Automation Airmanship®

Nine Principles for Operating Glass Cockpit Aircraft

Christopher J. Lutat
S. Ryan Swah

McGraw Hill Education

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Automation Airmanship is dedicated to the countless pilots, instructor pilots and aircrew who, for over a century, have worked tirelessly to smooth the integration of advanced technology into safe, reliable flight operations.

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Preface

As this book was going to press in the fall of 2012, Pierre Sparaco, now-retired Paris Bureau Chief for the industry journal *Aviation Week and Space Technology*, wrote a brief commentary entitled, "Airmanship Anew." This article was largely centered on the report of Qantas flight 32's recovery, by its captain, Richard Champion de Crespigny, after a catastrophic in-flight engine failure. Sparaco's comments echoed those of many in our industry who believe—even as technology has changed the nature of everything from air traffic control to security to flight deck protocols—that there has been too little emphasis on the concept of airmanship compared to the focus on improving profit margins gained from efficiencies and cost cutting.[1] Along with the dramatic engines-out landing on the Hudson River of U.S. Airways flight 1549, Qantas flight 32 joins the ranks of those popularly recognized heroic saves resulting from the display of expert airmanship—and rightfully so. Both of these now widely discussed events seem to evoke qualities of a special kind of airmanship that their crews displayed in saving the lives of hundreds of passengers and crew, following catastrophic failures aboard normally reliable, highly advanced aircraft. It is the search for this "special kind of airmanship" that has led us for the past decade into the field where we have been involved in helping organizations to adopt advanced aircraft of all kinds, and ultimately, to write this book.

In the early part of 2003, as a result of our work with the U.S. Marines and U.S. Coast Guard (both organizations had just begun acquiring aircraft with new, highly automated flight decks), we began to sense that an undertaking like this book might be necessary. The airplane that both organizations were bringing into service was a completely new version of the venerable—*and legendary*—Lockheed-Martin C-130. The new airplane was the C-130J, and both the Marines and the Coast Guard had been flying earlier models of C-130s for decades. We were in the midst of projects with both organizations to streamline procedures and flight deck processes to fit their individual cultures and each organization's unique mission.

In the process of creating everything from new checklists and procedures to training and evaluation standards, we began to come up against a common problem at nearly all levels of the project. Our colleagues in uniform (the Marine and Coast Guard flight crews we were working with) simply wanted to capture the lessons from industry (mostly in civil air transport) of almost two decades of experience with glass cockpit transports. They would blend the experience of the broader industry into their own operations, capitalizing on industry best practices, and thus bring additional safety margins and operational efficiencies to their own flight operations. We wanted to transfer this knowledge to them, and in the process help both organizations through their respective acquisitions without the accidents and incidents that often accompany such leaps in technological capability and complexity. Most of this was fairly straightforward, made easier by our entire team's rich experience in both military and civil transport aviation. Both organizations had unique missions for the C-130J (the Marines for transporting troops and equipment and serving as airborne refuelers for tactical aircraft, the Coast Guard for transport, search and rescue, law enforcement, and humanitarian missions). Both organizations also operated the same "basic aircraft" but with significant differences in aircraft configuration, mission equipment, and even the composition of the "normal crew" that the aircraft would be operated with. And though we were successful in applying many of the industry's early lessons in adopting advanced aircraft, the same problems continued to the surface, no matter what organization we were involved with.

You might think—as we first did—that the problems we encountered would be unique to each organization, and to the unique configuration of each service's aircraft. Yet the challenges we most frequently encountered were basically the same: *how to impart the successful practices of experienced glass cockpit crewmembers from across the industry on an operation with little experience in operating fully integrated glass cockpit aircraft, without requiring years of service gaining experience, and without the attendant lessons of accidents and incidents that are not uncommon in such transitions.* As we have already said, some of this was easy, and we were able to build such practices directly into the procedures, checklists, and other SOPs that these robust flying organizations depend on. The problem, however, persisted and was in every case reduced to the simple fact that the more nuanced skills and techniques of experienced glass cockpit crewmembers staunchly resisted such "proceduralization," and it would be up to each operator to provide the follow-through required to build this airmanship discipline within their flight crews. Although we knew of most of the elements that comprised this family of skills and successful practices, we could do little more than add them up and provide them as a list of recommendations—and then hope they took hold. We went on from these projects to experience the same results with customers in other organizations, civil and military, always with similar outcomes. At the end of a project, we had the same "extra parts" left over, comprised mostly of a list of skills, techniques, and "tricks of the trade" that experienced top performers had been accumulating for decades, which we could not fit into the detailed operational materials we were providing.

By 2005 it was clear that it was time to organize this family of information and bring it more concisely to our colleagues across the industry. And so at the 2005 North American Corporate Aviation Safety Seminar (CASS), sponsored by the Flight Safety Foundation, we rolled out the foundational concepts that would later lead to the principles outlined in this book. Soon after that we began to learn more about other rising disciplines within and outside of aviation that would sharpen our knowledge across every area of glass cockpit airmanship, further refining what we felt had become the core principles of operating complex aircraft in an increasingly complex environment. Over the next several years we continuously worked to simplify and clarify what we consistently found were the central skills of experienced top performers in our field. Eventually these were organized into 12 skills and finally, over the course of several more years, into nine principles that could be learned, further developed, and adopted by individual aviators and broad organizations alike. What we present in this book represents not only years of fieldwork and background research, but also the summation of decades of experience by aviators and their supporting organizations engaged in flight operations with advanced aircraft of every type.

