HF/E Issues Involved in the Disappearance of and Search for Amelia Earhart

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An examination of factors that may have led to the failure of the famous flight around the world and the subsequent search effort.

THE DISAPPEARANCE OF THE AVIATRIX Amelia Earhart, the subject of a recently released Hollywood movie, is one of the greatest ongoing mysteries of the 20th century. Indeed, Earhart has been described as "America's favorite missing person."

The story, in outline, is well known. As the first woman to fly solo across the Atlantic Ocean, and arguably the most famous woman in aviation history, Earhart disappeared during one of the final homeward legs of her 1937 flight around the world. She and her navigator, Fred Noonan, failed to complete the flight between Lae in New Guinea and the small atoll of Howland Island in the Pacific, where she was to refuel her customized Lockheed Electra 10E for the penultimate segment of the flight.

Recently, there have been a number of developments in the case, including a more detailed analysis of the extant records of communications, which cast further light on the circumstances of the failure of that fateful and fatal journey (Gillespie, 2006). The purpose of this article is not to enumerate all of these new developments in detail but to set the disappearance in context, with special reference to the potential human factors/ergonomics issues involved. As with all forms of failure, the episode can be instructive and help render insight into those circumstances that divide success from disaster (see Hollnagel, 2009; Reason, 2008).

The Seeds of the Disaster

Earhart was not the first to attempt to circumnavigate the globe by flight. By the time of her attempt in the summer of 1937, the feat could even be achieved using a connected series of then-existing commercial flights. Many commentators have treated the notion of her "research exploration" with short shrift, especially because Earhart's husband, George Palmer Putnam, seemed so adept at tapping into the publicity and subsequent financial return on what Earhart sought to achieve. Regardless of the specific motivations involved, Earhart's record of bravery and innovation cannot be questioned. This is not to say that her piloting skills have not been criticized; indeed, as I will show, the perception of her competence may well have played a role in her eventual disappearance. All this was into the future when Earhart set out on her first attempted around-the-world flight with the leg from California to Hawaii.

On St. Patrick's Day – March 17, 1937 – she completed the successful crossing to Oahu on what was planned to be a *westward* journey around the world. This trip was familiar to Earhart given that, in 1935, she had been the first flyer (man or woman) to accomplish this particular feat of aviation. On this first leg of the first around-the-world attempt, Earhart was accompanied by Harry Manning, an expert navigator, and Paul Mantz, a pilot and technical advisor, as well as navigator Fred Noonan, whom I will discuss later in the article. Having made this auspicious beginning, what happened next was an untoward interruption. On takeoff three days later from Luke Field, her plane spun out along the runway and was badly damaged in the resulting crash. No specific cause for this crash has ever been determined, and speculation ranges from a blown tire to pilot error. Regardless of the cause, the damaged plane had to be shipped back to Burbank, California, for repairs, and plans for the flight around the world had to be put on hold temporarily.

During repairs to the plane (see Figure 1), a number of changes were made that were to play a crucial role in its subsequent disappearance. It is probable that the trailing wire antenna, which could be used to enhance the aircraft's systems communication capacity, was removed. This might well have been done to reduce the overall weight, which was a continual concern in relation to fuel capacity and flight distance. Partly because of changes in weather patterns during the delay, Earhart then decided to make the attempt in an *eastward* direction. This second effort began on June 1, when she left

Figure 1: Amelia Earhart in front of her specially built Lockheed Electra 10E, which was financed by Purdue University. Reproduced from the George Palmer Putnam collection of Amelia Earhart papers, courtesy of Purdue University, Karnes Archives and Special Collections.

