Introduction

Instrument flying has changed in many important ways in the short time since I published *IFR: A Structured Approach.* My purpose with the present book is to bring you up to date.

The big news is that the Wide Area Augmentation System (WAAS) has been commissioned, and along with that has come a family of vertically guided almost-precision approaches–LPV, LNAV/VNAV, and approaches with what is called "advisory vertical guidance." These approaches allow us to fly final descents with cockpit displays showing ILS-like glidepath deviation indications even though our runway is not served by ILS facilities. Given that CFIT (Controlled Flight Into Terrain) accidents on approach are about five times as likely when the approach lacks vertical guidance, WAAS will certainly be a significant benefit to a substantial subset of the aviation community. (See "Killers in Aviation: FSF Task Force Presents Facts about Approach-and-Landing and Controlled Flight into Terrain," *Flight Safety Digest*, November-December, 1998.)

What do you need to know before you start flying confidently with WAAS? I suggest the list goes something like this: How does WAAS work? What do all those new acronyms–HAL, VAL, HPL, VPL, LPV–really mean? What new rules apply to WAAS users? How are WAAS-based approaches constructed? What are the similarities and differences between WAAS-based approaches and ILS, VOR, or non-augmented GPS? Why is the LNAV minimum sometimes lower than the LNAV/VNAV minimum? How can you use that to your advantage? What should you be leery of when the LNAV/VNAV minimum is 300 feet above the LPV minimum? And the list goes on. Those of us who got our instrument ratings more than a month ago have some homework to do. We will explore all this, and much more.

While WAAS is certainly the most significant innovation of the past few years, there are many more. Some sort of Terrain Awareness and Warning System (TAWS) is now required on all turbine aircraft with six or more passenger seats, and thanks to the relatively low cost of these systems, they are now appearing on a large number of smaller turbine and higher-end piston aircraft. And non-certified terrain awareness systems are available as low cost options on certified panel-mounted GPS units such as the Garmin 430/530 and even on hand-held GPS units. These too have the potential of bringing down the number of CFIT accidents. I think they are especially valuable when getting radar vectored or when conducting GPS-direct off-airway navigation, especially at night. But have you done your homework? Do you know what triggers the various alarms? Do you understand the system's blind spots? What exactly are you supposed to do, or entitled to do, when you get a terrain warning? We will be discussing these topics in depth.

Besides these new hardware innovations, there are also a number of important new procedures and rules. We have already mentioned the WAAS-enabled LPV approach, which we will study in great detail, but there are also new RNAV SIDs and DPs. If you get one of these in your clearance, when you study the procedure, you might see that it is "Type B." What does that mean? How is it different from Type A? Can you fly it with your Garmin 530? What about your KLN-90B? If the procedure is an RNAV DP and it says "OBSTACLE," can you fly it even though it is not in your clearance? Should you? Maybe it's time to research these new procedures. That is why I am writing this.

Finally, there are some important new rules besides those that relate to the new equipment and new procedures. For example, for many years a staple of instrument flying was that there are only two ways to get established on an approach: (i) radar vectors to the final approach course and (ii) via an initial approach fix or feeder fix. The FAA has recently approved ATC granting clearances RNAV-direct to the intermediate fix under certain circumstances. Do you know when this can be done, and, more importantly, why it sometimes cannot? You may find that ATC is behind the learning curve on this one, and it will be up to you to spot an occasional mistake and refuse a clearance. We are going to explore this topic in considerable depth and use this new wrinkle as a prompt for an exhaustive review of both radar vectoring, including a look at Minimum Vectoring Altitudes, and the complex topic of getting established on an approach.

One of the innovations of this book is that we will draw on the ATC Handbook (officially FAA Order 7110.65) and the TERPS (U. S. Standard for Terminal Instrument Procedures) to an extent that is uncommon in the general aviation literature. The ATC Handbook is for the controller the rough equivalent of what the FAR/AIM is for the pilot. It is the official source telling the controller how he or she is to issue clearances, vectors, safety alerts and all of the myriad of other chores at ATC. It is not quite true to say that the FAR/AIM only gives us pilots half the picture, but there is much to be learned by studying the constraints and s.o.p.'s that are imposed on controllers and approach designers. The rules that ATC lives by have evolved over the years partly in response to intense periods of soul searching in the wake of aircraft accidents. (TWA 514 at Dulles in 1974 is a case in point.) But how are we pilots to know if we are being handled in accordance with the ATC Handbook, and getting the benefit of the accumulated wisdom that it contains, if we have no idea what the Handbook says?

In the same way, we as pilots learn how to interpret and fly the charted black lines on the approach plate, but we don't know much about the constraints that the chart builders face when they construct an approach. The TERPS is an extensive series of documents detailing the rules under which approaches are constructed. How much obstacle protection do you get at the MDA? What is the maximum turn allowed at the intermediate approach fix on an RNAV (GPS) approach? How much lateral separation is there between you and a nearby tower when you fly an LPV approach? How is that different on an RNP approach? I think these issues are more important now, in the era of GPS, than they ever were. And the reason I feel this way is that with GPS some controllers seem to feel that it is okay to clear an aircraft along any string of random waypoints, even waypoint strings that TERPS would never permit. I've seen this firsthand on a number of flights, and we will study an accident which followed this sort of clearance. If we were all better versed on TERPS, we might look at such a clearance and think: *TERPS would never allow that*. And this might prompt us to question the clearance.