As pilots ourselves with experience in both traditional "round-dial" or "steam-gage" aircraft and advanced global transports, we know that the demands on our own personal airmanship have changed over the past several decades, and we feel quite confident that this is true for many thousands of other aviators as well. As instructors, check airmen, and procedures and training designers, we are quite aware of the demands that technology has placed on cockpit and mission crews worldwide. Likewise, across every organization in our industry, the pressure to preserve increasingly precious assets has never been greater than it is today. Even with all the changes that technology has brought to the industry over the past decades, we are attempting not to redefine airmanship as much as to update its practice wherever automation factors into its execution. We believe that certain aspects of airmanship are timeless and enduring, and that much has been written about those qualities. To each of the authors, *Automation Airmanship* can be defined simply as *the understanding and application of automation to airmanship, to ensure balanced situational and mode awareness and crew workload through the full realm of automation, from no automation to fully coupled, in order to provide for the safest and* *most efficient flight.* We are not seeking to be "additive" to the fundamental notion of airmanship, but rather to be multipliers of how airmanship is practiced.

Much remains to be learned about glass cockpit airmanship, and we hope that this book helps to generate the enthusiasm and resources to conduct this research and debate across the industry in the coming decades. Along with Mr. Sparaco, we feel strongly that "Principles governing airmanship certainly deserve better treatment and, without reinventing the romance of flying, could produce astonishing results."[2] We are pilots, not human factors experts, flight deck engineers, or aircraft designers. We want what all pilots want—clear objectives to accomplish and a reliable system of actions that support the mission. Although we discuss human factors and complex aircraft and systems in this book, our emphasis is on the essential knowledge from both of these domains that we feel is required for aircrews. We discuss both new and timeless concepts of human factors that influence outcomes on the advanced flight deck, beyond what is traditionally taught in human factors training. At a minimum, we hope to blend a simplified (for pilots) foundational knowledge of the technology and a new way of looking at performance on the flight deck with nine core principles around which individuals can organize their own successful habits. We are convinced that this will result in not just an accident- and incident-free career for many pilots and mission crews, but a career that returns much more professional satisfaction to pilots and aircrews than ever before.

The book is organized in five parts: Part I outlines the foundational knowledge that allows the reader to understand the principles presented in Parts II, III, and IV (the nine principles themselves), followed by Part V that shows how these principles have been successfully integrated into flight operations within several unique and diverse organizations, all of which operate advanced aircraft. Following each chapter that deals specifically with the individual principles, there is a short Checklist for Success that can be applied directly to flight operations of any size and scale. At the end of the book, an appendix contains a definition of each principle and examples of best practices and techniques. Throughout the entire book we provide detailed footnotes that provide the most careful readers with the necessary information to investigate further the research and knowledge we use to build the case for a concise family of principles around which glass cockpit airmanship should form.

We want this book to be both a source of sound technical information and an inspiration for every pilot, instructor, crewmember, support crew, safety team, manager, commander, or even enthusiast to seize upon to help guide a career of understanding and professionalism in flying glass cockpit aircraft. What we have learned ourselves in accumulating the experience and knowledge that went into this book has deepened our appreciation for the amazing aircraft that comprise the global aircraft fleet of the twenty-first century, and greatly contributed to our own satisfaction in pursuing our own love of flying in just a few of those aircraft. Our simple hope is that you will experience the same result.

Christopher J. Lutat and S. Ryan Swah
Memphis, Tennessee

Notes

1 Pierre Sparaco, "Airmanship Anew," *Aviation Week and Space Technology*, October 8, 2012, p. 19.
2 Ibid., p. 19.

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PART I

The Call, the Concept, the Technology

Our theory posits internal mechanisms of great extent and complexity, and endeavors to make contact between them and the visible evidences of problem solving. That is all there is to it.

—Newell and Simon, 1972[1]

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CHAPTER 1

The Call for a New Approach to Modern Airmanship

It is handicraft which makes the artist, and it is not in BOOKS that one can learn to manipulate. —Diderot[2]

Airmanship, Error, and Automation: Air Inter 148

On a cold winter evening in January 1992, an Airbus A320 passenger jet operated by Air Inter as ITF 148DA was being flown by its crew from Lyon, near the French border with Switzerland, to Strasbourg, near the Dutch-French border, only about 300 mi away (see Fig. 1-1). The Airbus A320 being operated by the crew of flight 148DA was a derivative of the original A320 and was new to the airline industry in 1992 (the aircraft the crew was flying was barely 4 years old). A highly successful design, the A320 family would become one of the most popular aircraft in the history of commercial aviation over the next 20 years, with more than 3000 in service across dozens of airlines around the world. Since its first flight in 1988, thousands of pilots have, by now, collectively logged millions of hours of accident-free flight time in the A320 family. And as new and updated derivatives of the original begin to enter service today, A320 pilots across the globe will certainly attest to its marvelous handling qualities and the remarkable technology that makes it one of the most enjoyable commercial aircraft to fly today, more than two decades after its introduction. Almost certainly, the crew of Air Inter 148DA counted themselves fortunate to be flying one of the most advanced and capable aircraft in service. Following a short and uneventful flight from Lyon, the crew of flight 148DA prepared for a normal descent and approach to Strasbourg, no doubt looking forward to a routine arrival.