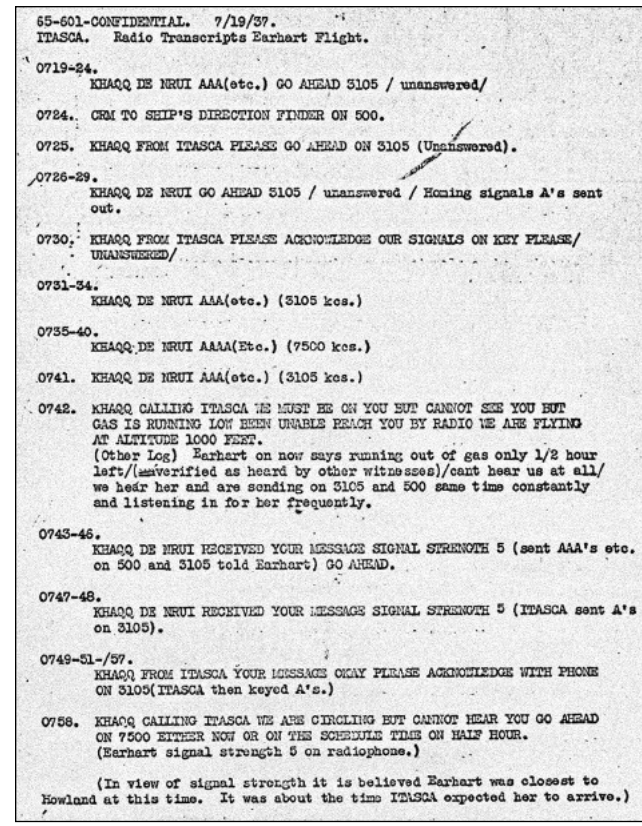
Miami, Florida, heading across the Caribbean for South America, Africa, and beyond. She disappeared on the longest leg of the journey over the Pacific. It is reasonable to postulate that some HF/E issues were ingredients in the eventual failure of Earhart's endeavor, and in what follows, I consider some of these dimensions.

HF/E Issues in the Disappearance

The primary factor involved in Earhart and Noonan's disappearance concerns the crucial problem of communication, and it is the human factors issues associated with these communication failures that I discuss first.

Communication. At exactly 00:00 hours Greenwich Mean Time (GMT) on July 2, 1937, Amelia Earhart and Fred Noonan left Lae in New Guinea, bound for their refueling site on the minuscule atoll of Howland Island, some thousands of miles away in the vastness of the Pacific Ocean. There can be little doubt that the primary reason that the Earhart flight did not reach its destination was because of a failure in communications. However, given that there are records of transmissions received from Earhart's plane (call sign KHAQQ) by the U.S. Coast Guard cutter *Itasca* stationed at Howland Island, this statement may at first seem to be simply incorrect (see Figures 2 and 3). One transmission appears to indicate that Earhart also received a message (albeit a series of repeated Morse letters) from the *Itasca*. How, then, was there a communication problem? As I will show, these two exceptions unfortunately do not mean that the clear, two-way communication essential to the success of the rendezvous was ever fully established. As a result of this, it is important first to understand the navigation strategy that Earhart and Noonan were looking to achieve. This can be presented using a simple analogy.

The leg from Lae to Howland Island can be conceived as analogous to the way the human motor system achieves a skilled ballistic movement (see Hancock & Newell, 1985). The first and largely open-loop phase is a preprogrammed action designed to get the entity within the "ballpark" of its final target. Thus, in order to get the Electra within wireless range of the *Itasca*, Noonan and his celestial navigation and dead-reckoning skills, honed in the service of the fledgling Pan Am China Clipper Service, would have been critical. In this effort Noonan was apparently successful, because the Electra stayed very much on its direct course during the parts of the flight that could be tracked (see King, Jacobson, Burns, & Spading, 2001, pp. 291–292). Indeed, Earhart was heard by the *Itasca* as she approached Howland Island, and the recorded strength



65-601-CONFIDENTIAL. 7/19/37.
ITASCA. Radio Transcripts Earhart Flight.

0719-24.
KHAQQ DE NRUI AAA(etc.) GO AHEAD 3105 / unanswered/

0724. CRM TO SHIP'S DIRECTION FINDER ON 500.

0725. KHAQQ FROM ITASCA PLEASE GO AHEAD ON 3105 (Unanswered).

0726-29.
KHAQQ DE NRUI GO AHEAD 3105 / unanswered / Homing signals A's sent out.

0730. KHAQQ FROM ITASCA PLEASE ACKNOWLEDGE OUR SIGNALS ON KEY PLEASE/ UNANSWERED/

0731-34.
KHAQQ DE NRUI AAA(etc.) (3105 kcs.)

0735-40.
KHAQQ DE NRUI AAAA(Etc.) (7500 kcs.)

