MH370 – What can be learnt from Kate Tee's sighting?

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Executive Summary

The analysis presented here reviews the full testimony delivered by sailor Kate Tee from May to July 2014 of her sighting of an aircraft in the night of March 8th, 2014. It identifies one by one the key elements included in Miss Tee's sighting and details them in a more systematic way than previously examined in [10] for example. These elements are found coherent and provide confidence in Kate Tee's reporting.

Clear conclusions can be drawn from this testimony, in particular on the possible trajectories passing nearby her boat within a distance of approximately less than 1.5Nm which is the maximum distance to be able to see the aircraft as she described it.

The aircraft was probably flying at an altitude somewhere between 2000ft and 10000ft.

Two types of acceptable trajectories have been found identified as possible candidates:

1- Straight-line directories along the great circle have been identified and form a family of paths with a true track from $\sim 196^{\circ}$ to $\sim 211^{\circ}$ with operationally acceptable ground speed.

2- Two-segment trajectories with a slight turn nearby the boat have been identified and form a family of paths covering the full field of view sectors identified by the sailor as illustrated in Figure 1. Their corresponding ground speed is operationally acceptable.

The results of this analysis provide clear indications on the characteristics of trajectories to be "Kate Tee's sighting compliant" which should include NOPEK waypoint at about ~19:19:30 UTC.

If one admits that it was Flight MH370 and keeping in mind the visual nature of the sighting measurements, these conclusions could be considered as good indications for reconstructing plausible trajectories.



Figure 1: Possible 2-leg broken line paths with a turn at NOPEK

¹ CAPTION Initiative, more at <u>www.mh370-caption.net</u>

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1. Introduction

On her blog on 31 May 2014 [1], sailor Katherine Tee firstly reported her sightings of an airplane during the night of 8 march 2014 at different times, thus possibly of the MH370. She posted subsequent reports [2] to [10], published her boat (Aaza Dana) GPS data [11] as well as the notification mailed to the ATSB on 12 June 2014 provided in Annex1.

In that night, somewhere from about 2:05 Indonesian time i.e. 19:05 UTC on March 7th, heading to Phuket (cf Figure 2) on board her 40foot Bermudan rigged sloop, she and one crew member witnessed the flyby of an aircraft very close to the sailing boat.

All related facts analysed in this study are extracted from publicly available sources listed in the references section and in the annexes of this paper. But also, from further information provided to the author via private direct communications with Miss Tee [15].



Figure 2: Extract of Aaza Dana's journey to Phuket. The orange leg inside the yellow circle is of interest (from K. Tee's web site)

2. Objective

The objective of this paper is to review in details the reported facts, their time sequence, their location and their relative geometry in order to reduce the potential ambiguity of some of the reports and put them in perspective with our own sailing experience². In accordance with the level of precision of the visual sighting, a set of characteristics or pseudo constraints or indications only will be subsequently derived for a trajectory to be "Kate Tee's sighting compliant".

3. The sighting and the facts

In essence, Miss Tee explained that her sighting included four different observation periods.

Initially she saw a kind of "rising star" while she was helming on a northward starboard tack. It was "dead ahead of her", in line with the mast and sails. She moved on to the deck to continuously observe this for some time to work out what it was, leaving the boat temporarily with no steering until an unexpected changed of tack occurred from starboard to port tack. It took her few minutes to set the sails and stabilise the boat on this new course. Thereafter, during this new port tack leg (wind coming

² *The author has sailing ocean navigation experience*

from the left hand-side with a recovered forward speed) she saw a plane coming from 8 o'clock relative and contemplated it for a short while, then she went below inside the boat cabin to make some tea and eventually went up. After this, she resumed her watching of the plane from behind as it went away towards half past 5 relative. Later, time-to-time, she came back to it now flying towards 5 o'clock relative.

Table 1 presents in more details the chronology of the facts (or events) provided by Miss Tee's testimony in the different identified sources coming mainly from direct communication with her and from her blog on 31 May 2014 [3] to [8]. Additional information was used like [9] & [10], the notification mail to the ATSB on 12 June 2014 provided in Annex 1 and the GPS data reproduced in Annex 2.

Item #	Fact/Event	Extra Info / source
E1	Aaza Dana boat was progressing closest to upwind	
	with a speed relative to the water between $\sim 2kt$ to $\sim 4kt$	
E2	While she was sitting behind the wheel, KT's saw a	[15]
	tiny orange twinkle up high, like a huge orange star	In line with the mast and
	rising (Sighting Part-1)	sails i.e. 12 o'clock relative
E3	It was coming towards the boat like a kind of a missile	[15]
E4	That's what distracted me from holding our course. I	[15]
	was trying to work out what it was, and forgot to steer.	
E5	The aircraft had considerably descended form the first	[15]
	second of observation until the accidental change of	
	tack (event E/)	
E6	Lull encounter (very calm wind zone)	Annex I
	Water was flat, barely a ripple. A gentle breeze had	[15]
	Just died. Hence the loss of boat speed and accidental	
F 7	change of tack	
E/	Accidental change of tack due to an upwind turn,	Annex I & $[15]$
	making the boat moving backwards mainly because of	Initially described as a gybe
	the water's current.	(gybe = tack change under
E 0		
Eð	After I had set the sails and got us stabilised on the	[15]
	new course, I turned my attention back to it, and	noles:
	devoted every ounce of my altention to it from that	a- the Genoa had to be put
	moment until the when the engine went on	the best This involved
		the boal. This involved
		it needed pulling around
		n needed putting dround manually due to its weight
		and the lack of wind
		b the boat resumed
		progressing forward
F0	KT's sighting Part 2 of an orange glow coming	Impression of a plane on fire
	towards the boat at ~ 8 o'clock relative. She was the	The a/c crossed behind the
	only witness	stern from port to starboard
	only whitess.	
		At 8 o'clock relative in [3]
		note #5 and Annex 1
E10	I saw like a black smoke behind the orange glow	[3] So the plane was not
		heading directly to her as she
		could see a smoke behind.
E11	A few times I checked behind it	[3] she could see the a/c from
		a side

