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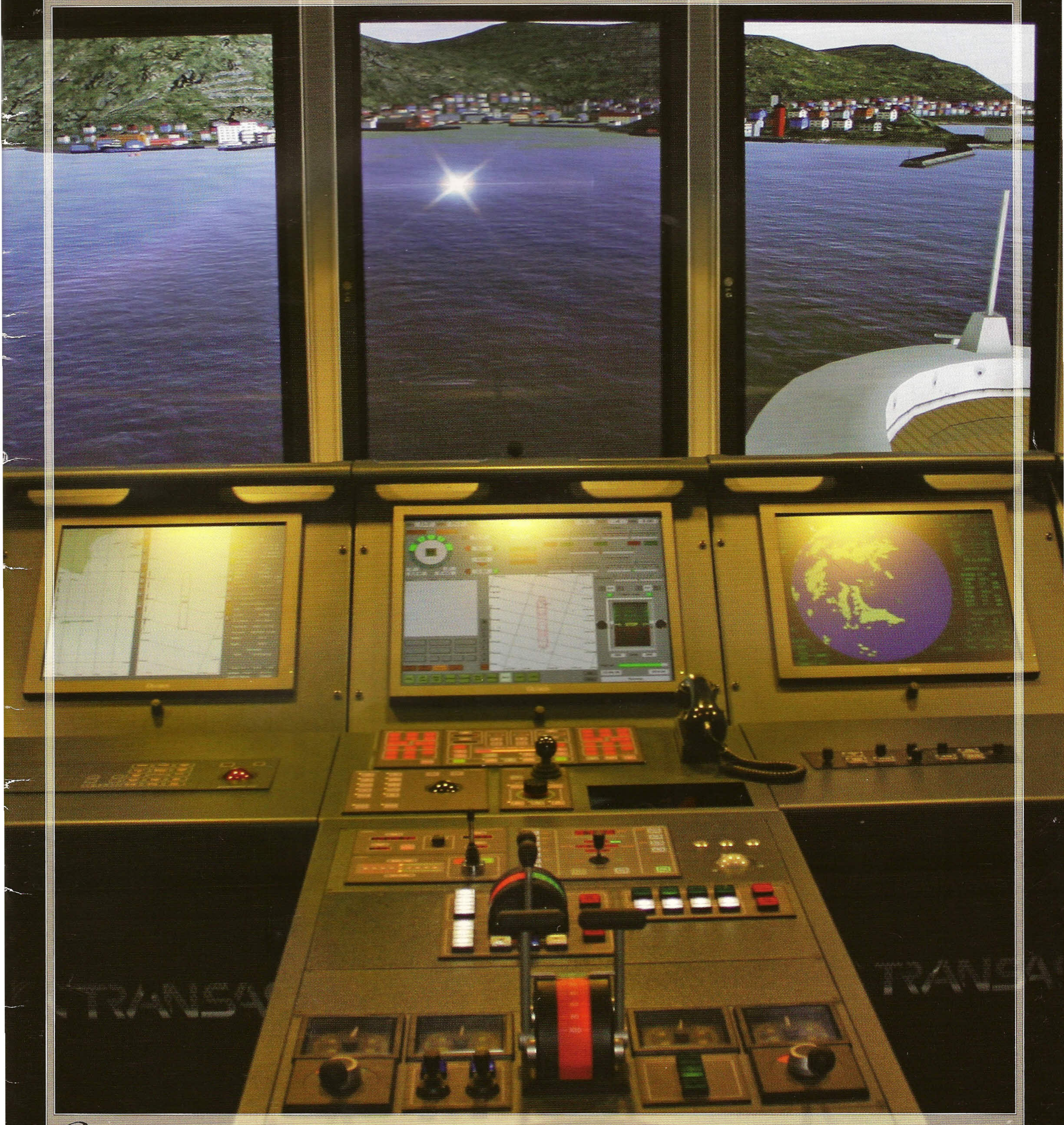

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POS - NAV - TIME

A quantitative theory

Where to Search for the Earhart Lockheed Electra

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The Earhart–Noonan 1937 incident is called enigmatic due to inadequate information about the last stages of a flight to Howland Island, Pacific, which they never have reached. It however seems that synchronisation of remaining radio communications records into a model of navigational systematics of the era brings questions and answers together, close enough to open new vistas so that a final solution for the origin which sealed the crew's fate may have come nearer. The article below contains a concise review of the concerning exploration which has been developed through the years 1988 to 2006.

