The Crash Detectives
The Forensics of Fatal Transportation Accidents

by Christine Negroni

Chapter One
The Happy Death

"Hypoxia is the greatest single threat to any one who flies."
Richard M. Harding and F. John Mills British Medical Journal April 30, 1983

"In case you're wondering, I think he's dead."

It was 9:39 in the morning, eleven and a half minutes after the Jacksonville air traffic controller heard the pilot confirm her clearance to ascend. Russell Sloan had been trying to get the Learjet on the radio, but he got no answer. He assumed the silence on her end was bad news.

The other controllers around Sloan grew silent. They kept monitoring the airplanes assigned to them, but their chatter was replaced with an exchange of knowing looks. Pilots climbing to their assigned altitude just don't stop communicating. Sloan had probably called it right.

The pilot of an airplane plane flying in the vicinity of the Learjet radioed the controller to say that he, too, was unsuccessful getting a response from the Lear's flight crew. Sloan verbalized his fears. "I think we got a dead pilot up there. He's through his altitude and off course now so we don't know what's going on." It was tactless, harsh even to state it outright like that, but by that time, no one aboard the jet could possibly have heard it.

What happened after the first few minutes of the flight from Orlando to Dallas was still a mystery a decade later. In the thin air miles above the earth, golfer Payne Stewart, his traveling companions and the two-person flight crew died from oxygen starvation known as hypoxia. Their plane, flying on auto pilot, continued on pilotless for another four hours.

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At his office in Washington, D.C., National Transportation Safety Board senior investigator Robert Benzon, then 50, watched the T.V. as special reports about the runway flight were broadcast.

Benzon had worked nearly two hundred airplane accidents but never had he imagined he would see the prelude to crash unfold before his eyes.

Hypoxia was nothing new to Benzon. As a cause of death for aviators, it dates back to the 1899 demise of French balloonist Gaston Tissandier. But an unpressurized airship is not a Learjet. What failed aboard the flight carrying Payne Stewart baffles Benzon to this day.

Payne Stewart's ill-fated flight took off on October 25, 1999. Captain Michael Kling, 42, was flying the airplane and co-pilot Stephanie Bellegarrigue was handling the radios and coordinating the ascent. Both pilots worked for SunJet Aviation of Stanford, Florida. Bellegarrigue had been hired in February 1999, and the company trained her on the Lear. Her roommate, also a pilot, liked to call the Learjet "a little go-cart" because it was small and fast.

Stephanie Bellegarrigue qualified on the plane in April and she spent so much time flying it that her time on the Lear exceeded Kling's even though he was the more experienced pilot overall.

On the day of the crash, twenty-seven year old Stephanie woke to a telephone call from her boss at SunJet. He asked her to come in and do a maintenance flight. The plane was not scheduled to depart until shortly before eight, but when she arrived at the airport at 6:45, Michael Kling was already there.

Not all repairs on an aircraft can be checked in the maintenance hangar, so sometimes pilots take a test flight after the work is done. Maintenance flights are common after repairs are made to an airplane's pressurization system, a system which only engages after the plane leaves the ground.

Yet for some unknown reason and despite the early morning call, pilots Michael Kling and Stephanie Bellegarrigue did not take the maintenance flight to check the

pressurization repairs. Instead, Captain Kling ordered the jet fueled and did a pre-flight inspection. They took off at 7:54 in a 26-year-old airplane with the tail number N47BA.

Sixteen minutes later they picked up their famous passenger, golfer Payne Stewart at Orlando International Airport. With Stewart were his agents, Van Ardan and Robert Fraley and Bruce Borland, a golf course designer. It was a clear and sunny Monday in Orlando, 59º with light winds.

The Learjet's eight leather seats were arranged in four rows, two on each side of a narrow aisle. It wasn't roomy - the men couldn't even stand upright once inside - but there was a picnic basket with snacks for the two-and-a-half-hour flight and each seat had its own window. The passengers could see Disney World and its associated tourist sprawl, glistening lakes and flat Florida scrubland as they ascended.

Stephanie Bellegarrigue, pretty and petite, turned around in the cockpit to face the passengers seated behind her to give them the safety briefing. She instructed them on the proper use of the drop-down oxygen masks, used in case of a loss of cabin pressure. Pilots refer to the masks when they fall as the "rubber jungle".

Many air travelers ignore these safety briefings. They simply can't imagine the inhospitable environment outside an airplane in flight. Yet just a few miles above even the warmest places on earth, the temperature is already below zero; the molecules of oxygen in the air so thinly distributed debilitating hypoxia comes on in seconds.

The cabin pressure in the Lear was not like being on the ground in Florida, more like being in Denver - the Mile High City. During normal flight, cabin pressure is maintained at five thousand feet. On commercial airliners cabin altitude is even higher, seven to eight thousand feet. In other words, on a typical airline flight, passengers might feel much as they would in the mountains at altitudes of seven or eight thousand feet. Hikers and climbers know the body works harder to get the oxygen it needs in the thinner air.

Keeping air pressure in an airplane cabin at these levels is a design decision made in the 1940s when airplane manufacturers Boeing and De Havilland were applying World

War II flying experience to the building of passenger jets. Unpressurized combat planes flew at eight thousand feet with no discernable ill effects on the pilots.

"Aircraft designers want the altitude as high as possible," explains Dr. John Ernsting an aerospace physician and expert in hypoxia. The lower the cabin altitude, the stronger the airplane structure has to be to accommodate the added pressure on the fuselage. More strength means more weight requiring more fuel and reducing the capacity for passengers and cargo. For these reasons things that add weight to an airplane are to be avoided.

While modern aviation technology is highly sophisticated, airplane pressurization is a relatively simple process. Air density is increased by pumping air into the cabin and it is reduced with its controlled escape.

Anyone who has blown up a balloon knows the air inside will rush out at the slightest leak as the gas inside seeks equilibrium. In the same way, though not as dramatically, when the plane takes off, the ground level air pressure drains away through vents in the airplane as the air outside gets thinner.

At a certain point as the plane ascends, the pressurization system begins to pump air into the cabin, until the altitude inside reaches the level set by the pilots. To keep cabin pressure where it should be, the vents to the outside close down. The air to pressurize the cabin comes off the engines and is distributed through ducts. On many airplanes the system is also used to heat the cabin.

