Analysis of the 1952 Crash of the Search and Rescue B-17 in Tull Canyon; by Paul Eisenberg, 2021

The remnants of a B17G Search and Rescue (SAR) aircraft (AF 44-85746A) lie in Tull Canyon in the Buckhorn Wilderness area of Washington's Olympic Mountains. The site, located at 47.85 degrees N latitude and 123.09 degrees W latitude, is visited by many hikers every year.

The Aircraft and the Mission:

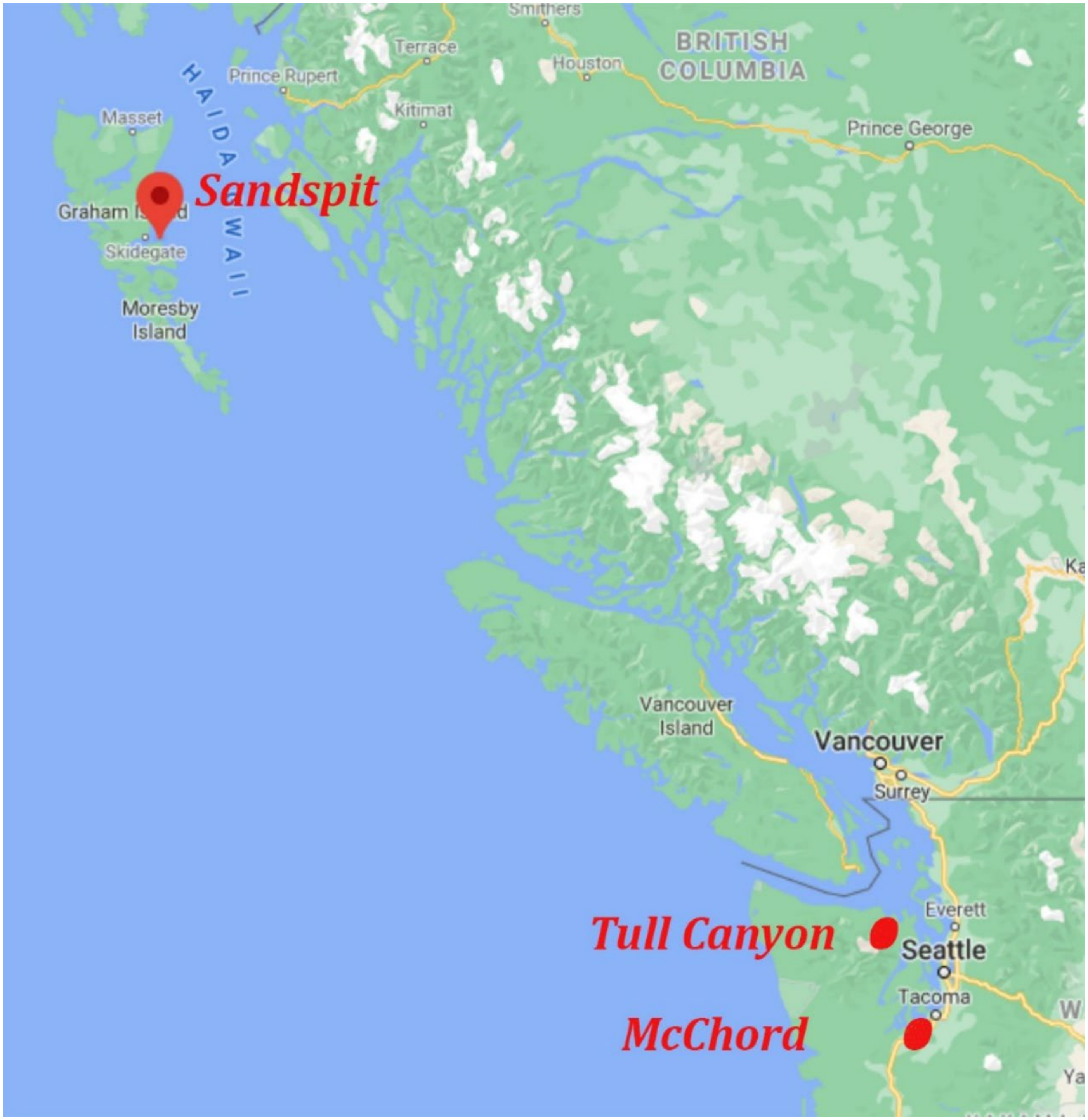
The aircraft was a WWII era bomber built near the end of the war and it never saw combat. The B-17 was deployed to several overseas post war missions, and then was converted for SAR operations and stationed at McChord Air Base located between Tacoma and Olympia in Washington State. On January 19th, 1952 it was dispatched on a SAR mission to Sandspit in the Queen Charlotte Islands, BC, Canada. A chartered 4 engine Northwest Airlines DC-4 lost an engine while transporting 40 soldiers home from Korea on emergency furloughs. The plane crashed in the water short of the runway. Of 43 people on board 36 died from exposure and drowning.

After completing the aerial search for survivors, the B-17 landed at Sandspit, refueled and filed an IFR flight plan for a return flight to McChord. It took off at 15:35 PST with pilot Hybki at the controls and climbed to its assigned initial altitude of 9,000 feet MSL. The B-17 crashed that evening in a blizzard, killing three crew members. Five survivors were rescued the following day.

SAR B17G AF 44-85746A warming up at Sandspit prior to its final flight

The Final Flight:

The following graphic depicts Sandspit, Tull Canyon and McChord Air Base for orientation. The next two graphics illustrate relevant portions of the IFR airways that applied to the flight per 1951 and 1952 World Aviation Charts (WAC). Note that the magnetic variation in this area in 1952 was approximately 23 degrees east, meaning magnetic compass headings for the airways are 23 degrees easterly of chart True directions related to the lines of latitude and longitude.



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SANDSPIT RADIO
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RED 4
BLUE 38
HECATE STRAIT
BANKS
Cape George
Browning Entrance
McCAULEY ISLAND
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BANKS ISLAND
Principe Channel
Grenville Channel
PITT ISLAND
Gp Fl
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LOUISE ISLAND
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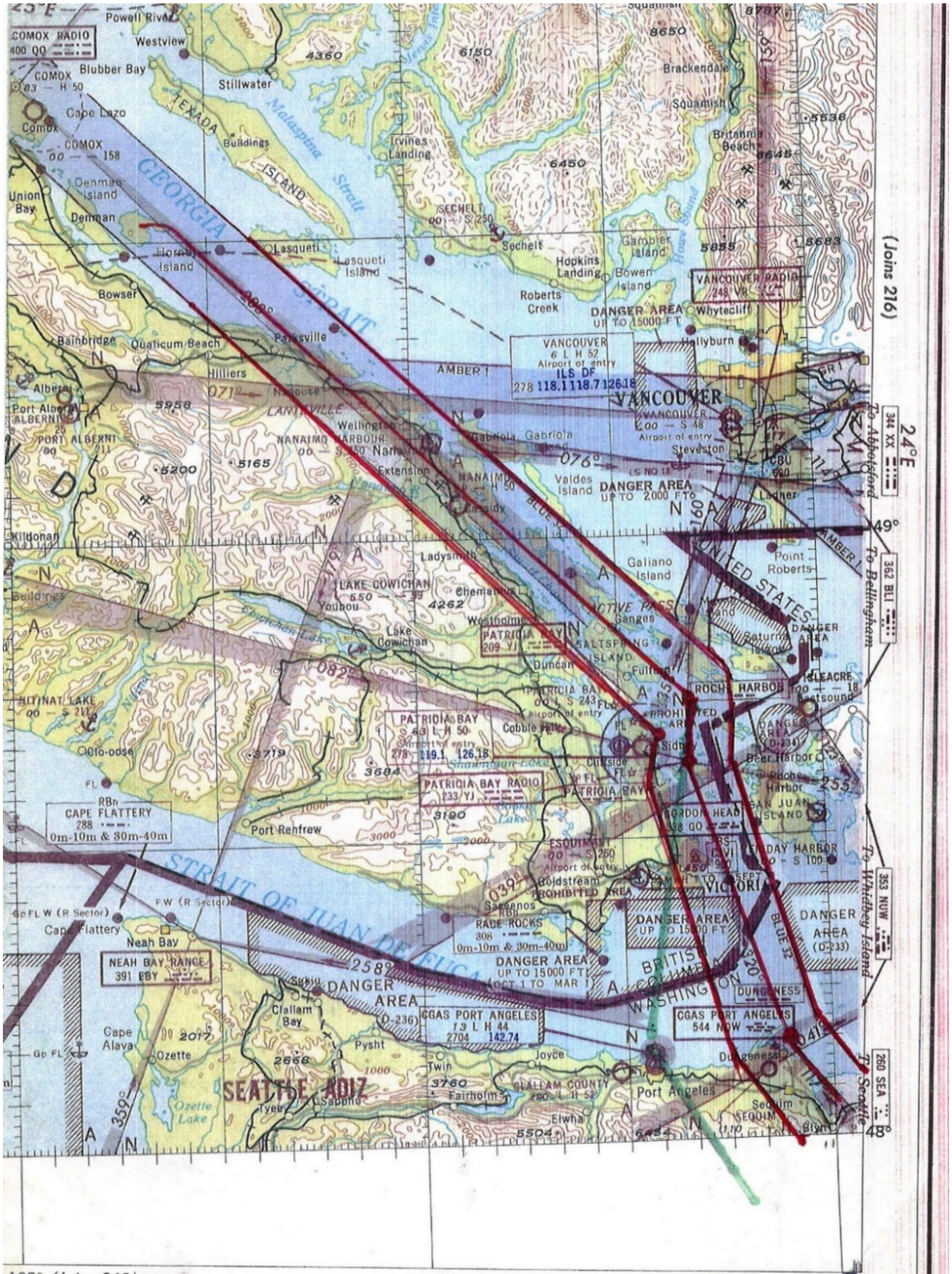