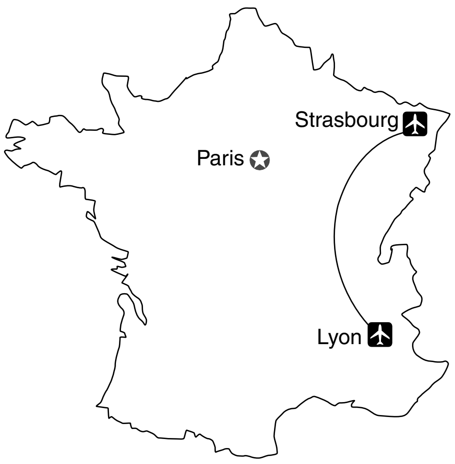

FIGURE 1-1 The approximate flight track of Air Inter 148DA, January 20, 1992.

On their initial radio contact with French air traffic control nearing Strasbourg, the crew made a normal, predictable request to arrive via an ILS approach to runway 23 (an instrument approach which combines an electronic "glide slope" with a "localizer," to provide precise vertical and lateral guidance to the runway) followed by a visual transition to another runway, runway 05, in order to reduce the time and distance the aircraft would have to cover during the arrival. The ILS approach would allow the crew to descend to a safe altitude above runway 23 and then "break off" the approach in order to fly a visual, circling maneuver to runway 05. This was not an unusual request for this crew, or for this airport, and was certainly within the capability of the A320.

Since there was another aircraft preparing to depart from runway 23 and there was an instrument approach to runway 05, the air traffic controller working the flight cleared flight 148DA for the VOR/DME approach to runway 05—not the ILS 23 that they had requested and planned for. Although the VOR/DME approach (depicted in Fig. 1-2) was not a precision approach like the ILS, it did have the advantage of allowing the flight crew to align the aircraft for runway 05 without the challenge of a circling maneuver, at night, conducted mainly by visual (outside) reference. The approach that air traffic control was directing flight 148DA to fly did not meet the crew's objective of saving time and distance, but it had other advantages. The tradeoff that this crew faced in accepting the VOR/DME approach certainly outweighed the risk involved with the precision, ILS approach to runway 23 followed by a circling maneuver—and is like many

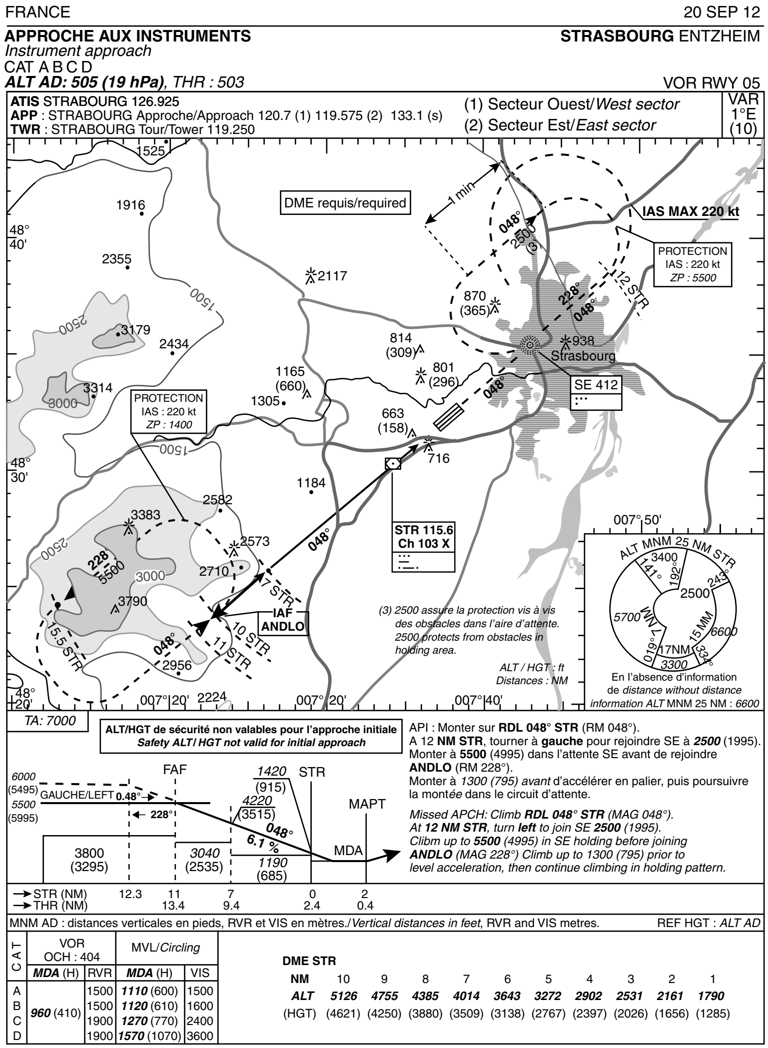

FIGURE 1-2 The VOR RWY 05 approach chart for the Strasbourg-Entzheim airport.

thousands of decisions made daily by experienced flight deck crews around the world.