Table 1: List of facts as reported by Kate Tee from May 2014 till July 2015 and in July 2021

E12	Altitude estimated at 10000ft to 20000ft	[1], later in [9] and [10]
	2000 or 4000 feet	
E13	Held same tack for 5 minutes	Annex 1
E14	The glow turned into a visible plane with a fuzzy halo	No fire [3] within the 5 minutes
E15	I saw 2 airliners cruising at higher altitude from South to North with regular nav lights	[3]
E16	Glowing plane did not have navigation lights	[3]
E17	I thought it was coming to land	[3]
E18	I felt it was travelling slowly	[3]
E19	As it moved behind the boat, I could see the shape very clearly = passenger plane	Possibly light mat grey [3]
E20	I could see where the windows were supposed to be	[3] This gives a good indication of the [short] distance between the a/c and the boat.
E21	It came behind the boat, the estimated elevation angle $\sim 30^{\circ}$	[3]
E22	Clear sight of the hull: so angle 30° or lower and aircraft close to the boat	[3] note #4
E23	There were no wheel gears down	[3] note #3
E24	I went below to turn engine battery on and kettle on	[3] KT got inside the cabin of the boat
E25	Engine went on and crew (Guy Nazarin) woke up	[8] and Annex 1 Not confirmed by GN cf [9] due to a conflict of interest
E26	Re-established new course and made tea	[3] back to the piloting deck
E27	Resumed glow watching (Sighting Part-3)	[3]
E28	KT and GN sighting the aircraft going away	[8] and Annex 1 Not confirmed by GN cf [9] due to a conflict of interest
E29	The aircraft had moved past and was at half past 5 relative	[3]
E30	Black trail seemed more obvious	[3]
Note:	From this time, observations time to time	[3]
E21		[2]
E31	Appeared to be moving to the South, (sighting Part-4)	[3] (sighting Part-4)
E32	but getting away from us at 5 o'clock relative, west of south	[3] and Annex 1, [9] and [10]
E33	The skies were clear and stars visible between the orange plane and the 2 airliners	[3]
E34	Black trail was much clearer (as the plane moved away at 5 o'clock relative)	[3]
E35	Caught some sleep. When I awoke: orange glow (like a dome) over the horizon in approximate direction I felt the plane had flown	[3]

4. The boat's path

Miss Tee's sightings were made relative to the "perceived" longitudinal axis of the boat at the moment of the "observations". By experience we know that the instantaneous direction of a boat is very much dependent of the local conditions of the wind, the waves, the swell and the water current as well as the ship's rig and her sails setup. Unfortunately, these conditions are not completely known. But the global resulting path of the boat is available thanks to its GPS which is the main foundation of this analysis.

Aaza Dana's GPS data has been made available to the IG, which in turn nicely made it publicly available at [11] and partially reproduced in the table of Annex 2. Its analysis helped dating and geolocalising the facts and events in Table 1 and subsequently provided their relative geometry. Figure 3 sketches the path and the key events.



Figure 3: Kate Tee's sailing boat GPS recorded path with major events with the 4 sighting episodes

In this figure, let's firstly consider the red path reconstructed thanks to Annex 2 data.

From 19h00 UTC to a short time before 19:10 UTC the ship was sailing on starboard tack (wind coming from the right-hand side of the sails which were on the left side of the boat) along a quasinorthern track at ~343°. The 8kt wind (3Beaufort), coming from ~70°, initially stable decreased to almost lull. It is during this leg that Miss Tee saw the aircraft for the first time (Part 1 of the sighting). The difference between the wind direction and the ~343° GPS measured track (or ~ -17°) is equal to 70° - (-17°) = 87°. This fact is peculiar as usually the standard capability of a boat to progress upwind and close to the wind direction is of the order of ~40° to ~50° relative to the wind depending on the wind speed. At this geographical location, Phuket destination was basically in the upwind direction. Thus, the boat intentional route was aiming to navigate as close as possible upwind i.e. on a track direction between ~10° and ~30°. This means a 25° to 45° difference between the expected (or intentional) route and the actual route followed. This is probably the result of a low wind speed at this particular point in time (eventually becoming a lull as can be read in Annex 2) and a large contribution of the water current. Thus the "direction" of the boat actual speed relative to the water (along to its longitudinal axis) was somewhere between $\sim 10^{\circ}$ and $\sim 30^{\circ}$. Consequently, the boat was drifting away significantly in a westerly direction. A rough estimation of the boat true speed and the speed and direction of the current could be made as a function of the boat axis orientation. Typically, for a boat orientation at $\sim 15^{\circ}$ the boat speed is found at $\sim 2kt$ and the current speed is $\sim 1.8kt$ with a current coming from $\sim 120^{\circ}$. This hypothesis is supported by the analysis of the leg at $\sim 117^{\circ}$ (cf below).

