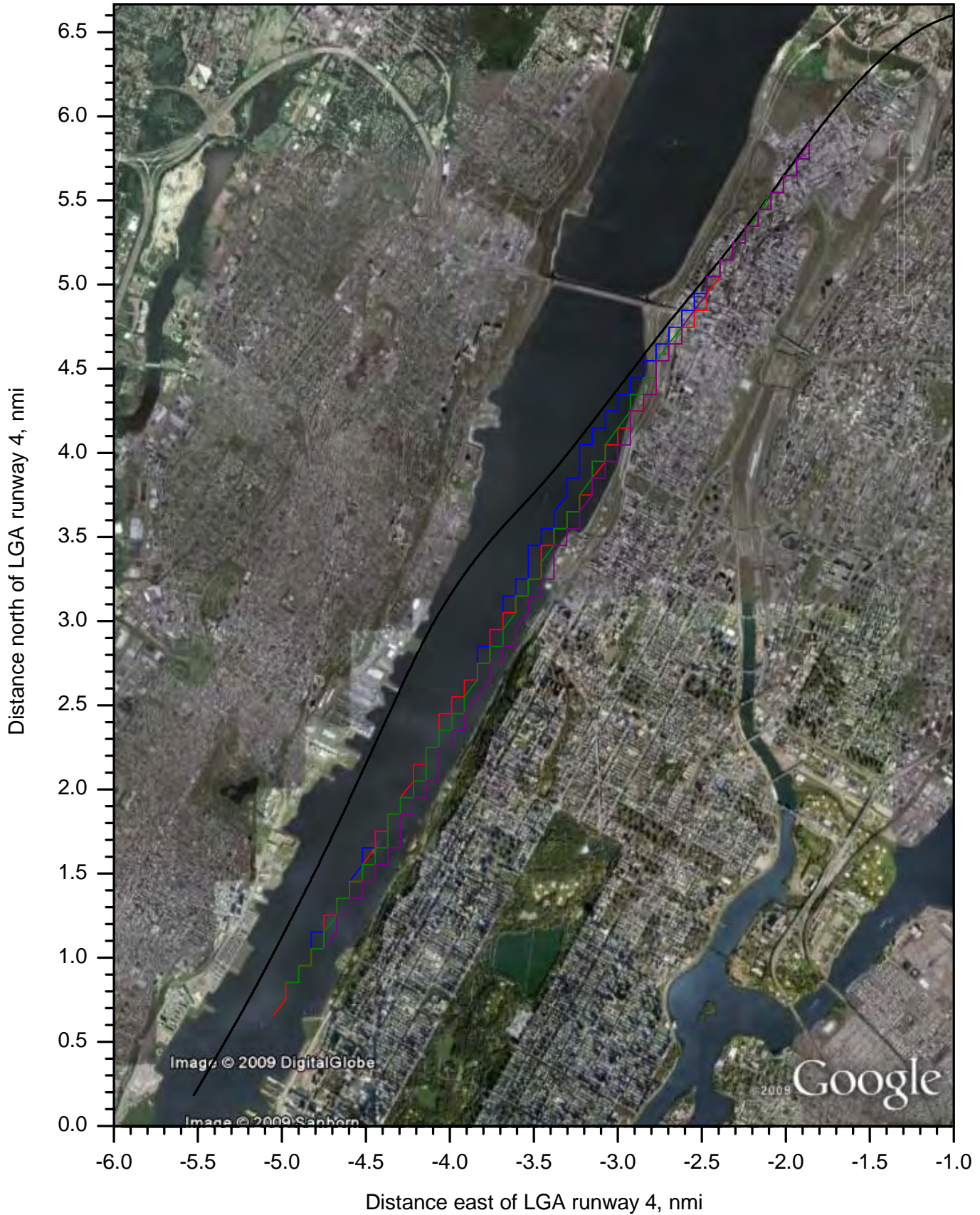
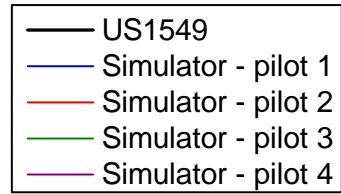
Simulation results: normal landing