When the pilots program their planned cruise level and desired interior altitude into the cockpit controls, everything is accomplished automatically. The engine air - inflating the cabin - flows in. It is distributed through the ducts. The overflow valves – making sure the cabin doesn't over inflate - open and close to equalize pressure and it's all accomplished in happy harmony.

If something goes wrong, display lights or illuminated messages alert the crew. If the cabin altitude exceeds fourteen thousand feet, the altitude at which people can quickly become affected by a lack of oxygen, a loud horn sounds and oxygen masks drop – the rubber jungle - to give passengers an emergency supply of breathable air.

by Christine Negroni

There were no horns sounding aboard N47BA at 9:27 a.m., when air traffic controller Wesley Kutch radioed Stephanie, “Contact Jacksonville Center.”

Kutch turned control of the flight over to Russell Sloan, who was responsible for traffic at the higher altitude and Sloan cleared the plane to ascend.

Had the plane not been pressurized at that point, the controllers would have heard the sound of the altitude warning horn in the background. And just as surely, if the pilots had turned the horn off off while trying to fix the problem, they would not have requested clearance to a higher altitude.

When Stephanie dialed the new radio frequency Kutch had given her, it took her seventeen seconds to complete the simple process that ordinarily takes around five. She spoke clearly and used proper radio jargon in confirming Sloan’s transmission and no one seemed to notice her delay in responding to Sloan. In retrospect, Stephanie’s slow switching from one radio frequency to another might have been an early sign that all was not right aboard N47BA.

With its permission to ascend to thirty-nine-thousand feet, the plane continued to climb. Four minutes later it made a six degree change to the north, a turn so slight that at first it was not even noticeable to the controllers. But with each mile, the plane was flying farther from its destination.

“N47BA, contact Jax center,” Sloan radioed the Lear in preparation for handing it over to the next controller along the plane’s flight path. There was no reply. He tried again.

Sloan touched Wesley Kutch’s arm and asked him to call the pilot again. The request was not alarming. Kutch, an experienced air traffic controller and student pilot himself, knew there were benign reasons why a flight crew might go “nordo” (non responsive) on the radio temporarily. He remembers thinking, “Maybe her elbow hit the switch and she accidentally reset the radio frequency…” If so, he reasoned, she might hear them calling on the frequency she’d used previously. But there was no response on his channel, either. The dark, windowless control room was silent, and every controller’s eye was drawn to the dot on the radar screen that was N47BA.

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"That 47BA, in case you're wondering, I think he's dead," Sloan broadcast over the radio. "Dead, he ain't even turning on course," he repeated not half a minute later.

Sloan said aloud what his co-workers were thinking.

Even if the six people on the plane were dead, there was more to worry about. The jet was flying fast and still climbing. With enough fuel for four and a half hours of flight, no one could say where it might come down.

"I expected just to look in and make eye contact with the pilot and get a thumbs up that everything was okay," said Captain Christopher Hamilton, an Air Force F-16 fighter pilot dispatched at the request of the FAA, and the first person to get a glimpse of the runaway Learjet. He knew very little about his mission when he was diverted from a regular flight training exercise and told to check out a business jet that had been nordo for half an hour.

"I figured it was just a radio malfunction or something."

But what he saw as he maneuvered around the Learjet - by this time flying over Memphis, Tennessee - was spectral: a windscreen dense with frost, a dark cockpit beyond and no sign that the airplane was under a pilot's control.

Hamilton flew around the plane for eighteen minutes, his fighter jet closer than any pilot ever wants to be to a passenger plane. He saw with his own eyes the fragility of life outside of its natural environment. His F-16 and the Lear were flying in the stratosphere. On autopilot and at forty-five thousand feet, the Lear was fourteen-hundred feet above the manufacturer's recommended maximum altitude and it seemed to be flying fine. But there's no pushing the design limits on the human body.

Investigator Bob Benzon spent more than a year trying to figure out what happened on the airplane and when. The former Air Force pilot is sun tanned, courtly and soft-spoken. His unassuming nature makes him an unlikely candidate for celebrity, yet he had many high-profile investigations.

A few years earlier, he'd been part of the mammoth probe into what caused the in-flight explosion of TWA Flight 800. During the Stewart crash he was being featured on network television and written about in major newspapers, *People* and *Sports Illustrated*.

Working any airplane crash is like "putting a jigsaw puzzle together without having a picture on the front of the box to look at," Benzon told me. On this one, the full picture never emerged.

In its final report on the flight of N47BA, the National Transportation Safety Board using the information provided by Benzon and his team narrowed the critical moments to the six minute window bracketed by two events; Stephanie's last call to Jacksonville Center and the plane's slight change in direction.

"Somewhere west of Ocala, the crew became incapacitated," Benzon said, "maybe not dead, but they couldn't answer the radio. We could never prove it, but where the course change occurred could be the time of depressurization."

The airplane changed course at thirty-two thousand feet. If Benzon is right, it explains the deadly consequences. Losing cabin pressure at that altitude starts a cascade of calamities on the airplane both physical and mental.

As the plane ascended, the volume of air in the occupants' lungs, ears and sinuses had expanded by about 30%. In the decompression, that air raced out as if a vacuum was sucking at every orifice. Tender membranes ruptured with the sheer speed of it. Other bodily gasses also ripped through their bodies seeking equilibrium. All hell would have been breaking loose in a riot of stinging eyes, pounding ears and belching organs. If they had time to think, those aboard N47BA might have thought they were imploding.

With loss of the pressurization system, there would be no heat in the airplane. So the temperature in the small cabin dropped quickly as the arctic air seeped in. A swirl of ice crystals attached like needles to the passengers exposed skin and deposited a frigid shell of ice on their light-weight clothing.

In the cockpit, the pilots' color vision would have been reduced adding to their initial difficulty seeing through the decompression fog. If they had tried to put on their

emergency oxygen masks, they would have to feel their way to them and do it before they became too uncoordinated by the spasmodic contraction of the arms that typifies severe hypoxia.

Restrained by lap and shoulder harnesses, the captain and first officer may have had some control over their wracking bodies. But the passengers could have been thrown free of their seats as the convulsions in their extremities increased.

Through it all, the airplane continued rising forty one feet every second into ever thinner air. But the curse and the blessing on this flight was that there was little time to think.

The abrupt loss of air pressure, the extreme cold and panic would have sped up the heart rates and breathing of both pilots and passengers. The involuntary convulsions of their bodies increased the need for oxygen and reduced their final moments of consciousness.