During their descent, in radio and radar contact with Reims Control (the air traffic control for that region of France), the pilots of flight 148DA continued to discuss the change to their original plans, conduct normal routine checklists, and communicate with the passengers and cabin crew. They accurately recognized that they were entering icing conditions and successfully turned on the aircraft's anti-ice systems, a "routine" distraction that was handled with predictable ease by this crew, but a distraction nonetheless. The change in expected runways and the "work" which that created on their advanced flight deck would contribute to the spike in the crew's workload; but with no other complicating conditions or problems with the aircraft, this, too, was manageable. At the height of their workload for this flight, the crew of flight 148DA was given a radar vector by air traffic control to ANDLO, a waypoint 11 mi on the straight-in, final approach course to runway 05. It would seem that the controller was serving up runway 05 on a platter for this crew—whose aircraft, procedures, and automated systems were designed to execute approaches like the VOR/DME 05 with relative ease. They would have to manage the flight path of the aircraft through a combination of manual and automatic controls with the same high level of knowledge and skill that many cockpit crews must on a routine basis—and that this crew had likely done many times before.

After they reached ANDLO, the approach vertical profile called for a 3.3° glide slope, or angle of descent, to the airfield, for the final descent portion of the approach. Although this was slightly greater than the normal 3° glide slope afforded by most ILS approaches worldwide, 3.3° is both well within the capabilities of the A320 and not unusual for similar, "nonprecision" approaches at hundreds of commercial airports around the world.

The crew of flight 148DA chose to fly the approach to runway 05 "fully coupled" to a point just a few hundred feet above the airport. Again, this is a common practice in which the autopilot and autothrottles are engaged and controlling the aircraft's speed and vertical and lateral flight path with respect to the approach course to the runway. Surely by now, the crew had long forgotten their initial intentions for an ILS to runway 23 and was fully committed and well along in conducting preparations for the VOR/DME approach to runway 05. Their decision to fly the approach fully coupled was sound—a practice that many global operators of advanced technology aircraft have since mandated as "normal procedure" for nonprecision approaches, allowing the flight deck crew to perform the higher-level functions of monitoring the aircraft's flight path while the more routine task of flying the aircraft is delegated to the precise and predictable flight guidance system, autopilot, and autothrottles. In view of the fact that many aviation human factors researchers have long proved—and continue to find new ways to prove again—that the final approach phase of flight often carries with it the highest workload of the entire flight, this was an excellent decision by the crew, allowing them to delegate the physical "flying" to the automation, while monitoring the aircraft performance in preparation for the landing, which would be done without the autopilot.

Acting in accordance with their procedures, the crew programmed the aircraft's flight guidance system to fly the required 3.3° glide path by manually selecting –3.3 on the flight control unit (FCU), which is the panel in the cockpit that allows the pilots to make inputs and modifications to the aircraft's vertical and lateral flight path. Thus, with the FCU electronically coupled to the flight guidance system and autopilot, A320 pilots can—just as all pilots frequently do in the "glass cockpit" of aircraft like the A320—control the aircraft flight path through an electronic interface (literally, "flying" the aircraft with their fingertips through electronic interfaces such as buttons, dials, and knobs), and not the aircraft controls. In approaches such as the VOR/DME runway 05 at Strasbourg, when the pilots judge that the aircraft is in a safe position to land with respect to the runway, the autopilot is disconnected, the pilots land the airplane using conventional flight controls (in the case of the A320, a "sidestick" controller located at both pilots' sides and throttles placed in the center of the cockpit). The pilots of flight 148DA were doing what pilots of automated aircraft frequently do—they were using the automated systems to efficiently manage their workload, allowing the limited processing capacity of each pilot—the *wetware*—to be used for higher-level tasks such as monitoring, communicating with air traffic control, configuring the aircraft for landing, assessing the developing situation with the aircraft's flight path, and the kind of nuanced decision making that cannot be delegated to automated systems.

After a century of powered flight, aircraft accidents and incidents continue to favor the weakest component in the highly dynamic, tightly coupled system typical of high-reliability organizations: the human operators. The crew of flight 148DA, at the moment they programmed the FCU to accept a –3.3° glide path, also were required to do something else—something that has proved to be much more difficult than programming the automation—not just for this crew, but for countless pilots who have since made similar mistakes, some of whom did not live to recall and apply the lesson on future flights. At the critical moment when –3.3° was programmed into the FCU, neither pilot recognized that the autoflight system was in heading/vertical speed (HDG/VS) mode, instead of the correct track/flight path angle (TRK/FPA) mode. By conducting only what equates to just a portion of the complete procedure—*programming*—without *confirming* their actions with the flight guidance and various annunciators in the cockpit, the crew of Air Inter 148DA were commanding the aircraft to fly a vertical speed of 3300 ft/min, almost *four times* the rate of descent that they would certainly have expected the aircraft to fly if they had in fact selected –3.3°, as they had intended. This trajectory, left unnoticed and unmonitored by the crew, would take flight 148DA dangerously short of the runway and leave the aircraft in an energy state, which would require a feat of heroic airmanship to reverse.

