Cockpit GPS

A practical guide to using GPS in the cockpit

By

John Bell

PREFACE and DISCLAIMER

Although I say essentially the same thing in the introduction, I believe that it bears being said separately for emphasis.

Both the e-book and print on demand versions of this book are not professionally edited or published. Professional editing adds a layer of confidence in that the text is checked for both writing errors as well as factual errors. Although I consider myself to be knowledgeable and I have tried to make this information accurate to the best of my knowledge, this book has not been edited.

Although I have hopefully provided accurate information that will increase your safety of flight, I take no liability for any of the material.

If this book proves to be sufficiently popular, I may have it edited and published in a more formal manner. By doing so I will have to freeze the content and updates will be harder to make and fewer.

The grammatical and general stylistic errors will be the easiest to fix by hiring somebody with more writing skill. Although I am open to such corrections, these are not my primary concern. I would very much like to hear about substantive errors. These are cases where I was outright wrong or explained something in a manner that while being logical to me, was actually confusing.

I would also like to hear if this book helped you and if there are things that you wish that I had included but did not. Not that I will necessarily include them, there has to be some winnowing of subject matter, but I do appreciate any ideas.

Sincerely,

John Bell
handheldgps@hotmail.com

Acknowledgments

Richard Kaplan, www.flyimc.com has been extremely helpful in providing counterpoints to help me refine my views on CANPA for general aviation, which is not to say that he endorses my conclusions.

Greg Bell, no relation, provided a very enjoyable London layover by taking me for a ride in his Yak 18 and West London Aero club.

Jay Noyes has taken quite a bit of time to edit much of this work. I have not had the chance to incorporate many of his changes yet. In any case, I will take credit for any mistakes.

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Chapter 1 Introduction

Disclaimer

I have written this book with the intention of making you a safer pilot by showing you how to use GPS. Although all the information is given in good faith, I cannot be responsible for the misapplication of any material in this book; nor can I be responsible for errors and omissions in the material that I pass along to you. Ultimately, you as the pilot, using your own airmanship and common sense must be responsible.

Pay the Author

Most likely, you downloaded this book from the Internet. However, I also permit copies to be sold and distributed freely without direct payment from whoever is printing or distributing them.

Thus, the burden for this falls on you and your conscience. If you find this book worthwhile, go to www.cockpitgps.com and drop me a few dollars, Euros, Pounds, Swiss Francs, or whatever. You can also provide feedback on my site.

Purpose and Applicability of this book

I think that GPS is a great boon to aircraft navigation, but I think that many pilots are missing out on GPS and many who are using GPS are using it to a fraction of its potential.

My emphasis is on handheld GPS because of the accessibility of the technology. However, the basic principles of navigation are the same for using a certified IFR GPS. In fact, the basic principles of navigation are applicable whether you paddle a kayak at 3 knots or fly a jet at 500 knots.

The primary emphasis of this book is on how to navigate with GPS. Although I have some information on using IFR certified equipment for flying IFR, much of this is procedural in nature. For many of the procedural aspects I defer to other and better sources of information. This is because I do not have experience flying IFR GPS equipped general aviation aircraft in an IFR environment.   I do discuss aspects of IFR use that are more about principles than bout procedural specifics.

I use examples from several different GPS receivers throughout this book. This is a book on GPS navigation, not a book on how to use a specific

model. Although I do have a couple of tricks and techniques for specific receivers, this not the primary intent of the book—that is the province of the owner's manual.

This book mostly discusses Garmin receivers. Although I will admit that I am a Garmin fan, I am not a shill for Garmin. With the exception of the Honeywell FMS on the MD-88 and 757, most of my experience is with Garmin. Although I will be the first to admit that this text has a Garmin handheld orientation, my goal is to explain how to use GPS and the principles of GPS in general. If you have another brand of GPS, I hope that you will find that this book still has some relevance.

I do not think that most GPS owner's manuals explain how to actually navigate with GPS. They explain how to operate specific features and then people figure out how to use these features to navigate using the GPS. Unfortunately, I have seen many pilots who only know how to use their GPS at a very minimal level. I have also seen many pilots using techniques, which although they are not wrong, do not exploit the features that GPS offers. I have even talked to some pilots who use GPS in a manner that I would consider as being actually incorrect—following the GPS bearing like homing on an ADF.

I really do not fault the owner's manuals. The scope of the owner's manual is very different from what I am trying to accomplish. Consider the example of a scientific calculator. The owner's manual will teach you how to operate specific functions, but it will not teach you math. Your GPS owner's manual is a useful reference for learning how to use specific features of that GPS. There are some cases when I will tell you some tricks that I think that you might otherwise miss in the manual. However, most of the time I will leave out the specifics of how to actually operate the GPS for a given function.

Many of my examples use routings that would not be typical for general aviation. Often these are routes that I am most familiar with, so I used them. You might be a VFR pilot flying C-172 and you may never fly a jet airway or an IFR arrival procedure. Even though my examples may use a jet airway or instrument arrival, the principles of using GPS are the same even if the routes are not something you would ordinarily fly.

Nomenclature

GPS is an acronym for Global Positioning System. The key word is system. GPS consists of satellites, ground monitoring stations, and receivers. However, GPS is commonly used to refer to the receiver portion. Although this is not technically correct, I feel that it is fair usage

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as the context is usually clear when the system is being referred to and when the receiver is being referred to.

Furthermore, the average GPS is much more than just a simple receiver. The GPS receiver portion only provides position, velocity, and time (sometimes referred to as PVT data). Thus what is commonly referred to as a GPS receiver is actually a receiver integrated with a sophisticated navigation computer. However, I feel that GPS receiver is an adequately descriptive term.

Learning to Use Your GPS

Learning to use a GPS is just like learning to use any other technically sophisticated item. There are necessary basics that you must learn first and there are more sophisticated functions that you can learn later or as you need them. I like to use the example of learning to use a word processor. Initially, you need to learn how to type a document and then print and save it. Other things such as creating headings, tables of content, page numbers, headers, and footers, can all come later as you need them. Some people may never need them.

Furthermore, different people have different learning styles. Some people like to sit down with the manual and read it cover to cover. Other people like to jump in and experiment. Obviously, the cockpit is not an ideal place for the jump in and experiment method. However, one of the advantages of GPS is that there are many ways to facilitate the experimental method outside of the cockpit. I cover some of these methods in the *How to become proficient* section on page 2-5.

What is in this book

Although I hope that I provide you with a lot of useful information in this book, it is not necessary to digest it all before you can get some utility from your GPS. I have purposefully laid the book out with a logic in mind. You may find that some chapters do not apply to you. For example, if you already have a GPS, then you can skip or quickly scan the chapter titled *Which GPS*. If you have or are going to purchase an aviation GPS, then the *Aviation Waypoint Data* chapter will mostly be unneeded, although you might want to read the section on *Connecting your GPS to the Computer* page 5-6.

- Usage Issues

  Issues such as legality of use and what a handheld GPS is appropriate for.

- How it Works

  This is the back of the napkin purposefully over-simplified version. I have references to more detailed explanations if you desire.

- Which GPS

  This chapter deals with what to look for in choosing a GPS. Although I have some specific model information, my main goal is to point out the factors to consider in purchasing a GPS receiver. The discussion is mostly aimed at handheld GPS choices.

- Aviation Waypoint Data

  Among the handheld GPS choices are non-aviation models. The disadvantage of non-aviation GPS receivers is that they do not have a database of navaids and airports. I have information on where to get this information and how to get it into the GPS if you have a non-aviation GPS.

- GPS Preflight Route Planning

  Before you can navigate with a GPS, the GPS must know the route that you want to navigate along. This is not a detailed lesson on flight planning in general, but a lesson on how a handheld GPS can be used in the flight planning process. Special emphasis is given on how a mapping GPS can be used to plan a VFR flight.

- Navigation

  You have to know what the GPS is telling you and how to use it. I have several examples with screen captures to show you how to navigate with a GPS.

- Route Intercepts

  Often, it is not possible to fly a route as shown. This chapter deals with how to intercept a route and modify how the route is flown.

- Miscellaneous

  This is a discussion of some of the extra features and more esoteric details of using GPS, with one exception. If you have a mapping aviation GPS receiver, use it to avoid a runway incursion. This is too simple and effective not to use.

- GPS and Student Pilots

  There is the issue of when or if student pilots should be introduced to GPS. However, this is not the point of the chapter. There are ways in which the GPS can be used, especially outside of the cockpit to let the student become more comfortable with basic navigational concepts.

- IFR use of GPS

  If you have an IFR certified GPS receiver, navigating using the GPS is similar to navigating with any other equipment. There are some added issues about the actual operation of the GPS as well as legal requirements. I have some comments and sources of information for using an IFR certified GPS during approach.

  For non IFR receivers, there are issues about the appropriateness, legality, and safety of using a handheld GPS during IFR operations. Although not legally binding, I express my opinions on using a handheld GPS during IFR operations in this chapter.

- Vertical Approach Profiles

  This is a chapter on how to use GPS, especially with VNAV, to increase your vertical situational awareness on non-precision approaches.

Why you should have a GPS

- The GPS service is free

  There is no charge for using GPS. You have to buy the receiver, but the signal is free. Certainly if you pay U.S. taxes, one could argue with the meaning of the term "free." So perhaps for U.S. taxpayers, I should rephrase this point to say that "you paid for it, you might as well use it."

- Ease of navigation

  Conventional navigation instruments such as ADF and VOR only give bearing or angular displacement from course information. The required heading to compensate for winds must be guessed at, even if

systematically so. The GPS gives actual track information and takes away this guesswork.

- GPS receivers are relatively affordable.

  Almost anybody who can afford to fly should be able to afford a GPS. One of the points that I make in the *Which GPS* chapter is that although worthwhile, an aviation GPS receiver is not necessary. Usable non-aviation hand held GPS receivers are available for under $200. Decent non-aviation receivers are available for under $300. In fact several of the examples on this site were created using a Garmin GPS III Plus, which is a non-aviation unit available for under $300.

- Emergency use:

  A handheld GPS is independent of the aircraft's pitot and electrical system. This is a useful feature whether you are flying a C-150 close to home or an airliner in the middle of the ocean 90 minutes from the nearest suitable landing field. In addition to navigational information, it will give track, altitude, and groundspeed. Track and groundspeed are not heading and airspeed, but both could be useful in an emergency. The GPS altitude is the least accurate of all of the GPS parameters, but it sure would be useful in an emergency when there was no better source of altitude. John Ruley has written an article on this very point on Avweb at http://www.avweb.com/news/system/183178-1.html.

- Accuracy:

  A GPS gives much more information and the information that it gives is generally more accurate than other forms of navigation. The VOR signal is accurate within 1 degree. The VOR receiver has to be accurate within +/- 4 degrees for IFR flight. This means that VOR navigation can be up to 5 miles off for every 60 miles from the station. Let's not even discuss long range NDB's. Even inertial navigation systems drift when not updated over the ocean. GPS should usually be accurate to within 15 meters.

- Situational Awareness

  It is always good to know where you are. GPS has the potential to suck your eyes to it. However, if properly used by a proficient pilot, it can free time to look out the window. A GPS is much less distracting than being heads down with charts flailing around the cockpit trying to cross tune VOR radials to figure out where you are. I am not advocating that you ignore the charts, just that you know where you are on them in a quicker and less distracting manner.

- Point to Point VFR flying:

  A GPS can be used to navigate from any point on earth to any other point. A less than obvious effect of this is that you can plan a route with multiple waypoints to carry you around terrain and airspace that you would rather avoid. When using VOR navigation, traffic comes together over the VOR. By using GPS, the collision risk of traffic coming together over VORs is reduced. I cover this more in the *GPS Preflight Route Planning* chapter.

Who am I?

I think that it is important that you know a little about me so that you can understand the perspective from which I am writing. Also, I hope that my experience gives some credibility to what I write.

I am currently an international 757/767 first officer for a major airline in the United States. I have also flown as a 737-200 and BA-3100 (Jetstream) captain, co-pilot, and as a flight engineer on the L-1011 and 727. Before my airline career, I flew a variety of general aviation aircraft. I have an Aerospace Engineering degree and my background is civilian. I have flown glass cockpit airliners and I have flown single engine aircraft with no navigation radios at all. Even though my intended audience for this book is primarily general aviation, the principals of GPS navigation are the same whether you are flying a jet at 500 knots, a Cessna at 100 knots, or paddling a kayak at 4 knots.

A couple of friends wanted my recommendations on specific GPS receivers. As I e-mailed each one of them, the e-mail grew with each cutting, pasting, and sending. This e-mail grew into a web page, which grew into a web site, which has been recompiled as a book.

One thing that I am not is a writer. For that matter, I barely made it out of freshman English. An additional factor that I hope that you will grant me some extra tolerance for is that it is almost impossible to edit your own work, even for professional writers.

One of the things that I like about publishing over the Internet is that I can update the material as I think of things to add. This keeps the material current. However, sometimes it is hard to add new material so that it flows smoothly. This new material may be like a separate article rather than an integrated part of the text.   Often I think of something that I would like to add and forget that I have essentially said the same thing somewhere else in the text.

For these faults and several others, I beg your indulgence. However, I hope that you will find this useful and that it will make you a safer pilot.

Chapter 2 Usage Issues

Safety Warnings

Disclaimer:
These warnings are not the result of significant research and statistical analysis. These are issues that I think that you should consider with regard to GPS navigation.

➢ **Terrain**

Just because you can navigate directly to a destination does not mean that the terrain will permit it. Make sure that you use the proper charts and techniques to assure obstruction and terrain clearance. Make sure that you are familiar with the maximum elevation levels on visual charts and the MEA and grid MORA's on IFR charts. The way in which GPS increases the risk is in that it is much easier to operate off airways. A mitigating factor for GPS is that you are much more likely to be where you intend. Thus, if you pay proper attention to the charts, your safety margin could increase with respect to terrain clearance.

Many of the certified receivers are starting to offer TAWS (Terrain Avoidance Warning System). This feature has made it into the handheld GPS market. Several manufactures have introduced or are in the process of developing various levels of terrain and obstruction data to there GPS receivers or PDA software.

I consider TAWS to be like a guardrail on a road. It is sure nice to have if you mess up, but it is not for primary guidance.

➢ **Loss of Signal**

There is the issue of about the manner and speed that a handheld GPS will warn you if it loses the satellite signal. I will this later in the chapter from an overall system standpoint. However, I wanted to get your attention in the beginning of this chapter to warn you in that a handheld receiver might not give you a timely warning that it has lost the signal and is no longer navigating.

The Magellan 315, and possibly the rest of the Magellan receivers, will just stop updating the navigation information if it loses the satellite signal unless you enable the loss of signal warning. A good way to demonstrate

this is to get a satellite lock and then walk indoors. The GPS will lose the signal yet still display position information with no direct warning that the receiver really has no idea where it is. Fortunately, this is recognizable as long as you display a distance or a speed. The distance will stop changing and the speed will go to zero. However, it will still show a distance as well as track and bearing information so it is easy to miss the signal loss. It is possible to set the Magellan to warn of a signal loss, but this is not the default setting.

Most of the Garmin handheld receivers with which I am familiar have a feature called dead reckoning. If the GPS loses satellite coverage, it projects your position based on your last known position, speed, and track. This only happens for less than a minute before a message is displayed indicating the signal loss. The purpose of this feature is to avoid nuisance warnings of signal loss.

A good way to demonstrate the dead reckoning feature is in the car. Just before approaching an intersection and while still moving, cover the antenna of the GPS. Make a turn at the intersection and observe that the GPS will show you continuing on your original track through the intersection before warning you that it has lost satellite coverage.

The good news is that many newer handheld GPS receivers are better at maintaining a satellite lock than even older IFR receivers. However, a certified IFR GPS installation has an antenna mounted on the outside of the aircraft. The bad news is that the antenna of a handheld GPS is used inside the aircraft and has a much higher chance of being blocked by parts of the aircraft.

Normally this is not a problem, especially for enroute navigation. However, if you were to be use a handheld GPS for primary guidance without proper crosschecking from the facilities that properly define an instrument approach or if you were flying an illegal and ill-advised homegrown approach with a handheld GPS this could be a significant and insidious problem.

➢ Collision Risk

GPS allows a new level of precision navigation. If two aircraft are navigating between the same points using GPS, they are going to be closer to the theoretical line between the two points than with most previous navigation methods. This is readily apparent when two GPS equipped aircraft pass each other at different altitudes. One will pass directly over the other on the airway. In fact, it is not uncommon for an airliner to get a radar altimeter indication or even a false terrain warning from the lower aircraft as it passes above.

If you look at an airway like a road, GPS has made the road narrower. The good news is that eventually GPS will enable technologies that will help reduce the chance of collision. Technologies such as free flight and Automatic Dependent Surveillance – Broadcast, ADS-B, come to mind.

Instead of fixating on the GPS to get that last bit of accuracy following the airway, use the GPS to free up some of your brain power to scan for traffic better. GPS navigation generally does not require the concentration of a hand flown ILS to minimums.

When flying VFR, GPS allows you to navigate freely from point to point without having to fly in the concentration of traffic along airways and over VOR's.

Dependency

Some pilots are concerned that using GPS will create a dependency on GPS and degeneration of navigation skills. This fear is not without basis. However, at the same time, I think that mastering GPS navigation might actually increase your navigation skill in general.

I think that it is possible to learn some very basic GPS techniques that will suffice without fundamentally knowing what the GPS is telling you. For example using an aviation GPS, all you really have to do is hit the GOTO button, spell out your destination and follow the pointer to your destination. If this were the depth of your knowledge and understanding, then I would say that you have used GPS as a substitute for learning fundamental navigation skills. I think this is a real danger.

The GPS will certainly spoil you because it will tell you so many things accurately. However, I also think that if you truly master GPS navigation and know what it is telling you in the broader context of courses, bearings, tracks, etc. then there is no reason that you will necessarily become navigationally inept and dependant on the GPS. GPS will directly indicate information that other navigation systems do not directly indicate and must be derived. You should be able to understand other ways of navigating in the context of what they are telling you, how accurate the information is, and techniques used to derive the information that the other systems may not directly indicate. For example, the actual track of the aircraft must be deduced when using VOR or NDB navigation because it is not directly indicated like it is when using a GPS.

To put this another way: If you learn to navigate using GPS as opposed to using GPS to avoid learning to navigate, then I think you will be well served.

Proficiency

A GPS is a powerful tool. It is up to the pilot whether it is used like a hammer in the hands of a two year old or in the hands of a craftsman. Human Factors Ph.D. theses have been written about the application and pitfalls of cockpit automation. These are issues that are general to automation in aviation as well as being applicable to GPS use. GPS can be a distraction, it can create complacency, it can take you to the to the wrong destination with great accuracy. However, when wisely and proficiently applied, GPS navigation can significantly improve your situational awareness and the overall safety of the flight.

One of the biggest limitations of GPS is pilot proficiency. Proficiency is the key to extracting the maximum capability of any system. It is possible to reach task saturation with any system. I have seen pilots flailing around the cockpit with charts and cross tuning VOR radials.   Fumbling with a complicated gadget can also be a distraction. In either case, proficiency is critical.

Airline pilots receive much training on the specific navigational equipment onboard their aircraft. The training philosophy is not that the advanced navigation tools are crutches, but that they are important tools to operate the aircraft. Therefore, a considerable amount of training emphasis is spent on navigation and automation. If you went to surgeon would you be impressed if he felt that anything more than a scalpel was for sissies or would you prefer that his operating room was well equipped and that he was a proficient in the use of every tool available to him?

Many GPS units available to the general aviation market or even to the general consumer offer a level of sophistication approaching some of the glass cockpit airliners and exceeding the capability of many older airliners. In the general aviation community, rather than GPS being a core-training subject, it is often treated as a peripheral subject. In addition to dedicated training, an airline pilot will fly with the same equipment and use it as much in a month as some general aviation pilots fly in a year. A general aviation pilot may fly an aircraft equipped with one GPS one time and fly another aircraft equipped with a different GPS a different time.

A GPS is not a simple device. A VOR has a frequency selector and an OBS – two controls.   Compare the two controls of a VOR with the number of buttons, screens, data fields and menus of even a simple handheld GPS. However, the capabilities of GPS make the time spent mastering GPS worthwhile. Also, GPS navigation has applications beyond the cockpit whether it's hiking in the woods, boating, or simply finding an address while driving.

I find that there is an interesting irony in adopting new technology like GPS. In many ways, the new technology makes the task(s) that it address easier to accomplish. However, there is a high price in that the technology itself demands mastery. I have seen pilots move from traditional technology such as the DC-9, 727, and 737-200 to more advance cockpits such as the newer 737's, 767, 757, MD-88 and 777. I have also seen the opposite transition. I would argue that mastery of the new technology is more of an issue than dependence on it.

Despite differences between specifics of operation for each unit, there are many similarities. To some degree, navigation is navigation. This is why a marine or generic GPS works well in the aircraft – the navigation principles are similar. I would hesitate to call most GPS units easy to use. However, I think that the manufacturers have made the newer GPS receivers about as easy to use as is possible considering their sophistication.

With the exception of shooting an IFR approach, I would rather see a pilot navigate with a generic handheld GPS that he was proficient with, than to fumble with a panel mounted GPS that he was not proficient with.

How to become proficient

The only way to become proficient with GPS is to use it. Actually flying with GPS is a good way of maintaining proficiency once you know how to use it. However, learning to use the GPS in flight can be a distraction.

As I started to proofread some of this text, I realized that I had used the term "play with" in a section that I have now revised. This is exactly an approach that you might consider -- play with the GPS. How many kids do you know that go through a training program to learn Nintendo or X-box? They just start playing with the games. I would highly recommend this approach for learning GPS – on the ground.

➢ Learning GPS in the airplane

If you have a panel mounted GPS, turn on the master, turn on the GPS, and play with the GPS. I suppose that this statement is nothing more than a statement of the obvious, but on some panel-mounted receivers this might be your only viable option. Certainly, you are limited in that you cannot use all of the features in context while on the ground, such as approach modes, but even this basic familiarization can be valuable.

Learning how to use the GPS in the air is somewhat problematic. Obviously, there is much to be said for getting some dual from a competent instructor, although finding an instructor who is knowledgeable

about GPS may be somewhat problematic. The airlines faced many of the advanced cockpit issues that are facing general aviation now when they introduced the 757/767 to pilots who were used to the "steam gauges" on the 727, DC-9, and DC-8. I remember a CRM (Cockpit Resource Management) instructor commenting that one of the worst cockpit distractions is when an experienced pilot flies in an automated cockpit with a pilot who is not as proficient in the automation. Both heads go heads down, one to teach and one to learn – not good. Make sure that someone is flying the airplane if you are getting dual.

Finding an instructor who is up on GPS, especially your particular model, may be difficult. Again, I think that some lessons from the airlines might be useful. In a non-normal (official Boeing terminology) situation, one pilot concentrates on flying the airplane and the other pilot concentrates on working the problem. In fact, it is often preferable that the captain delegates the flying to the co-pilot leaving more concentration to make decisions and coordinate actions. Where this is relevant to learning GPS is that you might go flying with another pilot. When you want to concentrate on learning a feature of the GPS, let the other pilot fly while you fiddle with the GPS to your heart's content. Just make sure that he knows that his job is to concentrate on flying and resist the distraction of your fiddling with the GPS. Also make sure that there is a positive transfer of control – make sure both of you know who is flying the aircraft.

➢ Emulators on your computer

An emulator is a program on your computer that imitates the functioning of the GPS. The advantage of an emulator is that you can learn the functions of an emulated hardware without having to have the hardware. This is especially useful for hardware that is expensive and not very portable. The disadvantage is that often it is a little awkward turning knobs and otherwise operating the emulation with mouse clicks.

Garmin offers emulators for many of their panel mounted GPS units. They are free and can be downloaded from Garmin's website, www.garmin.com. These can be especially handy if you have a laptop because you can play with them whenever you have a little free time.

Garmin also offers PC simulators for its G1000. They are on CD rather than downloadable and are priced for not much more than I would imagine it costs to manufacture the CD's and ship. The ordering information is available on the G1000 page of the Garmin website, www.garmin.com. The only caveat is that you should check the hardware requirements of the simulator to see if your PC is sufficient.

Bendix/King only appears to offer a simulator for the KLN89B and GNS-XLS at http://www.bendixking.com/static/simulators/. I do recall some third party simulator software, but every link to the software that I have found is a dead end leading me to think that the software company that made the simulators is out of business. Bendix/King representatives at Sun-n-Fun 2004 have told me that they are working on a simulator for the KLN-90B.

Lowrance, www.lowrance.com, offers several downloadable product emulators for their handheld GPS products. The emulators for the AirMap GPS receivers lack the aviation database. However, you can download a Jeppesen database from the Lowrance website and save it in the Maps0 folder of the emulator. On my computer this folder was located in C:\Program Files\Lowrance Electronics\Unit Demo. For purposes of using the emulator, the Jeppesen database worked for free on the Airmap 500 and 1000, but not on the Airmap 2000.

The problem with the AirMap simulator is that you turn it on and you have a GPS whose buttons appear to work, but what now? The way to use the emulator is just like you would use the actual GPS in that you can have to put the GPS in simulator mode. On the AirMap series, the simulator mode is reached via MENU->MENU->GPS SETUP -> GPS SIMULATOR. It is also possible to use the AirMap emulators with Microsoft Flight Simulator as I will discuss shortly.

I like the AirMap emulators in that it has given me the opportunity to test some of the functionality of the Lowrance line without actually having a test specimen. The emulator is also handy if you have a laptop because you can run the emulator and play around with it when you have a couple of free moments. Overall, I think that it is preferable to learn on the actual hardware if you have it available to you.

➢ Simulator or Demo mode on the actual GPS

Most handheld GPS receivers offer a simulator mode where you can give the GPS a location, speed, and direction from the comfort of your chair. Using this feature you can practice navigating using real waypoints and the actual hardware at realistic speeds.

Garmin handhelds

On most of the Garmin receivers, press the MENU key from the satellite page. Select SIMULATOR or USE INDOORS. Press MENU again with the satellite page and select NEW LOCATION or INITIALIZE POSITION to set the location. Go to the HSI or Pointer page. Up and down on the rocker pad will increase and decrease the

speed. The GPS will automatically follow the route, but you can manually change the track with left and right inputs on the pad. On the Garmin GPS 196, the zoom keys will change the altitude when you are on the HSI page.

An exception appears to be the Garmin eTrex series. The eTrex series has a "Demo Mode" option in the System Setup menu. In this mode, it is impossible to change the speed and track. The GPS will just follow the route.

Garmin Panel mounted GPS

There is a demonstration mode in the Garmin 400 and 500 series receivers. This mode requires activating a pin and cannot be done while installed in the aircraft. Lonestar aviation, www.lonestaraviation.com, makes a docking station that allows you to operate the GPS outside of the cockpit.

Lonestar also manufactures docking modules for other Loran and GPS receivers, but not all of the receivers have a demonstration mode. The demonstration mode is essentially a program built into the GPS and is not a function of the docking station.

Lowrance

On the AirMap series, the simulator mode is reached via MENU->MENU->GPS SETUP -> GPS SIMULATOR.

➢ Microsoft Flight Simulator

Simulator programs such as Microsoft Flight Simulator are a very useful training tool, especially for instrument training. I used early versions of Flight Simulator on the Commodore 64 as well as on the (at that time blazingly fast 12 Mhz. IBM PCs when I was working on my instrument rating. As primitive as those configurations were compared to what is available today, they were still very useful.

I realize that there are many different flight simulation programs such as X-Plane, Elite, and others that are worth investigating. I will limit my discussion to Microsoft Flight Simulator because that is the one that I am familiar with and it is widely available and relatively inexpensive. Often Microsoft Flight Simulator is written off as a game, which it is. However, I contend that it can be a useful training and proficiency tool in the proper context, especially for instrument scan and procedures.

I was curious to see if it was possible to integrate GPS into Flight Simulator in such a way that it would actually be a useful training tool. I found that the built in GPS capabilities of Flight Simulator were very poor, but could easily be supplemented with some third party solutions. The GPS implementation in earlier versions of Flight Simulator has no resemblance to any known GPS and is completely worthless for training use. Even worse, the value reported as TRACK in Flight Simulator versions prior to FS 2004 was actually HEADING. This was not some little nomenclature issue, but a fundamental conceptual error. FS 2004 fixes the heading and track error, but the Microsoft implementation of the Garmin GNS 500 has significant differences from the actual GNS 500. If you were to use the built in GPS capabilities of Microsoft Flight Simulator, it would be negative training.

Garmin 430/530

There is a third party solution from Reality XP, www.reality-xp.com, which provides an interface so that the excellent Garmin GNS 530 trainer can be used with Microsoft Flight Simulator. There is also a version for the Apollo GL-50. At the time of this writing, Reality XP only offers a version for the Garmin GNS 530 and Apollo GL-50.

If you try the Reality XP interface for Microsoft Flight Simulator, make sure that you read the manual. The mouse activates the GPS controls slightly differently than running the Garmin trainer in stand-alone mode. I have a basic computer that will only run Flight Simulator in 800 x 600 screen resolution. Each view (the outside, the instrument panel, and the GNS 530) runs in its own window. If you shrink the GNS 530 to fit in the panel, the screen is hard to read due to the way the pixels are calculated. If you run the GNS 530 at normal size, too much of the panel is blocked to fly the aircraft. My trick is to shrink and move the instrument panel so that I can see the main flight instruments while running the GNS 530 at normal size. It looks strange, but it works.

Figure 2-1

GPSout

GPSout is a program by Peter Dowson,
http://www.schiratti.com/dowson.html, that outputs GPS data from Flight
Simulator through the serial port of the computer that is running Flight
Simulator.

GPSout allows you to use some actual GPS receivers as well as some
emulators and other software running on another computer or PDA.

The readme file explains the setup, but it is pretty simple. Basically, copy
the gpsout.dll and gpsout.ini into the Modules folder of Flight Simulator.
You will have to edit the gpsout.ini file. The ";" turns a line into a
comment, so the settings that the computer actually uses are the lines not
preceded by the semicolon.

Garmin Handhelds

Using GPSout, I have been able to use Microsoft Flight Simulator with
both the Garmin 196 and III Pilot. Although I have not tried GPSout with
the Garmin 295 and 296, they would also work. It may also work with the
195.   Unfortunately, I was not able to get a non-aviation GPS to work.

I have found the following settings to work in the GPSout.ini file:

Sentences=AV400

        Interval=200
        Port=Com1
        Speed=9600

The GPS must be set to *Aviation In* mode in the setup menu. The GPS is then put in simulator mode. The non-aviation Garmin handhelds do not offer this *Aviation In* mode. I have experimented with using NMEA (National Marine Electronics Association) sentences, but was unable to get GPSout to work with non-aviation Garmin handheld GPS receivers. This is not to say that it is impossible, but I suspect that it is.

There is a slight problem where the position of the GPS slowly drifts from the Flight Simulator. I suspect that this is because the GPS starts with the Flight Simulator position and then updates its position from the TRACK and SPEED it gets from GPSout and ignores the GPSout position. This is a minor issue, just shut off and reactivate the simulator mode on the GPS to align the GPS with Flight Simulator. My guess is that this is not the fault of GPSout, but a function of the simulator mode on the GPS. Considering that the GPS was not designed to function with the computer like this, I do not fault Garmin for this problem.

Garmin Panel Mounted GPS

As I mentioned before, it is possible to operate the Garmin panel mounted GPS receivers outside of the cockpit using a docking station from Lonestar aviation, www.lonestaraviation.com. I do not know if it is possible to use GPSout with the actual hardware using a docking station and GPSout, but I think that it might be possible. If you try this, please let me know of your success or failure!

Lowrance

The Lowrance emulators that I have previously discussed also work with GPSout. The emulator is run on a separate computer such as a laptop. The computer running the emulator is linked to the computer running Flight Simulator with a null modem cable.

Although you may have to do some experimentation, I have found the following GPSout.ini settings to work with the emulator:

        Sentences=RMA, RMC, GLL
        Interval=200
        Port=Com1
        Speed=4800

There are some settings to allow the GPS to take NMEA input. The emulator also allows you to change these settings. However, do not change these settings to operate the emulator with GPSout. After you have GPSout installed and configured as well as the computers linked, just run the emulator. Do not change the emulator NMEA settings or put the emulated GPS in simulator mode.

A reader, Tom Pallechio sent me some of the settings that he found worked with an AirMap 500 (actual hardware) and should with the rest of the AirMap series. These settings and a variation on the menu selections should work with other AirMap receivers:

GPSout.ini:

[GPSout]
Sentences=RMC,GSA,GGA
Port=Com1
Speed=19200
Interval=200

Airmap 500 settings:

menu | menu | gps setup | use indoors
menu | menu | system setup | comm port
Baud 19200
Checked NMEA GPS Input
Configure NMEA
checked RMC and RMB
checked GGA
checked GSA and GSV

Notes:

On the Airmap 500, RMC and RMB are turned on or off together (one check box).

ON the Airmap 500, GSA and GSV are turned on or off together (one check box)..

Altitude wouldn't work unless I had both "GGA" and "GSA and GSV" checked.

Other GPS receivers and programs

GPSout should also work with a variety of other programs and hardware. Especially likely to work is anything that is designed to use an external GPS input such as the variety of PC software and PDA software.

Minor issue with GPSout

You may find that the magnetic TRACK reported by a GPS using GPSout may vary a couple of degrees from the TRACK in Flight Simulator. The problem is that the magnetic variation in Flight Simulator is static and represents a point of time sometime during the development of the program. Most GPS receivers use a magnetic variation model that includes time as a factor. This is usually a minor issue at worst. What is important is that comparing TRACK to BEARING on the GPS or software that uses the GPS out data will result in the proper behavior.

This will also manifest itself as other magnetic values such as runway alignments varying from current data by a couple of degrees.

Certainly, this is no fault of GPSout.

➢ Use GPS for other uses

There was a television commercial for Amazon.com where a man with a new GPS is walking around the house navigating with his GPS. His look is the same as a kid with a new toy. My wife just shook her head when she saw it because she had seen similar such behavior.

The commercial is somewhat inaccurate because the GPS will not get good reception in the house, but a similar type of approach in a field, parking lot, or park is not a bad way to learn how to navigate with a GPS. You can create several waypoints (look in the manual for how to do this) at either end of the area and navigate to them, between them, as a route, etc. Just remember that the GPS has no idea of which way you are pointing. It only knows track. This means that you should practice in the park at a brisk walk. It's your choice as to whether you simulate a crosswind component by walking sideways or twisting the unit. You can also walk backwards to demonstrate that you could fly a helicopter backwards and the GPS would indicate the same as if you were flying forward-- just don't trip or run into a tree while looking at the GPS screen!

Using GPS for other purposes will probably increase your navigational proficiency in general and should certainly increase your proficiency in using GPS. There are many recreational uses for GPS such as boating and hiking. The problem is that you have to have waypoints to navigate

to. You might think that this would mean that you have to have a mapping GPS or use expensive maps with latitude and longitude information. There are many sources for waypoint information, including free Internet sources, relatively inexpensive computer mapping programs, and even ordinary road maps. For this information I suggest my other text, *Basic GPS Navigation*, available on my website at www.cockpitgps.com.

Errors

You are going to make mistakes using a GPS. There are simply so many mistakes that can be made with such a complex piece of equipment. Although it is better to not make errors in the first place, it is even more important to be able to recognize the errors that you will inevitably make so that you may correct them. The following is just a short list of possible errors that come to mind:

➢ Navigating to the wrong point

Among the problems is that the GPS can execute erroneous commands. If you try to go to BARIN intersection instead of the phonetically similar BAIRN intersection, the GPS is fully capable of giving you guidance to the incorrect one even though BAIRN is 664 nm. from BARIN. If you tune in an incorrect VOR frequency, there is a reasonable chance that the incorrect frequency would be out of range and no erroneous navigation information would be given. If you put a W instead of an E in front of the longitude for a manually entered waypoint, the GPS is fully capable of navigating to this incorrect point even though it may be on the other side of the world.

Although an aviation database could contain incorrect data, it is not nearly as vulnerable to error as manually inputting coordinates for waypoints into a generic non-aviation GPS. The first generation of jumbo jets using the Litton INS required manual entry of coordinates. In fact, you could only enter nine and they were identified by the position they were entered into memory, 1-9.   If you are measuring waypoints directly from a chart then you have added another source of possible error. Not that manually measuring and inputting waypoint coordinates is dangerous, but it is more vulnerable to errors than selecting named waypoints from an internal database.

➢ CDI HSI mode confusion

Mode confusion is a human factors term that basically implies that the pilot thinks the aircraft is doing one thing but the airplane is in a different mode. For panel mounted GPS receivers, depending on the GPS, the CDI or HSI can indicate VOR/LOC data or GPS data. Furthermore, the OBS can

select a bearing or radial or it can do nothing and be irrelevant in the GPS mode. There is much potential for the CDI to be indicating something else than what you think it is.

➢ Solutions

Obviously it is better to not make the mistake in the first place. I see a dual approach. I see the first layer as trying to avoid the mistakes in the first place. The cure for this is proficiency. However, even more important is to be able to catch any errors that you have made.

Think of things you can do to help reduce the vulnerability to mistakes. For example; if you are using a generic GPS, use one of the sources in the *Aviation Waypoint Data* chapter of this book to download waypoints instead of manually entering them. If you are using an IFR GPS, make a CDI mode check part of selecting the approach.

Obviously a double check of what you do is important. However, this sometimes fails. One of the best analogies that I can think of is proofreading a text that you have written. You can go back and re-read an erroneous text and not catch it because you see what you expect to see even if that is not what is written on the page because you know what you meant. The same thing happens with GPS or any other systems such as autopilots.

One of the best methods is to check the action another way. Use the analogy of grade school arithmetic: the best way to check an addition problem is not to re-add, but to subtract one of the additives from the sum to make sure that you get the other. Check the action by the results rather than revisiting the input. Take going direct to a waypoint as an example: If you execute a direct GOTO with the GPS, make sure that you see the line going to the correct waypoint on the map display and that the distance and other navigation information look correct.

The biggest cross check is what I call the reasonability filter. This is simply being aware enough to catch a clue that something is wrong. Usually there is a clue such as an unreasonable direction or distance that should tip you off, but you have to display the data that will tip you off as well as having your personal reasonability filter operating. If the next waypoint is 600 nm. away and you are flying to a destination which is approximately 100 nm. away, then you have probably incorrectly programmed the GPS!

During the preflight stage, things like checking the route distance for reasonable distances and checking that the course between waypoints is approximately the correct direction will make a big difference.   Looking at

a graphic depiction to make sure that the route "looks about right" will also help. This is especially helpful if you are using a mapping GPS, but is still useful if you just look at the route plot on a non-mapping GPS.

In flight there are also things you can do. I am a big fan of operating in the map mode. I like to have it zoomed out so that the next waypoint is visible so that I can do a reasonability check on its location. This is also why I like to have the next waypoint displayed as a field. Although it is not technically needed to fly a track, distance to the next waypoint is also very useful. If the distance is not reasonable, something is wrong.

If you are flying VFR, a cross check might be as simple as looking out the window and verifying that you are seeing landmarks that you should be seeing.

If you are flying IFR and using a handheld GPS, you should tune the radios that you normally would tune if you did not have the GPS—this is for legal reasons as well as a cross check. If you are flying enroute IFR with a certified GPS you should look at the map display or your aeronautical chart occasionally to know where you are if the GPS quits -- in other words, keep your situational awareness above just knowing that you are on the preprogrammed route.

I have had the GPS catch a mistuned VOR and I have had the VOR catch a mis-programmed waypoint on the GPS. The point is to actively keep your situational awareness and have a cross-check.

A rule of thumb that I use is with a minor disagreement between the GPS and a VOR I have usually found the cause to be the lack of accuracy of the VOR compared to the GPS. Every time I that I have cross-checked with ATC, the accuracy of the GPS has been verified. If there is a large discrepancy, I investigate. The possibility that the VOR has somehow changed physical locations is slim, but there is a very reasonable chance that I have incorrectly programmed the GPS.

Although GPS opens up a whole new set of possible errors, the situational awareness and accuracy that GPS provides in many ways make these errors possible to catch if you use sufficient vigilance, common sense, cross checks, and airmanship.

Task Saturation and Prioritization

Your first priority is to fly the airplane. It is easy for the GPS to become a distraction and to become overly involved in trying to program the GPS at the expense of other more important tasks such as basic aircraft control. If you are not proficient at a specific GPS task it might be better to find an

alternative means. Even if you are proficient, there are times when it is better just to leave the GPS alone.

For example, if you have to intercept a radial and you are having trouble trying to figure out how to do it with the GPS, it might be better to use the way that you know such as using the VOR rather than to get wrapped up with the GPS task. When you get on the ground, figure out how you could have done it with the GPS and you can try using the GPS next time.

Dependability

Whether or not GPS will work or not has a couple of components. I will deal with the system issues shortly. Certainly, any electronic equipment can fail. My personal experience is that I have found GPS to one of the most dependable forms of navigation that I have used. However, always have a backup. This backup might simply be a chart so that you can look out the window to navigate using pilotage.

As an aside, even something as simple as pilotage can fail. In my youth, well before GPS, I was ferrying a skydiving plane which had no radios. This plane was a C-182 with the right door hinged at the top for skydiving and the forward bottom corner cut out so that the simple latch at the bottom of the door can be accessed from outside. I set my chart on the floor and by the time that I diagnosed the flutter and whoosh, my chart had passed through the cutout in the door. Since I was in unfamiliar territory, the landmarks were relatively useless without the chart to correlate them to where I was and wanted to be. I luckily found a small airport and was able to land and buy a new chart.

Anyway, carry spare batteries if you have a handheld, know where you are, and have another way of finding your destination--this is just good airmanship. Based on my non-statistical personal experience, I think that you will find GPS to be one of the most reliable navigation systems that you can use, but you still want to be prepared if it fails.

GPS System issues

The three main system issues are integrity, accuracy, and availability. Where these issues really become a factor is in deciding the limits of what GPS can be used for in the future. From a practical standpoint, I think that you will find GPS to be the most accurate and dependable system available.

➢ Integrity

Is the GPS information good? If there were an error in the navigation signals, how would you know and how quickly would you know. This is an issue for IFR approaches. For enroute navigation, especially VFR with a handheld, I do not see this as a significant issue. This is especially important for eventually using GPS for ILS type approaches. IFR receivers have a feature called RAIM, Receiver Autonomous Integrity Monitoring that uses redundant satellite signals to cross check the position solution. Monitoring of the GPS signal is also one of the features of WAAS. Both of these are discussed more in depth in the *How it Works* chapter.

➢ Accuracy

For enroute navigation, the accuracy available from GPS far exceeds the requirements. The Aeronautical Information Manual, AIM, quotes a GPS accuracy of 100 meters with a 95% probability and 300 meters with a 99.9% probability. The GPS receiver itself will give its estimate of accuracy based on the factors such as satellite geometry. Usually, you will see the accuracy far exceed that quoted in the AIM. WAAS, Wide Area Augmentation System, will increase this accuracy to 7 meters horizontally and vertically.

To keep this in perspective, the inertial navigation systems that guide airliners across the oceans can be several miles off course by the time they reach the other side of the ocean. There is also a common problem on some of the first generation glass cockpit aircraft such as the 757/767 known as map shift. Map shift is when the navigation computer suddenly recalculates the position and shifts. This can sometimes be up to several miles. Obviously, both the pre-shift and the post-shift positions cannot both be correct.

A good way to get a feel for GPS accuracy is to drive along in the car with a mapping GPS that shows roads. There will be some inaccuracy added to the position error from the inaccuracies in the map. However, it is nothing short of phenomenal that a widely available handheld device can show me traveling down a road, let alone showing a consistent displacement traveling back on the same road on the other side!

➢ Availability

In addition to whether or not the system is operating, there is the issue of whether you can get a signal-- are there enough satellites in view to

navigate with? As a practical matter, I have never been in an open area where I have not received sufficient signal coverage to navigate.

I have been in cities where the buildings have blocked the signal. This is an issue for road navigation, but it is generally not a problem for aviation navigation. I was on a bike ride through Manhattan once (www.bikenewyork.org) where there were several times that the bicycle traffic was so thick that there were traffic jams. During these stopped times, because of some signals being blocked and others bouncing off buildings, my GPS indicated position would bounce around Manhattan. While moving, the satellites would not be permanently blocked, but would come in and out of view. While I was moving, my track indicated within a city block of where I was supposed to be. I have also used the GPS while on a boat in the fjords of Norway being surrounded on both sides by mountains with little problem.

Compare this to VOR navigation where many areas are totally without coverage below a certain altitude.

Areas that will be affected by service interruptions are published by the Coast Guard at http://www.navcen.uscg.gov/gpsnotices/ .

➢ Radio interference

I have read of problems with some radios interfering with GPS receivers. The problem appears to be with other receivers in the range of 115 to 119 Mhz. Stan Protigal has quite a bit of information on his site at http://www.scn.org/~bk269/gps.html.   I have not found this to be a problem, but if you find your GPS losing a lock on the satellites, you might consider this as one possible cause.

➢ GPS backup

Although there has been talk in the past of using GPS as a sole navigation system, it has pretty well been accepted that there must be some sort of backup. It appears that the VOR system will be kept around for a while longer.

Interestingly enough, the FAA is considering updating the Loran system as a cost effective backup for GPS. Although, not quite as accurate as GPS, with newer technology the potential accuracy is much improved over Loran receivers in the past. Other issues such as Loran's vulnerability to P-static have also been addressed. See www.loran.org for more information.

It is also possible that technology may develop to make some sort of inertial navigation (see page 3-7 for an explanation) feasible for general aviation.

Lastly, the nature of technology is such that something not even under consideration yet may appear.

Legality of using a GPS
(U.S. rules)

➢ VFR

By default handheld GPS is legal for VFR navigation. Short of calling Miss Cleo's 900 number on a cell phone for Tarot Card based vectors, you can use any method that works to find your way. This brings us to the certification standards for handheld GPS units. There are none—even for aviation specific units. They are not certified and cannot be certified. Handheld GPS essentially operates outside of the FAA regulatory sphere.

➢ IFR

A GPS has to be certified for IFR use. Furthermore, the specific aircraft installation has to be certified. However, a VFR GPS, including a handheld GPS is still of considerable use and is a safety enhancement as well as being legal when used properly. This subject is covered separately in Chapter 11 .

Database Currency

IFR GPS installations must have a current database for all practical purposes. According to the footnotes in the AIM (Table 1-1-8, note 2) at the time of this writing it is possible to use a non-current database as long as you verify the waypoint data for IFR enroute and terminal use. However, it is required to have a current database for approach use.

There is no database currency requirement whatsoever for VFR use. Handheld GPS receivers come under this category. However, many pilots have violated airspace by using an out of date GPS database. I personally think spending several hundred dollars a year for a handheld GPS is not necessary. What is important is that you make sure that you have some form of current information. I recommend having a current chart, creating a route on the chart before flight and cross checking the GPS route against the chart before flight as opposed to just depending on the airspace depiction on the GPS.

How often do you need to update the database on a handheld GPS? There simply is no good answer. It would be wonderful to update it on the regular 28 day cycle, but this is not realistic. Some people update the database every year whether it is needed or not. This is probably fairly prudent and is reasonably inexpensive. Some people do not update the database for years unless they find a compelling change. This is probably fine as long as you are prudent and check a current chart which you should do in any case and you don't do a lot of long cross-country flights.

GPS assisted airspace violations

Many pilots are still violating airspace even with GPS onboard.

I have already mentioned in my discussion of database currency that you should set up a routing around any airspace and check it with a current chart before flight. Even with a current database, it is possible for the GPS to get you into trouble with airspaces.

Aviation receivers can be setup to display airspace boundaries and to give warnings before entering certain airspace classifications such as Class B airspace. These warnings can be a great benefit or a nuisance depending on the type of flying that you are doing. Thus, most receivers allow you to turn them on or off. Additionally, which boundaries will display and at what zoom level they will appear and disappear can be set. The ability to make these settings is a good feature and I would not want to see this changed. However, it is possible to have the GPS not display or not warn of an impending airspace violation if you have the GPS set up incorrectly for the mission.

Even if the airspace boundary is displayed, it is often difficult to decide what boundary a given line applies to. On the Garmin aviation receivers it is possible to cursor over the point to get a description. On a handheld GPS just press the rocker pad up, down, left, or right to start moving the cursor. On the Garmin 400 and 500 series, press in on the knob and then start moving the cursor. Move the cursor to highlight the line and press the ENTER button to get information on the airspace.

I think one of the keys to avoiding a GPS assisted airspace violation is in preplanning and preprogramming the route. This is important for not only airspace, but terrain also. When the route is pre-planned using a current chart or perhaps flight planning software, then the airspace depiction features of the GPS become a valuable cross check and situational awareness tool.

Also beware that the Garmin and some other GPS receivers will first navigate to the second point on the route rather than the first point. The

first point is used to define the beginning of the first leg. This is logical once you understand it. I have a more thorough explanation on page 6-1.

Airline Passenger Use

If you want to use your handheld GPS as a passenger, it is at the policy discretion of each individual airline. My airline allows passenger use without an external cable from takeoff through touchdown. Some airlines totally prohibit GPS usage. I would suggest the following sources for individual airline policies.

- Contacting the airline. The airline may have a policy on its web site.

- www.gpsinformation.net. This is an excellent GPS site maintained by a couple of retired engineers. There are a couple of links to articles on using GPS as an airline passenger.

  If you find that the airline that you are flying on does permit GPS use, you will need to book a window seat. You should be able to "view" enough satellites by holding the receiver to the window.

Chapter 3 How it Works

I took on this project because I did not find good coverage on how to actually best exploit the features of GPS to actually navigate. However, practically every book on GPS has an explanation on how it works. There are also many good free sources on the Internet. I have listed several sources towards the end of this book if you are interested in a more in depth explanation of how GPS works. What follows is a purposely very brief sketch of how GPS and a couple of other systems work.

Basic GPS

The GPS system is designed to have 24 satellites. The number may vary slightly as new ones are launched and old ones are retired. Each satellite is in an 11,000 mile orbit and transmits a very weak signal. The system is monitored and maintained by the U.S. Military. The satellites only broadcast to the user and the user only receives. There is no charge for use.

To start with, assume that all of the satellites and the receiver have a perfect internal clock. The clock in the GPS is closer to the accuracy of a cheap watch, but for purposes of explanation pretend that it is as accurate as the GPS clocks for now.

Consider the GPS signal to be like the peaks and ridges along the edge of a super long key. This code is generated as a function of time. The receiver is also able to generate the same code. The receiver matches the incoming code to the internally generated code except that there is a delay caused by the signal's travel time between the satellite and the receiver. The receiver measures how much it has had to shift the timing of its code to match the incoming code. Since the receiver knows how much time it took the signal to reach the receiver and the speed of travel of the signal, it can then calculate the distance from the satellite.

If you know how far you are from one satellite then you know that you are somewhere along an imaginary sphere around that satellite. If you know how far you are from two satellites, then you are somewhere along the intersection of where these two spheres intersect which is a circle. If you add another satellite, then you are somewhere where this third sphere intercepts the circle created by the intersection of the other two spheres. The sphere will most likely intercept the previous circle at two points. One of these points is where you are, and the other is not a reasonable solution – somewhere in outer space. Thus by knowing where you are relative to these three satellites the receiver with a perfect clock can know where it is.

Although no clock is perfect, the satellites have atomic clocks—pretty close. The clock in the GPS receiver is closer in technology to a digital watch. Light travels at 186,000 miles per second. If the receiver time was off by 1/100 of a second the calculated distance would be off by 1,860 miles.

For each receiver to have its own cesium clock would make GPS technology prohibitively expensive and non-portable. What the GPS receiver does is to use a cheap clock similar to a digital watch and add one more satellite to the calculation to correct the time in the receiver. The receiver shifts the time signal back and forth so that all of the imaginary spheres around the satellites intercept at one point.

For three-dimensional navigation you need to receive four satellites. Think of it as one satellite for each dimension and one for the time. For two-dimensional navigation you can scrape by with only receiving three satellites. If you know your altitude, the GPS can treat the center of the earth as a satellite reducing the number of required satellites by one. Your distance from the center of the earth is the radius of the earth plus your altitude. This is why aviation GPS models have baro-altimeter input and you may occasionally see a handheld GPS ask for your altitude during poor reception conditions.

If you remember a little algebra you can look at the GPS position solution as four simultaneous equations with four variables. The distance from the satellite to the receiver for each of four satellites are the equations. The variables are each of three dimensions for the location of the receiver as well as the correct time.

The receiver has to know where the satellites are. Consider this to be rough data and fine data. Each satellite transmits the rough data for all of the satellites. This is called the almanac. Each satellite transmits the fine data for itself. This is the ephemeris data. When your GPS is "acquiring" the satellites it is downloading this data.

Most GPS receivers directly measure velocity using the Doppler effect. The Doppler effect is the change in frequency as an object moves away or towards you. Think of an approaching train blowing it's horn. The pitch is higher as it comes towards you then when it goes away – this is the Doppler effect. The GPS receiver is able to use this principle to measure how fast the receiver is moving toward or away from each satellite. Knowing where it is, where each satellite is, how fast each satellite is moving, and what direction each satellite is moving, the GPS receiver is able to derive it's own velocity.

I should add that satellite geometry is also a factor. Ideally, the position of the satellites should be spread out. If all the satellites used to find a position are too close to being in the same plane, the accuracy of the position will be degraded or the GPS will be unable to find a position.

RAIM

If four satellites or three and an altitude are required for the GPS to calculate a three-dimensional position solution, the GPS can use the other satellites it is receiving above the minimum necessary to cross check for errors in the satellite data. This is basically how RAIM, Receiver Autonomous Integrity Monitoring, works. This is a required feature on IFR certified GPS receivers.

Newer GPS receivers, including inexpensive handheld GPS receivers, use the extra signals above the minimum that is required to further refine the accuracy of the position solution. The technical difference between RAIM and the possibly proprietary algorithms that consumer handhelds use is well beyond the scope of this discussion or my knowledge. However, I think that it is fair to say that an IFR receiver is optimized to give as quick of a warning as possible to bad or insufficient satellite data, whereas a consumer GPS and the aviation handheld receivers that they are based on them are not designed with this in mind. In fact, consumer handheld receivers are probably more designed to not give nuisance warnings than they are to give timely warnings of bad navigational data. This is not necessarily bad design as much as it is a reflection of differing design parameters for different uses. For the most part, this is not a big issue, but it is a very good reason why you cannot use a handheld receiver as if it were IFR certified.