The blaring of the altitude warning horn and the sight of the passenger oxygen masks bobbing on tethers were, in all probability, only briefly frightening because at some point - perhaps thirty seconds after the plane completely depressurized - those onboard were no longer tormented. Their oxygen-starved brains disengaged and all logical thought receded. Fear turned to ease and then to euphoria and then to sleep. And like the final scene in a disaster movie, Russell Sloan’s voice came over the radio in grim narration.

“That 47BA, in case you're wondering, I think he's dead.”

With hypoxia, the line between life and death is not finely drawn. It is blurred by the fact that intellectual life, the ability to think, succumbs very quickly to a lack of oxygen.

The cortex, or upper brain, controls thought, reason and calculation. To do this, it needs blood with 93% oxygen saturation. Below that level parts of the cortex shut down even while other organs keep on ticking.

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“If there is enough oxygen in the blood for the heart and some brain function, then you can still be alive but in an unconscious state,” is how Ulf Balldin, a doctor of aviation medicine and physiology at Brooks Air Force Base in Texas describes it.

“You are still breathing and most of the body is functioning, such as the heart and other organs. You can't think and you cannot see, but you still have oxygen to the respiratory center and to the lower parts of the brain.”

At altitudes above thirty-thousand feet, the people on N47BA were drastically deprived of oxygen, but they were not entirely without it. No one can say at what point there was no longer enough oxygen to sustain brain function - it is an entirely individual calculation in any event. But as the minutes ticked by, their intellectual lives ended.

At 1:13 p.m. the Lear finally ran out of fuel and plunged into a grassy field near Aberdeen, South Dakota. Hitting the ground at 400 miles per hour, the plane pulverized completely. Little was identifiable beyond the wings, a fuel tank and a bag of golf clubs.

The length of time between the death of the mind and the end of bodily function was not known. Sometimes, even after hours without oxygen, organs and systems continue to live. “Sleep”, is how one expert characterizes it. Dreamless, endless, sleep. But six years later, Bob Benzon would be called to the scene of a similar accident and again wonder, when does the sleep of oxygen deprivation become death?

Arriving at the crash scene in South Dakota, Benzon supervised of a team of aviation specialists that include representatives from Bombardier, the manufacturer of the airplane; Honeywell, which made the engines; and SunJet, the plane’s operator. The crater made by the plummeting jet was "an archaeological dig,” Benzon said, “we have to go down layer by layer." And so they did, but he could just as well have been speaking metaphorically.

Suspecting that depressurization had incapacitated the crew, the investigators needed to dig deeper to find out how it happened and when and then find out why the pilots couldn't handle the problem. Even today, there are no certain answers, only possible scenarios.

The first plausible scenario is that N47BA never pressurized properly after takeoff from Orlando and two cabin altitude warnings, one audible and one visual, either didn't trigger or didn't alert the crew. Several other cues had to have been missed as well: the passenger oxygen masks dropping at fourteen thousand feet and, of course, the discomfort of everyone onboard as their ears kept popping with the un-arrested loss of ground-level atmospheric pressure.

In this version of events, Stephanie Bellagarrigue's delay in switching frequencies from one control sector to another is the first silent symptom of impaired judgment typical in the initial stages of oxygen deprivation. Adding weight to this theory is Captain Michael Kling's incorrect change of heading at thirty-one thousand feet.

This kind of hypoxia is referred to as insidious because the debilitating effects of a loss of oxygen to the brain are unnoticeable. Worse, they are seductive. Like the drunk at the party who's convinced he's the funniest guy in the room pilots suffering oxygen deprivation feel a heightened sense of competence and well-being.

In a cautionary article in an aviation publication, pilot Linda D. Pendleton wrote: "It sneaks up on the unwary and steals the first line of sensory protection - the sense that something is wrong - dreadfully wrong."

Nothing better illustrates Pendleton's point than an accident in Greece nearly six years after N47BA crashed. Bob Benzon assisted Greek authorities examining what happened to Helios Flight 522, a Boeing 737 flying from Cyprus to Prague with an intermediate stop in Athens on August 13, 2005.

Tragically, it appears the cockpit crew of Flight 522 was the first to succumb to hypoxia leaving the passengers and cabin attendants trapped on a pilot-less flight that continued to ascend on autopilot until reaching thirty four thousand feet.

Unlike crew oxygen, passenger masks are not intended for prolonged use. Supplied by small canisters in the ceiling of the airplane, they last about twelve to fifteen minutes just long enough for the pilots to take the airplane down to a level suitable for unassisted breathing. With the pilots unconscious and the plane flying its pre-programmed route, there was no one to initiate the descent. When the passenger oxygen ran out, everyone on Flight 522 was doomed.

Just five and a half minutes after takeoff from Larnaca on the south west coast of Cyprus, the flight was clearing twelve-thousand feet when the pilots were startled to hear the loud beep, beep, beep of the cabin altitude warning horn. Less than two minutes later, the passenger oxygen masks dropped sending another alert to the cockpit. But Captain Hans Jeurgen Merten and First Officer Pambos Charalambous did not put on their emergency masks, deciding instead to search for the source of the problem. The impaired judgment that led to this decision is entirely consistent with the onset of hypoxia.

For nearly eight minutes, Captain Merten, a pilot with five thousand hours of experience on the 737, conversed with the Helios operations center in Cyprus, an exchange that grew increasingly incomprehensible to the men on the ground. Marios Franciscos, a flight operations engineer, said Captain Merten was speaking in German and it was hard to understand him. At first Merten said he was concerned that “the ventilation cooling fan lights were off.” This confused Franciscos because those lights were supposed to be off.

Then Captain Merten asked, “where are my equipment cooling circuit breakers?”

“Behind the captain’s seat,” he was told.

The problem Merten detected with the overheating of cockpit electronics was related to an underlying problem he had not diagnosed. The cabin pressurization control knob was not set to automatically pressurize the airplane and because the system is also used to cool the heat-generating electrical panels in the electronics bay, that wasn’t working either. But Merten did not relate the equipment overheating to the larger and more serious problem.

Franciscos told a public inquiry into the crash that he asked the captain if he was going to bring the plane back to Cyprus, and Merten said, “We’ll see how it goes.” And all the while the airplane was climbing at a rate of fifteen-hundred feet per minute.

The crucial moments between initial oxygen deprivation to the brain and inability to think is called the “time of useful consciousness”. Merten’s time of useful consciousness was abbreviated because in his agitated state, troubleshooting a problem he could not seem to diagnose, his body was in need of even more oxygen than normal.