I must here take note, that indeed our error in Longitude can never be great, so long as we have so good a guide as watch (Captain James Cook, *Journal of the Resolution*, Second Voyage, 1772)

First Stages of Flight

After take off from Lae, New Guinea on July 1, 2356:18 GAT (Greenwich Apparent Time) the actual weather on the first track to Nukumanu Island showed a change from the forecast. Namely the wind direction and velocity, later found (R.Nesbit) to have been 25 mph from due East declined from the predicted 15 mph from ESE. Navigators revere the professional weather report, the "Metro"

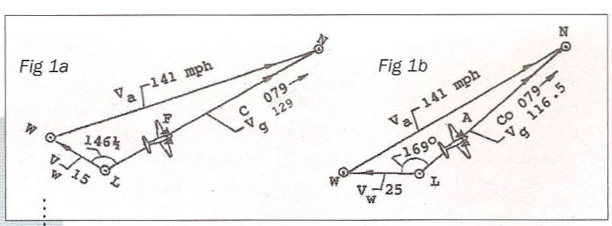

Figure 1a - Speed vectors flight in Metro weather, Lae to Nukumanu.
Figure 1b - Speed vectors flight in actual weather, Lae to Nukumanu.

and will abandon its previews, only if the actual weather considerably and structurally declines. Given this discipline, navigator *Frederick Noonan* will have based his initial D.R. (Dead Reckoning) flight plan on the for July 2 forecast as received from Fleet Air Base, Pearl Harbour.

Figure 1b shows the speed vectors for the actual flight from Lae to Nukumanu as derived from the position transmitted by the aircraft, aircraft's radio (159°07'–E;04°33'.5–S) at 1720 GMT.(vs Table II). The position is 27 miles off Nukumanu which was reached at 0726:33 GAT after flying the 874 miles section at a mean groundspeed of 116½ mph from 141 mph airspeed. This airspeed has been transposed to the vectors of Figure 1a which after application of the cosine rule and solving the resultant quadratic equation gives a 129 mph "Metro" groundspeed vector. Thence, the due adverse weather delayed ATA–Nukumanu is calculated as by Table 1.

Take off Lae, July 1	GAT	$23^h56^m18^s$
874 mls @ 129 mph		$06^h46^m31^s$
		$30^h42^m49^s$
		24^h
ATA as from forecast	GAT	$06^h42^m49^s$
ETA actual July 2	GAT	$07^h26^m33^s$
ETA Nukumanu, delay		$00^h43^m44^s$

Table 1 - Delay 43^m44^s, Lae to Nukumanu.

The Position Fix is situated exactly on the loxodromic curve from Gagan, True Course (TC) 081.5, (reached 0439:53 GAT) on Buka Island to Nukumanu and has been evidently established by a precomputed Time Sight on the sun at central sunset with the bubble sextant. This statement is beyond doubt since the time points, the loxodromic parameters and the algebraic algorithms of geographical and astronomical spherical trigonometry are inviolably interconnected. Recomputation by using H.O.no.208 *Navigation Tables for Mariners and Aviators* (Dreisonstok), by Noonan used since first issued in 1928, is more complex but gives with direct spherics congruent results, which is indicative for Noonan having calculated the same way. Figure 1c is the diagram of the recomputed sunset Fix.

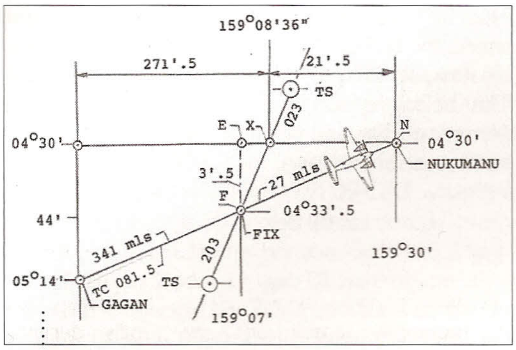

Figure 1c - Sunset Fix 0719:30 GMT near Nukumanu Island, aircraft at Gagan 0439:53 GAT, Nukumanu 0726:33 GAT.

Nukumanu Island to Nikunau Atoll

The Fix, (F 1 in Figure 2) virtually within visual range of Nukumanu after flying over Gagan supports the assumption that Noonan preferred to fly via as many as possible identifiable landmarks, islands and other contingent aids to navigation, to avoid the hazard of going astray from a long (2,556 mls, 4,113km) great circle route, partially to be flown in adverse weather. Figure 2 contains the flight plan model which has accordingly been developed.