0741. KHAQQ DE NRUI AAA(etc.) (3105 kcs.)

0742. KHAQQ CALLING ITASCA WE MUST BE ON YOU BUT CANNOT SEE YOU BUT GAS IS RUNNING LOW BEEN UNABLE REACH YOU BY RADIO WE ARE FLYING AT ALTITUDE 1000 FEET.
(Other Log) Earhart on now says running out of gas only 1/2 hour left/(unverified as heard by other witnesses)/cant hear us at all/ we hear her and are sending on 3105 and 500 same time constantly and listening in for her frequently.

0743-46.
KHAQQ DE NRUI RECEIVED YOUR MESSAGE SIGNAL STRENGTH 5 (sent AAA's etc. on 500 and 3105 told Earhart) GO AHEAD.

0747-48.
KHAQQ DE NRUI RECEIVED YOUR MESSAGE SIGNAL STRENGTH 5 (ITASCA sent A's on 3105).

0749-51-/57.
KHAQQ FROM ITASCA YOUR MESSAGE OKAY PLEASE ACKNOWLEDGE WITH PHONE ON 3105(ITASCA then keyed A's.)

0758. KHAQQ CALLING ITASCA WE ARE CIRCLING BUT CANNOT HEAR YOU GO AHEAD ON 7500 EITHER NOW OR ON THE SCHEDULE TIME ON HALF HOUR.
(Earhart signal strength 5 on radiophone.)

(In view of signal strength it is believed Earhart was closest to Howland at this time. It was about the time ITASCA expected her to arrive.)

Figure 2: Copy of the transcript of the wireless communications between the Coast Guard Cutter Itasca *and KHAQQ, Amelia Earhart's Lockheed Electra 10E. Reproduced from the George Palmer Putnam collection of Amelia Earhart papers, courtesy of Purdue University, Karnes Archives and Special Collections.*

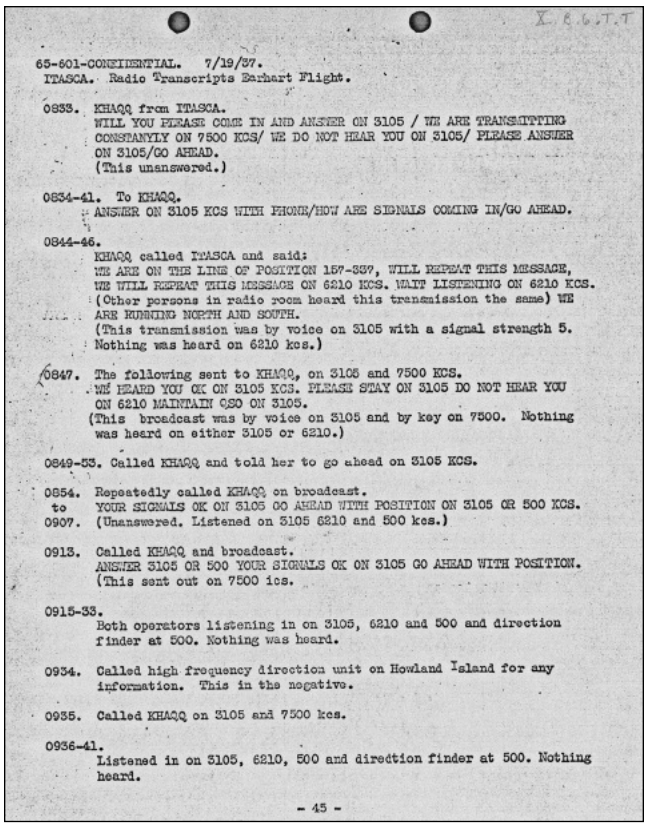
of her messages improved as she apparently approached her target. However, as with the human motor system, the second and arguably more critical phase can be characterized as closed-loop in nature. Here, there needed to be carefully interchanged signals between the aircraft and the ship in order to bring Earhart within visual range. This part of the plan proved to be fatally flawed.