If the captain decided to get out of his seat to access the circuit breaker behind him, the effort would have pushed him into unconsciousness. At any rate, there were no more radio calls from Flight 522. Two minutes later the autopilot brought the airplane level at its cruise altitude.

One thing was certain from Merten’s communication with the ground. The cabin altitude warning horn did not focus the pilots’ attention on cabin altitude. That was a reasonable mistake under the circumstances. The alarm’s insistent staccato actually has two functions. In addition to warning about cabin pressure it is also used to warn pilots that the airplane is incorrectly set for takeoff. The alarm design is dependent on pilots knowing which alarm is which.

Distinguishing between the two seems straightforward. The incorrect takeoff setting alarm will only sound when the plane is on the ground. In the air, the same sound signifies a problem with pressurization. But what is obvious on the ground is not so obvious at ten thousand feet, especially when cabin altitude is already high enough to affect a pilot’s ability to think.

This is what happened to the crew of the Helios flight. Merten’s first report to the Helios operations desk is that the “*take-off configuration warning (is) on*.” Captain Merten was not the first, the second or even the last pilot to make that mistake. It has been reported on passenger flights around the world.

“The simplicity of the error” is what struck Benzon. “There were one hundred and twenty one people who died on a modern airliner and all through a simple error. That’s the thing.”

by Christine Negroni

In the months after the Helios accident, aviation authorities in several countries started sharing similar experiences. There had been a flight in Norway in 2001 in which the pilots took off unaware that the cabin pressure system on their 737 was inoperative. They disregarded the warning horn indicating an improper pressurization setting and continued to ascend.

Grete Myhre, a spokeswoman from the Norwegian Air Accident Investigation Authority said in response to that event her agency sent a safety recommendation to Boeing in 2004, calling for them to discontinue the dual use of a same-tone alarm. “So many planes have had this problem; they should look into it,” she said.

Boeing was hearing the same thing. Two years earlier, at a flight operations symposium the manufacturer admitted, “Boeing is receiving an increasing number of reports of flight crews who are failing to configure the pressurization panel correctly.”

At the time of Helios Flight 522 the dual function warning had still not been altered. Captain Merten was one of many pilots to find it confusing.

With his thoughts scattering and his brain going dim, Captain Merten collapsed unconscious in the cockpit. First Officer Charalambous passed out against the airplane control yoke.

The passengers were aware that something was amiss. They had the supplemental oxygen provided by the drop down masks. Passengers on flights where the oxygen masks deployed provide an idea of what Helios Flight 522 might have been like.

In their confusion, people base their own response on the reactions of others and search for clues in the faces of fellow passengers. Oddly, in spite of pre-flight safety briefings many flyers can recite from memory, not everyone puts on the emergency oxygen mask when it falls. Instead, they wait for someone in authority to direct them.

Once the mask is on, the rigid cup-shaped plastic can dig into the skin and the adjustable elastic band makes an imperfect fit. People inhale deeply, expecting to feel the oxygen, but there is no sensation, so some people pull the mask away, sampling the cabin air, to see if there is a difference. Others take off their masks if they are too uncomfortable, especially if they already doubt that the oxygen is flowing.

by Christine Negroni

Parents tell children to keep their masks on, reassuring them that everything will be okay. But they exchange doubtful looks, unsure if their words are really true.

An icy draft seeps in as the plane looses heat to the frigid atmosphere. The 737 is much larger than a Learjet, so it takes longer for the cabin to cool. Still, the temperature drops precipitously. The passengers are soon shivering. One or two might get up to look for a blanket or a sweater. If they remove their masks, stand and step into the aisle they will not make it back to their seats.

The loss of cabin pressure has the same physiological effects on the Helios jet passengers as it had on those on the Payne Stewart flight, but the onset of these symptoms was probably more gradual. As the oxygen for the passenger masks is depleted, they begin to feel lightheaded. Some develop headaches. Their arms begin to jerk about, lips and fingernail beds turn blue.

Yet as hypoxia sets in all of this seems normal. Waves of new sensations lap over them and fade away until their minds go blank. They are no longer waiting to hear from the captain.

For a while, a miracle was in the works on Flight 522. The flight attendants had higher capacity emergency oxygen bottles than those provided to the passengers and the masks were portable, so they could to move around. With more than an hour's supply of oxygen, the flight attendants were conscious long after the passengers languished.

Onboard Flight 522, flight attendant Andreas Prodromou, 25, was also a licensed pilot. He would have known enough to have been concerned that the 737 continued to climb even after losing pressurization. Like the other flight attendants, he might have waited at first, expecting to learn from the pilots what was going on. But at some point he got up from his seat by the back galley and took action.

In all likelihood he became alarmed by the sight of the passengers, muscles slackened, sagging in their seats, the masks having ripped off their faces with the weight of their slumping torsos. Prodromou and the other cabin crew members could see that time was running out.

Did Prodromou begin to assist people who had fallen in the aisles? Did he search for more oxygen bottles or something to keep himself warm? His attention may have been drawn to his girlfriend, fellow flight attendant Haris Charalambous. Did he and the others gather somewhere to come up with a plan - communicating in gestures so as not to remove the masks from their faces?

Benzon has a theory. “Hypoxia can affect people in different ways,” he says of Prodromou. “He was in reasonably good physical condition. His physiology allowed him to hang in there.”

From the sounds recorded in the cockpit and views of the airplane as described by two F-16 fighter pilots who approached the 737 near Athens, some disturbing facts are known.

Flight attendant Prodromou decided he had to get into the cockpit if they were going to survive, but he did not attempt it for more than two hours after the depressurization occurred.

Entering the code on the cockpit door keypad, he waited while the chime sounded inside, signaling to the unhearing pilots that someone was trying to access the cockpit. If the pilots did not override the unlock code, which of course they did not, the door would open in thirty seconds. Prodromou waited while the call chime joined the persistent beeping of the altitude horn and the chorus of air traffic controllers coordinating flights in the region.

When the door unlocked, Prodromou opened it. As much as he might have anticipated the incapacitation of the crew, the sight of the vacant captain’s seat and the co-pilot lifeless at the controls had to have been startling. Captain Merten was partially on the floor and partially on the center console. Prodromou probably had to step over Merten or struggle to move his body from the crowded space to get to the left seat and to Merten’s oxygen mask.

The rubber mask was untouched it its box by the captain’s seat. Lifting it activated the flow of oxygen through the thick gray umbilical cord that also inflated the face straps. This design keeps the mask fitted tightly to the head.