At 19h10 UTC the track was already established around ~258°, thus the boat had completed the unexpected change of tack before this time. This came as the sailor was trying to figure out what she was seeing. The boat luffed up i.e. turned towards the wind, putting the boat in an awkward attitude: its bow was facing the wind and its Genoa was still tightened on the port side of the boat and not yet set of the starboard side (right side) corresponding to the new port tack. This was because of the low wind speed and also because Kate Tee was distracted from holding the course of the boat as George (nickname of Aaza Dana's autopilot :-) was not engaged. At this low speed of wind, this made the boat moving backwards for few minutes because of the current and a small contribution from the low wind pressure on the inversely positioned Genoa sail.

Therefore from 19h10 UTC to a short while before 19h15 UTC the boat had a reverse speed and its true track was westwards at $\sim 258^{\circ}$ quasi along the current and downwind. During this leg Miss Tee dedicated her time on the foredeck to pull the sail around manually and stabilise the boat course on the port tack.

A short while before 19h15 UTC, the boat resumed its course forward. Subsequently a change of track occurred from ~258° to the measured established route at ~117° at 19h15 UTC as a result of the increase of its own speed forward. The ~117° port tack direction is fully in line with the standard capability of a boat to progress close to the wind (upwind) at a minimum of ~40° from the wind direction established at ~70° at that time with a regained wind speed. The difference $117^{\circ} - 70^{\circ} = 47^{\circ}$ confirms that at this point in time the boat was powered by the wind and that its attitude was close to its track direction. This and the slow absolute speed of ~1.4kt provide an indication that the boat was not far from moving against the current (estimated at 1.8kt) whose direction was roughly estimated at 120° (cf above). Thus, the boat drift did not create a significant difference between its attitude and its true track direction but slowed it down mainly.

The GPS data show then that the leg along this true $\sim 117^{\circ}$ track lasted approximately 5 minutes which corresponds to the second part of Kate Tee's sighting (sighting part-2) occurring after she had got the boat stabilised on the new course.

Then at 19h20 and according to the GPS data, the boat was progressing on the port tack but already on a more eastwards direction at $\sim 88^{\circ}$. This track is too much upwind to be compatible with wind power from the sails alone: $88^{\circ} - 70^{\circ} = 18^{\circ}$ incompatible with the 40° wind sailing minimum angle to allow the wind to provide an effective power. Thus, at 19h20, the boat was already powered by the engine as mentioned in item E24 in Table 2. This leg corresponds to part 3 of Miss Tee's sighting.

Furthermore at 19h25 UTC, the ship turned even more head wind at a true track of \sim 78° and at 19h30 UTC she became full head wind at \sim 71° and stayed like this, powered by the engine for a while. This leg corresponds Miss Tee's sighting Part 4.

5. The consolidated list of factual items

Before consolidating the factual items, few points should be clarified first:

- 1- Considering sailors' habit in estimating a relative direction, one should consider the local attitude of the boat due to the intentional route, the swell, the local waves, the local current, the wind and the reading of watch bearings and its low precision. In fact, the measured watch bearing is an indication of an angular sector within which the eyes caught the plane. The boat longitudinal axis is used as the reference at 12 o'clock. Thus, a reasonable margin of error has to be considered for an acceptable precision (explained further below).
- 2- An aircraft turn is mentioned several times. Miss Tee had difficulties to assess the level of a possible turn. This impression of a turn will be taken into consideration especially when recognising that the boat was near NOPEK waypoint.
- 3- The GPS data provides the true track of the boat and its actual journey with absolute coordinates. One should note that in her testimony the directions are indicated relative to the boat longitudinal axis. Thus, in the following analysis some margin will have to be further added, as the drift of the boat must have had some influence. Typically, at this velocity magnitude of ~2kt a typical drift angle is at least about ~5° to ~20° for a 40ft boat being wind powered depending on the wind speed. In addition, the seawater current is to be encountered for. Some estimation of the current magnitude in this area concluded that the current was around ~2kt in a westerly direction. The sailor confirmed this verbally in [15].

Table 2 presents the consolidated key factual items. They include the facts from Table 1 complemented with the estimated timings derived in Section 4 above and with additional deductions from the yacht path analysed above.

Item #	Fact/Event	Time (UTC)	Location	Extra Info / source
E1	Aaza Dana boat was progressing closest to upwind with a speed relative to the water between ~2kt			
Ela	The ship was sailing on starboard tack on average track ~343°	19:00 - before19:10		[GPS], Nullschool 8kt wind (3Beaufort) was stable and coming from ~70°
E2	While she was sitting behind the wheel, KT's saw a tiny orange twinkle up high, like a huge orange star rising (sighting Part-1)	19:05 - before19:10	6.6252°N 94.4412°E	[15] Sighting Part 1 in line with the mast and sails i.e. 12 o'clock relative
E3	It was coming towards the boat like a kind of a missile			[15]
E4	That's what distracted me from holding our course. I was trying to work out what it was, and forgot to steer.			[15]
E5	The aircraft had considerably descended from the first second of observation until the accidental change of tack (event E7)	19:05 - before19:10		[15]
E6	Lull encounter (very calm wind zone) Water was flat, barely a ripple. A gentle breeze had just died. Hence	Before 19:10 i.e. ~19:09	6. 6 288°N; 94.4405°E	Annex 1 & [15] True track changed from ~343° to ~258° (~140° turn)