15th EDITION

Consult Coast and Geodetic Survey Radio Facility Charts and Civil Aeronautics Administration Airman's Guide for changes in aeronautical information on this chart after *April 3, 1952*
Next scheduled edition Oct 1952

VANCOUVER ISLAND (215)

UNITED STATES-CANADA

Analysis:

My wife and I explored the B-17 crash site in person on a backpack trip in 2020. I had read the official reports and found myself puzzled regarding how and why this B17 was so far off course. It could not have struck the ridge from the direction it did if the official accounts were correct. Upon returning home I explored more websites, collected data, read more crew accounts, studied photos, re-read the official accident findings, and learned about the IFR navigation systems in use in 1952.

As a pilot, my interest in this accident was heightened because it occurred near where I live today, although at the time of the crash I was 3 years old living in Tucson, Arizona. My wife and I backpack in the Olympic mountains and frequently sail our boat across the Strait of Juan d Fuca and along the eastern side of Vancouver Island. We are quite familiar with the entire area. As I look out the window from my desk, across Hood Canal, I can see the ridges into which the B17 crashed, as well as the lower elevation terrain where they should have been. If the B-17 had been less than 1 mile farther north, or 1,000 feet higher it would have missed that ridge despite all the mistakes described in detail below.

Details of the IFR airways and system in use at the time are described in more detail later in this article. In general, it can be said that the Low/Medium Frequency Four Course Radio Range system was both challenging and problematic. A system of radio transmitters, directional antennas, and airborne receivers provided route guidance to pilots using audio signals without any visual reference to the ground.

Using this knowledge and the reliable portions of reports from the time, I reconstructed the final flight which is briefly summarized as follows. The B-17 departed Sandspit outbound over open water, flew along the east side of Vancouver Island to Port Hardy and continued to Comox. Copilot, Sentner took control at Comox. As required, at the Patricia Bay Radio Range station, Sentner reported their position to Air Traffic Control (ATC) stating: "seeing Patricia Bay in the clear" as they passed overhead. ATC cleared them to descend to 6,000 feet MSL. In order to remain on the airway a 20-degree left turn was required at Patricia Bay. Descending from 9,000 feet to 6,000 feet would have taken about 6 minutes so they would have leveled off over the Strait of Juan d Fuca as night fell. The airway they should have been on leads to the Dungeness intersection, where it intersects the airway to Seattle's Boeing Field. If on the airway, upon reaching the intersection, they would have observed the illumination of the white marker beacon light on their console. IFR procedures required them to listen to its Morse code audio identifier to confirm it was the correct beacon. There is no evidence that they did so. The marker illuminated at 18:27 PST and, as required, they attempted to report their position to Seattle ATC as "Dungeness at 6,000 feet MSL." No acknowledgement was received from Seattle ATC, but Everett ATC did receive it and forwarded the report to Seattle.

Assuming they had been at the Dungeness intersection, they would have then turned left onto the inbound airway leading to Seattle, and they would have flown over relatively low and flat terrain. In 1952 the major Seattle airport was Boeing Field and that was also the location of the Seattle Radio Range Station. However, they crashed into the mountains within 5 to 8 minutes of making their turn, but they hit the mountain range at a spot 23 miles directly south of the Dungeness Intersection. They should have been about 20 miles farther north and 14 miles farther to the east if they were on the airway. This major discrepancy is dismissed in the official report by asserting that the aircraft was blown off course to this extent, which I will demonstrate is virtually impossible.

In his accident report Sentner stated that he turned to a heading of 120 degrees magnetic (left turn) at Dungeness Intersection. That is close to the published magnetic heading for the Seattle northwest inbound Radio Range leg of 119 degrees. He said they had switched their Radio Range receiver from Whidbey (not from the Patricia Bay Radio Range) to the Seattle Radio Range. Sentner reported hearing the audio quadrant signal, but Sentner did not describe that audio signal. Hybki concurred with the preceding and also stated he "knew" they were at Dungeness because the marker beacon light on the console had illuminated. He says nothing about confirming the beacon identifier. Then Hybki described the Seattle Radio Range signal he heard as a “distinct A” (meaning he heard a repeating series of “di dah..di dah..etc.”). No other crew member reported listening to the marker beacon audio identifier signal to confirm it was the Dungeness intersection marker, which was a required procedure.

It is significant that the crew stated the Radio Range unit was tuned to Whidbey Radio Range prior to Dungeness, and that means they were not tracking the outbound airway from Patricia Radio Range. Hence, they were not receiving airway course guidance between Patricia Bay and Dungeness. In this situation on course airway guidance could only be done using the Patricia Bay Radio Range station. Whidbey could not provide airway course guidance unless they were on an airway inbound to Whidbey. Dungeness is just an intersection of two airways and did not have a Radio Range Station. It was simply identified by a marker beacon. This means they did not know whether or not they were on the airway from Patricia Bay to Dungeness. Instead of following procedure, they used a cross check bearing from their position to the Whidbey Radio Range station. While this cross bearing could help determine when they would reach the Dungeness intersection, it was far less important than being on the actual safe airway.

There is other important information in the accident reports. The flight engineer, Seargall, reported all 4 engines were operating smoothly at 31 inches of manifold pressure and 2,000 RPM, and the aircraft was traveling at 170 MPH indicated airspeed, which is approximately 189 MPH true airspeed. The anti-icing systems were on, flashlight inspections of the wings found the anti-icing was working properly. All other instruments were indicating normally until impact.

Hybki stated that the plane crashed within 5 minutes of passing what he was certain was Dungeness, at approximately 18:32 PST. Sentner stated the crash occurred between 5 and 10 minutes after he reported their position as Dungeness. Farmer, who was sitting in the left scanner position, reported the crash occurred 5 minutes after he heard Sentner report their position as “at Dungeness.” However, the Official Accident Report states the crash occurred 8 minutes later at approximately 18:40 PST, which is 13 minutes after the position report at Dungeness, and does not correspond to any crew reports or any other facts.