Simulation results: normal landing

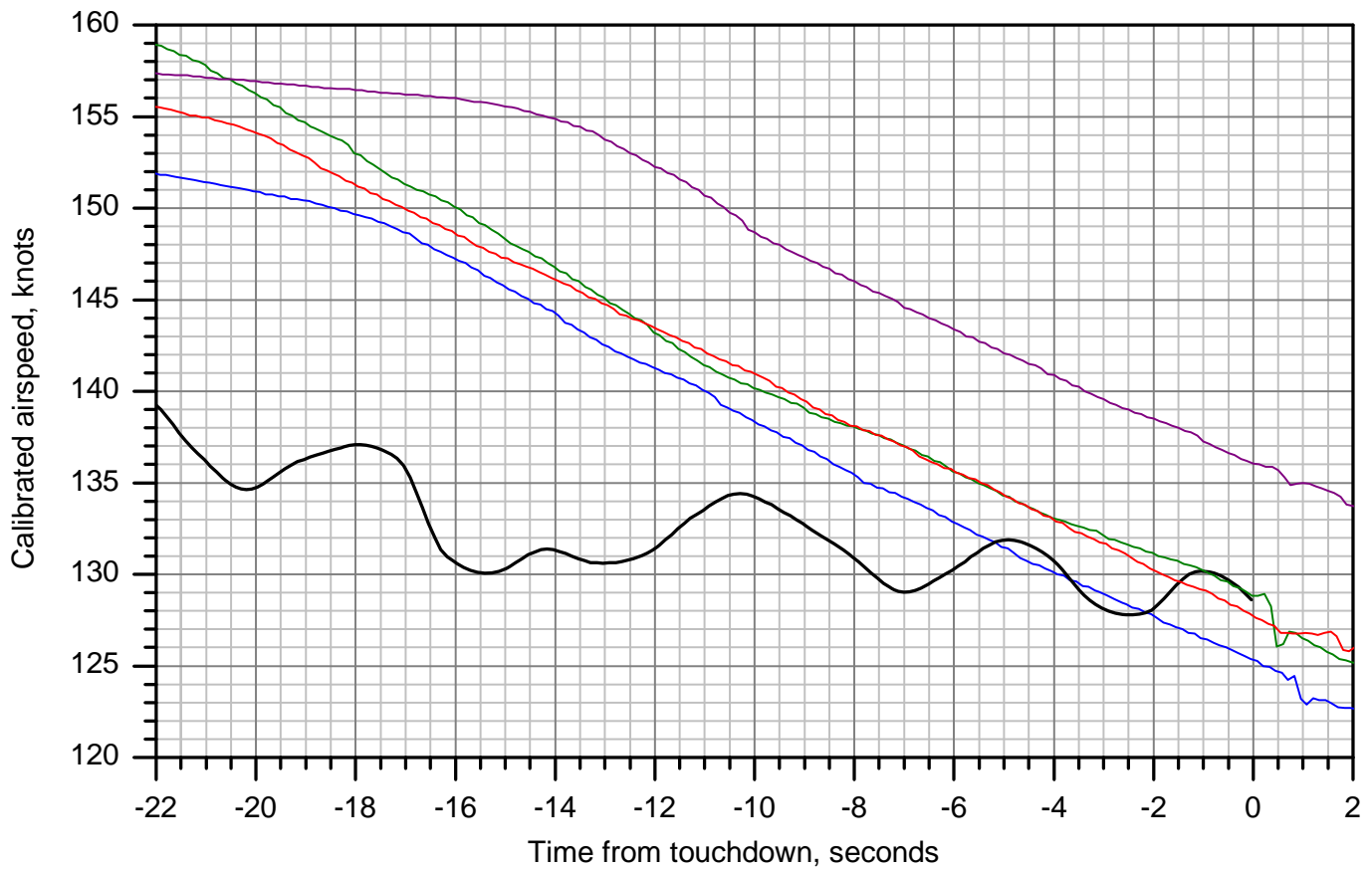
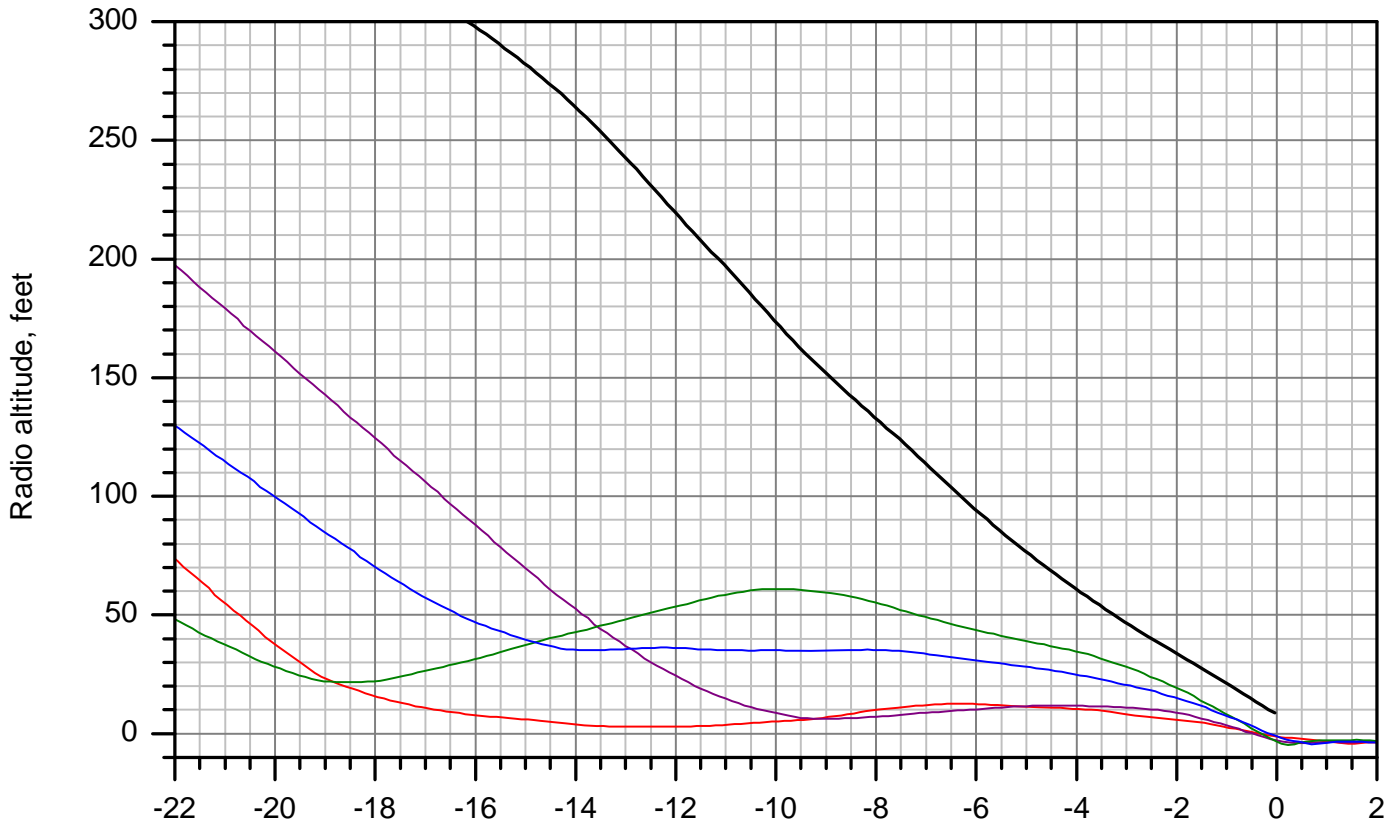