Table 2: List of facts as reported by Kate Tee complemented after the analysis of her boat path

	the loss of boat speed and			Initially described as a gybe (gybe =
	accidental change of tack			situation)
E7a	Accidental change of tack due to an	~19:09	6.6288°N;	Ship turned downwind
	upwind turn, making the boat		94.4405°E	Ship still on a mixed port-starboard
	moving backwards mainly because			tack
E7h	of the waters current.	10.00 10.14		Current nowered with some wind
ETU	current mainly	19.09-19.14		contribution on the misplaced sails
E8	After I had set the sails and got us			[15]
	stabilised on the new course, I			notes:
	turned my attention back to it, and			a- the Genoa had to be put on the
	attention to it from that moment			involved walking to the foredeck
	until the when the engine went on			since it needed pulling around
				manually due to its weight and the
				lack of wind.
				b- the boat resumed progressing
FQ	KT's sighting Part 2 of an orange	~10.14	6 6278°N:	Jorward
L9	glow coming towards the boat at ~ 8	~19:14 -	0.0278 IN, 94.4385°E	Impression of a plane on fire. The
	o'clock relative. She was the only	17117	Position	a/c crossed behind the stern from
	witness. (Sighting Part 2)		of the	port to starboard [1]
			mid-leg	At 8 o'clock relative in [3] note #5
				and Annex I
F9a	Ship true track $\sim 117^{\circ}$ and average	~19.14 -		Wind powered @ 47°
Lyu	speed 1.5kt, on port tack	~19:19		
E10	I saw like a black smoke behind the	idem		[3] So the plane was not heading to
D11	orange glow	• 1		her as she could see behind it.
EII E12	A few times I checked behind it	idem		[3] she could see the a/c from a side
L12	20000ft approximately. Later	Idelli		The calibration session took place
	refined as an altitude of about 2000			near Phuket airport approach.
	or 4000 feet after calibration session			
F12	with Blaine Gibson	101.14.00		
E13	Held same tack for 5 minutes	$\sim 19h14:00 - $ $\sim 19h19:00$		Annex I
E14	The glow turned into a visible plane	idem		No fire [3]
D 1 <i>6</i>	with a fuzzy halo			within the 5 minutes
E15	I saw 2 airliners cruising at higher	1dem		[3] Drahahly flying on route D574
	regular nav lights			Frodably flying on route F 574
E16	Glowing plane did not have	idem		[3]
	navigation lights			
E17	I thought it was coming to land			[3]
E18	I felt it was travelling slowly	idem		
E19	As it moved behind the boat, I	ıdem		Colour: possibly light mat grey [3] Moved behind the boat:
	passenger plane			a/c passed north of west of the boat
E20	I could see where the windows were	idem		[3] This gives a good indication of
	supposed to be.			the distance between the a/c and the
DO01 :		• 1		boat.
E20bis	Early in her	ıdem		[10] The aircreft was not coming fully
	view of the cockpit windows which			towards the boat but passing by its
	were lit, but during most			west
	· · · ·	•		•

	of her observation the cockpit was seen from the side			
E21	It came behind the boat, the estimated elevation angle $\sim 30^{\circ}$	idem		[3] The boat was on $\sim 117^\circ$ track, thus a/c passed North of West of the boat
E22	Clear sight of the hull: so angle 30° or lower and aircraft close to the boat	idem		[3] note #4
E23	There were no wheel gears down	idem		[3] note #3
E24	I went below to turn engine battery on and kettle on	~19:18:30		[3] in the cabin of the boat
E25	Engine went on and crew (Guy Nazarin) woke up	~19:19:00		[8] and Annex 1 Not confirmed by GN cf [9] conflict of interest
E256	Re-establish new course and made tea	~19:19:00		[3] back above
E27	Resume glow watching (sighting Part-3)	~19:19:30		[3], sighting Part-3
E27a	Ship true track ~88° and average speed 1.5kt	After 19:19:10		Engine powered, eastward head wind direction, against current
E28	KT and GN sighting the aircraft going away	After 19:19:30		[8] and Annex 1 Not confirmed by GN cf [9] conflict of interest
E29	The aircraft had moved past and was at half past 5 relative	After 19:19:30		[3] a/c passed west of the boat
E30	Black trail seemed more obvious	After 19:19:30		[3]
Note:	From this time, observations time to time			[3]
E31	[a/c] appeared to be moving to the South (sighting Part-4)	After 19:19:30		[3] sighting Part-4
E31a	Ship true track ~71° and average speed 5.3kt, engine powered eastward head wind direction	~19:30:00	6.6280°N; 94.4443°E	Considering item E32 below and the slight change of read bearing, this should have happened after the ship took its final stable true track ~71°
E32	but $[a/c]$ getting away from us at 5 o'clock relative, west of south	After 19:30		[3] and Annex 1, [9] and [10]
E33	The skies were clear and stars visible between the orange plane and the 2 airliners	After 19:30		[3]
E34	Black trail was much clearer (as the plane moved away at 5 o'clock relative)	After 19:30		[3]
E35	Caught some sleep. When I awoke: orange glow (like a dome) over the horizon in approximate direction I felt the plane had flown	After 19:30		[3]

6. The 4 identified sightings

Concentrating on the angular sectors around the different bearings of the 4 sightings (Items E2, E9, E27, E31), one can summarise their estimated position and estimated geometrical characteristics thanks to the knowledge of the boat attitude and path direction as presented in Table 3.

