

Table S1. Summary of turbulence properties in each flow conditions. x, y & z represent the longitudinal (downstream), lateral and vertical directions with respect to the wind tunnel

Flow Condition	Turbulence Intensity (Ti)				Integral Length Scale (L), cm		
	Ti _x	Ti _y	Ti _z	Ti _{Tot}	Lxx	Lxy	Lxz
Smooth Flow (No Grid)	1.2%	1.1%	1%	1.2%	-	-	-
Turbulent Flow (4 x 4 cm grid)	14.33%	16.21%	15.65%	15.97%	4.12	3.6	4.64

Table S2. Standard deviations of distance maintained between the head and feeder, and absolute mean accelerations experienced by the head and body of each bird along the longitudinal, lateral and vertical directions

Bird	Flow Condition	σ Distance between head and feeder (mm)	Head accelerations (m/s ²)			Body accelerations (m/s ²)		
			Longitudinal	Lateral	Vertical	Longitudinal	Lateral	Vertical
1	smooth	0.24	0.90	0.49	0.54	1.09	2.05	2.32
2	smooth	0.64	1.23	0.61	1.51	1.11	2.67	1.41
3	smooth	0.44	0.45	0.48	0.92	0.72	1.17	1.81
4	smooth	0.25	1.15	0.62	1.35	0.85	2.44	1.25
1	turbulent	0.21	0.69	0.64	0.99	2.04	4.61	2.86
2	turbulent	1.28	0.90	0.80	0.85	2.77	12.11	4.58
3	turbulent	1.61	1.30	0.72	0.94	1.53	4.76	3.22
4	turbulent	0.33	1.43	1.03	1.53	3.22	9.92	5.11

Table S3. Absolute mean rotation rates of the head, body and tail of each bird around the longitudinal (roll), lateral (pitch) and vertical (yaw) body axes

Bird	Flow Condition	Head rotations (deg/s)			Body rotations (deg/s)			Tail rotations (deg/s)		
		Roll	Pitch	Yaw	Roll	Pitch	Yaw	Roll	Pitch	Yaw
1	smooth	101.43	26.31	20.94	172.37	138.53	75.95	168.18	176.03	171.16
2	smooth	211.93	39.82	40.56	208.78	95.59	105.58	238.01	218.57	188.83
3	smooth	120.26	66.49	28.79	137.24	106.26	107.33	367.61	231.96	96.286
4	smooth	181.79	63.68	23.63	153.65	104.81	42.05	100.43	87.018	67.525
1	turbulent	176.25	27.96	43.31	635.98	160.35	275.14	401.26	387.99	379
2	turbulent	123.58	65.65	50.23	711.33	246.80	208.87	449.33	356.99	687.88
3	turbulent	110.05	80.91	45.56	702.25	261.08	392.11	781.82	412.74	341.86
4	turbulent	148.94	82.28	62.02	977.01	333.95	371.59	651.24	510.98	598.69

Table S4. Mean and standard deviation of tail fan angle for each bird

Bird	Flow Condition	Mean Tail Fan Angle (deg)	σ Tail Fan Angle (deg)
1	smooth	61.11	7.71
2	smooth	57.12	7.09
3	smooth	56.82	4.22
4	smooth	65.20	1.84
1	turbulent	110.22	12.76
2	turbulent	70.89	18.27
3	turbulent	72.56	13.69
4	turbulent	88.14	12.75

Table S5. Lift and drag forces measured on a static hummingbird body with various body angles and tail configurations in smooth flow

Body AoA (deg)	Tail AoA (deg)	Tail Fan Angle (deg)	Lift, N	Drag, N
0	0	58	0.0091	0.0040
0	15	58	0.0093	0.0046
0	0	103	0.0095	0.0043
0	15	103	0.0097	0.0047
20	0	58	0.0156	0.0173
20	15	58	0.0160	0.0176
20	0	103	0.0170	0.0183
20	15	103	0.0174	0.0194