The “official” crash time adjustment may have been an attempt to make the math work for extreme winds to explain why they were so far south of Dungeness and off course. However, even this “extra” time does not make the math work. The official cause stated that severe winds blew the B-17 off course from Dungeness Intersection to the crash site. That would mean winds supposedly blew the aircraft 23 miles due south while it flying southeast at 189 MPH over the ground, and making no eastward progress. Earlier in the flight the winds had been from the left as the B-17 had flown south along Vancouver Island, which means those winds were from the east, not the north. Another aircraft had reported winds in the area of the Strait were from the east or southeast.

We can further test the official findings by measuring headings and distances. The aircraft would have had to travel a course over the ground of 183 degrees true which is 160 degrees magnetic, while flying a heading of 120 degrees magnetic at 189 mph. That would require winds from the left, perpendicular to the 120-degree heading of approximately the same speed as the forward speed of the aircraft. Such 189 MPH winds would be class 5 hurricane force winds. If these occurred at 6,000 feet MSL they would have also existed near the ground. There were no such winds. Even if the aircraft had been at the most extreme west edge of the Dungeness marker beacon, the direction to the crash site would only change by about 10 degrees, and the required winds would only be reduced to around 160 mph. Such winds did not exist. Further, if the aircraft was essentially coming from true due north, it would not of struck the ridge the way it did, and it would have travelled further up the canyon in a southerly direction. It did not, it slammed into the west face of the ridge. These realities render the official explanation highly improbable, if not impossible.

All the surviving crew members stated they had no idea they had crashed in the mountains until sunrise the following day. It seems clear the crew did not know they were 14 miles off course laterally and flying through the mountains.

If the official report is wrong, then how did the accident happen? What scenario could be consistent with all the actual known facts? This accident was not due to mechanical failure and that leaves pilot error. Most pilot error accidents result from a series of mistakes and untested assumptions, and this accident seems to fit that typical profile.

Since we know where the B-17 crashed, and its heading at the time, the best approach is work backwards from the crash site. Assuming the B17 was flying the heading stated by the crew of 120 degrees magnetic when it crashed, and that it was tracking a course of 120 degrees magnetic over the ground, we can plot the inverse of that heading to determine from where the aircraft came. Since we also know the reported indicated airspeed and altitude, we can convert that to true airspeed, and approximate the ground speed. Then we can also estimate where the aircraft would have been along that course 5 to 8 minutes before the crash. This will correspond to the time the marker beacon light illuminated, and the time when the aircraft turned to 120 degrees. That plot and calculations place the aircraft directly over the Coast Guard Air Station (CGAS) at Port Angeles.

For that to be correct there at least 6 questions that arise and must be answered affirmatively for this theory to fit the known facts and accounts:

1. Are there reasonable and explainable errors the crew could have made, but not easily recognized, resulting in the aircraft flying to Port Angeles CGAS from Patricia Bay instead of to Dungeness Intersection?
2. Would the white marker beacon light have illuminated if the aircraft flew over Port Angeles CGAS?
3. Would the direction finder bearing from the Port Angeles CGAS to the Whidbey Radio Range Station be significantly different from the direction finder bearing from Dungeness to the Whidbey Radio Range Station?
4. If the aircraft was at Port Angeles when it turned to 120 degrees and switched the radio range receiver to Seattle Radio Range, would the crew have heard the "distinct A" quadrant signal they described? Would they have heard that "distinct A" if they were at Dungeness or would they have heard something different?
5. If the aircraft was at Port Angeles, at 6,000 feet MSL, would it have been able to communicate with Everett via line-of-sight VHF radio due to lower terrain towards Everett, but not been able to communicate with Seattle due to high terrain towards Seattle?
6. Would there have been a noticeable difference in the flight time from Patricia Bay to the Port Angeles CGAS compared to the flight time from Patricia Bay to the beacon at the Dungeness intersection?

When I obtained my pilot's license in 1976 the Radio Range system was no longer in use and I had no personal experience with it. To address each of these questions I assembled more historical documents about the Radio Range system, airways, the marker beacons in the area, the frequencies, the Morse code identifiers, etc. I used historical tables and copies of vintage aviation charts, and other published documents regarding the old LF/MF Four Course Radio Range navigation system. I found training documents to learn how to use the system. I plotted the locations of the Radio Range stations, airways and the details of the procedures that should have been followed per the US Department of Commerce Pilot's Radio Handbook of that time.

This was necessary to determine if the accident was caused by pilot error, and to pinpoint those errors. With this information we can reconstruct the 1952 an IFR clearance from Sandspit BC to McChord. The clearance would have been via the IFR Low/Medium Frequency Four Course Radio Range airways. More detailed information about these, and links to the specifics of how this system worked are included at the end of this article.

The official statements and reports do not detail the entire route, but in this instance, there was only one practical IFR route along the airways from Sandspit to McChord at the time. The airways were carefully designed to provide adequate lateral and vertical terrain clearance as well as separation from opposite direction traffic due to the limited radar coverage environment of the time. All the following headings and directions stated in the following are magnetic.

The route would have been along the Amber 1 and Blue 32 airways. With Hybki piloting, the first leg was outbound on the southeast Radio Range course from Sandspit on a heading of 105 degrees. At approximately 100 miles along the airway, they would have switched to the Port Hardy Radio Range inbound course and upon receiving it, turned slightly right to 110 degrees. At Port Hardy they would have made a slight left turn to intercept the southeast outbound Radio Range course from Port Hardy on a heading of 95 degrees. They would have flown this until intersecting and the Comox northwest inbound Radio Range course, while continuing on the same heading. The co-pilot took over at Comox. The next leg would have been a left turn at Comox onto the Comox outbound southeast Radio Range course on a heading of 108 degrees until intersecting the northeast inbound airway to the Patricia Bay Radio Range. At that intersection they would have turned right to a heading of 163 degrees inbound to the Patricia Bay Radio Range. As they passed over the Patricia Bay they reported being in clear conditions and seeing the bay. They were cleared to descend to 6,000 feet. As they crossed over the Patricia Bay Radio Range Station they should have turned left 20 degrees to 143 degrees placing them on the southeast outbound Patricia Bay Radio Range course. If they had turned to remain on the airway, they would have received airway guidance from Patricia Bay Radio Range to Dungeness, and they would have arrived at the Dungeness Intersection which is marked by the 75 MHz beacon. They should have listened to the audio from the beacon at Dungeness to confirm that it was Dungeness, and then they should have turned to a heading of 119 degrees onto the center of the inbound Blue 32 northwest Seattle Radio Range course. The remainder of the planned route is academic. Where in the above process could errors have occurred that result in the crash specific details? We can return to the 6 questions.

1. Are there reasonable and explainable errors the crew could have made, but not easily recognized, resulting in the aircraft flying to Port Angeles CGAS from Patricia Bay instead of to Dungeness Intersection?

The IFR route described above appears to have been flown correctly to Patricia Bay. But substantial inconsistencies and irregularities arise upon departing Patricia Bay. The crew reported that they believed they had flown from Patricia Bay to the Dungeness Intersection, but they did not mention making the turn from 163 degrees to 143 degrees at Patricia Bay. The consequence of failing to make that turn means continuing to fly a heading of 163 degrees which leads directly to the Port Angeles CGAS, not to the Dungeness intersection. The crew stated that they were certain they were at Dungeness for two reasons. First, they overflew the 75 MHz marker beacon that illuminated the white marker beacon light on the console. That light only illuminates when flying over a 75 MHz beacon. Second, the radio operator reported that he was "on the loop" (ie the radio was switched to the direction finder antenna) and he was tuned to Whidbey NAS. The loop antenna allowed him to measure the bearing from their position to the Whidbey Radio Range Station, and that bearing was consistent with being over Dungeness. But, no crew member reported listening to the morse code identifier to confirm it was in fact the Dungeness transmitter.