Sighting #	Estimated	Ship location	Ship True	Sighting clock	Sighting
	Time (UTC)		Track °	bearing relative	bearing °
1 (items E2 to E5)	~19:05/19:09	6.6252°N;94.4412°E	~343	12 o'clock	~5/~30
2 (items E9 to E23)	~19:16:40 *	6.6278°N; 94.4385°E	~117	~8 o'clock	357
3 (items E27 to	~19:20:00	6.6273°N; 94.4394°E	~88	~half past 5	253
E30)					
4 (items E31 to	After 19:30	6.6280°N; 94.4443°E	~71	~5 o'clock	221
E35)					

 Table 3: Characteristics of the three sighting sectors

 * mid-time of the sighting

Sailing navigation experience shows that reading the bearing of a visual target from a boat's deck is approximate due to the local conditions around the ship as noted above. The reading error, the instantaneous orientation of the boat (at least $\sim 5^{\circ}$) added to the sailors' custom to digitise the reading by the closest half hour ($\sim 15^{\circ}$) make that a contingency margin of $\sim 20^{\circ}$ should be applied on each side. This leads to consider the readings as angular sectors within which the aircraft was seen flying.

Sighting Part-1 is particular due to the low wind and relative high drift leading to a large divergence between the true track and the intentional direction thus with the instantaneous orientation of the boat. Furthermore, it is limited on the eastern side by the "unbreakable" minimum sailing angle of 40° from the wind direction (which could increase depending on the wind speed). The reading error margin was thus added to the left only leading to a reduced angular sector compared to the following sighting parts. In addition, the alignment of the sails, the mast and the skipper position make the relative reading more accurate. In Section 4, the instantaneous orientation of the boat was estimated between 10° and 30° .

Respective graphical illustrations of the four identified sectors based on Table 3 items are provided from Figure 4 to Figure 7.



Figure 4: +/- 12.5° Angular sector around the 12 o'clock relative estimated direction of the sighting Part-1 from 19h05, the low wind speed and local drift component are the reason for the discrepancy between the boat attitude and the true track.



Figure 5: +/- 20° Angular sector ~ 8 o'clock relative estimated direction of the sighting Part-2 at 19h15



Figure 6: +/- 20° Angular sector ~ the half past 5 relative estimated direction of the sighting Part-3 at 19h20



Figure 7: +/- 20° Angular sector ~ the 5 o'clock relative estimated direction of the sighting Part-4 after 19h30

Figure 8 puts the four sighting sectors into the global context and allows visualising the situation of the sailor when she observed the plane at the different occasions.



Figure 8: +/- 20° Angular sectors of Kate Tee's 4 sightings (1&2 alone and then with the crew) - Closeup

In order to refine the scale of the sectors, let's consider the range of the sailor' visual horizon. For this, one should consider the witness' eyes height, the altitude of the flying aircraft and the atmospheric

propagation of the light which is a non-negligible phenomenon at sea especially at night. To that effect, in the computation, the Earth radius value is increased by 20% as a commonly accepted correction for mitigating this phenomenon.

Item E6 of Table 2 indicates aircraft altitude values refined by Miss Tee. She initially estimated the altitude between 10000ft and 20000ft. Later, she corrected them as being between 2000 to 4000ft. These latter estimations appear more in coherence with our own visual experiments done at Brussels airport when observing aircraft during their final approach. At daylight, we could barely distinguish the passengers' windows at a distance of less than 1.5Nm for aircraft flying at an altitude of ~1000ft and certainly not at all for a greater distance.

Thus, being conservative, we will consider that the aircraft could have flown up to 10000ft when overflying the boat. At 10000ft, the physical horizon the visual would be \sim 110Nm leading to a visual horizon at \sim 120Nm when corrected for the light atmospheric propagation. For an altitude of 5000ft, this visual horizon is \sim 86Nm and for 2000ft it is \sim 56Nm.



These horizons with the overall visual zone limits are illustrated in Figure 9.

Figure 9: +/- 20° Angular sectors of Kate Tee's 3 sightings with visual horizons versus aircraft altitude

7. Four valuable indications on the aircraft location

As the sailor was not expecting an aircraft to appear in her field of view, the first sighting did not necessarily start when the aircraft was entering inside the visual horizon of the sighting Part-1 angular sector. But the reporting of a "rising star" indicates that if it was not at the entry it was not that long after.

Thus, using the boat attitude deduced above i.e. a mean direction of 22.5° and using a typical ground speed corresponding to a flight at an altitude of ~10000ft, one can roughly estimate the position of the aircraft at ~19h05. This is illustrated with the D pin inside the green sector in Figure 10.



Figure 10: Area of the early start of the sighting Part1 at ~19h05 – the D pin indicates a rough estimation of the aircraft position at that time illustrated at an altitude of ~10000ft

Later between ~19h14 and ~19h19, according to items E9, E19 and E21 of Table 2, the airplane was seen closer and moving past the ship. Thus, taking the boat location as an approximation of the plane location at 19h19 and going backwards one can estimate the gross area where probably the aircraft was seen for the second time. This is reported in Table 4. Thanks to items E17 and E18 describing an aircraft flying at slow speed, typical ground speeds are considered in their lower ranges for the considered altitudes. The justification for the estimation of the typical low speed is provided further below.