Selective Availability, SA

SA is an intentional error introduced into the GPS signal to make it less accurate. SA is no longer used. I mention it because you will still see it in mentioned in literature on GPS.

Not only is GPS good for flying airplanes, but it is good for guiding bombs. To prevent somebody else from doing this, the military added a little random time shift to the satellite signal available for civilian use. This added some inaccuracy to the calculated position.

Error correction technologies such as differential GPS, WAAS, and LAAS take out much of the SA induced error. Thus a sophisticated enemy could negate the effects of SA. SA was turned off before September 11th, 2001. The New York Times had an article discussing the fact that the hijackers

had purchased Garmin GPS III Pilot GPS's. As a 767 pilot with extensive knowledge of the Garmin GPS III Pilot, I can say that the presence of a handheld GPS is totally irrelevant. The heating element layer of the cockpit windows blocks the satellite signal to a level that makes a GPS practically unusable.

Differential GPS

If you have an inaccurate piece of equipment, but know exactly how inaccurate the output is, then you know the correct value. For example, if your watch was exactly 6 minutes slow, you could look at your watch and add six minutes to know exactly what time it was.

Differential GPS technologies use a receiver at a known point to measure the error in the satellite signals and then broadcast this error. The receiver then corrects its position for this error.

WAAS and LAAS are both differential type of technologies. What is commonly called Differential GPS requires a separate receiver, which then provides input into the GPS. Several harbors have differential broadcasts, but it is not used in aviation.

WAAS, Wide Area Augmentation System

WAAS is a differential technology that uses approximately 25 ground stations across the U.S. and Canada to calculate the errors. Europe and Japan are also developing this technology, which will be known EGNOS (Euro Geostationary Navigation Overlay Service) and MSAS (Multi-Functional Satellite Augmentation System). The corrections are then broadcast via a geo-stationary satellite. A WAAS capable receiver is required, but no separate hardware is required.

WAAS will get GPS to an accuracy of 7 meters horizontally and vertically. This is good enough for standard ILS type of approaches. This means that any runway in the WAAS coverage area can have a basic ILS approach without having to install an ILS. ILS transmitters are very expensive to purchase, maintain, and certify.

Perhaps even more important than increasing accuracy, WAAS is designed to provide superior integrity monitoring compared with RAIM.

LAAS, Local Area Augmentation System

This is a quite some time in the future. This gets GPS to a category II and III ILS standard. Category II and three ILS are the low visibility and in

some cases blind landings made by airlines and business jets. This will use a local receiver to detect errors and transmit these errors via VHF.

What your GPS does when it starts up

You may have noticed that the amount of time it takes for your GPS to calculate a position varies. It may take an especially long time to get an initial fix when you use the GPS for the first time after purchasing it and it will get a fix very quickly when you start it again after just shutting it down.

The GPS has two types of data on the location of the satellites and their orbits. The first is a rough idea of where each satellite is located and is called the almanac. This almanac data is good for a couple of months. If the GPS does not have a current almanac it will take about 15 minutes to download.

The second type of data is the fine data more technically referred to as the ephemeris data. Each satellite broadcasts the almanac which is applicable to all of the satellites, but only broadcasts its own ephemeris data. The ephemeris data takes 18 seconds to download and is good for a couple of hours. It is this ephemeris data that the GPS actually uses for deriving a position. The almanac is used for deciding which satellites to "look for."

For most 12 channel parallel receivers, the GPS will start looking for the satellites that it expects that it can receive based on its current position and time using the almanac data. The GPS assumes that it is where it was last shut down and the clock is correct. However, you can change the position and time, this is called initialization.

No accuracy is required in this initial position. I have shut down my GPS in Florida and turned it on in Europe and was able to get a position. The GPS did not attempt to look for satellites that would be in view to the east because they would be invisible from Florida where the GPS was assuming that it was. Likewise, the GPS was attempting to download data from satellites that would be well over the western horizon from Europe that would be visible from Florida. However, there are usually enough satellites that would be visible from both Europe and Florida and eventually the GPS will get a position and sort things out.

As an experiment, I have been able to prevent a GPS from getting a lock by purposefully mis-initializing the position. However to do so, I have had to trick the GPS into thinking it was on the other side of the planet. The point of this is that accuracy of the initialization position is not important. Anywhere within a couple of thousand miles might work and within a couple of hundred miles is more than sufficient.

Since the GPS uses the almanac data to determine which satellites to attempt to receive, if the almanac data is grossly out of date the GPS will not have the correct data to calculate which satellites to look for. The almanac data takes 12.5 minutes to download. Thus, you should leave the receiver on for at least 15 minutes to a half our every couple of months to get a fresh almanac. Where I have seen this to be a problem is that someone buys a new GPS and goes outside to test his new toy but does not leave it on long enough to load a fresh almanac. Every time he operates the GPS it takes a long time to get a position fix. The solution is simple – leave the GPS on long enough to load a current almanac.

Most receivers have a mode where they can just start searching for satellite signals by cycling through the list of satellites in a trial and error manner. Obviously this will take longer than starting a GPS with a current almanac and a good time and position initialization, but the advantage of this mode is that it does not depend on an initialization position, time, or current almanac.

Quite honestly, getting an initial first fix usually is not a problem. When it is a problem, it is simply dealt with by giving the GPS a new position or using the automatic mode. Most receivers will prompt if you would like to use the automatic mode, continue trying, use a new position, or ignore the problem because you are indoors.

Once the GPS starts to receive data from a satellite, it will show a hollow bar on the satellite page. There are some minor variations as to when the bars go solid as to whether the particular satellite is actually being used for a position fix or if it is merely capable of being used for a fix because it is being received and the current ephemeris data has been downloaded. The point is minor and really just means that in the first case you may not see any bars go solid until at least four go solid simultaneously as you start up. In the second case, you may see the bars go solid independently and see a solid bar for a satellite even though you are not receiving enough satellites to obtain a position.

A "D" for differential superimposed on the bar means that WAAS corrections are being applied.

FMS (Flight Management System)

This is still a book about GPS. However, I quickly want to explain FMS to give you an idea of how the airlines fly if you are interested. FMS's are very expensive and are only on airliners and corporate jets. An FMS integrates not only navigational data, put performance and air data. The navigation portion of an FMS system makes navigation calculations by taking multiple inputs and then weighting them for accuracy. The actual raw input data, although available, is transparent to the pilot.

Many of the older FMS units just use VOR/DME. If you had a chart and several VOR/DME receivers, you could track your position by plotting radials and DME circles to see where they intersect. This is essentially how a basic FMS works – nothing magical.

FMS was introduced in the late 70's and early 80's.   GPS was introduced in the early 90's. FMS also takes input from inertial reference when available and GPS in more modern installations. If inertial or GPS data is present, it weighs the respective data according to its assumptions about each systems accuracy to calculate navigation information.

Inertial Navigation

Inertial navigation systems are very expensive and are only found on more expensive aircraft such as business aircraft and airliners.   Initially inertial units were very heavy and ridiculously expensive and were only used for rockets and missiles. Eventually the technology was available on international jumbo jets. Now, all recently manufactured airliners have inertial systems.

I think inertial navigation is an interesting navigational technology and I also think that a form of it might eventually find its way into general aviation cockpits.

Inertial navigation is called INS (Inertial Navigation System) if it is stand-alone, and IRU (Inertial Reference Unit) when it is used as an input to another system.

Inertial navigation is conceptually very simple, but it is amazing that it works. In a way it is nothing more than an advanced computerized and instrumented form of dead reckoning. Two things that you can measure about motion with no external reference are acceleration and turning. Acceleration can be measured as a force and is proportional to

acceleration, which the change in speed as a function of time, which is the change in position as a function of time.

For inertial navigation, you start with a known position and speed. Actually most INS units require you to be still while they initialize, but one of the parameters the INS takes into account is the speed of the aircraft in that an airplane that is not moving relative to the ground is still moving because of the earth is moving. This is a function of the initial location on earth.

If you know where you were and how fast you were going, and if you can measure your acceleration, a short period of time later, you can estimate your speed. If you know where you started and the cumulative effects of your speed since you started, then you can estimate where you are. If you do this along two axis and add some gyros to tell you which direction that you are going, then you have an inertial reference system.

What is absolutely phenomenal is that this is navigation without any outside inputs. However, inertial navigation drifts over time. After crossing an ocean, an inertial system may be several miles off course.

Transoceanic airliners without GPS use a trick where they use the middle position of three INS units to navigate. The term is "triple mix" and is different from averaging. The INS units are compared and the position is a combination of the middle latitude and the middle longitude of all three units. The advantage of this is that one INS could drift off course very badly and not affect the triple mix position. If the positions were averaged instead of triple mixed, the drifting INS would affect the average position also.

Inertial systems when working properly drift very slowly. Once over land an FMS will update the inertial position by comparing it to VOR/DME information. On many of the older INS units, the pilots would do this update manually by flying over a known point and comparing it with the INS position and then updating the INS. Many newer aircraft use GPS to constantly update the INS.

The inertial position will be as accurate as the last update source minus the drift from that time. If the update is frequent and accurate, such as constantly through GPS, this position is very accurate. If the GPS signal is lost, the INS will drift slowly, but the starting point of the drift is the last GPS update. The big navigational advantage over GPS alone is in redundancy. GPS updated INS is about the best navigational solution available today in terms of accuracy and redundancy.

As inertial navigation has advanced, spinning mass gyros have been replaced by ring laser gyros and quartz resonators. However, the principle of inertial navigation remains the same. Needless to say, this is a gross over simplification. However, it should give you an idea of how it works.

Few things can be developed just for aviation that will be economical. However, off the shelf accelerometers and solid-state gyros are being produced on a chip to measure acceleration forces for automotive airbags and traction systems and other non-aviation uses.

The GPS signal is line of site and thus blocked by buildings. In an urban canyon this can be a significant problem for automotive navigation systems. Many of the more expensive systems use various techniques similar to inertial navigation to orient the navigation system while the signal is temporarily blocked.

To be used for additional redundancy, a general aviation system would not have to have the stability to navigate for hours and thousands of miles, but minutes and tens of miles.

Affordable solid-state attitude reference systems are finding there way into general aviation. I can see it as only a matter of time before affordable inertial systems are designed to give general aviation navigation a sufficient level of navigational redundancy of inertial and GPS combined. This will be important if the VOR system is phased out.

Chapter 4 Which GPS

This book is not meant to be a buyer's guide. My primary purpose is to discuss relevant factors to consider in your purchase. Furthermore, since my experience is primarily with handheld GPS receivers, this is my primary emphasis.

In general, information on specific models of electronic gear has a short life span. Information becomes quickly outdated and the best source of information is from the Internet or periodicals. However, I feel that many of the specific receivers that I mention will be in use for quite some time both because they should continue to function for a long time and because they will trickle down through used markets as many owners upgrade to the "latest and greatest."

Thus, with the above caveat of an introduction, I offer this chapter.

Which GPS is best?

There are simply too many highly individual and competing factors to give a simple answer to the question of "Which GPS is best?" For one pilot a non-aviation Garmin GPS III is optimum if he were able to find a good used one at a good price. For another pilot, a certified panel mounted GPS would be best. The question you should ask is which GPS is the most suitable considering a variety of factors such as how you are going to use it and your budget.

Take the example of a new student pilot of modest financial means. Some would argue that he should not even be using a GPS. Setting aside this argument for the context of this chapter, I would argue that a generic GPS such as an Garmin GPS V, Garmin GPSMap 76, or Lowrance iFinder would be ideal. It is enough to learn some of the basics of GPS navigation, it is still an effective tool, and it can be used for a variety of non aviation uses. The money saved by buying this less expensive generic GPS as opposed to a much more expensive aviation specific GPS would be better spent on a couple more hours of flight time.

At the other extreme is a person who owns his own airplane, has an instrument rating, and flies into general aviation airports where having an IFR certified GPS adds greatly to the utility of the aircraft. A certified IFR GPS such as a Garmin 430 or 530 would be an excellent choice. Additionally, a Garmin 396 using the 430/530 output for input would add weather and terrain capability as well as being an excellent battery powered backup.

Of course, this is not to imply that a generic GPS is for the poor and that certified GPS receiver is a toy for the rich, just that there is a wide continuum or needs. What is an ideal GPS depends on many competing factors including usage and budgeting factors.

Update the software

If you purchase a handheld GPS, go to the manufacture's website and download the latest software. Sometimes the update is to fix bugs and sometimes it adds extra features. Most newer receivers include a computer interface cable. If you have an older Garmin GPS that does not include a cable and you do not want to purchase one, you can refer to page 5-6.

Aviation Handheld vs. Non Aviation vs. Certified Aviation models

One of the first decisions is whether or not to buy an aviation GPS. Aviation GPS receivers are usually at a substantial price premium compared to their non-aviation equivalent. There are many factors such as the extra engineering, extra liability, the logistics of an extra model, and in the end a relatively small market compared to the generic model. I would like the premium to be smaller, but I am not sure that the premium is unjustified.

I do not wish to steer anybody away from buying an aviation GPS receiver. I recommend an aviation GPS if you can justify it and budget for it. However, a non-aviation receiver is also a very effective tool when used with proper technique, legal limitations, and good airmanship.

➤ Non-Aviation GPS receivers

One of the points of this text is that a non-aviation GPS is a great tool for navigating an airplane. An expensive aviation GPS is not required for basic navigation. There are still many pilots who are missing out on the benefits of flying with GPS because they cannot justify the expense of an aviation handheld GPS. The shame of it is that many of these pilots would be very well served with a generic GPS. As fantastic as some of the new aviation hardware is, I almost find it more fascinating that a generic GPS for less than $100 can be used as an effective tool.

Essentially, a generic GPS will allow you to navigate from any point on earth to any other point on earth as accurately as an aviation receiver. The main limitation is in the lack of stored data. An aviation GPS will have

every fix, navaid, and airport stored in the country or region of the main database. Outside of the main database region, it might even have some navaid and major airport data. The non-aviation GPS is generally restricted to 500, but sometimes 1000 or more, user defined waypoints. Thus, you must enter the location of points as opposed to having a GPS with the points pre-loaded. The amount of data that that you can store as user waypoints is a fraction of the data available in an aviation GPS receiver. I have several sources of this data in the Aviation Waypoint Data chapter of this book.

To put this issue in perspective, the Litton inertial navigation units that have guided many L-1011's, DC-10's, and 747's across the oceans of the world would only store 9 waypoints. Compare this to a simple non-aviation handheld GPS that stores 500 waypoints. By the way, a handheld GPS is much more accurate than these inertial navigation computers.

With one exception, the Magellan 315 and its updated sibling the basic Sportrak, I know of no way of upgrading the software of a non-aviation GPS into an aviation GPS. Since the Magellan 315 is a special case, I discuss this receiver later in this section on page 4-30. Even though the Garmin Street Pilot Color Map looks like a 295, there is no way to upgrade the software on a Color Map to get a 295. Likewise, there is no way for the user to make the III Plus into a III Pilot. Furthermore, I know of no way to add a full aviation database to the non-aviation Garmin units.

➢ GPS units to avoid

Generally, any GPS made for general or marine use will work well. The receivers that I recommend that you avoid are those that are specifically made for automotive use or the very bottom of the line receivers such as the basic yellow Garmin eTrex.

Examples of such receivers are any of the specific automThese are fine GPS receivers and certainly I could get some navigational use out of any of them. However, they are either oversimplified or too tailored for automotive use for me to recommend purchasing with aviation use in mind.

➢ Data Fields

If you are looking at non-aviation receivers, make sure that it displays enough data on one screen to be useful.

The GPS has to give you a way of knowing the direction that you need to go, the direction that you are going, and how far off course that you are.

Furthermore, it is important to know what point you are navigating to and how far you are from it. Thus, the GPS should be able to display bearing or desired course, track, and distance to waypoint on one page. My recommendation is that you look at mapping units that are able to display at least four fields on the map display. I find that generally four data fields is sufficient, but more is better. I have more detail about what each data field means and which ones are most useful in the Navigation chapter.

➢ Aviation handheld GPS

I do not want to leave you with the impression that aviation receivers are a waste of money. If you look at the price of an-aviation handheld GPS in terms of its capability rather than the price premium over a similar non-aviation receiver, the aviation GPS is in many ways a bargain.

The fundamental difference between the aviation units and the non-aviation units is that the aviation units have a Jeppesen database of fixes, navaids, airports, and depiction of special use airspace. Also, many of the aviation units add some E6-B type of functions and some other bells and whistles such as descent planning.

Although aviation handheld receivers are designed to be used in an aircraft, they are not in any way certified. In many comparisons between an aviation handheld and a certified GPS, the handheld is in many respects more capable. This is especially true when comparing an older certified GPS with a newer handheld GPS. An exception is that most handhelds do not include the full instrument approach in the database, but rather the final approach leg. Where this becomes an issue is when a handheld GPS receiver is used in IFR operations. This is a very significant topic and I discuss it in more detail in Chapter 11 IFR use of GPS.

➢ Certified GPS

As capable as some aviation handheld GPS receivers are, they are not a substitute for a certified GPS if you need to fly GPS approaches. Again, I cover this in more detail in Chapter 11 IFR use of GPS.

Processor Speed

Manufactures do not publish processor speeds. If they did, it would probably be a useless metric anyway, because I am sure there is more to overall performance such as the chips that run the display.

For the most part, this is probably not a factor in purchasing. Since there is no standard metric, my purpose in bringing this factor up is that if you

buy an older model GPS the processor is one of the improvements that has been made in newer receivers. This means that an older receiver might be a little slow when doing tasks which take a lot of processing such as panning the map or calculating a turn by turn auto route.

Handheld interfaced with IFR GPS

It is possible to interface some handheld GPS receivers with a panel mounted IFR GPS so that any routes or directs that are entered in the panel mount are automatically reflected in the handheld without having to separately enter the flight plan in the handheld. The data comes from the RS-232 port on the panel-mounted unit in the handheld through the serial cable. The handheld interface must be set to "Aviation In." This should work on the Garmin aviation mapping handheld GPS receivers such as the 195, III Pilot, 295, and 296. There may be other receivers that this will work with, but I will leave that to your investigation.

Map vs. Non-Map

Mapping displays have dramatically increased the usability of GPS. This is why I advocate using the map display for navigation as opposed to the course guidance pages such as an HSI page. You can still buy a non-mapping GPS, but I would highly recommend buying a mapping unit. Mapping provides both situational awareness and an error check that you have programmed the GPS to navigate to where you really want to go.

Additionally, the map in conjunction with other methods can be used to help plot routes for flying VFR flights as well as provide situational awareness in flight. I have more information on this technique in the GPS Preflight Route Planning chapter. Once you have used a mapping GPS, you will not want to go back to a non-mapping GPS.

Most GPS receivers are sold as area specific models, such as Americas, Atlantic, etc. Within this area, the basemap coverage shows major bodies of water, roads, cities, railroad, etc. An important feature for non-aviation use is the ability to load more detailed maps for non-aviation uses. These maps are proprietary and non-aviation receivers have offered this ability for a long time. This is a feature that the more recent aviation handhelds such as the Garmin 196 and 295 and the Lowrance 500 and 1000 offer. Older designs such as the Garmin 195 and GPS Pilot do not offer this feature.

With the exception of compensating for the lack of coverage of the basemap in some regions of the world that I will discuss in the next

section, the extra detail offered from unloadable maps is not an important feature for flying. In fact, screen clutter is more of a consideration than lack of detail for flying. Some receivers, such as the Garmin 196, 295, 400 series, and 500 series have ways to quickly de-clutter the screen by eliminating detail. The GPS III Pilot and non-aviation mapping receivers allow you to adjust the detail with the map setup page.
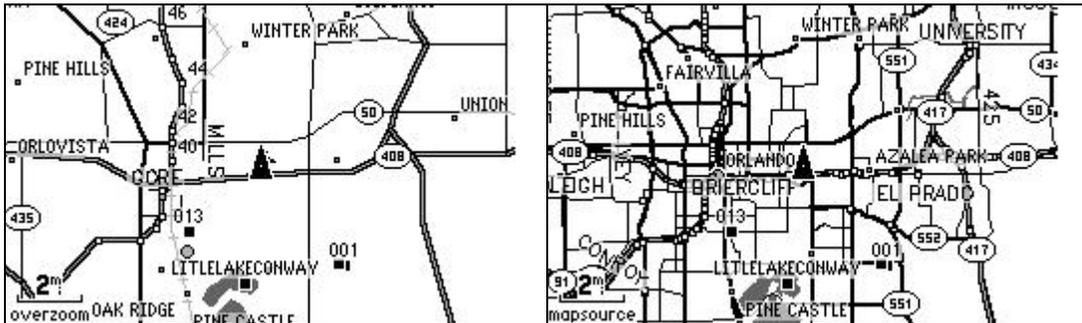
Figure 4-1

Figure 4-1 shows the difference between the internal basemap and the added maps. In this case, the comparison shows a Garmin GPS V internal map compared with the Metro Guide Map. If I were to zoom the GPS on the right even further, it would show most residential streets within the area that I have the extra maps loaded.

Figure 4-2

Figure 4-2 shows approximately how large of an area will fit into the 19 megabytes of memory in the Garmin GPS V. Obviously, there is quite a bit of variation in the area that will fit in a given amount of memory because of the difference in density of the information. You can fit quite a bit more data for more remote areas than for more urban areas. Not shown is that in the areas of the extra detail, it is possible to look up addresses, intersections, and points of interest directly on the GPS.

The extra downloadable maps may or may not be included with the purchase of the GPS. In the case of the Garmin 196, 295, 296, and 396 you will also have to purchase a memory module as well as the extra maps on CD-rom. Optionally, Garmin sells an automotive kit that includes the memory and maps.

If you are on a budget, the price of the mapping software is part of the total. However, it is something that you can purchase later. If you buy a non-mapping GPS, you will not be able to upgrade later. If you buy a mapping GPS, you can always buy the extra maps later. In the mean time, the basemap is very useful for flying and general orientation.

For all practical purposes, the only maps that can be loaded are those that are created and sold by the manufactures in a proprietary format. The type of maps available and the areas of coverage vary from manufacture to manufacture and compatibility varies somewhat with different GPS models of the same manufacture.

I often see people asking why the manufactures do not design receivers that allow you to scan your own maps instead of requiring the manufactures' proprietary software. No doubt, there is an economic argument, but the main problem is technical. The display of a map on a GPS or a computer program is a display of much more in-depth data. Take any paper map, such as a country or state map. Look at a city, now get a magnifying glass and look at the same city, lastly pretend you are looking at the same city with a microscope. At each stage of magnification things got bigger but the map gave no more information.

As you zoom in with a computer-mapping program at each new stage, more information can be displayed. Starting at a far zoom and moving in, you might see national boarders and oceans, then you will see state borders and highways, then you will see lakes rivers and major roads, etc. The point is that there is much more information than scanning a map would provide.

It is worth noting that there is point which zooming beyond will give no more information, on many GPS receivers you will see "Overzoom" displayed near the scale at this point. Zooming beyond this point just results in magnifying the current data rather than getting to another layer of detail. There is no harm in this and it may be useful – you just are not going to get more detail.

Non U.S. basemap caveat
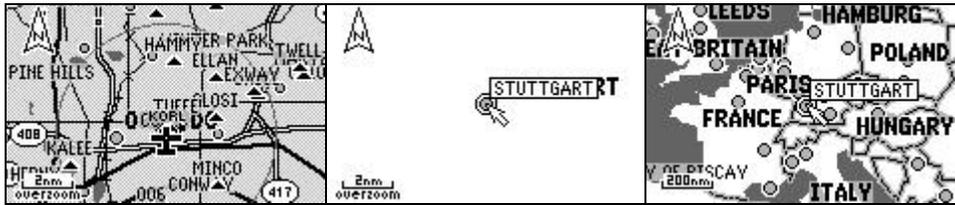
Figure 4-3 Garmin GPS III Pilot

Most mapping GPS receivers are regional. For example, Garmin sells Americas, Atlantic, and Pacific versions of their hardware. The aviation data and basemap detail is very sparse outside of the coverage area. As memory prices continue to plummet, I expect that this limitation will eventually disappear.

For many non- U.S. residents, it is usually less expensive to buy a GPS in the US. There is a catch in that the basemap of an Americas GPS lacks the detail for European countries. The Atlantic version purchased in Europe would have this detail.

Figure 4-3 shows the detail for Orlando, FL for reference on the 2 nm zoom and then the detail, or lack thereof, for Stuttgart, Germany at the same zoom. The screen shot of Stuttgart would have aeronautical features if I had loaded the Atlantic Jeppesen data. However, it would lack terrain features such as roads and bodies of water that are nice for VFR flying.

In the case of an aviation GPS, it is possible to purchase Jeppesen data for other regions of the world. However, it is impossible with most mapping GPS receivers, aviation or non-aviation, to update the basemap.

Depending on the GPS, it may still be possible to work around this problem. The work around is to load more detailed maps into the memory. If you have a Garmin GPS with the capability of loading extra maps, you could load Map Source World Maps into the memory of a Garmin mapping GPS.

The Garmin III Pilot does not offer memory for extra maps and the 1.4 megs of the GPS III Plus is very limited. However, for a variety of other GPS receivers, this might be an option.

Figure 4-4 is from a Garmin GPS Map 76 with Garmin MapSource World Map loaded for the Stuttgart area. Without the extra detailed maps, the detail is similar to the example with the Garmin GPS III Pilot in Figure 4-3. The detail is similar in most areas to what you would expect in a basemap

although some areas may have more coverage than others. The highlighted area of Figure 4-5 is 7.94 MB worth of WorldMap to give you an idea of area verses memory requirements.
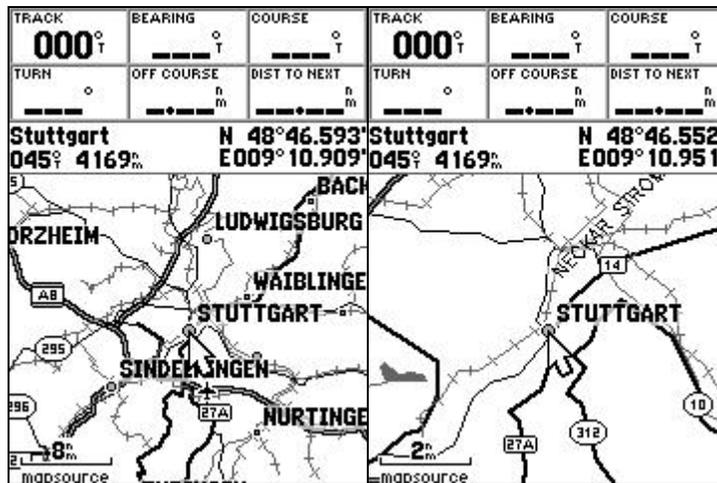
Figure 4-4 Garmin GPSMap 76 with MapSource WorldMap

Figure 4-5 7.94 MB of Garmin MapSource WorldMap

Terrain and Obstacle

Terrain and obstacle databases are separate features. Both are things that you can smack into, but terrain is the topography of the earth and obstacles are things like buildings, towers, etc. Terrain is a surface which virtually does not change with the exception of volcanic eruptions. The

data comes from the Space Shuttle Radar Topography Mission. For more information go to http://srtm.usgs.gov/index.html.

Obstruction databases are problematic in that they depend on proper documentation of structures such as buildings and towers being properly documented. Obstruction databases are primarily available in the U.S. with limited coverage for Canada, Mexico, and the Caribbean.

Garmin and Lowrance both offer models with terrain and obstruction data. Obviously, the handheld models are not certified. The terrain feature has the potential to save many lives when used properly and kill some people if abused.

Consider the difference between a railroad track and a guardrail along a road. A railroad track is used to guide the vehicle. It is critical that every inch is exactly where it should be. A guardrail is hopefully never used. If a guardrail is used, it is to prevent the car from going over the cliff if the driver has failed to keep the car on the road. Although it is desirable that every inch of guardrail is in place, it is still good to have a guardrail on most of the road even if a section is missing.

The terrain feature is analogous to the guardrail! You still need to be aware of the MEA, MOCA, grid MORA, etc.

If you find missing areas, take the time to inform the manufacture.

Weather

Garmin recently introduced the GPS 396. It offers the ability to display XM satellite weather. There are also some non-aviation versions such as the 396's sibling, the 376, that offer some of the non-aviation weather features.

Here is my layman's understanding of XM weather:

Think of this setup like a TiVo recording the Weather Channel. The XM satellites continually broadcasts the data and the GPS or computer goes into the cache for the data.   I have read somewhere where the update cycles are on the order of 5 minutes.

Because the receiver does not have to transmit requests to the satellite, the cost, size, and power required are considerable reduced. Also, since the satellite is not sending individualized data to every receiver, XM is not limited by the number of users.

Coverage is only available in the Continental U.S., coastal waters, and parts of Canada and Mexico. There is also a subscription fee involved.

I expect that the major U.S. airlines will have this within the next 10 years! (Sorry, I could not resist a little sarcastic commentary)

Antenna Issues

Another factor is where you actually intend on using the unit in the aircraft. Therefore, the physical shape and antenna configuration is important. How you would mount and orient a GPS would be different in a hang glider as opposed to a conventional cockpit. This has an effect on what antenna configuration will work best.

The GPS signal is basically line of sight and is prone to being blocked by the aircraft. There are many variations, configurations, and possible solutions. You will have to experiment to find a good location and as to whether or not you will need an external (to the GPS – internal to the airplane) antenna. Generally, the metal skin of a fuselage or high wing will block the signal and the windows will be transparent. I have no experience with fabric or fiberglass aircraft and GPS, but I suspect that the fabric is transparent, but some coatings may affect this. If you plan on using the GPS on the yoke, the ability to have an external antenna is important.

Several GPS's, such as the Garmin GPS II and III series, can be used on the glare shield. I am particularly fond of this location. The disadvantage is that a bigger GPS could block your view slightly. The advantage is that it keeps your eyes closer towards being out of the aircraft. Usually in this position the satellite reception will probably be adequate without having to hassle with an external antenna.
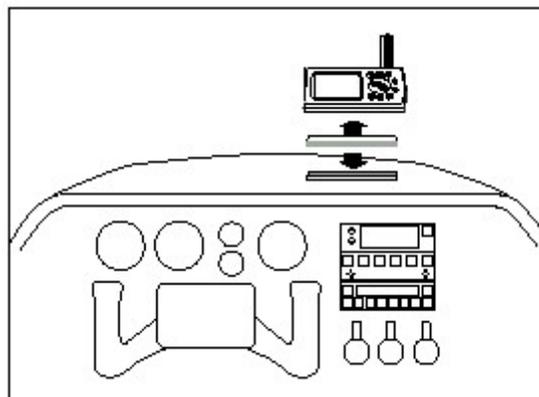
Figure 4-6

The antenna type is an issue in that it effects how you should orient the GPS in the aircraft. There are two types of antennas-- helix and patch. The helix antenna is designed to be orientated perpendicular to the earth like a flagpole and the patch antenna is designed to be orientated parallel to the earth.

It used to be possible to tell the type of antenna just by looking at the receiver. The patch antennas were the built in types such as on the eTrex, Garmin 12, and Garmin 195. The helix antennas usually had some form of protrusion such as on the Magellan 300 series or the Garmin receivers with the detachable antennas. However this visual distinction is no longer true. The Garmin 72 and 76 as well as the Magellan Meridian series have helix antennas. The good news is that a unit that might appear to have a patch antenna judging by the appearance of the case such as the Garmin 72 might have a helix antenna but I cannot think of a case where the opposite would be true.

In general, the helix antenna is better for aviation use. A patch antenna is fine for a GPS that is going to be held in your hand in front of you while hiking. It is less than desirable when you try to mount it vertically in an aircraft. While we are on the subject of holding the receiver in this manner: There is a very good reason why the buttons are at the top rather than the bottom on many GPS receivers. Hold one of these receivers in your hand and notice the proximity of the buttons to your thumb. This configuration, with the buttons on top, is ideal for single-handed operation.

There are many cases where a patch antenna might be fine. Cases that jump to mind are ultra light or hang gliding mountings.   This is not to say that a patch antenna unit would not work vertically, especially if the angle is more like 45 degrees -- it is just not optimum. The Garmin 195 has a patch antenna, but it also includes a separate external antenna. I have a Garmin eTrex Legend that amazes me at how well it maintains a lock for having a patch antenna while being held totally vertical.

Some aircraft have windshield heat layers that will absorb quite a bit of the signal. In this case, you can usually place an external (to the GPS) antenna in an unheated window. You might find that although degraded, the reception through this layer is still sufficient without having to resort to the hassle of the external antenna.

If you find that you need an external antenna and have a GPS with a removable antenna such as the Garmin II, III, V, 176, 196, or 295 a piece of coaxial cable with the proper fittings can be purchased from a place such as Radio Shack very inexpensively. Suction cups with clips to hold the antenna are available at office supply stores.

I have devoted enough discussion to this antenna issue to make it sound like it is a major complication. One of the things that amazes me is how well modern twelve channel receivers maintain a lock on the satellites in less than optimal conditions. Antenna type and location are certainly necessary to consider, but I think that you will find it easy to get a handheld GPS to work in the aircraft.

Mounting

Most of the manufactures sell various mounts for their units. In addition to standard mounts, Garmin makes a clever bean-bag mount for the glare shield. You might also check out:

> Ram Mounts, www.ram-mount.com
> Gilsson technologies, http://www.gilsson.com
> VersaTrue, www.versatrue.com
> PropellerHead Pilot Essentials,
>   www.propellerheadpilotessentials.com
> Lobster Mounts, www.lobstermount.com

Be careful that you are not making a change to your aircraft that would require FAA approval.

GPS mounting is an opportunity for a little "recreational engineering" activity. In addition to the official solutions, clamps, Velcro, rubber bands, tape, etc. can also be useful.

Recently, I discovered another unique "recreation engineering" mounting material that you might experiment with for a temporary installation—Silly Putty. Silly Putty will keep the GPS from sliding around on the glare shield. When you are done, the Silly Putty will peel away from solid surfaces. This is for a very temporary installation such as for a couple hours in a rental aircraft.

Silly Putty will not support a cantilever type of installation like a GPS standing straight up. You might be able to use Silly Putty to anchor the base of a GPS with the top resting against the windshield also anchored by Silly Putty. Obviously, be careful not to block your view. Silly putty will slowly flow over time and should not be left in place. Also, it is probably only marginally better than chewing gum for your carpet and fabric upholstery, test the material you plan on using it on first.

I have used Silly Putty instead of the removable disks that come with the Garmin GPS 196 to anchor the GPS to the dashboard of my mini-van. I stretched the Silly Putty into a string and put a small bead around the

base. The bead worked like a suction cup on the textured dash. I found that it held well even after several weeks on the dash in the Florida sun. It was also removable.

Receiver effectiveness (sensitivity)

What I mean by receiver effectiveness is sensitivity in the layman's sense – how well can the GPS get a signal. I would defiantly qualify as a laymen in with regard to understanding the various receiver issue.

Essentially, some GPS receiver receive much better than others. Generally, I recommend avoiding any of the older non-parallel receivers.

There are some newer receivers that are significantly more sensitive that are just coming on the market. At the time of this writing, none of the aviation GPS units have these new receivers. Although the extra effectiveness will always be welcome, any relatively recent 12 channel parallel receiver is fine for aviation and most other uses. The primary benefits of these new super sensitive receivers are for non-aviation situations where the GPS signal is only marginally useful such as through a coated automotive windshield, urban environments, and under a thick wet canopy of leaves.

Examples of GPS units with this increased sensitivity are the Garmin 60cx, 76cx, and Legend Cx. I have found the effectiveness of my 60cx to be significantly better than other receivers in marginal situations.

I do not know of any manufacture that still manufactures anything less than a twelve channel parallel receiver. However, you can find and should avoid them on the used market. If you remember, there are 24 satellites in the system. Up to 12 of satellites could be in view above the horizon. The other twelve are on the other side of the earth. A twelve-channel receiver basically has 12 separate internal receivers on a chip with each dedicated to one satellite. At the other extreme are some older GPS units that only had one internal receiver that time shifted between receiving different satellites. An 8 channel serial receiver is a receiver that will track up to 8 satellites, but it does so by shifting between the 8. Some of these receivers will not work above 100 knots.

There are a couple of variations between the single channel multi-plex and the 12-channel parallel. To keep it simple, only consider the 12-channel parallel units if you are looking at used GPS's.

WAAS

➢ IFR receivers

WAAS (explained on page 3-4) will offer increased accuracy and integrity. The biggest initial advantage of WAAS will be the integrity offered for IFR certified receivers. The promise of WAAS is that eventually it will add the capability to provide an ILS type of approach based on GPS without needing an expensive ILS installation at the airport.

For IFR receivers, WAAS is a big deal. I would perhaps argue that WAAS isn't that big of a deal in isolation, but because of a whole new certification standard and set of capabilities that come with it. The new WAAS TSO is C146, rather than TSO C129a. Among other changes, the receivers will have to take a position 5 times per second rather than once each second. Obviously, the software will include vertical navigation capabilities. This involves much more than a simple software upgrade.

Much of the benefit from WAAS is not so much because of the increased accuracy as much as it is from the improved integrity monitoring of the system that it allows. Because of this, new certification standards allow more capability to be built into the boxes and approaches to be designed around this improved capability.

➢ Handheld receivers

Because of their non-certified nature, handheld GPS receivers have been offering WAAS for quite some time. It is only more recently that WAAS has been certified for IFR use. Thus, with handheld receivers WAAS has been much easier to implement, but it has also not been a significant change.

I would not go so far as to say that WAAS is nothing more than a marketing gimmick for handheld receivers. More accuracy is always nice. However, I know of no handheld receiver that makes special use of WAAS in its software design.

The GPS signal used to be degraded by the government, this was known as Selective Availability, SA. The elimination of SA resulted in a significant increase in accuracy. The addition of WAAS to consumer handheld receivers has resulted in an incremental and sometimes unnoticeable increase in accuracy, but insignificant compared with the elimination of SA.

For a handheld receiver, WAAS is not a purchasing decision that is made in isolation. Generally, a newer handheld design such as a Garmin 196 will offer WAAS and an older design such as the Garmin III Pilot does not. I would not recommend buying a WAAS receiver just because it has WAAS but basing the decision on other factors. Using this comparison as an example, I would not recommend buying the GPS 196 because it has WAAS, nor would I recommend against the III Pilot because it does not have WAAS. I would recommend that you evaluate all of the other features and consider WAAS or the lack of it to be just one more feature, and perhaps a minor one at that.

WAAS is nice, but I have found that the going from 25 ft accuracy to 15 feet accuracy is not critical for finding an airport, but it could be useful for finding a tree stand, wreck to dive on, or for other non-aviation recreational uses. With SA off, the accuracy improvement offered by WAAS is going to be more like a factor of 1 to 2 rather than 5 to 10.

Battery Life

Battery life may or may not even be a factor. If you can plug the GPS into a cigarette lighter, the battery life is a non-issue. Take the manufactures claims to be optimistic. Some of the figures quoted for the non-aviation units are for operation in the battery saver mode. Battery saver mode is where the GPS saves power by taking fewer position samples. I would recommend against using GPS in the aircraft in the battery saver mode.

I have seen claims on that NiMh batteries last longer than alkaline batteries. It is my understanding that this is true in some applications, but GPS is not one of them. A GPS provides a steady draw over several hours rather than short periods of high drain. Under this type of load NiMh batteries do not last as long on a charge as alkaline batteries. NiMh batteries are still very good for GPS use, just do not expect a charge to last as long as alkaline batteries.   For reference, I find my GPS III Pilot lasts between 15 and 18 hours with generic alkalines and between 6 and 8 hours with NiMh. Garmin quotes a life of up to 10 hours.

Screen Issues

➢ Resolution

When comparing different mapping units look at screen resolution in addition screen size.

➢ Color

Color is now very practical for battery powered GPS receivers.

I have a relatively new cell phone with a color screen. It looks fantastic in the store. When I go outside, it is very difficult to read. This has traditionally been a problem with color LCD screens. One way to overcome this is with sufficient backlighting, which takes power. If you are using the GPS on batteries, this has been a real issue.

The newer color screens are very readable in direct sunlight. I have a Garmin Vista C that is very readable in direct sunlight and although I have not directly measured it, the battery life is very good. I have been very impressed with the Garmin Legend C, Vista C, 60C, 76C, 276 and 296 with regard to the screen. Not that these are the only GPS units with a good color screen, but if you are looking to purchase a color GPS and planning on operating it on batteries look at the sunlight readability and battery life.

➢ Backlighting

With a color screen such as on the Garmin GPS 295, backlighting is not a separate issue – either you like the screen and it is bright enough to see or not.

Most GPS receivers have backlighting. The specific technologies vary. Older monochrome GPS receivers tend to have electroluminescent background lighting. Some of the newer monochrome GPS receivers, such as the Garmin GPS 196 and GPS V, have white LED backlighting. In addition to the white LED displays looking better, I have found they are even useful during the day. The buttons also must be visible to use the GPS at night. On all of the Garmin receivers that I know, the buttons are also lighted.

One of the biggest things to look for with backlighting if you plan on flying much at night is multiple adjustment levels. For example, the GPS 76 and entire eTrex series only offer on or off. Several others such as the III, V, and 196 offer many settings between off and full.   Not having an adjustable backlight level or having the old green electroluminescent backlighting may not be a problem, especially if you don't fly much at night, but it is one more factor to consider.

By the way, the default is for the backlight to shut off after a couple of minutes. This can be changed in the settings to stay on indefinitely when selected. Obviously, the batteries will last longer with the light off, but

I have found that using a GPS with an LED or electroluminescent screen on continuously is surprisingly feasible using batteries.

For the most part, monochrome screens are readable in daylight. However, when wearing sunglasses even a good monochrome GPS screen can be difficult to see if the screen is shadowed. With white LED backlighting such as on the Garmin GPS 196 and GPS V, I found that the backlighting is sufficiently bright to help out. On other GPS receivers, the glare from a well-placed piece of white paper often helps to illuminate the screen.

Internal Compass

Several non-aviation receivers such as the Garmin GPS MAP76S and the Garmin eTrex Vista have an internal electronic compass. With the possible but doubtful exception of helicopter use, this feature is irrelevant for aviation use.

In order for the GPS to get directional information it must be moving. The only directional information that the GPS uses is based on this movement – it has no idea which way it is pointed. If you are using the GPS for something like hiking and are stopped then there is no movement and therefore no track data. This is where the compass comes in. Below a certain speed, which is adjustable but is usually a couple of knots, the GPS will use the internal electronic compass data instead of the GPS track data.

Internal Altimeter

Some GPS receivers such as the Garmin GPS 76S and Vista have a barometric pressure sensor. I do not know of any aviation handheld that has a barometric altimeter such as this. Remember that GPS will calculate a 3-dimensional position that includes altitude. Some of the certified aviation receivers have an input for barometric altimeter input.

Although I am not convinced that there is much if any benefit of the internal altimeter for aviation use, both the Garmin GPS 76S and Vista offer limited vertical navigation, VNAV, features that may be useful for flying. I have a discussion on VNAV and how to use it on page 9-8 as well as the IFR use in the *Vertical Approach Profiles*

Although irrelevant for aviation, both the GPS 76S and Vista offer more memory for maps and an internal compass in addition to the VNAV features.

Proximity Waypoints

This feature allows you to specify a waypoint and then draw a circle around it of a given radius. When you reach this radius, the GPS gives a warning that you are approaching the proximity waypoint. The warning doesn't come until you are inside the circle and there is even a little delay on top of that. So if you use this feature, add a margin. However, the circle is accurate that is drawn on the map page is of use for routing around things such as TFR's.

This appears to be somewhat of a marine GPS feature. By no means a complete list, but the Garmin 70 series, the 176, and the 196 have proximity waypoints. The Garmin 295 and III series do not have them.

Proximity waypoints are a nice feature. If you fly VFR and you buy a GPS that has them, I want you to know what they are. However, I do not see them as much of a deciding factor in choosing a GPS for aviaton use. I have more details of how they can be used as well as how you can avoid TFR's without this feature on page 9-24.

Non-aviation use

You may or not be able to find one GPS that suits all of your activities. There are so many competing considerations that you will probably have to compromise the suitability for one activity in favor of another or just have different GPS receivers for different activities.

Most handheld GPS models are a variation of a non-aviation GPS. In the past, the aviation version often had some of the functionality of the non-aviation receiver compromised.   For example, the Garmin GPS III Plus offers 1.4 megabytes of memory to load extra maps into. The Garmin GPS III Pilot uses this memory for aviation data and has no room or capability to load extra maps. Remember, at one time 1.4 megabytes was considered to be a fair amount of memory, this was a whole floppy disk worth of data!

This has changed. The newer aviation receivers offer the aviation functionality in addition to rather than in lieu of the non-aviation functionality. For example, the Garmin 96C, 196, 296 would be just for non-aviation use as their brothers the 76C, 176, and 276. In fact the aviation Garmin 196 offers automobile routing and the non-aviation 176 series does not.

Although no compromise must be made with respect to the functionality of the aviation verses the non-aviation version, you still may have to make a compromise if you plan on using the GPS for different activities.

The Garmin 276 is probably one of the finest and most versatile handhelds. The 276 is also excellent for use on a boat and in your car. However, it would be a poor choice for hiking kayaking. It is too big for hiking and although it would work well on my kayak, the expense would make me uncomfortable putting it at risk. Although a 276 would be nicer for flying, a 96C would work well for general outdoor use such as hiking and kayaking.

My point is that if you are using a GPS for different activities, you will have to decide how much of a compromise you are willing to make and which activity you want to optimize. Perhaps little compromise is even necessary. In my case, if I had a bigger boat instead of a kayak, the 296 would be a top pick for both flying and boating. You may find, as I have, that you want a separate GPS for other activities. Your alternative uses and budget will be the biggest factors in choosing a GPS that will also be useful for other activities.

The bright side to this is that even though it is may be hard to find a piece of GPS hardware that will suite all of your activities, proficiency and knowledge gained from one use will help in another use. To some degree the same principals of navigation hold true whether you are paddling at 4 knots or flying at 400 knots.

For other information on using GPS for non-aviation use, I would suggest a browse around www.gpsinformation.net. I would also recommend my other text, Basic GPS Navigation which is also available at www.cockpitgps.com. I have information on where to get non-aviation waypoints as well how to use ordinary maps with a GPS.

➢ Automotive Mapping

The Garmin 96, 196, and 296 as well as numerous non-aviation receivers offer automatic road routing. The key to auto routing is loading in extra detailed mapping data.
I thought that auto routing was interesting, but personally not that useful. Most of the streets in Orlando, FL, where I live, are laid out on a north-south and east-west orientation. It is relatively easy to find your way in a car.

I was in Atlanta for several weeks for training and found the auto routing of the GPS V to be tremendously useful. Atlanta roads are winding and definitely have no relationship to a grid type layout and half of them are

named Peachtree something or other. The GPS V processor is a little over taxed and takes a while to find a route, but it does work. The Garmin 196 has a very fast processor and the auto routing works very well.
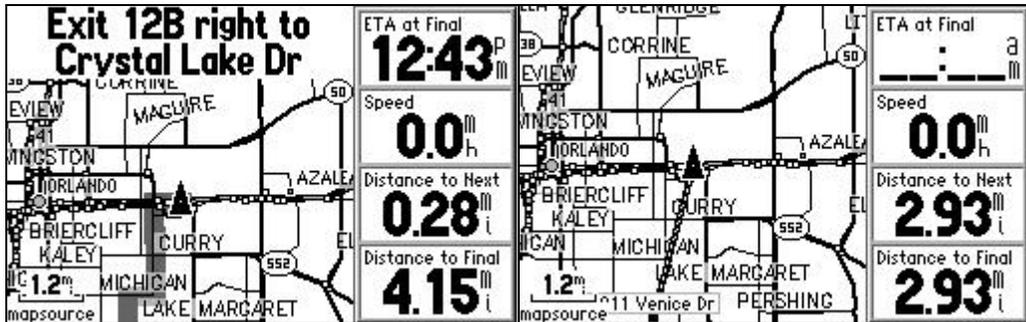
Figure 4-7

Figure 4-7 shows the difference between an auto route and a direct route. Both cases are using a Garmin GPS V. In the first screen I had the GPS calculate the fastest time to an address. While actually driving the route, messages pop up to alert you to the next turn. In the second screen, I had the GPS create an off road routing to the same address.   This second screen is the way in which a wide variety of non-auto routing GPS receivers can be used in the car.

Auto routing is slick technology. However, just because a GPS does not have auto routing, does not mean that it is useless in the car. Often just being able to know your position in relationship to the final destination is 90% of the utility. If you are truly unfamiliar with an area, you can create a route from the origin of the automobile trip to the destination. You can then use the map editing features to drag the route to intersections where you have to turn along the way. This is the same technique that I later describe for creating routes for VFR flights. Thus, you will be reminded of not only where you are in relationship to the destination, but also where you are in relationship to the next turn. I have used a Garmin eTrex Legend very effectively in this way.

For GPS receivers without the ability to load extra street level maps, or with no mapping ability at all, you still might occasionally find it useful to find the coordinates of an address and using the GPS to help find the address. A couple of sources of coordinates are:

- Computer mapping programs such as Delorme Street Atlas and Microsoft Trips and Streets. Many PC programs also allow you to use the GPS linked to a laptop computer for added function.

- On the web, most mapping sites do not give latitude and longitude, but some such as www.mapsonus.com do give them. Note that this site gives latitude and longitude in NAD-27 datum. If you enter the

waypoints in this format the error should not be more than a couple of hundred feet, but if you change the GPS to NAD-27 before entering a point, the location will be more accurate. Just make sure that you change the datum back to WGS-84 after you enter the point.

Marine Receivers

Some receivers are marketed as marine units that are otherwise very useful in the cockpit as a generic GPS navigator. Two examples come to mind, the Garmin 76 and 176 series. Both of these units have tide tables that are useless for aviation unless you plan on landing on the beach. However, this just makes them excellent GPS units with some features that do not apply to your intended use.

Where to get more information

The next section is by no meant to be an exhaustive evaluation of the handheld GPS units on the market. These are just some of the more common generic and aviation receivers. Garmin manufactures most of the ones listed. These are the units that I am most familiar with. I am not a shill for Garmin, but I might as well admit that I am a big Garmin fan.

The information on specific GPS units quickly becomes outdated. One of the best sources of information is the manufacture's web site. In addition to the product information, most of the manufactures offer the manuals for the specific GPS units online. The manual is a good way of investigating details of a specific GPS before purchasing. I have links to several of the GPS manufactures below. Garmin is the largest maker of handheld receivers followed by Magellan. However, Magellan no longer makes an aviation GPS. Lowrance still makes aviation handhelds.

- Garmin, www.garmin.com
- Magellan, www.magellangps.com
- Lowrance, www.lowrance.com
- AvMap, www.avmapnavigation.com
- Avidyne, www.avidyne.com
- Bendix/King, www.bendixking.com

Garmin

➢ **Legend C, Vista C, 60C, 76C** (non aviation)

I have a Vista C. The screen really is sunlight readable. Although I find the 30 hr battery life to be optimistic under real life conditions, I find the

battery life to be very good. The Legend C, Vista C, 60C and 76C vary in some features, memory, and case design. I think that any of these are suitable for using as a non-aviation receiver used for flying.

The biggest negative that I have is that the size of the data fields is such that when you display four of them on the map page, there is not much map space left. Ideally, I would like to see smaller data field blocks with smaller fonts.

Overall, I like these receivers.

➢ eTrex Venture, Legend, and Vista (non aviation)

My complaints about the original eTrex have been more than fixed with the new series. The Legend series, which includes the Venture and Vista, are fine little GPS receivers. They are designed to be small and easily usable with one hand for a variety of recreational activities. There are some design issues if you plan on using one in the cockpit which you should consider.

The first issue is the antenna. These newer eTrex versions still have a patch antenna with no provision for an external antenna. You will probably have to use it on the glare shield to get a good view of the satellites. The satellite reception with the unit vertical seems to be reasonably good considering that the optimum reception angle is horizontal with the patch antenna.

The second issue is the location of the buttons. The Legend series is controlled with buttons on the side and the click stick on the front. This is an excellent ergonometric design that allows easy operation with one hand when it is held in your hand. However, this is less than ideal when operating it while mounted such as in aviation use. You just have to realize that when you use it, you will have to more or less grab it. For example, even though you may have it in a mount of some kind, to use the buttons on the side you will have to brace the opposite side with your finger or thumb as appropriate – a grab. This is not a big deal and you can still do it with one hand, just do not expect to be able to operate the GPS with your index finger.

The last issue is the screen size. The screen is very small. However, it is also sharp and clear. I could see some vibration or presbyopia making it hard to read.

If you can tolerate and work around the factors that I just mentioned, the Legend series is an excellent little GPS for the price.

The Legend offers a course pointer or bearing pointer, which are essentially an HSI or RMI. As phenomenal as it is to think that you can get an HSI or RMI for the price of a Legend, use the map to navigate. Select the options of DISPLAY NAV STATUS and DISPLAY DATA FIELDS on the map display. Then select one data field to TURN and one to OFF COURSE. The trip computer page can be customized to display a variety of other data fields.

➢ The Garmin II, III, and III Plus (non aviation)

The Garmin II, III, and V have a case that allows it to operate in either portrait or landscape mode. Avoid the non plus II, the 8 channel serial receiver is insufficient for using in the aircraft. The II+ offers an amazing amount of performance for less than $200, and is sufficient in many ways; but the price of mapping GPS units has reached the point that to give up this feature is false economy. If you go with the II Plus, there are two versions. The later models include a database of cities. These are displayed dots with a label.

The III series has mapping, a better menu driven interface, and a higher resolution screen than the II. The III is a big improvement over the II. The III+ adds the ability to download 1.4 megabytes of MapSource maps and the III Pilot is the aviation version. Due to the limitation of 1.4 megabytes, the III Plus cannot load all MapSource products. It will handle Roads and Recreation, but not MetroGuide. Many of the examples in this book are made using screen captures from a III+.

The ability to upload extra MapSource maps for more detail is nice for non-aviation use. However, this capability makes no difference for aviation use. Both the III Pilot and III (non-Plus) lack this ability. Because of the lack of ability to upload more detailed maps, the III is considered obsolete. Because of this, you might be able to find a deal on a used III.

Do not let the size of the III series deceive you, especially the III Pilot. These are very capable receivers.