If, instead of switching to the loop antenna, they had remained tuned to the Patricia Bay Radio Range system they would have received guidance signals confirming whether they were on, left of, or right of the airway from Patricia Bay to Dungeness. Instead, by switching from Patricia Bay Radio Range to the loop to measure the direction to Whidbey Radio Range, they had no airway guidance.

Looking at the chart it is clear that the airway needed to turn 20 degrees at Patricia Bay. But how did the engineers who designed the Radio Range system create radio signals that effectively create guidance for such a "turn." At most Radio Range Stations the airways continue straight when passive over a station. Making the station transmitters and antennas accomplish this "turn" was complex and imperfect. An anomaly exists where a false "on course" steady tone can be heard by an aircraft after it has passed over the station, until it has flown a few miles past the station when that false indication fades out. This can disguise a missed turn, and tuning off the Radio Range guidance too soon after crossing a station where the airway turns can allow a pilot to think they are on the airway when they are not, but this anomaly only existed for a relatively short distance from the station. If they had continued to listen to Patricia Bay the steady tone signal would have quickly transformed into a very clear “off airway” signal. If they were still receiving an on course signal when they switched from the Patricia Bay station, they would not have caught their mistake.

It is helpful to further explain the technical problem at stations like Patricia Bay where the airway must turn and the airway does not pass through the station in a straight line. At most of these stations the antennas were arrayed at the corners of a large square or parallelogram. The turn is partially addressed by changing the physical arrangement of the antennas. In addition changes were made to the amount of transmitter power applied to each antenna, and they also adjusted the phasing of the transmitted signals. There were a few other techniques and pieces of equipment used. The goal was to transmit the guidance signals in such a way that the left/right signals only overlapped along the centerline of a long narrow triangle. While these techniques did dramatically reduce the unwanted overlapping “false” on course signals transmitted in the wrong direction, it was impossible to avoid those false signals when very close to the station.

If this B-17 failed to turn at Patricia Bay, it may not have learned of the mistake soon enough. It appears that after switching to the loop antenna and to the Whidbey Radio Range station, they never switched back to Patricia Bay to check that they were on the airway. There was no terrain hazard at this point, since they were over the sea level Strait of Juan d Fuca. They had no visual cues of the mistake because the sun had set and they had flown into clouds.

The answer to Question 1 is that failing to turn left at the Patricia Bay station, and failing to remain tuned to Patricia Bay Radio Range for airway guidance are reasonable explanations for how they could have mistakenly flown to Port Angeles CGAS and not known it. And being over sea level water, they were not overly concerned with terrain clearance at this point of the flight.

2. Would the white marker beacon light have illuminated if the aircraft flew over the Port Angeles CGAS?

My research confirmed that in 1952, in addition to the 75 Mhz intersection marker at Dungeness, there was also a 75 MHz beacon (MRLZ) at the Port Angeles CGAS. See table below from 1952 Federal Register. If they had passed over that 75 Mhz beacon the white marker beacon indicator would have illuminated. The only way to distinguish between these two beacons was by listening to the audio morse code identifiers. The Port Angeles CGAS was located at the end of a long spit, and repeatedly transmitted a Morse code audio identifier of CLM (dah di dah di, di dah di di, dah dah.). The Dungeness fan marker beacon was located at the tip of the Dungeness spit and was co-located at the lighthouse. It transmitted a simple dah dah dah dah. The Port Angeles beacon is 14.2 miles west of Dungeness beacon. Note that the crash site is also approximately 14 miles west of the actual Seattle inbound airway where they should have been.

Port Angeles 75 Mhz beacon

Dungeness 75 Mhz Marker Beacon

LOCATION	CLASS	IDENT	FREQ. Trans/Gds	RANGE COURSES
WASHINGTON				
(3)Hoquiam	VORW	HQM	113.1	
Larson AFB	MHW	MSK	528	
"	CA		201;126.18,121.5/4495,#	
McChord + AFB (A)	SBMRAZ	TCM	272;121.5/ 4495,#	54 A 158 N 234 A 339 N
"	CA		396;121.5,126.18/(1),#	
Neah Bay	SRAWZ	EBY	391	100 N 179 A 258 N 359 A
Port Angeles (P)	MRLZ (prior req & airline oper)	CLM	329/3105	73 N 163 A 253 N 343 A
" (N)	HW	NOW	544 (08-21 prior req)	
" CGAS	CN (on req)		2704;142.74/3105,#	
Renton	CI (09-17)		335;126.18/(1),#,122.5	
Richland	CI		126.18/3105,#	
Seattle +	SBRAZ- DTXPV	SEA →	260;V,126.7/ (3)	117 N 186 A 269 N 356 A
" Boeing	C(g)		278;126.18,118.3,121.5/(2),#	
"	Seattle Center		120.3 For tfc clearance	
" NAS	MRLZ	NEJ	212;135.9 same as twr	53 A 143 N 233 A 323 N
" NAS (N)	HW	WN	532	
" NAS (N)	HW	X	414	
"	CN		230;121.5,126.18,(132.3 req), 142.74/(1),#	
(1) " Tacoma	BVOR	SEA	113.9	
" "	AC(g)		245;119.5,126.18,121.5/(2),#	
Shelton +	MRLWZ	SHN	371	43 A 139 N 223 A 319 N
Spokane	SBRAZ- DTV	GEG	365;V,126.7/ (3)	1 A 56 N 181 A 238 N
(1) "	BVOR	GEG	115.5 ←	
" Geiger	AC(g)		278;118.3,121.5,126.18/(2),#	
Stampede Pass	V (factual wea only.)	SMP	122.8/122.8	
Toledo	BMRLZ- DTV	TDO	239;V,121.5, 122.2/(3),#	62 N 177 A 248 N 333 A
Walla Walla	SBMRLZ- DTV	ALW	356;V,121.5, 122.2/(3),#	2 A 92 N 182 A 272 N
Whidbey (N) Island NAS	SBMRLZ	NUW	353/(1)	41 A 123 N 221 A 303 N
" (N)	MHW	K	522	
" Ault	CN		278,3295;121.5,126.18,142.74/ (1),#	
" Oak Harbor	CN (24 hrs req or emerg)		278,2870;126.18,142.74/ 2870,#	
Yakima	BMRLZ- DTV	YKM	320;V,126.7/ (3)	8 A 98 N 188 A 278 N
(1) "	BVOR	YKM	116.0	
" Arpt	C(g)		278;119.1,121.5/(2),#	
WEST VIRGINIA				
Charleston	SBRAZ- DTV	CHW	400;V,126.7/ (3)	100 A 178 N 276 A 358 N
(1) "	BVAR	CHW	109.5	17 BA 107 NB 197 YN 287 AY