Simulation results: CONF2 ditching

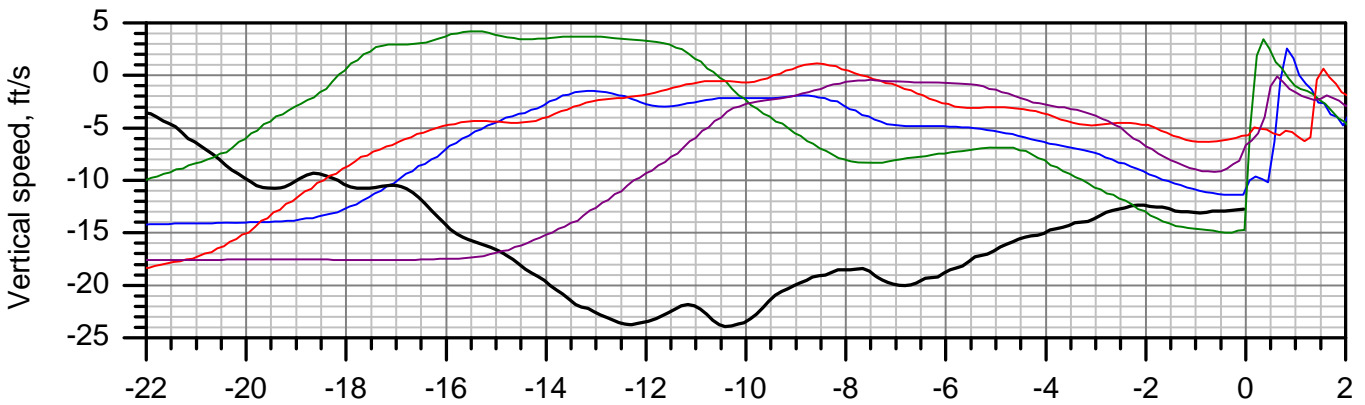
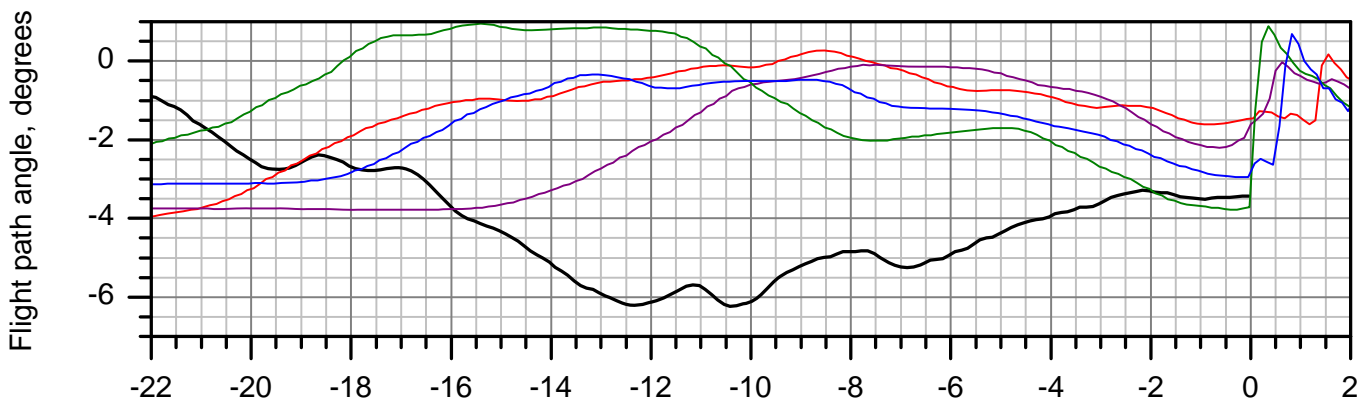
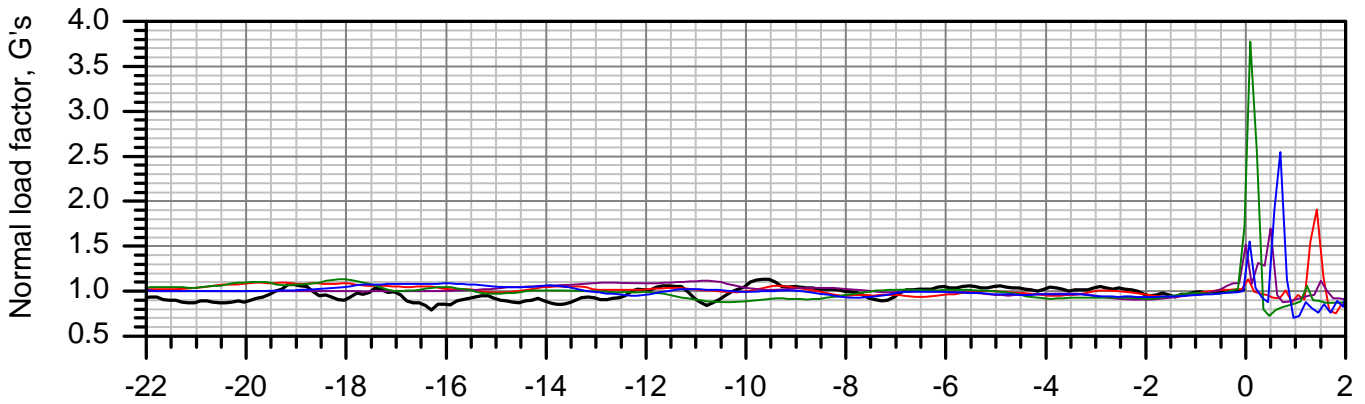
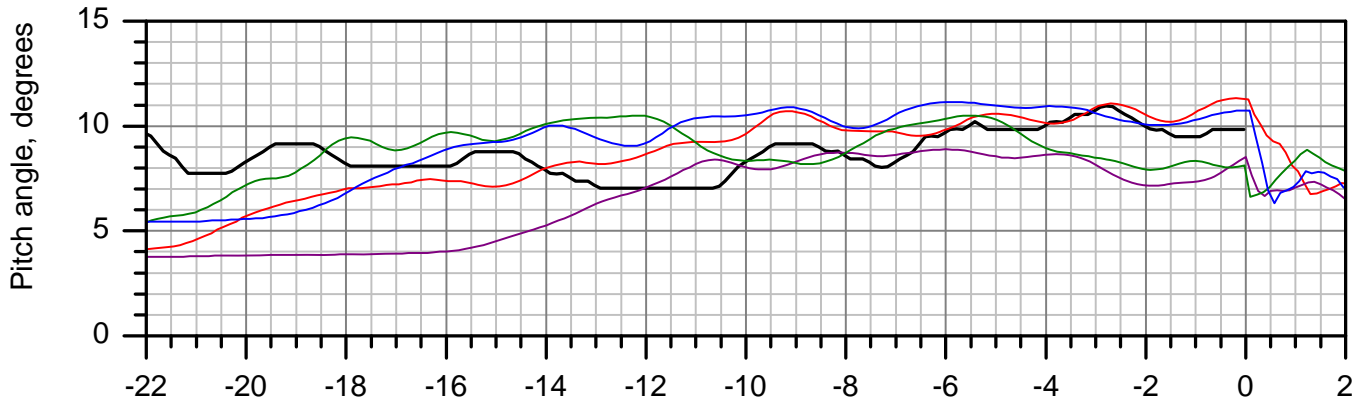
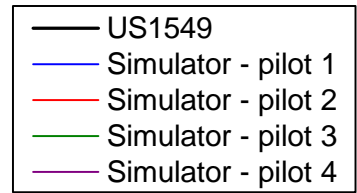