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Prodromou had a difficult time putting on the mask. Simultaneously, the last of the fuel for the left engine was spraying into the combustion chamber. In moments, the engine would slow and like the people aboard the airplane, it would starve for that which it needed most.

“Bank angle, bank angle”

“Bank angle, bank angle”

A computerized voice was warning that the imbalance of thrust between the left and right engines was causing the airplane’s left wing to go down. Prodromou searched the control panel for something familiar; something that connected this complicated airliner to the small planes on which he learned to fly. If he could relate to this machine maybe he could find a way to bring it down safely. He mumbled something and again the cockpit voice spoke.

“Bank angle, bank angle”

“Bank angle, bank angle”

The altitude warning horn and the speaking alarm were already tearing at his concentration, when the control wheel in front of him started to vibrate. The stick shaker warning is as dramatic as it is urgent, a multi-sensory advisory to the pilot that the plane is about to stall. The Boeing 737 can fly with only one engine, but control surfaces have to be adjusted to compensate.

For two and a half minutes Prodromou scanned the instruments in front of him while the airplane picked up speed in descent. The sound of rushing air added to the cacophony of warnings. Whatever hope Prodromou had for surviving the nightmare was probably extinguished as in a frail and frightened voice he called for help.

“Mayday, mayday, Helios Flight 522 Athens…”

And forty-eight seconds later

“Mayday”

“Mayday”

“Traffic, traffic,” the mechanized voice of the 737 was the only reply.

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The radio was not set to the proper frequency to transmit the message. Prodromou hadn't sent his mayday beyond the microphone recording the sounds in the cockpit. The airplane was nose down and plunging.

For the last thirty minutes of the flight, two Greek Air Force F-16s had been on either side of the 737. Their view through the plane's windows of lifeless passengers must have been only slightly less horrifying than what they first anticipated when dispatched to see and report back on the situation onboard the Helios jet. Five years after four commercial airliners were commandeered by terrorists and crashed into American landmarks in New York and Washington D.C., the Greek Air Force officers expected to find a similar scenario. Instead, they saw First Officer Charalambous unconscious in the right-hand seat. One Air Force pilot even saw Prodromou enter the cockpit.

As the plane approached the ground and ambient air pressure increased, the cabin altitude warning horn turned off and one contributor to the din in the cockpit subsided. It was then that Prodromou first noticed the fighter jet escort.

Years later one of the Air Force pilots explained that he gestured for Prodromou to follow him to a military airfield nearby. To this signal, the young flight attendant raised his own hand and, with weary resignation, pointed downwards. Even if he could have followed the F-16, it was too late. The right engine was shutting down. The plane was seven thousand feet above the ground with three and a half minutes left.

Helios Flight 522 crashed into the countryside near Athens International airport. The flight attendant who aspired to work his way up from the cabin to the cockpit could not save the day. Too much was working against him.

When Prodromou's role in the story made the news in Cyprus, many asked the "what if" question; what if Prodromou had entered the cockpit earlier?

A better question might be: What if the Helios flight crew had put on their emergency oxygen masks at the first warning? Or: What if Boeing had heeded earlier complaints about the confusing nature of the altitude alarm? Many factors could have changed the course of Flight 522. But at its heart, what claimed these victims was a

problem that by its nature resists solution. Hypoxia kills because it destroys its victims' ability to save themselves.

So seductive are the symptoms of hypoxia that aerospace physician Dr. Dennis Shanahan calls it the happy death. "You are blissfully unaware. You don't recognize you're confused, you can't speak properly. You're just unaware."

Several people knowledgeable about the Payne Stewart crash believe the only possible explanation for why the pilots on the Learjet failed to don oxygen masks upon depressurization is that they experienced the same unknowing slide into mental dysfunction as the Helios pilots.

Examining the wreckage of N47BA, investigators found that the flow-control valve for engine bleed air - the source of air for pressurization - was closed. If it had been incorrectly set or malfunctioning at the time of takeoff, the plane would not have pressurized at all, making the slow onset of hypoxia the probable scenario. But with the evidence available, it was impossible to know if the valve was closed on takeoff or if it had been closed, perhaps in error by the crew, after takeoff.

Those who knew the two pilots do not accept the notion that the decompression occurred at altitude, because the crew would have handled it differently.

"Stephanie was extremely conscientious." Helena Reidemar was First Officer Bellegarrigue's former roommate. A pilot for Northwest Airlines with a master's degree in air safety and operations, she is an accident investigator for her union, the Air Line Pilots Association. Had the Learjet encountered a depressurization between twenty-five and thirty thousand feet, Reidemar is convinced Stephanie would have had the time and the training to put on her oxygen mask.

"The time of useful consciousness going through the twenties, well you'd have time to react," she said. "It wouldn't have impaired you so you were knocked out completely."

She could be right. In the case of a rapid decompression at the altitude considered likely by Benzon, the effective performance time for a young, healthy non-smoking athlete and even Captain Kling - fifteen years older but similarly fit - would be between

forty-five to seventy-five seconds. Moreover, as a pilot for the National Guard, Kling had experienced a depressurization emergency earlier in his career.

Kling was the pilot of an E-3 Sentry, an Air Force version of the Boeing 707, when the pressurization malfunctioned during a flight in 1983. His military records don't go into specifics, but the regional commander for whom Kling was flying praised him for correcting the problem and remaining "unflappable" and "cool and calm under pressure."

William Schwab, a line pilot for SunJet who worked with both Kling and Bellegarrigue, told investigators that based on his flights with Kling, had the plane encountered a rapid decompression, Kling "would have initiated an emergency descent".

All military pilots are required to undergo regularly scheduled high-altitude physiological training in a hypobaric chamber. This is a special room where ambient air pressure can be manipulated to mimic a high-altitude environment. The trainee, without supplemental oxygen, learns the symptoms of hypoxia as a "buddy" wearing a mask stands by to make sure the trainee puts a mask on before it's too late.

Since Capt. Kling had this training and knew about hypoxia, it seems logical that if the Learjet suddenly lost pressurization, he would have put on his emergency mask and instructed his co-pilot to do the same. Examples show pilots with high-altitude training learn this lesson well.

In May 1996, an American Trans Air Boeing 727 was en route from Chicago's Midway Airport to St. Petersburg, Florida with 104 passengers and a three-man flight crew. At thirty-three thousand feet the cabin altitude warning horn suddenly sounded in the cockpit. The altitude inside the cabin registered fourteen thousand feet.