When first heading for Nauru Island after passing over Nukumanu and consequently change to a due eastwards (TC 090) course when reaching the (01°23'–S) parallel of Nikunau intersection (the Initial Point) with the (165°21'–E) meridian on the to Nauru rhumb line, a navigator struggling with scattered and from time to time 8 octa (10/10th) overcast that obstructs observing more than one star simultaneously while long distance flying, can substantially escape the scare crows of winddrift and overconfidence in Rogues' Gallery of early air navigation. On the Initial Point to Nikunau 766 mls leg, one navigation star per 20 minutes (∂–Ophiuchi to nos.53 & 54 Deneb and Enif) ran in transit with the aircraft's meridian so that by Course and Distance Position Lines the flight could be securely kept in the latitude for proceeding longitude. At 1030 GMT the aircraft was just southwestwards of the Initial Point and 130 mls off Nauru (visual range 135 mls from 12,000 ft) when Amelia announced to have the glare of the island's industrial lights and the 560 feet high fixed light in sight. (Nauru residents heard the aircraft's signals, "..but it did not come nearer.."). Aboard the guard ship Ontario, on station halfway the great circle Lae to Howland, unless appointments and with watch kept, Captain Blakeslee and his men observed no aircraft, neither audibly nor by radio. The above navigation model delivers a good assessment concerning this phenomenon: the shortest distance aircraft to ship was 100 mls south-eastwards at about 1000 GMT. The flight was on the Nauru meridian at 1113 GAT (2217 LZT), distance 58 mls, north of vessel *Myrtlebank*, 1108 GAT, 20 mls, south of Ocean Island (now: Banaba), 1227 GAT, 36 mls and arrived over Tabiteuea, 1451 GAT (0151-0251 LZT), to reach Nikunau at 1540 GMT, (time equation 3m49s) this being the time figure for the as usual 20 minutes interval D.R. flight plan. Captain Irving of the yacht Yankee of Gloucester, having explored the Gilbert Islands region in 1939 for The Amelia Earhart Foundation, reported negative results except one: an aircraft had been heard passing over Tabiteuea in the night of July 2, 1937, but no time indication was given.

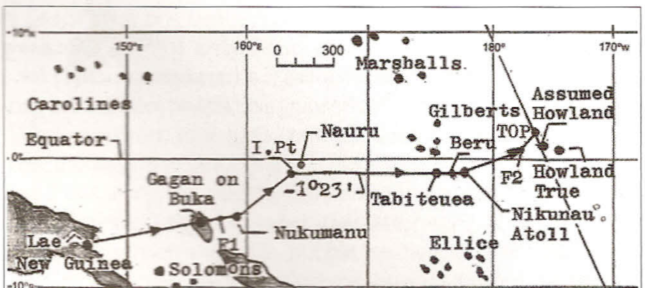

Figure 2 - 2,626 miles Flight Plan Lae to Howland via Initial Point below Nauru Island. All figures and diagrams, this Figure 2 excepted, are for clearness unscaled.

Nikunau Atoll to Howland

Introduction

By consulting Lippincott's Atlas of the World at the Hydrographic Office in the beginning of 1937, navigational consultant C.Williams copied the Howland coordinates 176°43'–W; 00°49'–N which is a position 5.8 mls westwards of the true coordinates pair (176°38'–W;00°48'–N). These latter, by the later guard ship Itasca established figures appeared too late in files, thereby leaving Williams and consequently Noonan unaware of the decline. Nikunau is an atoll in (176°26'–E;01°23'–S), with 498 mls the closest to Howland westwards landmark. Due to the delay incurred when flying the Lae–Nukumanu section it would be dawn before a position would be reached where the One Line Approach could be commenced.

Usually such position was marked by a reliable Fix (F 2 in Figure 2) from where an offset course to one side, heading to a Turn Off Point where course was altered in the direction of the destination, could be set in. The method was first used by Captain Thomas H. Sumner when he navigated the Irish Sea in the winter of 1837. During a bright interval in dense fog he succeeded to take one sight on the sun and sail along one position line in the direction of a light vessel which in fact ran in sight after some time.The fashion was also successfully used by Francis Chichester to find small islands (Norfolk, Lord Howe) when crossing the Tasman Sea. Noonan was an adherent of this "Find the Island" methodology and he practised its implementation during his career with Pan American Airways. At sunset near Nukumanu, 0719:30 GMT, he observed by the bubble sextant (refraction corr^{n} –37 arcmin, Coriolis corr^{n} nil). The period of "darkness" on board is in astronomical terms defined as the time interval between 0715:45 GAT central sunset and the instant at which the true sun's centre is again in the horizon at next morning's sunrise in the event that for the observation sextants with similar reference lines are used. Any deflection contrary to this definition leads to an artificial, non conceded abridgeing, or if conversely, extension of the astronomical on board night length.