LOCATION	CLASS	IDENT	FREQ. Trans/Gds	RANGE COURSES
WEST VIRGINIA				
Charleston Kanawha	AC(g)		317;120.7,121.5,126.18/(1),#, 122.5	
Clarksburg	HW	CKB	353	
Elkins	SBMRAZ- DTV	EKN	281;V,121.5, 122.2/(3),#	82 A 173 N 269 A 353 N
(3) "	VORW	EKN	114.5	
Huntington	BMRLZ- DTV	HTW	236;V,121.5, 122.2/(3),#	75 A 135 N 255 A 315 N
Martinsburg	SBMRLZ- DTV	MRB	209;V,121.5, 126.7/(3),#	35 A 101 N 215 A 281 N
(3) " +	BVOR	MRB	113.2	
Morgantown +	SBMRLZ- DTV	MGW	269;V,121.5, 122.2/(3),#	35 A 139 N 215 A 319 N
" +	VORW	MGW	113.0 (NON-COMM)	
(1)Parkersburg +	BVAR- DTVJ	PKB	109.1;V;212; 121.5,126.7/#, (3)-4495	34 BA 124 NB 214 YN 304 AY
Paynesville	HW	PVL	356	
(1)Wheeling	BVAR- DTVJ	HLG	108.3;V;121.5; 275;126.7/#,(3)-4495	43 BA 133 NB 223 YN 313 AY
White Sulphur Springs, Greenbrier Arpt	CI (08-sunset)		278/3105 ;122.5	
WISCONSIN				
(1)Eau Claire	BVOR- DTV	EAU	117.7;V,121.5,126.7/#,(3)- 3105,4495	
(1)Grantsburg	BVOR- DTV	GTG	112.9;V;121.5,126.7/#,(3)-4495, 3105	
(1)Green Bay	BVOR- DTV	GRB	117.0;V,121.5,126.7/#,(3)-4495	
(3)Janesville	VORW	JVL	116.5	
La Crosse	SBRAZ- DTV	LSE	371;V,121.5, 126.7/(3),#	57 A 121 N 237 A 308 N
(1) " +	BVOR	LSE	115.7	
Lone Rock	BMLZ- DTV	LNR	278;V;121.5, 126.7/(3),#	8 A 98 N 188 A 278 N
(1) "	BVOR	LNR	113.6	
Madison	BMRLZ- DTV	MSN	400;V,121.5, 122.2/(3),#	44 A 134 N 224 A 314 N
" Arpt	AC(g)		248;119.9,126.18/(2),#	
Manitowoc (P)	V (08-sunset)		278/3105	
Milwaukee	SBRAZ- DTV	MKE	242;V,;126.7/ (3)	99 A 172 N 256 A 358 N
(1) "	BVOR	MKE	115.1	
" Mitchell	AC(g)		278;119.1,126.18,121.5/(2),#	
(1)Wausau	BVOR- DTV	ALX	112.5;V,121.5,126.7/#,(3)-4495, 3105	
WYOMING				
Casper	SBRAZ- DTV	CPR	269;V,121.5, 126.7/(3),#	76 A 159 N 256 A 335 N
(1) " +	BVOR	CPR	116.4	

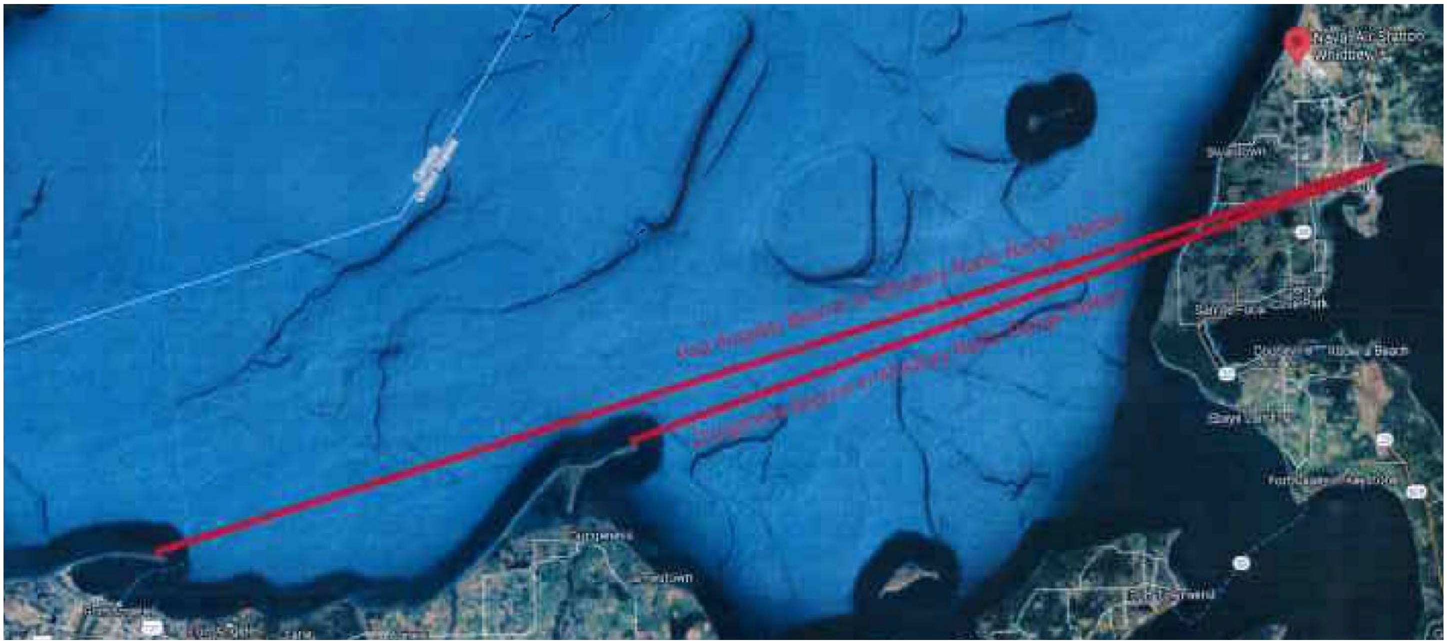
LOCATION	CLASS	IDENT	FREQ. Trans/Gds	RANGE COURSES
WYOMING				
(1)Cherokee INSAC-Rawlins	BVOR-DTV	CKW	115.1;V,121.5,126.7/#,(3)	
Cheyenne	SBRAZ- DTV	CYS →	326;V;126.7, 126.7/(3),#	102 A 161 N 256 A 347 N
(1) "	BVOR	CYS	112.3	
" Arpt	AC(g)		278;118.7,126.18,121.5/(2),#	
Douglas	BMH-TV	DGW	251;V,121.5,126.7/(3)	
(1) "	BVOR	DGW	114.1	
Ft. Bridger	SBRAZ- DTV	FBR	382;V,121.5, 126.7/(3),#,3117.5	67 A 152 N 237 A 332 N
(1) "	BVOR	FBR	113.9	
(1)Kemmerer INSAC-Ft. Bridger	BVOR- DTV	EMM	116.0;V,121.5,126.7/(3),#,3117.5	
Laramie	SBRAZ- DTV	LAR	245;V;121.5, 126.7/(3),#	47 A 137 N 227 A 317 N
(1) "	BVOR	LAR	117.6	
Midwest	VORW		(being relctd)	
(1)Moorcroft	VORW-TVJ	MFW	115.9;V;121.5,122.2,126.7;278/#,(3)-4495	
(1)Rock River + INSAC-Laramie	BVOR-DTV	RKR	115.5;V,121.5,126.7/(3),#	
Rock Springs	SBRAZ- DTV	RKS	290;V;121.5, 126.7/(3),#	66 A 156 N 246 A 336 N
(1) "	BVOR	RKS	114.7	
Sheridan	SBRAZ- DTV	SHR	239;V;121.5, 126.7/(3),#	28 A 118 N 208 A 298 N
(1) "	BVOR	SHR	113.3	
Sinclair INSAC-Rawlins	SBRAZ- DTV	SIR	368;V;121.5, 126.7/(3),#	67 A 164 N 251 A 344 N
NEW FACILITIES (or facilities out of alphabetical alignment)				
Moody AFB, Ga.	CA		201;126.18,137.88,121.5/4495,#	
Spence, Ga.	CA (0645-18 Mon-Fri)		278;126.18/4495,#	
Shaw AFB, S.C.	HW (19-09;durg IFR)	SSC	526	
Whiting NAAS, Fla. S. Field	CN (0630-17 wrk days)		(269 req)3065;142.74(121.5 req)/ 4495,3065;142.74	
Moody AFB, Ga.	MRLWZ	VAD	212	45 A 135 N 225 A 315 N
(3)Quitman, Tex.	VORW	UIM	114.0	

(8-28-51)

The answer to the second question is that the white marker beacon indicator would have illuminated at both the Port Angeles CGAS and at Dungeness making it essential to have identified the beacon.