What I really like about the II and III series is that due to their small size, they can often be used by setting them the glare shield. They have a triangular cross section, so some type of mount is required to keep the face vertical. You might try the Garmin beanbag mount (Part 010-10195-00). You might also try the Garmin dash mount. The dash mount comes with Velcro to keep it secure on the dash. If you are unable to attach Velcro to the glareshield, a small bead of Silly Putty around the edge of the mount will anchor the receiver pretty well. The Silly Putty should just peal up with no problem. However, this is not true for all surfaces. Test the surface before making an embarrassing mess.

One of my favorite mounts for the III series is to use a mouse pad and epoxy a triangular piece of balsa from a local hobby shop to it. Velcro is then epoxied to the hypotenuse of wood and the mouse pad. Self-adhesive Velcro is attached to the GPS. I attach the hooks to the mount and the wool to the GPS. This allows the GPS to work with the beanbag mount as well as allowing it to slip into a case without catching. The Velcro can later be removed from the GPS. Thus, no permanent modification is made to the GPS. The advantage of this homemade mount over the Garmin dash mount in addition to cost is that the battery is easily accessible and it is more compact. As with the Garmin dash mount, a little bead of Silly Putty or Velcro will keep the receiver from sliding around.

Locating the GPS on the glareshield has many advantages. This location is close enough to read the relatively small screen. The small size is relatively unobtrusive. Ideally, the GPS on the glareshield will not even block any outside field of vision. This location is good for scanning being between the instrument panel and the windshield.

Another advantage of the II and III series is that when used on the glare shield, it is unlikely to need an external antenna. All of these factors make the III Pilot very portable and hassle free.

Only the III Plus includes a computer interface cable, I have more information on making a homemade cable on page 5-6.

➢ Garmin III Pilot (aviation)

The III Pilot is the aviation version of the III series. It adds such features as VNAV, an aviation database including airspace boundaries, and E6-B functionality.

Cons: It does not have the ability to upload extra detailed maps, it lacks final approach legs, it is not WAAS capable, and the OBS mode does not compensate for the misalignment of the VOR receivers (see page 9-25).

Despite all of these "nots", this is still one of my favorites. Perhaps it is just like a comfortable pair of shoes. As I have mentioned, I do not think that WAAS is a big deal for a handheld receiver. The ability to load extra maps is really only useful for non-aviation use. For non-aviation use, you might consider purchasing another GPS. I think that the GPS 196 is a fantastic GPS, but I am not going to take it on my kayak. It is a little too big, but it is definitely too expensive to put at risk. For kayaking, I prefer to take my Take the GPS 196 is an example. As gThe III Pilot offers the functionality that you will use 99% of the time

➢ **Garmin V** (non aviation)

The Garmin V has the same case design as the GPS II and III. However, the screen is sharper, the backlight is a very clear white LED, the processor is faster, and it has 19 megabytes of memory for additional maps. It also has turn by turn routing for automotive use.

There is much I like about the GPS V. The Garmin V is usable for aviation. However, as of software 2.50, I do have some disappointments with regard to aviation use. This is especially disappointing because of the potential of this GPS.

There is no active waypoint page. It takes several keystrokes to drill down through the menus to find the active route. On most Garmin receivers, if you execute a GOTO to a point beyond the active waypoint, the GPS will continue to sequence along the active route after reaching the GOTO point. On the GPS V, a GOTO cancels the route. The GPS V will allow you to GOTO a waypoint on the active route, but will not continue to navigate beyond without re-activating the route.

In spite of these faults, the GPS V is worthy of consideration in the non-aviation GPS category.

It has been my experience that Garmin is very good about updating software. If Garmin fixes these problems, the V will be an upgrade over the GPS III series.

➢ **Garmin GPS 72**(non aviation)

The Garmin 72 is non mapping GPS similar to the 76 except that it has a lower resolution screen, no ability to attach an external antenna, and it does not include a data cable. I could see where the lack of external antenna may be a problem if you were trying to use it on a yoke in a high wing metal skinned airplane. If you can mount the GPS to get a good view of the satellites, the GPS 72 offers a good capability for the money. I have information on connecting the GPS to the computer with a homemade cable on page 5-6.

➢ **Garmin pre color 76 series** (non aviation)

The GPSMAP76 works well. It might be a little large to have in your field of vision on the glare shield, so you might need to use it on the yoke. The good news is that there is a provision for an external antenna if you use it on the yoke. Of course, that is extra. One complaint that I have, which I hope will be updated, is that there is no way to select a data field to display the waypoint being navigated to on the map screen. If you use a

76, I would suggest setting the map to auto zoom so that you can always see that you are navigating towards the waypoint that you intend. The screen resolution is good and you can display up to twelve data fields if you so desire.

Garmin has announced new color versions of the 76. In addition to the color screen, they will offer auto routing and much more memory. I have no reason to believe that these will not be very good non-aviation receivers suitable for cockpit use.

➢ Garmin 176 (non aviation)

This is available in both a color and gray scale version. The biggest advantages are a 320 x 240 resolution screen, 3000 waypoint capability, and ability to add memory chips to add Mapsource maps. The color version is advertised to be readable in sunlight which is unusual for color screens. This screen technology is similar to the Compaq iPaq PDA. This is a big GPS but it is perhaps smaller overall than the 295 and Street Pilot GPS. It looks like this would be ideal for automotive and marine use in addition to being a suitable non-aviation GPS for flying use.

➢ Garmin 276 (non aviation)

My comments about the 176 apply to the 276. The 276 is the non-aviation brother of the 296. The 276 has auto-routing, a bright color screen, fast processor, and a built in rechargeable battery. If you buy the City Select maps and the memory card to load them in, the 276 would be excellent in the car. If you are considering a non-aviation unit for flying, the 276 would be one of the better GPS units for cockpit use.

➢ Garmin 376 (non aviation)

The 376 is the non-aviation sibling of the 396. The 396 offers XM weather. The XM weather features are different from the 396. For example, it appears that METARS are available on the 396 but not on the 376 as one might expect. However, Nexrad radar is available on the 376.

➢ Garmin 92 (aviation)

Although a GPS 92 offers an inexpensive aviation GPS, it is non-mapping and I would not recommend it. The price of the III Pilot has come down to the point that I would consider the money saved by buying a 92 over a III Pilot to be false economy.

➢ Garmin 96 and 96C (aviation)

The 96C is an aviation version of the 76C and the 96 is a monochrome version of the 96C. The 76C is available at a variety of boating and outdoor stores.

I have two complaints. The 76C and 96C screen has less resolution than the GPS MAP 76 and is slightly smaller. I have the feeling that this has to do with the availability of choices of the new color screens available to Garmin. I have a Garmin Vista C that has the new color screen technology similar to the 96C and am quite pleased with it. Although I wish that the 96C had a larger and higher resolution screen than the GPS MAP 76, this is still an excellent screen. The color is very nice and the sunlight readability is very good.

My other complaint is that the size of the data fields is such that there is not much map display left after using all four. As I discuss else ware in this book, I am a big fan of using the map display for situational awareness and the data fields for precision. I would prefer to see an option of displaying smaller data fields with smaller fonts and not wasting the pixels on the status bar at the top of the screen.

On the good side, the 96 series is very versatile and can be used in a variety of applications.

➢ Garmin 195 (aviation)

Garmin has just introduced the 196. The 195 was an excellent design for its time, but it is several years old. If you like the big screen, I would recommend the 196. The 196 screen is 3.8" instead of 4.1", but it is 320 x 240 pixels as opposed to the 175's 160 x 240.

➢ **Garmin 196** (aviation)

The 196 has been eclipsed by the 276. However, it is still an excellent GPS.

The 320 x 240 pixel screen is a sharp. The white LED backlighting is bright enough to improve visibility during the daytime. Even with the backlighting on, I find that I get at least 5 hours on some not so new NiMh rechargeable batteries and well over 10 on alkalines. The processor is also fast enough to handle such functions as panning on the map screen and automotive routing very well.

If you do not live near an aviation dealer and are considering mail order, you should be able to find a GPS 176 locally to get and idea of the basic physical form of the 196.

To take full advantage of the non-aviation features, you will need to purchase a memory cartridge and Map Source software. You can load the extra maps from your computer to the GPS directly with the cartridge installed or you can purchase a separate USB programmer to program the cartridges.

➢ **Garmin 295** (aviation)

My only experience with 295 is playing with it at the Garmin booth at Lakeland. The biggest feature of the 295 is the color screen. Until recently, the 295 has been the top of the line handheld GPS. The 196 offers everything that the 295 offers and more, except the color screen. Even though the 295 is a couple of years old, it is still an excellent GPS. The downsides are the battery life and size

The 295 is physically the same as the Street Pilot III. The operating software is very different, but if you need to get an impression of the physical characteristics the Street Pilot III might be easier to locate.

The 295 offers the ability to load more detailed MapSource products if you add extra memory modules. Even thought the 295 does not offer automatic road routing, it is still useful for automotive use. You can upload MetroGuide maps and look up addresses and business. You will then get a bearing and distance as well as an RMI.

The 295 will run from batteries, but I would consider the primary power source to be the cigarette lighter.

➢ **Garmin 296** (aviation)

I have seen and had the chance to briefly play with the 296 and it is very nice.

The screen is the same as the iQue and is very sharp. There are some angles where it is hard to read in direct sunlight, but overall it is very good. It might take adjusting the angle just a little for best viewing.

The size is similar, but slightly smaller than the 176/196. The 296 has a built in rechargeable battery. When it is externally powered, it also charges the battery. Battery life should be around 10 hours. For a small percentage of pilots without a power source, loosing the ability to replace the AA batteries is a loss. Worst case; buy an extra battery from Garmin. For most pilots, the built in rechargeable battery is a nice enhancement.

The terrain warning is nothing short of awesome. You can move the cursor over any spot and it will tell you the terrain height. Furthermore, the GPS 296 will warn you of impending terrain or obstructions.

See my general philosophy regarding the terrain feature on page 4-9.

➢ **Garmin 396** (aviation)

The 396 is essentially a 296 with XM weather capability. XM weather is an incredible feature, see Weather on page 4-10.

Magellan

Magellan, now Thales Navigation, has pulled out of the aviation market. However, they still produce several non-aviation GPS units. Of these, the 315/320 or Sport Track is the only product that I would recommend for the purpose of using in the cockpit. The SporTrak is just the newest version of the 315. Magellan has added WAAS and changed the case, but the operating system appears to be the same as the 315/320. Thus, my comments about the 315 and 320 apply to the SporTrak .

➢ **Magellan 315/320 and SporTrak**

Magellan produced an aviation version of the GPS 315, the 315A. The 315A was a package that included a computer interface cable, the 315 receiver, and a special version of the Data Send software containing aviation Data. The 320 is just a 315 with some preloaded nautical waypoints. Although you might still be able to find a 315A or the aviation

Data Send software separately, Magellan has stopped updating it and the last one that I know of is at least a year old. The good news is that this aviation data is available for the United States only on the web for free and will work with the generic Data Send software.

If you are familiar with the 315, the site for the aviation database is http://home.stny.rr.com/bkw/315/. I followed the instructions on the site and it worked as advertised. If you use this update please e-mail the creator, Brian Wade, a note of thanks and encouragement so that he continues to provide them. It is also my understanding that the SporTrak, the basic non-mapping model, will also work similarly to the 315 with regard to loading this data.

Recently, I have found, but not personally tried, a similar source of international data at http://fly.to/gavdb.

Most GPS receivers will handle 500 user waypoints—some will handle up to 3000. However, many GPS receivers have many more non-user waypoints such as cities, highway exits, etc. These waypoints are known as Points of Interest, POI. The Data Send software lets you send various categories of these POI's to the GPS. The limitation on the number of POI's on the 315 is 18,220 as opposed to the limitation of 500 user waypoints.

Using the Data Send software you select what types of POI's to upload, select a rectangular area, and then send them to the GPS. While it is not possible to upload a full worldwide database into the 315, it is possible to upload 18,220 points. This is enough to upload all of the U.S. navaids, public airports, and fixes approximately east of the Mississippi. It is enough to load every public airport, private airport, and navaid within the continental U.S. There are no airspace boundaries or any other of the neat things associated with the most aviation GPS receivers – just the capability to upload 18,220 aviation points.

If you want to sample this database before you buy the Data Send software or 315, you can download the free Data Save software from the Magellan site, http://www.magellangps.com/products/datasend.htm. This site has the information on Data Send as well as a link to the free Data Save software. Unzip the aviation database into …/Program Files/DataSave/Backgrounds folder. You will not be able to upload this data unless you have Data Send rather than the free Data Save software. You will see the names rather than the identifiers; for example, Executive instead of ORL. When you upload these points into the GPS using Data Send and then look them up on the GPS you would look for ORL. Data Save, in this context, only lets you see what aviation data is available.

Here are some notes about specific features:

- There is no warning of a lost signal. The 315 just continues to show the last position before loosing the signal. The key to catching a loss signal is to note the lack of speed or change in distance to the waypoint.

- There are only two of the Nav Screens that I would recommend using for navigation. These are Nav 1 and Nav 2. The problem with the Compass and Road screens is that they do not allow you to show a cross track error value.

- Even thought there is not a dedicated nearest airport feature. Just GOTO the airports sorted by distance instead of alphabetically.

- If you create a route and execute a GOTO, you can cancel the GOTO by pressing GOTO -> MENU->CLEAR GOTO->ENTER.

- Selecting a waypoint is not as good as some of the other GPS units that I have seen. However, left or right on the cursor pad will jump a page at a time. If you are looking for a point in the second half of the alphabet, start at the end and work backwards by pressing up or left on the cursor pad. The smaller the region that you load, the quicker you can select a waypoint.

Conclusion: The 315 a very basic GPS receiver. If it were a computer, this would be the DOS 12mhz model. Although it is not one of my favorite GPS receivers -- for the price, when you add the availability of the aviation data, I think that it is a good receiver. It has adequate functions to navigate. I have seen the 315 with a cable and Data Send for $140 on eBay. Purchased separately at full retail you will spend a little over $200.

You could probably get a Garmin GPS III+ in the same price range as the 315, cable, and Data Send software. It is a tough call as to whether mapping or being able to load all of this aviation data is more valuable. If you are flying VFR and usually not making long trips, the 500 user waypoints are probably sufficient and the mapping of the Garmin III+ would probably be more valuable. If you are flying IFR and/or fly beyond a local region, the large amount of data offered on the Magellan 315 would probably be more valuable

➢ **Magellan 330, Meridian series, and SporTrak Pro** (non-aviation)

I find that the Magellan mapping GPS receivers have some significant shortcomings for aviation use. I used to recommend against purchasing one for aviation use, however the database of airports in the basemap is

significant enough that they are worthy of consideration for basic VFR routings as an inexpensive non-aviation GPS. However, this is still not an enthusiastic recommendation.

Figure 4-8 shows the ability to look up airports in the basemap on the 330. All of the Magellan mapping receivers appear to operate in a similar fashion and offer similar data. Select MENU -> DATABASE ->AIRPORTS. Before you actually select AIRPORTS, you will see a selection at the bottom of the screen labeled "Find By." Move the selector pad left and right to choose ALPHABETICAL or NEAREST TO. If you choose ALPHABETICAL and then AIRPORTS, you will be able to type in the name of the airport.

If you choose the NEAREST TO and then select AIRPORTS, the next screen will list the airports with a box at the top where you can select what you specify nearest to. The default is POSITION, but press the ENTER button and you can select several references. Among the references is that you can move the cursor to a position on the map screen before you start this whole process and then you can select CURSOR as one of the options.

Figure 4-8 Magellan 330 v. Garmin III Pilot

When I compare the airports listed in the Magellan 330 basemap to those in the Garmin GPS III Pilot in Figure 4-8, I find that the coverage is very good. In fact, I found in a couple of test spots that the Magellan listed airports that the Garmin III Pilot did not. The Magellan uses the airport name instead of the identifier. Their is no way to update the data for new airports or to delete closed airports. I do not know the Magellan's source for the location data. I would not trust this data to the level of a current database in certified IFR panel mounted GPS or even an out of date database in an aviation handheld. However, if you double check the location and use some common sense, I think the data can be useful.

Based primarily on my experience with the Magellan 330 and also experimenting with the SporTrak and Meridian I will specify some of my gripes:

- The map page only displays two data fields.

  While I could find my way with two data fields, this is really too few to use the map as the primary navigation interface other than basic GOTO navigation. Certainly, you can set the display to TURN and DISTANCE and adequately navigate to a point, but if you want cross track error for following a route, you will have to sacrifice one of these two data fields. There are other pages that offer more fields, but why have a map display if you cannot navigate with it.

- Choosing user waypoints is unwieldy.

  I loaded over 300 waypoints into the 330. There is no easy way to select a waypoint by name. If you choose to select one from the list, you must sort through the whole list. If you have just a few waypoints, this is not a big deal. With the 300 that I loaded in, this was just unworkable.

  To choose points of interest such as a city, Magellan offers a key grid. This is like a keyboard displayed on the screen where you select the keys with the cursor. This is an acceptable and effective way of making a selection. Unfortunately, Magellan does not offer this for selecting user waypoints. The 315 at least allows you to jump by a page of waypoints by using the left and right cursor.

  Certainly a mitigating factor is the extensive list of airports in the database and the ability to search for them. This means that you can get by without having to use user waypoints to store airports. With fewer user waypoints, this gripe is less significant. However, if you want to load navaids or intersections, this is a factor.

- The map setup choices are too limited.

  The worst example of this is that you can show all of the waypoints or none of the waypoints. If you show them all, the map becomes a blob of overlapping waypoint symbols at far zooms. If you show none, the route waypoints do not show. Most of the Garmin products allow you to show the route waypoints but filter out the other user waypoints at far zooms.

- Route editing with the map is poor.

  It is possible to create a new waypoint with the cursor and add it to the end of an existing route. However, it is only to a the end and only to an existing route. There is also a trick where you can choose VERTICAL

PROFILE (yes, I did say vertical to create a horizontal route) -> PATH CHECK to create a route graphically, but this is somewhat of a kludge.

Executing a GOTO to a waypoint on the active route will cause the GPS to discontinue navigating beyond the waypoint. However, it is possible to activate a leg, which will serve some of the same function. See page 8-5.

Lowrance

www.lowrance.com

I should start with the disclaimer of my level of personal experience with the products, or lack thereof. I have used the AirMap 500 and 1000 emulator on my PC, played with the 500, 600, 1000, and 2000 units at Sun-n-Fun, and have had a non-aviation iFinder.

Especially when price is considered, the AirMap series is very credible.

Lowrance offers product emulators on their website in the software section that you can download to your PC – sorry Mac fans. This allows you to play with the GPS if you cannot find a local dealer that stocks it. I have found these to be very useful and am glad Lowrance publishes these. However, if you actually have one of the GPS's, I would recommend playing with the actual GPS rather than the emulator.

If you download the emulator for one of the aviation units, it does not include the Jeppesen database. However, you can go to the Jeppesen update portion of the Lowrance site and download the Jeppesen update into Maps0 folder of the emulator. If you need help finding the Maps0 folder, on my computer it is C:\Program Files\Lowrance Electronics\Unit Demo\Maps0. If you download multiple emulators, this folder is common to them all.

What follows are some general comments on the AirMap. In no way is this meant to bash the AirMap line, but just to point out things that you may not notice if you are new to GPS. Just to reemphasize: Especially when price is considered, I consider the AirMap series to be worth considering. Also, some of the things that I mention could be updated with new software.

Compliments:

- For VFR use, I really like the feature of being able to edit the route directly on the map. Although this feature is implemented slightly different from the Garmins, it works well on the AirMap series. When adding waypoints to a route, it is simply possible to choose the ADD TO MAP option, move the cursor to the desired point, and press

ENTER.

- There are a variety of screens to choose from. The screens are also very customizable.

- I like the fact that Lowrance uses SD memory cards for storing extra maps. SD memory cards are widely available at a variety of retailers since many common consumer devices such as PDA's and digital cameras use them. The Garmin 96 and 96C are limited to external memory and the 196, 295, and 296c use proprietary Garmin memory cards that are more expensive per unit of memory and are only available from Garmin dealers.

- The AirMap 600 has a very bright and sharp display.

- The AirMap units come with Ram mounts instead of a proprietary Lowrance mount. The Ram mounts are a little bulky, but otherwise excellent.

Complaints:

- The AirMap series do not offer the AV400 mode. I do not know about the 2000. This mode in the Garmin handhelds allows an IFR panel mounted GPS to update the active waypoint and route on the handheld GPS. Unless you have an aircraft with a panel mounted GPS that has been wired with a serial port this is probably a non-issue.

- I simply do not like the VNAV (vertical navigation) features of the AirMap series. It is always necessary to drill down several menus to get to it and when you are navigating it only gives you a warning that it is time to start the descent. It also appears that it is only possible to reference the active waypoint rather than any waypoint along the route. Thus, if your destination is several waypoints away, it is not possible to pre-program the crossing restriction.

  For comparison, the Garmin series will let you program a restriction and then display data fields such as VS to TARGET and GLIDE RATIO to TARGET.

- Overall, I find that it just takes a couple of keystrokes more to get things done with the Lowrance. Without spending a lot of time to evaluate certain tasks, you will just have to take this as an impression rather than a well researched conclusion. Overall, I did find the Lowrance menu structure to be logical.

- I have heard that the AirMap 2000 uses batteries quickly when using AA batteries. If you are able to plug it into a cigarette lighter, this is not an issue. Even though the 600 has a color screen, it uses a different display technology. I have heard that 6 hours on 2 AA batteries is very realistic.

- I have learned to like the automotive routing. Obviously, this has nothing to do with the aviation functionality. The AirMap units do not

➢ Non-United States usage

The basemap for non-U.S. areas is typically sparse. However, the international version includes an SD card with the international Jeppesen database and the World Reference map. The World Reference Map adds detail for most of the world showing major roads, bodies of water, and cities. If you plan on using your unit outside the U.S., including Canada, make sure that you buy the international version.

The U.S. version includes the Americas database, but to use the International version in the U.S., you will need to purchase and download the Americas database to the an SD memory card, $35offer this.

➢ iFinder

The iFinder seems like a very capable option for a non-aviation GPS that can be used in the cockpit.

The iFinder is uses small memory cards, SD or MMC, to store map information and to transfer data to the GPS. It is possible to purchase a cable so that the iFinder can be used to provide GPS information such as to a computer-mapping program. However, transferring waypoints, maps, and other information is done through the cards. In some ways getting the data to the GPS using these memory cards is a little more trouble, but it adds quite a bit of flexibility. The memory cards and readers for the computer to use the cards are widely available and reasonably priced at a variety of electronics and discount stores.

The basemap does not include airports. While certainly you could manually input locations for things such as airports and navaids it is possible to load this data onto a memory card from a computer source and then load them into the memory of the GPS from the card. The GPS will only hold 1,000 waypoints, which is about standard. However, the card will handle multiple sets of waypoints that can be loaded as needed until reaching the 1,000 waypoint limit. You can store many sets of data on a card. I have more information on how this is done on 5-8.

With the data loaded, I found the iFinder's interface worked well. It was easy to create a route. The route creation feature worked well once I got used to it. It was possible to use waypoints, map features, and the cursor on the map. I created the same route as the example on 6-10. First, I created the route directly from DED to OCF. Then I pressed ENTER with DED highlighted and inserted the city of Eustis, FL. I then pressed ENTER with Eustis highlighted and was able to drag the route to a bend in the highway. Although, the specific key presses are different from the Garmin receivers, the functionality is similar.

The map display offers enough data to be an effective navigation interface. In the map customization menu, each field selected goes to the top. Think of the order that you want the data displayed and click each selection starting at the field that you want at the bottom of the map display. Figure 4-9 shows the map display with the example routing and what I would consider to be useful data for navigating.

Figure 4-9 Lowrance iFinder

AvMap Aviation (C-Map)

www.avmapnavigation.com

The selling point of the EKP is the large screen.

My experience with the EKP involves no more than a few minutes at the NBAA convention. The screen is nice and the data fields were configurable to show sufficient data on the screen. From my brief exposure and taking into account that my awkwardness in using the EKP was probably due to my being used to other GPS receivers, the interface appears to be logical and capable.

Sporty's Pilot Shop

www.sportys.com/gps

Sporty's sells an aviation version of AvMap's non-aviation GeoSat called the GeoPilot. My only recommendation is that the AvMap EKP is a credible product and the GeoPilot is may be worth investigating.

PDA GPS Combinations

I have softened somewhat on my prejudice against using a PDA as a navigational interface. My main objection was in having wires running all over the cockpit. I just put my GPS III Pilot on the glare shield and I have one integrated robust piece of equipment. However, the idea is not without merit. If you make the comparison of the PDA setup to the case of a GPS with a yoke mount, external antenna, and power cord there are the same number of wires. The only difference is that one wire runs to a GPS instead of from the GPS to the antenna. Remote GPS units are available that are smaller than a computer mouse. Additionally a Pocket PC is slimmer and trimmer than most GPS receivers.

Another argument for the use of a Pocket PC is that if you configure the Pocket PC to work with GPS, there are several reasonably priced programs for ground navigation. For more information on non-aviation PDA navigation programs, try http://www.gpsinformation.org/dale.

Additionally, if your setup is based on hooking the Pocket PC to a basic GPS, you can use the GPS autonomously for activities such as hiking and kayaking where the GPS/PDA combination might be too fragile and short of battery life. Basically, you have three modes of operation: PDA/GPS aircraft, PDA/GPS ground, and GPS ground autonomously.

Several of the Pocket PC's have reflective screens which can be read better in daylight than some of the old color LCD screens such as on laptops.

I am a Palm fan. I carry my Palm V with me everywhere. However, I an not a fan of using a Palm OS device as a navigational interface. The Palm has a 160 x 160 pixel display. The little Garmin eTrex Legend has a 180 x 288 pixel display. The Garmin 176 has a 320 x 240 display. Palm screens are improving in resolution among other things. However, I have yet to see a Palm navigational interface that I considered to be an improvement over using the GPS itself.

A factor to consider is the usability of the interface during turbulence. How hard is it to use the stylus and what functions can be activated with the buttons. I have no personal experience in this regard, but I have read of pilots finding this to be an issue and I have heard pilots argue that it is a non-issue.

If you already own the appropriate PDA, these programs are economical. If you have to purchase the PDA, then the expense increases dramatically. However, you also now have the PDA for other uses.

What I would like to see is a program that used the PDA for flight planning and data storage and then was able to upload waypoint and route data into the GPS. The GPS would still be used as the navigational interface.

➢ **Nav GPS, http://www.flynavgps.com/** Pocket PC and Windows

I have tested the demo Pocket PC version and think that this is a very viable cost effective program. It lacks the bells and whistles of Control Vision's Anywhere Map, but it is considerably less expensive. The author is constantly updating and improving the program. I was in the process of writing an updated review when I realized it was unnecessary for two reasons. First of all, the NavGPS web site gives a good description of the product. Secondly, it is shareware; you can download the program for free and check it out yourself for 30 days. Why read a long review by me when you can try it for yourself?

The only caveat that I would suggest is that you might pay for one of the database upgrades to use with the demo program. The databases are reasonably priced. I think that you might get an unfairly limited opinion of the program based on the limitations of the demo data rather than the capability of the program. Thus, consider it an inexpensive rather than a completely free demo.

➢ **Anywhere Map, www.controlvision.com**
Pocket PC

I have not used any of Control Vision's products, but I have seen the Pocket PC version of Anywhere Map at Lakeland. This is a popular program with some innovative features.

➢ **PocktFMS, www.pocketfms.com** (Pocket PC)

This is a shareware program. It looks intriguing, but I have not tried it.

➤ **Teletype, www.teletype.com** (Pocket PC)

The maps were impressive, but the last time that I looked, I found the software lacked some essential navigation features. The two biggest problems that I found were that there was no way to put in a multi-legged route or navigate on a line between two waypoints-- you can only navigate to one waypoint at a time. This also means that you cannot use it to stay on an airway other than by visual evaluation of the position of the aircraft on the map display because you cannot navigate from one point to another, just directly to a point. You have to select waypoints by tapping them on the map that is loaded. If the waypoint is not on the loaded map, such as a low altitude intersection not being on the high altitude chart that you have loaded-- you can't navigate to it. The maps do look nice though. I visited Teletype on a layover, and they seemed eager to make improvements, but I could not recommend it for navigation at this point. If you used a stand alone GPS for actually navigating, you could use Teletype for a nice map display.

➤ **WinPilot, www.winpilot.com** Pocket PC only iPaq at the time of writing

This looks like a clean interface. There is international support. I have not personally tried it. The price seems a little high though.

➤ **Flight Master, www.flight-master.com** Palm

Flight Master looks like it might be one of the few viable Palm navigation programs for aviation. It has the capability of using flight plans created using Co Pilot, which is a good Palm flight planning program.

➤ **GPS Pilot, www.gpspilot.com** Palm

I loaded the demo version into an old Palm III that I had sitting around. It looks like it lacks the ability to orient track up as well as the ability to give a value of cross track error.

➤ **Flight Companion, www.flightcompanion.com** Pocket PC

I have only looked at the website. Other than this, I have no familiarity with this program. One of the versions of this software offers terrain avoidance features. This terrain avoidance capability is one of the great potential applications of GPS technology to avoid CFIT (Controlled Flight Into Terrain). Eventually, I hope to see this capability in all aviation GPS receivers. Airlines are just now introducing this technology. They have had GPWS for a long time, but this has been based on radar altimeter

readings rather than aircraft location relative to terrain location. I also believe that AnyWhere Map also offers a similar feature.

➢ **Mountain Scope, www.pcavionics.com** (Pocket PC)

I have no more knowledge about this program than appears on the website. It appears to be a useful terrain avoidance program.

➢ **Approach Systems**
http://www.approach-systems.com/apic.html (pocket PC)

➢ **Flightsoft Express, www.rmstek.com** (pocket PC)

This is a flight planning program which might be usable as a moving map.

➢ **Other PDA resources**

Not all of these sites are necessarily devoted to flying with a PDA. However, they are some good sources for information for using a PDA for GPS navigation in general.

- http://www.palmflying.com/
  Despite the name, there is both Pocket PC and Palm information on this site.

- http://www.pocketgps.co.uk/menu_aviation.php
  There are a couple of reviews of Pocket PC aviation navigation programs. You might find this site particularly useful if you are a European, especially British, pilot.

- http://www.gpspassion.com

- http://www.gpsinformation.org/dale/

Laptop Computer

The laptop computer has potential for being a navigation interface when attached to a GPS. The good points are that the screens are large and they can hold and display very detailed maps and data. The disadvantages are mainly bulk, most screens are hard to read in the daylight, and some of the operating systems are less than stable and dependable. Perhaps as the Tablet PC technology develops, this will become a more useful solution.

The same general advice that I give for choosing a GPS, I would give for choosing a moving map program. For a list of some of the moving map software available, I refer you to the Internet at www.landings.com. Select the expanded list for the Aviation Directory and pick flight-planning software. Many of the flight planning programs listed have moving map capability. You might also look at Ram Mounts, www.ram-mount.com for a way to mount the computer. You should also check with the FAA or your local mechanic about the legalities of installing such a mount before you actually install it.

Chapter 5 Aviation Waypoint Data

Overview

If you have an aviation GPS, this chapter is irrelevant to you. Aviation GPS receivers have a database with the location of airports, navaids, intersections, etc. However, if you are going to use a non-aviation GPS, where do you get the data and how do you put it into the GPS?

First of all, let me emphasize that you are not going to be able to turn a non-aviation GPS into an aviation GPS by going online and getting some free data. However, depending on the type of flying that you do, you may find that a non-aviation GPS is a very suitable tool.

GPS receivers allow you to enter waypoints and add a name. These are called user waypoints. For example, you can enter a location and label the point "My House." Most units allow you to store 500 or more waypoints in this manner. You can use this same feature and use it with aviation waypoints. Taking this one step further, you can load user waypoints from your computer into the GPS.

Some newer GPS receivers either have or offer the ability to download numerous Points of Interest, POI. These work like waypoints in that they have a name and a location, but they also add extra information. An example of this is that you might look up pizza restaurants and get the information on the nearest ones. In addition to location, they have phone numbers, street address, etc.

These POI's work differently from waypoints in that it is not possible to directly enter them into the unit. This must be done with an external program. Storing aviation data as POIs has the advantage that the limitation of how many points you can store is based on the memory available and far exceeds the number of user waypoints by an order of magnitude or more.

Manually Entering Data

The first solution is to simply enter the waypoints into the GPS manually. It is obviously tedious an impractical to manually input hundreds of waypoints. However, if you usually fly locally and all you need is your home airport and a couple of nearby airports, you might find that this is a simple solution that is more than adequate.

I have information toward the end of this chapter as to where to actually find the waypoints.

Beware that it is very easy to transpose numbers or otherwise incorrectly enter a point. Double check your work carefully. If you have a mapping GPS, an easy double check is to look on the map display to make sure that the waypoint that you entered appears where it should relative to towns, highways, bodies of water, etc.

Garmin Points Of Interest

The newer Garmin mapping GPS units support custom Points Of Interest, POIs. The primary advantage of POIs over user waypoints is that you can load many more points than the 500, 1000, or 3000 points available as user waypoints. I easily loaded over 14,000 aviation POIs and it took under 3 mb of memory.

First of all, make sure that your GPS can support custom POIs. Generally, only the newer models with extra memory support this. If you are contemplating purchase of a GPS, check the specifications for this feature.

Download the Garmin POI Loader program. It is free at http://www8.garmin.com/products/poiloader.

There are probably other data sources, but the easiest source is Paul Tomblin's excellent http://navaid.com. This site is free, but I would highly encourage you to make a voluntary contribution towards the site.

When the website has generated the points, right click on the "yes, I agree" and save the file. Change the name to something descriptive such as US Airports.gpx.

When you run POI Loader you will be prompted for the folder and it will load all of the data files that it recognizes in that folder.

Figure 5-1

Figure 5-1 shows data from Navaid.com on a Garmin GPSmap 60CSx. Notice that the default is to show the airports sorted by proximity. However, it is possible to look up an airport by using the Nearest Containing option which is accessed through the Menu key. Nearest Containing is actually a text search feature which allows you to enter text and have the GPS search for that text in the names.

A cool look up trick is to use the Find feature to find a nearby city, select the city and then select the Map button. This will put the cursor at the city. Press Find again and search for Custom Points of Interest. The list of will be referenced by proximity to the cursor location.

Garmin Maps

Garmin offers a variety of cartography products that can be loaded. Some of them such as City Select offer the ability to look up airports. There is the caveat that some products such as MetroGuide only allow you to look up airports with airline service. Furthermore, later editions may or may not offer this feature.

However, if you have a GPS with City Select, but does not support Custom POIs, you may find that the airport database is useful.

Figure 5-2

Figure 5-3

The airport list is relatively extensive. The airports are identified by name as opposed to identifier. The default order is by proximity, but pressing the menu key allows you the options of Find by Name and search by Nearest Containing.

In addition to using the text searching through options, you can use the trick described for custom waypoints of finding a nearby city, displaying the map location, and then executing the find again with the search referencing the cursor location.

Caveat: Remember that this data is made for other purposes such as automotive and general use. However, if you use common sense and reasonable precautions, you may find it suitable in some cases.

Garmin mapping non-aviation GPS basemap:

The mapping non-aviation Garmin receivers also include many airports in the basemap. The airports that are included are generally public such as municipal and county airports and larger. Most smaller airports are not included. Unfortunately, it is only possible to look them up as points of interest if they are large enough to offer airline service. Otherwise, you have to find them as airplane icons on the map display.

In all cases, the basemap airport locations in a non-aviation GPS are not designed for aerial navigation. This does not mean that they are unusable, but that you might want to use just a little more caution and double check the location – use common sense and verification.

Magellan Mapping GPS:

The Magellan mapping GPS receivers have a very good list of airports even though they are non-aviation receivers (more detail on this on page 4-32).   Most of the Magellan mapping receivers also have a very poor ability to look through a large number of user waypoints. If you have a Magellan mapping GPS and only need airport locations, you will probably find it unnecessary to load additional data. You might also consider only loading navaid data and using the internal data for airports. When cross checking the data, it is unlikely that the data will match exactly. If you are using a printed source to check a waypoint, it is highly unlikely that the data will agree exactly. How close is close enough is up to you, but one minute of latitude is approximately 1nm. This is approximately true for longitude at the equator, but the distance that 1 degree of longitude covers reduces as you move away from the equator, reaching zero at the North Pole.

Magellan 315, 320, and basic SporTrak:

Although it is possible to store data as user waypoints, there are data sources to save aviation waypoints as POI, Point of Interest, information. Using this capability, the amount of data that can be stored is much greater. The data as well as information on how to use it is available at http://home.stny.rr.com/bkw/315/.

How to get the waypoints into the GPS:

Entering tens or hundreds of waypoints into your computer can be tedious at best. However, there are several free programs for loading waypoints from your computer into the GPS.

➢ Connecting your GPS to the Computer

Update note: Many of the newer receivers use a USB connection which is much faster. Most of the units that offer USB connectivity come with USB cables.

Several GPS receivers do not include a cable. The official Garmin cable is about $40. There are cheaper options, such as www.pfranc.com. However, it is relatively easy to connect a Garmin GPS with the round plug such as the GPS 12, II, III, and 72 for $2 worth of parts at an electronics store such as Radio Shack. The part from Radio Shack is 276-1428, 9-Position Female D-Sub Connector. You can enter this part number at www.radioshack.com to see better what it is. You will need 3 wires about 1 foot long. Strip about 3/8 inches off of each end and crimp the metal fittings onto each end of each wire. The holes of the connector are numbered, you will need to stuff the metal ends into the housing. The wires should connect to the GPS as follows: pin 2 – receive (T on the GPS), pin 3 – transmit (R on the GPS), and pin 5 ground (- on the GPS). You will want to somehow mark the wires for future references. The fittings on the loose ends should clip onto the pins on the GPS.

The source for this information as well as information on other Garmin connector types is: http://www.garmin.com/support/faqs/faq.jsp?faq=68).

If you just need to occasionally update the software, waypoints, or database this solution should work. Beware that there is the possibility that you could damage your computer and the GPS. However, the risk is relatively low. I initially connected the transmit and receive wires backwards. It didn't work until I switched the wires, but it didn't harm the GPS or the computer.

➢ Using a PC with generic software

There are three free programs that I am familiar with that allow you to load waypoints from your computer into your GPS.

- **G7ToWin,** http://www.gpsinformation.org/ronh

  G7toWin is a very useful program for saving waypoints, routes, and

screen captures. Most of the screen shots in the book were made with G7ToWin. There is also a Windows CE version.

G7toWin works with a variety of receivers, including most Garmin, many Magellan, and some Lowrance receivers. The default is Garmin and you must select another receiver by selecting FILE -> CONFIGURATION -> GENERAL.

G7toWin offers the ability to read a variety of file formats including GPX format. This means that G7toWin can use files from AeroPlanner.com and Navaid.com.

You can also create your own files, which can be generated with a combination of spreadsheet and text editor. These files are in the form of comma-separated values, .csv. These files can be created in most spreadsheet type programs and edited in a simple text editor such as WordPad or Notepad on a personal computer. The best way to find the specifics of the format is to load some waypoints into G7toWin, save them as .csv, and then open the file in a text editor.

The following is a the specification for a waypoint, which is in the top of a G7toWin generated .csv file:

"Type","Name","Lat","Long","Month#","Day#","Year","Hour","Min","Sec" ,"Comment","Symbol#","SymbolColor","SymbolDisplay","Altitude (Meters)","Depth (Meters)","Ref Dist","Ref units"

Each waypoint is stored as one line of text. However, some of the data is not necessary for creating a waypoint. Each piece of data must have a column up until you stop inputting data. When the file is saved as .csv from a spreadsheet, blank columns become the nothing between two commas. For example, I created a file where I did not put in a SymbolColor or SymbolDisplay. A sample line of text defining a waypoint is:

W,KMCO,28.428889,-81.316028,12,6,2003,0,0,0,ORLANDO INTL,16384,,,29.3

When creating a G7toWin .csv file, I open the spreadsheet generated file in a text editor such as Notepad or WordPad and add the header lines from a G7toWIn created .csv file before loading the data. It is important that you save the text file with a .csv extension and select .csv when opening the file in G7toWin.

- **Easy GPS**, http://www.easygps.com
  Most major GPS manufactures

EasyGPS is as its name implies. On the plus side, it is very easy to install and use. Easy GPS stores data in its own format or an open XML format called GPX. AeroPlanner.com has Data Chunks available for download in EasyGPS format and Navaid.com offers data in GPX format.

- **Links to other third party GPS software**, www.gpsinformation.net

There is a variety of other third party software, including some programs that are Macontosh compatible. Many allow maps to be scanned and calibrated and various other features. I have just listed some free programs that offer the ability to store and upload wayoints

➢ Lowrance iFinder format

The iFinder uses SD or MMC memory cards to carry data from the computer to the GPS. The GPS itself can only store 1,000 waypoints. This is a fairly standard capacity, but nothing compared with the capacity of the memory card. The waypoints are stored in internal memory, but are loaded from the card. You can load whole files until you fill up the 1,000 user waypoint capacity. After you fill up the 1,000 user waypoints, you can delete the all waypoints and load new files with different adjoining areas.

An example of how you might use this is that you could have a file on the memory card for airports in each state. You could load your home state and then continue to load states until you fill up the 1,000 points. The memory cards come in various sizes, but they will store a lot of waypoints. A file with 470 Texas airports takes up 24KB (approximately .024 MB).

The offset to the advantage that the SD card offers when compared to a Garmin GPS is that it takes more computer savvy to find and format aviation data to work with the iFinder.

Lowrance offers a free waypoint management program on their site, GPS Data Manager V.6. Using this program it is possible to load a text list of waypoints and store them on a memory card in the proper format. The format for each waypoint in the text file is decimal latitude [comma][space] decimal longitude [comma][space] waypoint name. I find that a space after the comma was important. The best thing to do is click on the map to create a couple of waypoints and then export them as text to examine the format.

Below are some the steps that I went through to import all of the airports and VOR's in Georgia and Florida. Whether the following steps are a

hassle, challenge, impossible, or somewhat enjoyable depend on your comfort level using the computer.

1. First you must get a list of data with latitudes and longitudes that can be formatted into decimal latitude, decimal longitude, and waypoint name. I have multiple sources in this chapter. If you are computer savvy and have a fast connection, one of the better sources is to use the National Geospatial Intelligence Agency (formerly National Imagery and Mapping Agency) data (see page 5-6).

   Another fairly easy to use option is to get data from Paul Tomblin's excellent navaid.com (page 5-10), open the file with G7toWin (5-6), and save the file as a .csv (comma separated value) file.

2. I then opened the file in Microsoft Excel. I then deleted unnecessary columns and moved the remainder of them so that they were ordered correctly. Finally, I saved the file as a .csv (comma separated value) file.

3. I then opened up the .csv file in WordPad. I simply used the replace feature of WordPad to replace [comma] with [comma space]. I then saved this file as a text file.

4. I imported the file into GPS Data Manager and saved the data as a user file. If you have a real iFInder, you would have to save this file onto a SD or MMC card. If you use the emulator, you have to save the file into the map0 folder.

5. To get the waypoints from the card into the GPS or from the map0 folder on the emulator, press MENU -> MENU -> SYSTEM -> TRANSFER MY DATA. If you try to show all of these waypoint on the map, it will be unreadable. Next go to the map page and press MENU -> MY DATA -> MAP CATEGORIES and deselect MY WAYPOINTS.

This is a little bit of a hassle, but it works. Once you figure out the process, it is less of a hassle. There is one other hope, a program called GPS Babel, http://gpsbabel.sourceforge.net. The last time that I checked there was no option to translate data into a format for iFinder, but perhaps somebody eventually will.

Where to get the waypoints:

When you load waypoints from the computer into the GPS, the new waypoints will be loaded into the GPS in addition to the previous waypoints with the exception of co-named points. Generally, a waypoint with the same name as a previously loaded waypoint will override the previous waypoint. In other words, the two sets of waypoints will combine as opposed to one set replacing the other. Thus, you might want to load multiple sets of points. For example, you might load a set of every airport and VOR in your state. You might also load a more detailed set of waypoints for your home airport or those that you frequent.

➢ Publications

- **Publications such as the AFD and Jepp Guide**

- **Charts:**
  IFR charts have latitude and longitude information depicted on them. For VFR, you can always use the latitude and longitude markings and measure a point directly off of a sectional or other chart.

➢ Web:

- **Paul Tomblin's web site**
  http://www.navaid.com

  This is a site that has data available in several formats. Although I have discussed loading this data as POIs into newer Garmin receivers, the data can also be loaded into older GPS receivers as user waypoints with programs such as G7ToWin or EasyGPS, both of which are free. Another format allows data to be loaded into a free flight planning program for Palm OS called CoPilot.

- **AeroPlanner.com**, www.aeroplanner.com
  Most major GPS manufactures

  This is a web based planning and data tool. AeroPlanner has a premium and a basic service. There are several different price plans. Using the free basic service, you can create a route and then click on the "i" icon beside the waypoint to get the latitude and longitude for each waypoint.

  Additionally, you can download GPS data that can be loaded to your GPS using either EasyGPS or G7ToWin. For example, you can upload all of the airports and VOR's within x distance of your local airport or all of the airports within a given distance of a route. The cost is $4.95 per data set unless you have the premium service which includes unlimited Data Chunks. Additionally, the monthly and yearly

plans give you access to many features which I have not had time to explore.

DataChunks are downloaded as zip files, which must be extracted. There are several programs available online such as Win Zip, www.winzip.com , that will allow you to extract these files.

When downloading a U.S. DataChunk, there is an option as to whether or not to append a K in front of the airport name to differentiate the airport from a VOR with the same identifier. If you do not select the K, the last co-identified waypoint will overwrite the first co-identified waypoint. For example, ORL the VOR would load into the GPS, and then ORL the airport would load in. When you used the GPS to navigate to ORL, you would be going to the airport. If you selected the K option before the airport name, KORL would be the airport waypoint and ORL would be the VOR waypoint.

I am glad that AeroPlanner gives this option. However, if you fly VFR you might want to consider not using the K option to save waypoint space. Usually the co-named VOR is close enough to the airport to make having a separate VOR waypoint and airport waypoint almost redundant. You can click on the TYPE label at the top of the column in EasyGPS to determine whether the VOR waypoints override or the airport waypoints override. The bottom waypoints override the top.

- **AirNav,** http://www.airnav.com

AirNav only allows you to look up one fix, navaid, or airport at a time. However, it is a quick interface with no log-on and there is good information on airports, FBO's, and fuel prices. The coordinates are either given in degrees, minutes, and seconds or decimal degrees rather than the more conventional degrees, minutes, and decimal portion of minutes. It is a simple matter to setup the GPS to accept either of the formats given.

➢ Flight Planning Software

One issue with many flight planning programs is that they upload a route into an aviation GPS as a series of user waypoints. For example if you loaded KFLL-LAL-KTPA into an aviation GPS and clicked on the information for LAL VOR in the route, you would not get the frequency information from the internal Jeppesen GPS database, but you would get the location of the user waypoint LAL. The guidance would still be the same assuming the flight-planning database was accurate. I tested this out on my Garmin III Pilot using Air Plan, and I have been told that this is the case with the more expensive Jeppesen software. This makes no

difference if you are using a non-aviation GPS. Some people may find this a significant issue, others may find it to be a minor irritant.

- **Jeppesen,** http://www.jeppesen.com/store/prods/flitestar.phtml

  Jeppesen offers several products that interface and are able to upload data to a GPS. It is my understanding that the latest versions of the VFR flight planning products are supposed to offer GPS upload capability.

- **Co Pilot,** search for "copilot" at www.palmgear.com (Palm with no GPS upload)

  This is a much more extensive program than Nav Plan. This is not an indictment of Nav Plan, I happen to like its simplicity – just a statement that they are very different programs. It has no database, but when you download the program, there are references for where to get databases in the readme file. Just like NavPlan, you can click on the waypoint and find latitude and longitude information that can then be manually loaded into the GPS.

- **NavBox**, http://www.navbox.nl/
  This is a European flight planning program.

- Flight Planning Software at landings.com
  http://www.landings.com/_landings/pages/planning-software.html

  I only had the chance to check out Air Plan. There are several different flight planning programs with various degrees of GPS capability. There are many links on this site.

Chapter 6 GPS Preflight Route Planning

Overview:

It is not my intention for this chapter to be a course in flight planning, but to explain some of the techniques and caveats with GPS routes.   The concept of a route is pretty simple in that it is a series of legs from the origin to destination. Flying each leg involves navigating to the waypoint that defines the next turn or the destination in the case of the last leg. With the exception of one GPS, the Garmin Geko 101, it is possible to program the GPS with a series of waypoints so that it automatically sequences to navigate to the next waypoint as it passes a previous waypoint.

Before flight, the GPS will give information such as distances between waypoints, cumulative distance at each waypoint, etc. Most aviation and marine receivers, and some generic receivers will allow you to input values for fuel burn rate and planned speed to get time and fuel burn estimates along the route. When airborne, the GPS will also give these various values based on the current speed and position.

Figure 6-1 shows an example of some of this information. These screens are from a Garmin GPS III Pilot. Moving the pad left and right will allow the selection of various fields to be displayed in the column. This is typical for Garmin handhelds. Press MENU and then select "CHANGE FIELDS?" on panel-mounted receivers such as the GPS 400 and 500 series. For other receivers and for more specifics, I refer you to the owner's manual.

Figure 6-1

Caveats

> ### Make sure you include the origin in the route

A route is simply a string of waypoints strung together. It is important to know which leg the GPS is navigating along. When a route is activated, the GPS makes the first leg from the first waypoint to the second

waypoint. Thus, the second waypoint is the active waypoint. This is not an error of design; there is logic to this even if it is not apparent at first.
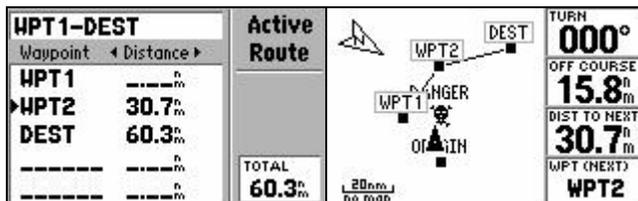
Figure 6-2

For example, let's say that your route is ORIGIN to WPT 1 to WPT 2 to DESTINATION as in Figure 6-2. You program into your GPS the following route: WPT1 to WPT 2 to DESTINATION. The GPS will set you up to navigate starting on the leg from WPT 1 to WPT 2. If you look at Figure 6-2, you can see that the active waypoint is WPT2 and that the TURN field is indicating that we are on course even though we are heading directly for the danger waypoint. If you had input this route to avoid airspace or terrain, you would end up cutting the corner created by WPT 1.

There are two ways around this. The first is to make sure that you include the origin in your routing as in Figure 6-3.
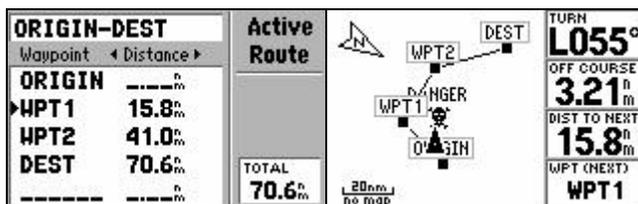
Figure 6-3

The second is to execute a GOTO to WPT1. Executing a GOTO to WPT1 makes the GPS navigate a leg from the present position at the GOTO execution to WPT1. Figure 6-4 shows this.
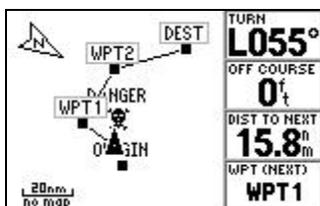
Figure 6-4

➢ Do not activate the route for preflight planning

When you are looking at GPS data during the preflight stage it is important not to activate the route. If you have already activated it, simply de-activate if it. If you activate the route, the GPS thinks that you are trying to

navigate the route. Thus the GPS will include the distance from your present position to a point along the route. In other words, the GPS is not telling you information about the route from start to finish, but from where it calculates that you are along the route to the destination. In some cases the first leg may be from your present position to the second waypoint. In other cases, the GPS might calculate from your present position to an interim waypoint and then along the rest of the route.

➢ Terrain and airspace clearance

Although I have already mentioned it, it bears repetition. Just because you can create a route in the GPS does not mean that you can fly it. It is your responsibility to check that your route will give adequate terrain and airspace clearance.

➢ Winds, climbs, and descents

The GPS route data information such as shown in Figure 6-1 is only the extrapolation of a speed along a distance. With units that allow for preflight planning, the speed and fuel flow can be input before takeoff for planning. During flight, the GPS will use the current speed. Thus, the effects of winds during preflight or a change in winds during flight are not calculated. On higher performance aircraft, the effects of descent on fuel consumption and speed are not taken into account.

This information can still be very useful. My point is not to discount the usefulness of the GPS route data, but to point out the limitations of the data. Take the example of a general aviation flight in a single engine aircraft that should take about an hour with fuel on board for four hours. The in-flight data such as fuel burn to destination, ETA, etc. based on the current groundspeed is probably quite sufficient. As long as the route is reasonably straight, the winds probably will not change significantly along the route. While at the preflight stage, inputting a groundspeed that reflects the average effects of winds over the routes will likely give you data of sufficient precision.

At the other extreme, consider a transoceanic airline flight. Nobody would use the route page on a handheld GPS to plan a transoceanic jet flight, but it is useful to the various factors that are not considered in the simple route page planning of a GPS. The winds will change considerably along a several thousand mile flight. The aircraft will descend at idle from cruise altitude and have to slow to 250 knots, which is half of its cruise speed below 10,000 feet. The effects of this on ETA and fuel burn are considerable. It is only possible to carry a fuel reserve that is a percentage of the planned fuel as opposed to a multiple.

Most general aviation flights are somewhere in between these two extremes. The flight planning functions of that some GPS receivers offer can be quite useful in the proper context when applied with some common sense and extra fuel.

IFR and airway setup

In many ways, it is easiest to set up the GPS to navigate along airways and predefined points such as navaid and fixes. The coordinates for these points are either published or contained in the GPS receivers database depending on whether you are using a non-aviation GPS or an aviation GPS. If you need these coordinates, I have more information in the Aviation Waypoint Data chapter.