Simulation results: CONF2 ditching

- US1549
- Simulator - pilot 1
- Simulator - pilot 2
- Simulator - pilot 3
- Simulator - pilot 4



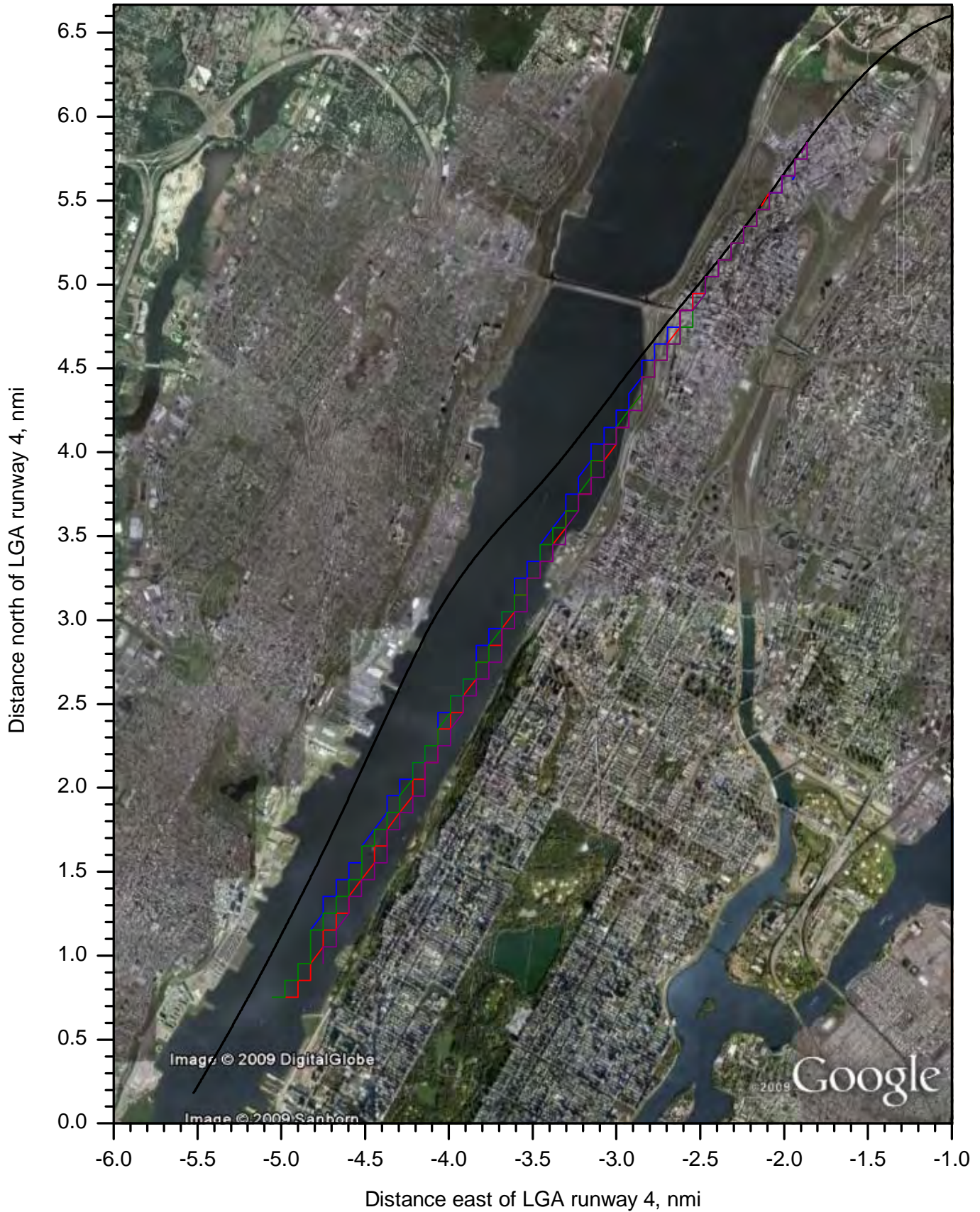