Table S6. Mean values of wing kinematic parameters for each bird

Bird	Flow Condition	Mean flapping frequency (Hz)	Mean stroke amplitude – left (deg)	Mean stroke amplitude – right (deg)	Mean stroke plane angle - left (deg)	Mean stroke plane angle – right (deg)
1	smooth	41.66	100.33	97.22	50.98	49.02
2	smooth	42.78	98.65	99.97	49.3	48.17
3	smooth	41.56	97.35	98.47	54.88	55.15
4	smooth	40.21	95.2	97.76	50.34	51.51
1	turbulent	42.78	103.72	109.45	66.81	63.47
2	turbulent	43.79	100.82	103.3	55.63	54.74
3	turbulent	43.47	107.68	102.4	56.72	57.66
4	turbulent	41.67	109.55	104.45	65.58	64.45

Table S7. Standard deviations of wing kinematic parameters for each bird

Bird	Flow	Flapping Frequency (Hz)	Stroke amplitude – left (deg)	Stroke amplitude , right, (Deg)	Bilateral asymmetry stroke amplitude, (Deg)	Max. bilateral asymmetry stroke amplitude, (Deg)	Stroke plane angle, (left) (Deg)	Stroke plane angle, (right) , (Deg)	Bilateral asymmetry stroke plane angle, (Deg)	Max. bilateral asymmetry stroke plane angle, (Deg)
1	smooth	0.18	5.97	5.87	6.87	15.76	2.11	2.11	2.55	5.34
2	smooth	0.11	6.67	5.71	7.17	14.72	3.51	3.11	2.39	6.72
3	smooth	0.08	5.57	5.16	7.94	17.22	1.56	1.25	2.36	3.29
4	smooth	0.15	2.73	3.66	2.88	9.53	1.81	1.77	2.65	4.90
1	turbulent	1.1	6.70	8.61	12.64	36.19	3.05	2.51	3.19	9.00
2	turbulent	0.5	11.97	13.31	13.40	46.47	5.34	5.84	4.13	11.40
3	turbulent	0.8	8.32	9.93	13.55	38.11	3.62	3.51	4.05	8.64
4	turbulent	0.8	15.76	16.76	26.17	40.21	4.25	6.11	5.26	9.45

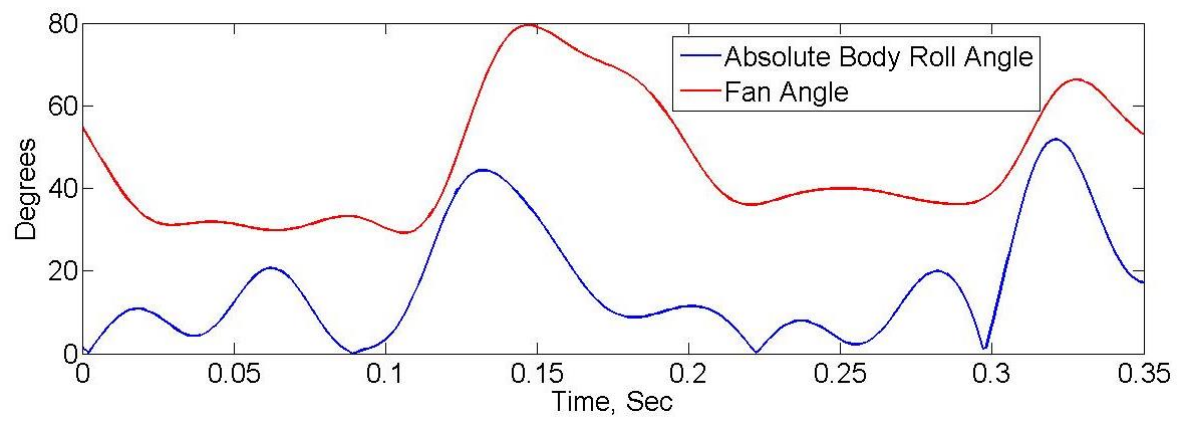


Fig. S1. Representative time series showing absolute roll angle of the body and tail fan angle for bird 2 in turbulent flow. Rapid increase in tail fan angle appears to coincide with high roll angle of the body.



Movie 1: Hummingbird flying in smooth wind. The video shows a hummingbird flying in smooth wind experiences minimal perturbations.



Movie 2: Hummingbird flying in turbulent wind. The video shows a hummingbird flying in turbulent wind. The bird's body experiences significant translational and rotational disturbances when flying in highly turbulent winds. The tail fan angle can also be seen to vary in flight. However the head remains stable in flight.