One basic issue was how the crew of the *Itasca* saw their role. Postevent commentaries reveal that they did not see themselves as especially active in or responsible for this latter phase of contact. Certainly prepared to help if they could, they did not believe themselves to be intimately involved in either the planning or execution of this "homing-in" phase of the longest leg of Earhart's flight. Under normal conditions, this might not have been especially problematic. However, with the restricted capacities and developing technical difficulties of the aircraft, the *Itasca's* role was to prove pivotal in the unfolding events. King et al. (2001, p. 293) commented directly: "By 1937, radios were standard equipment in most commercial and many military aircraft, but they were incredibly user-hostile." It is important to explore the aspects of that "user-hostility."

The first and most evident flaw in communication turned out to be time and timing. With the technology of that era, each respective station (either plane or ship) had to indicate in

FEATURE AT A GLANCE: A reexamination of the final flight of Amelia Earhart points to some human factors/ergonomics issues that may well have played a role in the failure of the aircraft to make its rendezvous at Howland Island. HF/E issues were also involved in the failed search to find the downed flyer and her navigator in the vastness of the Pacific Ocean.

KEYWORDS: Amelia Earhart, human factors, communication failure, fatigue.



65-601-CONFIDENTIAL. 7/19/37.
ITASCA. Radio Transcripts Earhart Flight.

0833. KHAQQ from ITASCA.
WILL YOU PLEASE COME IN AND ANSWER ON 3105 / WE ARE TRANSMITTING CONSTANTLY ON 7500 KCS/ WE DO NOT HEAR YOU ON 3105/ PLEASE ANSWER ON 3105/GO AHEAD.
(This unanswered.)

0834-41. To KHAQQ.
ANSWER ON 3105 KCS WITH PHONE/HOW ARE SIGNALS COMING IN/GO AHEAD.

0844-46.
KHAQQ called ITASCA and said:
WE ARE ON THE LINE OF POSITION 157-337, WILL REPEAT THIS MESSAGE, WE WILL REPEAT THIS MESSAGE ON 6210 KCS. WAIT LISTENING ON 6210 KCS.
(Other persons in radio room heard this transmission the same) WE ARE RUNNING NORTH AND SOUTH.
(This transmission was by voice on 3105 with a signal strength 5. Nothing was heard on 6210 kcs.)

0847. The following sent to KHAQQ, on 3106 and 7500 KCS.
WE HEARD YOU OK ON 3105 KCS. PLEASE STAY ON 3105 DO NOT HEAR YOU ON 6210 MAINTAIN QSO ON 3105.
(This broadcast was by voice on 3105 and by key on 7500. Nothing was heard on either 3105 or 6210.)

0849-53. Called KHAQQ and told her to go ahead on 3105 KCS.

0854. Repeatedly called KHAQQ on broadcast.
to YOUR SIGNALS OK ON 3105 GO AHEAD WITH POSITION ON 3105 OR 500 KCS.
0907. (Unanswered. Listened on 3105 6210 and 500 kcs.)

0913. Called KHAQQ and broadcast.
ANSWER 3105 OR 500 YOUR SIGNALS OK ON 3105 GO AHEAD WITH POSITION.
(This sent out on 7500 ics.

0915-33.
Both operators listening in on 3105, 6210 and 500 and direction finder at 500. Nothing was heard.

0934. Called high frequency direction unit on Howland Island for any information. This in the negative.

0935. Called KHAQQ on 3105 and 7500 kcs.

0936-41.
Listened in on 3105, 6210, 500 and direction finder at 500. Nothing heard.

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Figure 3: Transcript of the last certain broadcast from Amelia Earhart. She was just three weeks short of her 40th birthday. Reproduced from the George Palmer Putnam collection of Amelia Earhart papers, courtesy of Purdue University, Karnes Archives and Special Collections.

advance when it would broadcast a message and then listen for a return broadcast. Earhart had declared her intention, and the evidence shows that she adhered to that intention, operating on Greenwich Civil Time (GCT). Unfortunately, because of some still unresolved confusion, the *Itasca* chose to operate on Navy time. Normally, this might not have made a tremendous difference either, except in this case, the *Itasca* was operating on the half-hour rather than the hour. Thus, arrangements to broadcast and receive were confused from the start, and at the critical time when each needed to be clear about the other's intentions, such confusion exacerbated the problems that the shortfall in technological capability had initially induced. Indeed, failures of timing still prove critical in the failure to control almost all human-machine systems (see Moray & Hancock, 2009).