Altitude (ft)	Typical ground	Flown distance in
	speed (kt)	5min (Nm)
2000	200	~17
5000	280	~23
10000	360	~30

Table 4: Estimated boundaries of the area of the start of the sighting Part2 at ~19h14

The subsequent area is illustrated as a purple sector in Figure 11.

Note: In [15], Kate Tee underlined that between the sighting Part-1 and Part-2 she is noted that the aircraft had significantly changed altitude to a lower flying level



Figure 11: Area of the start of the sighting Part2 at ~19h14 after the accidental gybe

In the contrary, towards the end of the sightings and as the sailor was intrigued by this flying object, she observed it time to time only until it basically went out of her visual horizon in the sighting Part4 angular sector.

No indication is provided on the last moment of the observation, but item E35 of Table 2 mentions that the aircraft was basically observed until it disappeared at the limit of the visual horizon of the witness. Thus, some timing indication can be derived on when the aircraft visually disappeared. In item E35, Miss Tee declares that she caught some sleep. There exist 3 usual types of sleep sailors or drivers use to get rest while being on duty: Flash sleep (~5min) but with no real rest, parking sleep (~20min) with effective rest and full cycle sleep (~1h30 to ~2h) with full recovery. Considering the dimension of the sector (~86NM or ~120Nm) and the speed range of an aircraft (~200kt to 500kt) and the description of the end of the sighting part 4, the most probable type Miss Tee slept is a Parking sleep i.e. about 20min. This provides a very rough indication of the potential speed. If the altitude was at 5000ft, it would be 86Nm in 20min i.e. ~260kt. If at 10000ft, it would be 120Nm in 20min i.e. ~360kt. Both are compatible with a low altitude flight and with item E9, E19, E21 and E22 of Table 2.

At these various altitudes, a visual "exit area" can be grossly delimited as illustrated in Figure 12.



Figure 12: Area of the end of the last sighting at ~19h39 at the boundary of the visual horizon

Gathering the above elements, one can derive indications and characteristics useful for identifying a trajectory being "compliant" with Kate Tee's sighting, which are illustrated in Figure 13 and summarised in Table 5.



Figure 13: Overall view of Miss Tee's sighting 4 parts location and timing

Time (UTC)	Indication	Sector Corners	Area	Remarks
~19h05	Sighting part1	8.61°N/ 94.61°E	Green	Like a rising
		8.35°N/ 95.46°E		star
		7.85°N / 95.18°E		
		8.05°N / 94.57°E		
~19h14	Sighting part2	7.14°N /94.22°E	Purple	Approaching
		7.16°N /94.60°E	-	aircraft
		6.90°N /94.52°E		
		6.89°N /92.32°E		
~19h19	Sighting part 3	6.65°N / 94.40°E	Green	Closest view
~19h39	Sighting part 4	6.17°N / 93.62°E	Blue	Aircraft out of
		5.75°N /94.10°E		sight
		4.76°N /93.72°E		
		5.66°N /92.69°E		

Table 5: Characteristics and indications for a trajectory to be compliant with Miss Tee's sighting

8. Possible trajectory types

These four indications could help to reconstruct the segment of the trajectory between \sim 19h05 UTC and \sim 19h40 UTC.

What types of trajectories to consider?

There is an infinity of possible types of trajectories crossing the 4 sighting areas identified in Section 7. Keeping in mind that the Persons in Command (PIC) were concerned with distance and timing, the straight lines (great circle) and broken lines with two great circle segments appear the most realistic.

In the case of broken lines especially when recalling Miss Tee's indication of a possible turn, the presence of the waypoint NOPEK in the vicinity of the boat could be of use especially when considering the location of such a turn. If waypoints were to be used by the PIC and a turn occurred, NOPEK is the most logical place for it. Considering that BEDAX waypoint is well within the sighting Part 4 area, logically it may have been the next waypoint overflown by the aircraft. Other waypoints outside this area could also be of interest to a lesser extent like NIXUL on route P627 for example.

Recalling item E31 from Table 2 "aircraft moving to the south" and item E32 "west of South" - 5 o'clock relative - the focus should be on the eastern part of the sighting sector 4.

Miss Tee reported that she had the impression that the aircraft may have turned. It could be because of an actual turn like in a broken line trajectory. But it could also come from the fact that her boat had actually turned itself 4 times during the parts of the sighting of a... simple straight-line trajectory. This could have given the visual impression that the plane had turned while it was only the boat that actually turned. Thus, straight lines cannot be dismissed.

Straight lines (great circle)

Considering sighting part 3 area (Green spot in Figure 14) which is the most constraining area, one can draw the great circle lines at the edges limiting the angular sector containing the possible straight-line trajectories family as a function of altitude. Figure 14 illustrates the two extreme cases i.e. at altitude 2000ft and at altitude 10000ft.



 Figure 14: Families of possible straight-line trajectories passing through all sighting areas

 Left yellow: at altitude 2000ft
 Right brown: at altitude 10000ft

One can conclude that for all altitude between 2000ft and 10000ft, there exists a family of great circle trajectories compliant with Miss Tee's sighting. The estimated minimum and maximum true track are presented in Table 6.