First Officer Kerry Green was flying the airplane and immediately put on his emergency oxygen mask. But Captain Millard Doyle's first course of action was to tell the flight engineer to silence the alarm. In the process of doing that, Captain Doyle evidently thought he discovered the source of the problem, an air-conditioning pack switch that was off.

Instead of putting on his mask, Captain Doyle instructed Flight Engineer Timothy Feiring to turn the pack on. This instruction delayed Feiring from putting his own mask

on. So neither man was on supplemental oxygen, with quickly obvious consequences. Instead of fixing the pressurization problem, Feiring exacerbated it by opening an outflow valve, creating a rapid and total decompression of the airplane.

At this point, Feiring grabbed his mask, but Captain Doyle still did not. Instead, he asked a flight attendant to check the cabin to see if the passenger oxygen masks had dropped. Only then did he reach for his mask, but it was too late. So disoriented and uncoordinated he could not find his face with his hand, he passed out. The flight attendant, having finished her assignment, returned to the cockpit and promptly fainted in the doorway.

The first officer started an emergency descent, knowing the passenger drop-down masks provide only a 14-minute air supply. He had to get the plane to an altitude where the passengers could breathe.

The passenger cabin was deathly quiet. Flight attendants hadn't received any information from the cockpit and consequently did not make any announcement. Some travelers put on the masks. Others waited for instructions.

Passenger Stephen Murphey believed he was going to die and remembers feeling a sense of peace as he recited his prayers. Then the woman seated behind him started having convulsions and the man across the aisle began to claw at his ears.

"What bothered me was there was nothing I could do for him. It's not like you see on T.V., people don't grab portable oxygen bottles and walk around the cabin helping people. Had I had my full senses I'd like to think I could have helped somebody. But based on what was going on, I didn't. I knew I couldn't."

In the aisle seat of row seven, businessman Ralph Abruscato saw the passenger masks drop, but didn't put his on. The next thing he remembered food carts were tipping over and the airplane began falling "like the bottom's dropped out." He was sure the plane was crashing.

"Some of the weirdest shit creeps into your head," he said. "The thought that went through my mind was, 'I got to go back to the Elephant Bar in Simi Valley and have another margarita."

In the cockpit, Flight Engineer Feiring grew concerned about the flight attendant who had passed out, so he left his seat and put an oxygen mask from an unoccupied crew seat on her face. Struggling back to his desk was too much for him, and he was unable to replace his own mask. When the flight attendant came to, both the engineer and the captain were unconscious.

The flight attendant noticed First Officer Green was trembling, a common symptom of hypoxia, and that something was wrong with the microphone in his mask. In order to communicate on the radio, he had to pry the rubber seal away from his face and use the cockpit microphone. Still, he was on the job. His decision to put on his mask as soon as the alarm sounded had kept him conscious and saved the plane.

Green abruptly pushed the airplane into a steep descent. This was the dramatic drop felt by the passengers. As the air pressure increased with the lower altitude the captain and flight engineer were resuscitated by the increase in oxygen. American Trans Air Flight 406 landed safely in Indianapolis but it had been one man's breath away from disaster.

Of the three men in the cockpit, the first officer and the flight engineer had received decompression training in a hypobaric chamber. Captain Doyle, who waited the longest to put on his oxygen mask, had not.

In examining the episode, Benzon saw parallels between the ATA and Payne Stewart events, especially in how the pilots reacted to the depressurization emergency. He suspects an unexpected and rapid loss of pressurization somewhere around thirty-thousand feet, confused the pilots on Payne Stewart's airplane and started them on a search to correct the problem, the same mistake that nearly spelled the end of ATA Flight 406.

Benzon bases this conclusion on several things, including statements made by the crew's co-workers that both pilots were known for their conscientiousness. James Watkins, SunJet's chief pilot, said Kling was so compulsive about following procedural checklists he "probably used a checklist when he was going shopping." Likewise,

Stephanie Bellegarrigue was characterized as “not someone who abbreviated procedures or neglected checklists.”

Since both pilots were relatively new on the aircraft, sixty hours for Michael Kling and ninety-nine hours for Stephanie Bellegarrigue, they may have struggled in the cockpit chaos to pull out the Learjet flight manual and consult the appropriate page for such an emergency.

Had they done so, they would have found the manual instructed them to troubleshoot the pressurization system before putting on their emergency masks. This is another reason why Benzon believes the two go-by-the-book pilots may have made the mistake of delaying the use of emergency oxygen.

“In some cases TUC (time of useful consciousness) may be only seconds, during which time the flight crew may become incapacitated if troubleshooting is attempted before the donning of oxygen masks,” the NTSB wrote in a letter to the FAA after learning of the manufacturer’s recommendation in the manual.

On this, the FAA shared the safety board’s concern. Its review of the Lear flight manual led the agency to conclude that pilots could be misled. The next year, the FAA ordered that the donning of masks be listed as the first crew action following a cabin altitude warning horn at any altitude, on any airplane.

No less an aviator than Charles A. Lindbergh experienced oxygen starvation at altitude. In his book, *Of Flight and Life*, he tells of an event in 1943 when he lost the oxygen supply to his mask while testing an unpressurized fighter plane at 36,000 feet.

“Something must be wrong with the oxygen system. I know from altitude-chamber experience that I have about 15 seconds of consciousness left at this altitude-neither time nor clearness of mind to check hoses and connections. Life demands oxygen and the only sure supply lies 4 miles beneath me.”

Lindbergh sends the airplane into a dive. “the earth slants up-ward and the dive begins…35,000 feet…34,000…my cockpit roars through the air…the earth fades out…the instrument dials darken…breath’s thin; lungs empty-I’m blacking out-losing sight…I push the nose down farther…faster…33,000…30,000…the dials become

meaningless…down…down…I am dimly aware of a great shriek, as though a steam whistle were blowing near my ears…Compressibility dive?...I am not thinking about compressibility…it's oxygen I need...I'm blind…I can't see the needles…there are no more seconds left-it's a razor edge-a race between decreasing consciousness and increasing density of air…"

Lindbergh is on an airplane rocketing toward earth when he passes out. Not until he is at fifteen-thousand feet does he come to.

When he is safely on the ground, he learns that an error in a gauge hid an empty oxygen tank.