One would think especially with the knowledge of how abnormal a 3300 ft/min descent would both feel and look to almost any experienced flight crew (whether they were taking their cues from cockpit instruments or the outside environment, or even the "seat of their pants" so often referred to when talking about flying), that the cues would have been dramatic on the flight deck of flight 148DA. These cues would normally cause both pilots not only considerable alarm, but also the kind of conversation that normally goes along with such unusual situations on the flight deck. In fact, neither pilot appeared to recognize that they were in the wrong flight *mode*, and neither pilot said anything about the 3300 ft/min descent being inappropriate during the instrument approach. Although it is impossible to know for certain, it is not hard to imagine that this silence was not simply a result of inattention, but would have more likely been the result of significant confusion – confusion over why the aircraft was seemingly responding in a way that was not consistent with what both pilots thought should be happening, instead of what actually was happening.

Standard operating procedures, or SOPs, are generally accepted by all professional pilots and crews to be inviolable rules by which to operate; and they are, in every case, implemented by the organization's respective command leadership. Dr. Tony Kern, author of more than a few books on the subject of aviation safety, airmanship, and pilot error, has taught many of us the meaning of SOPs. They are not just regulations to reliably guide a pilot's thoughts and actions, but are a written pact between fellow crewmembers such that none will allow the others to even *accidentally* violate them and in so doing risk the safety of the flight.

Although SOPs for automated aircraft have evolved considerably since the first few years of the global adoption of large, advanced technology aircraft, decades of experience operating transport aircraft of the same basic performance envelope as the A320 have left no uncertainty about the significant deviation from standard of such a high rate of descent during a normally routine, nonprecision approach. What is it that caused this crew to fail to respond to the anomaly that their actions caused, while there was still ample time to intervene with the automation? How is it possible that neither pilot attempted to, or even spoke of the possibility to, modify, or even abandon, the programmed solution that the pilots provided when they initially programmed the FCU? Even as we look retrospectively at the accident at "ground speed 0 and 1.0*g*" two decades later, it is hard for the typical, inquisitive pilot or knowledgeable observer to reconcile what had to be obvious to the flight crew with their inaction during the exciting final minutes of flight 148DA. Still, the aircraft (which was not equipped with a technology known as *ground proximity warning system* (GPWS), which is now standard aboard most transport aircraft[3]) struck the ground 3 mi after crossing the ANDLO intersection, at an altitude of 2620 ft, near Mt. Sainte-Odile. Among the 96 passengers and crew who had embarked on Air Inter flight 148DA at Lyon, only nine survived.[4]

Certainly, the accident analysis report issued months later by the Bureau d'Enquêtes et d'Analyses (BEA), France's equivalent of the National Transportation Safety Board (NTSB) in the United States, would examine exhaustively the flight data and voice recorders, as well as every conceivable detail associated with the accident. And finally, in 2006, litigation associated with the accident would finally be settled.

New Technology, Traditional Institutions

Since 1992, several other accidents involving advanced technology aircraft made by virtually every manufacturer of commercial aircraft have each in their turn seemed to eclipse the significance of Flight 148DA, leaving the legacy of Flight 148DA obscured by time and since eclipsed by other accidents with similar aircraft. In fact, flight 148DA was not "accident one" among this new type of highly capable, highly complex family of aircraft which now comprises virtually all of every global and national airline fleet, worldwide. Indeed, it was not even the first accident involving the now venerable A320. Flight 148DA simply exists as one example from which pilots, airline training departments and, most recently, military organizations choose to examine and occasionally discuss on the way toward eliminating the risks that a similar accident could ever occur again.

Yet similar accidents do occur with what seems like alarming regularity. During one highly unusual, 5-month stretch from February to June of 2009, three major accidents occurred involving advanced aircraft built by three different manufacturers, operated by three different airlines, all with fatalities.[5] Yet we continue to be shocked and surprised when accidents happen, in part because we have grown to appreciate the reliability of automatic systems across our entire lives, not just in aviation. As pilots and crew, it is considerably more alarming to learn of such accidents on the evening news, especially when considering that aircraft designers, manufacturers, and the marketing departments which serve them have convinced so many in the global aircraft market that these aircraft are virtually foolproof, offering safety margins that can drive the probability of accident or failure to almost zero.

There have been other accidents—many known to all and some known to only a few—from which we might draw a list of virtually the same questions that we have about Air Inter 148DA:

- How could pilots have neglected to complete a routine procedure by failing to conduct an adequate cross-check of the flight guidance system after entering a flight guidance command?
- How is it that the mode selected by the crew did not meet with the mental model of the mode intended by both pilots,

yet did not produce counteractions or even a discussion of the incompatibility?