Simulation results: CONF2 ditching



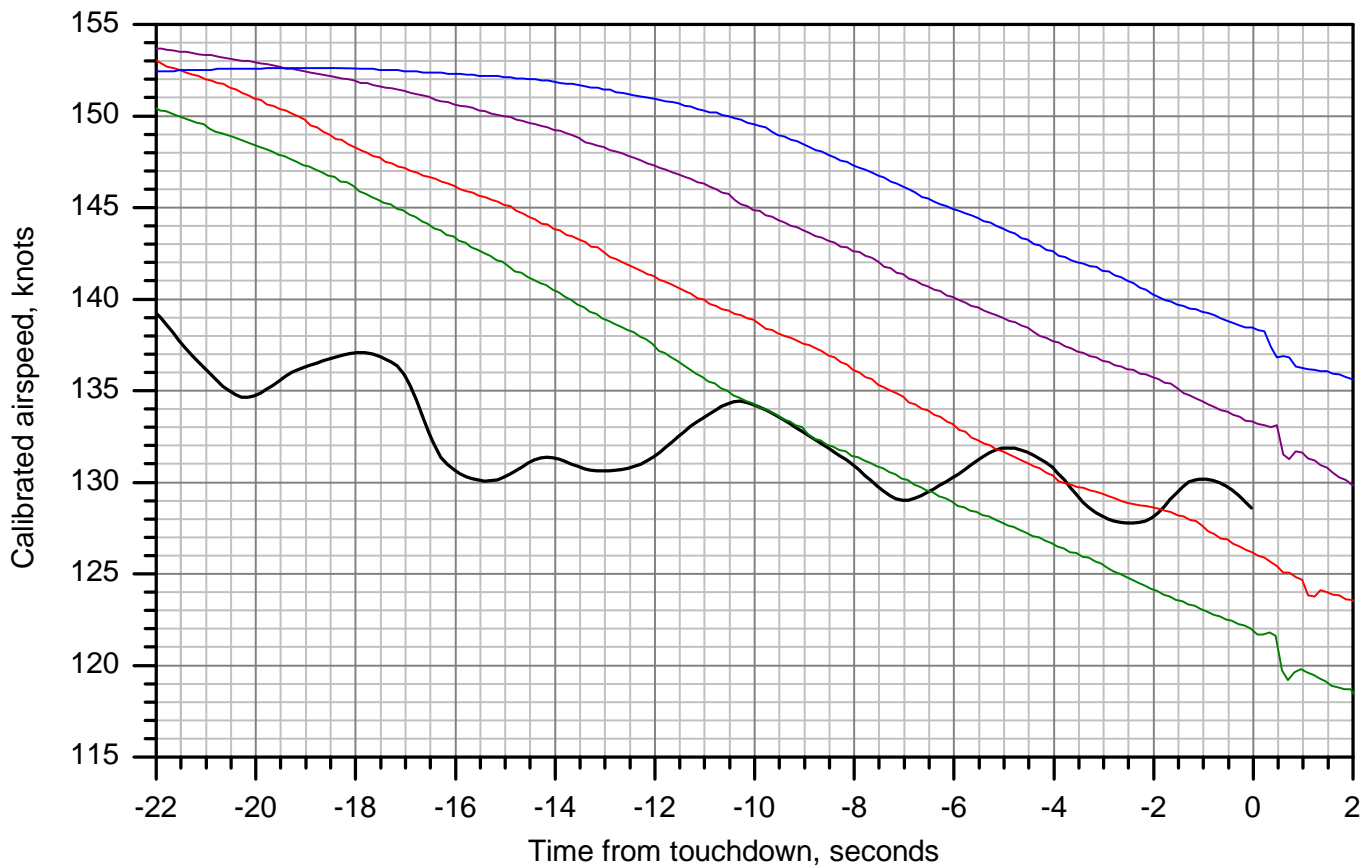
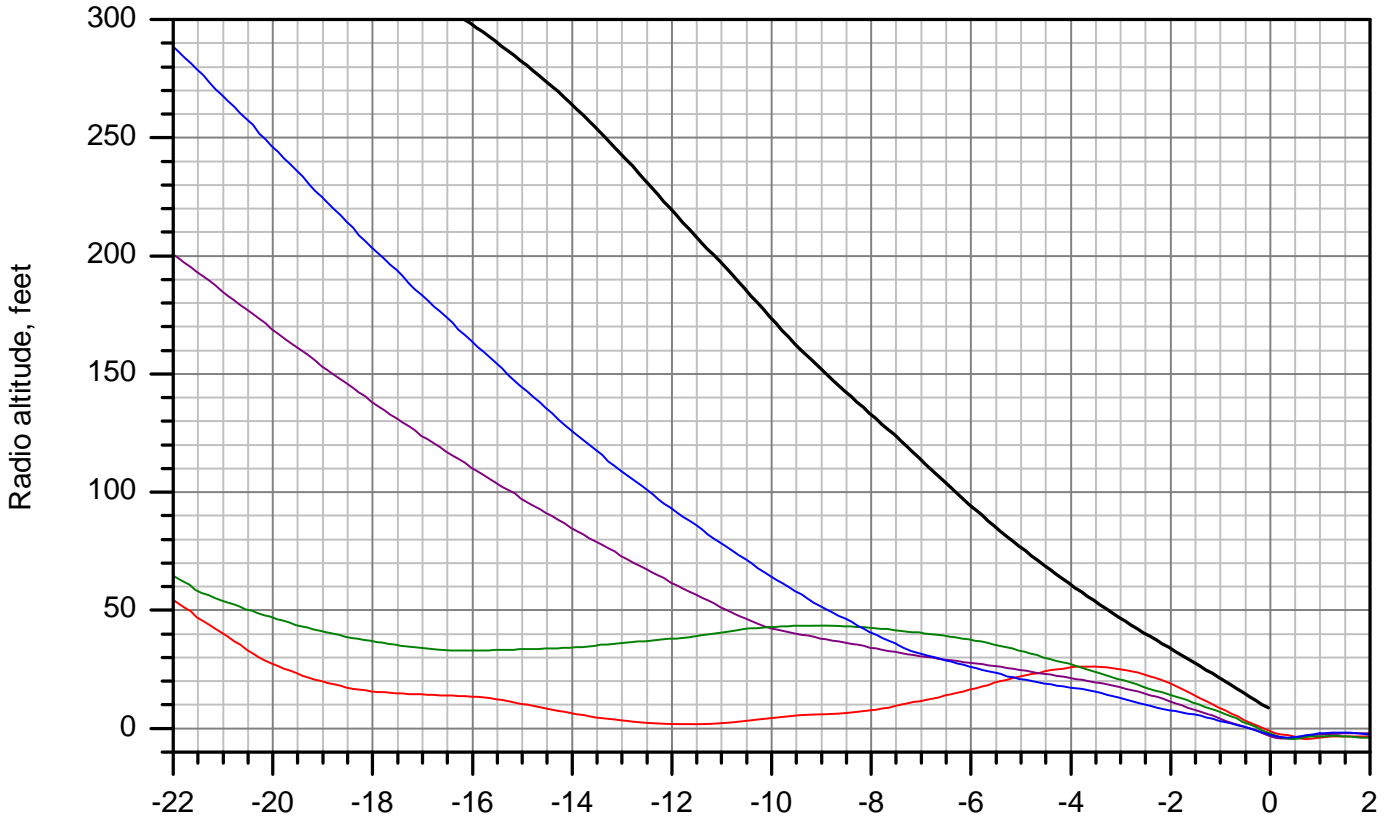
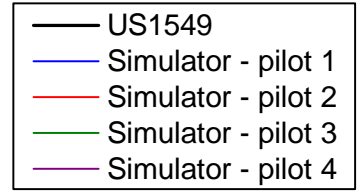
Time from touchdown, seconds