At the time of this writing GPS receivers only allow you to put in waypoints for routes. There is no way to put in a waypoint along an airway, specify the airway, and then another waypoint or intersecting airway and have the GPS navigate all of the twists and turns along the airway in between. For navigating the airway, it is only necessary to input the waypoints that define the route such as the navaids and the intersections between the airways where the route bends. It is not necessary to input every waypoint along the airway. Additionally, you might want to program interim waypoints you expect a direct routing to or otherwise might want as a reference.

VFR

I live within the coddled world of IFR. Please take any VFR advice from me with this disclaimer in mind. While I have not flown VFR in years, I wanted to pass along some techniques that I think could be useful.

IFR is set up along a route structure based on existing navaids. Even airliners with GPS updated INS often fly between VOR's even though the VOR becomes an abstract point of the airspace structure rather than a facility that the aircraft is directly using for navigation.

Although VFR flight has never been slaved to routing between navaids as a technical matter, it often is as a practical matter. Pilots often fly VFR routes to and from navaids and along navaid defined airways. GPS frees you from this former often self-imposed restriction. A GPS allows you to navigate to any point or between any points rather than being limited to navaids. There are some caveats though.

Even though you can use a GPS to navigate VFR directly from origin to destination, there are many times that this is not possible. Things in the

way might be temporary or permanent restricted airspace, large airports and their airspace, obstructions, or other detours. Instead of rendering GPS navigation useless, this is where GPS shines.

If you start flying directly from point to point also consider your crosschecks. Even though the GPS will probably be the most dependable navigation technology that you have used, nothing is 100% dependable. Even more important than the system dependability, GPS receivers are complicated enough that human error in GPS navigation is a very real possibility. Possible crosschecks include landmarks on the ground (pilotage), cross fixes from navaids, or some dead reckoning.

Terrain clearance has always been important, even when using airways. When flying off airway you lose some of the information that had been available such as MEA's along the route. **It is vital that you consult the appropriate chart to make sure that you will have proper terrain and obstruction clearance when navigating off airway routes!** Review what the sector altitudes mean for the chart you are using and how much clearance they give you from terrain and obstructions on the chart that you are using. Just as an example, in the U.S., a grid MORA on an IFR chart will give you 1000' to 2000' of clearance depending on the terrain and the MEF (Maximum Elevation Figure) on a VFR chart gives you the maximum elevation with no extra clearance.

➢ Non-System Waypoints

I have already dedicated a chapter to getting aviation waypoints – things such as airports and navaids. If you are going to fly off airways, you will need to define waypoints that are not predefined in the airspace system. There is a multitude of ways to get these locations and define them to the GPS. The best one depends on your purpose and which GPS receiver that you have.

For instruction on how to actually use these techniques with your specific receiver, you will have to look at the instruction manual for your GPS.

Directly from the map display of the GPS

Using a mapping GPS and moving the cursor to the desired point is one of the easiest methods. Every mapping GPS that I have seen allows you to pan the cursor to a point and create a waypoint at that point. You can reference road intersections, bodies of water, etc. to correlate the GPS map with the chart. On aviation GPS receivers, this ability is even more useful in that the GPS will show airspace, fixes, airports, and navaids.

When you create a waypoint, on many of the mapping GPS receivers you can press MENU from the waypoint creation screen to add the newly created waypoint to a route. On some Magellan receivers, you can only add the waypoint to an existing route. I'll refer you to playing with your receiver or reading the owners manual for details.

There are is a caveat in that the internal GPS base maps of roads, bodies of water, and landmarks are not created for aviation use are not updated. This is strictly a use at your own risk type of technique. However, when weighed against the likelihood of mis-measurement and mis-entry using other techniques and when used with common sense and crosschecks, I think that it is a reasonably prudent technique for VFR use.

Among the crosschecks are that you can plot the location of the created waypoint on the chart to make sure that it is where you intended.

The other caveat is to make sure that you don't accidentally create the waypoint at your present position rather than the cursor location. For example on the Garmin GPS III, pressing the ENTER button will create the waypoint at the cursor location. The ENTER key is also labeled in small print "mark." Pressing and <u>holding</u> the ENTER key will activate the MARK function and create a waypoint at the present position of the GPS rather than the cursor position. A simple check of the map display to see where the waypoint was created can be used for verification.

Directly measure latitude and longitude from the chart

It almost goes without saying that you can enter a waypoint directly using the latitude and longitude. Measuring directly from the chart is not that difficult, but it is certainly subject to human error. The corner of a piece of paper can be used to measure perpendicular to the latitude and longitude line. Make sure that you understand what each tick mark is. Usually, each tick will be a minute.

Especially in places with west longitudes, such as North America, be careful to measure the longitude correctly. A point 2 minutes east of the W 81° line on the chart is not W 81° 02", it is W 78° 58'. West longitudes increase right to left, which is not what we are used to for many things such as reading.

Relative position to a known waypoint

A final method of inputting waypoints is to define them relative to another waypoint that is already loaded in your GPS such as a VOR or an airport. Find the point on the chart and use a plotter to measure the distance and bearing FROM the known point.

A couple of equipment caveats: All of the Garmin GPS receivers that I am familiar with have this capability. On the GPS III series, there is a field for inputting a reference waypoint, bearing, and distance in the waypoint menu. On several of the other Garmin receivers, this is known as "projecting a waypoint" and there are a couple of menu selections to accomplish this – once again, I refer you to your owner's manual. I do not believe that the Magellan receivers have this capability.

Defining a point by referencing a bearing and distance from another point is very much like defining a point by a radial and distance from a VOR. As I explain on page 9-25, VOR's are set to magnetic north initially, but are not updated as the earth's magnetic field changes. If you specify a point as a magnetic bearing and distance from a waypoint that is a VOR, this may be several degrees off from the actual radial. The Garmin 400 and 500 series are the only receivers that appear to compensate for this VOR misalignment when defining a point.

If you use this feature, I would suggest that you set the GPS to use true rather than magnetic north and use angles measured relative to the latitude and longitude lines rather than VOR compass rose.

Use intersections and fixes on IFR charts

These are obviously part of the system. However, if you have an aviation GPS or are comfortable finding the location of aviation waypoints, you might consider consulting a low IFR chart even for VFR use. The low IFR chart will show many more fixes than the VFR charts as well as airspace boundaries. Using a GPS, you can then navigate directly between fixes in addition to navaids. This just gives you more predefined points to use for navigation.

IFR charts, at least in the U.S., show a grid MORA. The MORA is Minimum Off Route Altitude whereas the sectional chart shows the Maximum Elevation Level. The grid MORA assures 1,000 ft. of clearance if the maximum reference altitude and 2,000 ft. of clearance in mountainous terrain or when the maximum reference altitude is above 5,000 ft.

➢ GPS Pilotage

One technique I describe as GPS Pilotage. Pilotage is navigation by reference to ground landmarks. GPS Pilotage is using these landmarks to locate points on the GPS for creating the route as well as using these points as a cross check while flying.

For example, let's say that you want to fly VFR from Smithville airport to Jonesville airport but it will take you right through Metro International Airport's airspace. You look on the sectional and find that going over the little town of Lakeville will keep you well clear of Metro's airspace. From Lakeville you can go over Blue Lake and then to the point where US-29 intersects I-33. You can probably find all of these landmarks on the map display of the GPS and use them to create the route.

Mapping GPS receivers are especially useful for GPS pilotage. The Gamin receivers offer some excellent tools for editing the route with the map. I have some more specifics on the map editing features offered by the Garmin mapping GPS receivers, both aviation and non-aviation, on page 9-34. Lowrance receivers offer the ability to select a point on the map when adding waypoints to a route. Most mapping receivers offer the ability to create a waypoint by moving the cursor to a location and then marking the location of the cursor. This is the technique that you will need with to use with the Garmin 400 and 500 series as well as the Magellan mapping receivers.

The basemaps are not meant for aerial navigation and there is nothing guaranteeing that the roads, towns, and other features are correctly located. However, used with some prudence in VFR environment with visual crosschecks, I think the technique of using the basemap is quite reasonable. There is the very real risk that some of these items on the database are not accurate. However, I feel that there is an even greater risk of mis-measuring and mis-entry of data if you measure directly from the map and enter the waypoints. It would be a good idea to see if the location of the points derived from using the cursor and GPS map correspond with depicted location on an appropriate chart.

Although a mapping receiver is of great benefit in creating a route using GPS pilotage, it is not necessary. Similar techniques can be used with flight planning software and then uploaded to a GPS. Or very simply, waypoints can be measured directly off of a chart. It is even arguable that GPS pilotage is even more important with a non-mapping GPS in that the non-mapping GPS does not provide as much situational awareness.

Trip Planning:

The same techniques for creating a route using the map display of Garmin handheld receivers can be used to plan the whole trip. After planning where to make stops, you can then create individual routes for each leg. As an example, say that you want to fly from Florida to Osh-Kosh for the fly-in. The first step would be to create this as a route all the way from Florida to Osh-Kosh. You can then look at the route line to see where this route line passes near to get an idea of where you want to stop. Drag the

route to these stops as I I have described for adding intermediate points to a route.

Although you can fly the trip as individual legs of a long route, you will probably want to separate each leg into a separate route. The idea is simply to use the GPS as the equivalent of a large planning chart. Obviously you will want to consult charts for such things as terrain, airspace restrictions, and other things not shown on the GPS.

VFR Examples

➢ DED to OCF

This is an example of a flight from Deland to Ocala, Florida. The direct line from KDED to KOCF runs through a bombing range, R-2910. The task here is to use GPS to best navigate around the restricted area.
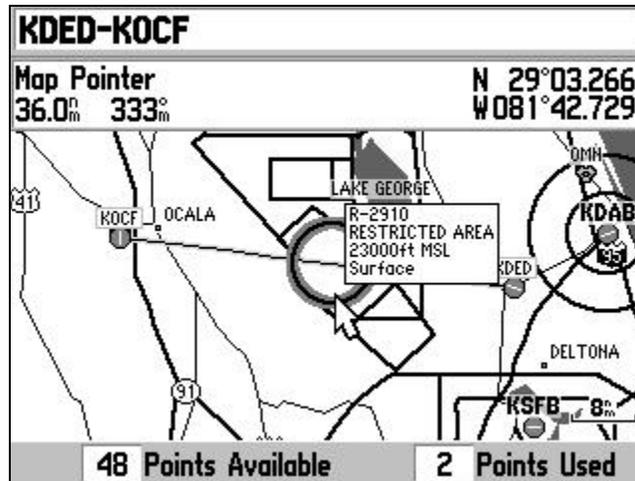
Figure 6-5 Garmin 196

Figure 6-5 shows a screen from a Garmin 196 depicting the route. It is possible to take off from KDED and use the map display of the Garmin 196 or any aviation GPS to navigate around the depicted airspace. However, I consider this to be a very bad idea. I have already discussed this on page 2-21 under GPS assisted airspace violations. One of the biggest problems is that airspace does not show at all zooms. Furthermore, the zooms at which airspace no longer appears can be set by the user. In fact most GPS receivers can be set to not display the airspace at all. The same is true for alarms that you are about to enter airspace. This is not a fault, I truly like the ability to adjust this.

When used with prudence and a preplanned route, this airspace depiction is very useful. The Garmin mapping GPS receivers have a very elegant way of directly editing the route graphically. However, this discussion is not limited to Garmin receivers. On other mapping receivers you can use the map display to create and check the detour waypoints. On non-mapping GPS receivers, you can measure the waypoints directly from the chart and enter them into a route.

We need to create a route that will go around the restricted area. The next issue is where we want to create the route. Although it is possible to just use any point, it is better to use a point that can also be identified by other means other than GPS. It is also possible to use the GPS to cut the clearance margin to a minimum. However, Jeppesen databases have contained errors in the past. Thus, a little margin is good.

Figure 6-6 and Figure 6-7 show the routing on a sectional chart. There is a highway that goes along our route and makes a distinctive bend before going to the west into Eustis, FL. This bend and the town of Eustis make good landmarks to mark route legs as well as visual references when we are actually flying

Here is the sectional chart depicting the route around the restricted area:

Figure 6-6 Courtesy of AeroPlanner.com

Here is a more detailed view of the area near the restricted area:
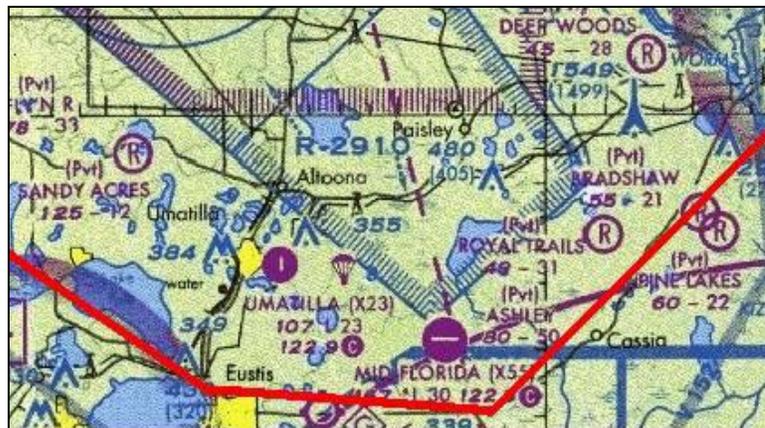
Figure 6-7 Courtesy of AeroPlanner.com

Figure 6-8 is a route created using these landmarks to route around the restricted area. On the mapping Garmin receivers (including the non-aviation receivers), it is a very simple matter of moving the cursor over the route line until it changes to a dotted line, pressing ENTER, dragging the route to an interim position, and pressing ENTER. There are some of the Garmin mapping receivers where it is the first pressing of ENTER to anchor the route will create a waypoint after which it is necessary to move the cursor over the new waypoint to add it to the route by pressing ENTER again.

Figure 6-8 Garmin 196

The airspace depiction on a screen the size of a Garmin 196 is nice. However, this technique works with any receiver. I originally used a non-aviation Garmin GPS III Plus to demonstrate this example. Figure 6-9 shows what you would see while navigating using a non-aviation Garmin GPS III Plus. This was edited entirely with the basemap just as with the Garmin 196. Although the screen is a little cluttered and the restricted area doesn't show, it is still possible to use the map for situational awareness since we know where the route is having created it at the preflight stage. The data fields provide precision, and the sighting of the actual road and city of Eustis provide a nice level of redundancy.

Figure 6-9

Additional notes:

This example works well because Florida has roads and towns. If the example was in the middle of the dessert, it might be harder to find references points. Any point that you can draw define on the map, you can enter as a waypoint in the GPS. In addition to visual waypoints, you can use a variety of other cross checks such as VOR radials.

This routing also goes under the Orlando class B in an area where there is a 6,000 ft. floor as well as near an area where the floor is 3000 ft. As long as you are less than 6,000 ft. with mode C and are navigating accurately, this should not be a problem. If you do not have mode C, then you can also avoid this area using GPS at the expense of some of the margin on the restricted area. The point is to show you how to set up a GPS routing with regard to areas that you want t avoid rather than to show you the best routing for this specific case.

Variations:

There are several minor variations depending on the specific receiver that is involved. There are also often several different ways of accomplishing the same thing with the same receiver.

Non-mapping receiver note: If you have a non-mapping GPS measuring latitude and longitude from an appropriate chart is actually not difficult, but it is more error prone. It can be done easily using a piece of paper and the latitude and longitude lines on the chart. Even though you may not have a mapping display, you probably have some sort of route depiction to check. Check to make sure that the route looks to be the proper approximate shape even though you may not have the map features to compare it to. You should also check distances and/or courses.

Lowrance note:

Lowrance allows you directly edit and create a route along using the map. To add a waypoint, move the cursor to (ENT to Add), press ENTER, choose Add From Map (see Figure 6-10), move the cursor to the desired point and press ENTER. You can continue to add points in this manner.

To modify a route, select the waypoint that you want to add a point in front off and press the ENTER button. Drag the route to where you like and press ENTER to add that point.
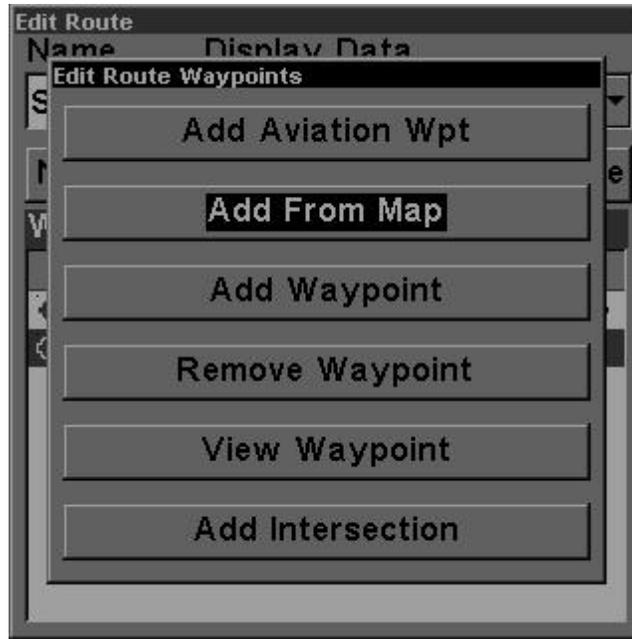
Figure 6-10 Edit Route Waypoints menu

Garmin non-aviation mapping note:

Figure 6-11 GPS III creation of route on map

Note that on some Garmin receivers, if you try to mark a cursor point by pressing a ENTER/MARK, the GPS might come up with a page describing the feature, for example: "HWY 44" rather than the waypoint creation menu. Press MENU and select "save as waypoint."

An even more powerful feature is to edit the route directly in the map as shown in Figure 9-10. I have not shown every screen after each key press, but this should give you an idea of the basic process. I have more detail on page 9-34.

The first step is to go to the route that you want to edit. Some receivers such as the GPS V and eTrex Legend have a MAP button on the route page already. Otherwise, press MENU and select EDIT ON MAP.

Move the cursor over the route until it becomes a dashed line. Press ENTER or the click stick and then drag the route to where you would like. Press ENTER at the point that you want. On some GPS receivers such as the Garmin 196, the point will be automatically added to the route. On others, such as the Garmin GPS Map 76, you will get a create waypoint menu. After you have created the waypoint, you will need to move the cursor over the new point to highlight it and then press ENTER again to add it to the route.

There are some variations where you can add points to the beginning and end of the route also. Press ENTER or MENU with the cursor on any of the points including the ends.

Legend C, Vista C, 60C, and 76C: If you press ENTER at a point at which there is no map data, it will ask you if you want to create a waypoint at this point. After you select YES, you will be given a waypoint creation screen where you can name the waypoint. What is not obvious is that to get back to the route, press QUITE (upper right side button on the Legend and Vista) to get back to the route. After you have created the waypoint, you can move the cursor over the new waypoint, press ENTER and add it.

Non aviation, non-Magellan notes: I recommend download all of the airports within your flying area using one of the sources listed in the Aviation Waypoint Data chapter. Even though, I have created this example using nothing but the basemap of generic mapping, but non-aviation, Garmin receivers. The advantage of downloading all of the airports near where you are flying is that you can select the NEAREST tab on the GOTO page and the nearest airports will be shown.

Garmin panel mount and non-Garmin mapping GPS note: Even though it may not be possible to edit the route directly on the map, it is possible to move the cursor and create a waypoint on the map at the cursor location. These points can later be used to create a route.

If you are flying an aircraft with a Garmin 400 or 500 series GPS, it might be easier to just get the latitude and longitude of the non-aviation waypoints from a chart or even a handheld GPS as applicable and then just enter the waypoint manually. This might save a little time during preflight, especially if the aircraft is a rental. Definitely check the route against the map for verification. Also, the basemap of some panel mounted GPS receivers is not as extensive as some of the handhelds making the creation of the waypoints with the cursor a little less useful.

You can use the map of the Garmin 400 and 500 to create waypoints. Press the cursor knob while displaying the map and press enter when you reach the point that you want to create a waypoint. In any case, the map makes a good cross check.

Flight planning software note: I essentially was able to create this example using AeroPlanner.com and AirPlan. I would imagine that this example could also be accomplished with a variety of flight planning programs on the market. I basically followed the same process that I described using the GPS except that I used the respective interfaces and then uploaded the data into the GPS. Before I confuse you: AirPlan is a PC flight planning software. It is possible to load maps from AeroPlanner.com into AirPlan to enhance the AirPlan graphics. It is also possible to plan a route on AeroPlanner.com independently, download it to the computer and then load it to the GPS using the free EasyGPS software.

Both AeroPlanner.com and AirPlan worked well. Both will take some experience to figure out. Each has their respective advantages. If you use AirPlan and load charts from AeroPlanner.com, make sure that you maximize the picture size in the menu rather than accepting the default to get the maximum amount of charted area for your money.

Creating the user waypoints for the turns around the restricted areas was the only non-obvious feature to each program. When you first set up the flight on AirPlan, create it from KDED to KOCF. Create the turn waypoints using Ctrl-left-click and then just drag the route line down to the turn waypoints. On AeroPlanner.com, select "Use Map" from the Create and Edit Points menu.
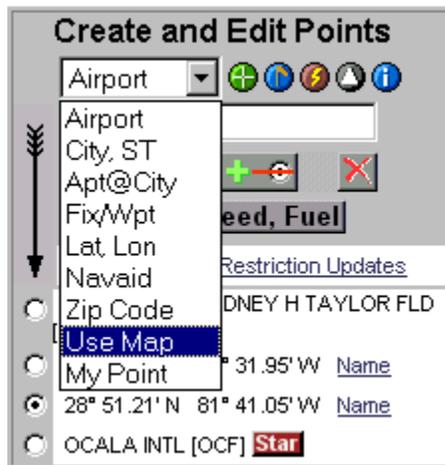
Figure 6-12 AeroPlanner.com menu

➢ **OCF to ORL**

In addition to being useful for avoiding areas, you can also flight plan to take into account entering airspace. Again I add the disclaimer that I only fly IFR and this is just and example of some tricks to using a GPS for VFR. It is certainly not an instruction on ATC procedures.

For example, lets say that you are flying VFR from OCF to ORL.
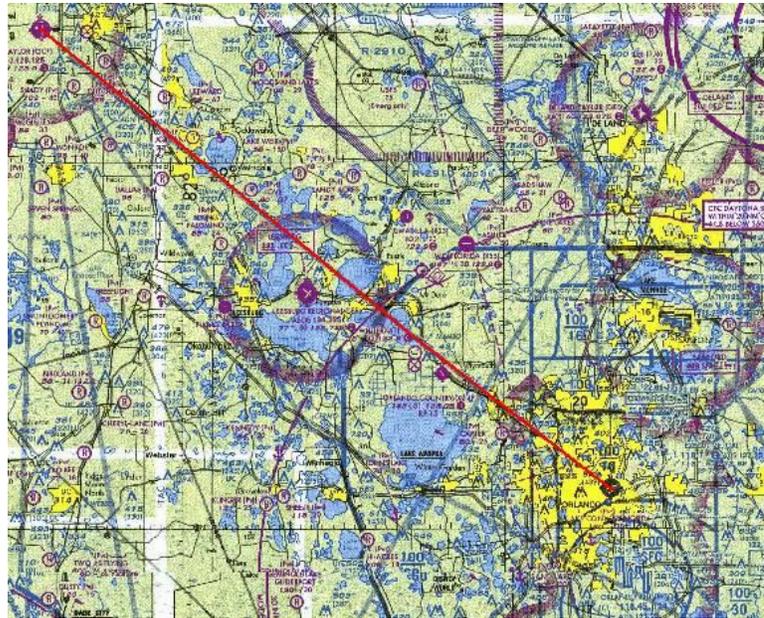
Figure 6-13 Courtesy of AeroPlanner.com

Figure 6-14 Courtesy of AeroPlanner.com

You can first enter a route in your GPS from OCF to ORL. You can then display the map. There is a flag to contact ATC over Lake Apopka. You can show a map of the route on the GPS. Correlate the location of Lake Apopka, the town of Apopka, and the route crossing US 441 splits from FL 436 and move the cursor so the it is directly over the route and create a new waypoint. The GPS will probably suggest a waypoint name. You can use the suggestion such as I did (US 441) or create a system such as proceeding the name by a U for user and then using the date or some such thing. You should then add the waypoint to the route and check it. One thing to check is to make sure you made a waypoint at the cursor position rather than the present position of the GPS.
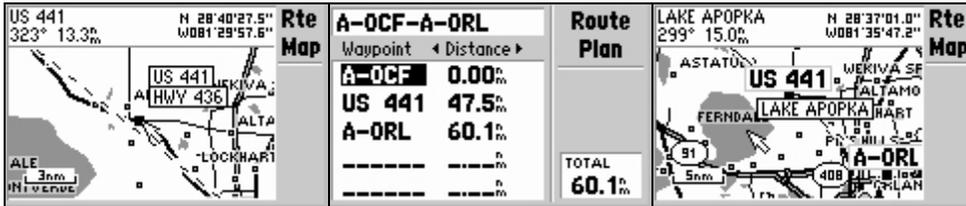
Figure 6-15

As you are flying, Figure 6-16 is what you would actually see on the GPS as you approached the waypoint to remind you to call ATC:
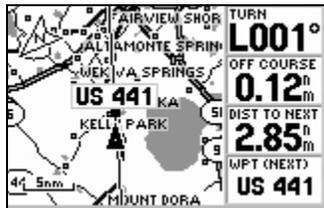
Figure 6-16

The waypoint is a reminder. Hopefully you should be looking for US 441 below you and Lake Apopka out the right window.

Chapter 7 Navigation

Terms:

This is not meant to be a discussion of all of the data fields that your GPS can display—just the more relevant ones to navigation.

Figure 7-1

Garmin GPS III+ screen captures approximating the above diagram. The screen is oriented North. In both cases the position is the same, but each capture displays some different data fields. The Garmin III does not display TKE, but it is 4 degrees left (35-31).	This is the same position as above. However, I have changed the map view to TRACK up instead of North up. I have also changed the fields to show a more practical setup.

Figure 7-2

➢ **Where am I going to?**

- **Active Waypoint**
  This is the point that the GPS is navigating to. In Figure 7-1, this is WPT 2.

- **Active Leg**
  The active leg is the line into the active waypoint. If the leg is a portion of a route, then the line goes from the previous waypoint in the route to the active waypoint. In Figure 7-1, this is the line from WPT1 to WPT2.

  If an enroute GOTO has been executed, the active leg goes from the point at which the GOTO was executed to the active waypoint. With an aviation GPS operating in the OBS mode the active leg can be set by creating a radial or bearing from the active waypoint—similar conceptually to dialing in a VOR radial.

  If there is no leg beyond of before the leg in question, the GPS extends the line indefinitely in the appropriate direction. For example, if you fly beyond the destination the GPS will give navigational data relative to a course line which extends indefinitely beyond the last waypoint. The map display may not necessary show this line. If you start a flight before reaching the first waypoint, the course line will extend indefinitely back. An example of this is given in Figure 7-14 on page 7-20.

- **TRACK—synonym TRK or COG (Course over Ground) or HEADING**
  This parameter is one of the most significantly useful features of GPS. This is the direction the aircraft is actually moving over the ground. The GPS has no idea where the nose of the aircraft is pointed; it only knows the aircraft's path over the ground.

  Conventional VOR and NDB navigation require the pilot to systematically deduce the track and find a correct heading based on how far he was drifting off course. The GPS will calculate the track. Thus, changes in heading can be easily calculated as the change required to make TRACK match COURSE or BEARING.

  Several handheld GPS receivers, such as the Garmin eTrex series, use the term HEADING for TRACK. For the most part, you can just consider this as somewhat of a misnomer.

  There are a couple of GPS receivers, such as the Garmin 76S and eTrex Vista, that have built in electronic compasses. When the GPS is not moving, there is no track. This is when the electronic compass

kicks in to provide orientation. The speed at which the GPS goes from using the GPS track to the electronic compass heading is user settable, but is generally only a couple of knots. Thus, with the possible exception of helicopter use, the GPS field labeled HEADING really is TRACK. Where this feature is useful is for such non-aviation uses as hiking. With an electronic compass, the GPS will provide direction orientation while you are walking very slowly, in an area of poor coverage such as due to a forest canopy, or stopped to look at a map.

Interesting but not important information: There are some marine GPS receivers that use GPS as a heading indicator. They do this by calculating the signal difference between two separate antennas. Stanford University used a similar method with multiple antennas to use GPS for attitude and heading. It's an interesting idea that holds some future potential. If you are interested, do some searching on the Web (start with Furuno for the marine unit).

➢ Which way do I need to go?

- **BEARING**
  BEARING is the direction to the next waypoint. For navigating, BEARING is most useful in terms of the track. If the bearing is 195, it does no good to head 195 if you have a crosswind. Adjust the heading so that the TRACK matches the BEARING.

  For sighting, BEARING is useful relative to your heading. For sighting, mentally overlay the BEARING on the heading indicator as opposed to comparing it to the GPS TRACK. Take as an example that the BEARING is 000, the heading is 015 to compensate for an easterly wind, and the TRACK is 000. This means that you are going directly to the waypoint. If you look at the GPS display, the waypoint might appear to be straight ahead. However, you should be looking for the waypoint 15 degrees to the left of the nose.

- **TURN**
  Most handhelds have a TURN field which is the difference between the TRACK and the BEARING already calculated by the GPS. It is both easier to interpret and takes up one less data field than using BEARING and TRACK separately.

- **COURSE-- synonym DTK(desired track)**
  COURSE or DTK is the TRACK required to parallel the active route leg. COURSE is relative to a line that extends backwards from the active waypoint to the previous waypoint in a route. If a GOTO has been executed, then the line is from the active waypoint backwards to

the point at which the GOTO was executed. This line is fixed and does not change with the position of the airplane.

Contrast COURSE with BEARING. BEARING is from the aircraft's position to the active waypoint. This is dynamic and constantly changes with the position of the aircraft.

I find the nomenclature somewhat confusing. Handheld GPS receivers tend to use the term COURSE. The term COURSE is usually to describe what the GPS uses the term TRACK for. I suppose that COURSE is really just short for desired course.

DTK or Desired Track, is also a bit of nomenclature that I am not fond of. I find that more often than not the TRACK that I desire is the BEARING.

I think a term such as PARALLEL TRACK would be more meaningful and less confusing. Even though I doubt the industry will take my suggestion, you might want to think of both of these terms in this way. BEARING is the desired track for going direct and DTK or COURSE is the desired track for paralleling the course.

- **TKE (Track Error)**
  Many panel-mounted units offer TKE, Track Error. This is the difference between TRACK and COURSE. This is how far you need to turn in order to parallel the course. TURN takes you to the waypoint -- TKE parallels the line defined by the two waypoints. The advantage of TKE is similar to TURN in that it saves a data field and easier to read than displaying TRACK and COURSE separately. Caution: TKE and COURSE will still give information on how to parallel the course line even though you have gone beyond the waypoint. The line defined the two points would actually encircle the earth. Theoretically, if you flew so that your TKE was zero, you would circumnavigate the earth.

  TKE is good information, but it must be used in conjunction with OFF COURSE and DISTANCE information.

- **TO COURSE, COURSE TO STEER**
  This is the GPS suggested track to get onto course. I find that it is too sensitive to be useful. It will suggest a 20-degree course correction to correct for being 1 nm. off course while traveling 450 knots. I would make about a 1-degree correction to correct back. Play with it if you want, but it does not come with my recommendation.

➢ How far off course am I?

- **OFF COURSE, XTK (cross track error)**
  This is just how far you are off course. Many handhelds give a value without a direction. Although this is not ideal, I discuss techniques for dealing with this later.

  Most panel mounted GPS receivers will tell you the direction to the course. A "<-" means the course is to the left. This works just like most aircraft instruments.

  Many handheld GPS units, such as the Garmin 76, 176, and 196 give an L or R to indicate the direction. The catch is that this is not the direction to the course, but the direction you are from the course. I suppose that this is a the proper interpretation of the term "Cross Track Error." The problem is that this is the opposite of the way that most aircraft instruments work. It is also the opposite of the way the TURN field works.

  For example, an "R" would indicate that the aircraft is right of course and that the course is to the left of the aircraft. The error is to the right, but the correction needs to be made to the left.

➢ Terminology example
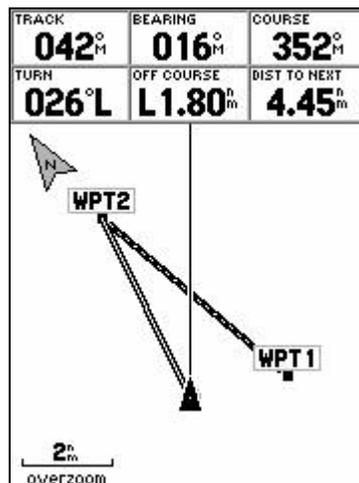
Figure 7-3 Garmin 76 showing various terms

Figure 7-3 is a screen shot showing some of the various GPS navigational terms along with the map. A nice feature on the Garmin 76 is that it can display a track line, bearing line, and course line simultaneously. Some other receivers, such as the Garmin 196, can also do this. Many receivers can only display a course line, which is quite sufficient. In fact, displaying

all of these lines might be too cluttered in actual use. However, for illustrating the various terms in this example, this is a very useful feature. By the way, the track line is labeled "heading line" in the map setup menu, but it has nothing to do with heading, just TRACK. Thus, "heading line" is a bit of a misnomer.

The purpose of Figure 7-3 is so that you can compare TRACK, BEARING, and COURSE. Look at the figure and compare the numerical data with the line that it represents. As you can see, TURN is derived from the difference between TRACK and BEARING.

If this were a panel-mounted receiver, it would probably have the ability to display TKE, which is the difference between TRACK and COURSE. COURSE would be called DTK, for Desired Track. TKE is the amount of turn necessary to parallel the route leg as opposed to going directly to the next waypoint. In this case, TKE would be $<-50°$.

Notice the direction of OFF COURSE and that the L means that the aircraft is to the left of course rather than that the course is to the left of the aircraft. If this were a panel-mounted receiver, the label would be XTK and it would have an arrow pointing to the right.

If a GOTO were executed, the course line and the bearing line would instantaneously be the same since the route leg would be defined as being from the position of the aircraft at GOTO execution to the next waypoint. The difference is that as the aircraft's position changes, the reference for the course line remains the position where the GOTO was executed and the bearing line is from the aircraft's position at any given moment. The bearing line is dynamic and the course line is static.

The GPS display

The GPS has various ways of displaying navigational data. There are a great variety of display capabilities from GPS to GPS. However, there are basic similarities.

There are basically two ways for the GPS to display data. One is a graphic depiction and the other is through numeric data fields. The graphic displays can further be broken down into mapping displays and graphic abstractions. The graphic abstractions are displays such as an HSI, or pointer type of screen.

I recommend that you primarily navigate with the map display supplemented by the data fields or graphic abstraction such as an HSI display. The map display is excellent for situational awareness. However, the precision varies with the zoom level and the update rate of the GPS

display. The shortcomings of the map are compensated by the precision of the data fields. If you are using a non-mapping GPS, you can probably still get a plot screen that will at least give you a map of the route without the background cartographic information. This is also true if you are using a mapping GPS in an area with little mapping information. For example, if you were to use a GPS with a North American base map while flying in Europe.

This recommendation is based on being able to display sufficient data on the mapping display. The Garmin GPS II+ and Garmin 12 do not have the user definable field that can be selected to display XTK. The Magellan receivers only allow you to display two fields on the map display. In both cases, there are other navigation pages that may be more suitable for the primary navigation reference. However, even in these cases, the map display may be adequate in some circumstances. For example, given the two data fields of a Magellan GPS map display, I could set them to TURN and DISTANCE. This would be sufficient to navigate to a point. I could even change to TURN and XTK and have enough information to navigate along a line, even though I would miss the distance display. Since TURN should keep me on course, I could also just pop back and forth to a page that displayed XTE while using TURN and DISTANCE on the map page.

Depending on the GPS, the default data fields on the map display may or may not be set up to be sufficient for navigation. Figure 7-4 shows the default data field setup for the Garmin GPS III pilot on the left side. The right side shows the data fields set up to provide the precision that the map lacks. On the left side, you can see that the aircraft is a little left of course and the pointer indicates that you need to turn a little to the right to go directly to the next waypoint. The right screen reflects data fields chosen to indicate exactly how far off course you are and exactly how much you need to turn to go directly to the next waypoint.
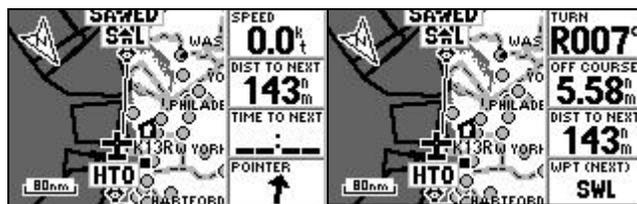
Figure 7-4

Here are what I consider to be the minimum data to display on the screen:

• Which way are you going and which way you need to go. The data field TURN satisfies both of these for most handheld receivers. Although POINTER is the graphic equivalent, I feel that it is not precise enough. The data field TKE satisfies this requirement for panel-mounted receivers. Remember that TURN is the amount to turn to go

directly to the active waypoint and TKE is the amount to turn to parallel the active route leg. If you have a sufficient number of data fields, you can also display TRACK, COURSE, and BEARING separately.

- How far off course are you. XTK, OFF COURSE, CROSS TRACK ERROR – these are all the synonyms. Remember that most handheld receivers, if they give a direction, tell you the direction of your error rather than the direction that you need to correct.

In addition, I like to know the distance to the next waypoint as well as a way to verify that I am actually navigating to the correct waypoint. I like to have the next waypoint displayed as a data field. This allows me to see that I am navigating to the correct waypoint even if that waypoint is off the screen. If you don't or can't display the next waypoint as a data field, make sure that you have the map zoomed to see that you are navigating to the proper point.

| Garmin GPS II+ | Garmin GPS 430 | Garmin GPS III+ |
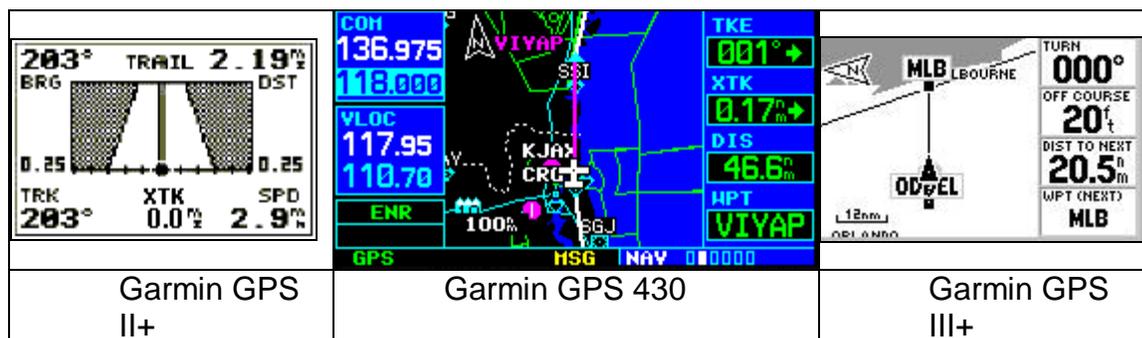
Figure 7-5

Figure 7-5 shows some examples of how I would suggest setting up the data fields for navigation. None of these configurations are the default set of data fields.

There are certainly variations based on individual needs. For example, flying a sailplane, I cannot think that OFF COURSE would be of critical importance. If I had only 4 fields, I might set them two of them to TURN and DISTANCE. The other two fields I would use for VNAV functions if I were using a GPS receiver that supported it, such as: VS and VS to TARGET or GLIDE RATIO and GR to TARGET.

The receivers depicted in Figure 7-5 have the minimum capabilities for navigating with the map display. This is not said as an indictment, they are all very capable receivers. However, as you go further up in price in each category of receiver, you get more display options. For example, the Garmin 295 offers the ability to display eight data fields or two data fields and an HSI. The Garmin GPS 500 overlays a CDI and a compass arc

over the map display. In either case, you can change and might want to change some of the default data fields.

In addition to the primary navigation data, you are going to want other information such as SPEED, ETE, ETA, etc. I consider these to be secondary data. If you run out of data field capacity on the screen that you primarily use for navigation, set up another display page to show this secondary data. When you want to see this information, quickly change the page and then change back to the main page when you are through. It is much quicker to select a page showing several of these secondary data fields than to change a data field to get one piece of data.

➢ HSI explained

HSI is an acronym for Horizontal Situation Indicator. It is nothing short of remarkable that I can go into a major chain store and buy a Garmin eTrex Legend which will give me an HSI type of display (referred to as a course pointer). However, given the choice between an HSI display and a map with data fields, the map option is far superior. Many aviation GPS receivers allow you to display the map and an HSI on the same screen. When it comes to choosing between an HSI and more data fields displayed on the map display, I leave this to personal choice. For example, the Garmin GPS 196 will allow you to display 10 data fields in lieu of 4 data fields and an HSI. The Garmin GPS 295 will allow 8 data fields in lieu of 2 fields and an HSI.
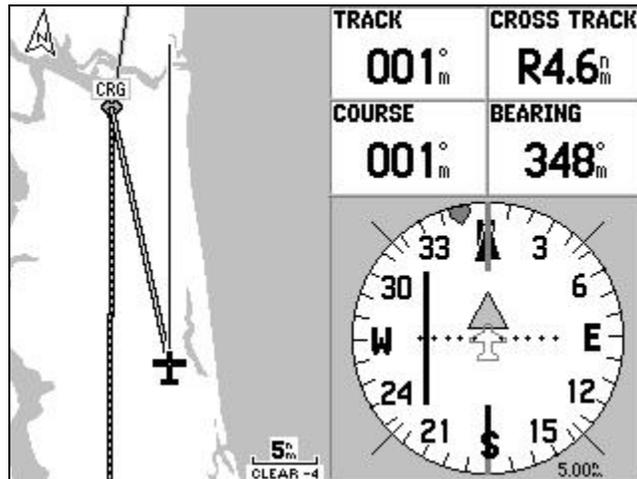
Figure 7-6 Garmin GPS 196 HSI

Figure 7-6 shows an HSI displayed along with the map on a Garmin GPS 196. I have the data fields set to show the same data the HSI itself displays.

Notice the track is displayed by the compass card's 12 o'clock position under the index mark or lubber line. The head of the needle points to COURSE. The D-bar, or center of the needle is displaced proportional to CROSS TRACK ERROR. Note the R in the CROSS TRACK data field indicates the aircraft is right of course. This is correct, but it is the opposite sensing of the HSI, which indicates that the aircraft must correct to the left. The HSI sensitivity can be adjusted by using the zoom buttons on the HSI only page. In this case, full deflection is 5 nm. as indicated in the lower right corner of the screen. Notice in the center that there is a little triangle above the displacement scale of the D-bar. This is the "TO/FROM" indicator.

The bug (little triangular thing at 348°) indicates BEARING. The Garmin GPS 196 and 295 both allow you to change the bug to indicate BEARING – this is very useful. With the bug set to display BEARING, the HSI becomes like a combined HSI and RMI. The bug on the Garmin GPS III Pilot is set to display TO COURSE and does not have the option of displaying anything else. I do not find TO COURSE to be useful. However, I recommend using the map display on the GPS III Pilot, so the HSI bug really isn't that important.

For illustration purposes, I have the heading line (which is really based on track), the course line, and the bearing line displayed on the map. In actual use, I find this to be too many lines; but it works well for illustration in this example. I also have the map detail at a minimum.

Where I have seen users get in trouble with the HSI display is when they try to follow the needle to the waypoint. This will work with an RMI display, but not with an HSI. Following the needle will only get you parallel to the course.

The GPS HSI display has some differences from the HSI of an aircraft. An aircraft HSI is basically just a VOR indicator in the middle of a heading indicator. Instead of adjusting the OBS, you rotate the course needle so that it points to the desired radial.

The aircraft HSI displays heading instead of TRACK. Thus, the heading and needle will be offset by the wind correction angle while tracking a radial. On the GPS HSI, the track and needle should line up except for minor corrections and intercepts.

The D-bar on an aircraft HSI works like a normal VOR needle displaying an angular error from the radial. The GPS D-bar displays the lateral distance from the course. Thus, on the GPS HSI there is no change in sensitivity based on distance from the waypoint.

These differences between the GPS HSI and an aircraft HSI are not deficiencies on the part of the GPS, but in the context of navigation are improvements over the aircraft HSI. In fact the HSI on the L-1011 could be set up to operate in a similar method to the GPS HSI display, but being driven by an INS or FMS rather than GPS. The cost of the HSI alone in today's dollars would buy a general aviation aircraft.

➢ RMI explained

RMI is an acronym of Radio Magnetic Indicator. Most handheld receivers have a form of this RMI type of display. I have seen it called various things, such as bearing pointer, but they are all variations on the same idea.
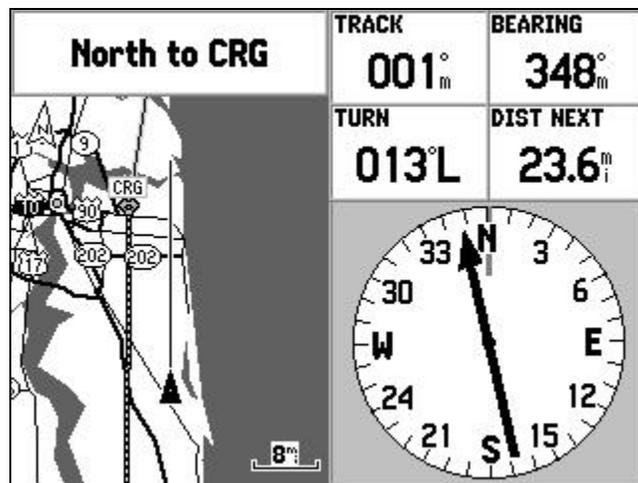
Figure 7-7 Garmin GPS 196 RMI

Figure 7-7 shows an RMI display from a Garmin GPS 196 with the associated data fields. This display is only available in land and water mode. The simulated aircraft position is the same as in Figure 7-6 for comparison.

The lubber line or index at 12 o'clock displays TRACK. The needle points to BEARING. TURN is just the difference between the BEARING and the TRACK.

There are some differences between and aircraft RMI and a GPS RMI display. An aircraft RMI is oriented to the aircraft heading rather than the track. When flown properly, an aircraft RMI will indicate the wind correction angle. Since the GPS HSI is based on track, it is possible to "follow the needle" to fly straight to a waypoint.

The Garmin 196 and 295 do not have the option of displaying the RMI in aviation mode. On other GPS receivers, displaying the RMI is in lieu of

the map display. Once again, I recommend the map display. The prime utility from the RMI can be gained from displaying the TURN data field on the map display.

➢ Other Displays

The HSI and the RMI are two of the primary displays that you will find on handheld GPS receivers. There are also other types of displays. For example, Magellan has a display similar to an RMI, but the compass card is a tape and the bearing is shown as a dot. This is the view of the RMI that you would see if you were a little man standing on the pivot of the needle looking ahead.

There are also highway types of displays. These are the graphic analogy of driving along a road and are reasonably easy to figure out.

Basic Technique

I choose to divide navigation into two primary problems: Navigating to a point and navigating along a line. The two are not mutually exclusive, but there are slightly different techniques for doing each.

Navigating to a point is when you want to just get to the next point from where you are. Navigating along a line adds the element that it also matters how far you are from a line drawn from some other point to where you are going. For example, if you are flying VFR and not worried about airspace or terrain restrictions, then you only care about navigating directly to where you are going.   If you are flying along an airway, it is not only important that you navigate to the next waypoint, but that you stay within a maximum distance of the airway.

It is possible to navigate by using either BEARING or COURSE based information. Ideally, you should navigate directly to a waypoint by comparing TRACK to BEARING and navigate along a line by comparing TRACK to COURSE. Where this gets slightly complicated is that some GPS receivers are optimally suited to be set up to fly primarily using one method or the other. With a little technique, it is a simple matter to fly along a course using BEARING data and it is likewise feasible to fly to a point using COURSE data.

Take the Garmin GPS III Pilot as an example. There are only four data fields to work with. By using TURN, you can combine both the actual track and the desired track into one field. This field, TURN, is just the difference between TRACK and BEARING. To divide the fields into TRACK and BEARING separately would require two data fields, and to add COURSE would take up three data fields. This would come at the

expense of other necessary data. The panel mounted Garmin 400 series has the same dilemma except that there is not option to display TURN, but there is the option of displaying TKE, which is the difference between TRACK and DTK.

If you have an HSI type of display such as the Garmin 295 or 196, then this is the graphic abstraction of COURSE type of data. However, you can set the bug to display BEARING or set a data field to display TURN. This allows you to use both BEARING and COURSE based data. Similarly, a Garmin 500 series allows you to display enough data to display TRACK, BEARING, and COURSE. The efis page displays a BEARING bug as well as a CDI indicator in addition to the user selectable fields. Thus for these receivers, you can easily use all four techniques.

I would suggest that if your GPS can display TURN, then you use the BEARING based techniques. This will apply to most of the handheld receivers. If your GPS can display TKE, then use the COURSE based techniques. This will apply to most of the panel-mounted receivers.

➢ How to Steer:

All of the navigation information that the GPS indicates should be considered in the context of the track that the GPS indicates. The GPS will not tell you what heading to fly, but how much to turn left or right. I recommend starting with the philosophy that the GPS indication is a navigation instrument rather than a flight instrument.   Fly by the heading indicator or outside reference and make corrections proportional to the amount indicated by the GPS rather than directly flying by the GPS.

Depending on your receiver, you may find this distinction is not so important, but start with this philosophy until you find otherwise. Certainly as GPS receivers improve with faster processors, this becomes less of a consideration.

➢ Navigating to a point using bearing information.

Tracking to a point using bearing information is simple. Just make a turn corresponding to the difference between TRACK and BEARING. Making heading corrections so that TURN is zero is the same thing. Your heading does not matter in an absolute sense. It only matters that you make the proper change in your heading.   You could take all the numbers off of the directional gyro and this would still work.

Since the GPS uses track and not heading, homing is not a problem with this technique. Homing is when you follow an RMI or ADF to the station

by pointing the nose at the needle. As you fly, the wind causes drift and the line flown to the station is curved rather than straight.

Interestingly enough, it is possible to home by flying visually to an object by just aiming straight ahead out the windshield. If you are tracking towards an object with a crosswind, the object will actually slightly skewed to one side when looking at it out the windshield.
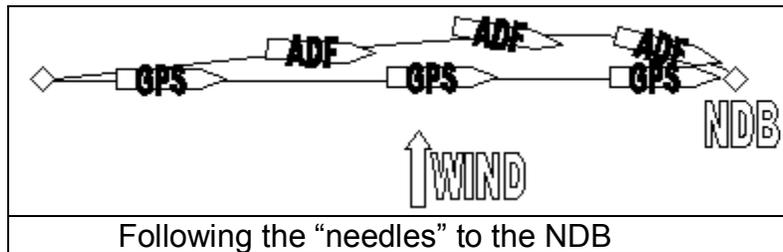
Following the "needles" to the NDB
Figure 7-8

Figure 7-8 shows the difference between homing and tracking. In the case of the GPS, the needle is just the graphic equivalent of the TURN field. Interestingly enough I talked to a student at a local flight school about what he was being taught about GPS and how he used it. He said that GPS works great. All he does is looks at the bearing to the waypoint on the GPS and flies that heading. Of course, this technique would result in homing just like an NDB. I always find it interesting when new technologies can be applied to propagate bad old techniques!

If the track change required is large, there might be a slight difference between the heading change required to create the desired track change and the TURN shown on the GPS. Let's say that you are flying with a tailwind and suddenly decide that you want to navigate to a waypoint that is 90 degrees off of your right wing according to the GPS. If you make a 90-degree heading change suggested by the GPS, you will not be going directly to the waypoint because your tailwind is suddenly a crosswind from the right. Additionally, due to the turn radius, you will have flown beyond the point where the 90-degree turn was accurate. As you roll out on the new heading, TURN would still be indicating that a further right turn was required. After making this second adjustment to the heading you should be going directly to the waypoint. In reality, course changes are usually not this dramatic and you could probably combine the two corrections dynamically in the turn. Figure 7-9 shows an example of this.

A right turn of 59° is indicated.	The right turn of 59° had been made, but 4° more is still needed.	The extra 4° has been made and we are now on course towards SEY.

Figure 7-9 Navigating to a point using bearing information.

➢ Navigating a leg using bearing information

There are many times when you will have to fly a route between two points instead of going directly to a waypoint. This will certainly be the case if you are flying on an IFR flight plan.

If you are tracking a route as opposed to going directly to a waypoint, you will need to add the management of OFF COURSE to the problem. At its simplest, flying directly towards the next waypoint will get you closer to the course line as you get closer to the waypoint. However, this makes the assumption that you are reasonably on course to start with.

Unless you are some combination of close to the waypoint or very far off course, the bearing line and the course line are reasonably parallel to each other. Thus you can use TURN or the difference BEARING and TRACK as an indication of your convergence or divergence from the course.

GPS with OFF COURSE direction indication

Some handheld GPS units have an indication of the direction as well as magnitude of the COURSE error. It is important to understand the sensing of this directional information. Although it may not necessarily be true for all handheld receivers that give a direction of OFF COURSE, the ones that I have seen indicate opposite to standard aircraft instruments. Most navigation instruments tell you the direction that you need to go rather than which direction that you are. A CDI indicator deflects towards the course, the arrow on a certified GPS points towards the course, but the L or R indicating on the handheld GPS indicates which direction the aircraft is from the course. If the aircraft is right of course, the GPS will indicate this with an R. However, the course is to the left of the aircraft. This would be indicated by a left deflection is a CDI type of display were used.

I suppose that you could get used to this behavior and it will no longer be confusing. However, I have a little trick. Simply compare the TURN direction to the OFF COURSE direction. If they match, then TURN is an indication that you are correcting towards the course by however many degrees more than going directly to the next waypoint. If the directions of TURN and OFF COURSE do not match, then you should steer towards the direction indicated by TURN. My way of remembering this is that if the directions match, they are both working for me – this is good.

If you get confused and do the wrong thing, your error should become apparent by a steadily increasing magnitude of OFF COURSE.

GPS without OFF COURSE direction indication

Many GPS receivers give you a magnitude but no direction in the OFF COURSE data field. At large zooms on the map display, the direction is not apparent on the map display. However, this is easy to deal with. If the OFF COURSE is increasing, then the TURN is a measure of how much you need to correct. If OFF COURSE is decreasing, TURN is an indication of the angle that you are correcting towards the course. In this case, you do not need to correct for the TURN indication until you are on course or unless you want to shallow the angle at which you approach the course.