- What caused the crew to give away so much of the ground that pilots have traditionally held to the automation, without any intervention when it was clear the automation was not working as intended?
- How did the pilots fail to properly monitor the aircraft's flight path during what they both certainly knew was a critical phase of flight?

There are many more questions, and almost every accident involving advanced aircraft, large and small, civil and military, commercial or private, leaves investigators and analysts with similar questions, many unanswered. We will examine a few more accidents on the way to the conclusion of this book, as well as some seemingly "heroic" saves that provide dramatic evidence proving that accidents of this kind, involving complex aircraft, are not inevitable.

Aviation has proved to be a remarkably resilient industry in the face of dramatic—*though rare*—accidents that frequently call into question the science of aircraft design and the art of piloting. Like so many accidents prior to flight 148DA, and since, investigations proceed, findings are publicly proclaimed, and lessons are added to the many that already exist. The lessons stemming from accidents in *advanced* aircraft have been accumulating for nearly two decades, which is certainly long enough to generate a unified reaction by pilots and ownership, and even a comprehensive, systematic response that could serve to eliminate the errors that seem so common in so many accidents. As the evidence has piled up as a result of many now well-known failures, the industry has been less focused on collecting evidence from successful outcomes. Yet even when experienced pilots, managers, training designers, and instructors (just a few of the positions held by the authors) search for a unified strategy to combat what is certainly a unified family of likely errors, none can find a singular approach, or one that even comes close or is ready to be put into action.

For decades, rigorous and ever-expanding disciplines have developed around aviation safety: aviation human factors, accident investigation and reporting, flight simulation and training, as well as aviation psychology. These disciplines, and others, form a veritable patchwork of countermeasures that have been stitched into a wide variety of formats and media for the consumption of professional pilots and businesses, whose existence increasingly depends on safely operating glass cockpit aircraft. There are so many countermeasures that dedicated aviation professionals have hundreds of annual professional gatherings and a wide variety of professional journals to choose from where they can hear about or read the latest research results and absorb the most exciting new developments in flight safety and human factors. Crew resource management (CRM), risk management, threat and error management (TEM), to name just a few safety initiatives, have all run their course and permeated the industry so thoroughly that it would seem that all has been said, printed, or discussed in one of the hundreds of panel discussions that have taken place before and since Air Inter flight 148DA flew into Mt. Sainte-Odile in January 1992. Search as we may, we still cannot place our hands on a singular, widely accessible, comprehensive approach to the known problems, and known solutions, to safely operating advanced technology aircraft.

Since the dawn of aviation, the technology has come in advance of the operators. Writing about the advances in technology that were occurring almost 80 years ago, Franklyn E. Dailey, Jr., accurately observed, "Instruction follows innovation in performance; it does not lead. Pilots came before instructor pilots."[6] At roughly the same time that the industry was absorbing the shock of accidents involving what were surely the most reliable and safe aircraft ever built (at about the time that flight 148DA tragically impacted short of runway 05 in Strasbourg), practical pilots and flight instructors, and other professionals who lived with and operated these systems every day, began an often informal process that would ultimately lead to the many components of *Automation Airmanship*. Pilots—not the designers, researchers, and engineers—were learning to cope with the new technology and adopting strategies, habits, and routines that they were constantly shaping into practical tools for themselves, for their colleagues, and, if they were instructors and evaluators, for their student pilots. Nearly every experienced pilot of a glass cockpit aircraft can recall a "tip" or "trick" that he or she routinely uses in the practice of airmanship on the flight deck today, that was learned from some experienced instructor or check airman, or the revered and romanticized "salty old airline captain" (they *do* exist). The very best and most experienced instructors and captains are known, and admired for their ability to concentrate a large amount of knowledge into just a few useful and memorable "aids" which help to simplify the complex flight deck and which help crews organize and prioritize their flight deck actions. We all know a few great instructors, check airmen, and captains who have provided us with that one piece of knowledge that, like some brilliant insight, made simple so much complexity.

Unfortunately, much of this information is passed around the profession informally, outside of the research community and safety industry that support modern aviation. This is not surprising, given that for almost a century flight training has always had some informal quality about it that makes both the instructor, or veteran, and the student, or novice, feel as if they are passing on or receiving some special, unique knowledge or technique that, if internalized, can become another nugget of durable knowledge for the successful pilot.

Thus, seemingly invaluable skills in flying highly automated aircraft are often passed along like tribal wisdom: "You won't find this written down anywhere . . ." or "We do it this way on the line; forget what they taught you in the schoolhouse . . ." or even this one: "The most important thing you can do every day isn't part of the formal procedure." Many of these fireside lessons are invaluable, and all have come at the price of someone else's (sometimes fatal) mistake.

For nearly two decades, insightful veteran pilots, and many instructors, have been piling up these useful trade secrets, without so much as a Ph.D. in human factors or a Master's degree in instructional systems design. They have watched expertise develop, and they pass on as much as they can communicate to their less-experienced colleagues. Although accidents have produced their own truths, and researchers have generated valuable data and insightful findings across so many facets of the profession, we finally must recognize that collectively, though somewhat informally, glass cockpit airmanship has shaped itself into a largely intact body of expertise whose time has come for a full synthesis and open understanding across every organization that comprises our profession, and with all pilots who aspire to, or now find themselves in the cockpit, of today's advanced aircraft.