The takeoff from Lae was on a 3,000-foot grass runway, with the Electra virtually full of fuel. It is possible – and indeed probable – that the small mast of the receiving antenna, mounted below the aircraft, struck the ground during takeoff and was stripped off. This has not been categorically proven. However, local tradition has it that the remnants of this antenna were subsequently found on the runway. Although this has not been confirmed either, it seems likely that Earhart's reception of voice transmissions was seriously compromised by this suspected loss. Of course, a full understanding of the communication failure requires detailed knowledge of late 1930s wireless technology and speculations about Earhart's specific systems (see King et al., 2001, pp. 293–304). If this supposition is correct, it would go a long way toward explaining the later communication confusions and the interactive limitations on her approach to Howland Island, which were proposed to rely almost exclusively on voice communication.

Timing was not the only issue in communication failure; the type of communication also proved to be a critical "pathogen" (see Reason, 1990). Communication issues were exacerbated by inconsistencies concerning the use of voice and Morse code. Although on her first circumnavigation attempt, Earhart was joined by Harry Manning, who was fluent in Morse code, on her second circumnavigation attempt, neither she nor Noonan had any great facility with Morse. Although Earhart made clear her preference for communications in spoken English, this was apparently not clearly conveyed to the *Itasca*'s wireless operators, who often used Morse code. It is doubtful that the Electra's crew could readily understand messages in this medium, other than responding to a repeated series of the same letter. This limitation, combined with the loss of simple voice reception and the timing issue, made it appear to the wireless operators on the *Itasca* that Earhart was inconsistent and often unresponsive.

Current speculation is that Earhart never actually heard any voice communication from the *Itasca*; she responded only one time to a series of repeated Morse letters on a different frequency. The upshot was that the crew of the *Itasca*, perhaps reinforced by then-existing gender stereotypes, saw Earhart as the "incompetent" woman and an amateur. On the reverse side, Earhart must have wondered exactly where the *Itasca* was and why it was not providing voice response on the agreed schedules and frequencies. Until we have more certain information, it appears that this was the primary cause of the flight's failure. However, other HF/E issues surely also pertain.

Figure 4: Amelia Earhart, with headphones, adjusting the controls in the cockpit of her Lockheed Electra. Reproduced from the George Palmer Putnam collection of Amelia Earhart papers, courtesy of Purdue University, Karnes Archives and Special Collections.

Fatigue. One issue that rarely gets much play in accounts of Earhart and Noonan's failure to find Howland Island is the issue of fatigue. Yet in this case, it is a logical concern. Earhart and Noonan had been engaged on the flight since their initial takeoff from California on May 21. They had flown more than 20,000 miles in the month of June, which meant an average of 6 to 7 hours per day dedicated to preparation, flight, and post-flight activities. However, it is known that their schedule during the journey was much less uniform than this. They did not fly the same number of hours each day, and their rest schedule was sporadic at best. Although some days were rest days with no flight hours, other days were composed of long flights. This variability was important in the profile of fatigue. There were constant worries over the maintenance of the aircraft and its refueling and security as well. They had crossed multiple time zones and were destined to cross more. Even with a number of sometimes enforced breaks, it is likely that stress, tension, and fatigue had taken a toll by the time they faced the last three over-water legs of their journey.

Although Earhart and Noonan had some rest prior to their last flight, the segment from Lae to Howland Island was to be the most challenging. Furthermore, it would involve flying an extended night shift. The plane took off at 10:00 a.m. local time on July 1, and although their precise state, in either chronic or acute terms, cannot be known, it is reasonable to surmise that the early hours just after dawn on July 2 would have found a fatigued crew engaged in searching for a very small island "target" in a great deal of "nontarget" ocean. The third HF/E issue is thus the problem of vigilance and visual search.

Vigilance and visual search. Finding a small Pacific atoll against a background of a vast ocean while looking into the morning sun can have been no simple task for anyone who had been active and vigilant during the preceding hours of night. Formally, it is not possible to specify the vigilance parameters, because only the nature of the target (Howland Island: 2,000 meters long by 500 meters wide), not the multiple distracters that must have been present (e.g., clouds, shadows, whitecaps), were known. It is a problem that search-and-rescue personnel know very well (cf. Hilgendorf & MacLeod, 1974).