3. Would a direction finder bearing measured from Port Angeles CGAS to the Whidbey Radio Range Station be the same as the bearing measured from Dungeness to the Whidbey Radio Range Station?

The Radio Range Station at Whidbey was located well south of the actual Whidbey NAS runway, but placed in line with the main runway. Measuring bearings on the WAC chart illustrates that the bearing to the Whidbey NAS Radio Range Station would have been approximately 45 degrees (plus or minus a few degrees) whether measured from either the Port Angeles beacon or the Dungeness beacon. The illustration below shows the exact bearing lines on Google Maps to clearly illustrate the geometry. At the B17's speed of 3 mile per minute over the ground, perpendicular to these bearing lines, the difference in bearings to Whidbey represents less than 10 seconds of flight time. With the equipment in use at that time, on a moving aircraft the difference was not detectable. In effect, those bearing measurements were identical. This bearing gave the crew further false assurance that they were over Dungeness when they were not. In a tragic twist of fate there are only two places on earth where they could have measured a bearing of 45 degrees to the Whidbey Radio Range Station at the same time their 75 MHz beacon light illuminated.



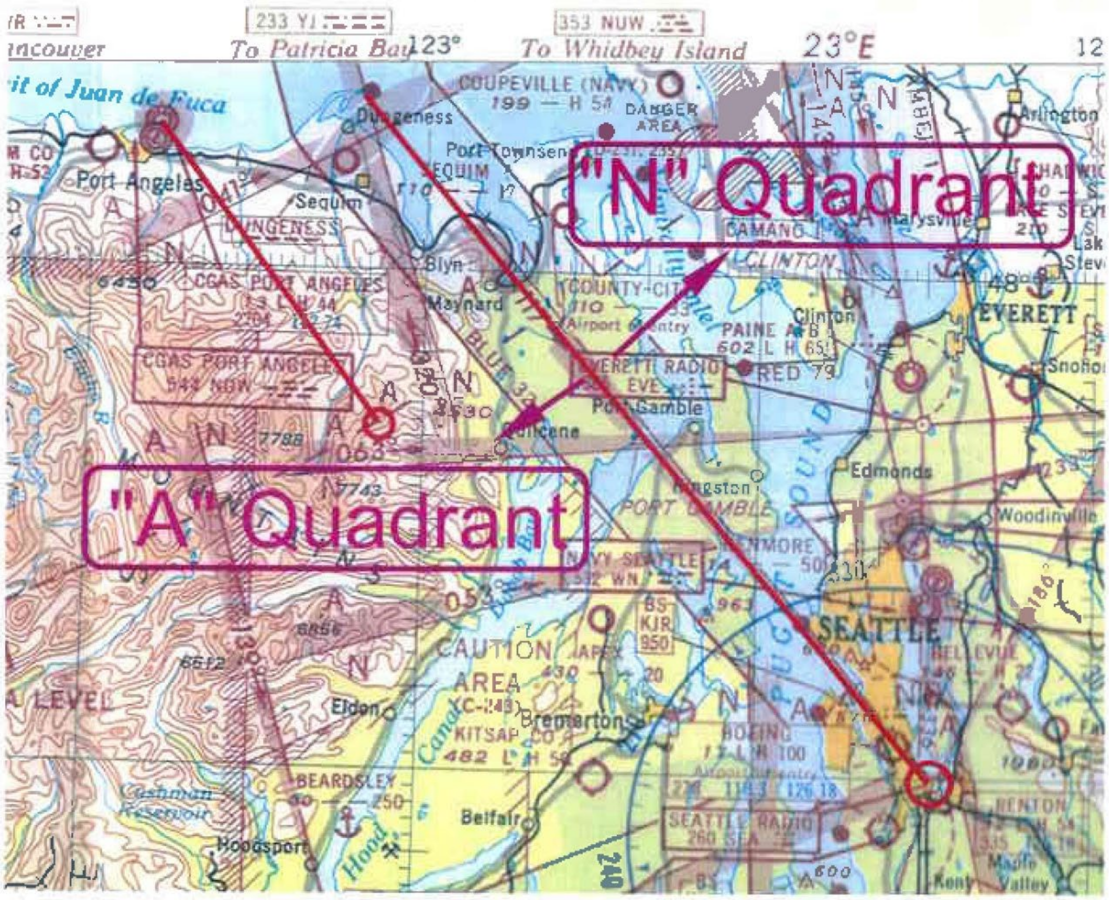
The answer to the third question is that the bearings from the aircraft to the Whidbey Radio Range would have been the seme from either Port Angeles CGAS or the Dungeness intersection.

4. If the aircraft was at Port Angeles when it turned to 120 degrees, and tuned to Seattle Radio Range, would the crew have heard the “distinct A” quadrant signal the described? And would they have heard that same “distinct A” at Dungeness?

The Low/Medium Frequency Radio Range system operated in the 200 to 400 Khz frequency range. These frequencies do not suffer from the line-of-sight limitations that affect VHF radio, and they can bounce off the ionosphere and can travel considerable distances, limited only by the transmitter power. This means the signals were not blocked by terrain. This means that unlike the VHF voice radio signals, the Radio Range signals could have been heard at Port Angeles CGAS despite high terrain between Port Angeles and Seattle. The chart below illustrates where the “N” quadrant lies (where the crew would hear “N” dah di dah di) northeast of the airway to Seattle, and where the “A” quadrant lies (where the crew would hear “A” di dah di dah) southeast of the airway to Seattle. The Port Angeles CGAS is very clearly deep in the “A” quadrant.

When the aircraft turned to a heading of 120 degrees and the radio was switched to the Seattle Radio Range station the crew heard a “distinct A” signal. That is consistent with being at the Port Angeles CGAS. At Dungeness Intersection they would have heard a steady tone where the “A” and “N” tones overlapped. At the worst the “A” or “N” would both be heard but one stronger than the other depending on which extreme edge of the airway they were on. That distinct “A” was a major warning that meant they had flown completely through the intersecting airway and were completely south of the airway. The illustration below makes clear that the correct response would have been to turn northerly until they heard both the dominant “A” and a weaker “N” signal. That would have indicated they had reached the right, southern edge of the inbound airway. Only then could they have safely turned right to the 119 degree heading to safely fly the airway towards Boeing Field.

In more detail, at Dungeness the triangle that forms the safe airway would have been 2.6 miles wide. If the aircraft had been off the centerline but within 1.3 miles north of it, they would have heard a strong “N” and fainter “A”. If off the centerline but within 1.3 miles south of the airway, they would have heard a strong “A” and fainter “N” signal. If on the center those would have merged to form a steady tone. The distinct “A” was a glaring warning that was ignored, because of the confidence placed in the unverified marker beacon, and the useless bearing to the Whidbey Radio Range Station.