Simulation results: CONF3 ditching

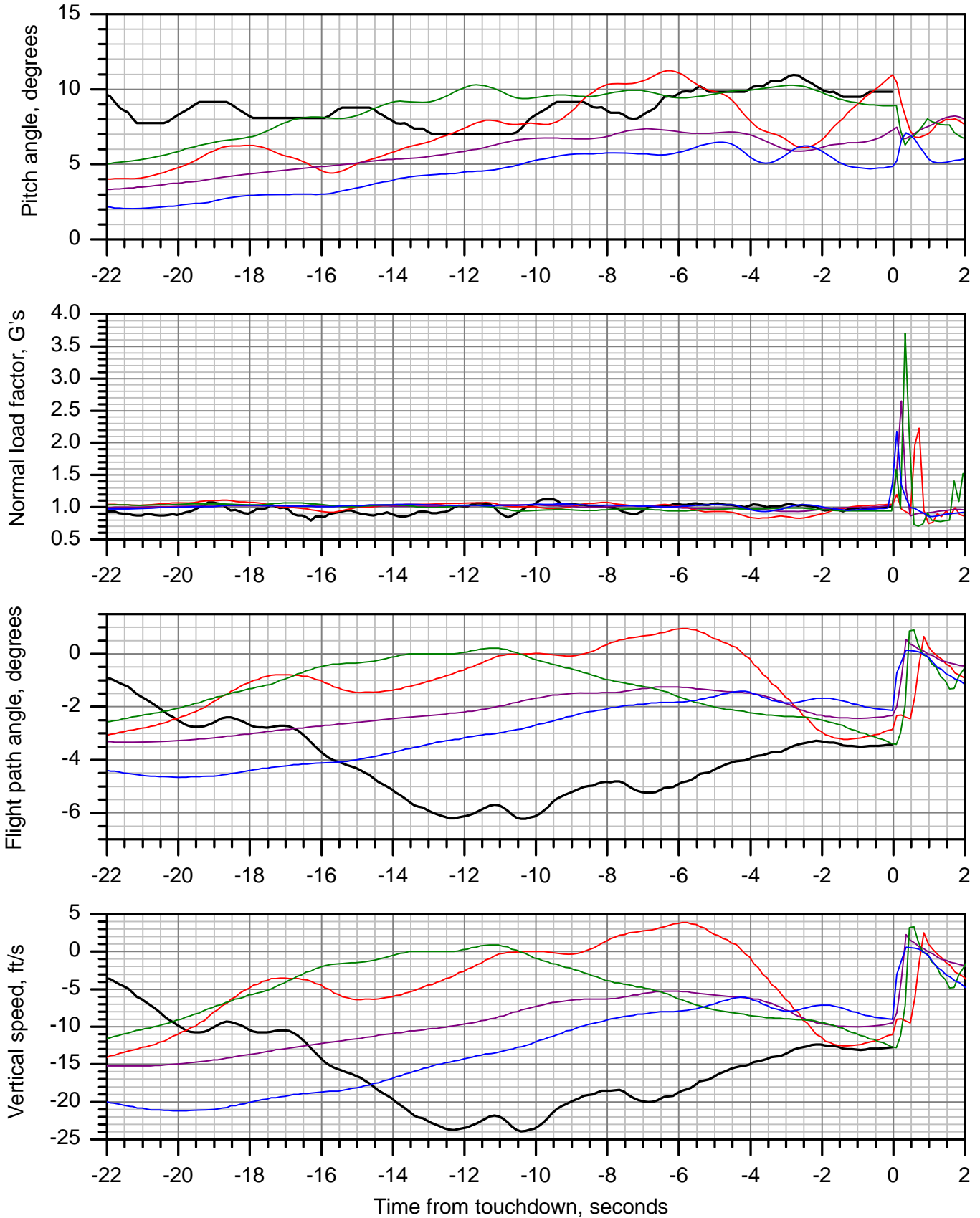
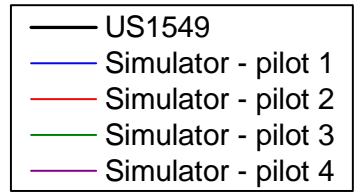
- US1549
- Simulator - pilot 1
- Simulator - pilot 2
- Simulator - pilot 3
- Simulator - pilot 4