While the difference between a World War II fighter plane and a Learjet designed in the 1970s is great, another theory is that the pilots of N47BA experienced Lindbergh's problem; no air for the emergency masks.

Before leaving Stanford to pick up their passengers in Orlando, the pilots were required to check that the oxygen flow control valve feeding the masks was turned on. To do this, the pilot would (from outside of the airplane) open a hatch on the nose and eyeball the valve itself during the pre-flight inspection. If the word "off" was visible, the valve was open and ready to use. "Off" meant "On" on the Lear. Confusing? Undoubtedly. Still, the chief pilot at SunJet told investigators he'd gone over this with Kling and the captain understood.

Perhaps Kling did understand and perhaps he didn't, but only one oxygen bottle was recovered from the scene and it was empty. This was curious. Since the pilots were overcome, and presumably overcome because they did not use the masks, what happened to the oxygen in the tank? Had the pilots tried to use the masks only to find there was no oxygen to supply them? This would explain how Stephanie Bellegarrigue and Michael Kling could have taken the correct action and still become unconscious.

But that wasn't a definitive answer because one of the two crew masks had an altitude trigger. Oxygen would begin flowing to the mask at thirty-nine thousand feet regardless of whether the pilot was wearing it. In that case a completely full bottle would have been exhausted long before the plane ran out of fuel.

by Christine Negroni

This was as far as Benzon's investigation could go. To this day he still does not know if the pilots did or did not put on their masks and if not, why not.

From Lindbergh's near fatal brush with hypoxia in 1943 to the massive loss of life in the Helios crash, there have been 3,000 loss-of-cabin pressure events in the United States since 1959, according to an FAA review. Boeing's 737 and the Learjet seem to have had more than their share.

Ireland's aviation safety agency investigated six remarkably similar depressurization events on Boeing 737s between 1999 and 2004. By 2005, then-air accident chief Kevin Humphreys was so familiar with the methods of pressurization failure on the 737 - he'd experienced one himself on a maintenance flight - that the Greeks asked for his research material to help with the Helios probe. Humphreys, intelligent and gregarious, is well known in the international circle of air safety investigators, far beyond what one might expect given his country's small size.

"The design of the system is such that it can catch you," the fifty-seven year old Humphreys said of the 737 pressurization design, explaining that on short runways or when planes are heavily loaded, pilots sometimes opt to take off with the system set to manual. Should they neglect to turn it back to automatic, warnings of the error can come too late. For a time, Humphreys was a 737 pilot with Dublin-based Ryanair.

"The rate of climb is pretty good, so you'll be through ten thousand feet." Humphreys fires off the numbers rapidly. "If you're climbing at three-to-four-thousand feet a minute, by the time you're one minute past ten thousand you can be at fourteen thousand feet and get the rubber jungle. It happens very quickly."

Humphreys' experience led him to believe that in addition to changing the dual use of the cabin altitude warning horn Boeing should also install a visual alert, a cabin altitude warning light in the cockpit.

On the Lear, the NTSB noted several previous events, two of which were remarkably similar to the loss of N47BA, right down to the fact that their causes are still unknown.

The Crash Detectives
The Forensics of Fatal Transportation Accidents

by Christine Negroni

In May 1983, three people were killed when a Lear en route from Vienna to Hamburg over flew its destination and ran out of fuel over the Atlantic off the coast of Scotland. Neither bodies nor wreckage was recovered, making a determination of cause impossible. The conclusion - that the event was a runaway flight - was made for two reasons: communication from the cockpit stopped forty minutes after takeoff and the plane flew as high as forty-one thousand feet, indicating the crew was not operating the flight controls.

The December 1988 crash of a Learjet-25 in Mexico was also frustrating to investigators, and there was potentially much more information to work with. The pilots, 39-year old Larry Morris and 27-year old aspiring astronaut Susan Reynolds left Memphis shortly before dawn to return to their home airport in Addison, Texas. They were not responsive to air traffic controllers after crossing twenty-thousand feet. When the plane flew past but did not land at its destination, military planes were scrambled to check it out. Frost on cockpit windows and no movement inside told the story.

The autopilot continued to keep the airplane in normal flight and as the plane descended, it came down on the top of a mesa in a remote region of north east Mexico. Much of the airplane remained together.

It wasn't as if the plane had landed on a runway, but it was in relatively good condition and the victims were intact. According to Texan Paul Camp, one of the first Americans to arrive at the crash site, an eyewitness, a miner who was working in the area said the person in the right hand seat was laid out and dead. "The person in the left seat was alive and continued to move and make noise. She was moving and making sounds."

"If people are not deprived of all oxygen, they can be unconscious but they can still live," says the Air Force's Dr. Balldin. An athlete in peak physical condition, First Officer Reynolds may have been getting enough oxygen for respiration and other reflex activities though with the plane flying as high as forty-three thousand feet for several hours, there was little chance the young woman would have emerged from unconsciousness with complex brain function still intact.

by Christine Negroni

The bodies were taken to Monterrey for autopsies. But even the most sophisticated technology couldn't determine if hypoxia was responsible for the crash. As one experienced medical examiner said, "That is not something detectable at autopsy; there is no test for it. It looks just like death."

After a month, Camp was able to get the Lear trucked back to the United States for an examination at his Air Salvage of Dallas, which offers storage and work space for accident investigations.

Some things were obvious right away, like the fact that crew oxygen masks had not been used. Other findings were puzzling.

"We took pictures of the panel of where the pressurization switch should be. Later we were given photos the Mexicans had taken and the switch positions were different. So really, we don't know where they were.

"The wreckage stayed here for a while and then they said to dispose of the salvage. It was a total loss. Nobody seemed like they were that excited about keeping it around or doing something about it," Camp said.

At the time, neither the NTSB nor the FAA were all that interested in an accident that one American investigator called an "open and shut case of hypoxia," as if there was such a thing.

Eleven years later, of course, when a similar team of pilots, with a similar lack of experience on the Lear, was similarly incapacitated on a runaway flight, the Mexican crash seemed a lot more compelling. The Payne Stewart and Helios crashes and many other near disasters had served as a wake-up call.

"Until Helios happened I thought 'its five or six people in a Lear, it's not that big of an issue,'" Benzon said. Going to Greece was an eye-opening experience for the seasoned investigator and for Akrivos Tsolakis the new chief of investigations in Greece who Benzon went to assist.