Altitude (ft)	Min True Track (°)	Max True Track (°)	Angular span (°)
2000	~196	~211	~15
5000	~198	~207	~9
10000	~199	~205	~6
	F 11 (F) 1	1.0 . 1 .	

Table 6:	Estimated	true	track for	great	circle	trajectories
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Note: BEDAX waypoint is within the angular span of these great circle trajectories for all considered altitudes.

Broken lines with two segments

In this paragraph the focus is placed on broken-line trajectories including a slight turn at NOPEK waypoint very closely located in the south-west of the boat position. A similar reasoning as for straight lines can be applied but with a turn within sighting Part3 area as the boat and the waypoint are separated by ~2Nm only. Thus, the respective resulting viewing sectors will be similar concerning the possible trajectories.

Starting from NOPEK, the limiting segments at the edges are first identified in each sector and then linked together to form the trajectories at the outer edges as a function of the altitude. Figure 14 illustrates the two extreme cases considered i.e. at altitude 2000ft and at altitude 10000ft.



Figure 15: Families of possible broken line trajectories passing through NOPEK waypoint (altitude 2000 to 10000ft)

One can conclude that for any altitude between 2000ft and 10000ft, there exists a family of broken line trajectories including a turn at NOPEK waypoint and compliant with Miss Tee's sighting. The estimated minimum and maximum true track per segment are presented in Table 7. These values are in fact independent of the altitude.

	Northern	Segment	Southern Segmen		
Altitude (ft)	Min True Max True		Min True	Max True	
	Track (°)	Track (°)	Track (°)	Track (°)	
2000 to 10000	~185	~199	~200	~242	

Table 7. Estimated	rue track limit	s for each sea	ment of broken	line traiectories
Tuble 7. Estimated i		s joi euch seg		

Note: For all considered altitudes, BEDAX waypoint is within the angular span of these broken line trajectories with a turn at NOPEK.

9. Possible trajectory profile

Very few indications are provided by Miss Tee's testimony about the vertical profile of the plane she saw. Nevertheless, some items are of value for getting a rough idea of the flying altitude.

Firstly, E12 in Table 2 reveals the uncertainty of the estimated altitude by the witness due to lack of knowledge in the field. So, this should be treated cautiously and considered as an indication only. After a second thought and a test and check session with a trained pilot verifying altitudes, Miss Tee's opinion was that the probable altitude was about ~2000 to ~4000 feet.

Secondly, considering her impression given by E17 "I thought it was coming to land" and item E18 "I felt it was travelling slowly" in conjunction with a distance indication from item E20 "I could see where the windows were supposed to be" combined with item E21 "It came behind the boat, the estimated elevation angle is $\sim 30^{\circ}$ ", one can make rough estimations as follows.

Seeing the passengers' windows location means a distance of about 1.0Nm or 1.5Nm at most. Considering that it looked like a landing phase with an estimated elevation of $\sim 30^{\circ}$, this means that the aircraft could have flown between 2000ft to 10 000ft at most. For example, an altitude of 20 000ft would lead to a too large distance between the boat and the aircraft (approx. ~ 3.5 Nm) to be seen the way Miss Tee saw it. Eventually, we took 3000ft as the working hypothesis.

Furthermore, Banda Aceh Radar coverage is an extra element to be considered. The maximum range of the radar coverage at the altitude of 5000ft is NOPEK. The PIC may have wanted to fly undetected below the radar ceiling as their transponder was off thus justifying a low altitude in addition to an additional justification provided in Section 10 below.

10. And the glow turned into a visible plane...

Item E14 of Table 2 raises the question of the strange orange fuzzy glow around the aircraft as seen by Miss Tee. The final investigation report [12], mentions that volcanic ash advisories were issued on that day because of ashes originating from Mount Sinabung volcano located at [3.17°N; 98.39°E]. The advisories releases were made at 06:27 UTC and at 18:37 UTC on March 7th. But the volcano had been active long before as documented by the volcanic ash advisories released by Volcanic Ash Advisory Centre (VAAC Darwin) from 10th January onwards.

The distance between the volcano and the boat was about 310Nm which is a short range. The volcano elevation is 8070ft. In the first quarter of 2014, its eruptions were reported and produced ash plumes as high as 2000m to 4000m (5500 to 13000ft).

In the analysis performed in "MH370 – What can be said about Sinabung Volcano ashes?" [13], it is shown that the orange glow could come from the burning of tiny ash particles like SiO_2 and of SO_2 gas inside the engines producing coloured exhaust gases.

Using NOAA simulations tools, it is shown that in this time period the ash cloud may have been transported up to the north of Kate's boat location and between sea level and the altitude of 20000ft.

The MH370 low level of flying could have come also from an avoidance manoeuvre to fly below the ash cloud. This is the recommended procedure to flight crew i.e. to reduce the engine operating temperature via a descent with the possibility to get cleaner air as described in Skybrary [14]. But they could not know that the actual ash cloud was in fact below 20000ft down to sea level.

This could logically explain the orange glowing phenomenon and also a later climb to get out of it i.e. above 20000ft.