Figure 7-10 TURN indicating convergence

Figure 7-10 shows the aircraft is obviously converging towards the route. TURN is a measure of the steepness of this convergence. You would also see OFF COURSE decreasing.
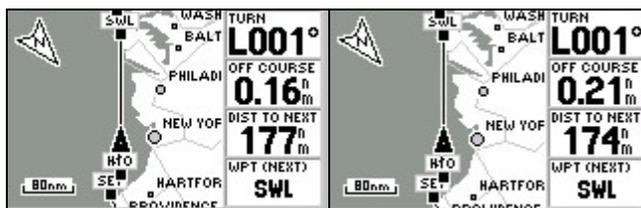

Figure 7-11 Diverging from the route.

A more subtle case is Figure 7-11. Looking at the map display it is impossible to tell whether the L001° is an indication of convergence or divergence. Since OFF COURSE is increasing from the left screen to the right screen, TURN is indicating divergence in this case.

It may not seem intuitive in Figure 7-11 that we are right of course. However, as you get used to this technique, you will not only be able to correlate the direction of the TURN with whether or not it indicates an error or correction, but you will also be able to deduce the direction of displacement from the course.

TURN and BEARING indications get sensitive approaching the waypoint. You just make your interpretation less sensitive. If you pass a waypoint .5 nm of course, TURN will indicate 90 degrees before you pass it. If you are flying at 400 knots, you are not going to want to make this 90 degree turn to correct the .5 nm course error. If you are hiking on the ground, you might. You will soon get used to this. It is a minor annoyance at worst. If you have the map display on auto-zoom, the information from the map will get better as the digital data gets worse.

➢ **Some Panel-Mounted GPS differences**

I was trying to convince my airline that retrofitting the 737-200 fleet with a Garmin 400 would be a tremendous improvement over the dual VOR/DME and single ADF configuration. It never came to be, more for non-technical issues than anything else. I have never flown with an IFR certified GPS such as the 400. Thus, I must add the disclaimer that these techniques are based on my experience with using handheld GPS in a similar manner to which I am proposing as well as using the free GPS 400 simulator that can be downloaded from the Garmin web site.

One of the points that I was trying to make to my airline is that if we could get the FAA to give us an exemption from requiring a separate CDI display or HSI integration, the GPS display itself would be sufficient for enroute navigation. As it was, we were navigating many of the routes using the heading mode of the autopilot referencing the ADF and HSI. Using the GPS 400 in this manner would be far superior to the ADF. Not only was I trying to keep the installation simple to keep it as inexpensive as possible and increase the likelihood of it getting approved, but I was also thought that using the GPS display rather than the HSI or CDI for navigation avoided the possible mode confusion that often occurs.

The reason that I am including this information is that I think that to use an expensive mapping GPS such as a Garmin 400 like it was a VOR by only using the CDI is a waste of its capability. The mapping provides excellent situational awareness and the data fields provide precision. Furthermore, the GPS display provides track information that is not provided by the CDI indication.

Of course, most installations of the Garmin 400 series are likely to be coupled with an autopilot for steering. The real benefit from some of these techniques is in the accuracy they can give to hand flying.

The whole idea of the CDI is that it brings the course deviation data into the primary scan. Also TSO 129a was written well before the existence of modern mapping GPS receivers such as the Garmin 400 and 500 series receivers. I will leave it up to you as to how you use the GPS display and the CDI in your scan, but I wanted to at least try to give you an idea of how the display itself can be used as a navigational interface.

The subtle difference from a handheld receiver which warrants this separate discussion is that most panel mounted GPS units offer TKE, which is the difference between TRACK and COURSE rather than TURN, which is the difference between TURN and BEARING.

I use the Garmin 400 series for illustration, but these techniques are to some degree applicable to other panel mounted GPS receivers.

➢ Navigating a leg based on course information

Many GPS panel-mounted receivers do not have the TURN field nor do they have a sufficient number of data fields to separate display of TRACK and BEARING without sacrificing other essential information. However, they have TKE, which is the required track change to parallel the course. In some ways, this is a better way to navigate a route leg.

| Diverging | Parallel | Converging |
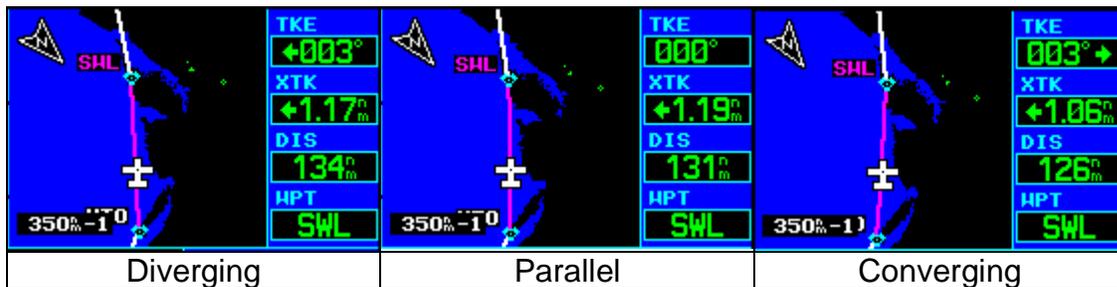
Figure 7-12

Consider the TKE field to be just one piece of the puzzle that is to be used in conjunction with XTK (cross track error – same as OFF COURSE) and distance. The only caveat for flying a route leg is that line defined by the two waypoints to create the route leg continues all the way around the world. You could fly beyond the last waypoint on the route without realizing it unless you are watching the distance to the waypoint. This is usually not an issue when flying a route, because the GPS will sequence to the next leg. This can be a problem at the destination or when flying directly to a point.

➢ Navigating directly to a point using course information.

If you have your GPS set up to navigate using course information such as in Figure 7-12, you can use this configuration to navigate directly to a point. You could change TKE and XTK to TRACK and BEARING, but this involves more time fiddling with the GPS than is necessary.

You simply change the problem from navigating to a point to navigating along the line defined by the waypoint and the position of the aircraft. First, execute a GOTO. This creates a line from the aircraft's present position to the active waypoint. Second, make the turn based on the TKE suggested by the GPS, perhaps adding just a little for the turn radius. Third, execute another GOTO to compensate for the turn radius. Finally, just navigate this leg.

Your are here after off from KRDU	When ready to go direct, execute a GOTO.
After turning by the TKE amount plus a couple of degrees you will be here.	Do a "clean-up" GOTO and fly track this leg.
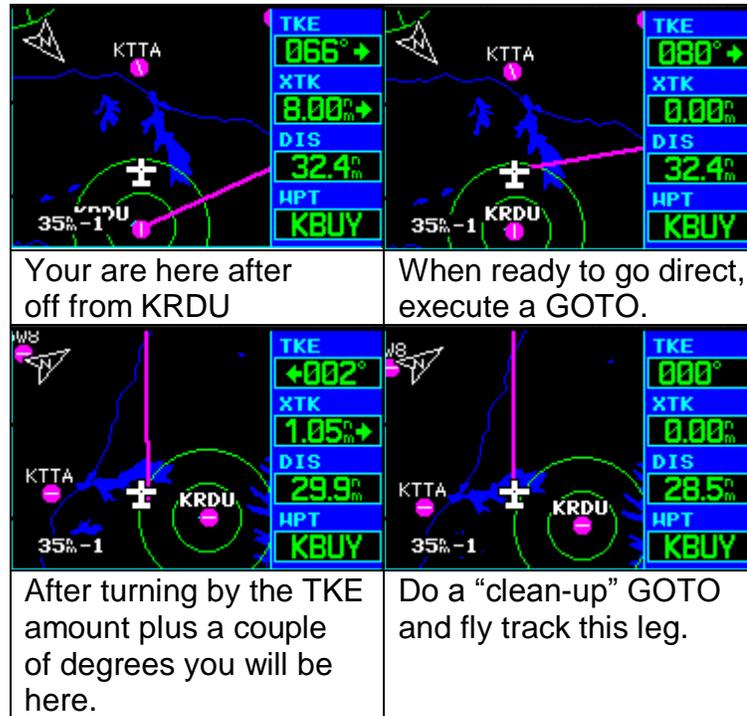
Figure 7-13 Navigating to a waypoint with course data

Note that in figure 6-9 if you only flew using TKE as displayed in the initial picture without reference to XTK, you would miss KBUY by 8 nm. TKE only gets you parallel to the course.

As I had mentioned before, there is the caveat that it is possible to stay on course and fly beyond the destination. The map display and the distance data should save you. This is no different from flying inbound on a VOR radial and then flying outbound. This is not a big deal if you know about it.

However, pilots have overshot the destination. Figure 7-14 gives an example of this.

Approaching the destination	Flying beyond the desti-nation on course.
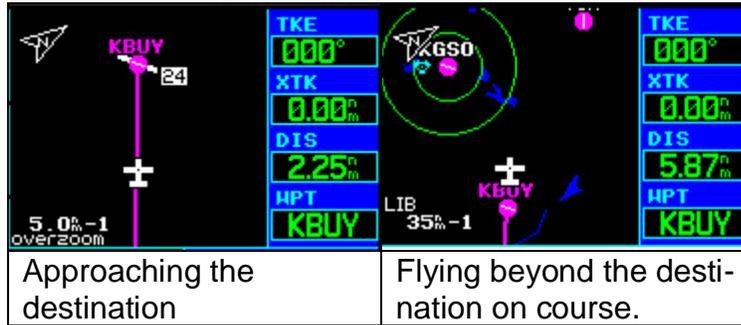
Figure 7-14 Destination overshoot

TRACK verses HEADING example

Situation A: Heading toward the navaids

Aircraft heading and navigation instruments
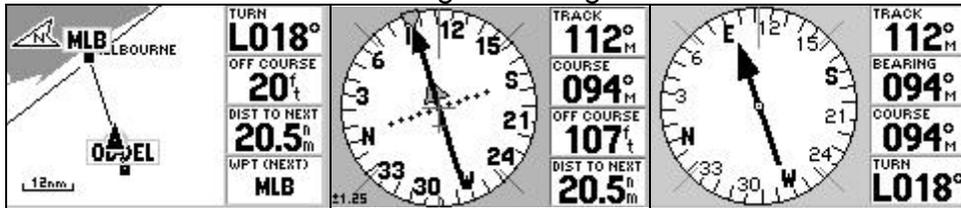
GPS indications (Garmin GPS III Plus, III Pilot, III Plus)

Figure 7-15

Situation B: Tracking toward the navaids

Aircraft heading and navigation instruments
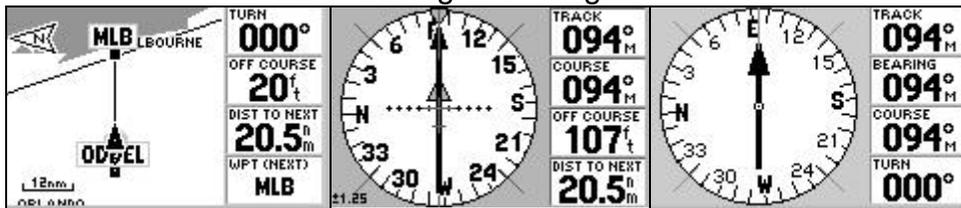
GPS indications (Garmin GPS III Plus, III Pilot, III Plus)

Figure 7-16

Scenario: Flying between ODDEL intersection and MLB VOR. Although, I do not show the chart, ODDEL is charted as the MLB 271° radial. SQT NDB is just to the east of MLB. MLB and SQT are close enough to be considered co-located for the purposes of this example.

Wow, there is a strong wind out of the north today! As you can see, there is a big difference between the indications for track and heading instruments. If we did not have a GPS and had no idea what the winds were, we would have to bracket the course. Bracketing is essentially systematic guessing of what heading might hold the course. The GPS in situation A indicates that we need to turn left 18 degrees to go directly to MLB—no guesswork.

In situation B, as indicated by the GPS, we are tracking directly towards MLB. The HSI and ADF reflect the crab angle being used to correct the wind drift. The GPS makes it appear that MLB is straight ahead. However, if we were to look out the window for MLB, we would have to look 18 degrees to the right. If we did not have the luxury of an HSI and ADF, we could compare the GPS bearing to the directional gyro to find where to look. Instead of changing data fields on the map page, which takes several steps, I have the GPS set up so that I can just switch to the pointer page quickly to see BEARING.

BEARING and COURSE both indicate 94 degrees. However, we are supposed to be on the 271 radial – 91 degrees inbound. As I discussed earlier, the GPS bearing and the VOR radial are slightly different because of the nature of the VOR. This is not a problem; the path over the ground between ODDEL and MLB is the same as the MLB 271 radial. The problem is that MLB set up for a magnetic variation that is 3 degrees different from the variation calculated by the GPS. The GPS variation is probably more accurate. The earth's magnetic field has probably changed 3 degrees since the MLB was aligned to it.

Chapter 8 Route Intercepts

Enroute GOTO

An enroute GOTO is where you want to go to a waypoint that is not the currently active waypoint. Hopefully, but not always, it is a waypoint further along the route. The point that you GOTO becomes your active waypoint. It also creates a new active leg which is the line from the point at which you activated the GOTO to the new active waypoint.

It is also possible to execute a GOTO the active waypoint if you want to navigate directly to the active waypoint from a point off the route. An example of such a case would be when cleared back direct to a waypoint after being vectored off of the route. If you execute a GOTO the active waypoint, the waypoint is already selected and it is a quick press of the GOTO (or Direct) button and then the ENTER button. This is nice to draw a fresh course line and update the OFF COURSE value to the new direct routing, but is not necessary if you are using BEARING and TRACK or TURN to navigate such as you might using a handheld GPS. A GOTO is necessary if you are navigating using DTK and TRACK or TKE such as on a panel mounted GPS.

If you execute an enroute GOTO to a waypoint further along the route, in other words skipping some waypoints, the GPS should continue along the route after reaching the point that you executed the GOTO to. A noteworthy exception and personal complaint is that the GPS V terminate the route at this point.

If the selected waypoint is not along the route, navigation along the rest of the route is cancelled.

Original Route	Original Route

Figure 8-1

GOTO CHS	GOTO CHS
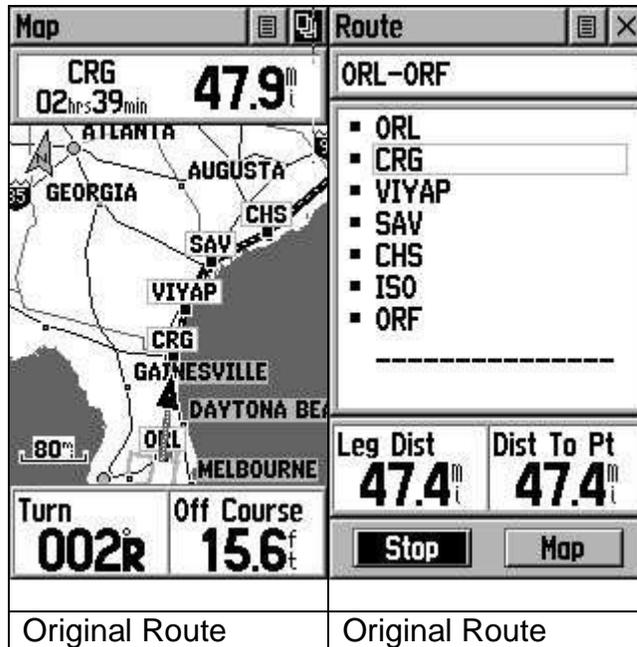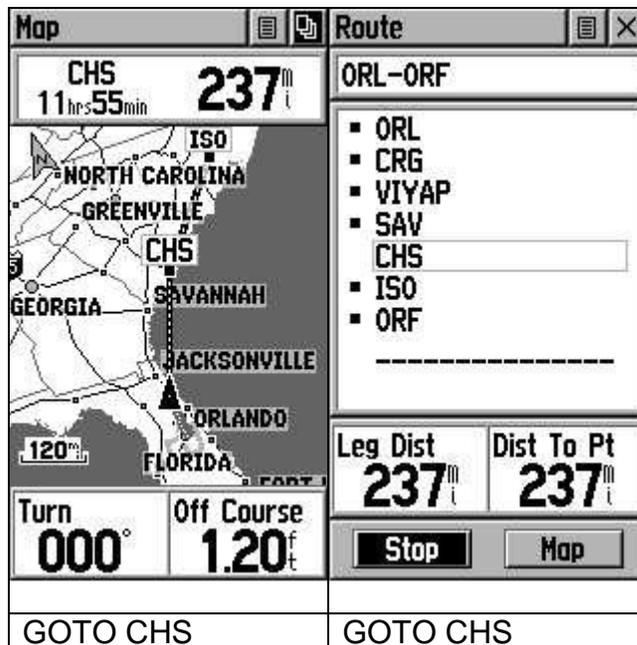
Figure 8-2

Figure 8-1 shows the original route and Figure 8-2 shows the route modified to reflect a clearance direct CHS.

Each different receiver seems to have a slightly different way of accomplishing this task. For the most part I would refer you to the instruction manual, but here are a couple of hints. Also of equal importance is learning how to cancel an enroute GOTO so that you can resume the normal route.

➢ GOTO tricks on Garmin receivers

GOTO or Direct (D with an arrow through it) button:

The most common method is that available on the GPS receivers with a GOTO button. It is much easier to select the desired waypoint from the active route list than to spell it in. Page through to the active route, move the cursor down to the desired waypoint and press the GOTO button.

It is also important to know how to cancel a GOTO. To cancel the GOTO: Press the GOTO button, then press the MENU key and select CANCEL GOTO. Some receivers have a RESUME ROUTE or other such menu option.

NAV key:

The Garmin 76 series lacks a GOTO key but has a NAV key. This works similar to the GOTO key. The only difference is that to cancel the GOTO, you must select NAVIGATE ROUTE and then reactivate the original route.

eTrex Legend, Vista, and Venture:

The problem with the new eTrex series (Vista, Venture, and Legend) is getting to the active route. The trick is to hold the FIND button (bottom left button on the side) until the active route appears. Select the point with the click stick, select "Review" from the menu, and finally select GOTO from the waypoint menu.

To cancel the GOTO, hold the FIND button. The STOP button will be highlighted on the active route. Click on it and it will become the NAVIGATE button. Click again and the full route will be reactivated.

Garmin 400 and 500 series

If the point that you want to go to is on the flight plan: Select the direct key. You will get a menu to select the waypoint. On this screen there is a box labeled "FPL." Move the cursor to this field with the outer knob and then use the inner knob to select points along the flight plan. This is quicker than selecting them by spelling them in the default field.

Using the map display:

Generally, I find it easier to select the text from the active route page to execute a GOTO. However, most of the Garmin receivers allow you to place a cursor on the map and press the Direct, GOTO, or Nav key as

appropriate to navigate directly to the point. If the selected point is on the route, it will work just like a normal enroute GOTO.

Intercepting the route further along

Often you will be given a heading to intercept a leg rather than going directly to a waypoint; i.e. a shortcut without the need to navigate directly to one of the waypoints. If this is part of the route, which it usually is, then often the easiest thing is to do nothing to the GPS – just wait until you intercept the route and start navigating again. Manipulating the GPS in flight can be a distraction and the less of it you have to do, the better.

In figure Figure 8-3 the scenario is that ATC has given a heading to intercept the VKZ 029 radial and the MRLIN4 arrival into FLL. Although I do not show the arrival plate, the VKZ 029° radial defines the MRLIN4. The MRLIN4 is also defined by the waypoints along the arrival, which are programmed into the route.

Figure 8-3

Auto sequencing to the next waypoint varies from receiver to receiver. In the case of the Garmin receivers, the legs and waypoints sequence very well. Essentially, the GPS will navigate along the closest leg. There is no need to pass directly over or even close to the active waypoint. In this case, TRIPL is the active waypoint and DIMND to TRIPL is the active leg. The aircraft will intercept the arrival around DUBBL. As the aircraft passes TRIPL, TURN will reach 90° and perhaps even a little more as the aircraft passes by TRIPLE before intercepting the course. It should be obvious that you do not want to turn 90° to the left to go directly to TRIPL. After passing TRIPL, the GPS will sequence so that DUBBL is the active waypoint and TRIPL to DUBBL is the active leg. When the OFF COURSE approaches zero plus a little bit for the turn to join and the active waypoint is ahead of the aircraft, then the GPS can be used for guidance again.

Notice the indication of a left TURN to get to TRIPL is an indication that the aircraft is going to intercept beyond TRIPL. A right value of TURN in the last screen is an indication that the aircraft will intercept before DUBBL. A TURN of zero would indicate an interception at DUBBL and a left TURN would indicate an interception beyond DUBBL.

Intercepting a leg

Several aviation GPS receivers, including such handhelds as the GPS 196, allow you to not only go directly to a waypoint but to activate a leg along the route. The first pressing of the direct button brings the option of going direct to the selected waypoint (enroute GOTO). Pressing the direct button again brings up the option of activating the route leg into that point rather than simply going direct. In this case, the active leg is a line formed by the previous route waypoint and the active waypoint. Contrast this with a GOTO where the GPS creates a leg from the point of that the GOTO is executed to the active waypoint. Thus BEARING and therefore TURN will be the same as for a GOTO, but XTE and TKE will be different. The hidden feature is that route leg extends indefinitely backwards – think of it as an extended centerline.

Figure 8-4 represents a slightly different scenario from Figure 8-3. In this case, ATC has given a heading to intercept the VKZ 029.° However, the heading does not intercept the route. The leg from DIMND to TRIPL is along the VKZ 029. By activating this leg, the GPS will give guidance to intercept the VKZ 029 outside of DIMND. After passing TRIPL, the GPS will continue sequencing along the route.

Figure 8-4 is a screen capture from the Garmin 430 simulator. The first screen is before activating the leg from DIMND to TRIPL. In this case the active waypoint is from HOBEE to DIMND. In addition to this leg being magenta, the values of TKE and XTK reflect the aircraft relative to this leg. For example, notice that the course is 8.51 nm. to the right of the aircraft. The second screen is after activating the leg from DIMND to TRIPLE. Even though the route does not graphically depict going backwards through DIMND, TKE, XTK both reflect this extension. The CDI (not shown) would also reflect this extension.

Figure 8-4

Magellan mapping handheld note: The Magellan mapping handhelds offer a GOTO. But if you GOTO a waypoint on the active route, the GPS will not navigate beyond this point. However you can choose a leg of the active route. Press MENU -> ROUTES -> cursor over the active route and

press MENU and then select SELECT LEG. When you select the leg, TURN and BEARING will be relative to the waypoint and you can therefore navigate directly to the point even though the map display and XTE will be relative to the chosen leg.

OBS feature of aviation receivers

Notice that I have progressed from easier to more complicated techniques. It is very seldom that you have to intercept a radial that is not part of the route or at least a leg further along the route. However, most aviation GPS receivers allow you to intercept any radial to any point using the OBS feature.

Essentially this works like the OBS on a VOR where the active waypoint functions like a VOR. OBS AND HOLD causes the GPS to not sequence to the next waypoint after the active waypoint is passed. This allows for flying outbound from the waypoint using the OBS or to hold on the waypoint. RELEASE HOLD allows the GPS to sequence to the next waypoint after passing the active waypoint.

A GPS course is often numerically different from a VOR radial for the same path over the ground. VOR's are aligned with magnetic north and not realigned as the earth's magnetic field changes over time. The GPS calculates magnetic variation with an internal algorithm that yields results that correspond very closely with the isogonic lines on an aeronautical chart. Thus, the magnetic course in the route of the GPS will often differ by several degrees from the published VOR radial. I discuss this more detail on page 9-25.

If the active waypoint is a VOR and the GPS is set to use automatic magnetic values in the setup menu on a GPS receiver such as the Garmin 196, 295, 400 series, and 500 series, the OBS works like selecting the VOR radial. The Garmin GPS III Pilot does not have this feature. With the receivers that have this feature, the GPS automatically compensates for this VOR misalignment. However, this only works when active waypoint is a VOR. In such a case, you may notice that the value for COURSE and BEARING differ slightly from the OBS value that you set -- even when you are on the radial.

We will continue to use the example of being given a heading to intercept the VKZ 029° radial outside of DIMND. There would be a slight error if you were to go direct to DIMND and set the OBS set to 209° (reciprocal of 029°).

I will use a GPS III Pilot in this example. With the GPS III Pilot, it is not possible to activate the leg from DIMND to TRIPLE. Since it does not

have the compensation for the VOR misalignment, it is not possible to execute a GOTO VKZ and just set the 209° (reciprocal of 029°) on the OBS.

DIMND, TRIPL, DUBBL, MRLN, and TRITN are all along the VKZ 029° radial and are already programmed in the route. This is shown on the approach plate, which I have not included. As you can see in Figure 8-5, a quick look at the route page shows that a COURSE of 211° into DIMND would be good to fly the VKZ 029°. A quick GOTO DIMND and setting the HSI OBS to 211° and then selecting RELEASE HOLD sets up the GPS to navigate as in the second screen of Figure 8-5.
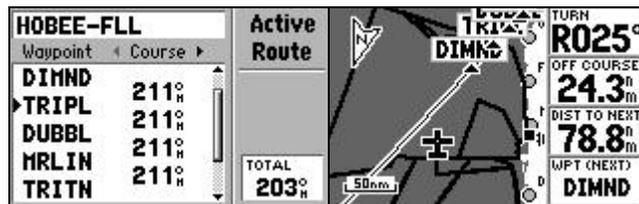
Figure 8-5

It is important to realize that just because you may use the HSI page on a handheld GPS or the physical HSI or CDI on a panel mounted GPS, you can still use the map page to navigate. The OBS mode is just a way of setting the course. Navigation is the same as navigating any other leg. Also make sure that properly set the GPS to sequence or not sequence after reaching the active waypoint as desired as you require.

If you do not have a predefined course along the radial, or a GPS that will compensate for the VOR misalignment issue, a little perspective on the issue might be in order. The error for using the OBS with the GPS radial when it is not correct to do so is generally not bad unless the VOR is very misaligned and the distance from the waypoint is large enough to make the cross track error significant. With all but the most misaligned VOR's, the inaccuracies introduced will probably still be more accurate than the VOR.

Always remember that you can use the VOR in the aircraft to intercept the radial and just execute a GOTO once you are on the radial as indicated by the VOR. The GPS will still be of use for finding a suitable heading to navigate along the radial.

Bearing intercepts without an OBS feature

It is possible to intercept and fly a specific BEARING without any of the techniques mentioned so far. All that is necessary is that you have a display of the BEARING field. The OBS or leg intercept features are nice

in that they allow you to draw the bearing line on the map and have an OFF COURSE value relative to that line. However, it is possible to intercept a bearing without them.

Although, receivers could be designed to show bearing *from* rather than *to* the waypoint, I have not seen any that are. Thus, if you have a bearing or radial from a station, then you must use the reciprocal. A simple mental trick is to ratchet the first digit up or down by two as necessary to keep it between 0 and 3 and correspondingly ratchet the next digit in the opposite direction. If you wanted the 029° radial, then ratchet the 0 up by two and the 2 in 029 down by two to get 209°. This is simply adding 200 and subtracting 20 or vice versa which is the same as adding or subtracting 180°.

To fly any bearing, the principle is that moving clockwise relative to the active waypoint will cause BEARING to increase, and moving counter clockwise will cause it to decrease. This works like any clock or a variety of other gauges. The way that I mentally picture this functioning is to picture the waypoint as a pivot on a needle and that I am moving the tail of the needle and reading the head.

One of the biggest principles of many things is that if you are getting the results that you want, continue doing what you are doing. If you forget that sensing of the BEARING field or are confused by it, generally you will be using it in the context of a heading to intercept. Keep the heading until the BEARING is close to the value that you want. If the BEARING is getting further from your target, then you are not on an intercept heading.

It would be possible to navigate using GPS with nothing else other than the BEARING field, like a digital equivalent of an ADF. However, once you are on the BEARING, execute a GOTO and go back to using OFF COURSE, and TRACK.

Figure 8-6

Figure 8-6 shows a heading to intercept using a non-aviation Garmin GPS III Plus which does not have the OBS function. This is the same example as we have been using of a heading to intercept the VKZ 029° outside of DIMND. As I have already discussed in the *OBS feature of aviation receivers* section, that this means that we want to intercept the 211° BEARING. It is a simple matter of changing the GPS to indicate

BEARING. Once we are on the 211° BEARING, it is a simple matter of turning so that TRACK matches BEARING to fly this BEARING inbound. In the third screen, I executed a GOTO and changed the fields back to how I would normally navigate with this GPS. Since the GOTO was executed while on the 211° BEARING inbound, this third screen is suitable for continuing to fly inbound to DIMND on the 211° BEARING.

If you are used to using an RMI, using the POINTER or COMPASS screen would have accomplished the same thing. However, setting a field to BEARING accomplishes the same thing, but still allows you to have the map display for situational awareness.

Chapter 9 Miscellaneous

In this chapter I have miscellaneous techniques and explanations that just didn't fit anywhere else. Some you might find relevant, others you might find obscure and useless. The one thing that I would like to reemphasize is that your first priority is to fly the airplane. Just because it is possible to do something with a GPS does not mean that it is worth doing. A neat trick with the GPS is great if you have the proficiency to do it with little distraction, but concentrating too hard on using the GPS at the expense of flying the aircraft is bad. Only you can be the judge of when you have crossed over the threshold of creating more distraction than benefit with the GPS .

Runway incursion avoidance

Runway incursion is a hot topic and a big threat. If you have an aviation GPS with a map display, use it on the ground also. All of the receivers that I am familiar only offer a runway depiction rather than a full diagram complete with taxiways. Even so, this is enough to provide orientation to let you know that you are approaching a runway. Although, I would like to see a full airport diagram, the runways are the critical item. Being on the wrong taxiway is embarrassing; a runway incursion can be fatal. Figure 9-1 is from a Garmin GPS III handheld and is typical of the detail of the airport diagram available on most GPS receivers.
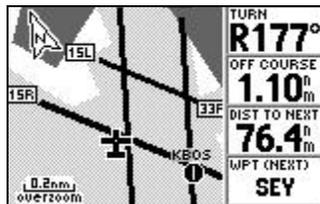
Figure 9-1

There is not much to the technique except to use the GPS in the map mode from taxi out to taxi in by zooming in so that you can see the runway diagram while on the ground. If you blissfully taxi along until the GPS shows that you are coming up on a runway, your safety margin will be reduced. If you have a copy of the airport diagram out, pay attention to the airport markings, and use the GPS for verification and orientation, your safety margin will be greatly increased. The conservative approach is that if the GPS indicates that you are clear of the runways you might not be, but if it indicates that you are on a runway you better suspect that you are.

One little caveat: The orientation of the diagram will not be correct until you start to move. Remember the GPS has no idea of heading, but only knows track. There is no track until there is movement.

In practice, I have found that the runway ends can be slightly off on my GPS III Pilot, but the lateral accuracy is amazing. If you are on the runway, the GPS will show you on the runway even though the runway ends might be a little off. The type of scenario that this could have prevented is the 1990 Northwest DC-9 crash. The DC-9 incorrectly taxied onto runway 3C in DTW. A 727 was taking off and hit the DC-9. Inexpensive handheld GPS receivers where not available at the time and would be prohibited today, but such a receiver would show the pilot that he was on the runway.

A corollary technique is to use the GPS to identify that you are taking off or landing on the correct runway. The immediate case that comes to mind is the crash of a Singapore 747-400 that took off on the wrong parallel runway in Taiwan. The runway that the pilot took off on had construction equipment placed well down the runway. A small handheld GPS with the proper database would have shown which runway the aircraft was on.

It will be years and maybe decades before this capability is officially available in airliner cockpits. Considering the layers of layers of study, certification, and budgeting I give it a decade at best before you see this capability in airliners.

As an aside and if you are curious: If you are a general aviation pilot you might think that glass cockpit airliners have a runway diagram. For the most part, the departure runway is programmed into the flight plan on the FMS. When the pilot reaches the end of the runway, he hits a button to update the FMS position to the end of the runway. The assumption is that aircraft's position on the airport is correct and the FMS gets updated to reflect this position.

Let's say the an airline pilot was cleared for takeoff at KXYZ in low visibility on 9L and takes off on 9R. If 9L were the intended runway, it would be programmed into the FMS. At the end of 9R, the pilot thinking that he was on 9L would update the FMS. The FMS will have been told that it is at the end of 9L when it was actually on 9R. Thinking that it was on 9L, the FMS would then initially be off by the distance between the 9L and 9R thresholds. The newer GPS enhanced aircraft such as the 777 show the departure runway and do not need to be updated, but they still do not show the other runways.

The point is that the airport orientation ability offered by the map display of a common aviation mapping GPS is not available to airline pilots. Furthermore, its use is prohibited in most cases by company policy.

TFR (Temporary Flight Restriction)

I am not suggesting that you use the GPS as your only means to avoid a TFR. I want to give you a trick or two for using the GPS as one more tool to avoid a TFR. Needless to say, I suggest that you add a good safety margin.

The FAA publishes the latest TFR information along with a graphic depiction at http://tfr.faa.gov.

Among other techniques, you may want to print out the graphic TFR and plot your route on the printout. You might also use the graphic depiction to help you choose waypoints that will allow you to create a route that will keep you well clear of the TFR. You can also use the text descriptions to plot the TFR on an appropriate chart. The GPS techniques that follow are just one more tool.

Here is the example. You are going to fly from KRDU to KBUY. The President is speaking at UNC in Chapel Hill after first visiting North Carolina's premiere university, NC State, in Raleigh. There is a TFR at N35°55.7' W079°03.1' with a radius of 5 miles (not a realistic number anymore) up to 3000 feet. In actuality, you would probably be talking to Raleigh approach, but play along for the GPS demonstration.

➢ Proximity waypoint technique

The first steps are to create a waypoint for the TFR and create the route without regard for the TFR. On most mapping GPS receivers, at least every Garmin receiver, the measure distance tool can be used to avoid the TFR. Several of the newer Garmin receivers support proximity waypoints. This is very handy for drawing a circle around a TFR.
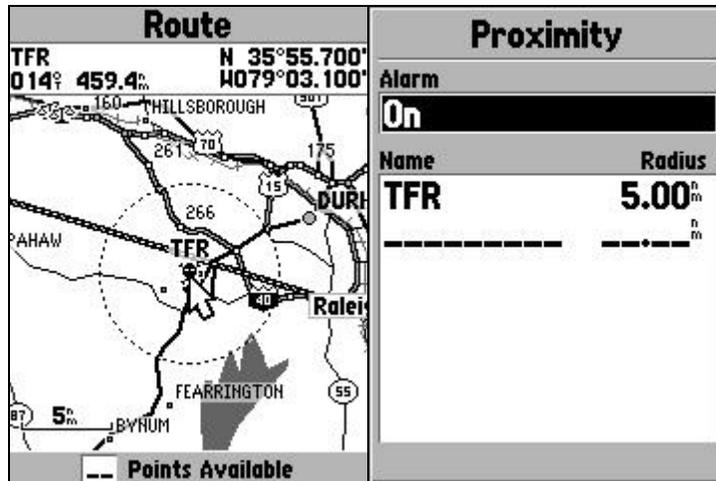
Figure 9-2

Figure 9-2 shows the proximity waypoint feature of a Garmin GPS Map 76. As you can see, the 5 mile radius is easy to see. A word of caution – the GPS warns you when you are within the circle defined by the proximity waypoint and its radius. By this time, you are busted. However, in this example we are not using the proximity waypoint feature for the alarm but for the plotting of the TFR for creating a route around it. Using the edit on map functions described on page 6-7 it is a simple matter to drag the route line and create a route outside of the TFR

➢ **Measure on map display technique**

If you have a GPS without the proximity waypoint feature, the "measure distance" tool can be useful to help create a route to avoid the TFR.

Figure 9-3 shows the same TFR point and route using a Garmin GPS III Pilot. Using the measuring tool, the route passes within .9 nm of the TFR. The cursor can be used to find the location of a couple of waypoints that can be added to the route that will be sufficiently far. How much of a buffer you want to add, I will leave to your discretion.
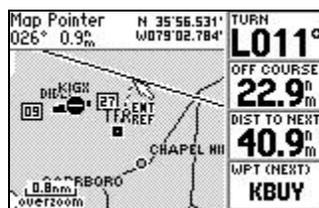
Figure 9-3

Unfortunately, there is no way to directly create these waypoints with the map display at the cursor position. If you press ENTER, the new reference for measuring distance will be set to this point rather than creating a new waypoint.

There are two techniques for creating the waypoints to the route. One is to note the latitude and longitude at the points that you would like to add to the route. These points can then be created manually and added to the routes. Another method is to note features on the map that will provide adequate distance and use the edit on map feature to create a route in reference to these features.
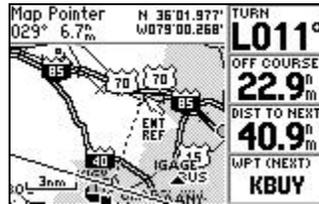
Figure 9-4

Figure 9-4 shows that staying north of U.S. 70 will provide at least 6.7 nm. of distance from TFR.

Figure 9-5

Figure 9-5 shows the steps of modifying the route. In the first frame the route is modified using the map display of the route. Using the map display from the route page, place the cursor on the route. After the route becomes a dashed line, press ENTER and drag the route. Press ENTER again to create a waypoint. On some receivers, you might have to press ENTER one more time at this newly created waypoint to add it to the route.

In the second frame, the map display of the active route using the distance measuring feature of the map is used to verify that the distance is sufficient along the route. The third frame represents what you would see in flight as you navigated along the route in flight. The cursor is placed on TFR to get a bearing and distance to the TFR as one more verification.

GPS Altitude

An altimeter serves two functions, it provides a way of measuring the distance of the aircraft from the earth and it provides a way of layering air traffic. It is basically just a calibrated pressure instrument. The GPS calculates a three dimensional position, of which altitude can be thought of as a component. WAAS (page 3-4) improves the position calculation of

the GPS and thus the altitude accuracy. In fact, the ability to provide vertical guidance is much of the reason behind WAAS.

The barometric altimeter has its errors and the GPS altitude is subject to position errors.   I doubt that you will see GPS altitude replacing the very robust if not always accurate barometric altimeter. I have seen various figures for GPS altitude accuracy. Receivers with WAAS capability should be more accurate. If you look in your GPS manual you will find quotes as to accuracy. In many cases, such as on very high or low temperature days or at high altitudes, I believe that the GPS altitude may actually be more accurate than the barometric altimeter.

There have been several cases in very cold weather where airliners have been flying at or above the minimum altitude and received GPWS (Ground Proximity Warning System) warnings. Although there are newer GPWS units based on terrain databases and GPS positioning, most are based on radio altimeters. Even thought the pilots thought they had adequate terrain clearance judging by the barometric altimeter, they were physically low as indicated by the aural warning from the GPS of "WHOOP WHOOP, PULL UP, TERRAIN!". The problem is that a cold column of air is shorter than a standard column. In one case, this barometric altitude error was 1,400 feet.

If this were a general aviation aircraft with no GPWS, it probably would have just hit the mountain and it would have been chalked up to pilot error. My point is that on a cold day with terrain, a GPS altitude indication might make a good double check.

If you have to climb based on the most conservative altitude between the GPS and barometric altimeter due to a significant discrepancy between the two, I would advise letting ATC know why you are climbing. If the problem is a suspected faulty altimeter, it will allow them to leave a little more space around you. If the problem is due to atmospheric conditions, it will allow them to alert other aircraft.

What constitutes a significant difference is a matter of judgment. It is not uncommon to get a difference of a couple of hundred feet at higher altitudes, but the difference should decrease at lower altitudes.

It is important to remember that everybody else in the sky is using barometric altitude. The other aircraft in the same area will have the same altimeter errors and separation will be maintained. For example, above 18,000 ft (U.S.) pilots set the altimeter to 29.92" Hg. Pilots at these altitudes are really just flying a constant pressure level which has a rough correlation to the distance from the earth. At these altitudes, the important

thing is to maintain separation from other aircraft and these other aircraft are also doing this same thing.

For reference to terrain clearance including stopping an IFR descent before reaching the ground, my arguments against trusting a handheld GPS as an altitude reference would be similar to my arguments for not using it for flying an approach which I have discussed under on 2-17. Basically, even though it is potentially more accurate in many cases, it is not necessarily more dependable or robust and there is no way to know when it is not accurate.

When the GPS gives an altitude, there is also the issue of what the altitude is in reference to. As I dug a little deeper into the subject, the concept of mean sea level, MSL, became more complicated. The issue is when you look at an altitude on a chart, GPS, or altitude, what is it really in reference to. For the environmentalist, tracking sea levels is important. For the pilot, all that is important is that the charts and altimeter are referencing the same thing and MSL is a useful abstraction for how high everything is.   This is usually taken for granted in that the altimeter setting that you dial in compensates for all sorts of factors and that your altimeter reading should agree with the charted field elevation at the airport reference point. When using a barometric altimeter with a local altimeter setting, these finer points of what your are really reverencing becomes somewhat of an obscure academic discussion.

For GPS use, this reference discussion can be an important discussion. For the most part, in most developed countries, with most newer GPS receivers if they are set to the WGS-84 datum, the GPS altitude and the charts should be referencing the same reference commonly known as mean sea level, MSL. However, this is not always true. In fact, I called the NIMA, the National Imagery and Mapping Agency and one of the things that they are trying to do is get all of their data to match this reference.

The earth is not round. It can be estimated by a rough shape called an ellipsoid. This is just an ellipse rotated around the earth's axis. If the earth were porous and there where no tides so that you could drill down to sea level at any point, the surface of this sea level would not even smoothly align with the ellipsoid. This theoretical surface is called the geoid. This geoid for all practical purposes is mean sea level. My research seems to indicate that most GPS receivers use this as the reference. However, it is important that the GPS datum is set to WGS-84 which is the default setting. Some the older GPS receivers use height above the ellipsoid rather than the geoid.

To further complicate the issue, there is the issue of how the charted altitude was surveyed and referenced. Just as navigational technology has increased in the last couple of decades, so has surveying technology. Most altitudes in most industrialized countries are probably surveyed recently enough or converted well enough from old data to be considered to reference the same thing as your GPS, but this might not be the case in less industrialized locations.

This brings me to the point of what use is the GPS calculated altitude. I consider it quite reasonable to use the GPS altitude as a cross check. This is especially true in areas where terrain is a factor. I can't see any harm in using GPS altitude as a check and emergency backup for the barometric altimeter. If the barometric altimeter fails and the GPS is all you have, it could be a lifesaver. When terrain clearance is a factor, I can't see any harm in using the most conservative data between the GPS and barometric altimeter to assure clearance.

For more information on this subject I refer you to:

o http://edu-observatory.org/gps/height.html
   This is a description as well as having several links. This is Sam Wormley's site to whom I owe thanks for helping me on some of this subject matter.

o http://164.214.2.59/GandG/datums/vertdatum.htm
   This a good explanation of various heights by the National Imaging and Mapping agency.

o Lies Your Barometric Altimeter Tells You, Peter Norman
   http://www.aircraftbuyer.com/learn/train06.htm

o The Use of Raw GPS Altitude for Vertical Navigation
   J.D. Andrew Graham, Nav Canada
   http://www.bluecoat.org/reports/Graham_2001_RawGPS.pdf
   The context of this article is that unaided GPS can be used for vertical navigation during approaches. Key to the discussion is the altitude accuracy of GPS.

VNAV (Vertical Navigation)

A GPS calculates a 3-deminsional position. Just as GPS can navigate in the horizontal plane, it can navigate in the vertical plane. There is the catch that the GPS altitude is not as accurate as the horizontal position.

For the most part, only aviation GPS receivers are set up for VNAV. However, both the Garmin VISTA and GPS MAP 76S (only the S model) have limited VNAV capability.

Setting Up a profile

Figure 9-6

Most GPS receivers have similar options in setting up the VNAV profile. Figure 9-6 is from a Garmin GPS III Pilot, but is typical of most aviation receivers.

Most of the fields are self explanatory, but a couple of them need a little more explanation. The target altitude has the option of MSL or Above Waypoint. In order for the Above Waypoint option to work, the GPS must know the altitude of the waypoint. For airports, *Above Waypoint*, is a useful option. For something like a VOR, you will probably get an error if you try to use *Above Waypoint*. This is not a problem -- usually in the cases that generate an error for using *Above Waypoint*, MSL would be the appropriate choice anyway.

The *Profile* field allows you to enter a rate of descent that you want to descend at. This allows the GPS to create a warning when you are approaching the point at which you want to descend. Some GPS receivers also have selectable data fields to indicate a time or distance to the point at which you will need to start down at the profile descent rate to reach the target.

As I mentioned before, the Garmin Vista and GPS MAP 76S do not offer the setup options of an aviation receiver. They only provide data directly to the active waypoint. Although these GPS receivers offer less VNAV flexibility than an aviation GPS, I can see where the capabilities might be quite adequate for something like soaring or hang gliding. There is some control in that you can change the altitude of the waypoint. For example, if the waypoint is an airport, you might consider storing the elevation as pattern altitude instead of field elevation.

How to use VNAV: VNAV alititude
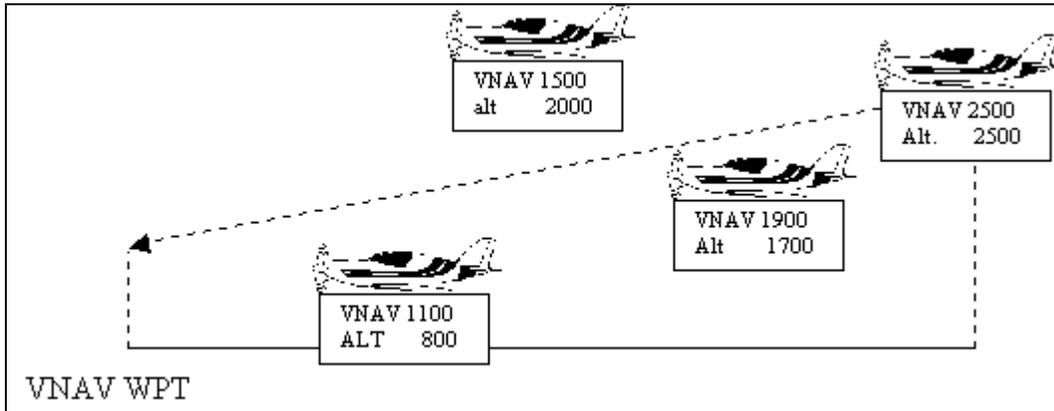
Figure 9-7 VNAV altitude (not to a precise scale or value)

The Garmin GPS 92 and some of the Bendix King GPS receivers are the only ones that I know that give a numerical value for the VNAV altitude. Many other handheld receivers offer a pseudo-glide slope needle on the HSI display that compares the GPS altitude with the VNAV alitude.

When the aircraft reaches a point at which the angle to the target is such that the aircraft traveling at the current groundspeed would have to descend at the set profile descent rate, the GPS draws a line from the aircraft position to the target for a reference for the VNAV altitude or HSI needle display. The aircraft can change groundspeed, but the GPS will reference the line created at the capture based on the original groundspeed.
Most receivers have an option of capturing a VNAV profile before reaching the profile point. On the Garmin receivers that have this feature, press MENU from the HSI page.

As far as the pseudo glide slope needle goes, I prefer to use a data field on the map display set to VS REQUIRED or GS REQUIRED rather than this feature. On a GPS such as a Garmin 196 or 295 where the HSI can be displayed concurrently with the map display, I am more open to its use.

How to use VNAV: VS to TARGET
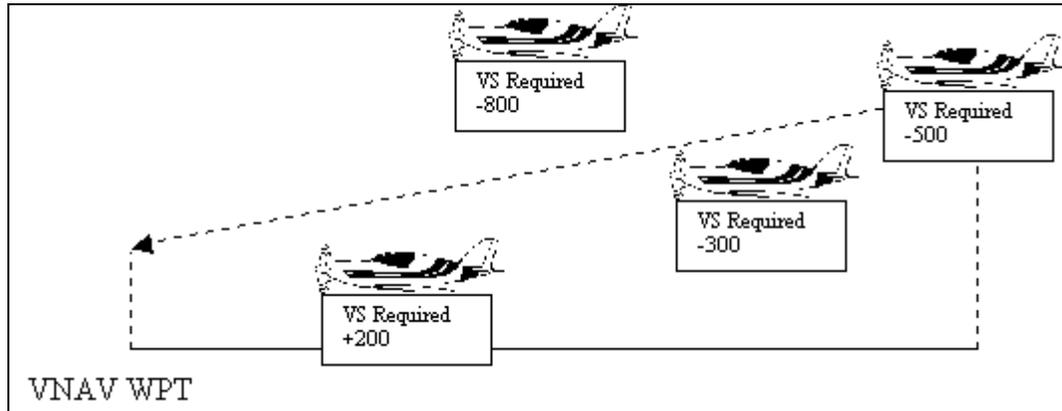
Figure 9-8 VS to Target (not to a precise scale or value)

I find the most useful VNAV mode to be to use the *VS REQUIRED* field. This only takes one data field, thus there are still enough data fields left on a receiver such as a Garmin GNS 430 or a GPS III Pilot to still use the map page for navigation.

If *VS REQUIRED* indicates that a higher rate of descent is required, then you are floating above the profile. If a lower rate of descent is required, then you are sinking below the profile. Figure 9-8 shows how it works.

There is a caveat in that *VS REQUIRED* is not only based on the geometry of the aircraft position relative to the VNAV target, but it also depends on the groundspeed. A decrease in groundspeed will cause a decrease in *VS REQUIRED* and vise versa even if the aircraft remains on the profile. You should understand that the groundspeed is a factor, but in general this is not a problem.

It is nice to also display the *VERTICAL SPEED* in a data field, but it is not required. Whether or not you also display *VERTICAL SPEED* depends on how many data fields that you have. If you have a Garmin GPS 295 with 8 data fields or a GPS 196 with 10 data fields, then you have plenty of fields to spend an extra one on vertical speed. If you have a Garmin GPS III Pilot or a GNS 430 with only 4 data fields, I usually not spend one on vertical speed. An expectation might be in a sailplane where the *OFF COURSE* field would be of minimum value.

The profile value for vertical speed such as in Figure 9-6 is useful in that it allows you to set a value so that the GPS can alert you that you are approaching the point to start down. You might also set a field on a secondary page to *TIME to VNAV* or *DIST to VNAV* so that you can occasionally check how far you have to go before starting your descent.

However, the only profile as such is a self imposed one. If the value of *VS to TARGET* has increased indicating you are above profile, you can increase the vertical speed to make sure that you make the VNAV target, or you can increase it even more to get back on the profile.

How to use VNAV: GR to TARGET
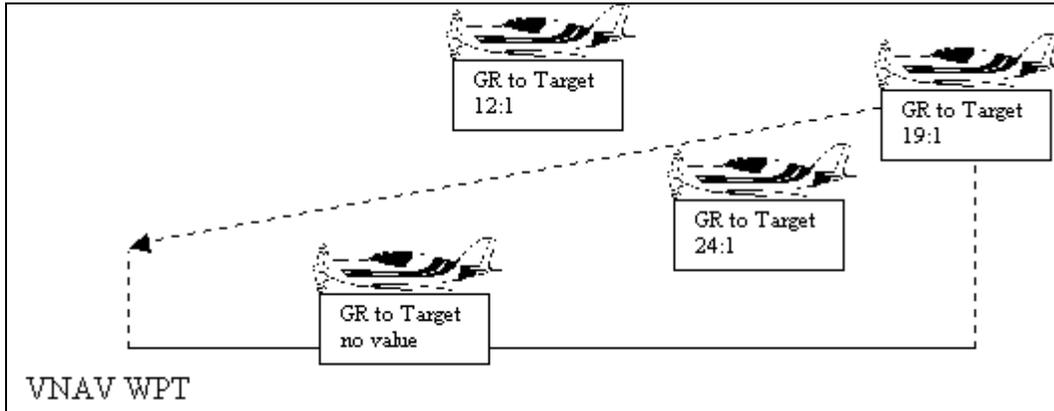
Figure 9-9 GS to Target (not to a precise scale or value)

Many GPS receivers offer *GLIDE RATIO to TARGET*. The higher the glide ratio, the flatter the angle. Figure 9-9 shows how the indications of *GR to TARGET* If the *GR to TARGET* is decreasing, the aircraft is floating above the profile. Note that if the aircraft is below the VNAV target, *GR to TARGET* blanks out.

GR to TARGET is independent of groundspeed in that slowing or speeding up while flying a constant descent angle will not change *GS to TARGET. GR to TARGET* is strictly a function of the geometry of the aircraft position relative to the VNAV target.

It is nice to be able to display *GLIDE RATIO* in addition to *GR to TARGET*. Just as in the vertical speed values previously discussed, it is not necessary. I would recommend whether or not to also display *GLIDE RATIO* as a factor of how many data fields you have to work with and what other data fields may be of more value.

There are many cases where I could see using either vertical speed or glide ratio. If you have lots of data fields, you might use both if you do not find the fact that *VS to TARGET* and *GR to TARGET* operate in opposite directions too confusing -- an increasing *VS to TARGET* means you are getting high and a decreasing *GR to TARGET* indicates the same.

Another factor to consider is that some GPS receivers, such as the Garmin GPS III Pilot round the *GR to Target* to the whole number making it less sensitive than *VS to TARGET*.

Some other notes on using VNAV

- VNAV values are based on going directly to the next waypoint. If you are tracking other than directly to the next waypoint for a vector, searching for a thermal, or for some other reason the values for *VS to TARGET* and *GR to TARGET* are based on the current position and groundspeed, but not on the direction of travel. The implications are that a lesser vertical speed than indicated by *VS to TARGET* will still allow the aircraft to make the VNAV target while the aircraft is flying off course. An actual glide ratio that is at least as good as *GR to TARGET* may be insufficient to reach the VNAV target unless the aircraft is tracking directly to the active waypoint.

- VNAV values only indicate as long as the aircraft is tracking more towards the active waypoint than from it.

- With the exception of GPS VNAV target altitudes, most VNAV calculations use the GPS computed altitude as a function. Generally, this is not a problem. However, sometimes GPS altitude can differ from barometric altitude significantly. Often this is more due to the quirks of barometric altimetry than GPS inaccuracy. I discuss GPS altitude in more detail on 9-5.