Genesis of an Observation Error

In the early morning of July 2nd in west longitudes the only for astro navigation available body to establish a last Fix before steering on the offset course to the Sumner Line intersecting the Howland A.P. (Assumed Position) coordinates was the rising sun. In the 1928 edition of Navigation and Nautical Astronomy (Dutton), art.311, p.348 where advantages and disadvantages of bubble versus marine sextants are discussed we read:

> *In any case (of using the bubble sextant), the pilot must fly the plane as steady as his skill permits while the sights are being taken. Because of the errors of the bubble sextant, the best results are obtained by flying very low and using the ordinary (= marine) sextant on the horizon.*

However, none of the textbooks on navigation of the era and no Explanation Section of Nautical Almanacs through history register caution that an air navigator shall never during one single flight exchange sextants with different reference lines for sights on a heavenly body also used to calibrate the flight time. While Noonan most probably used his Pioneer marine sextant to fix his position on the roads of Howland when flying at 1,000 feet altitude, with the sun in *mean* time whereas the *true* sun should be taken, it was, as we will presently see, this combination, although not being the flight's *laesio enormis*, that triggered the primary impulse to not sighting the island before the fuel ran out. Both theory and practice became antagonistic to safety because the bubble sextant has its reference line which is the artificial horizon, over sun's centre and the marine sextant at sunrise registers on the optical sun's upper limb in the horizon, since due to severe refractive distortion the lower limb falls into disuse.

Dynamic versus Static Sunrise

Usually the offset course for the One Line Approach was set at one hour off destination on the main course where the Offset Fix had to be established. In Noonan's case with the aircraft's 150 mph cruise speed, this Fix had to be precomputed for the coordinates pair (178°47'–W;00°09'–N) at 150 mls off. The belonging sunrise time was charted in the (American) Nautical Almanac (an Air Almanac was not issued for the year).

	Lat 00 deg		LMT 0600
July 2, 3, 4		U.L.H.	
	Lat 10 deg	N	LMT 0543

For 00°09'–N we find LMT 0600 – 9/600 × 17^{m} = 0559:45 LMT. By adding the West longitude in time units (11^{h}55^{m}08^{s}) it is found that Upper Limb Sunrise for the Offset Course Shift was at 1754:53 GMT. This point of time is for static sunrise (at sea level), i.e. the sun only is in motion and the observer is in one given geographical position. If both the sun and the observer are in motion, sunrise has the dynamic configuration and when an aircraft commences an eastwards flight before sunrise, the time T gone by at the instant of sunrise on board follows a function with prescription

$$T = \frac{\sum(C_a, C_s)}{\sum(V_a, V_s)} \qquad (1)$$

wherein the counter is the sum of aircraft's and sun's sub point's longitudinal shift and the denominator is the sum of aircraft's mean speed and sun's speed in orbit. The following operational formula containing the particular dynamics is a transposition of (1) for a north-eatwards heading aircraft and includes the geographic latitude L:

$$V_a = 1{,}038.\cos L.\frac{C_a}{C_s.\sin Co} \qquad (0 < L < 90°; Co > 0) \qquad (2)$$

The symbol V_a is aircraft's mean speed (mph, uniform acceleration by definition), C_a is aircraft's convey in geographic arc from an initial point to the position where sunrise on board appears, Cs is the heliographic true convey in arc degrees, Co is the true course as measured from North and 1,038 is the product (finished, additive) of dimensional constants in the particular equatorial region. ($15^{o/hr}$ × $60^{m/hr}$ × $1.153^{nm/m}$ × $1^{nm/arcmin}$). C_s is in units of Apparent Time to avoid the intricacies of the variable

Equation of Time figures to sneak in. Strictly, the acceleration of Apparent Time is not uniform but for isolated parts of one day the non congruency with the uniformity of the Mean Time may be neglected. Although of more complexity again, also the Sunrise Fix allows for complete recalculation using H.O.208 annex a Plane Traverse Table.