What we have come to perceive as the most effective flight deck practices have come from not only the most admired instructors and veteran captains. During the decade after the Air Inter accident in Strasbourg, some far-thinking researchers, both within and outside of aviation, were formulating valuable new approaches to expertise and expert performance, and gathering findings that would provide significant, complementary knowledge surrounding the discipline of the rapidly developing environment of glass cockpit airmanship. These individuals were bringing to maturity such disciplines as cognitive task analysis (CTA), naturalistic decision making (NDM), and advanced qualification program (AQP) training, among dozens of others. In the 1990s we also began to see that much was being learned about the way the human brain works, and how the brain learns new information and formulates decisions from an increasingly complex and high-risk environment. Scientists such as Robert Hoffman, Gary Klein, and Joseph LeDoux were all making significant strides in related fields that have helped significantly in developing a unified approach to making decisions in complex, tightly coupled systems that operate through complicated and often automated control channels, in high-stress/high-risk situations. The field of *human-computer interaction*, or HCI, has been maturing so rapidly during the past 20 years, and providing so much valuable insight on how humans interact with computers and automation, that it is difficult to reduce the information to a manageable amount of practical knowledge for aviation. Thousands of experts on safety and accident analysis working for government-sponsored organizations such as NASA and the FAA, at private institutions and foundations, international organizations, and private airlines, have provided invaluable understanding to the role of the human component in the complex system of contemporary aviation.

From Chaos and Complexity: Order and Excellence

For those involved in any dimension of the safety industry, particularly the aviation safety industry, it seems supremely difficult to proffer a comprehensive solution to a broad family of problems associated with such a complex, tightly coupled system as operating advanced aircraft in today's increasingly complex global aviation environment. There are so many components to this system that the complexity is staggering: not only complicated human factors involving those associated with skilled piloting, but also human factors engineering, ergonomics, and the myriad complexities involved in designing reliable interfaces between the highly trained crew and the aircraft itself—a tremendous feat of industry encompassing the latest in materials science, computer software design, propulsion, and flight controls (both power-by-wire and fly-by-wire systems are now the norm in most modern as aircraft) as well as dozens of other complicated support systems. Surely any comprehensive strategy to counter the risk of errors in such a complex system must involve years, if not decades, of research and hundreds of thousands of pages of analysis before the data are turned over to the designers of procedures, training, and evaluation programs for the hundreds of thousands of pilots and crews across the industry.

Or does it?

Fueled by the many seemingly parallel fields of research, for the past decade we have been combining a variety of disciplines that have been converging—intentionally and otherwise, but converging nonetheless—to provide a wide range of services to organizations as small as one-aircraft business jet operators, to large Western defense forces and their component branches, simplifying the transition from traditional or "legacy" fleets to the modern, up-to-date advanced aircraft fleets that dominate the industry today. This work has included task analysis, courseware design, interface and procedures development, and flight crew training and evaluation. Because of the need to make sense of the technology and define the crew experience for those new to advanced aircraft, we have employed a variety of disciplines and methods to concisely define expert flight deck performance for glass cockpit crewmembers (Chap. 13 discusses this in depth). Experience in designing procedures and flight crew interfaces helped us to pinpoint the essential flight crew skills that resist being turned into procedures and are included in many assessments of expert performance in high-risk/high-reliability domains such as aviation (Chap. 14 discusses procedures design in depth).

While all this has formed the core of our collaborative work involving advanced aircraft, we have also maintained active professional pilot careers, operating some of the world's largest and most advanced and capable transport aircraft while serving as airline captains, flight standards managers, check airmen, and instructors. Throughout all this work and in combination with real line experience, we have come to appreciate the many contributions of a wide range of professionals, and we believe that our consolidated views on a composite approach to pursuing a safe and rewarding career in flying glass cockpit aircraft is now inescapably within the reach of every pilot—experienced and novice, civil and military, young and old. We propose to provide the foundational principles of this discipline in the following chapters of this book.

The contemporary business author and speaker Marcus Buckingham has researched the phenomenon of excellent performance and writes extensively about it in his 2005 book, *The One Thing You Need to Know.* Buckingham explains the concept of the "one thing" by first asking, "Why are some explanations more powerful than others?" Instead of attributing them to deep truths, he suggests that *controlling insights* are at the center. More compelling, however, is what Buckingham asserts comprises a controlling insight—the building blocks of the "one thing" you need to know about almost any discipline. The test, he asserts, for something to qualify as the one thing is threefold: first, it must apply across a wide range of situations; second, it must serve as a multiplier; and third, it must guide action: "In short, no matter what the subject, the controlling insight should not merely get you onto the field of play. It should show you how to win and keep winning the game."[7]

The universal nature of the test for the "one thing" certainly helps to explain how a few glass cockpit pilots have come to help so many others develop their own expertise much more rapidly than their predecessors. It also helps explain how findings within aviation, and in related disciplines, can contribute so much to our understanding of how the best pilots interact with automation. In short, it helps us to capture these "controlling insights"—which to pilots equate to the best skills and techniques—consolidate them, and present them in a systematic way so that many can profit from the supreme efforts and, in some cases, *supreme sacrifices* of the few.