Emergency Glide

I have been thinking about how the GPS could be used in an engine failure in a single engine aircraft. I wish that I could tell you that I have tried them and they work. However, they are strictly theoretical. These techniques are something that you might play with if you are out in the practice area. Your first priority, as always, is flying the airplane. If you are proficient with the GPS to the point that you can operate it quickly, and you have tried one of these techniques, you might find it useful.

The first assumption is that you are not going to want to be distracted by the GPS during an emergency glide. As you fly along, you can use the GPS to keep an eye on possible landing areas and alternate airports.

The idea is to keep the distance that you could glide in the back of your mind. To do this you have to know how many nm. your aircraft will glide for each 1000 ft. of altitude. If you cannot find it published, you can measure it sometime when you are out flying. In a glide, divide the airspeed in knots by the descent rate in fpm and multiply by 16.7. Since

you will be measuring with the engine at idle instead of failed and you want a conservative number, indicated airspeed should work well enough. It might be worth timing a 1000 ft. descent rather than using the VSI. For example, if your aircraft has a 60 knot glide speed and descends at 600 fpm, the airplane will glide 60 / 600 x 16.6 = 1.6 miles for every 1000 feet of altitude. Ideally you should use TAS instead of IAS. However, we are looking for a rough estimate and IAS will result in a slightly more conservative value. Use 1.5 as a quick and easy number.

If you have an aviation GPS receiver that will give you a value of glide ratio, you can see what kind of glide ratio your airplane will get. You will want to try a couple of directions to cancel out the effects of wind. Multiply the glide ratio by .16 to get nautical miles per thousand feet. If your aircraft will get an approximately 10:1 glide ratio, this is about 10 * 1.6= 1.6 nautical miles per 1000 feet.

A tailwind during the glide will let you glide further, but it may also mean that you have to use some altitude to turn into the wind for landing.

After the engine fails and your body is filled with adrenaline it is not the time to calculate the gliding distance. Keep your gliding distance in the back of your head during cruise. In our example, if you are flying 3000 feet above the ground, you can glide 4.5 miles. As you fly along, you can use the map display to keep an idea of what is within gliding distance.

Aviation receivers with VNAV and nearest airport feature

Most aviation receivers have a nearest airport feature. On the Garmin receiver, using the knob or rocker pad select the appropriate airport and press the GOTO or direct button. You can now go back to the map and navigate directly to it.

It is possible to set parameters to filter out which airports display on the nearest airport list. Make sure that the parameters are suitable for your aircraft. This is a great feature, but for a single engine aircraft where there might not be much choice in an engine failure scenario, it might not pay to eliminate any choices.

If you execute a GOTO a waypoint that is not in the route, this becomes the VNAV waypoint. If you keep a default value of *TARGET ALTITUDE* set with an *above waypoint* value and keep a data field set to *VS to TARGET* or *GR to TARGET*, then you can use VNAV to let you know if you are going to make the airport or if you need to start planning on another option. Good indications are an increasing *VS to TARGET* to a decreasing *GR to TARGET*.

By setting a low default target altitude you would get an indication of whether or not you could make an airport with a relatively straight in approach. At the other extreme, a target altitude closer to an average traffic pattern height would give you some room to maneuver at the airport. The disadvantage is that the VNAV indications would indicate that you were unable to make the airport when you might be able to make a straight in landing. I can see arguments for either scenario. At any rate, make sure that the default value is set for above waypoint rather than MSL.

It is also a good idea to get know the glide ratio of your aircraft in advance. If you have a GPS that gives you *GR to TARGET*, it will most likely give you *GLIDE RATIO*. You can get an idea of some typical values if you are out in the practice area one day. Get a couple of values flying different directions so that the wind effects average out. For this purpose, I am just recommending that you have a rough idea – so that you can get an immediate first idea of the feasibility of a glide scenario. *VS to TARGET* is also fine for VNAV use.

Example:

I am flying along at 4500 feet on the way to KOCF. The know that the airplane that I am in will be able to glide about 1.5 nautical miles per 1000 feet in a no wind situation. Thus, I should be able to glide a little over 6 nautical miles. Before takeoff, I set the default VNAV profile on my Garmin GPS III Pilot as in Figure 9-10.
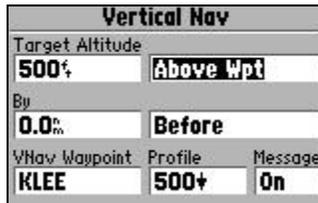
Figure 9-10
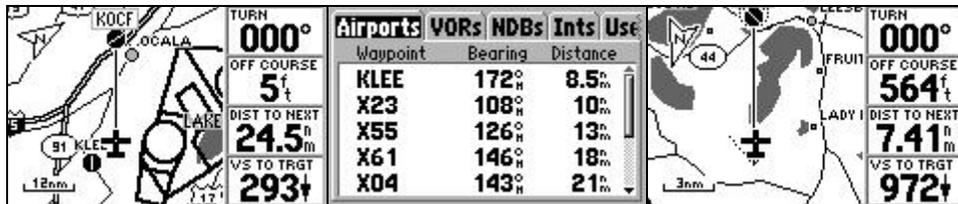
Figure 9-11

As I am flying along in the first screen of Figure 9-11 the engine starts running roughly. Although the engine is still producing power, I am not sure that I will continue to be able to maintain altitude. I press and hold the GOTO button to find the closest airport is KLEE. Although it is slightly more than my no wind gliding distance that I have in the back of my mind,

I can probably make it if the engine is still putting out some power. I start my turn towards 172° as indicated for the *BEARING* to KLEE in the nearest airports list. I highlight KLEE press GOTO and then ENTER to get the map display and navigational data shown in the third screen of Figure 9-11.

As long as I can hold a vertical speed of less than 972 fpm as indicated by *VS to TRGT* I should be able to make the airport. Needless to say, I am still keeping an eye on places to land if the engine quits completely as well as declaring an emergency and trying to get the engine to run smoothly.

Things are going fairly smoothly and I would like to know a little more about what KLEE has to offer.

Figure 9-12

Since things are relatively under control at this point and I am relatively unfamiliar with KLEE, I press and hold the GOTO button again to get the nearest airport list. I select KLEE, press ENTER, and move the tab to runway to see the runway information as depicted in the first screen of Figure 9-12. Note: There are other ways to get to this page. To get an idea of how I am approaching the airport, I zoom out in the second screen. Also note in the second screen that it is possible to cursor and select the data for different runways.

Using GPS to monitor climb restrictions

There are a variety of reasons that you might want to climb to a specific altitude by a given point. This might be for terrain or it might be for airspace restrictions.

For terrain considerations, software or GPS receivers with TAWS or a non-certified TAWS like functionality is a great boon to safety as long as it is used as a warning system rather than things like routing through canyons with poor visibility. However, even without TAWS, a GPS can be useful for monitoring climb restrictions.

One of the pieces of information even the most basic GPS will give you is the time until reaching a waypoint. If you are trying to cross XYZ VOR 6000 feet, are climbing at 500 feet per minute, have 2000 feet to go, and you are 10 minutes from XYZ, then you will probably make it. However, if

you are 4 minutes from XYZ, you probably will not make it. With my mental arithmetic abilities, this is only good for a rough order of magnitude reasonability check.

If you have an aviation GPS, you might be able to use the VNAV functions to monitor your climb progress. VNAV features vary widely in the industry, but the Garmin models are particularly good in that it is possible to set a climb restriction using a point on the route and then display the VS to TARGET. VS to TARGET is the vertical speed required based on the current SPEED and ALTITUDE to reach the point specified.
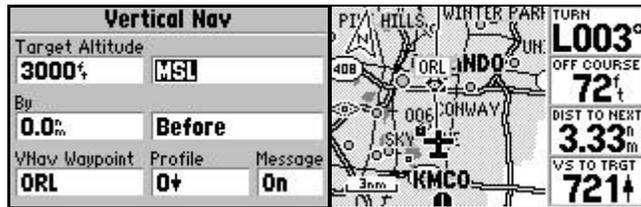
Figure 9-13 Garmin GPS III Pilot

The first picture in Figure 9-13 shows how the VNAV target is set up. Ignore the PROFILE and MESSAGE fields for setting up a climb restriction. The PROFILE is only used for descents. The second screen capture shows how the GPS will show the VS to TARGET.

The technique for using the Garmin GPS receivers is relatively simple. If your rate of climb exceeds VS to TARGET then at your current SPEED and climb rate, you will make the target.

In general, if you are climbing at a greater rate than is required, the VS to TARGET should decrease. Since VS to TARGET is based on speed, a change in VS to TARGET could be caused by a decreasing or increasing groundspeed also.

Note that even though you are able to maintain a vertical speed that exceeds the VS to TARGET at a lower altitude, you might be unable to maintain an adequate climb rate as you get higher. However, detecting this situation is the point of this technique in the first place.

If you make S turns or zig zags to gain altitude, the VS to TARGET is based on SPEED even if you are not flying towards the next waypoint. VS to TARGET is saying: "this is the vertical speed required to make the restriction if you were tracking directly to the next waypoint." Thus, you may find that the VS to TARGET is decreasing even though your vertical speed may not exceed VS to TARGET as you are flying an angle to relative to going directly to the next waypoint.

If you turn off course such as for a 360° turn, you will find that the VS to TARGET field will go blank when you turn such that your TRACK is more than 90° from your BEARING.

➢ Things that will get you in trouble!

It is easy to set the wrong altitude or waypoint in the VNAV setup page. If for some reason you re-activate the route, the GPS will set the restriction reference to the destination rather than the intermediate waypoint that you may want to use. This is a great case for using an order of magnitude cross check using your time to the restriction.

For example, something would be wrong if you had:
        3500 feet to climb
        ETE of 4 minutes away
        VS to TARGET of 120 fpm

A VS to TARGET of a little less than 1000 fpm would be correct – 875 to be exact.

At least on the handheld GPS receivers, the VNAV calculations are based on GPS altitude. As I discuss on page 9-5. However, this may be more of an advantage than a hindrance in that GPS based altitude is not effected by many of the factors, such as cold weather errors, that barometric altimetry suffers from.

WARNING

At the time of this writing, there is a problem with the VNAV on several of the Garmin handheld aviation receivers. If you specify a restriction beyond a waypoint the VS to TARGET will not be accurate after passing the VNAV waypoint.
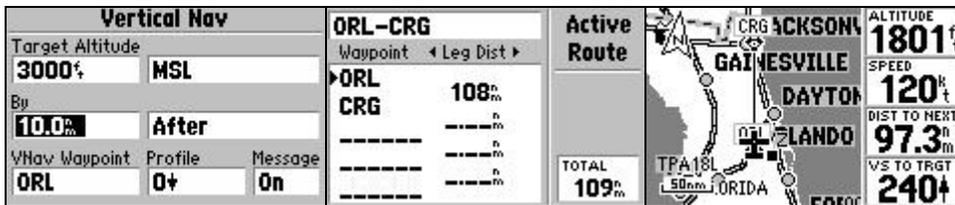
Figure 9-14 Garmin GPS III Pilot

Figure 9-14 gives an example of the problem with a Garmin GPS III Pilot. The first screen shows the setup. The GPS will give correct VS to TARGET information until passing ORL. After passing ORL, the VS to TARGET freezes. In this case, the aircraft is at the VNAV reference point, 10 nm after ORL. The GPS is telling me that I need

to climb at 240 fpm to reach a point directly 1200 feet above me – this is obviously wrong.

The work around is to ignore the VS to TARGET after passing the VNAV Waypoint. The other work around is to express the restriction as the distance to the next waypoint in the route, in this case 98 nm before CRG would be the same as 10 nm after ORL.

I have found this problem to also exist in the Garmin GPS 196 and 96. It appears from experimenting with the Garmin 500 simulator program, that the panel mounted Garmin GPS receivers do not suffer from this problem.

Reciprocal Bearings

Often the GPS gives you a bearing and you need the reciprocal. For example, the GPS gives the bearing to the airport, but you need to tell air traffic control where you are using the bearing from the airport. Obviously the calculation is to add or subtract 180 degrees. However, there are two tricks to doing this quickly.

The first is just to look at your directional gyro to see what is on the other side. If the bearing is 326, look to see that 140 is opposite 320 so the reciprocal of 326 is 146.

Another trick is to add or subtract 2 to the first digit of the bearing to keep it between 0 and 3. Next add or subtract 2 to the next digit. If you added 2 to the first digit, subtract 2 from the second digit and vice versa. This works because you are adding 200 and then subtracting 20 which is the same as adding 180 or likewise with subtracting.

Track data

I personally have not used the ability to download tracks extensively. I have experimented with it just enough to know that it is an interesting feature and potentially useful as a training tool. It may also be something you just find interesting.

One of the easiest ways of using the track information is to view it directly on the GPS. On most mapping handheld GPS receivers, you will see a breadcrumb trail of where you have been.

In most cases it is also possible to download this track data into a computer and view it on a variety of backgrounds. The best solution depends on what you are trying to accomplish by downloading the tracks,

what other use you might have for the software, and how computer savvy you are. There are just too many programs that I have not tried to attempt to give you all of the possibilities, but here are some leads to get you started:

- CompeGPS: I have not tried it but CompeGPS, www.compegps.com, looks interesting.

- Google Earth, http://earth.google.com: Google Earth is just a great program. It is free, but if you want to load GPS tracks, it is $20 per year.

- GS Flight Evaluator, www.appareo.com. Among other things, flight evaluator will allow you to see your flight path overlaid on the ILS.

- See You, www.seeyou.ws. This is mainly aimed at the soaring community

- There are a variety of non-aviation mapping programs that will allow you to superimpose a track over a map. The catch is that the maps are non-aviation maps. Examples are Garmin Map Source products, most of Delorme's GPS capable product line, some flight planning programs. A notable exception is Microsoft's Streets and Trips which only downloads the GPS active position with no other GPS capability. The advantage is that these programs are relatively inexpensive to purchase and easy to set up.

  I suspect that it might be possible to use some of the free aviation data listed in *Chapter 5 Aviation Waypoint Data* to enhance the generic maps with some aviation waypoints as reference. This will take a little computer savvy to convert the data though. There is a program called GPS Babel available at http://gpsbabel.sourceforge.net/ that could possibly be used by data such as from http://navaid.com/GPX/ and convert it into something DeLorme products could use. There are probably other ways to accomplish this also. Beware, I have not actually done this – I just think it could be done and wanted to give you a lead for further investigation if it interests you..

- Some flight planning software will allow you to download tracks. One solution that I have tried is Air Plan, http://www.razorsedgesoft.com/airplan.htm. I would imagine that there are other flight planning programs with this capability also.

- A free solution if you are using a Garmin GPS is by using Waypoint+ , http://www.tapr.org/~kh2z/Waypoint/. If you just download the track to Waypoint+, you will see the flight path drawn over a latitude and

longitude grid. If you have an aviation GPS and download the routes in it, then the path will be shown over the routes and route waypoints. Another solution (at least in the U.S.) is to got to Andrew Sarangan's data site, http://www.geocities.com/asarangan/aviation.html and download a set of aviation data. Open this data with Waypoint+ and then download the route. This way, you will have the context of the aviation waypoints to overlay the track onto.

- Another free solution is http://www.gpsvisualizer.com/. I saved a track as a Ozi Plot File using G7ToWin, http://www.gpsinformation.org/ronh/g7towin.htm, and then uploaded the file to GPS Visualizer.

- Ozi Explorer, www.oziexplorer.com, allows you to scan in maps and superimpose the tracks over the scanned map. After you scan the maps into the computer, you must calibrate or geo-reference them by giving Ozi Explorer some locations of points on the map. I had one gentleman send me some approach plates that he had scanned and overlaid his track and it was pretty impressive. Ozi Explorer is one of the more popular programs for doing this, but you can check www.gpsinformation.net for a variety of such software.

- Sailplane pilots use GPS data for analysis and proof of their flights. Thus, there is a variety of software for superimposing tracks onto maps. There are too many possibilities that I have not had the chance to try. However, you might try a web search. You might start with a phrase such as "GPS software for soaring."

- If you have any of the additional Garmin MapSouce products, it is a simple matter to upload tracks for viewing in MapSource. Of course, the track will be superimposed over whatever type of MapSource as opposed to aviation data.

Great Circle

The GPS uses great circle routings. There is excellent information in *Global Navigation for Pilots* (see Links and Miscellaneous chapter) on various map projections and the difference between great circles and rhumb lines. The concept is really pretty simple. If you draw a line on most maps between two points, the line will be different from a line made by stretching a string across the globe between the same points. This is due to how flat maps depict a spherical surface, a.k.a. projection.

Take as an example a flight from New York to Tokyo. It would appear from looking at most maps, that a southwesterly course out of New York

would be required. However, by stretching a string along a globe, the course is more northwest. Figure 9-15 shows the great circle route as it would appear by looking at a globe.

As a consequence, if you were to fly from New York to Tokyo, the values of BEARING and COURSE would change along the route. For distances involved in general aviation flying, this is a negligible factor.

Figure 9-15

I used the graphical route planning features of a Garmin GPS III+ to illustrate the difference in Figure 9-16. The dashed lines are analogous to straight lines drawn along a map with a ruler. The solid line is the great circle route between the points.

Figure 9-16

If you want to play with this yourself: Plan a route using the map display from point A to B to A. When you actually create the leg from A to B, the dashed line will turn to a solid great circle route line. Move the cursor back towards A and before you enter A as the next waypoint along the route, the dashed line will be just a line across the map.
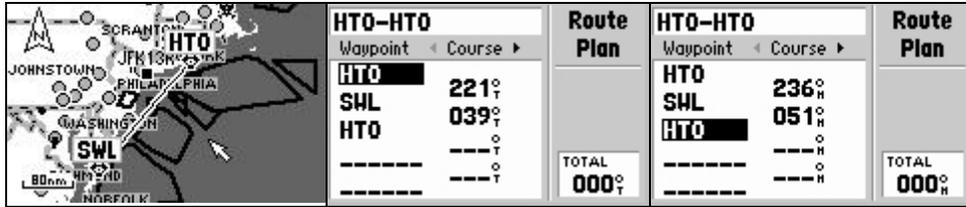
Figure 9-17

Figure 9-17 is a much more subtle example of great circle effects. HTO to SWL is a 225 nm. leg. You can see that the true course from HTO to SWL is 2° (219 is the reciprocal of 039) different from SWL to HTO.

Slightly off point, but since I am here: You will notice that the magnetic courses differ by 5°. With 2° accounted for with great circle effects, the other 3° are due to HTO and SWL having different magnetic variations. If you were to look at the isogonic lines on a chart, you would see this.

Finding a waypoint for intersecting airways

Many intersections between airways are named. Some are not. If the airway is not named, then it is a little more difficult to program a route, but there is a trick for making a waypoint using the map display of the GPS receiver.

Let us say that you wanted to fly from PIE on V492 and intersect the radial for V7 into RSW. V492 goes from PIE to LBV and V7 goes from LAL to RSW. The technique is to create a route from PIE to LBV to LAL to RSW, mark where V492 meets V7 and then modify the route to add this point and eliminate LBV and LAL.
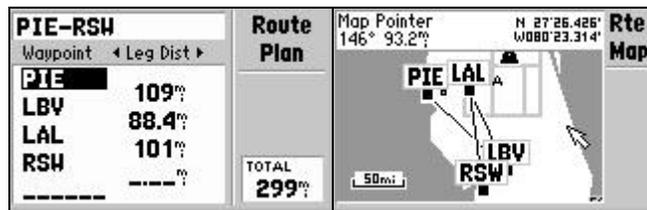

Figure 9-18
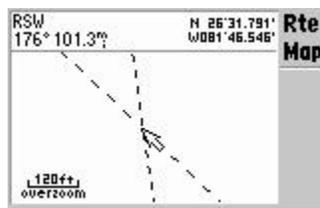
Figure 9-19

In Figure 9-19 I zoomed in as far as I could zoom. I then created a waypoint at this point. Since this is where the two airways intersect, I named the point as a combination of the two airways, 492007.
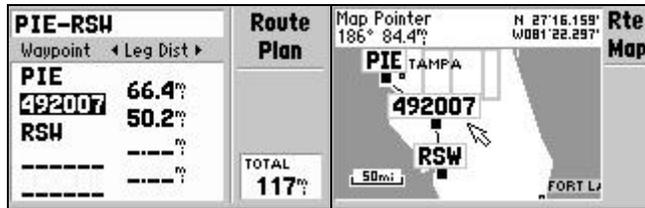
Figure 9-20

Figure 9-20 shows the route after the waypoint has been made, inserted into the route, and LBV and LAL have been cleared out. This is a contrived example in that there is a name, ROGAN, and therefore published co-ordinates for this intersection. I put in the published coordinates for ROGAN and created a route from ROGAN to the created waypoint, 492007. The route distance was .01 nm. Thus, the accuracy of the technique is pretty good.

This is one of those things that is a handy trick while flight planning, but may be more trouble than it is worth in the air. A quicker method that might work in the air is to input the route as in Figure 9-18 and to delete LBV as you get close to the intersection. By deleting LBV the GPS should sequence to navigate LAL to RSW. This is much quicker than setting up a waypoint at the intersection.

Measuring with the map

Most mapping GPS receivers have a tool to measure the distance from the present position or a selected reference position relative to the cursor. In addition to measuring the distance from the present position, you can measure the position between two points.

Many mapping GPS receivers have some variation of this feature. The owner's manual will explain how to use it, but here are two examples to give you an idea of what the feature is and how it can be used:

- You can measure your distance from the aircraft to the cursor point. An example where this is useful is it allows you to correlate the cockpit weather radar picture with your route of flight. As the aircraft moves, the cursor stays in the same position and the GPS updates the bearing and distance to the cursor.

  Take Figure 9-21 as an example. Let's say that radar was painting a cell 10 degrees to the right of the aircraft. Furthermore, let's say that we have 10 degrees of right crab. I moved the cursor straight out to

about 75 nm. The upper left corner indicates the bearing to this point. I then moved the cursor 20 degrees to the right of this bearing. The cursor as shown is about where this 10 degree to the right of the aircraft at 75 nm with a 10 degree crab would be.
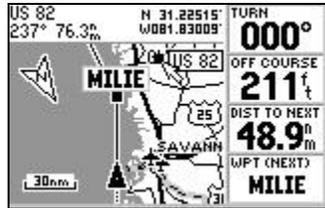
Figure 9-21

Obviously many general aviation aircraft do not have radar. The example with radar is just one example of an application of this feature.

- Instead of measuring the distance from the aircraft to the cursor, you can set another point to measure from. In Figure 9-22, I wanted to find the distance from a route formed by a direct GOTO to the shoreline. I used the measure distance feature and set the reference to the furthest point from shore along the route. At this point, the route is 60.6 nm from shore.
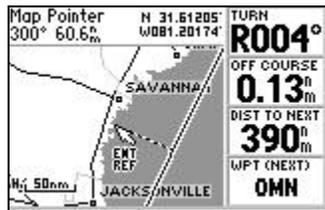
Figure 9-22

Difference between GPS courses and VOR radials

note: I only discuss several Garmin receivers in these examples. If your GPS is not discussed, a little quick experimentation will indicate whether your GPS compensates for VOR misalignment or not.

➢ Explanation of the problem

Often you will notice that the course between waypoints on the GPS does not match the published VOR radials on the chart. Usually, this is just a matter of curiosity. But if you use the OBS mode of an aviation GPS or create a waypoint as a radial and distance from a VOR, this could result in errors.

Figure 9-23

Let's take an example of J-174 from EMJAY intersection to SWL VOR. The charted radial is 047° from SWL. If we look at the GPS course from SWL to EMJAY which is representative of the radial, the value is 051°. This is 4° different from 047°. Furthermore, the inbound GPS course of 234° is 7° different from the published radial.

The path over the ground described by EMJAY-SWL in the GPS or the 047° radial are theoretically the same path even though the numbers differ. If you use the OBS function or fly random bearings, then you should understand the issue. Otherwise, what follows is just to satisfy your curiosity as to why this discrepancy exists.

I have already mentioned different methods of intercepting a route in the *Route Intercepts* chapter on page 8-1. There are very few cases where I would use the OBS function as opposed to just letting the GPS intercept a route leg or perhaps using the direct leg function. In this example, I use the OBS function to demonstrate the VOR alignment issue, but this does not mean that it is the best way to fly the route.

Here is the problem: VORs are aligned to magnetic north when they are installed, but are not re-aligned as the earth's magnetic field changes. Believe it or not, the magnetic field has totally shifted before. This is in a geological time frame, you do not have to worry that you will wake up one morning and find that your compass reads backwards. However, if you were to be able to jump back a couple of million years, your compass would point south instead of north.

Figure 9-24 http://www.geolab.nrcan.gc.ca/geomag/
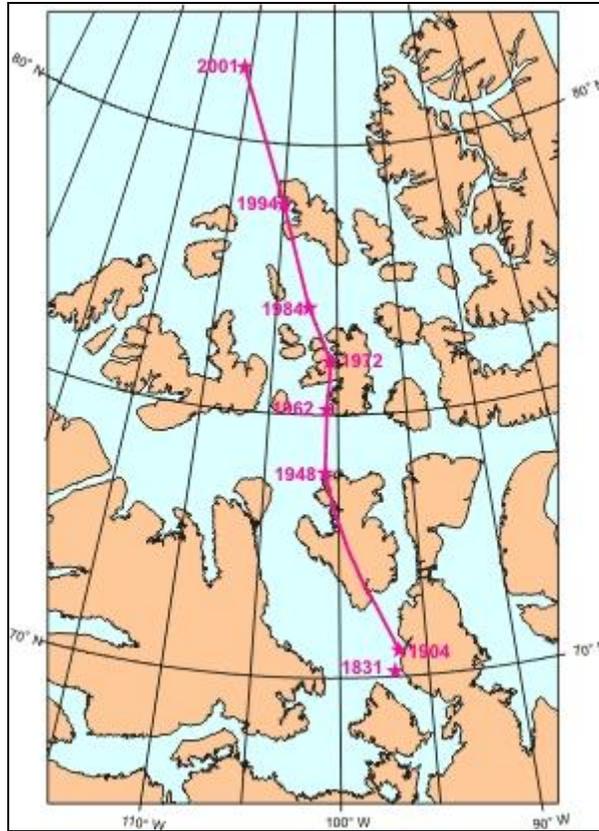
I have no idea what is involved in re-aligning a VOR or if this can even be done, but VOR's are not kept in alignment relative to magnetic north. This slow shifting of the magnetic field is why you will often find that a familiar runway has been re-charted with a new orientation to magnetic north. After several years the difference between the VOR radials and magnetic north can be several degrees.

➢ GPS OBS with VOR magnetic variation
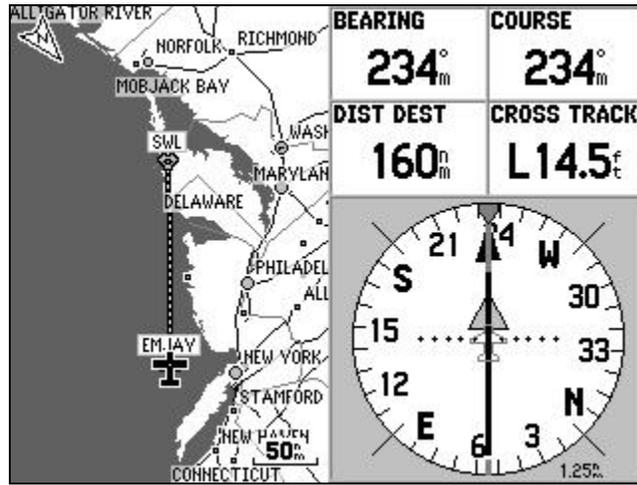
Figure 9-25

Figure 9-25 shows a route from EMJAY to SWL with the aircraft at EMJAY using a Garmin GPS 196. Notice that the BEARING and COURSE are 234° as opposed to 227° just as in the route page from the Garmin III Pilot in Figure 9-23.
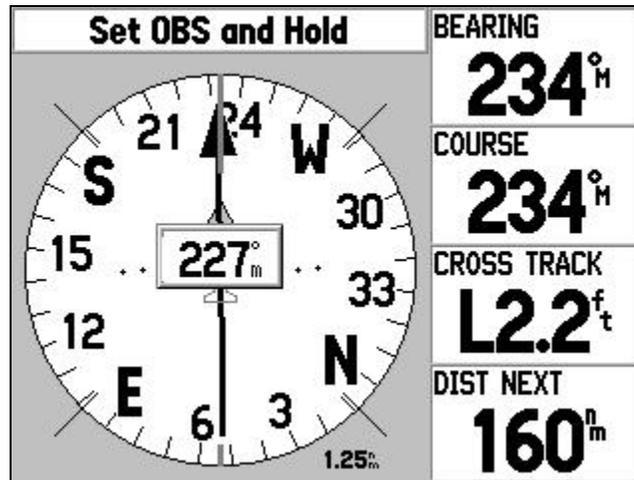
Figure 9-26

Figure 9-26 in the same place as Figure 9-25, however the GPS OBS is manually set to 227° magnetic with reference to SWL using the OBS mode of the GPS instead of navigating the route leg from EMJAY to SWL. Both the CROSS TRACK and the D-bar indicate that the aircraft is on course. Thus, the OBS selection of 227° refers to essentially the same line over the ground as the route leg from EMJAY to SWL. Some other things to observe in Figure 9-26 is that the COURSE and BEARING

indicate 234° even though the OBS value is set to and indicated at 227°. The head of the HSI needle, which is the graphic indication of COURSE, is also on 234°.

The manual setting of the OBS to 227° corresponds to the published radial of 047° even though the magnetic COURSE and BEARING are different. Thus, the Gamin 196 has compensated for this VOR misalignment of the SWL VOR by using the slaved value of the VOR stored in the aviation database rather than using the calculated value of the magnetic variation at the VOR. Some other receivers will work like this and some will not. From what I have been able to discover, the Garmin 196, 295, 400 series, and 500 series provide the compensation. The Garmin III Pilot will not. As for other receivers, you will have to experiment on your own.

It is important to realize that this feature only works when the active waypoint is a VOR in the built in database. If you use a waypoint such as a fix along the same radial, the GPS will not compensate for any VOR misalignment even if it has this feature. Also, for this to work, the GPS must be set up to calculate an automatic magnetic variation as opposed to true or a user input value. For any other waypoints other than for a VOR, the OBS works like the GPS III Pilot that I describe nest.

➢ GPS OBS without VOR variation correction

Figure 9-27

Figure 9-27 is a Garmin GPS III Pilot with the OBS also set to 227° with the aircraft also at EMJAY. Both screens in the figure are different depictions of the same situation. Unlike the GPS 196 depicted previously, the GPS III Pilot does not compensate for VOR misalignment. At EMJAY the OBS setting of 227° defines a line that is 11.7 nm. off the route from EMJAY to SWL as is indicated by the OFF COURSE value.

Notice that the BEARING of 234° matches the BEARING in Figure 9-25 and Figure 9-26. This BEARING is representative of the relationship of the aircraft's position at EMJAY to SWL and is independent from the route whether it is a conventional route leg or an OBS selected leg.

You will also notice that the COURSE of 230° is a new number that we have not yet seen. COURSE is the value to parallel the route leg. The critical difference is that COURSE is measured at the aircraft position and

the OBS value is for the same route line is measured at the waypoint. The 3° difference between the COURSE and the OBS setting is primarily due to the difference in magnetic variations between SWL and EMJAY.

Figure 9-28

In Figure 9-28, I rotated the OBS to find the closest 1° increment. Although this is 1.10 nm. from being on the exact setting, it is the closest 1° increment. This results in an OBS setting of 231°.
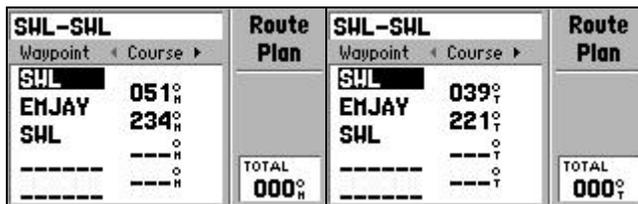
Figure 9-29

Figure 9-29 is just a copy of Figure 9-23 which shows both the magnetic and true courses between EMJAY and SWL. Notice that the 231° OBS setting arrived at in Figure 9-28 is the same as the reciprocal of the 51° course from SWL to EMJAY. The OBS uses the magnetic variation at the active waypoint rather than the location of the aircraft.

➢ **Waypoints based on VOR radials**

It is possible to create a new waypoint based on the bearing and distance from a previous waypoint. This whole VOR misalignment issue has implications for creating waypoints using this method. If you create a waypoint at x nm on the y radial from a VOR waypoint, will it be where you expect?

When I created a new waypoint at the charted location for EMJAY, SWL 047° and 160 nautical miles, on the GPS III Pilot and the GPS 196 the new waypoint was 11.1 nautical miles from EMJAY. When I created a new waypoint in the same way using the Garmin 400 and 500 series simulators, the waypoint was 1.0 nautical miles from EMJAY. The distance of 1.0 nautical miles demonstrated by the Garmin 400 and 500 is no doubt due to rounding error. Thus, it appears that the Garmin 400 and

500 series correct for VOR misalignment for created waypoints. However, the 11.1 of the Garmin 196 and III Pilot is very close to the OFF COURSE error in Figure 9-27 leading me to believe that these GPS receivers do not correct VOR misalignment when creating a waypoint using a radial and distance from a VOR.

➢ Further analysis

According to the information for the SWL VOR on www.airnav.com, it was aligned to a variation of 8° west in 1965. Looking at the isogonic lines on the chart, the variation should be about 12° west at SWL. Looking at Figure 9-29, the true course from SWL to EMJAY is 039°. The true course from the GPS adjusted for the VOR alignment variation results in a 048° radial. This corresponds pretty well with the published 047° radial. The true GPS course adjusted for the isogonic lines on the chart as opposed to the slaved value of the VOR corresponds with the 051°/231° values of the GPS III Pilot as also depicted in Figure 9-29.

➢ Practical implications

For the most part, this has been an explanation of why the COURSE or DTK (synonyms) do not match the VOR radials on the charts. Being able to use the OBS feature to fly a VOR radial is a nice feature. However, I can think of few times that I have had to fly a random VOR radial that was not better defined by an intersection and the VOR waypoint as a route leg.

Thus, the lack of the ability for the OBS mode to compensate for VOR misalignment is not an important issue as long as you realize that you are not getting the same thing as the VOR radial when you use the OBS on such receivers. In fact, in the example of intercepting a radial using he OBS mode in *Chapter 8 Route Intercepts* the feature is irrelevant since I use the waypoint along the radial as the active waypoint instead of the VOR.

➢ Finding VOR radials using GPS

It is possible to find the VOR radial using the GPS as a tool. I present the following discussion more as an academic exercise rather than a practical technique. This is also a technique to be used on the ground rather then in flight.

If you have the slaved magnetic variation of the GPS, it is possible to enter this as a user value in the UNITS tab of the Setup menu of the GPS. Some of the sources in the Aviation Waypoint Data such as as www.airnav.com and NavPlan for Palm at www.avedware.com give this information.

After doing this, it is then possible to use a VOR radial and distance to make a new waypoint in the GPS based on a previous waypoint. On some models, this may be explained in the owner's manual as "projecting a waypoint." It is also possible to use the OBS on aviation receivers such as the GPS III Pilot that do not automatically make the compensation for VOR misalignment.

Make sure that you return the GPS to TRUE or AUTO MAG when you are finished.

It is also possible, although it is probably more trouble than it is worth for the most part, to use the GPS receiver itself to find unknown VOR radials by comparing the GPS course values with the published radials for a point or airway. This method correlates the GPS course with a VOR radial for a known radial and applies the correction to other courses calculated with the GPS to find non-published VOR radials.

In this example, I will calculate the SWL radial required to fly directly to the ISO VOR. The radial turns out to be the 220 or 221 radial even though the GPS calculates a desired magnetic course of 224. As a practical matter, the 224 number is readily available and will be close enough if you ask for a clearance to fly the SWL 224 radial until receiving ISO. In fact ATC usually gives the radial as 225 for direct ISO from SWL. After receiving the clearance, you can then use the GPS to fly directly between SWL and ISO.

There is no published radial between the SWL and ISO.
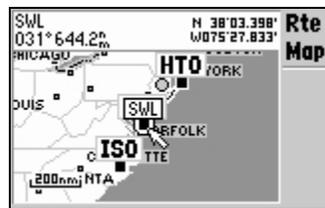
Figure 9-30

The first step is to find a published radial on an airway from SWL with the other end being a point of known location. The other point could be a fix or a navaid. It does not matter as long as you have coordinates for it or it is in the database. In this case, J-174 which goes between HTO and SWL is the SWL 047 radial.

In Figure 9-31, I substituted HTO for ISO in the route to find that SWL to HTO is 51 magnetic/39 true course. It is important that I use the course outbound from SWL to HTO rather than inbound. Due to great circle effects and also the difference in magnetic variation the outbound course

at SWL is likely to be different from the reciprocal of the HTO-SWL course calculated at HTO.

Figure 9-31

I can solve the problem two ways depending on whether I use the GPS in true or magnetic mode. I can see that the published radial of 047° from SWL to HTO is 4 degrees less than the corresponding GPS magnetic course of 051°. The other way is that I can use the GPS true course and the published radial to determine the variation that the VOR is set to. In this case, the VOR is set to 8°W (47°-39°). I replace HTO with ISO and find that SWL-ISO is 224 magnetic/213 true by the GPS.

Figure 9-32

Thus the SWL VOR radial to ISO is 220 when I correct the GPS magnetic course by 4 and 221 when I correct the true GPS course for the 8W variation. The solutions are within possible round off error of each other.

It is important to note that if I were to work this problem to find the ISO radial to SWL rather than the SWL radial to ISO, I would have to go through a similar process relative to ISO as opposed to just assuming the ISO radial to SWL would be the reciprocal of the SWL radial to ISO.

Clearing numbers on Garmin Receivers

This is just one of those handy little features that is probably buried somewhere in a manual. If you have a data block that accepts numbers, it is usually possible to clear the digits. The Garmin 400 and 500 series have a CLR key, but the handhelds do not. On the Garmin handhelds, after the data block as been selected, move the cursor all the way to the left.

Garmin map editing tricks

One of the most powerful features of the Garmin handheld mapping GPS receivers is the ability to edit a route directly using the map display. The map display can be used to create routes or it can be used to edit existing routes. For example, you can enter the route from origin to destination as text and then edit the route with the map by dragging the route line to intermediate points. You can even create this intermediate points while creating the route.

I have experience with several different Garmin receivers and there are some minor differences, but I will describe the basic process. The best way of learning how to use this feature is to sit down with the GPS and the owner's manual and experiment.

The first step is to go to a route, whether it is a new blank route or an existing route. If you are using an aviation GPS or have airports loaded as user waypoints, it might be easier to put the origin and destination airports in the route page textually. For a non-aviation GPS, you might go directly to editing on the map to see if you can find the origin and destination airports as part of the basemap.

If there is not a "map" button on the route page, pressing the menu key should offer an option such as EDIT IN MAP.

- **To add intermediate points to an existing route:**

Move the cursor over the route line. When it turns into a dashed line press ENTER and drag the cursor and route line to the desired point. When the cursor is at the desired point press ENTER. If this is a predefined point, it will be added to the route. If it is not a predefined point the new waypoint screen will come up to create a waypoint at this point. At this point there is some variation. On some GPS receivers such as the 196, this new waypoint will be added to the route when the waypoint is created. On some receivers such as the GPS Map 76 the waypoint will be created, but it will not be added to the route. In this case, move the cursor to highlight this newly created waypoint and press ENTER to add it to the route.

A quick word about the waypoints: If the point is already defined in some way it will be automatically added to the route. In addition to waypoints and aviation points, this will happen for landmarks and road intersections. For example if you click on a small town the point will be defined as a point of interest rather than a separate waypoint. If you want to create a user waypoint instead of using the predefined point press MENU and

select SAVE AS WAYPOINT. This will allow you to create your own name for this point.

Press QUIT or press MENU and select EDIT AS TEXT to return to the text mode.

- **To add points to the beginning or end of a route:**

   Proceed as I described for the adding intermediate points except move the cursor over the beginning or end as appropriate. On some receivers such as the GPS MAP 76 pressing ENTER will bring up a menu to select ADD TURNS. Other receivers such as the 196 require that you press MENU and select ADD.   You will see a dashed line from the beginning or end of waypoint to the cursor as appropriate. Move the cursor to the point that you want to add to the route and press ENTER. The same situation with some receivers as the GPS Map 76 apply here in that sometimes a waypoint will need to be created and then added to the route in two steps. Use the same technique as adding an intermediate waypoint to exit the map.

- **To create the route completely in the map:**

   Put the cursor where you want and press ENTER. Move the cursor to the next point and press ENTER again. To get out of this mode to edit parts of the route you have created press QUIT. To get back to the text routing, press QUIT again or press MENU and select EDIT AS TEXT.

   A similar technique can be used with flight planning software. The specific interface details may very, but on many flight-planning programs you can graphically create a route and upload it into the GPS. This might be an option to consider with a non-mapping GPS.

   The roads and waypoints in the GPS maps are not designed for flight purposes. I would not put on an IFR hood and drive down the road following the road depiction of a GPS, nor would I fly through a canyon in poor visibility following the road depiction of a GPS. However, I think that when used with cross checks and common sense this is a prudent technique.

   As I have mentioned previously, I am a big fan of cross checks. In fact, I think one airline is even using the buzzword "error management." When entering the route graphically with the map of the GPS, the main issue is the accuracy of the GPS map display. A crosscheck of the route waypoint's coordinates on the chart might be prudent in some cases. Likewise, the map of the GPS could be used to cross check coordinates

measured directly from the map. In flight the landmarks make an excellent crosscheck.

Other possible cross checks at the flight planning stage are to measure the leg distances and courses on the chart and to compare them with the GPS computed values. Even though mapping GPS units do not have a map as such, most have some sort of plot display. Even though a view of a plot display will not catch small measurement errors, it will catch gross errors that will be obvious by the shape of the route. As always, the best cross check is your own "reasonability filter."

Garmin handheld master reset

Every once in a while I have had some strange anomaly with a Garmin handheld receiver. It is possible to erase the memory and reset the unit to factory defaults by holding the QUIT key as you turn the unit on most receivers. On the eTrex Legend series press the click stick and page key (upper right side key) while powering on. This will erase all of your waypoints, routes, tracks, etc.

DME ARC

I cannot remember the last time that I flew a DME arc. However, I ran across the subject in the AIM and it occurred to me that the handheld GPS is perfect for flying an arc. This technique would certainly be interesting as a training exercise, but it might also be used to maintain a fixed distance from an airport or a TFR around a facility such as a nuclear plant. If you are using this for the later, add a generous buffer.

This technique should be very easy with a handheld GPS, but more difficult with a panel mounted GPS. However, if the DME arc is part of an approach transition, this technique may be irrelevant for many IFR receivers such as the Garmin 400 and 500 series. In such a case the DME arc is presented as a curved line and you can navigate it like any other line except that it will require that you maintain a turn to follow it. TKE will indicate whether you are parallel, or more properly tangent, to the line. XTK and the CDI will indicate your lateral displacement.

As far as the technique that I am presenting here, the problem with most panel mounted receivers is that they do not offer a TURN field.   If you do not have the TURN field, then you will need to calculate the difference between TRACK and BEARING in your head. This exceeds my personal arithmetic abilities. However, you can still fly the arc with reference to the distance to the waypoint. In this last case, the GPS offers nothing more than a DME except that the waypoint can be located anywhere.

Since the GPS uses TRACK rather than heading to calculate TURN, it should be very useful for maintaining a constant distance arc. Make the center of the arc the active waypoint on the GPS. Simply keep the TURN (TRACK- BEARING) at about 90 degrees and manage the distance to the waypoint. If you need to widen the arc increase TURN above 90, if you need to tighten the arc, decrease TURN to less than 90.

Chapter 10 GPS and Student Pilots

It has been 10,000 hours of flight time since I have been a student pilot, which hopefully is not the same as saying that I have stopped learning. Although, I think that I might enjoy instructing part time now, I am paranoid about the career and financial liabilities. So take the suggestions in this section with the disclaimer of my possibly being out of touch from the flight training environment.

I have read several opinions as to when it is appropriate for a student pilot to be allowed to start using a GPS. I would argue for introduction of GPS into the training curriculum sooner than later. It is my hypothesis that a pilot who masters GPS is in a much better position to learn to fly aircraft with more advance cockpits. A generic handheld receiver may be very different from a sophisticated FMS, but there are conceptual similarities.

Although I think that it is an interesting and important debate as to when to introduce GPS navigation to students, this is not the point of this chapter. I think that there are some ways to use GPS, especially a handheld GPS, as a training tool outside of using it directly for navigation.

GPS use on cross-country flights

We will leave aside the discussion of how much GPS training a student should get and where such training should be introduced in the curriculum.

Sailplane pilots use GPS for tracking flights, both for analysis and proof. I have mentioned the ability for most GPS receivers to store, display, and download track data on page 9-19. This track data can be used to analyze a flight, especially for cross-country flights demonstrating other forms of navigation such as pilotage.

It will be tempting for the student to look at a GPS, but it is certainly possible to cover the display. A paper lunch sack and a couple of pieces of tape come to mind. Having the ability to rip into the sack and get to the GPS might be a confidence builder. Of course, in such as case the task would be void.

Circles around a point

Since GPS uses track rather than heading information, it is possible to fly a very straight line between points. Handheld GPS receivers are usually capable of displaying a pointer page or displaying a field for TURN, which

is the difference between track and bearing. Using this data it is also possible to fly a very round circle relative to the ground.

The point of the exercise is to show the effects of wind. The bank will have to be changed throughout the circle assuming there is some wind and the groundspeed will constantly change.

GOTO a waypoint marking the center of the circle. Using the TURN field, pointer page, or pointer field along with the distance from the waypoint fly around the waypoint.   When the TURN is 90° you are flying a circle. When TURN is greater than 90° you are increasing the radius. When TURN is less than 90° you are reducing the radius. You can also display SPEED, which is groundspeed.

Another variation is to fly several constant bank turns and to notice the change in the radius reflected in the distance to the waypoint. The track can be examined later to see the effects of the wind.

Along a similar line of thought, the difference between GPS TRACK (make sure that the GPS is set to display magnetic values) and SPEED and aircraft heading and airspeed provide an tangible demonstration of the effects of wind and true versed indicated airspeed while flying straight.

Obviously, the windier the day is, the better the demonstration will be.

Using GPS to understand VOR and ADF navigation

Much of navigation is understanding fundamental concepts of bearings, courses, tracks, distances and what combination of these is required to fix a position. GPS makes this task simple. Most of this text is devoted to giving you optimum ways of using the GPS to navigate. However, the GPS can be used in a less than optimal manner to help you learn to work with bearings and distances.

I should note that although I am an obvious GPS fan, that I am not proposing that using the GPS is necessarily the best way to learn VOR and NDB navigation. I also recommend that you check out the navigation simulations in the Links and References chapter in the Navigation Simulations section on page 14-6 to help you to visualize VOR and NDB navigation.

Most GPS receivers have a display page that looks similar to an aircraft HSI, ADF, or RMI. The difference is that the aircraft instruments display heading rather than TRACK and the GPS HSI displays OFF COURSE

(see the navigation section) whereas a real HSI shows the difference between the OBS selected radial and the actual bearing. In many ways, these displays are improvements on the aircraft equivalent.   In the context of learning VOR and NDB navigation, they are similar enough to be of use.

➢ Comparing the VOR and NDB with the GPS

I have already explained the quantitative difference between a GPS course and a VOR radial on page 9-25. Let's look at the qualitative difference in how VOR's and NDB's are used.

A VOR basically tells you how far the bearing to or from the station varies from that selected with the OBS. Although some of the aviation handheld GPS receivers and all of the IFR receivers allow you to manually select a bearing to a waypoint, the course line is usually defined with the GPS by selecting one waypoint to another as opposed to manually selecting COURSE or DTK.

In GPS terms, the needle on the VOR indicates the difference between BEARING and COURSE. Each dot of the VOR indicator is a difference of 2 degrees. In practice, this needle is used similarly to the GPS OFF COURSE field except that the VOR needle gets more sensitive closer to the station. Although the VOR needle is actually indicating an angular error rather than a lateral distance, one degree of needle swing (1/2 dot) is equal to approximately 1 nm of lateral displacement (GPS OFF COURSE) for every 60 nm from the station.

By turning the VOR OBS so that the needle centers within the "to" range, the OBS will indicate BEARING to the station. If the VOR is centered in the "from" range, than the VOR will indicate the reciprocal of the bearing to the station. The BEARING field of the GPS only indicates the to bearing.

An ADF is used to find the BEARING to or from the station. The ADF needle points to the station. Relative bearing is the amount that the needle is displaced from the 12 o'clock position. By superimposing the needle over a heading card, a bearing relative to the NDB can be obtained. This can be done with a manual rotating compass card on the ADF, a compass repeater on the ADF (referred to as an RMI), or mentally superimposing the relative bearing on the heading indicator. Although the technology is different from the VOR, there are many similarities in that both the VOR and NDB are fundamentally bearing instruments. On a VOR, the OBS is used to set the desired bearing/radial and the CDI indicates the error from this set value. The ADF just displays the actual bearing.

Many more advance cockpits have an instrument called an RMI. The RMI looks like an ADF except that the compass card is automatically slaved to the heading system and there is usually an option of selecting one of the needles to display VOR information.

➤ Using the GPS like a VOR or NDB

Understanding where you are in terms of bearings and distances is essential for traditional navigation. The VOR is nothing more than a bearing instrument and the ADF can be used in conjunction with the aircraft's heading to give a bearing (see page 11-11).   Furthermore, a visual sighting can be used like an ADF needle to get a bearing. By estimating the relative bearing of a visual sighting and superimposing it on the heading indicator, it will give you an approximate bearing.

It is possible to find where you are with two bearings. Furthermore, you can substitute a distance for a bearing or another line of position such as a road or a river. There are some cases where a line of position is curved that the location might need other clues. For example, if a bearing line cuts across multiple bends in a river, you might have to use other clues or a little reasoning to calculate which bend you are at.

You are probably wondering where GPS ties into this discussion. It might take a little imagination, but use the GPS around town in a similar manner to conventional navaids. Mark a couple of waypoints and treat them like VOR's. For example make reference waypoints at, your house, the airport, work, and the grocery store. Observe the change in BEARING relative to these points as you drive around town. Notice that as you move clockwise relative to the waypoint, the BEARING increases. Conversely, as you move counter-clockwise, the value decreases. You can also note how your position correlates to bearing and distance to one of the waypoints, or bearing to two of the waypoints. Perhaps display one of the pseudo RMI or HSI screens or even use the OBS function of an aviation GPS. Watch how the fields and displays change as you are at different points around town. Obviously, your first priority is to watch the road if you are in your car.

Another technique is that you can try to see if you can pinpoint your location on aeronautical charts on the ground using your GPS to give bearings from VOR's and NDB's. Although, I address the fact that the VOR radial may vary several degrees from the magnetic bearing given by the GPS on 9-25, the difference for this purpose is usually not significant.

The point is that the GPS allows you the chance to internalize fundamental navigation parameters such as BEARING away from the airport in a low threat and inexpensive context. There are things that you

can't learn such as compensating for a crosswind. However, you can learn to get a feel and level of comfort for these fundamental values. The point is to get used to thinking in terms of bearings and distances from a point.

There is even a practical application of doing this. In my text, Small Boat GPS, I have an example where such a technique can be used for location while navigating a river. The scenario is all that is available is a simple road map and the GPS does not have the mapping capability to show the river.

Before I leave the house, I use a pencil and a cheap protractor to make compass roses at two reference points that I will pass on the way to the canoe rental. As for the technique itself, it is probably easier to use true north as a reference. However, for playing the game of learning to use conventional navaids it is more instructive to use magnetic north as a reference. In addition to the isogonic lines of an aeronautical chart, you can get the magnetic deviation from the setup page of the GPS. For west magnetic variations, draw the compass rose so that the north reference moves to the west (rotate counterclockwise). Rotate the opposite direction for east.

As I drive to the canoe rental, I stop to mark and save these two locations as waypoints in the GPS.

By taking bearings to each of the waypoints, I can locate my position using an inexpensive non-mapping GPS and an ordinary road map. One bearing and the fact that I am on the river is actually sufficient. I could also draw some range marks and use bearing and distance. This is fundamentally similar to orientating using VOR cross radials, a cross radial and landmark such as a road, or VOR and DME.

Certainly, there are other ways of learning to navigate using conventional navaids such as some of the navigation simulators that I mention in the *Links and References* chapter, but this is just one more possible method.
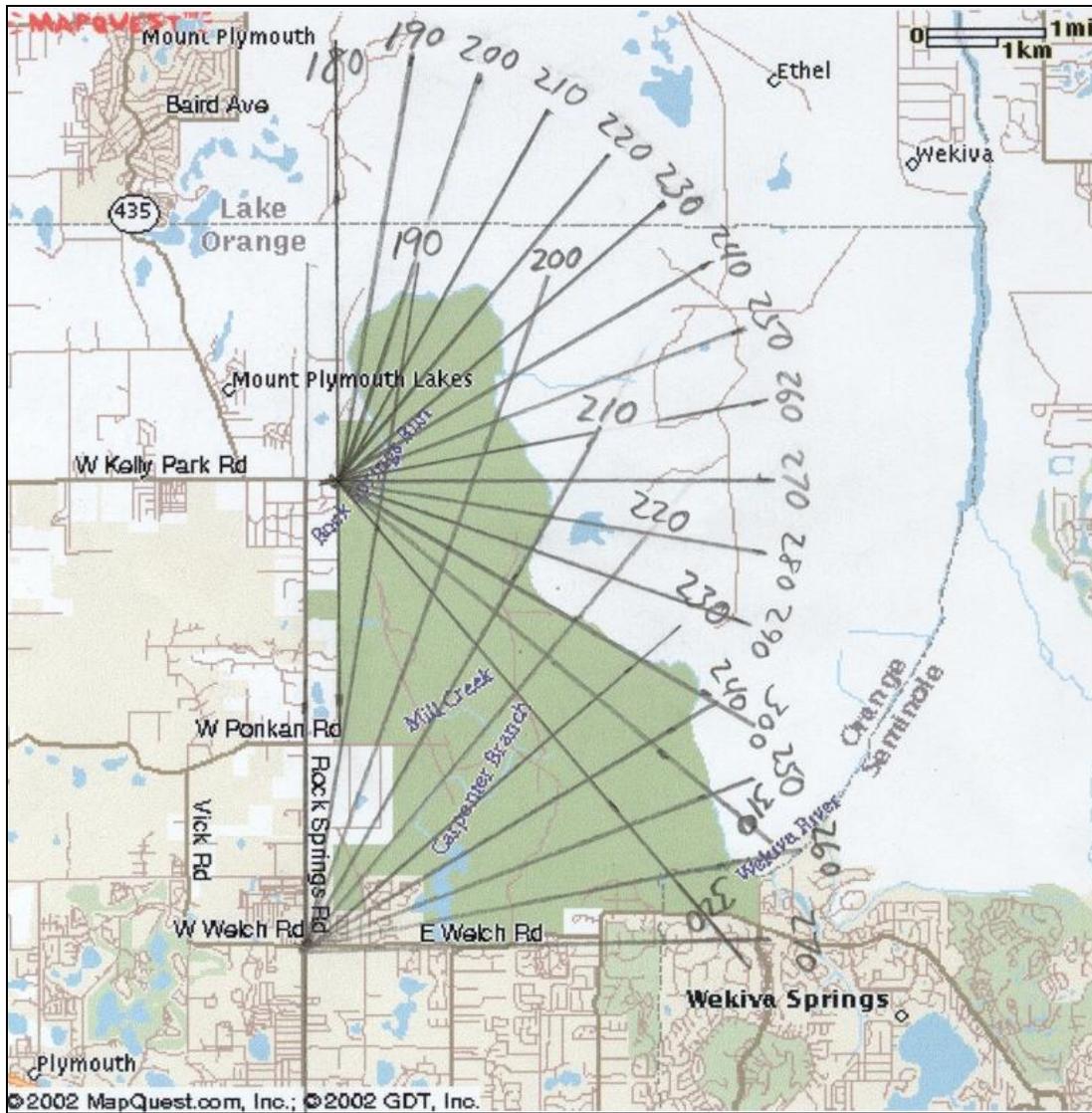
Figure 10-1

Figure 10-2

Figure 10-2 shows the screen of a Garmin GPS MAP 76 with the map data inhibited. By placing the cursor on REF2, I am able to display the bearings to both REF and REF2 simultaneously. Using Figure 10-1, I am able to locate my position on the river.