The Observation Error Translates to a Virtual Time Error

Figure 3 represents the situation for 1754:53 GMT when Noonan, coming from the Nukumanu–Nikunau night flight, observes sunrise, U.L.H., with the marine sextant preset (+25'.2 arcmin for 1,000 ft altitude, green filter) for dip and dazzle. At the precomputed 1754:53 GMT watch time he materially looks to the situation for 1751:03 GAT when the true sun's centre is 53 arcmin (refraction 37 ; semi diameter 16) below the horizon. Sun's velocity of rising (15'. Sin Z. cos L) was 13.8 arcmin per time minute and it would last 3^m50^s until sun's centre like at sunset was in the horizon. This 3^m50^s is *not* the Equation of Time, although it so happened that the Time Equation for July 2, 1937, equally was 3^m50^s for 1700 to 1800 GMT.

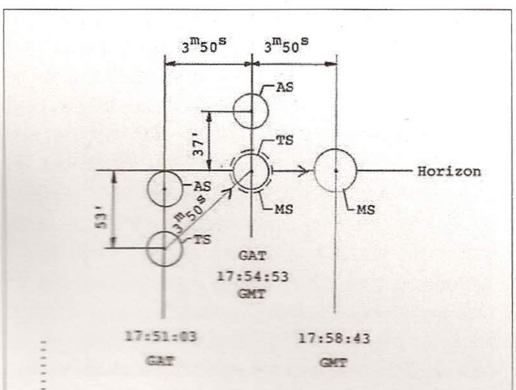

Figure 3 - Marine sextant observation 3^m50^s fast on bubble sextant observation for same Greenwich mean Time.

When however, true sun's centre rose to the horizon, the mean sun belonging to 1754:53 GMT travelled 3^m50^s along the celestial horizon to the position for 1758:43 GAT. Or: when Earhart's navigator observed sunset with the bubble sextant in the evening, whereas next morning the carried marine sextant has been without time correction used at sunrise, he induced a hidden time error, not of watch time but of Local Hour Angle (+57½ arcmin) configuration, biasing all further Dead Reckoning and with a westwards position error (Speed Line error) since for July 2 the true sun is slow (3^m42^s, increment $11^s.42$) on the mean sun.

The Time Error Causes a Distance Error

The Local Hour Angle P (LHA, always of the true sun) for 1754:53 GMT over the Fix coordinates was 90°03'50" (cos P = – tan d . tan L). We first demonstrate what would have happened if Noonan operated the bubble sextant for the Sunrise Fix. The angular diagram for this case I registers the true sun's centre in the horizon, parameter h_c (elevation)= 0. Sun's convey since 1536:11 GAT (LHA 129°31') for this case was 34°40'55". We establish aircraft's due eastwards convey, Case I, with formula (2):

$$150 \text{ mph} = 1038 \times \frac{C_{a[I]}}{34°40'55" . \text{Sin } 72°11'36"} \qquad (2\text{-I})$$

giving $C_{a\ (I)}$ = 4°46', bringing the aircraft within 1 mile from the 150 miles off Fix after a flight time of 1/15 (34°40'55") = $2^h18^m44^s$ for 347 miles. The one mile difference is trivial in air navigation. Figure 4 is an illustration for this Case I. Figure 5 shows Case II where the marine sextant registers on the sun's upper limb at 1754:53 GMT for which applies LHA = 91°01'20" (cos P = –tan d.tan L+cos Zd.sec L.sec d).

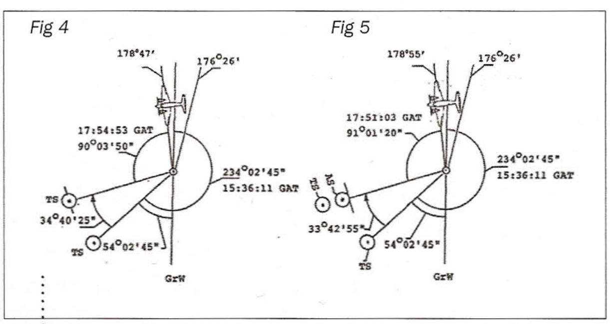

Figure 4 – 1536:11 GAT to 1754:53 GAT convey of True Sun and position of Aircraft at Central Sunrise sighted by Bubble Sextant.