In the following chapters we attempt to represent the best of all the research, the accident and incident lessons, and the most practical experience collected from interviews and observation of some of the finest and most experienced pilots, instructors, and check airmen in the business, as well as the myriad researchers, of whom a few have already been mentioned. We will present the basic environment that all glass cockpit pilots find themselves in by introducing the very technology that comprises the modern flight deck, objectively and without preference to any manufacturer. We will put the *contemporary* in the context of *history*, so that every glass cockpit aviator will better understand the foundations on which the current technology was built over 75 years ago and still relies as we surge into the future of air transport. In subsequent chapters we will introduce the *Nine Principles of Automation Airmanship*—designed to be applied by any pilot of any advanced aircraft (and useful for pilots of less advanced aircraft, as well)—along with other concepts, which will undoubtedly help all pilots manage their equipment and environment to higher levels of not just safety and efficiency, but reward and satisfaction in the practice of their own craft. Along the way, we will present evidence from accidents, incidents, and the research community to solidify your individual understanding of what it takes to develop a highly reliable, personal level of Automation Airmanship.

Given all this information, every pilot, instructor, manager, safety professional, or flight crewmember whose performance is somehow connected to the actions of the flight crew in advanced aircraft will come away from this book with a substantially improved understanding of glass cockpit airmanship. What we have known and promoted as a "lens" through which to view airmanship as a whole—*Automation Airmanship*—will become as natural in executing flight deck responsibilities as planning and executing a routine instrument approach. In fact, it will be *the same* as planning and executing a routine instrument approach.

We do not propose to have all the answers, but think that by the end of this book you will surmise that we have put forth a discipline of airmanship, embodied in practical strategies, that meets most of the challenges faced by pilots and crews of most advanced aircraft. If you are an experienced captain, you may see some familiar principles that you have been practicing for many years; only now you will be able to place them in the context of a concise discipline for what may be the first time in your career. As a copilot or first officer, mastering Automation Airmanship with novice credentials may not help you make captain or aircraft commander any faster, but it will help make you a better captain when you do; in the meantime the flight deck crew that you are a part of will be better because of the way you undertake your flying job. If you are part of an organization that operates advanced aircraft as part of the mission crew, are in a command leadership position, or serve in some other specialized support role, you will better understand the dynamics of the glass cockpit airmanship, increasing the level of integration between you and the crew in the cockpit. We will not explain everything you need to know about the specific advanced aircraft that you are checked out in, but we will explain how any individual crewmember can systematically build a reserve of essential knowledge that she or he can rely on across an entire career, no matter the aircraft. We boldly propose that when you have completed this book and begin to apply its actionable steps in your routines as you interact with the technology on the modern flight deck, you will achieve a noticeably increased level of safety and will enjoy greater professional satisfaction than you thought possible on the highly automated flight deck.

Notes and References

1. Allen Newell and Herbert A. Simon: *Human Problem Solving*. Englewood Cliffs, NJ: 1972. Prentice Hall. pp. 9–10.
2. Diderot, D., & d'Alembert, J. (Eds.). (1751–1772). *Encyclopédie ou dictionnaire raisonné des sciences, des arts et des métiers* [Encyclopedia or systematic dictionary of the sciences, arts and crafts]. Paris: Briasson, David, Le Breton, Durand. Page xl.
3. GPWS technology was not installed on the Air Inter A320 fleet because of a number of operational and commercial constraints identified by investigators; in response to the Bureau d'Enquêtes et d'Analyses (BEA) accident investigation, Air Inter equipped its entire A320 fleet with GPWS: "The analysis in §22.36 does not conclude that the carriage of GPWS could have prevented this accident. It does show that statistically the carriage of this equipment is beneficial and, with appropriate procedures, it is very likely that the crew would have reacted positively to the alarm." The French personnel investigating the accident would go on to recommend installation of GPWS on aircraft with capacity of 31 or more passengers.
4. Details were obtained from the official report of the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA): RAPPORT de la commission d'enquête sur l'accident survenu le 20 janvier 1992 près du Mont Sainte-Odile (Bas Rhin) à l'Airbus A320 immatriculé F-GGED exploité par la compagnie Air Inter. [Office of Investigations and Analysis for Civil Aviation Safety (BEA): Report of the Commission of Inquiry into the accident January 20, 1992 near Mont Sainte-Odile (Bas Rhin) with Airbus A320 registered F-GGED operated by Air Inter.]
5. Colgan Air flight 3407 (Bombardier Q400; February 12, 2009: Buffalo, NY, USA), Turkish Airways Flight 1951 (Boeing 737-800; February 25, 2009: Schipol, Netherlands), and Air France 447 (Airbus A330; June 1, 2009: North Atlantic Ocean).
6. Franklyn E. Dailey, Jr., *The Triumph of Instrument Flight,* Dailey International Publishers, Wilbraham, Mass., 2004, p. 56.
7. Marcus Buckingham, *The One Thing You Need to Know*, Free Press, a Division of Simon and Schuster, New York, NY. 2005, p. 15.