11. Conclusions:

Clear conclusions can be drawn from Miss Tee's testimony and from the geometry analysis of the reported events presented above:

- 1- The reported facts, their timing and their identified geometrical relative position (observation sectors, boat journey etc.) provided by Miss Tee are coherent providing confidence in her reporting.
- 2- The potential path followed by the plane within the four sectors is timely reconstructed. The sighting period started around ~19h05 and finished after ~19h40.
- 3- As she saw the cockpit in the first place and then the cabin windows, the plane came to her and eventually passed close aside of the boat by its west
- 4- The closest point must have been less than about 1.5Nm in order to distinguish the cockpit from the windows and it occurred between 19:14 and 19:20.
- 5- The flight altitude was somewhere between 2000ft to 10000ft and most likely close to \sim 2000/ \sim 4000ft.
- 6- The aircraft appeared first as an orange glow probably because of ashes encounters (this will be explained in a separate paper)
- 7- The aircraft went away in the west of south direction
- 8- Straight-line trajectories and two-segments broken lines trajectories of the aircraft have been identified satisfying the time and speed constrains. Their true track directions and subsequent ranges have been identified.

If one admits that the aircraft was flight MH370, then this testimony provides a pseudo waypoint for a possible reconstructed trajectory. This point is at a distance less than \sim 1.5Nm from Kate Tee's boat at \sim 19:19:00 UTC.

But considering, the presence of air navigation waypoint NOPEK at about 2Nm southwest, one could better infer that it was the actual waypoint overflown by the aircraft. Thus, considering the aircraft low altitude, its low speed and the proximity to the boat, NOPEK waypoint at about ~19:19:30 UTC should be considered as an additional waypoint for reconstructing any MH370 trajectory.

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- [15] Private direct exchanges of information with Katherine Tee, MA, BEd(hons), July-August 2021.

Additional:

https://saucysailoress.files.wordpress.com/2014/10/a-simulated-flight-of-mh-370-2.pdf

Duncan Steel archive:

https://web.archive.org/web/20140820220703/http://www.duncansteel.com/archives/899

13. Glossary:

Port	The left-hand side of the boat				
Starboard	The right-hand side of the boat				
Tack	Heading of a sailing boat with reference to the wind direction				
Stern	The back of the boat				
Winward	Towards the wind; upwind				
Luffing up	The boat turns into the wind				
Leeward	Away from the wind; downwind				
Bearing away	The boat turns away from the wind				
Astern	Behind the boat				
Ahead	In front of the boat				
Bow	The front of the boat				
Aft	Inside the boat towards the stern				

Annex 1: K. Tee's email to the ATSB

On June 12th 2014, K. Tee notified the ATSB via email that she and her crew eye witnessed the aircraft.

me

To Alex.Talberg@atsb.gov.au

Jun 12, 2014 🔺

Hi Alex,

I really don't know if my fuzzy recollections can add anything to your investigations, but somebody sent through a flight plan that he believes could fit in with my sighting of what could have been MH370 at 1920 UTC (he mentioned something about GIVAL) and which jolted my memory...

Remember I believed (on the diagram I added in the green lines) that the plane had born away where I recall seeing it at 5oclock relative when I came up from the cabin? If that was the case, and this is the time we saw it, then looking at our own track, at this time we gybed, and then changed course onto the new tack.

Looking at our track, seems likely that we hit a lull and went into an accidental gybe (not unusual in itself) then I decided to stay on the new tack. It would have been at this time my scan picked up the orange glow coming towards us from 8 o'clock relative. I held that tack for 5 minutes, which would have been the time in which I watched the glow turn into a plane.

At that stage I would have gone below to turn on the engine battery (there is no question about the engine having gone on at this stage, since that's the only thing which would have allowed us to head up as we did) and probably put the kettle on whilst I was there. By the time I had re-established the new course, probably made tea, and got back to the business of glow watching, the relative angle of that plane to the boat would have increased, making it look as though it had borne away.

Again, not sure if this helps at all, but it would explain why I thought the plane had turned, and I do now recall the crew waking at this stage when the engine went on. I now recall I pointed it out to him and asked him if he knew why it was orange, and I recall him saying it was rather unusual but he didn't know why, he'd never seen it before. But I have no idea if he recalls that. We saw quite a few unusual things on this passage, and he had just woken up! That said, he's an aeronautical engineer, so if it had been a plane on fire, he would probably have recognised it as such, so it was probably nothing of concern anyway, and his response did reassure me at the time that it wasn't a problem.

Regards, Kate

Annex 2: Aaza Dana's GPS data from 02:00 to 02 :45 (Thailand's Time)

Note: In Thailand, March 8th, 02:00 corresponds to 19:00 UTC on March 7th.

Thailand's Time	Leg duration	speed	Track	GPS recorded coordinates
08/03/2014 02:00	00:05:00	5 kt	347° true	N6 37.075 E94 26.577
08/03/2014 02:05	00:05:00	3 kt	343° true	N6 37.454 E94 26.488
08/03/2014 02:10	00:05:00	2 kt	258° true	N6 37.720 E94 26.408
08/03/2014 02:15	00:05:00	1.4 kt	117° true	N6 37.690 E94 26.264
08/03/2014 02:20	00:05:00	1.4 kt	88° true	N6 37.638 E94 26.366
08/03/2014 02:25	00:05:00	2 kt	78° true	N6 37.643 E94 26.483
08/03/2014 02:30	00:05:00	3 kt	72° true	N6 37.678 E94 26.657
08/03/2014 02:35	00:05:00	3 kt	71° true	N6 37.759 E94 26.906
08/03/2014 02:40	00:05:00	3 kt	72° true	N6 37.840 E94 27.147
08/03/2014 02:45	00:05:00	3 kt	70° true	N6 37.920 E94 27.391