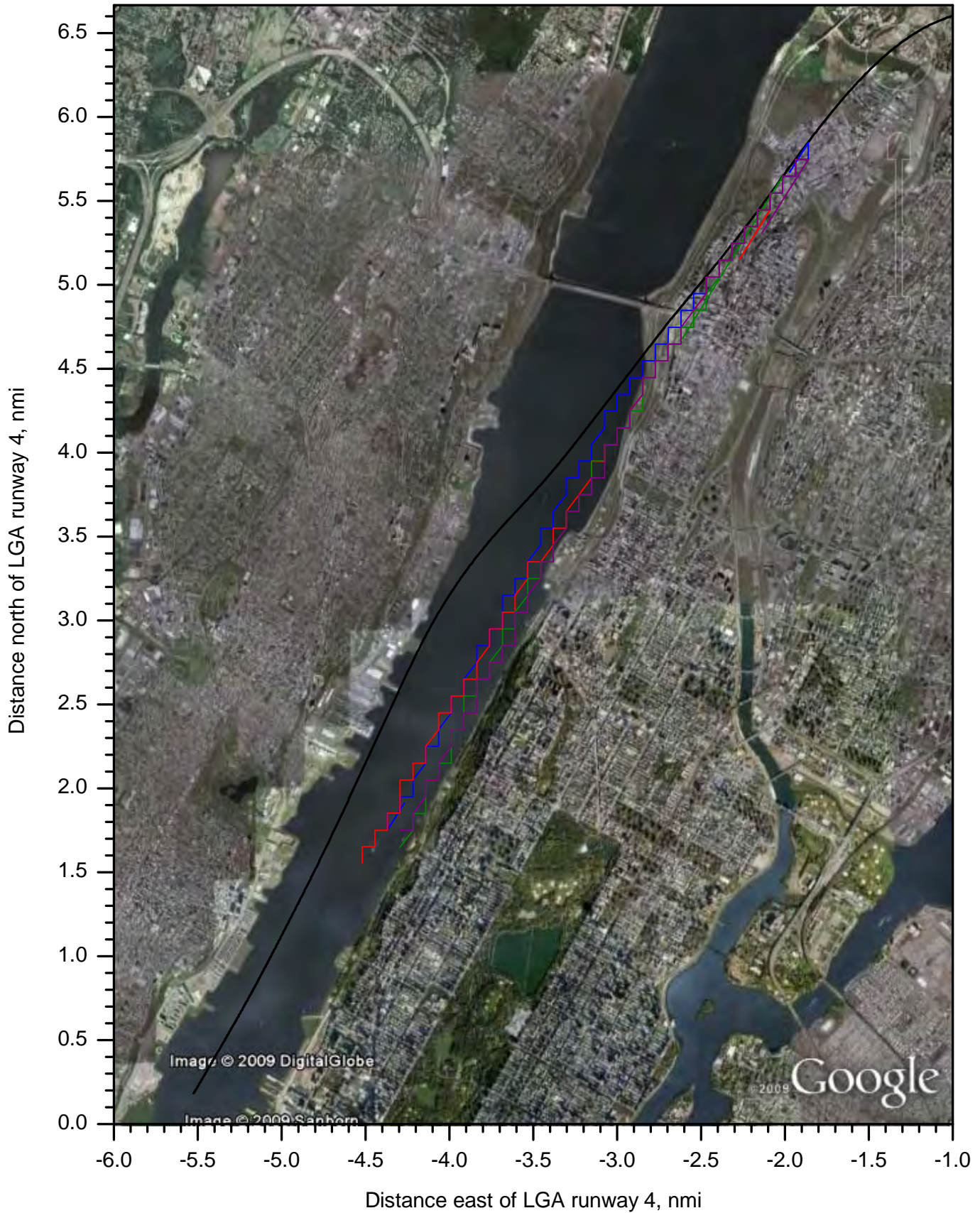
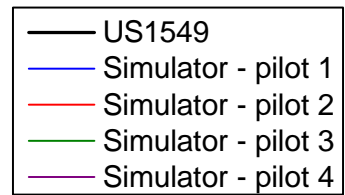
Simulation results: CONF3 ditching