Figure 5 – 1536:11 GAT to 1751:03 GAT convey of True Sun and position of Aircraft at Sunsrise U.L. sighted by Marine Sextant.

For this Case II formula (2) as inserted for the 150 mph cruise speed with Cs = 33°42'55" gives

$$150 \text{ mph} = 1038 \times \frac{C_{a(II)}}{33°42'55" . \sin 72°11'36"} \qquad (2\text{–II})$$

and $Ca_{(II)}$ = 4°39' bringing the aircraft to (178°55'–W;00°06'–N). This position is 10 miles spot off, course 252, from the Offset Fix. We here meet with a plausible explanation for the proximate cause of the accident by which the aircraft did not come within the Howland visual range. When seeing sunrise as precomputed, likewise on the precalculated 1754:53 GMT point of time, Noonan estimated to be 150 miles off Howland A.P. But he had made good 337 miles only in lieu of the belonging 348 miles from Nikunau and the actual distance off was 160, not 150 miles. The time-longitude group is sensitive since sun's angular velocity was a factor 7 greater than aircraft's: for earlier ETA–Nikunau the eastwards decline increases (slowly) and conversely the westwards decline increases (swiftly) for later ETA-Nikunau.

An Old Misconception Vanishes

Earhart's 1745 GMT radio signal announced the aircraft to be approximately 200 miles off Howland, whereas at 1815 GMT the distance was reported 100 miles out. At first sight the groundspeed between the time points would have been 200 mph and a variety of possible origins for the phenomenon has over the years passed in review ("inching down", make up for lost time, sailing before the wind, getting below cloud) but a consistent numerical explanation cannot be found in the current literature. The on apperence discrepancy unfolds as follows. Most probably the 1745 GMT message concerned the by D.R. plusminus 300 mls distance made good at 1740 GMT schedule time, 2 hours after leaving Nikunau and plusminus 200 mls to go on TC 072. When Noonan however, after having flown in the dark for 10½ hours, saw sunrise at 1754:53 GMT he applied correction by implicitly revoking the 1745 GMT signal since he now was 150 mls out according to his precomputations. Twenty minutes later (progression 50 mls) Amelia received instruction (Noonan supposedly in the copilot's seat since sunrise) to transmit the 100 mls out message at 1814:53 GMT and she so did at 1815 GMT. At that instant the aircraft was on the point of altering to TC 055, reason to additionally ask for a bearing (to confirm if their offset was northwards) in half an hour: at 1845 GMT they would have made good 70 mls (from 1815 cruise down to 139 mph) of the 102 mls offset path and they had 32 mls to go for the (erroneous) Turn Off Point where they would alter to TC 157. The first demand for a bearing, on the next hour, was at 1744 GMT, evidently to check having Howland straight ahead when over the Fix and thus simultaneously verifying for the latitude. Usually the Offset Track was flown by D.R., especially with low sun giving less reliable position outcomes due to difficult assess of refraction.

Where Runs the of All Times Most Famous Position Line ?

When opening a can of worms there is one way only to get them in again: take a greater can.(this being Zimurgi's First Law of Evolving System Dynamics). For Noonan this escape was even double sided: he would have found Howland without further aid to navigation by either steering on the offset course at (1751:03 GAT + 3^m50^s) + 3^m50^s = 1758:43 GMT, or by increasing the aircraft's mean groundspeed after passing over Nikunau to 348/337 × 150 mph = 155 mph (3.3% over economy). He neither applied the one, nor the other remedy and the conclusion must thence be that the position line along which the crew looked for land ran through Howland E. P.(Erroneous Position) with coordinates (176°51'–W;00°46'–N) between compass points 157°–337° perpendicular to sun's 67° azimuth (cos Z = sin d / cos L), this line being the advanced sunrise Line of Position. The erroneous line runs 14 arc minutes (16 mls, 26 km) due westwards of Howland T.P.(True Position)