There are many reasons to work at improving your aeronautical skill and knowledge. You can, for example, study engine leaning to improve your fuel economy, or study the short field procedure to improve your takeoff performance. But economy and performance pale in comparison with safety of flight, which is the ultimate aviation topic. In the present book, I focus on the safety implications of all the new gadgets, procedures, and rules.

If we are to fully understand the safety ramifications of the new instrument flying gadgets, procedures, and rules, we have to embed our study in a reasonably complete context of overall IFR operations. To that end, I am going to go into detail on some older gadgets, procedures, and rules that typical IFR pilots don't understand sufficiently–primarily ATC's MSAW (Minimum Safe Altitude Warning) system, radar vectors, and instrument departure procedures.

My effort to explore the safety implications of the recent innovations in instrument flying has led me to a study of aviation accidents. For the first time in my aviation writing, I am going to take an in-depth look at a couple of sad examples. I confess that I am uneasy moving into this territory. My purpose here is not to assign blame or fix cause, and it is certainly not to gratify any voyeuristic urge to eavesdrop at the scene of an impending tragedy. My purpose is to study various accidents looking for weak spots in pilot education, for subject areas that, if they were better understood by the pilot community, would reduce the likelihood of similar accidents in the future. Rote learning of rules in the abstract, even when laced with admonitions about the safety implications of those rules, simply does not carry the visceral impact and lasting power of a concrete example of how misunderstanding of the rules can lead to tragedy.

I examine only two cases. One, already mentioned, involves the blurring of the line between radar vectors and RNAV-direct clearances, and the other involves the pilot-wide pandemic of misunderstanding of IFR departure procedures, which is a perennial killer. Clearly there is something seriously wrong with pilot education when there is a virtual template that is followed with these accidents.

Here is a quick outline of the book: The first three chapters deal with WAAS. Chapter 1 investigates how WAAS is able to correct GPS position estimates. The next chapter looks at the TERPS criteria for WAAS-based approaches. And the following chapter examines the topic of flying with WAAS.

Chapter 4 brings us up to date on recent changes in RNAV departure procedures and adds a brief section on RNAV Q- and T-routes.

Chapter 5 discusses new rules on TAWS, but more importantly it also explains how TAWS works, what its various warning/alert messages mean, and what you can and should do in response. Most pilots are unaware that ATC has its own TAWS-like system called MSAW, Minimum Safe Altitude Warning system. MSAW alerts controllers when an aircraft is or is expected to be too low, and then controllers are supposed to alert pilots. But, what prompts the alert, and what are you supposed to do when you get one? Are you automatically getting MSAW protection when you are assigned a transponder code and talking to ATC? We will address these questions in chapter 6.

Chapter 7 deals with radar vectors. Special attention is paid to the meaning of the MVA and the issue of when it is permissible for ATC to issue a vector when you are below the MVA.

Chapter 8 tests our knowledge of the above topics by examining the chain of events leading to an accident in San Diego during a night departure, when a Lear 35A impacted terrain while trying to maintain VFR under an overcast while following a vector below the MVA. If nothing in the last sentence strikes you as odd, you are likely to really benefit from reading this book.

Chapter 9 covers the surprisingly complex topic of transitioning onto an approach. What is permissible as you fly "GPS direct" from one fix to another toward the FAF, Final Approach Fix? Is it okay to go direct to the FAF from anywhere as long as you are so cleared? Is it okay for ATC to clear you GPS direct to the FAF or to issue a vector to the FAF? And, what is wrong with the following clearance? "...two miles from the outer marker, turn left heading 050, maintain 4000 until established, cleared ILS runway 36 left." Hopefully, when chapter 9 is finished, you will have a clear idea of some of the problems created by any of the above.

Finally, in chapter 10 we study the sad case of a relatively new instrument pilot struggling against a barrage of ATC handling mistakes as he tries to get established on an RNAV (GPS) approach. This accident touches on many of the major themes of the book–getting established, radar vectors, TAWS, MSAW, and more.

I must thank a number of good people for their help with this project. Thanks to Fred Zanegood at Elite Simulation Solution for his kind permission to use screenshots from the amazing Elite family of desktop simulators. Thanks also to Ken Terada at Garmin for allowing screenshots of the Garmin 430/480/530 and G1000. I don't know where I'd be without them. Thanks to Mike D. Turner at Raytheon for the stunning cover photographs. And thanks to Georgia Wolf at Jeppesen for providing the instrument approach plates. Thanks also to Maria Reyes for the copy editing.

John Maynard Keynes, the famous British economist, said something characteristically brilliant in the Preface to his classic *The General Theory of Employment, Interest, and Money*. He said that it is amazing what garbage you can believe, at least for a while, if you do too much thinking by yourself. As a good Keynesian, I've enlisted the help of a lot of bright people. Many thanks to all of them: Several people at the FAA provided much-appreciated assistance. Thanks to Andy White, Brad Rush, Steve Jackson, Don Brown, Will Buklad, Lou Volchansky, Mike Werner, and Rich Cote. Needless to say, their help with a question or two does not constitute an FAA endorsement of the content of this book. Todd Walter at Stanford and Ed Williams of Lawrence Livermore National Lab helped with some key questions, as did Quentin Deck at Garmin, Brian Moore at FlightSafety, and Kevin O'Hara at Honeywell. Ron Zasadzinski and Randy Bailey of the Bonanza/Baron Pilot Proficiency Program, Judy Cadmus of Avionics Training Unlimited, and Walter Atkinson of Advanced Pilot Seminars all read early drafts of select chapters and offered great suggestions. Like all authors, I must accept full responsibility for any remaining mistakes.