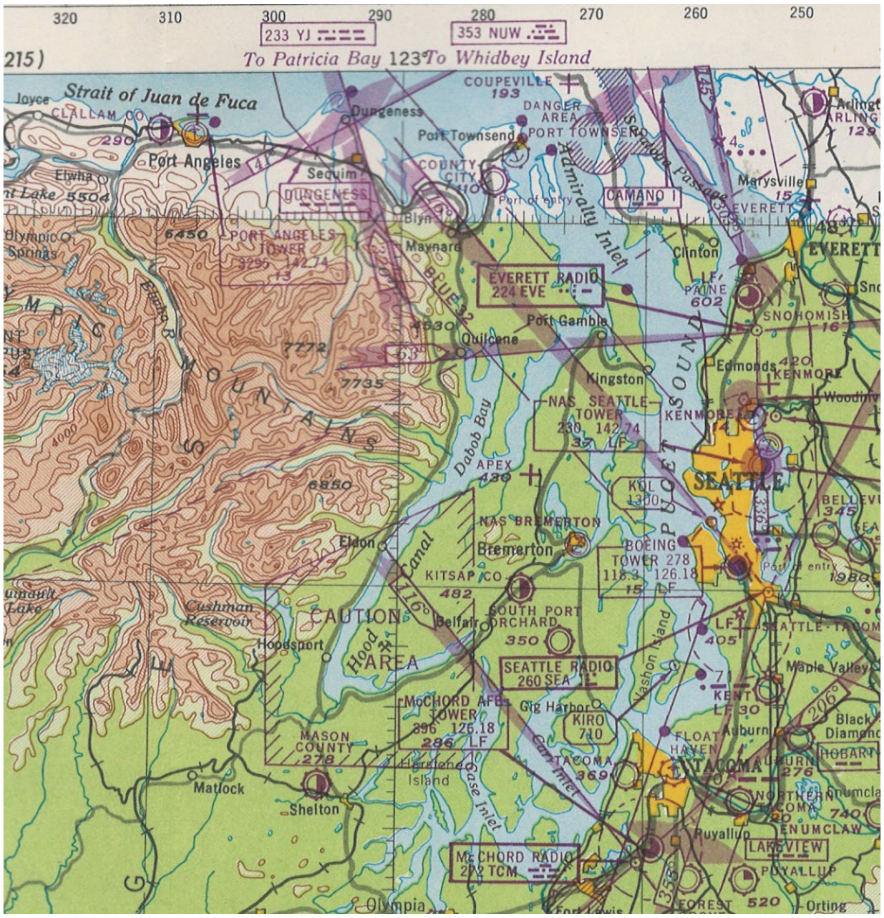


The answer to the 4th question is that the "distinct A" the crew reported is fully consistent with the aircraft being over the Port Angeles CGAS. Failing to properly respond to that distinct "A" was the most critical, and fatal error.

5. If the aircraft was at Port Angeles, at 6,000 feet MSL, would it have been able to communicate with Everett via line-of-sight VHF radio, due to low terrain towards Everett, but not been able to communicate with Seattle due to high terrain towards Seattle?

The fact that the crew was able to contact Everett via VHF means the line of site to Everett was not blocked by high terrain. At 6,000 feet MSL, line of sight to Everett is clear from either Dungeness or Port Angeles. Everett is north of Seattle at approximately the same elevation. Additionally, Seattle and Everett are both approximately the same distance from the Port Angeles CGAW and from Dungeness. These facts suggests that if the aircraft was at Dungeness, static would have affected communications equally with both Everett and Seattle, but only Seattle was affected. The problem reported was not static at all, it was terrain. The communication problem is consistent with higher terrain between the aircraft at Port Angeles and Seattle, and clear line of sight due to significantly lower terrain between the aircraft at Port Angeles and Everett.

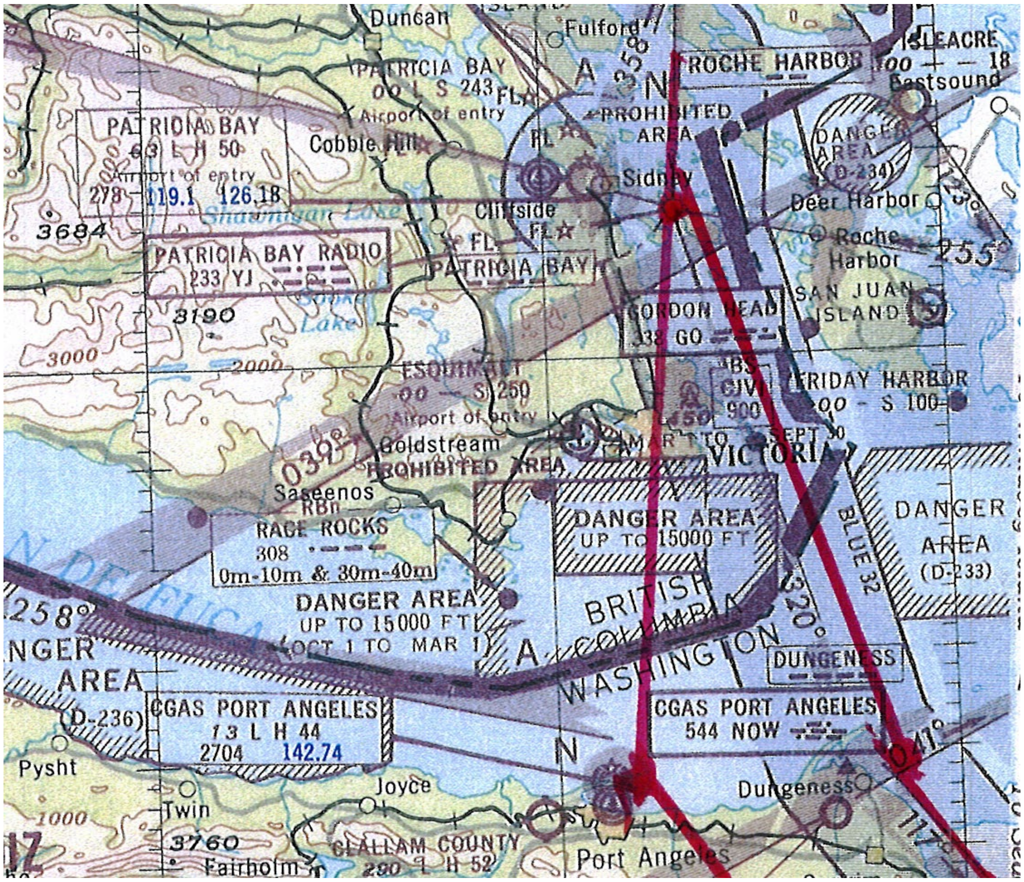
The following chart illustrates the preceding, showing terrain rising above 7,700 feet MSL along a line from the Port Angeles CGAS to Seattle, on the route they flew. Note the orange coloring and spot altitudes. Along a line from the Port Angeles CGAS to Everett the terrain does nor rise more than 1,000 feet MSL. Eventually, as the aircraft flew into the mountains, even the line of sight to Everett became blocked. The low terrain is shown in green from Dungeness and along the actual airway to Seattle. Note how much terrain clearance the aircraft would have had at 6,000 feet MSL had they actually been on the airway (the narrow purple triangle with its tip at Boeing Field.)



The answer to the 5th question is that from Port Angeles at 6,000 feet MSL (and for the following few minutes) the aircraft could have communicated via VHF voice radio with Everett, but could not have communicated with Seattle.

6. Would there have been a noticeable difference in the time to fly from Patricia Bay to the Port Angeles CGAS compared to flying to the beacon at the Dungeness intersection?

The following illustration shows courses from Patricia Bay to Dungeness and Patricia Bay to Port Angeles CGAS on a 1952 WAC chart. correct airway route from Dungeness to Seattle.



The distance from the Patricia Bay Radio Range Station to either Dungeness or the Port Angeles CGAS is the same; 35 statute miles, which would have taken 11 minutes to either destination.

So the answer to the 6th question is that there was no difference in the time from passage over Patricia Bay to either the Dungeness marker beacon or the Port Angeles CGAS marker beacon. At either location the marker would have illuminated at the expected time if they had been on the actual airway.

Conclusion:

Based on the preceding analysis, the only scenario that fits the facts is that the B-17 flew to the Port Angeles CGAS, not the Dungeness intersection, and the turn to the heading of 120 degrees took them directly into high terrain where they crashed.

Studying the topographic maps along their course from Port Angles CGAS into the mountains at 6,000 feet, they would have flown just left of Blue Mountain at 6004 feet, then through a saddle with Baldy at 6,814 feet and Grey Wolf 7126 on their right side and Tyler 6125 feet and Peak B 6376 feet to their left, then crashed into the ridge just north of Hawkes Peak 6545 feet. Other high peaks on each side of this route include Mt Townsend 6280 feet, Buck at 6,985 feet, and Iron Peak at 5824 feet. Had they been a mere 2 miles farther north, they would have just cleared Dirty Ridge at 5748 feet. Had they not been cleared to 6,000 feet and remained at 8,000 feet they would have successfully cleared all terrain. This terrain explains why they experienced such violent turbulence at 6,000 feet and why they could not make VHF radio contact with any station after they entered this high terrain. Because they were in the clouds at night, they saw none of this terrain until the following morning.