The Balances Drawn Up. Murphy's Law at Work

At 1912 GMT (0742 U.S.N-LZT Howland) when Amelia expected having the island below the APL (Aircraft Progression Line), its true position was 15 mls, not ahead (also the TC 055 to 157 Turn Off Point incurred a 10 mls westwards shift) but on the port beam as well as 1.4 times the average 10–12 miles distance from which Ann Pellegreno, copilot Payne, navigator Polhelmus, viewed a contour of Howland after engineer Koepke saw a first glimp, then looking like the shadow of a small cloud, when they repeated the Earhart–Noonan flight in 1967 with an almost identical Lockheed 10E in ideal weather. The unexpected on the port beam position has probably played the greater role in the breakdown of a timely identification in 1937. About 1929 GMT the standard gas ran below 11 gallons and the tank selectors had to be reset for supply by the port wing container with 22 gallons 100 octane fuel remaining, shortly before 1945 GMT when the 80 octane Stanavo would be on the point of exhaustion. It was due this action possibly that no radio signal from aboard appeared at the 1945 GMT transmission time (this may be a conjecture due to ambiguity: a second option is that the crew tried to tune in for the 1815 GMT expected bearing result). At 1912 GMT one was aware to have a fuel reserve of 45 gallons (23 Stanavo, 22 Special) for 1^h05^m at 41.5 gph low level cruise, the 23 gallons sufficient for ½ hour as announced in the 1912 GMT radio signal. The quantity complies with Itasca's Captain Thomson's testimony – he in person heard Amelia say they were low on fuel – and the entry in the ship's secondary radio logbook kept by radioman *O'Hare* reading: *"0740 Earhart nw sez running out of gas only ½ hour left can't hear us at all"*. The ½ hour reserve also follows from a quantitative inquiry (1996) based on Aircraft Performance Theory. Evidently (1912 GMT) Noonan was certain to be over the correct position line while he did not take the risk to leave it for a wasteful on fuel Fixed Square Search and he will have divided the remaining flight time in three 20 minutes legs to first continue southwards (TC 157 up to 1925–1930 GMT) and afterwards look further northwards (TC 337) on the line since he had no confirmation of his 1800 GMT latitude. To anticipate that one engine is first on cut off by fuel starvation it would be wise that a pilot facing such calamity let not things push too far and bring his airplane down

GMT and Approximate Elapsed Time	Signal Strength	Local Zone Time	Earhart to	Recorded Signals
0500		1500	Lae	At 10,000 ft but reducing altitude because of banks of cumulus cloud.
0700		1700		At 7,000 ft and making 150 mph.
0720		1720		Position Latitude 4 degrees 33'.5 South – Longitude 159 degrees 07' East.
0800		1800		On course for Howland Island at 12,000 ft.
1030		2130	(Nauru)	Lights in Sight Ahead. (Ship in Sight Ahead improbable)
1415	0	0245	Hwlnd	Cloudy and Overcast.
1515	0	0345		Itasca from Earhart – Overcast – Will listen on hour and half hour On 3105.
1624	1	0454		Partly Cloudy.
1744	3	0614		Bearing on 3105 – on hour – will whistle in mike.
1745	3	0615		About 200 miles out approximately- Whistling now.
1815	4	0645		Plse take Bearing on us and report in ½ hour I will make noise in microphone – about 100 mls out.
1912	5	0742	[1]	KHAQQ calling Itasca we must be on you but cannot see you but gas is running low been unable to reach you by radio we are flying at altitude 1,000 feet.
1928	5	0758	[2]	We are circling but cannot hear you – go ahead on 7500 either now or on the Schedule Time on half hour.
1930	5+	0800		KHAQQ calling Itasca we received your signals but unable to get a minimum – Please take bearing on us and answer 3105 with voice.
2014	5	0844	Hwlnd	We are on the Line of Position 157–337 will repeat this message on 6210 kcs – wait–listening on 6210 kcs – we are running north and wouth.

[1] Secondary Radio Log of Itasca reads <0740 Earhart on nw sez running out of gas only ½ hour left can't hear us at all / we hear her and are sending on 3105 es 500 same time constantly and listening in for her frequently>

[2] 1929 GMT Itasca signal 7500 kcs received by Earhart who confirmed 1930 GMT. Signal was 8 times <A> followed by <Go ahead on 3105>. (Distance 30 miles).