It has been suggested that the Electra may have even flown specific flight patterns that were designed to help with such a search using the less distorting side windows of the aircraft to view the ocean's surface. Indeed, there is evidence in the transmission logs that Earhart may have been flying as low as 1,000 feet above ground level (AGL; see Figure 2), perhaps to try to facilitate this search. With Howland Island only at most some 3–4 meters above sea level, this could not have been an easy task.

People are poor at vigilance-based visual search tasks, especially under conditions of fatigue and environmental stress such as glare obstruction (Hancock, 1984). Out of the front of a high-mounted cockpit window, such a search would have been even more difficult. Although Earhart had considerable experience on long-distance flights, her previous targets had involved approaches to continental land masses (for example, in her Hawaii-California flight). But now the two aviators were aiming for an atoll barely over a mile long and only 1.6 square kilometers in size after a flight of some 2,223 miles. We know that they got close – frustratingly close. Earhart's 7:42 a.m. transmission reads: "KHAQQ [Earhart's plane] 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 1,000 feet." Despite the observation that the fuel was running low, it has been postulated that Earhart had up to 20% of the 1,100 gallons left in reserve as she arrived in the vicinity of Howland Island. However, there continues to rage a debate about this fuel reserve and to what degree and for what time she could have sustained flight with the fuel on board (see King et al., 2001, pp. 285–292).

HF/E Issues in the Search

If Earhart and Noonan had been searching for a small target in the almost endless Pacific, an enormously inflated version of the same challenge now faced the searchers. Initially, the Coastguard cutter *Itasca* searched an area to the north and east of Howland Island, which had been identified as the most likely location for the presumably ditched aircraft. This effort met with no success. Further U.S. Navy resources were subsequently dispatched to the area, including many search aircraft that were flown from the battleship *Colorado* and more later from the aircraft carrier *Lexington*. Despite the largest search ever mounted up to that time, no trace of Earhart, Noonan, or their downed aircraft was ever found.

In many ways, the human factors/ergonomics issues associated with the search are similar to those involved in Earhart's failure to find Howland Island in the first place. Principal among these was again the continuing failure of communications.

What followed in terms of radio communications is perhaps the most puzzling of all parts of the Earhart story. The technicians at Lockheed were aware that Earhart would be unable to broadcast if she had come down on water, because of the configuration of the electrical system supplying the onboard radio. Searchers in the vicinity of Howland Island, however, initially did not know this. Thus, there was the hope and expectation that the empty fuel tanks of the downed aircraft would help it stay afloat for an extensive period and that its crew could send radio messages for help. It was a forlorn hope. Any messages that were received would have to indicate that the aircraft had managed to land successfully on one of the small islands and atolls that dotted the Pacific, assumedly somewhere south or west of Howland.

The last ubiquitously acknowledged transmission from Earhart and Noonan came at 8:43 a.m. on July 2. The question ever since has been, "What happened?" Although there have been some intriguing developments, no one has any definitive evidence as to their eventual fate. What follows is speculation based on a balance of probabilities. It is a rehearsal of what the primary search group, The International Group for Historic Aircraft Recovery (TIGHAR), have termed the *Niku* (Nikumaroro) *hypothesis*. The speculation is that Earhart and

Noonan, early on the morning of July 2, found themselves close to what they believed should be Howland Island. The brief radio transmission they had actually received convinced them that they were in the vicinity, and yet they could not establish visual contact. Under these conditions, the purported standard approach was to divert to an alternative landing site. The reception of the 8:43 a.m. message suggests that they had begun to fly on a specified line of progress. They said: "KHAQQ to *Itasca* we are on the line 157 337 wl rept msg we will rept this on 6210 KCS wait, [3105/A3 S5 (?/KHAQQ xmission we are running on N ES S line)]" (see King et al., 2001, p. 31).