The bearings are the reciprocals of the radials that would be on a VOR compass rose. However, I think that this a minor difference compared to the conceptual similarity.

Chapter 11 IFR use of GPS

IFR with a certified IFR GPS

I have never flown an IFR approach using one of the certified IFR receivers available for the general aviation market. However, I have flown numerous approaches, both precision and non-precision using the FMS (Flight Management System) of the 757/767. There are many differences, but there is a conceptual similarity.

Although this text has relevance to GPS navigation in general, there are some specific and detailed points to IFR navigation using a certified GPS receiver that are beyond the scope of this book. Although I have a couple of points to make, I see no reason to go into great depth when there are sources such as the AIM which treat the subject well and represent official FAA doctrine. Here is some other source material on flying IFR with certified IFR equipment:

Aeronautical Information Manual (AIM), http://www1.faa.gov/ATPubs/AIM/. The AIM, Chapter 1 Navigation Aids/ Section 1 Air Navigation Aids/ GPS is an absolute must read for anybody flying IFR using an IFR certified GPS.

IFR a Structured Approach by John Eckalbar, www.skyroadprojects.com. This is an excellent book with a good discussion of GPS in the IFR environment.

Cockpit Automation for General Aviators and Future Airline Pilot's by Stephen Casner (reference 7, Links and References). I would set up the GPS to take more advantage of the mapping display and I would often use the intercept leg feature instead of the OBS feature. You can get those techniques from this book. Casner's book is not a discussion of all the tricks of using a GPS, he properly refers the reader to the owner's manual for that. It is more like a dual flight stepping you through various IFR considerations. In fact, the book steps you through an example flight and approach from San Jose to Oakdale, CA. One of the things that I really like about the book is Casner's philosophy of automation.

AOPA Air Safety Foundation Safety Advisor, http://www.aopa.org/asf/publications/sa01.pdf
This is an excellent overview of GPS use, including using GPS for IFR approaches.

Garmin Syllabus for GNS 430/530, www.garmin.com/aviation
This is a suggested instructional syllabus for learning the GNS 430/530.

The above sources should explain the procedures for flying an IFR approach fairly well, but I do have some comments that I would like to pass along.

➤ Use the track and map information

In many ways flying a GPS approach is just like flying any other GPS routing except that the HSI/CDI has a higher sensitivity. Many of the techniques that I advocate in the Navigation chapter of this book are also applicable to flying approaches. Two important points:

1. If you have a sophisticated mapping GPS, use the map display for situational awareness. For example, many GPS receivers offer a CDI display. Instead of using the CDI page, use the map display for situational awareness and the data fields for precision.

2. Another point from the Navigation chapter is to use the track data and compare it to the DTK or bearing data; or you can use a data field such as TKE. This will make following the course much easier and precise whether the approach is a GPS approach or not.

➤ Some GPS receivers will fly DME arcs

The AIM implies that GPS receivers are only capable of navigating to a point. Many GPS receivers are capable of more sophistication. For example, the Garmin 400 and 500 series receivers will follow a DME arc transition. The DTK, TKE, and XTK values will reflect flying along an arc rather than navigating along a straight line to the next waypoint.

What is interesting is that the AIM (February 19, 2004 edition) gives a technique for flying a DME arc in that the DME facility is made the active waypoint. If you have a GPS which has the ability to select a DME arc transition for an approach, the AIM method is a much more complicated way of flying the arc with no benefit. The beginning of the section has the following disclaimer:

> The following provides general guidance which is not specific to any particular aircraft GPS system. For specific system guidance refer to the AFM, AFM supplement, pilot's guide, or contact the manufacturer of your system.

I think that you could argue that this paragraph allows you to fly the DME arc as is in the approach database. However, this is just my opinion.

➢ Approaches permitted with GPS

To fly the approach using the GPS as the sole reference, the approach must be labeled GPS. For example NDB (GPS) 23 could be flown with a GPS and no NDB, but NDB 23 would require an NDB. Even so, the GPS database may contain approaches that cannot be legally flown with the GPS as a sole reference. An obvious example is an ILS approach. The approach may be in the GPS database, but it obviously must be flown with the ILS receiver rather than the GPS.

Make sure that your CDI is set to the correct source for the approach. If the approach is a GPS approach, make sure that it is set to GPS and if it is a VOR approach with no GPS or RNAV, then the CDI should be set to the VOR.

➢ Approaches not permitted with GPS

If the approach is not labeled GPS, the GPS can still be extremely useful for situational awareness. Let's say that you have a nice panel mounted Garmin 430 or 530 and are flying an ILS approach. The CDI will be on the ILS, but the map display will provide quite a bit of situational awareness. Furthermore, if you apply some of the navigational techniques in *Chapter 7 Navigation*, you can use the data fields to help you correct for cross winds and basically refine the accuracy of the approach as well as provide situational awareness. Needless to say, you will need to decide how you want to include the GPS in your scan so that it is more of help than a distraction.

➢ Transitions

When you select an approach with a transition, the GPS may include the course reversal. This is fine if you intend to fly the course reversal or holding pattern. However, if you do not plan on flying the course reversal, you will have to modify the approach or create an intercept. Modifying the approach outside of the final approach fix is permissible.   Modifying the approach inside of the FAF is not permissible.

Figure 11-1

Figure 11-1 shows the case for the RNAV 27R approach to KFLL. The approach has been selected with a JUMAR transition for illustration purposes. There are a number of ways to deal with this:

- First of all the easiest thing would have been for me to have selected vectors instead of the JUMAR transition. This would have given me the final approach course into the FAF, SNAPE.
- I could delete the hold by selecting "hold" on the route page and pressing the CLR button.
- I could intercept the leg from JUMAR to SNAPE by pressing the direct key one more time after selecting SNAPE, but before pressing ENTER.

The point here is not specific techniques on the Garmin 400 series. There are several ways of accomplishing the same thing and each receiver does these things a little differently. The points that I would like to make are to make sure that what you selected is what you wanted, make sure that you know how to make the GPS give you what you want, and that you can usually make modifications outside of the FAF.

➢ Legality of using a VFR GPS for IFR

It may seem that a handheld or VFR GPS has no value in the IFR world. Nothing could be further from the truth. Without a doubt, an IFR certified GPS is the ideal tool. I do not want to sell the handheld GPS as a substitute for an IFR certified GPS installation. However, the benefit of having an aid to situational awareness during normal operations as well as the added benefit of emergency use should not be discounted.

The best way to describe the legal status of using a handheld GPS is to quote the AIM.

> Visual flight rules (VFR) and hand-held GPS systems are not authorized for IFR navigation, instrument approaches, or as a principal instrument flight reference. During IFR operations they may be considered only an aid to situational awareness.
> The entire AIM is online and I encourage you to read the section on GPS in its entirety at http://www.faa.gov/ATPubs/AIM. The AIM is actually a good text on GPS usage. This is also an excellent text in that it discusses approach issues using an IFR certified GPS for approaches and as a substitute for DME and ADF.

If you have an old VFR panel mounted GPS in the aircraft with a limited display, it might be more trouble than it is worth as a backup for IFR approaches. Not that it would be totally useless if you were sufficiently

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proficient. However, let's say that you have a mapping handheld GPS and are flying IFR in an aircraft without a certified GPS. Just knowing where you are while waiting to be vectored to intercept a conventional approach or as a crosscheck to confirm that you are where the needles say that you are is a huge benefit.

Furthermore, I can see little harm in using a non-certified receiver for "refinement of navigational precision." If you reference a handheld GPS on an ADF approach to help track the course, I think that you have increased your safety level. Also, the TRACK or TURN field of a GPS will often indicate drift before the CDI of a localizer.

It is important that if you use a non-certified receiver during IFR operations that you still reference the primary navigation source for the approach. For example, if you are flying a VOR approach, you still must still reference the VOR. The important thing is that you do not substitute the GPS for the required equipment for the approach and that you actually reference the required equipment.

For GPS approaches, substituted "IFR certified GPS" in you mind. You may have a nice aviation handheld that allows you to select a GPS approach, but you are no more allowed to use this GPS than for a VOR, NDB, or ILS approach.   At first it might seem pointless gimmick to have the ability to select a GPS approach on a handheld receiver that cannot be used to fly the approach. However, consider the case of having an older IFR certified GPS installation with a less than intuitive alphanumeric display linked to a CDI. Having a new mapping handheld receiver will considerably improve situational awareness during a GPS approach even though it is advisory only.

Somewhat repetitively, but let me put it a slightly different way for clarification: The required equipment controls the approach.   You are not on the approach because the GPS shows you on the approach, but because the ADF, VOR, or localizer shows you on the approach. In order to know this, you have to have the appropriate facility dialed in and you must monitor it.

Take as an example an ADF approach with the NDB on the field where the procedure is to fly outbound, make a procedure turn, and then fly inbound.
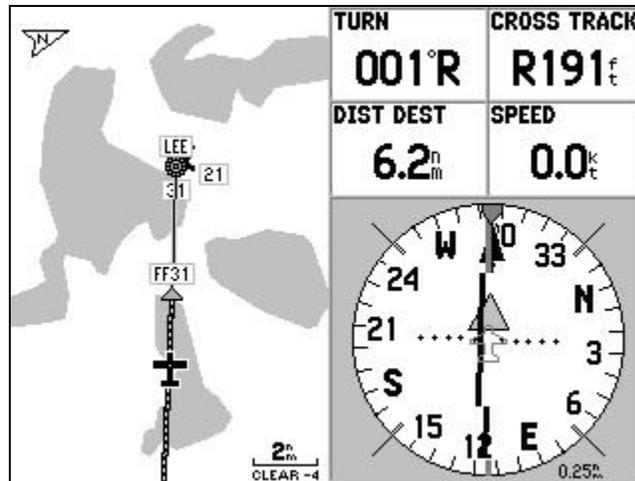
Figure 11-2 Garmin 196 KLEE NDB 31

Figure 11-2 is an example of just such a case where the situational awareness can be invaluable. There is no doubt where the aircraft is in this example. Reference must still be made to the ADF. However, the GPS will allow you to refine the accuracy as well as providing situational awareness. A couple of notes: The map is purposefully sparse. I used the de-clutter mode by pressing the ENTER button to get to the 4th level of de-clutter. By changing one of the fields to DIST DEST, the GPS displays the distance to the LEE NDB rather than FF31.

Needless to say, a handheld GPS is useful for following airways. It is always useful in that it takes the guesswork out of correcting for wind. It is especially useful for following airways where traditional navigation facilities poor, such as AR routes using NDB's. There are also some airways defined by notoriously bad VORs. SWL is a good example. I have seen pilots centered on course as indicated by the VOR but 4 nm. off course as indicated by the GPS. A radar crosscheck from the controller has always confirmed the GPS position. A few minutes later the VOR will swing and indicate the approximate course error only to indicate back on course a few minutes after that.

I have seen some discussion on newsgroups as to whether or not it is legal to file IFR or whether it is legal to take a direct routing from ATC without receiving the navaid using a handheld or VFR GPS to navigate. The argument is that if you are in radar coverage and within the service volume of certified navaids than it is. This is beyond my personal comfort zone. I am certainly not advocating this position, but John Deakin makes some fairly good arguments in an article on AVweb at:

http://www.avweb.com/articles/pelperch/pelp0011.html.

I am comfortable with using a handheld GPS to tweak a "heading until receiving" clearance from ATC as long as the heading indicated by the GPS is within several degrees of the ATC heading. I consider 5 degrees to be within the margin of error allowed for the heading and it is in line with the intent of such a clearance.

With the notable exception of an emergency backup, operating IFR with a handheld GPS does not give you any more capability. However, it lets you use the capability that you and the aircraft are certified for more effectively and safely when used within the bounds of the FAR's, good airmanship, and common sense.

➤ Why handheld receivers are not a substitute for IFR receivers

In many ways, the capability of many handheld receivers is comparable and in many cases exceeds to the capability of certified IFR receivers. Obviously, there are legal reasons why a handheld receiver cannot be substituted for an IFR receiver. However there are also some substantive differences between IFR receivers and VFR only receivers such as handhelds and good reasons why a VFR receiver is not a substitute for an IFR receiver.

Certified IFR receivers have a feature called RAIM, Receiver Autonomous Integrity Monitoring. I explain RAIM in slightly more detail in the How it Works chapter. The short explanation of RAIM is that the GPS receiver uses extra signals above the minimum required to crosscheck to navigation solution. For an IFR receiver, there are two thresholds of satellite reception or lack thereof. The first threshold of poor satellite reception is the warning that the GPS is receiving an insufficient number of satellites to cross check the navigation solution, i.e. no RAIM. This is still good enough for enroute navigation, but not for approaches. The next threshold is reached when the GPS is not receiving enough satellites to even figure out where it is. A handheld GPS will only warn of this last threshold and in many receivers this warning is delayed several seconds by the dead reckoning mode (described on 2-1) or hidden by just locking up.

I also think it is fair to say the testing of the operating software, or firmware, on handheld GPS receivers is not quite to the same level as on certified GPS receivers. I have found minor errors in some handheld receivers. These have been corrected in later software revisions. I have also seen software errors in expensive certified FMS units.

In order to fly an approach with using the GPS, the whole approach must be programmed and selectable as opposed to built using the individual waypoints. The handheld GPS receivers that I am familiar with only have

the final approach segment. The purpose having the approach programmed into the database so that the pilot may recall it from the receiver's memory rather than programming it point by point is to keep the pilot from messing up the approach by mis-programming it. I would like to see the full approach available on handheld receivers even if it is only available for reference. I suppose that it could be argued that having the full approach programmed would tempt pilots to use the GPS as if it were a certified receiver. If a pilot is going to shoot illegal approaches using a handheld GPS, I cannot see the lack of the full approach being in the GPS stopping him.

Certainly, a handheld receiver could be manufactured that would have RAIM, the more thorough firmware testing, and full approaches programmed in.   However, much of the appeal of handheld GPS is its relatively low cost, even the aviation versions. If you were to add the cost of certification, extra liability, and subtract the savings from being based on ordinary consumer hardware, the cost would increase substantially and the savings compared to the cost of a IFR certified GPS would diminish. I doubt that you will ever see a certified IFR handheld receiver.

Some Technique Notes

➢ GPS Altitude

I explain the difference between GPS altitude and barometric altitude in more detail on page 9-5. Certainly, GPS altitude cannot substitute for your altitude, but you might occasionally use it to check your altimeter. You might want to do a quick altimeter check using the GPS before a non-precision approach. I don't recommend this as a calibration method, but as a way to catch a gross error.

➢ Generic approach techniques with a generic or aviation non-approach handheld.

Note: These are techniques to be used with GPS receivers that do not offer the capability of selecting an approach or final approach segment. Not that these techniques will not work, but that they are not necessary with more sophisticated aviation receivers.

Just to reiterate. I am not suggesting that you set up your GPS to fly the approach, but that you use it for situational awareness. The closer that the GPS navigation is correlated to the approach, the better the situational awareness. Thus I have no qualms explaining how to set up a generic GPS to navigate an NDB approach. However, at no time am I advocating

that you use a GPS, especially a non-certified GPS, to substitute for a required navaid.

IFR panel mounted receivers have the ability to select an overlay approach. Many aviation GPS receivers have the ability to select the final approach segment. Non-aviation handheld receivers and some aviation handhelds such as the Garmin GPS III Pilot do not have this ability. These receivers can still be of benefit during approaches.

I find that even a basic GPS with no approach capability is very valuable for situational awareness during the approach. Even the least expensive GPS can give bearing and distance to the field. Even though it is possible to set up a generic GPS receiver to better mirror an approach, it is not worth the distraction unless you have done it before flight. Often it is adequately useful to change the setup of a couple of data fields and use the data relative to the final destination airport for reference rather than going through the trouble of setting up the GPS for a specific approach.

Well before the approach, one method is to just change the data fields displayed to TRACK, BEARING, DIST TO NEXT, and SPEED. The active waypoint to be used is the destination airport or perhaps an on field VOR or NDB.

BEARING and DISTANCE especially when using a map display is useful for positional awareness while being vectored for the approach. Assuming the GPS is set up to display magnetic values, BEARING is compared to the heading rather than the track to be able to correlate the aircraft's position relative to the airport or navaid. If you are using the airport as the final waypoint, this refers to the airport reference point. If you are flying an approach such as an ILS, as you get closer to the airport, the BEARING and TRACK will often become further apart because you are flying towards the runway not the airport reference point.

TRACK is independent from the selection of waypoint. This should align very closely with the published course for the localizer. Obviously, you will have to adjust the heading to center the needle, but knowing the actual TRACK will help in establishing a baseline heading.

SPEED is a nice to have to compare with the airspeed to get an idea of the headwind or tailwind component on approach. Obviously, groundspeed may differ from indicated airspeed even with no wind, especially at higher elevations. However, SPEED is still a useful field for judging the energy state of the aircraft.

Let me use an ILS approach as an example of this generic technique. As soon as we are on vectors, I change the fields as I have just described

and leave the GPS alone. I also like to use the map page and have it set on auto-zoom. The approach is no time to be fiddling with the GPS.

For the approach, Figure 11-3 is what you see as we get vectored. Initially, it is just nice to have the bearing and distance to the airport for situational awareness.
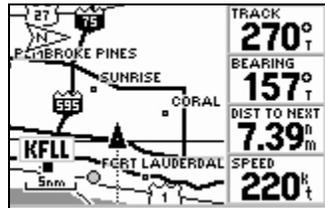
Figure 11-3

As we turn base in Figure 11-4 we can use the bearing to anticipate when we are approaching the final approach course. Even though the bearing is to the airport reference point, the bearing to the airport will be close enough to the inbound course this far out to be help in anticipating the localizer interception.
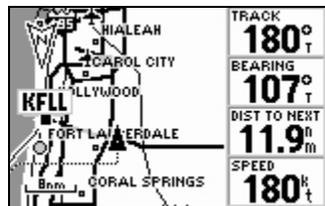
Figure 11-4

In Figure 11-5, we are on the ILS. As you can see, the bearing starts to differ from the inbound course as we get closer. However, at this point we are not really using the bearing. What is useful is the track. If we are tracking within a degree or two of 93 degrees we will be parallel to the localizer. This helps with finding a wind corrected heading to hold the localizer. The localizer needle is what is used to stay on the localizer. The distance is useful when there is no DME. In this case it is referencing the airport reference point so distances will not match the published values on the approach plate. However, it is still very useful for knowing where we are. Glass cockpit aircraft have a wind vector displayed. Absent the glass cockpit, the speed display is very useful for getting an idea of the headwind or tailwind.

Figure 11-5

11-10 Handheld GPS in the Cockpit
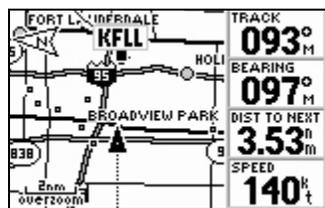
The previous screen shots were with the non-aviation Garmin GPS III Plus. Aviation models will even show the runway as we get sufficiently close to the airport if we are zoomed in. Figure 11-6 is a screen shot from a Garmin GPS III Pilot.
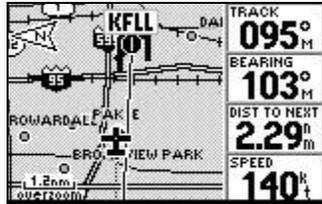
Figure 11-6

Note that during the approach, I have done nothing more than what is allowed by the FAA. I have just used the handheld GPS as an aid to situational awareness, which it is very useful for. I feel that such usage is within the letter and spirit of the regulations.

➢ NDB approaches with a GPS

Using the ADF seems to be a matter of great consternation for many pilots. I have even read newsgroup postings where pilots have tried to placard their ADF as inoperative so that they will not be required to demonstrate an NDB approach on a check ride.

I have not had to fly an actual NDB approach in years. The last time that I had to fly with one, I at least had an RMI, which is an ADF with a compass card that is slaved to the heading system.

ADF review

Before we start on the GPS portion of the discussion, I want to quickly review some techniques and opinions with regard to the actual NDB.

The ADF needle points to the NDB; but if there is any crosswind, following he needle will cause you to fly a curved path. At best, this is sloppy technique. At worst, this might cause you to miss the airport or hit terrain on an approach.

The first thing that you must do in learning to use the ADF is to calculate your bearing to or from the NDB. The ADF needle only points at the station, it is only by correlating the ADF indication to the heading that the bearing can be indicated. .

Do the following at least in your imagination. Even better yet pull out a chart or even a ordinary piece of paper a plotter and try it: Put an imaginary airplane somewhere on the chart and draw a line from the NDB

to the airplane. Pretend that there is a compass rose aligned with magnetic north around the NDB, you can draw it in or just measure with your plotter.   You can look at the compass rose on the chart and read the bearing to or from the NDB, just like a VOR. The problem is that there is no direct way to do this in the airplane. As long as you measure the bearing relative to magnetic north, you can measure it anywhere along the line, including at the airplane. You have the line drawn in your airplane – the ADF needle. You also have the compass rose in the airplane – the heading indicator.

An RMI is very easy to use in that it lays the ADF needle over a compass indication. You can look under the head or tail of the needle and immediately read your bearing to or from the station. This is the line over the compass rose.

The problem is that many airplanes have a fixed card ADF. You may have heard that the bearing to the NDB is equal to the heading added to the relative bearing. While this is true, don't try to use the numerical values to make the calculation. I recommend that you use an RMI instead. If you do not have an RMI, you simply build one in your imagination. Look at the ADF needle and mentally superimpose it over the heading indicator. If the ADF needle is showing 10° to the left, look at the heading indicator and imagine an ADF needle overlaid upon it with the needle pointing 10° left of the nose. Now you have an imaginary RMI.

The next step is to know which way to turn to make the ADF needle move the desired direction. You care about getting the needle to overlay the desired bearing (even if this is the imaginary needle that I described in the previous paragraph) not going straight towards the needle. Treat the head of the needle like a VOR needle and treat the desired bearing as the reference for being centered. For example, if the needle is to the right of the desired bearing, turn more to the right and vice versa. The needle will work the opposite for flying away from the NDB. For flying from the station, think of dragging the needle toward the desired bearing.

If you are doing things correctly; the needle, whether actual or imaginary transposition from the fixed card ADF, will overlay the bearing and the nose will be displaced from the bearing by the required crosswind correction.

The only way this is not going to be confusing is to practice. I used to occasionally turn the HSI to some meaningless radial and fly the VOR using the RMI needles, which requires the same technique.   In addition to using computer flight simulation programs, there are several dedicate navigation simulations that I list on page 14-6, several of which are free.

Overview of GPS techniques for NDB approaches

Even if you are proficient with using the ADF, there are a couple of limitations with the ADF. When ranking the precision of various navaids, the NDB is near the bottom. The needle usually oscillates a couple of degrees at best and several more at worst. Since the bearing is calculated using the heading, the bearing also includes any possible heading errors. When flying towards and NDB, these errors decrease as you approach the station. When flying away form the station the effect of these errors increases proportionally to the distance.

There are several ways of using the GPS as a backup to NDB navigation depending on what kind of GPS you have. It is possible to use some GPS receivers with all of the methods. In order of recommended preference I would suggest the following:

1. Use the built in overlay if you have it in a database. IFR receivers may have the entire approach, and many aviation handheld receivers such as the Garmin 196 and 295 will offer at least the final approach segment. This is a simple matter of pulling up the approach and navigating as you would any other route on the GPS.

2. Build a final segment using the location of the NDB and a waypoint created using the bearing and distance from the NDB. The disadvantage is that this is really something that is only practical to set up before flight.

3. If you have an aviation GPS with the OBS feature, but without the approaches, you can use this to set the final course. This requires no preflight action. However, option 2 is better for outbound legs with certain aviation receivers that offer the OBS mode, such as the Garmin III Pilot. This will permit you to use the VNAV feature on outbound legs to fly a constant angle approach.

4. If you have no other option, it is possible to use the GPS itself and navigate to and from a waypoint representing the NDB. Even if you have any of the previous options available. There is an elegance to this solution. Even if you do not have to resort to using this, I would suggest that you skim through this section.

Once again for emphasis: I think that the GPS can make a very useful reference during an NDB approach, especially if you do not frequently fly them and have a fixed card ADF. I am not suggesting that you take your handheld GPS, especially a non-aviation model, and fly NDB approaches. The ADF is your primary reference. I am merely explaining how the GPS reacts during the approach when used for reference. I do think that it is

fair to use the map display and distance reference of the GPS for situational awareness. I also think that it is reasonable to use the BEARING field to verify the ADF and to use the TURN field to help track the bearing. However, the ADF is still the primary reference!

Using the GPS in a way similar to an ADF

Many non-aviation receivers offer some variation of an RMI type of page. The critical difference is that these are based on TRACK rather than heading. This is the same as an RMI in that the needle should overlay the desired bearing. It is different in that the if you are on the desired bearing, you want the bearing on the GPS compass card depiction and needle to be straight up and down rather than skewed for a crosswind. A good comparison between the GPS RMI and ADF can be found with Figure 7-15 and Figure 7-16 on page 7-21.

Almost all handheld GPS receivers, even the lowest non-aviation handheld, offer some form of RMI even though it may be called something different.

On the aviation receivers, often an HSI type of display is substituted for an RMI type of display. However, often the HSI can be made to function both an HSI and RMI. On the Garmin 196 and 295, the RMI display is only available in non-aviation modes. However, you can go to the HSI page and set the HSI bug to indicate BEARING rather than TO COURSE. When you do this, the bug functions like the head of an RMI needle. This feature is not available on the Garmin III Pilot HSI.

Many other GPS receivers offer a similar type of display function. The navigation display of the Garmin 500 series has a green pointer on the compass arc and the Lowrance 500 and 1000 have a bearing pointer. You may have never noticed the bearing pointer on the Lowrance HSI because if you are on course it will be hidden under the head of the HSI pointer. These bearing pointers are also very useful when intercepting a course using the HSI.

If you understand how to use and ADF, then the RMI or HSI with a bearing pointer need no more explanation from me. However, almost any GPS will give you a value for BEARING and TRACK. To match the function of flying an NDB bearing, make sure that your GPS is set to use magnetic north as a reference.

Even the most humble GPS will give a value for BEARING. Mentally superimpose BEARING onto the heading indicator and you now have an imaginary GPS based RMI needle that works just like a real RMI, or at least an RMI with the tail of the needle broken off.

www.cockpitgps.com

In addition to using BEARING mentally superimposed on the heading indicator, there is a different mental model to allow you to navigate directly with the BEARING value. The principle is simple. Moving around the waypoint clockwise causes BEARING to increase. Moving counterclockwise causes the BEARING to decrease. This is just like a clock, altimeter, or the myriad of other gauges we use. Obviously, this means that when you are flying inbound to the waypoint that you will increase the BEARING by turning left and decrease it by flying to the right. The opposite will be true when flying outbound. However, think clockwise and counterclockwise.

BEARING is the value to the waypoint. If you are flying an outbound leg, you will have to use the reciprocal of the inbound bearing. For example, if you fly outbound on the 115° bearing from the waypoint, you want to fly so that the BEARING is 295°. No mental math is required here if you use the technique on page 9-16. Simply ratchet the first digit one direction by 2 and ratchet the second digit the opposite direction by 2. Whether you are inbound or outbound, still think in terms of clockwise or counterclockwise.

Once you are on the desired bearing, fly so that TRACK matches BEARING or the reciprocal of BEARING as appropriate depending on whether you are flying inbound or outbound. If you have a TURN available as a data field you can fly so that TURN is 0° or 180° as appropriate. As an implementation note you probably will not be able to actually get a TURN value of 180°, but will have to alternate between L179° and R179°. You can use this as a reference point to make small changes to keep the BEARING at the desired value.

If you are using a mapping GPS, you can execute a GOTO when you are on the proper bearing. This will give you a line and a value for XTK or OFF COURSE.

If you get totally confused, ask yourself if BEARING is getting closer to the desired value or further from the value. If the value of BEARING is moving towards your the value you seek – you do not have to turn until it reaches the desired value. If BEARING is getting further from the desired value, then turn towards a value of TURN being 0° or 180° as appropriate and continue through to the other side. Now, BEARING should start moving towards the desired value.


IFR use of GPS 11-15

Figure 11-7

The bearing for the LEE NDB 31 approach is 295°. The first screen in Figure 11-7 shows a position inbound on the procedure turn prior to the intercept. The OFF COURSE value is a reflection of the GOTO executed while established outbound on the 295° bearing. You will also notice a line segment going into LEE. This is the segment from the GOTO point into LEE. The second screen shows where I managed to get 2° off the BEARING and am correcting slightly. Once re-established, flying a heading so that TURN is zero should keep me tracking along the bearing with little deviation.

Creating a route leg for the NDB course

Another way of accomplishing the task of flying an NDB course is to create a route leg. As a practical matter, this is usually a preflight task. The approach may be from the NDB to a predefined fix or intersection. If you have an aviation GPS, you can enter this as a route. If you have a non-aviation GPS, you can do the same except that you will have to find the coordinates for the NDB and fix. If there is no defined fix or you can't find the coordinates create a waypoint at x magnetic degrees at y miles from the NDB. You can then create a route leg from this waypoint to the NDB or vice versa for outbound final legs. You might find this described as "projecting a waypoint" in your manual.

Once again, lets use the LEE NDB 31 as an example. The final course into the NDB is 295°. I created a waypoint at 10 nm and 115 degrees from the NDB. The final approach course will be from this reference point to the NDB. I would suggest creating a separate route with just these points and activating it before the approach. Therefore, there is no problem with auto-sequencing and being on the wrong leg. You certainly want to set this up and check it before you fly. Figure 11-8 and shows an example of this technique using a non-aviation Garmin GPS III Plus.
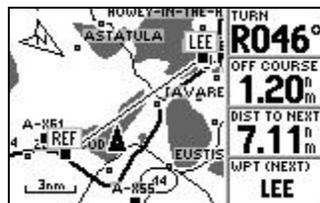

Figure 11-8

With the GPS setup in this manner, the final leg can be navigated just like any other GPS leg.

NDB using the OBS feature of an Aviation GPS

For NDB approaches it is possible to use the OBS feature to set the final course (described in detail on page 8-6). If the approach is inbound to an NDB set the OBS for the final course with the NDB as the active waypoint. Just make sure that you have the GPS set up to use magnetic north values.

Even if you use the OBS mode to set a course, I still recommend using the map display. Figure 11-9 shows the KLEE NDB 31 as an example. The OBS and Hold mode of the HSI was used to set a 295° course into LEE. However, the map page can still be used in conjunction with the OFF COURSE value to navigate toward the 295° bearing to LEE. The Garmin GPS receivers also depict a line on the map for the OBS bearing into the waypoint.
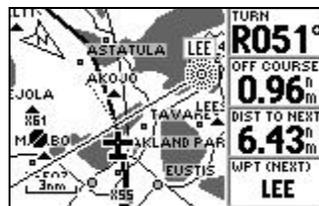
Figure 11-9

Figure 11-10

Figure 11-9 shows an example where the final segment is into the NDB. Figure 11-10 shows an example where the final segment is from the NDB. The two screens depict flying the TPF NDB or GPS 3. This final segment is from the NDB out the 064° bearing. In the first screen I set the OBS to 064° and in the second screen I set the OBS to 244°. Both settings give the same navigational data depicted in the data fields, but there is a line on the map to also reference when I use the inbound bearing instead of the outbound bearing to set the OBS.

To fly outbound, small adjustments must be made from a reference of TRACK being equal to the reciprocal of the bearing to the waypoint. This is the same as TURN being 180°. As an implementation note, some receivers will only display L179° or R179°.

The line on the map is a nice feature, but not necessary. The Lowrance GPS receivers do not display a map line corresponding to the OBS setting.

Most Garmin receivers, with the exception of the GPS III Pilot, that offer the OBS and hold feature also offer the approach or at least final segment in the aviation database. Using this feature is preferable to using the OBS and hold feature.

When the final approach segment is outbound, in the case of the Garmin III Pilot, it is better to set up a route leg by using the ability to create a waypoint as a bearing and distance from the NDB. The advantage of this is that the VNAV feature can then be used to assist in flying a constant angle approach. The disadvantage of setting up a route leg is that this is something that is practical as a preflight function.

Even though I suggest you use the map display even if you use the HSI OBS and hold mode to set the inbound course, it is a good time to illustrate that the HSI can be set to the inbound or outbound bearing and it still gives the same sensing. This is depicted in Figure 11-11. Both indications are at the same point, which is also the same point as Figure 11-10.
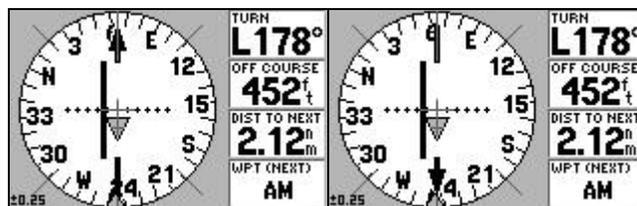
Figure 11-11

➢ VOR approaches with a Generic GPS or a GPS III Pilot

While the ADF approach is troublesome for many pilots, especially when the aircraft has a fixed card ADF, and the GPS is easy to setup once you figure out how to do it, the opposite is true for the VOR approach. Tracking a VOR is not difficult, but setting up the GPS to compensate for the VOR misalignment (explained on page 9-25) is usually not worth the trouble. The GPS models that have automatic compensation for VOR misalignment using the OBS are also the ones that have built in approaches or at least final segments.

If the approach has named waypoints that define the final approach then these points can be used in a route. This is likely to be the case in many VOR/DME approaches. However, on some VOR/DME approaches the final approach leg is to the runway threshold, the coordinates of which may be hard to find. It is not difficult to measure on an airport diagram or

use the cursor of the GPS III Pilot to create a waypoint if you want to do so before flight, but it is more trouble than most pilots are probably interested in.

For VOR approaches that you cannot create a route from named fixes, I recommend using the generic technique described in the *Generic approach techniques with a generic or aviation non-approach handheld* section on page 11-8. If the approach is to a VOR on the field, I would recommend navigating to the VOR rather than airport waypoint. Once established on the radial as indicated by the actual VOR needle, execute a GOTO. This will establish a line on the map display and a reference for OFF COURSE. From this point, you can use TURN to compensate for wind and help track the radial inbound. Adjusting the heading so that TURN equals zero results in a heading that has the proper wind correction.

The distance to the VOR waypoint is still very useful, especially for if the VOR does not have DME, as is the situational awareness from the map display. Although the GPS BEARING field may vary several degrees from the VOR radial, it is still sufficiently useful for situational awareness while being vectored or while in the procedure turn.

Unfortunately, using the OBS on the Garmin III Pilot or creating a waypoint using bearing and distance will not quite work with a VOR like it will with the NDB. Figure 11-12 shows the problem when the GPS is off field and the only way to define the final approach leg is by the radial outbound from the VOR. As you can see, the route to PNS9 is less than ideal.
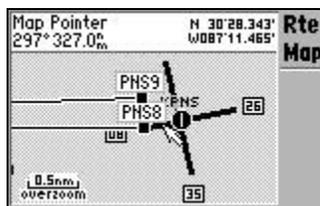
Figure 11-12

The KPNS (Pensacola, FL) VOR 8 is a typical VOR with no DME approach. The approach is to fly outbound on the NUN 089° radial. The approach is based on timing, but the profile view shows that from NUN to the runway is 7.3 nm. I went to www.airnav.com and found that the NUN VOR was slaved to E01° variation in 1985. I set up the GPS to use a variation of E01° in the setup menu. I then created PNS8 as being the NUN 089° at 7.3 nm. Figure 11-13 shows how this was done.
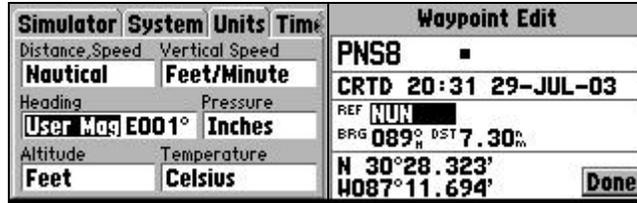
Figure 11-13

PNS9 in Figure 11-12 was created by just using the NUN 089° at 7.3 nm. using the magnetic variation that the GPS calculated rather than the slaved value of the VOR.

Certainly, you could go through this trouble if you wanted to. However, I cannot see it being worthwhile except to illustrate a point as in this example.

Chapter 12 Vertical Approach Profiles

Caution: I think the techniques in this chapter have great potential for increasing the safety level of non-precession approaches. However, it is only fair that I warn you that I am not a currently active general aviation pilot and I have not had the chance to test these procedures in actual flight. I have used Microsoft Flight Simulator to verify the feasibility of these techniques, but I realize that this is different from actual flying. Use these techniques at your own risk.

In spite of the disclaimer, I think these procedures are very valid. I did not simply pull them out of thing air. They are based on philosophies in use at major airlines. I am an airline pilot with over 10,000 hours of flight time. I present my flight time not as a brag, but as a humble statement that I have been flying long enough to know human beings are subject to failure. Any procedure that helps to reduce the chance of pilot error or mitigate its consequences is boon to safety.

I am confident in my abilities as a pilot. However, I am even more confident in my fallibility as a human. There are concepts floating around the airline industry such as "error management and trapping." This is idea is the philosophical background of this chapter.

What I wish to discuss is how a GPS, even a non-certified GPS can be used for vertical situational awareness during approach. Mainly, my discussion centers around non-precision instrument approaches. However, the same techniques can be used for visual approaches or as a double check of ILS data.

There has been talk about flying non-precision approaches as a constant angle descent rather than the old "dive and drive" approach of getting down to the MDA in order to see the runway. The acronym for this is CANPA, Constant Angle Non-Precision Approach. Unfortunately, not much of this discussion has made it outside of the academic, airline, and policy world to the general aviation community. The irony is that I think that general aviation has the most to gain from CANPA or adaptations of CANPA. If there is little discussion of CANPA, there is even less information regarding practical techniques to implement this philosophy. I hope to give you an idea of what the concept is as well as some practical techniques for executing the concept.

Even if you do not decide to use the techniques to fly non-precision approaches with a constant descent angle, the same techniques can be used to enhance your vertical situational awareness for traditional non-precision approach techniques or for visual approaches.

Certified VNAV/LPV approaches

Before I start discussing how any GPS can be used for situational awareness, let me quickly discuss the topic of the new VNAV/LPV approaches.

LPV approaches are precision approaches using the new generation of certified WAAS GPS receivers. At the time of this writing, approaches with vertical navigation are just being introduced. Using these approaches requires an IFR approved GPS certified to a new standard of TSO-146a instead of the old TSO-129a. The obvious thing is that these new boxes have WAAS (see page 3-4 for an explanation of WAAS). However, the changes go much deeper. Among other things, a TSO-146a box must have a position update rate of 5 times per second as opposed to the standard 1 time per second. Also, the vertical profile information will be stored as part of the data for a given approach so that the user cannot mis-program the vertical profile.

You will also start to see VNAV approaches that can use barometric aided GPS or FMS, but will be to a higher minimum than the LPV approach. The concept is similar in that the GPS will derive a glide slope based on its three dimensional position, but that it will use the barometric altitude instead of the three dimensional WAAS fix in its calculations.

If you have a TSO-145a or 146a GPS, flying the vertical navigation is much like flying an ILS. Select and activate the approach and then fly the computed glide slope.

Since I have no personal experience with any of the new IFR certified WAAS GPS receivers and some of the LNAV and LPV issues are still evolving, I will defer explanation of using these to the user documentation and the various FAA publications as these receivers are introduced. But basically, you will need to have a GPS that is certified for LNAV and/or LPV approaches and the approach will have to be certified. The approach will then be flown similar to an ILS.

Although the information will probably soon be superseded, here is a link to the FAA's information on WAAS VNAV approaches approaches:

http://www.faa.gov/ntap/NTAP04MAR18/GEN03003.HTM

Plain old GPS

I like the idea of VNAV/LPV approaches. However, there will be many pilots who will not have the equipment to exploit the advantages of these new vertical approaches and many runways that will not get VNAV/LPV approaches for quite some time.

Even if you do not have the certified equipment and a certified approach, GPS can be used to fly a vertical profile for non-precision or even visual approaches. Before you get the idea that I am talking about cheating the system, I am actually talking about creating a more restrictive box within the legally defined limits of the approach. The certified equipment and approach will get you lower minimums, what I am discussing still leaves you obligated to respect the MDA.

To be blunt, I think that it might be tempting for some people to use a non-certified GPS, especially some of the newer handhelds, or even a certified GPS that is not certified for VNAV approaches to stretch minimums because they have a device which will get them very close to the runway just like an ILS. I think that this is one of those things that will work most of the time, but will eventually lead to a bad end.   With the possible exception of an emergency -- don't do it.

If you are using a handheld GPS, I am recommending that you use it within the technical meaning as well as the spirit of "situational awareness only." For a further discussion of the appropriateness of using a non-certified GPS for IFR, see page 11-4.

There are some practical reasons for my admonishment against using these techniques for "busting" minimums. An ILS glide slope gets increasingly more accurate the closer you get to the runway. A GPS does not. A newer handheld receiver may have WAAS, but the TSO-146a GPS receivers have quite a bit of cross checking logic in addition to the position update rate that is 5 times as fast. Additionally, depending on the handheld GPS there is also a slight lag introduced by the speed at which the processor calculates the VNAV data.

Another principle involved in allowing GPS receivers to be used for approaches is that the pilot selects the approach rather than "build" it by creating a route from individual waypoints. This is to avoid the very real danger of incorrectly programming the GPS. This is just as applicable to the VNAV realm. As long as you respect the MDA, an incorrectly set up CANPA approach should be of little consequence. If you incorrectly set up a CANPA approach and use it to bust minimums, the consequences could be fatal!

Lastly, if you are tempted to use a handheld receiver to get special double secret homemade low minimums, experiment with the dead reckoning feature. Put the GPS on the dash of your car. Place your hand over the antenna and make a turn. You will notice that as you block the signal, the GPS will continue along the original path for several seconds before realizing that it has lost the signal. This feature avoids nuisance loss of signal warnings. However, if you were to trust a handheld GPS to function like an ILS, this could get you into trouble.

Enough of the warnings, when used prudently, a GPS can be a great boon to safety when used for vertical situational awareness.

CFIT (Controlled Flight Into Terrain)

There are too many accidents where pilots fly perfectly good airplanes into the ground. This is known as CFIT, Controlled Flight into Terrain. Many of these accidents happen during approaches, especially non-precision approaches.

Think about what you are actually doing during a non-procedure approach. To descend to the MDA, you are aiming at the ground somewhere short of the runway with the intent of leveling off before reaching the MDA. Unfortunately, many pilots have continued the descent to impact. Who knows why? Perhaps, it is fixating on other aspects of the approach, perhaps it is a misreading of the altimeter, misreading of the approach plate, mis-setting of the altimeter, etc. This has even happened to two pilot professional crews flying good equipment.

Even if you level off at the MDA, the descent from the MDA to the runway can be hazardous. Instrument training can be unrealistic in that if the instructor allows the student to succeed with the approach, the student lifts the hood and has the runway in sight along with all of the visual cues for a VFR flight. In an actual IFR approach, at night, or in poor visibility often the hardest part of the approach is flying from the MDA to the runway even though the runway may be in sight.

If the runway is sighted early, the temptation is to descend even though the aircraft is not at a point where it is prudent to do so. The other extreme is that the runway may be sighted at a point that while even though it is before the missed approach point, it is after a point where the aircraft can safely descend to the runway.

Using the GPS in conjunction with some techniques for vertical awareness can be one more safety tool when used properly to help you prevent becoming another CFIT statistic.

CANPA

➢ Explanation

Several, but not all, major airlines have adopted a concept called CANPA, Constant Angle Non-Precision Approach. The essence of CANPA is to make one smooth descent from the initial approach altitude to the runway using VNAV or various techniques to correlate position with altitude (manual VNAV). Instead of the glide slope being a radio beam, it is derived through various techniques.

On an ILS approach, the runway or runway environment must be in sight at a DA (Decision Altitude). On a non-precision approach, the aircraft is not permitted to leave the MDA (Minimum Descent Altitude) without having the runway in sight.   The difference between an MDA and DA is that the aircraft may descend below the DA on a missed approach if the missed approach is initiated at the DA.

When flying a non-precision approach using CANPA, the MDA is treated somewhat like a decision altitude by adding a buffer to accommodate the round out in the event of a missed approach. My airline uses MDA + 50' and refers to this altitude as a Derived Decision Altitude, DDA. If you initiate a missed approach at the DDA, the 50' buffer should prevent you from penetrating the MDA. If you get to the DDA and have the runway environment in sight per FAR 91.175 then you continue. If you do not have the runway in sight, then you start the missed approach by climbing.

The philosophy behind not leveling off at the MDA during a CANPA approach is that if you are on a reasonable glide slope for the runway, leveling off at the MDA and continuing to fly along at the MDA would put you in a situation that if you did get the airport in sight, you would be in a position where you would have to dive for the airport. Thus, leveling at the MDA would be counter-productive at best.

I have flown many "dive and drive" non-precision approaches where I got the runway in sight, but it was at a point that would require a dangerously un-stabilized descent to get from the MDA to the runway. Thus, I had to make a missed approach anyway. Among other things, CANPA removes the temptation to dive for the runway in these circumstances. I do not have the statistics, but I would not be surprised if more than a few aircraft have been lost while going for the runway when it is sighted before the missed approach point, but after a safe descent can be made.

It is important to note that although the climb for the missed approach is initiated at reaching the DA, turns associated with the missed approach should not be made until the missed approach point is reached.

You may notice some approach charts with a note saying that only approved operators can use DA in lieu of MDA. This does not mean that you have to be an approved operator to use CANPA techniques, it only means that you have to be an approved operator to use the MDA as a DA without adding some margin for round out in the event of a missed approach.

Most non-precision approaches are designed on the premise that your really do not know how far you are from the runway so it is important that you get down to the MDA so that you can see the runway in time to be able to make a safe descent when you get it in sight. GPS is the enabling technology that justifies a change in philosophy regarding non-precision approach procedures.

Along the theme of "error management and trapping," realize that if you make an error setting up or executing a CANPA approach, the MDA (or DDA) is your safety net. In such a case, you are not much if any worse off than you would be with a standard dive and drive approach.

➢ Links to more articles on CANPA

Here are some further references on the subject, both pro and con:

- http://www.aircraftbuyer.com/learn/train03.htm
  Flight Safety article by John Wiley outlining CANPA.

- http://www.avweb.com/news/airman/182402-1.html
  The Black Hole Approach: Don't Get Sucked In! by Linda Pendleton

- http://www.avweb.com/news/columns/182091-1.html
  John Deakin of www.avweb.com comments on using CANPA. This is the "con" side.

- http://www.avweb.com/news/atis/181950-1.html
  This is a pro-CANPA response to John Deakin's article from an SAS captain.

- http://www.avweb.com/news/columns/182092-1.html
  This is a follow up by John Deakin's to his original article.

- http://www.bluecoat.org/reports/Graham_2001_RawGPS.pdf
  Paper by J.D. Andrew Graham of NAV Canada that argues that raw

GPS altitude data with appropriate monitoring could be used for vertical profile calculations.

- http://www.tc.gc.ca/civilaviation/ansanda/aarna/new198.htm#CFIT1
  This is not directly a CANPA reference. This is a Nav Canada article that basically says that just because you can legally descend to an altitude, that does not mean that it might not be more prudent to wait a little before descending.

- http://www.jeppesen.com/download/aopa/dec99aopa.pdf
  This an excellent article explaining MDA and charting for CANPA.

Improved Dive and Drive

CANPA is definitely a philosophical shift.   You may decide that it is a shift that you are not ready to make. You may also rightfully decide that there are situations where the old dive and drive might still be the best decision.

The techniques involved in flying a CANPA approach are still very useful if adapted to the old dive and drive.

If you are flying along at MDA, just because you see the airport does not meant that you should start down out of the MDA. Conversely, if you sight the runway late in the approach, but before the MAP, this does not mean that you can safely descend without diving it in.

The visual descent point, VDP, is a point at which leaving the MDA results in a normal approach descent to the runway. Some approaches have published VDP's, but most do not. The same techniques that are used for calculating a CANPA profile can be used for calculating a VDP at the MDA. The VDP is where the CANPA profile intersects the MDA.

Just as GPS gives you a way of correlating altitude and distance during the descent to MDA on a CANPA profile, it also gives you a way of determining an accurate VDP point.

If you fly the approach CANPA style, you will fly along the glide slope. If you use the dive and drive, you can use the CANPA techniques to make sure that you are getting down to the MDA in time, which means that you will want to be below the CANPA profile until your reach the MDA. Once your reach the MDA, you level off until the MDA meets the CANPA profile before you descend. This point is the VDP.

I recommend that if you don't have the runway in sight by the VDP, then you should consider missing the approach. Generally, when I have actually had to fly a non-precision approach it was to airports where I did

not have much margin between the runway length available and the runway required for the aircraft that I was flying. Not only is the VDP the point at which I would wait until descending from the MDA, it is also the point that if I did not get the runway in sight by, I was going to make a missed approach.

I should point out that if you execute the missed approach at the VDP, that turns associated with the missed approach should not be executed before reaching the missed approach point.

As you get comfortable with using the CANPA for calculating a VDP to verify that you are below the CANPA profile, you can reduce the margin by which you need to be below the profile. Eventually, you will end up flying the CANPA profile. Thus, you can introduce yourself to CANPA gently using a gentler dive and drive.

In summary: You can use CANPA techniques to get down to the MDA in time to facilitate a normal after a descent from the MDA. After leveling off at the MDA, you can use CANPA techniques to stay at the MDA until you reach a calculated VDP that will facilitate a normal descent to the runway.

The problem with CANPA for general aviation

The problem with CANPA for general aviation use is that it causes a severe operational penalty in low visibility situations. Before I discuss the solutions, let me discuss the problem.
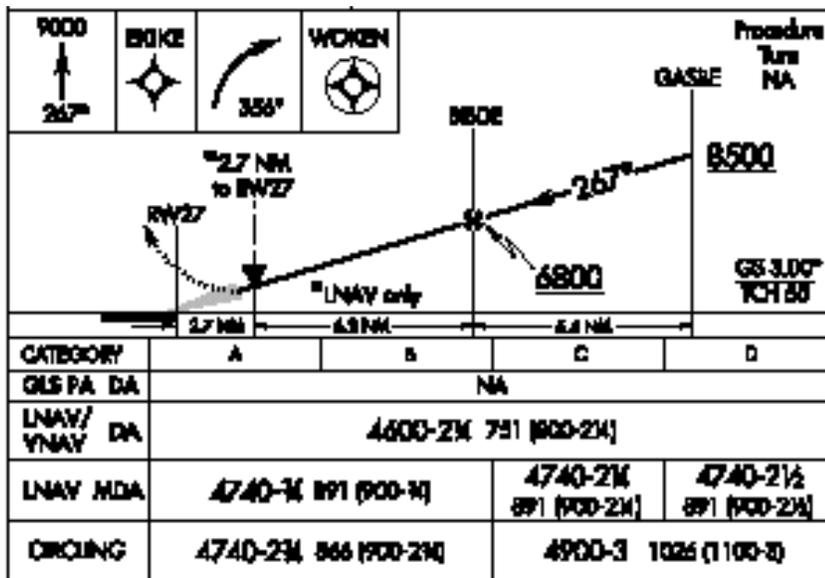
Figure 12-1 KHLN (Helena, MT) RNAV GPS RWY 27
http://www.naco.faa.gov

The RNAV (GPS) RWY 27 to HLN (Helena, Montana) makes a good example. What appears to be odd is that the LNAV approach requires a ¾ mile visibility as opposed to the LNAV/VNAV approach, which requires 2 ¼ visibility. Even stranger is that if you look at the profile view, you will see a note of 2.7 nm to RW27 with an asterisk noting that this applies to LNAV only.

If you were to fly a CANPA approach and are on the 3° slope with LNAV only, then you would still be 2.7 nm. from RWY 27 at the MDA. If the visibility is less than 3 statute miles, there is a good chance that you will not see the runway at this point.

If you have the certified VNAV option, you can get a DA that is 240' lower than the LNAV only MDA. However, you will still be 2.2 nm. from the threshold by my calculations. You will need an actual visibility of 2.5 statute miles to see the runway.