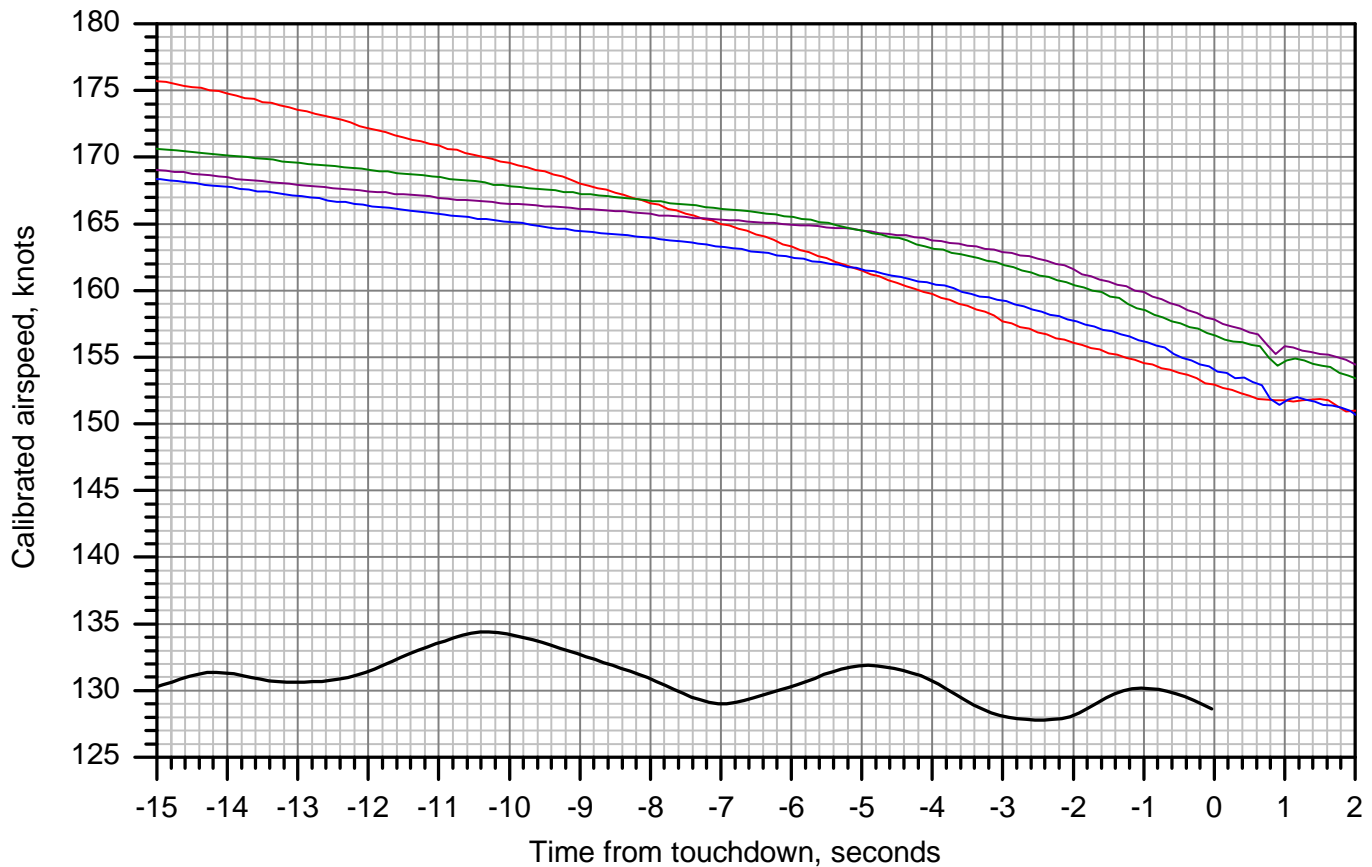
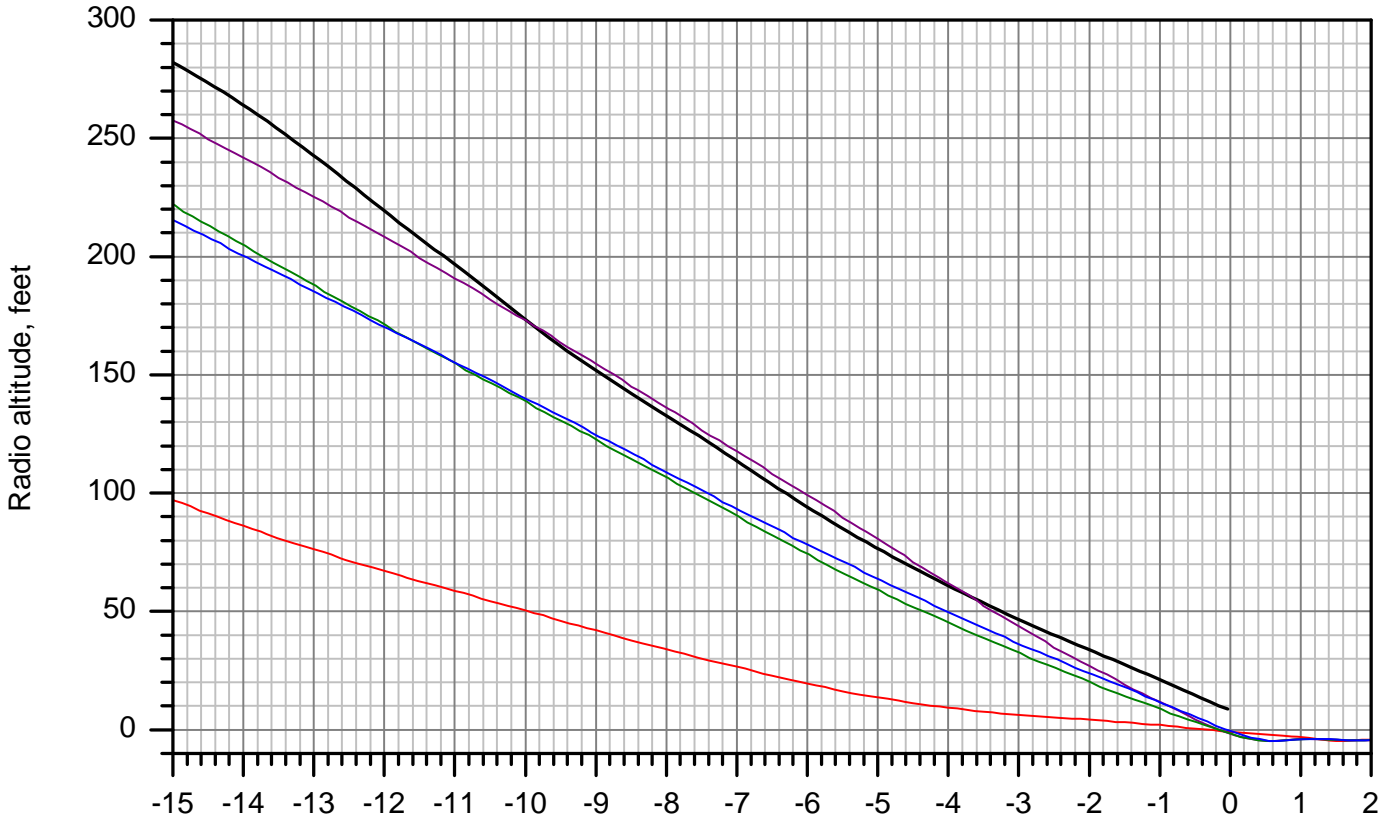
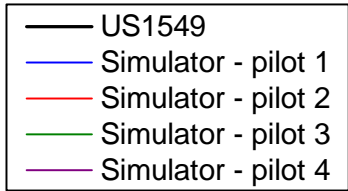
Simulation results: CONF3 ditching



Simulation results: slats only ditching



Simulation results: slats only ditching



Simulation results: slats only ditching

