Aircraft Magnetic Navigation Failure

A possible explanation for the disappearance of aircraft in the "Bermuda Triangle" before modern avionics.

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As a geophysicist, I have made it my life's study to research applications of measurements of the earth's magnetic field. This research included such diverse examples as its use in finding 3,000 year-old stone monuments in Mexico, assisting in finding sunken ships and submarines (Including U.S. and Soviet), making the first widely-used airport security gun detector in the 60s, predicting earthquakes, improving the discovery of oil and mineral deposits from aircraft, ships and on the ground, writing the widely-used Applications Manual for Portable Magnetometers and founding and managing Geometrics, the principal manufacturer of magnetometers for geophysical use and formerly, a principal world-wide airborne magnetometer survey contractor.

Some years ago, while on a commercial visit to Japan, I was greeted by a customer, the Geological Survey of Japan, with a request to accompany them on their aircraft conducting a regional magnetic survey in the Sea of Japan, northwest of Honshu. The reason was to verify that the equipment purchased by them from our company, Geometrics, would on occasion, fail to operate properly, in spite of it being sent back repeatedly for inspection and test.

Taking off from Sendai, we flew off the NW coast of Honshu in their aeromagnetic survey plane, a 60-passenger airliner called the YS-11. The survey consisted of flying a set of parallel lines 100 kilometers long and about 10 kilometers apart to cover eventually the entire offshore area of Japan. The purpose was to analyze the magnetic data for subsurface geology to depths of 15,000 meters for rock structure, its oil potential and plate tectonic information to shed light on earthquake hazards.

The aircraft's principal mission was to carry a device to measure with high precision the strength of the earth's magnetic field, using an instrument called a proton precession magnetometer, the then standard instrument for such purposes. The device operates on the same principal as the magnetic resonance imaging (MRI) systems later used in hospitals, except that instead of using large magnets around the patient, there is no magnet except the ambient, or earth's, magnetic field.

Inasmuch as the aircraft is magnetic due to its many industrial parts and electrical currents (with associated magnetic fields), the sensor was towed away from the plane on a 100 meter-long cable behind and beneath the plane. The sensor, itself, is a small, milk bottle-sized container housed in a streamlined airfoil housing called a 'bird' the whole tow system looking like a bomb on a cable. The sensor was comprised of a solenoidal coil around a bottle of a kerosene-like chemical (containing a high density of hydrogen nuclei to generate the "proton precession" signal.).

The signal out of the sensor was a few microvolts that had to travel up the long cable to the magnetometer display console. The cable had two wires to carry current to polarize, that is, temporarily magnetize the protons, and then, after the current is terminated, pick up the signal from these protons which, like tiny spinning bar magnets, would precess or spin, in the earth's magnetic field inducing a small signal in the same coil used to polarize, at a rate directly related to the strength of the magnetic field. For strength and shielding of unwanted electrical noise, an outer mesh of wire surrounded the cable.

<u>Survey Aircraft</u>

The day was partly cloudy, high humidity, a calm day for flying. The crew was only five of us on the entire plane: two flight crew, a technician, geophysicist and I. As we began the flight, the magnetometer was working just fine – the usual circumstance when you get someone from the factory to observe the failure and nothing goes wrong. But just in case, the technician had an oscilloscope hooked up to the magnetometer to observe the raw signal coming up the cable.

Then, out of nowhere, the signal was suddenly all noise, and not able to measure magnetic field. In fact, the noise filled the 'scope' screen in a way that I had not seen before. I changed the sweep rate to analyze the nature of the noise, its frequency content, amplitude and general characteristics. Of course, I looked outside and did not notice anything special. We were not flying through a cloud, which I at first thought might be producing a predictable signal from the electrical charges in the cloud droplets. We could not see the bird from inside the plane. This noise condition lasted for about 10 seconds and just as suddenly, ceased and a clean signal returned. We made the turn at the end of the line and came about on a parallel line 10 kilometers away. The navigation system being used was Loran C, the standard at the time. Our airspeed was about 200 knots and we were flying about 500 meters above sea level on a straight level flight.

Again, suddenly, more-or-less adjacent to the last line, the signal was again replaced by noise apparent on the screen and, of course, no coherent magnetometer trace. Again, I looked out of the window. I could see cumulus clouds everywhere, covering about 20% of the sky. But precisely where we were at the time and more importantly the location of the sensor, it was perfectly clear – at least to my *visual* senses. This noise appeared once or twice on every line while surveying that day always with the sudden onset characteristics. Interestingly, the amplitude of the noise, as observed on the oscilloscope, tended to be greater when flying one direction compared to the other [which I believe might be related somehow to a local electric field in a non-vertical direction??].

From my extensive experience with such systems and survey flights I knew that this was not an electronic system fault. The loss of signal, or more correctly and diagnostically, the presence of high-intensity wide-band apparent noise was occurring from something in the atmosphere around us, possibly related to some unusual condition related to position on the sky. My curiosity was really piqued. I still had one other diagnostic test to perform that I suspected might at the very least, lead me to the local source of this noise, if not the actual cause.