Table 2 - Radio communications.

when still in possession of full traction by both power plants. Earhart's 2014 GMT sign off did not point in the direction of such action: she must have been overtaken by a major malfunction like one wind milling propeller or both, by which she was unable to hold the microphone and transmit again when in the course of switching to 6210 from 3105 kcs the engines' carburetors gave first sign of running dry. At least ten Lockheed Electra on sea touchdowns are filed in F.A.A. archives of the era. By the alighting itself no aircraft got damaged to fatal disintegration but the average before sinking period never surmounted 10 minutes due to the mass of the engines as compared to the mass of the medium size airframe. Evidently, Murphy's Law decided upon the day of judgement, what could go wrong *went* wrong: the false island's coordinates registration, the distance versus time error, the crippled voice communications, potentially the 10 percent excessive fuel consumption due headwinds (0000 GMT to 0727 GMT), the aircraft's minor floating performance and eventually flying at a for observation not permitting low altitude when searching for Howland. Leaving no flight plan behind, however afterwards comprehensible, was a carelessness of the crew themselves. None of the six here mentioned provocations can however be earmarked for the first line responsibility. The first line *and* in last resort responsibility is constituted by the initiative to use non standard RDF (Radio Direction Finding) equipment. It was large scale inattentiveness letting a for that specific technical field inexperienced crew operate with an experimental RDF receiver (the batteries low when they were needed) on the island on not with the on

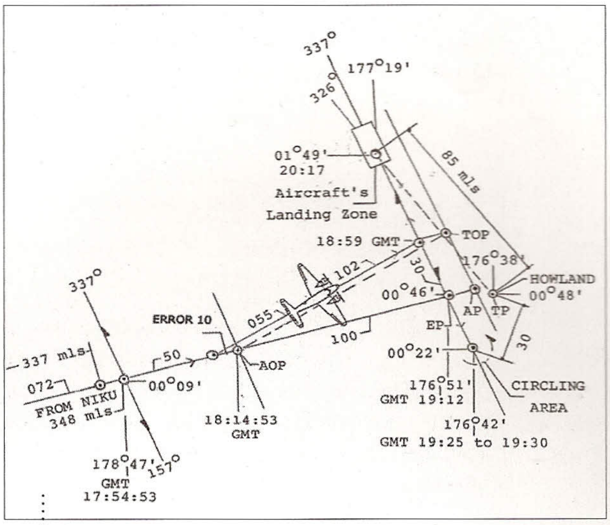

Figure 6 - Speed Line error for Marine Sextant observation 3^m50^s fast on Bubble Sextant observation and resulting landing zone of aircraft.

board of aircraft's installations (e.g. the loop aerial) compatible RDF frequencies. Figure 6 eventually shows the Sunrise Fix diagram with its later occurring consequences.

The last navigational draw back the crew had to cope with was the following. Suppose that Noonan who estimated to be on the over Howland (A.P) line, checked for sun's altitude at any time between 1900 and 2014 GMT. For 2014 GMT he would have found 33°33'.0 on the E.P. line, whereas the elevation for the line over Howland A.P., same time same latitude, 9 arcmin eastwards, was 33°42'.0. The 9 arcmin difference translates to a mean ½ (9 ^{arcmin} x4 $^{s/arcmin}$ x 139 ^{mph}) / 3,600 $^{s/hr}$ = 0.7 mile distance for 18 seconds flight time. Such small differences did not in any possible way allow for practical detection of a small line error in air navigation of the era: the smaller the longitude error and the longer one continues on a wrong line, the more one gets convinced to be over the correct one so that the default holds the tendency to first encapsulate, then to continuously duplicate itself and in the end by snowballing to escape beyond recovery. Noonan would have possibly noticed his error by computing sunrise time by direct spherics. This however, was unusual in an era wherein even experienced navigators necessarily worked with logarithm tables and the Dalton disc calculator.

The computed zero fuel point in Figure 6 lies 126 miles north of the equator and 186 miles east of the Greenwich lower meridian with coordinates (177°19'–W;01°49'–N), 85 mls off Howland (T.P), course 326 as calculated for 139 mph groundspeed after 1815 GMT. For after 1815 GMT groundspeeds between 125 and 150 mph the landing zone has a 51 mls length. With advanced equipment it might in the future be possible to locate and dive for parts of Electra NR 16020 (landing gear, tires, engines, chronometers). Such operation if successful would add one definite conclusion to the not too many known about aircrew who did not come home from a mission over the high seas and it would confirm the old saying that navigators do in the long run not get lost: they go astray for a restricted period of time.

Ephemeris July 2, 1937

0000 GMT sun's declination 83134".8, shift per 24h (–) 261".9
0000 GMT equation of time 221^s.62 . shift per 24h (+) 11^s.42
0000 GMT Apparent Right Ascension of Sun 24129^s,01 = 6^{h}42^{m}09^s.01, shift per 24h 247^s.97
Lae 10 hrs ahead of, Nauru 11 hrs ahead of, Howland 11½ hrs slow on GMT

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Biography of the Author