As is common, there were multiple pilot errors and wrong assumptions leading to this accident. These errors include: failing to make the turn at Patricia Bay, failing to monitor the Patricia Bay Radio Range outbound for course guidance to Dungeness, failing to identify that the marker beacon was Dungeness, and failing to properly respond to the distinct "A" from the Seattle Radio Range Station.

<u>Additional Relevant Details, and Helpful Background:</u>

<u>Marker beacons</u>: Marker beacons are part of the old IFR route systems and the current ILS landing systems used to indicate distance from a runway and locations along a route. Most transmit on 75 MHz. There are 4 basic types of marker beacons; 3 types of markers are used for every IFR runway approach and consist of an outer marker, middle marker and inner marker. Fan marker beacons were used to mark positions along IFR routes and to mark the intersections of the old airways. Marker beacons were also placed at each Radio Range station. They transmit low power, very directional vertical signals that can only be received when the aircraft is in a cone directly above the station. For the ILS system markers, when a marker is received, if the audio is turned up, a tone is heard and the pitch of that tone defines what kind of marker is being heard, which corresponds to a colored light on the console. A white light corresponds to the ILS inner markers and to fan markers. Non-ILS markers also transmit audio Morse code identifier letters that tell the pilot which beacon is being received, or its type.

<u>Thoughts about the failure to respond to the "distinct A" quadrant signal</u>: Hybki stated that at the time the copilot made the turn to 120 degrees he definitely heard a distinct "A" from Seattle. Why would a pilot fail to properly respond to such a signal when he expected to hear a steady tone or a combination of "A" and "N"? Most likely because the crew's expectations dwarfed the actual information they were receiving. The strong, unverified and incorrect belief that they were at Dungeness was given more credence than the quadrant signal. But to give some benefit of the doubt, pilots who used this system frequently had to deal with the flaws in the LF/MF Four Course Radio Range system. This included ambiguity and other problems such as ionospheric bounce that sometimes gave erroneous information to pilots. Just like AM broadcast radio, at night these signal reflections that became stronger and traveled farther at night. Pilots were accustomed to imperfect information from the system, particularly when far fromremain the stations. The lack of confidence in the system and these problems were some of many good reasons why the Four Course Radio Range System was replaced as better technology emerged. The following is a link to an excellent website regarding this system for those interested in more details and graphics. The site also includes a link to a video of a modern flight around the only operating radio range station in operation:

http://home.iwichita.com/rh1/hold/av/stories/avionics/radiorange.htm

Technically the radio range worked because each radio range station along the route broadcast carefully tuned directional signals that created approximately four quadrants and four airways centered at the station. Two transmitters at the same location, transmitted on the same frequency but on separate very directional antennas. One transmitted a dot dash and the other a synchronized dash dot. Each 30 seconds the dots and dashes were paused and replaced with the 3 letter Morse code identifier of the Radio Range station. The transmitters and antennas were set up such that their signals overlapped along a very long and relatively narrow 3 degree wide triangular area. At a distance of 100 miles from the station the total width of the airway was only 2.5 miles, narrowing to a point at the Radio Range station. When an aircraft was on the centerline of an airway the overlapping signals were equal and the sound of the dot-dash from one station precisely filled the quiet spaces between the dash dots of the other, blending into a steady tone. If an aircraft moved away from the centerline of the airway, one of the overlapping signals would be weaker, and gradually fade out with distance from the centerline. At one edge of an airway the pilot could hear louder dot dashes and weaker dash dots which gave a clue about which direction the airway centerline was. At the other edge this would be reversed. For collision avoidance, pilots were urged to fly along the right edge of the airways, which was defined as the area where both tones were clearly heard, but the right quadrant signal would be stronger than the left quadrant signal. When the aircraft was completely off any of the 4 airways the pilot would hear only the dot dash ("A") or only the dash dot ("N") depending on which quadrant they were in. The pilot had to have a general sense of where the pilot was and what direction to fly to use the system.

Radio range station signals faded out as an aircraft flew directly overhead in an area called "a cone of silence." This was one way a pilot knew they were directly above a radio range station, and while in the cone of silence they would be able to receive its 75 MHz marker beacon.

Critical to this particular incident is that hearing a distinct "A" with no weak "N" meant they were completely south of, and off the airway. But that did not tell them how far they were from the airway. Intercepting an airway at an angle such as occurred at Dungeness, while flying 3 miles per minute, meant the plane would complete fly across the airway in about 45 seconds. For airways that turned at some point between stations, the marker beacon at the intersection were critical to alert the pilot to switch stations and make the turn. It was very important to remaining within the airway when near mountainous terrain because the minimum safe altitudes only apply within the airway boundaries.

Reference: Four Course Radio Range Stations and Airways for Patricia Bay and Seattle

PATRICIA BAY BC	**Inbound**	**Outbound**
Northwest course	163 magnetic (186 true)	343 magnetic
Northeast course	258 magnetic	78 magnetic
Southeast course	323 magnetic	143 magnetic (166 true)
Southwest course	85 magnetic	265 magnetic
Code:	YK	
Morse Code:	**-.-- .-.**	
Frequency:	201 Kc	
Airport:	CYYJ	
Airport Details:	CYYJ R27 265M/3.8nm	
Latitude:	48.6295°	
Longitude:	123.3207°	
Magnetic Variation:	21.0°	

SEATTLE, WA	Inbound	Outbound
Southeast course	271 magnetic	91 magnetic
Northeast course	358 magnetic	178 magnetic
Northwest course	119 magnetic (142 true)	299 magnetic
Southwest course	175 magnetic	355 magnetic
Code:	SA	
Morse Code:	**... .-**	
Frequency:	260 Kc	
Airport:	KBFI	
IAP:	View chart	
Latitude:	47.4940°	
Longitude:	122.2615°	
Magnetic Variation:	20.0°	

Port Hardy Radio Range: ID ZT; located at 50-41'-56.73W by 127-25'-37.47"W
Comox Radio Range: ID QQ; located at 49-45'-13.89"N by 120-25'-37.47"W
Whidbey Radio Range; ID NUW; located at 48-17'-51.60"N by 122-36'-58.73"W

Reference: The 1952 magnetic variation at 48 degrees north latitude was 23 degrees east at the time of this accident, consistent with the 1952 WAC chart. Magnetic variation changes from year to year. The 1956 WAC chart used above to illustrate the airway from Dungeness to Seattle shows the magnetic course for the Seattle Airway as 117 degrees, while in 1952 it was 119 degrees. The airway was not moved, but the magnetic variation changed. This is also why tables about various radio range stations will show the airway courses with different magnetic headings depending on the year of the table. This article uses the 1952 data. Pilots are required to use current charts and information which is updated regularly.

Reference: Crash site coordinates: 47.854 degrees north latitude; 123.088 west longitude

Reference: Bearing from Dungeness Intersection to crash site: 147 magnetic 180 true. Distance is 23 miles.

Reference: The distance from Dungeness intersection to Port Angeles CGAS beacon is about 14 miles. Consistent with this, the course the B-17 was flying was parallel to the actual airway, but offset 14 miles to the west, and the crash site is 14 miles west of the actual airway.

links:

https://746project.wordpress.com/
http://members.peak.org/~mikey/746/index.htm
https://www.aopa.org/news-and-media/all-news/1997/october/pilot/four-course-radio-ranges (Barry Schiff article)

There is a good debris map on one site to help you find things. Please look, take pictures, but do not disturb or take or deface what you find.