The shield around the cable did not carry signal, but was used only for strength and shielding purposes. But, maybe it could carry noise or worse yet, act as a pickup of some kind. So, I carefully disengaged the connector behind the magnetometer console connecting the console to the cable coming from the bird. As I did so, a large, 5 centimeter-long spark jumped between the console and the cable – indicative of perhaps 30,000 volts static discharge.

Instantly, I knew the problem and in moments, my mind indexed my experiences, knowledge of the meteorological conditions and even my mental library of other such customers' problems when we received returned equipment and could not discern the cause. When we had returned airborne magnetometers claiming malfunction without apparent cause, it was typically from customers from Brazil, Indonesia, The Philippines, Central Africa – all countries where the humidity is high and cloudy conditions.

My explanation was that the clouds around us are comprised of droplets that condensed due to slightly lower local temperatures causing the condensation of water droplets from the otherwise invisible water vapor. In order for droplets to form, each needs a particle, maybe salt, dust, other airborne particulate matter around which to nucleate. Each particle has an electrical charge. When clouds form, assembling a large number of such charges, they sometimes discharge causing lightning between clouds or discharge to the ground causing normal lightning. I figured, but did not know then that while I cannot see water vapor, there are probably insipient clouds with large numbers of droplets, each with its electrical charge, which, at the right local temperature, condense and form visible clouds. The only difference between the "charge clouds" and the physical clouds is that we can see the latter. Electrically, they are the same.

Thus, we have a very good electrical charge detector, which, unfortunately cannot be, at the same time, a good magnetometer.

The mechanism at work here is that the skin of this large aircraft intercepts clouds of charges, or generate charges through triboelectric effects of the particles rubbing against the aircraft surfaces. In either case, this causes charges to accumulate on the metal skin of the wings and fuselage. The charges want to repel and so scatter best they can wherever they can. An ideal distribution mechanism is the long cable with metal shield and bird, effectively a long dipole, allowing the charges to escape down the cable and fly off the external housing of the bird. Since the housing completely surrounds the sensor, these moving charges – the very definition of electrical current – induce this incoherent noise in the coil normally used to pick up the tiny microvolt signal from the precessing protons. The bird housing acts just like the small half-meter long black rubber-looking “static discharge” rods one sees on the trailing edges at the wingtips of aircraft.

I thought of everyone’s experience on a summer day in the Midwest watching the fringes at the edge of a cloud disappear while on other places at the margin of the clouds other fringes would appear, this process going on all the time. Add this to the litany of my other static discharge-moist air experiences, such as St. Ellmo’s fire which exploded on a plane in which I was flying during a rainstorm and bent the wing, forcing us to land. A former Navy friend on an aircraft carrier told me that, during a rainstorm, he touched the skids of a helicopter, just before it landed on the deck, sending him flying 10 feet as he reacted to the muscle contraction from the giant electrical static discharge.

Since that time about 35 years ago, I have inquired from the odd meteorologist about this phenomenon, that is, the accumulation of electrical charges as a putative cloud waiting to form. No one has ever enlightened, er, ‘enlightned’, me on the subject.

Bermuda Triangle

So, what does this have to do with the Bermuda Triangle?

Aircraft of long ago, vintage 40s to maybe early 70s did not have elaborate navigation systems -- no GPS, no inertial navigation, no Doppler radar. Loran C was expensive did not work everywhere and was not for small aircraft on ordinary missions of going from point A to point B. A pilot used a magnetic compass with an almost religious dependence, and for good reason. It was, after all, his/her lifeline.

An aircraft’s magnetic compass is on or above the panel in front of the pilot. But, remember, that in order for the magnetometer to operate successfully and not be affected by the magnetic parts and electrical currents (with their associated magnetic fields), the sensor had to be outboard far from the cockpit, engines and such? The same holds true for the compass. The display on the cockpit panel is only a display and not the whole compass. The “flux-valve” or magnetic sensor for the compass is usually out on the wing and its signal transmitted via wire to the compass. The compass display is always highly damped by placing the moving indicator in a viscous fluid to give an average reading and not jump around due to aircraft motion.

Electrical current has an associated magnetic field. If an aircraft flies through humid air, air with electrical charges, air with clouds (maybe nimbus or cumulous types??), an electrical current of constantly and widely varying current will flow across and around the wing and around the flux-valve sensor of the magnetic compass. Watching the compass with its highly-damped response, will not reveal how fast it might be changing. Several planes, like the Avengers described by the Bermuda Triangle crowd, will each display different headings. One is the leader and would probably have heard chatter from one or more of the others claiming that he is flying the wrong heading and he would have assured him that all is okay. The somewhat unique aspects of the Bermuda Triangle is that there are no roads or land masses to guide you and warn you that you are changing heading. The area is commonly cloud-covered and so the sun angle is not a confirming guide. A pilot flying through both clouds (with their electrical charges) and electrical clouds alike, will end up not exactly flying in circles, but certainly flying in a much longer path tracing a series of meandering lines until he runs out of gas.

This is one explanation for such disappearances of aircraft in the years gone by. GPS and modern avionics are immune to such problems. How many mysterious plane disappearances have been reported in the past couple of decades?

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