Some have opined that the flyers would have turned back toward the Gilbert and Ellice Islands, suggesting that this would have been the preferred, traditional strategy (i.e., a standard operating procedure) in case of becoming lost. This is part of the continuing contention. However, given Earhart and Noonan's knowledge of the area from contemporary maps, it is obvious that turning north was a dangerous (almost certainly fatal) option. Had they been south of Howland Island, this would have worked out, but north of Howland, the option to turn north (i.e., 337 degrees) would have left little, if any, land between them and the Kamchatka Peninsula some 4,000 miles away. In contrast, turning south provided a comfortable option. If they were north of Howland, they would strike it soon. However, if they were south of the island, they would still see land at some later juncture. The consensus is that they turned south, affording them the chance to see land approximately 350 miles away on that bearing, specifically the Phoenix Islands group, which includes McKean Island and Gardner Island (today called Nikumaroro). The latter is much the larger of the two and would have provided the greatest chance of a successful landing.

The possibility of such a landing is supported by what appears to be subsequent radio messages received from the pair. The veracity of these messages is often debated, but if they are real, it would mean that Earhart and Noonan must have been on land in order to successfully broadcast. The most telling empirical question that emerges is why the pair would have maintained a two-hour period of radio silence and not continued in their efforts to contact the *Itasca* on their way to an alternative landing site. It is a point in favor of the major alternative position, often termed the *crash and sink hypothesis.* The official search was called off on July 19, 1937, and although Earhart's husband did initiate his own efforts, no indisputable, concrete evidence of either flyer has ever been found.

Summary and Conclusions

As with virtually any accident or disaster, there are a number of human factors/ergonomics issues that can be raised in relation to the Earhart/Noonan disappearance. Their story serves as a conduit through which to promote our science and emphasize the criticality of understanding the combinatorial system interactions that can precipitate both failure and success (see Reason, 2008). Like many such untoward events, the more one explores the issue, the greater the depth of detail that is needed to specify the exact cause(s) of failure (see Hollnagel, 2009). This necessary level of exploration then serves to generate even further interest in the subject. However, this process also illustrates the problem of requisite complexity, whereby this progressive sophistication in analysis sequentially emphasizes the unique, idiographic details of each specific event. In contrast, traditional forms of explanation generally prefer the shallower and yet psychologically more satisfying nomothetic tendencies as we in our discipline have seen with the use of umbrella terms such as *pilot error*. One pivotal issue in the present case is the unprecedented conditions involved with the flight. It was the longest Earhart had ever undertaken and involved finding and then landing on a very small piece of land in the largest body of water on Earth. *Unprecedented* is always a word that should give those in the design and operations of human-machine systems pause for thought.

A Final Warning

Space limitations prevent my addressing the many additional factors and issues involved in Earhart's disappearance. The debate rages long and hard about the eventual fate of the flyers and the technical dimensions that may or may not lead to their eventually being found. There are a number of interesting Web sites devoted to the topic, but these should be approached with caution. The whole issue is, to this day, still fraught with controversy.

References

Gillespie, R. (2006). *Finding Amelia: The true story of the Earhart disappearance.* Annapolis, MD: Naval Institute Press.

Hancock, P. A. (1984). Environmental stressors. In J. S. Warm (Ed.), *Sustained attention in human performance* (pp. 103–142). New York: Wiley.

Hancock, P. A., & Newell, K. M. (1985). The movement speed-accuracy relationship in space-time. In H. Heuer, U. Kleinbeck, & K. H. Schmidt (Eds.), *Motor behavior: Programming, control and acquisition* (pp. 153–188). Berlin: Springer.

Hilgendorf, R. L., & MacLeod, S. (1974). Effect of lens color on target visibility for air-sea rescue. In *Proceedings of the Human Factors Society 18th Annual Meeting* (p. 171). Santa Monica, CA: Human Factors and Ergonomics Society.

Hollnagel, E. (2009). T*he ETTO principle: Efficiency-thoroughness trade-off – Why things that go right sometimes go wrong*. Farnham, UK: Ashgate.

King, T. F., Jacobson, R. S., Burns, K. R., & Spading, K. (2001). *Amelia Earhart's shoes: Is the mystery solved?* Walnut Creek, CA: AltaMira Press.

Reason, J. T. (1990). *Human error*. Cambridge, UK: Cambridge University Press.

Reason, J. T. (2008). *The human contribution: Unsafe acts, accidents and heroic recoveries*. Farnham, UK: Ashgate.

Moray, N. P., & Hancock, P. A. (2009). Minkowski spaces as models of human-machine communication. *Theoretical Issues in Ergonomics Science, 10*(4), 315–334.

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