Tsolakis had been an Olympic Airways captain and a military pilot with the Hellenic Air Force before that. He knew about hypoxia. As in America, the Greeks trained military pilots to recognize oxygen deprivation.

by Christine Negroni

“When we switched from propeller planes to jets we went through the altitude chamber” Akrivos said. “We found out about the signs of hypoxia.”

The crash of Helios Flight 522 was Tsolakis’ first major accident probe. Thinking back on the value of his own hypoxia training he lobbied the European Aviation Safety Agency to order all commercial pilots to undergo the same kind of education, actual exposure to a controlled low pressure environment, just as military pilots had been required to do. The new regulation would apply to airlines registered in the European Union.

"Believe me, without a shred of exaggeration I can say we've shaken up the aviation industry,” he told a reporter in Cyprus. “Hopefully, we've done our bit to make flying that much safer."

The FAA does not require altitude chamber training for airline pilots, and the NTSB has not asked for it.

FAA spokesman Les Dorr said the American regulators wanted to see what the Europeans did. Addressing the pilots of Helios Flight 522 specifically, Dorr sent an e-mail that was especially telling for how it overlooked the debilitating effect of hypoxia on pilot judgment.

“Apparently they did not believe several warnings that the cabin was not pressurized,” Dorr wrote. “They did not believe it even when the oxygen masks deployed. They still did not don their own masks and basically ignored all of the signs that their flight was in trouble until they passed out.”

While an experienced pilot’s failure to put on an oxygen mask is difficult even for safety experts to comprehend, new research may provide insight. At altitude levels even below that at which warning horns blare and masks drop, flight crews may already experience symptoms of hypoxia. A study conducted for the U.S. Air Force Research Laboratory in 2007 suggests that cognitive function may suffer even at altitudes considered safe since the dawn of the jet age.

by Christine Negroni

Dr. Balldin, the Air Force researcher who supervised the study says the real danger remains at altitudes above ten thousand feet, though other factors can blur the boundaries.

"Hypoxia may be gradual and individually different," he said, "and that is all complicated by all the other contributing factors, such as fatigue, darkness, boredom, nutritional state, hydration level and so on, which all may be minor factors, but are contributing when added to each other."

In Dr. Balldin's study of ninety-two people at various altitudes there were only "minor differences" in grammatical reasoning and problem solving on two of four tests of cognitive function. Dr. Balldin, a Swedish-born civilian scientist at Brooks Air Force Base International Academy of Aviation and Space Medicine found the results heartening. Assumptions about safe altitudes were still valid. It was the glass-is-half-full approach.

But to eighty-year old Dr. John Ernsting the glass is half-empty. Anything that impedes the judgment of a pilot is a big problem to the revered author of *Ernsting's Aviation Medicine*, the holy-grail for three generations of aerospace physicians.

Dr. Ernsting did his own low-level hypoxia study on a smaller number of pilots at the Royal Air Force Institute of Aviation Medicine and didn't like what he learned. "Breathing air at 5,000 feet impairs performance of novel tasks such as might arise in an emergency in flight," he said. "When presented with an unexpected task it took two to three times as long for pilots to accomplish."

This meant that during normal flight, pilots may be compromised. It threw into question every error in handling an unanticipated situation. Low-level hypoxia could have been a factor, but how to know? The symptoms are stealthy, sneaking into the mind of the pilot and leaving without a trace.

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"That's why we've had these long arguments about whether we should bring the cabin altitudes down," Dr. Ernsting said.

Despite white hair and frail frame, the elderly professor holds his own in an argument. Then again, he has lots of experience. In the 1970s he convinced British aviation regulators that the maximum cabin altitude of the Concorde, the first passenger carrying supersonic jet, should not exceed six-thousand feet.

Nearly four decades later, still teaching physiology and aviation medicine full time at King's College London Dr. Ernsting was pleased when Boeing announced its new 787 Dreamliner would keep cabin pressure at seven-thousand feet, a slight change to be sure but at least it was in the right direction.

The Concorde no longer flies and the Dreamliner is just beginning to and reducing cabin altitudes on other airliners remains a controversial idea. On both sides of the issue people are asking the question: will the benefit justify the cost?

"To reinforce an aircraft to a six-thousand-foot altitude would be expensive and cause increased fuel consumption. And you have to ask, 'Is it worth doing that for reasons not well defined?'" said Dr. Russell Rayman, president of the Aerospace Medical Association in Virginia.

Even now, hypoxia isn't sufficiently understood.

"I think the cognitive effects of very low altitude hypoxia are under researched, under evaluated, under trained and under discussed," Dr. Mitchell Garber the NTSB's medical officer said during an interview at the Aerospace Medical convention in Boston in 2008. During four days of seminars on various aviation related medical issues, the effect of hypoxia on flight crew performance got no more than an hour's attention.

Dr. Balldin's young associate from Brooks presented the results of the Air Force study while Dr. Balldin watched from the audience. Dr. Garber, lean and energetic, listened intently and when it was over sprang from his seat to question whether the cognitive tests used for the study - number recall and pattern matching - were relevant to determining how well a pilot would perform in the cockpit.

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"I don't know of any aircraft that can be recovered by counting backwards from 1000" was the way he put it to me. Standing at the audience microphone, just ten feet from Dr. Balldin, and amid more than a hundred colleagues, the former Air Force Major, son of a career Air Force officer was more diplomatic. Dignified in a dark suit he directed his question at the young presenter.

"What about more complex problems?" he asked her. Are the tests sensitive enough?

He found her answer unconvincing. To really count, he said later, "you have to put people on simulators and have them perform operationally significant tasks, novel tasks, that require them to do some fairly significant decision making while they are at those altitudes."

In the ongoing debate over whether the current state of knowledge is adequate or out of date, the Irish Aviation Authority's Humphreys is as passionate as Garber, though as an amateur historian his view is more focused on behavior than physiology. He paraphrases British Prime Minister Winston Churchill's comments on the safety of Royal Air Force fighter pilots during WW II.

"Churchill identified the primacy of the pilot's role. The whole system was there to support the pilot. If the pilot wasn't supported and if the reasons he made mistakes were not understood the activity was unsustainable."

Few in Churchill's time could have imagined the philosophies of combat aviation remaining relevant sixty years later. So much has changed. What hasn't changed is the lethality of the world just outside the airplane.

In a farm field in South Dakota and on a hillside in Greece, Bob Benzon has concluded he does not know why the pilots acted as they did. Hypoxia is "the greatest single threat to any one who flies," because the errors that lead to it are as imperceptible and as fleeting as breath itself.