If you are flying an airliner, the 2 ¼ mile charted visibility for the LNAV/VNAV is a realistic reflection of the actual visibility that you will need. The ¾ mile visibility is simply unrealistic. If you were to be at the MDA and acquired the runway at ¾ statute miles from the runway on an LNAV only approach, it would take a 7.3° descent angle to land 3000' down the end of the runway (atan (891/(.75*5280+3000)). The margin for flying a safe descent in a jet is pretty small. In reality, a 4° approach angle is at the outer limit.

I would argue in a jet aircraft, that the LNAV/VNAV operation offers a true advantage over the LNAV only approach since the published visibility for the LNAV only approach does not reflect the visibility that will actually be required to safely complete the approach. Similarly, flying a stabilized CANPA approach on an LNAV only approach represents a small penalty in operational terms and big safety benefits.

The big operational hit from CANPA happens to the light plane pilot. Most pilots flying something like a single engine Cessna should be able to land from the MDA after sighting the runway ¾ statute mile from the end of the runway or approach lights as applicable.

➢ Solution 1: A steeper approach angle

One solution is to fly a steeper approach than 3°. Within limits, a steeper approach is better in many respects, especially with regard to terrain on the approach path. For a jet, 4° might be as steep as practical. For a single engine light aircraft, a 6° descent angle may be very practical. Let's say that we flew the approach in Figure 12-1 with a 6° descent angle. At

the DDA (MDA +50') the aircraft would be 1.4 nm. from the runway. This is much better than the 2.7 nm. with a 3° descent angle.

There are just too many factors for me to suggest what would be an appropriate angle. Most airplanes can descend very steeply, but I suggest you experiment on a VFR flight to find an angle that is reasonably steep yet still safe. For some aircraft such as a jet, the practical limit may be 4°. For a single engine Cessna, you may find that a 12° descent is possible with full flaps and idle power – this is not what I meant, but a 6° descent angle is a reasonably steep, yet still quite comfortable.

Calculating glide angle

The easiest way to calculate the glide angle is to use a GPS and measure it directly. Most Garmin aviation GPS receivers will give you a direct measure of glide angle expressed in feet forward to feet descended. If you do not have an aviation receiver with the capability to directly measure the glide angle, you can divide the true airspeed in knots by the descent rate in feet per minute and use Figure 12-2.

Figure 12-2 shows the angle equivalent of a glide ratio as well as the number of feet descended per nautical mile and the nautical miles descended per 1000 feet of descent.

All of my examples use angles close to 3°. This is a standard descent angle. Perhaps I will eventually get the time to update the examples, but if you understand the techniques for 3°, you should be able to adapt them for another angle.

What about the LNAV/VNAV approach? If you have the certified equipment and use the VNAV as a floor while flying a steeper angle instead of flying on the profile, then I think that the intent of using the VNAV has been met and there is no reason that you could not use the lower DA instead of the higher LNAV only MDA with 50' added for a DDA.

Glide Ratio	TASkts/VSfpm	Glide Angle	ft/nm	nm/1000ft
19	0.19	3.0	320	3.1
18	0.18	3.2	338	3.0
17	0.17	3.4	358	2.8
16	0.16	3.6	380	2.6
15	0.15	3.8	405	2.5
14	0.14	4.1	434	2.3
13	0.13	4.4	468	2.1
12	0.12	4.8	507	2.0
11	0.11	5.2	553	1.8
10	0.10	5.7	608	1.6
9	0.09	6.3	675	1.5
8	0.08	7.1	760	1.3
7	0.07	8.1	868	1.2

Figure 12-2

➢ Solution 2: Artificial displaced threshold

This is somewhat hypothetical, but I put the following section forth for your consideration:

It is somewhat unnatural to intentionally land down the runway. However, it is done all the time with full approval by the FAA. Runway 13R/31L at JFK has 14572' of pavement, but it has a displaced threshold of 2606' displaced threshold landing on 13R and a 3,324 displaced threshold landing on 31L. This still works out to be an effective runway length of 11,966' for 13R and 8976' for 31L.

In the example that we have been using, KHLN, if you are flying a single engine Cessna, is it really necessary to fly a profile that intersects the runway 1000' (or 500' with a 6° angle) from the end of a 9,000' runway? Why not fly to a self imposed displaced threshold so that you will be closer to the runway threshold at the DDA.

Let's keep the example of a single engine Cessna. Let's say that 4000' is a nice comfortable runway length to fly into. If the CANPA profile is set to intersect the runway 5000' (about .8 nm) feet down the runway, this should still give a nice comfortable 4000' beyond the profile point. A 6° descent angle to a point 5000' feet down the runway should intercept the MDA at a point .65 nm from the end of the runway (5000-(891+50)/tan(6))/6078.   Thus, you should be able to complete the approach using CANPA with ¾ mile visibility.

I would suggest that you have a very conservative number in mind for how far from the far end of the runway you are willing to create an artificial displaced threshold target. You can then use this number for setting up the CANPA profile. I would also suggest that you consider what kind of indications that you will get for remaining runway in terms of center line lights, edge lights, and runway markings.

You may ask what's the point? Even though we have had to use a steeper descent and purposefully aim down the runway in this example, we have done so with conservative margins in a controlled way. This is different from sighting at the last minute with a dive and drive and then having to guess whether we will be able to descend fast enough and still stop by the end of the runway.

Obviously, the safest technique is not to use an artificially displaced threshold. However, I think that using CANPA in a low visibility situation to an artificial, yet very conservative, displaced threshold may be much safer than a dive and drive with a dive for the runway at the end.

This technique would fail miserably if it were necessary to make all of these calculations to fly a CANPA approach. All that is necessary is that you have a good conservative figure in mind for how much runway you want to have left and an angle that is you are comfortable flying, but is hopefully steeper than 3°. You then fly a CANPA profile based on this information. If you sight the runway at the DA or DDA (MDA plus a little for round out), then the approach is continued to the runway with relatively minor adjustments to the flight path. If the appropriate visual reference is not established at the DA or DDA, then a climb for the missed approach is initiated and appropriate lateral navigation is initiated at the missed approach point.
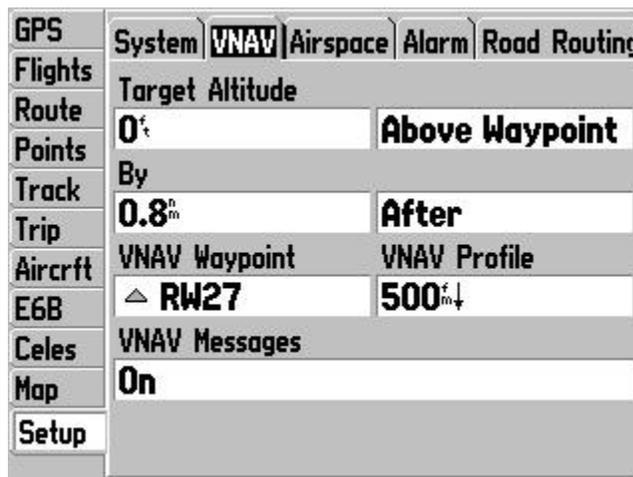
Figure 12-3 Garmin GPS 196

Techniques Overview

There is no single technique for using GPS for vertical situational awareness. The best technique depends on your equipment and to some degree the type of approach. I will give you a couple of different techniques that should at least get you started. You will no doubt have to do some adaptation. The technique for flying a CANPA approach in a two pilot cockpit with a certified GPS coupled to an autopilot with vertical speed mode will be different from flying single pilot, single engine, with no autopilot.

I will leave it up to you as to which techniques are applicable to your aircraft, personal abilities, and specific approach. As I have mentioned before, a well flown dive and drive approach is safer than a task saturated and distracted CANPA attempt. I would highly suggest that you try any techniques in VFR first.

Many of these techniques are only practical if you do some preflight work. In no way am I suggesting that you pull out a calculator and create a chart of distance verses altitude in flight. Many pilots have a policy of minimizing in-cockpit mental math. Mental computation is not one of my strong points and is definitely error prone.

I list some formulas -- some even have trigonometric functions. These are for those who would like to sit down with a calculator or a spreadsheet to do some further analysis. However, for those that do not enjoy such endeavors, I give some rules of thumb that are usually sufficient as a reference point. Keep in mind the old expression of absurdity in: measure with a micrometer, mark with chalk, and cut with a chainsaw. While more accurate profile calculations are better, the extra effort may be nullified by the fact that calculations are much more accurate than you can fly the profile.

I also feel that it is appropriate that I disclaim my experience or lack thereof with some of these techniques. I do not have the need to fly general aviation aircraft IFR and am not IFR current in general aviation aircraft. Thus, I have not had the chance to use all of these approach techniques.

At the same time, I did not pull these techniques out of thin air. These techniques are based on some of the techniques used with major airlines, except that I have adapted them to GPS. I have had the chance to simulate them with Microsoft Flight Simulator using GPSout and a handheld GPS (see 2-8 for a further discussion of using Microsoft Flight

Simulator with GPSout). Anyway, try the techniques in good weather and see if you like them first.

Many of the examples that I give use handheld GPS receivers. A handheld GPS is not an IFR approved device. I discuss my opinions on using a handheld GPS for IFR more fully on page 11-4. In no way do these techniques advocate substituting required navaids or any other requirements for flying a given approach. If used properly, I feel that a handheld GPS can be used effectively not only in compliance with the FAR's, but also within the spirit of the concept of using a handheld GPS for "situational awareness." Of course, this is not a legally binding opinion.

The angle for a standard ILS is a 3°. The examples that I use are close to a 3°. There is nothing sacrosanct about 3°. Often you will find that a steeper approach is needed. The approach may be designed for a steeper angle or you may just be more comfortable with a steeper angle. I would not advise that a no flap, power off dive would be a viable alternative. However, in no way do I want to leave the impression that a 3° slope is sacrosanct or even appropriate for all circumstances.

If you find that you want a steeper approach, you may find that you would rather calculate a steeper approach. Certainly, the VNAV techniques are quite easy to adapt. Another option is that you might use this 3° slope as a floor rather than a target.

➢ A Technique that I dislike

There is a CANPA technique advocated by the FAA and used by some airlines on their conventional navigation equipped fleet that I simply do not recommend. The idea is that upon reaching the final approach fix, you start a constant vertical speed descent based on your ground speed. This is simply vertical dead reckoning.

Ideally, your vertical flight path should take you from the final approach point to the runway. The problem with this technique is that an error on the initial descent to the MDA (DDA) results in a disproportionate change in glide angle to get from the MDA (DDA) to the runway. If your initial descent is a little steep, then you will reach the DDA at a point where the descent angle to the runway from this point will be excessively shallow. Conversely, if your initial descent is slightly shallow, then the final glide will need to be excessively steep.

This technique does not correlate your position with your altitude except at the final approach fix. The real advantage of CANPA is in correlating your position with your altitude. GPS allows you to do this.

NDB CANPA and VDP example
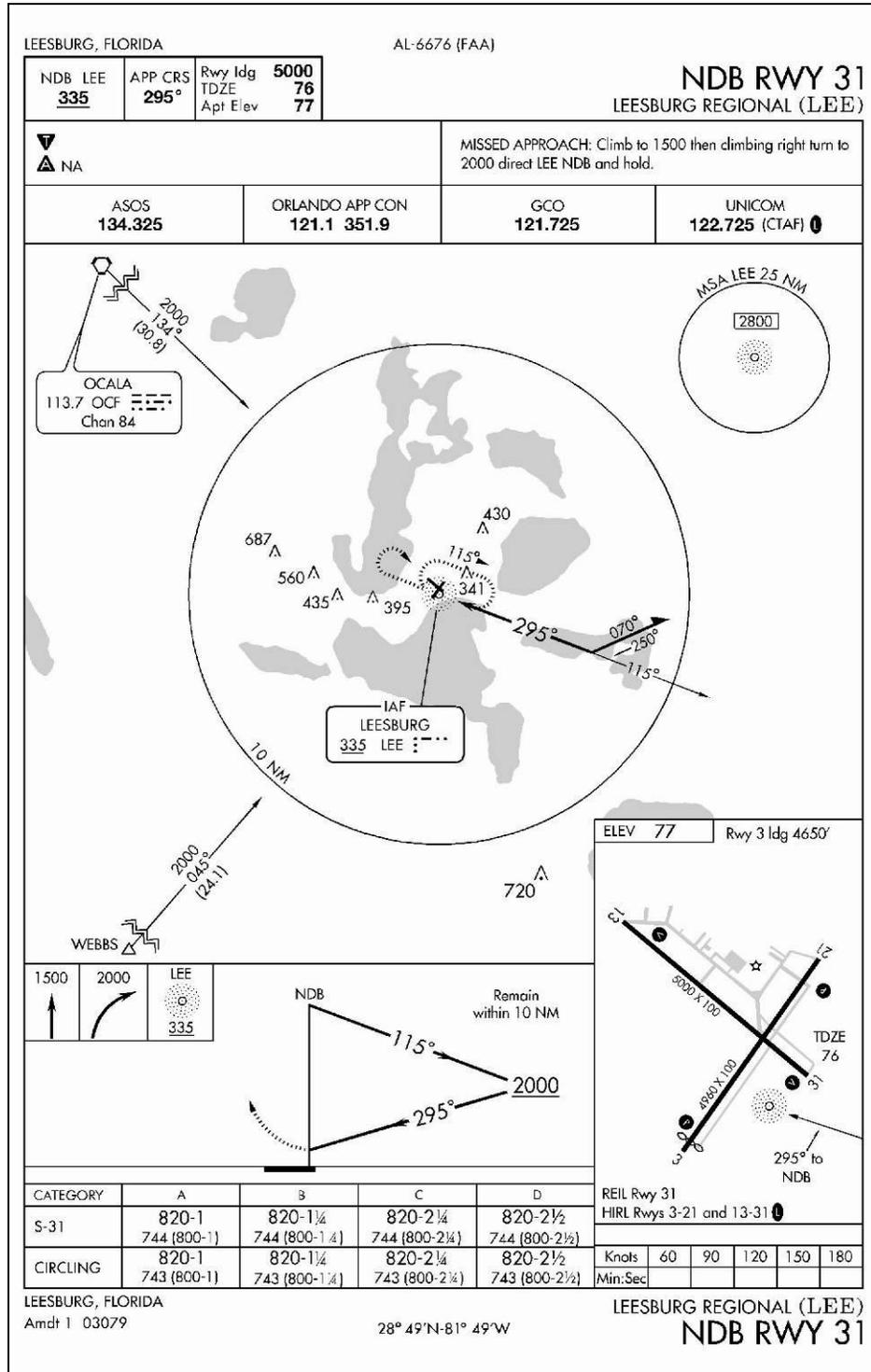
Figure 12-4 KLEE NDB RW 31. Not for navigation, available for download at www.naco.faa.gov under the TPP link.

The KLEE NDB 31 approach in Figure 12-4 is designed with the assumption that you have no distance reference. Hopefully, your timing will have kept you within 10 nm. of the NDB. However, when you roll out on the 295° bearing after the procedure turn, without GPS you only have a rough hope of your distance to the NDB. Thus, it is prudent to immediately start down to the MDA.

A GPS gives you a distance reference. As depicted in the airport plan view on the approach plate or the GPS 196 zoomed view in Figure 12-5, the NDB is pretty close to the end of the runway. Thus, the distance to the NDB should reasonably closely with the distance to the threshold for all but the very close final portion of the approach.
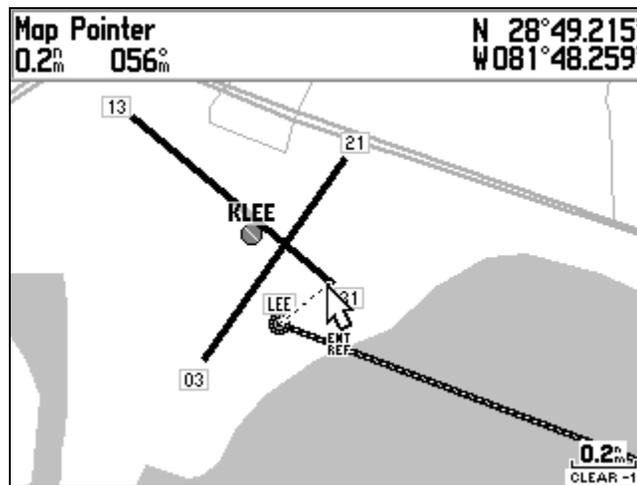

Figure 12-5 Garmin GPS 196

➢ Distance altitude correlation

Let's start with a correlation of distance with altitude. A 3° glide slope is a standard descent angle. This correlates to 318'/nm. The initial approach altitude is 2000'. Using a standard threshold crossing altitude of 50', the 3° glide slope intersects 2000' at 5.9 nm.

$$\frac{(2000'-50'TCA - 76'TDZE)}{(318'/nm)} = 5.9nm.$$

I used 318'/nm. because I am sitting at my computer with a calculator. A more common approximation is 300'/nm. which results in a 2.82° slope.

Using a GPS, we can know the distance to the NDB. If we fly a CANPA profile, we will want to start down at approximately 5.9 nm. If we are flying the approach as a dive and drive, then 5.9 nm. also gives us a reference point in that we want to have started our descent by this point.

The MDA is 820'. Using the same analysis, the 3° glide slope will occur at 2.2 nm. If we descended to the MDA and leveled off early, this 2.2 nm. reference makes a good VDP (Visual Descent Point). We should wait until reaching this point before we descend for the straight in approach.

If we had flown a CANPA profile, we would intercept the MDA+50' about a tenth of a mile before at 2.3 nm.

This approach is somewhat unique in that the straight in approach minimums are the same as the circling minimums. Ignore this fact for the purposes of discussion. It is interesting to note that if we had the 1 nm. visibility listed for a category A aircraft we would be unlikely be able to see the runway as at 2.2 nm.

The further we fly beyond 2.2 nm, the steeper the final descent to the runway will have to be. In a higher performance airplane, the VDP often represents the practical limit of getting the airport in sight. If you have gone beyond the VDP, you may get the airport in sight but not be able to safely descend to the runway without an excessive rate of descent.

If you want to fly a CANPA profile based on correlating distance with altitude, it is possible to create a table altitudes verses distances such as in Figure 12-6. In fact, Jeppesen is starting to publish just such a table for many approaches.

Dist to LEE	1	2	2.3	3	4	5	5.9
Altitude	444	762	870	1080	1398	1716	2000

Figure 12-6

As you start descending, a good reference for a desired descent rate is to halve your groundspeed and add a zero this will give you the descent rate for a 2.82° slope.   For example, a 90 knot groundspeed results in a 450 fpm. rate of descent.

➢ VNAV
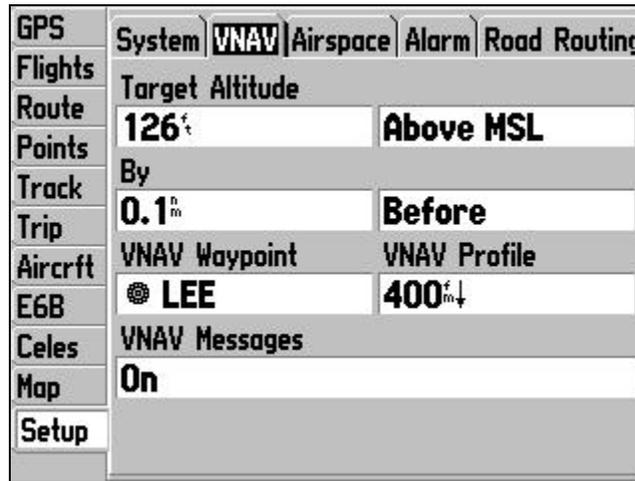
Figure 12-7

VNAV makes things much easier. I explain the general operation of VNAV on 9-8. On the Garmin 196, I would set up the VNAV as in Figure 12-7. The Garmin receivers allow you to specify a height above waypoint for some waypoints. The catch is that the waypoint must have an altitude stored in the waypoint or the reference to "height above" is meaningless and the VNAV will not work. If the final waypoint were a threshold waypoint such as RWY31, then I would have specified 50' above the waypoint. Since the final waypoint is the NDB, I specified the threshold crossing altitude, TCA, based on TDZE from the approach plate plus 50'.

I chose .1 nm before LEE based on a "eyeball" estimate from the airport depiction on the plate as well as the map display in Figure 12-5.

The VNAV profile allows the GPS to calculate an estimated time until the VNAV point is reach based on the desired descent rate. When the aircraft reaches a point that the specified descent rate will carry you to the target defined by the VNAV setup, a pseudo glide slope needle on the HSI display will appear for a descent reference. I do not like the HSI pseudo glide slope, but you might set the target to somewhere near half your groundspeed with a zero added to get the VNAV profile alert and to allow the TIME to VNAV data field to work. For example, if you have a groundspeed of 80 knots, use 400 fpm.

While the pseudo glide slope is not without its good points and you may find some utility with it, here are some of the reasons that I do not like the pseudo glide slope display on the Garmin handhelds for CANPA:

1. The pseudo glide slope depends on being at the proper groundspeed to capture the VNAV profile. If you are too fast, the VNAV will capture early resulting in a low approach.

2. You can manually go to the HSI page and manually capture VNAV at the proper point such as the final approach fix. I find this a little cumbersome.

3. I think the map is an important display for situational awareness. The Garmin 195 and III Pilot do not allow the simultaneous display of the HSI and map. Thus, any explanation would be specific to the Garmin 196 and 295.

4. The pseudo glide slope disappears at 500' from the target by design. I think that this is Garmin's way of saying that you cannot fly the pseudo glide slope and be assured of landing on the runway. I can't say that I disagree with this.
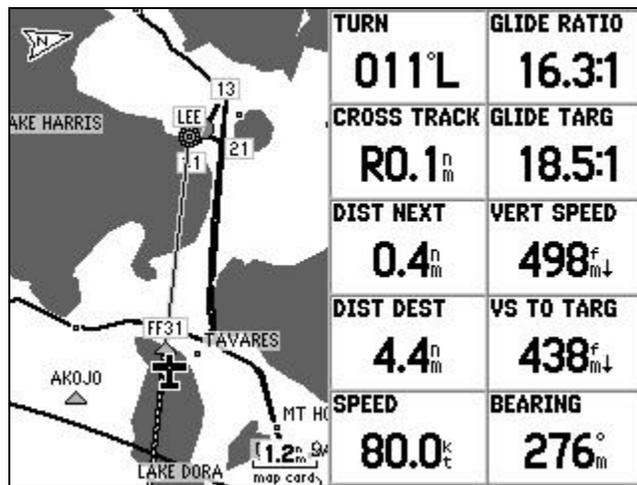
Figure 12-8

Rather than use the HSI with the pseudo glide slope, I prefer to use either GLIDE RATIO to TARGET, which is the desired glide ratio to reach the target as shown in Figure 12-7 or VS to TARGET, which is the vertical speed required to reach the target. I display both values along with the values of VERTICAL SPEED and GLIDE RATIO for illustration purposes. However, for a GPS with limited data field space such as a Garmin GPS III Pilot, displaying VS to TARGET or GLIDE SLOPE to TARGET is sufficient.

Think of waypoint navigation in a vertical plane. It is possible to navigate to a waypoint just by using the value of BEARING. By interpreting the change in BEARING, you can detect navigation errors and correct correspondingly. Likewise, it is possible to fly a vertical profile with just the target information such as VS to TARGET or GLIDE RATIO to TARGET.

However, it is better to display TRACK information in addition to BEARING. GLIDE RATIO to TARGET and VS to TARGET are analogous to BEARING and GLIDE RATIO and VS are analogous to TRACK.

GLIDE RATIO to TARGET is how many feet you must travel forward for each foot of altitude in order to reach the target as set in Figure 12-7. As a reference, a GLIDE RATIO of 19:1 corresponds to a 3° slope. A higher value indicates a flatter approach is required. If the GLIDE RATIO to TARGET is increasing, then you are sinking below the glide path. If the GLIDE RATIO to TARGET is decreasing, then you are floating above the glide path.

VS to TARGET is dependent on the groundspeed as well as glide ratio to the target. If the VS to TARGET is showing that an increased rate of descent is required then the aircraft is floating above the glide path. If VS to TARGET is indicating that a decreased rate of descent is required, then the aircraft is sinking below the glide path. Slowing will decrease the rate of descent required for the same glide path and speeding up will increase it. Thus, a constant speed is helpful. A vertical speed of half the ground speed with a zero appended represents a 2.82° slope. For example, a 90 knot ground speed corresponds to a 2.82° slope at 450 fpm.

I think that it could be argued either way as to whether VS to TARGET or GLIDE RATIO to TARGET is the preferable parameter. GLIDE RATIO to TARGET is a direct measure of the glide slope, whereas VS to TARGET depends on groundspeed. However, VS to TARGET is more tangible. Also, on the GPS III Pilot, GLIDE RATIO to TARGET is only offered to the precision of the nearest whole number.

There are a couple of ways to know the initial descent rate to start down. One of the easiest methods is to note the suggested value of VS to TARGET passing the FAF. Many approach charts have the value published. A good starting point is to divide the ground speed by 2 and append a zero. For example, a 90 kt. ground speed would have an initial descent rate of 450 fpm. This rule of thumb actually results in a 2.82° slope, so you may want to bump up the target rate a small bit for most approaches.

If you prefer dive and drive, the VNAV values are still useful in that they allow you to know where you are in relationship to the imaginary glide angle. For the descent to the MDA, this you would want to be below the glide slope so that you can level at the MDA. After leveling at the MDA, when the VS to TARGET approaches half your groundspeed with a zero appended or your GS to TARGET approaches 19:1, then you are at the VDP.

Localizer Example
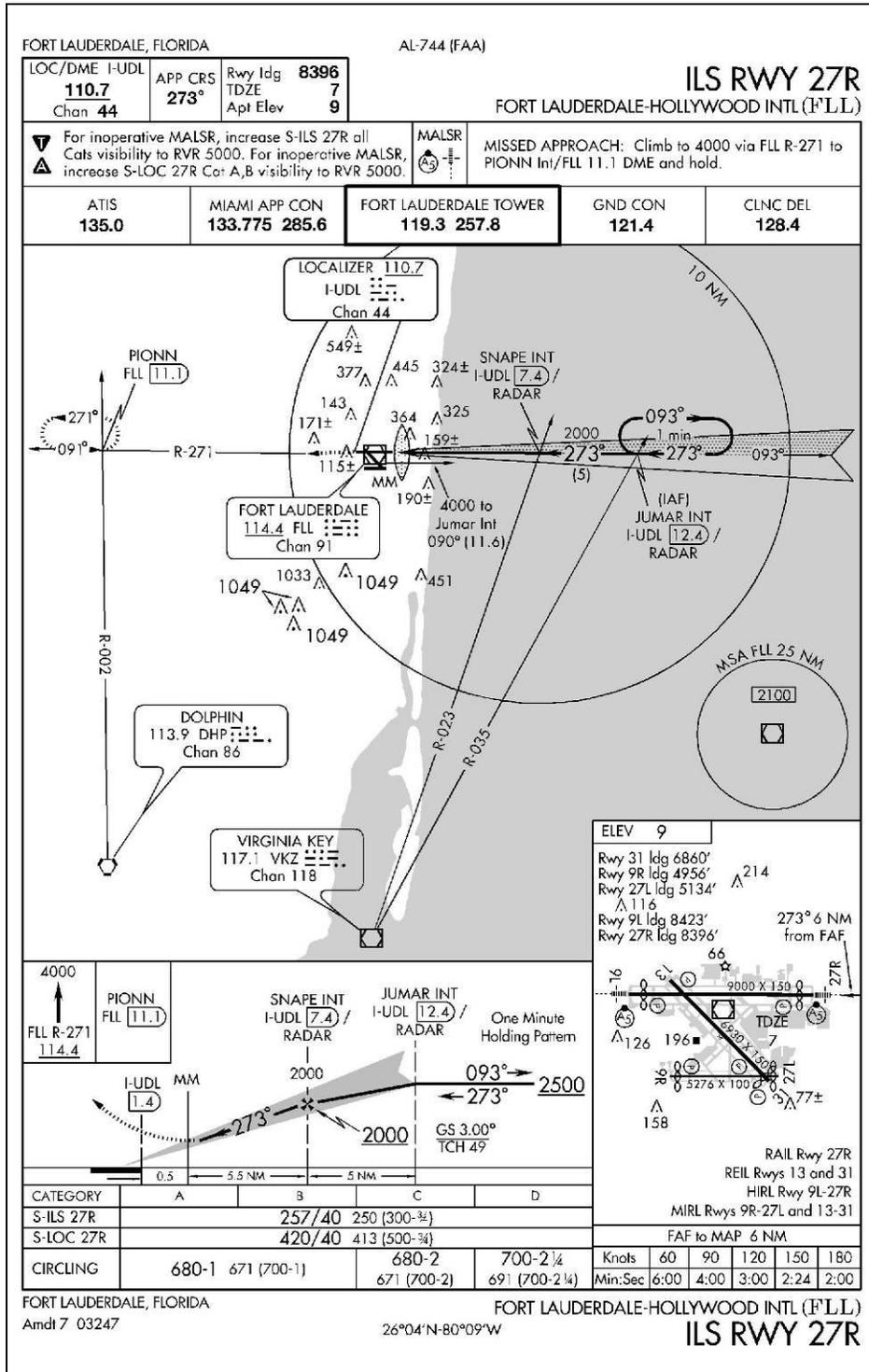
Figure 12-9 FLL ILS RWY 27R. Not for navigation, available for download at www.naco.faa.gov under the TPP link.

Figure 12-9 is the ILS 27R approach into KFLL. I have seen some ILS anomalies and VNAV can be a nice double check for decent planning before getting to the approach. For this example, consider the glide slope to be inoperative which leaves us with a non-precision localizer approach.

➢ VNAV setup
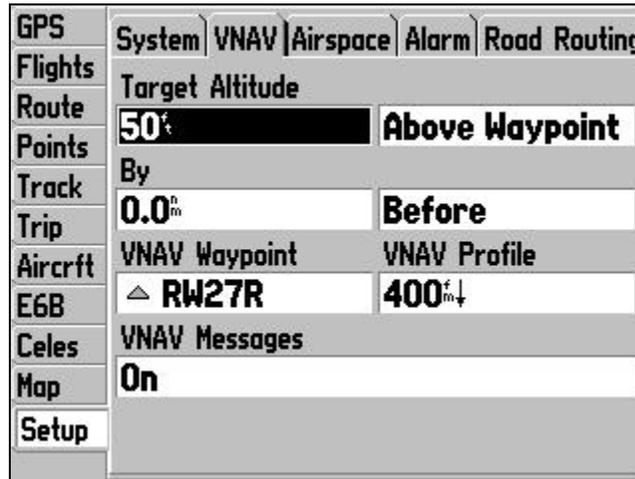
Figure 12-10 Garmin GPS 196

Figure 12-10 is the VNAV setup page for a Garmin 196. This approach works out well because it is to the runway threshold. Thus the VNAV Waypoint is RW27R. The GPS has an altitude in its database for RW27R so it is possible to specify 50' above waypoint.

Crossing the runway threshold at a proper crossing altitude is the goal of the CANPA profile. The problem is that it may not be possible to directly specify the runway threshold as the distance reference. This is the case with a GPS such as a Garmin III Pilot that does not have approaches, but it is also the case in a variety of non-precision approaches. Other examples would be a VOR or NDB approach to a navaid in the middle of the airport. The goal to cross the runway threshold at a proper altitude from a given descent angle does not change, the profile is just calculated indirectly from another reference.

In the case of the Garmin III Pilot, a point that is easy to find is the airport reference point, ARP. As you approach the airport, the path to the runway threshold and the path to the ARP are generally close. It is only close in to the threshold that the path to the ARP and the threshold start to diverge significantly. Obviously, there are some exceptions like flying to a far runway of a massive complex such as DFW. However, you are unlikely to be flying a non-precision approach to minimums in poor visibility to such an airport.

There is going to be an error in basing VNAV profile calculations to a waypoint that is not inline with the approach. As a rule of thumb, as long as the distance reference is with about 25°, the calculations for altitude verses distance are still useful. What follows is detail and further analysis.
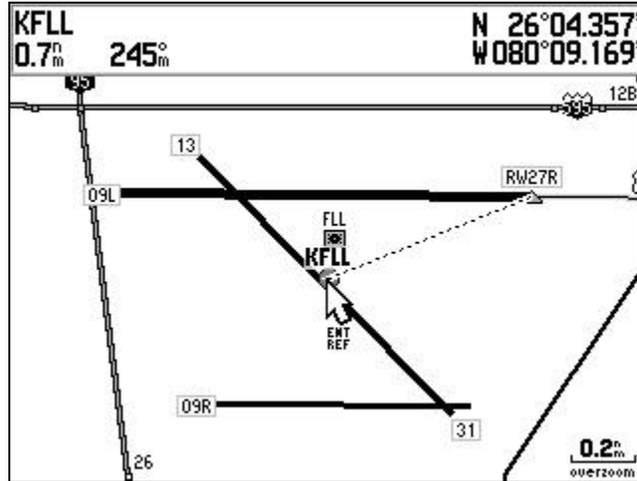
Figure 12-11

Figure 12-11 is a screenshot from a Garmin GPS 196 showing the relationship of the FLL 27R threshold to the ARP. I have just demonstrated that the GPS 196 has the ability to reference the runway threshold for this approach. I am using the Garmin 196 screenshot for the ability to show a graphic of the relationship. For cases where you would need this technique, you would probably use the airport diagram to get an estimate of the distance from the runway to the ARP, although you could use the screen on a GPS III Pilot in such a way.

If you want to estimate the distance from the threshold to some point such as the airport reference point, there are 6,078 feet in a nautical mile. Runway 27R is 9,000 fee long. This is about 1.5 nm. The airport reference point is a little more than halfway down the runway, so .7 is about what I would get from just "eyeballing" the airport diagram. You can also use the scale on the airport diagram or the measure with cursor feature such as in Figure 12-11.
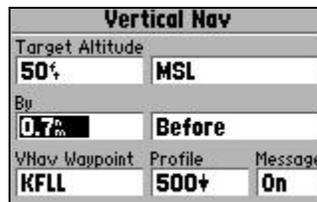
Figure 12-12 Garmin GPS III Pilot

In Figure 12-12, I have specified that I want to cross the runway threshold at 50' MSL. However, I have had to do this in an indirect way by specifying .7 nm before the airport reference point, KFLL, at 50' MSL since the GPS III Pilot does not have a way of selecting a threshold waypoint.

Ideally, the reference point should be in line with the approach. The KFLL ARP is about .7 nm from the 27R threshold and about 30 degrees from the approach path. However, the further out the aircraft is on the approach, the less the difference there is between the bearing to 27R and the ARP.

If you would like some detailed analysis on the effects of the lateral displacement of the ARP from the centerline. I ran some calculations to compare a 3° glide slope calculated from the KFLL runway threshold with a 50 ft. crossing altitude to a 3° glide slope calculated to the ARP:

Distance to threshold	0	1	2	3	4	5
Distance to ARP	0.7	1.6	2.6	3.6	4.6	5.6
Angle error to ARP	30.0	12.3	7.6	5.5	4.3	3.6
Altitude for 3° G/S from .7 nm. to ARP	50	351	665	981	1299	1617
Altitude for 3° G/S from threshold	50	369	687	1006	1325	1643
Altitude error	0	-18	-22	-24	-26	-26
GS to threshold from ARP calculated altitude		2.83	2.89	2.92	2.94	2.95

Figure 12-13

Figure 12-13 shows a minimal error calculating the altitude verses distance with a reference point that is somewhat offset. This is true whether the calculation is done manually or by the VNAV function of a GPS.

On page 11-8 I discussed how a GPS such as Garmin GPS III Pilot could be used on an instrument approach for situational awareness. Even though the III Pilot does not have approaches, it does have VNAV. Figure 12-14 shows how the Garmin III Pilot would give situational awareness not only in a horizontal context, but in a vertical context on a non-precision approach (remember the scenario that the glide slope is inoperative).
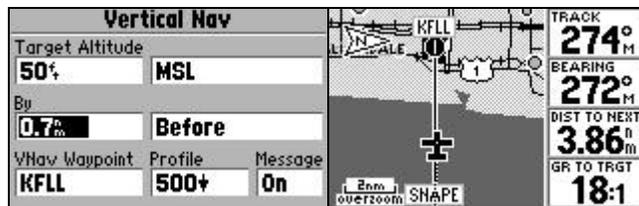
Figure 12-14

➢ Distance verses altitude calculations

Before you can correlate the distance to altitude, it is important to know what the GPS will reference for a distance on the final approach segment. Figure 12-15 shows the display of a Garmin 430 on the KFLL ILS27R. Notice from the WPT field that the GPS is referencing the runway threshold. In most cases, this is significantly different from the DME.

Jeppesen has started to include tables to correlate altitude with distance in many countries, now including the U.S. However, these are usually based on a DME reference. The approach chart (FAA, not Jeppesen in Figure 12-9) shows that the DME at the runway threshold is 1.4 nautical miles. This makes a big difference if you are making a table to correlate altitude with distance. Usually, you will see distances from the missed approach point and runway threshold published on the profile view of the approach chart.

Figure 12-15

Using FLL 27R as an example again, the threshold crossing altitude for FLL 27R is about 50 ft. MSL. If you were to use a GPS that used the runway threshold as the distance reference, the altitudes in Figure 12-16 would be the result. This is simple enough that it might be feasible to calculate mentally.

RWY27R	1nm	2 nm	3 nm	4 nm	5 nm	6 nm
300:1	350'	650'	950'	1250'	1550'	1850'
3°	380'	704'	1028'	1352'	1676'	2000'

Figure 12-16

Using 300 ft./nm. is reasonably easy to calculate in your head when the distance reference is the end of the runway. If you are using a GPS where it is not easy to get a distance reference to the end of the runway, the calculations are slightly more complicated and less amenable to mental calculation on the fly.

Let's change the scenario to use the airport reference point ARP as depicted in Figure 12-11 and as discussed on page 12-23. In this case, the runway threshold is .7 nautical miles from the reference.

If the ARP is .7 nautical miles beyond the threshold, it should be .7 nm * 300 feet/nm = 210 ft. lower than the threshold crossing altitude. Since the threshold crossing altitude is 50 feet MSL, the ARP would be 160 feet below sea level on the 300 feet to 1 nautical mile slope. To get the altitude at a distance, multiply the distance from the ARP by 300 feet and subtract 160 (add –160).

ARP dist.	1	2	3	4	5	6
300:1	140'	440'	740'	1040'	1340'	1640'
Ideal 3°	148'	481'	804'	1125'	1445'	1764'

Figure 12-17

Figure 12-17 shows the altitudes calculated using a 300:1 estimate from the ARP. Having established that the 300:1 is just a little flat and represents a minimum, I think that the correlation to the ideal value is reasonably good in the context of the purpose of CANPA.

Lastly, Jeppesen is starting to publish such tables. In we were using a Jeppesen chart and the chart had been updated to reflect such a table, it would most likely be based on the DME and would look like Figure 12-18. I present this for comparison.

IUDL DME	2.0	3.0	4.0	5.0	6.0	7.0
ALTITUDE	240'	569'	890'	1220'	1540'	1870'

Figure 12-18

The VNAV Whiz Wheel

Although it is not impossible to use the 300 ft./ 1nm. rule of thumb to calculate the correlation between distance and altitude and it is possible to use more precise values and a calculator to develop a chart during preflight, I wanted a simple useful way of calculating CANPA profiles.

I came up with a simple gadget for computing 3 nm per 1000 ft. descents. It consists of two wheels. The outer wheel has altitudes and the inner wheel has distances. The mileage scale is 3 times the altitude scale. This results in a 3.14° descent. For cruise descents, the altitudes are in thousands on the outer wheel and the distances are used as nautical miles on the inner wheel. For CANPA approaches, the altitudes are in hundreds and the mileage is in tenths. The negative mileage scale represents distance before the reference and the positive scale represents

mileage after the reference. This is the same convention as FMS computers.

Due to some peculiarities with Microsoft Word, Adobe Acrobat, and the kludge that I had to use to create the Whiz Wheel, I have the VNAV whiz wheel available for download in the *Other Articles* section of www.cockpitgps.com rather than publishing it in this text.

The VNAV Whiz Wheel can be printed or copied onto card stock and easily made. It is not necessary to constantly rotate the inner and outer wheels like an E6-B. Once the altitude restriction is set, there is no more need to rotate the wheels. In fact, I put a paper clip at the altitude restriction to mark the restriction and to keep the wheels from rotating. Thus, I find the performance of a Whiz Wheel made from card stock to be sufficient.

The restriction of 4,000 feet for approaches and 40,000 feet for cruise altitudes was based on my needs at the time that I developed it. For those of you flying to higher airports, please accept my apologies and realize that this was developed for my own use.
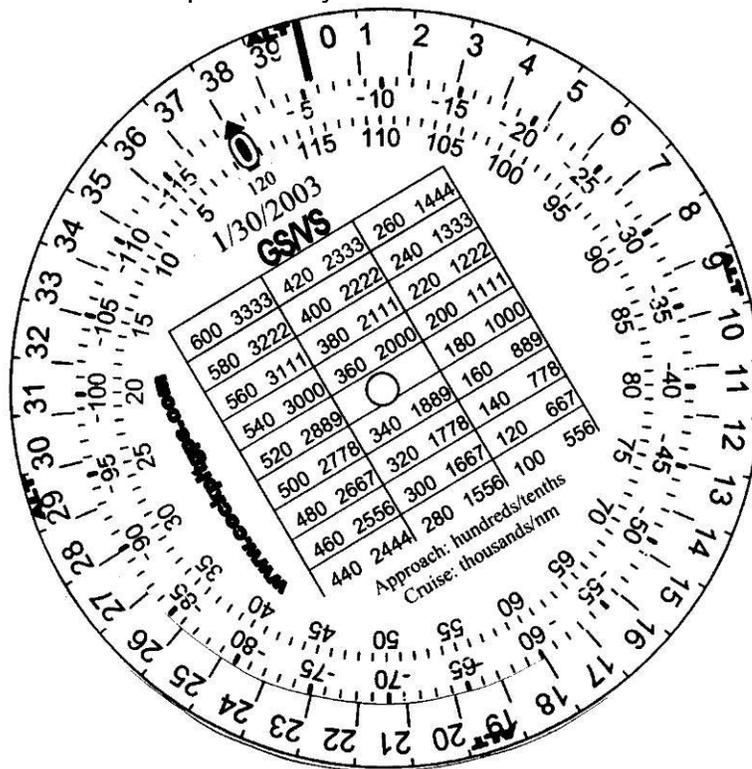

Figure 12-19

Figure 12-19 show the example of the FLL 27R with the ARP as the reference point. The restriction is that the threshold is .7 miles before the reference at a crossing altitude of 50 feet MSL. The TCA of 50' (halfway

between 0 and 1 on the outer scale) is put over -.7 nm (-7 on the outer scale of the inner wheel). All of the distances and altitudes are now correlated on a 3.14° slope from this restriction point.

Looking at Figure 12-19, some altitude and distance pairs are: 1000 feet at -3.6 nm., 1500 feet at -5.1 nm, and 2000 fet at -6.6 nm.

Some other comments:

The Garmin IFR panel mounted GPS receivers do not give VNAV information beyond the final approach fix. One option is to use a distance to altitude table. Often these are in a dual configuration. It may or may not be possible to execute a direct leg for the final approach segment on one to get VNAV for this leg.

The VNAV calculations are based on GPS derived altitude. Although the altitude is not as precise as the lateral position, the VNAV works relatively well as long as you use it just as a situational awareness reference. The fact that the VNAV does not use the barometric altimeter makes somewhat of a cross check. Barometric altimeters also have their faults and in some cases the GPS altitude is a more accurate reflection of altitude than the barometric altimeter.

There is nothing magic about a 3° approach. It makes a useful reference point. Many approaches require that you fly a steeper angle. Even for approaches that do not require a steeper angle you may want to fly a steeper angle anyway. On one extreme is a power off maximum drag dive to the runway, on the other extreme is hitting the terrain short of the runway. Somewhere in between, you will have to decide what is proper. However, the 3° slope and the associated rules of thumb should make a useful reference.

A little more math

If you would like more precision than is available with the rules of thumb, here are some more precise formulae.

➢ Descent angle from descent ratio

Depending on the approach type, the approach angles are usually published on the profile view.

For the descent ratio expressed in feet lost divided by nautical miles traveled, approach_ratio:

descent_angle= atan(descent_ratio/6978)

Spreadsheet note: Most spreadsheets use radians instead of degrees
for trigonometric functions.   You can multiply degrees by pi/180 or some
spreadsheet programs have a conversion function.

For angles involved in approaches, this is approximately:

descent_angle = descent_ratio/106

➢ Glide ratio in ft per nautical mile

descent angle	ft./nm
2.9°	308
3.0°	319
3.1°	329
3.2°	340

Figure 12-20

Where the glide ratio in ft/nm and the angle is in degrees:

descent_ratio = 6078 ft/nm * tan(descent_angle)

For the range of reasonable approach angles:
note: Most spreadsheets use radians instead of degrees. Either multiply
glide_angle by pi/180, which is about .017453, or use radians (glide_angle) to
convert from degrees to radians.

For the range of reasonable approach values, the following is a
good approximation:

descent_ratio = 106 ft/nm* descent_angle

➢ Glide ratio in matched units

glide_ratio=1/tan(descent_angle)

For the range of reasonable approach values:

glide_ratio=57.3/descent_angle

Glide Ratio	Glide Angle
17:1	3.37°
18:1	3.18°
19:1	3.01°
20:1	2.86°
21:1	2.73°

Figure 12-21

➢ Descent speed

Where rate of descent is in fpm, ground speed is in knots, and descent angle is in degrees:

rate_of_descent=101.3 * ground_speed * sin(descent_angle)

For the range of reasonable approach angles:

rate_of_descent=1.768 * ground_speed * descent_angle

Chapter 13 Setup

There are a variety of settings. Some such as time format are a personal choice. An aviation GPS will probably have most of the defaults optimized for aviation use. Many of the generic GPS receivers will need a couple of changes. Below is a list of settings to look for. Not all receivers will have all of these settings options.

System

- **Backlight:** Always On

- **Power Saver:** Off
  This takes fewer position samples to save battery life. I do not know of any aviation models that have this.

- **WAAS:** On or OFF
  I have not done a thorough evaluation to see how much battery life WAAS costs. If are running on battery power, you might consider using the GPS with WAAS off. You probably will not even notice the difference in accuracy. If you have external power, why not use it.

- **Distance and Speed:** Nautical

- **Units/ Heading:** Auto Mag Var
  Both settings, True and Magnetic have their advantages. I would suggest that you probably try Magnetic first if you are undecided. If you navigate the way that I suggest, this setting will not matter. You should be comparing your GPS desired course or bearing to your GPS track. The actual values will be different if you use True as opposed to Magnetic, but the difference will be the same.   If you use the TKE or TURN field, the magnetic variation will cancel anyway.

  Magnetic allows you to correlate the GPS track information with the heading of the aircraft for crosswind information. It is advantageous for pre-published bearing information on approaches. I have previously discussed on page 7-22 that a VOR radial is not quite aligned with magnetic north.

  True allows you to correlate courses and measurements on a chart with GPS. This is especially useful for flight planning. True might also be recommended at more extreme latitudes.

- **Time/ Time Format:** Your choice.

- **Position/ Position Format:** There may be occasions to use other formats, but the predominant format for aviation is hddd mm.mmm'

- **Position/ Map Datum:** WGS 84, This is the default, leave it there.

  WGS 84 stands for World Geodetic System 1984. The earth is not quite spherical. This is a mathematical model for the shape of the earth. With the possible exception of some third world countries, aeronautical charts use WGS 84. Where this becomes a factor is for non-aviation use. I discuss this more fully in another text, Small Boat GPS.

  The short explanation is that just as the ability to measure location for navigation increasing precision in the context of navigation has increased, so has the ability to survey positions. Surveying across large bodies of water, especially oceans has been even more difficult. Thus, much surveying has been done relative to local datums. Thus a latitude and longitude surveyed relative to one datum may describe a slightly different point than the same coordinates in another datum. This is an oversimplification, but I at least wanted you to know what this setting means.

Map

- **Road Lock :** OFF This is a feature on many non-aviation units. With this on, the GPS assumes that you are driving on a road and tries to locate you on the nearest one.   This will result in the map shifting and twisting to try to find itself along the road. I don't know the exact parameters. Road lock is not a bad feature, it just is not useful for flying.

- **Orientation:** I recommend track up.

- **Bearing Line and Course Line:** Course if forced to choose, but you might consider both if available.

  Many GPS receivers do not offer the bearing line. Some map displays offer the choice between a course line and a bearing line. Some offer the possibility to display both. The bearing line draws a line from your position to the active waypoint. The course line draws a line from the previous waypoint or GOTO point to the active waypoint.

- **Heading line:** Several newer GPS receivers offer a Heading line. First of all, this has nothing to do with the aircraft's heading. The Heading line is a projection of the TRACK. My recommendation is to try it and keep it if you like it. I personally don't use it, but I consider this to be a personal preference.

- **Map detail:** In this context, detail and clutter are the same thing with the difference being the perspective of value. The map display can become quite crowded. Additionally, cluttered screens can take longer to redraw. However, the detail can also be useful. Different levels of detail may be desired in different circumstances. For example, a highly detailed map may be useful while creating a route, but may be cluttered while flying the same route.

  Some receivers allow you to set a general level of detail, other receivers require you to set individual map parameters to desired zoom levels. Some higher end units, such as the Garmin 196, 295, 400 series, and 500 series allow you to change the detail (de-clutter) by pressing the ENTER button.

  Setting the display of an item to a selected distance shows the minimum zoom at which it will display. For example, on Garmin units, if you set the option to 50 miles it will display at zooms 50 miles and closer, but not further out.

  Many of the non-aviation Garmin receivers show airports in the base map. They are generally pretty accurate and the base map includes a good number of public airports. Thus, the depiction of airports in the base map of non-aviation receivers is a useful feature. However, these are certainly not meant for aviation navigation. I recommend you either use them with verification or as verification for data from another source. I have discussed the other sources in the Waypoint chapter. Use your common sense.

  Some GPS receivers are more likely than others at displaying these airports by default. You might adjust the value of GEO points in the map setup to better display airports. Try setting the GEO points to the maximum value. The airports will display or not display as a function of this GEO point setting, zoom level, and in some cases the general detail level selected.

  If you look carefully at Figure 13-1 you can see several airports depicted in the second screen. To zoom in closer on one, as with any other point, move the cursor and press the zoom IN button and the map will zoom and re-center on the cursor position.

  If you move the cursor over the point and press the ENTER button information will appear on the waypoint. On some receivers such as the GPS III Plus, you will end up with a screen with the latitude and longitude with a suggested name for the airport as a waypoint. On most of the newer Garmins, a press of the MENU key will give you a menu where you can select "Save as Waypoint."

GPS V with GEO points in AUTO (default)	GPS V with GEO points at max
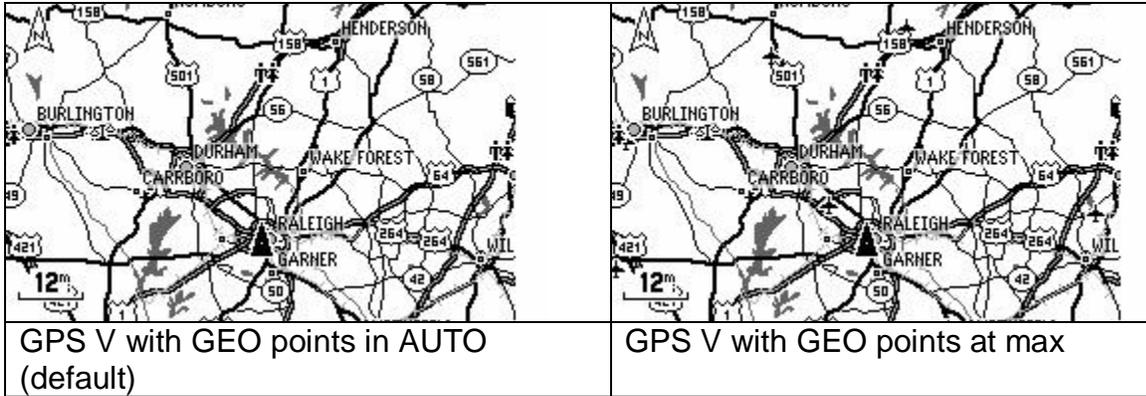
Figure 13-1

- **Data Fields:** I have thoroughly discussed which data fields to display on page 7-6.

Chapter 14 Links and References

Aviation GPS information:

1. *Global Navigation for Pilots, 2nd Edition*
   Dale De Remer, Ph.D. and Donald W. McLean
   Aviation Supplies & Academics, Inc., 1998, ISBN 1-56027-312-7
   http://www.asa2fly.com/author_dderemer.htm
   Great book for explaining GPS. Although some information is only
   relevant to long range transoceanic type of flying, there is also good
   information on map projections, FMS, INS, and general navigation theory.

2. GPS Explained, Paul Bertorelli of IFR magazine
   http://www.avweb.com/articles/gpsexpln.html
   One of the best explanations that I have seen on how GPS works.

3. GPS Guide for Beginners, http://www.garmin.com/aboutGPS/manual.html
   This is a Garmin pamphlet that is good at explaining the basics of how
   GPS works. There are also basic introductory explanations of elementary
   navigation terms.

4. Trimble GPS tutorial, http://www.trimble.com/gps/index.htm
   This is a Flash explanation of how GPS works.

5. Navtech GPS Seminars and Supply, http://www.navtechgps.com
   If you want a post graduate electrical engineering text on GPS, Navtech
   would be a source.

6. IFR: A Structured Approach
   John Eckalbar
   www.skyroadprojects.com

7. *Cockpit Automation for General Aviators and Future Airline Pilots*
   Stephen M. Casner
   Iowa State Press
   ISBN 0-8138-2300-5
   http://www.iowastatepress.com/casner
   Cockpit Automation is a book with details on using IFR panel mounted
   GPS for navigation. There is additional information on autopilot and radar
   use as well as philosophical comments on cockpit automation.

   The shortcomings are that I think that there should be more emphasis on
   using the map display. I describe this in my Navigation chapter. Also
   there are several examples where the OBS mode is suggested, but I think
   that a Direct to leg might be better. However, if you are reading Cockpit

GPS (this text) you already have that information and Casner's book might be very useful to you.

8. AOPA Air Safety Foundation Safety Advisor, http://www.aopa.org/asf/publications/sa01.pdf
   This is an excellent overview of GPS use, including using GPS for IFR approaches.

9. Flying with GPS, www.gpsbook.co.uk
   This is a book aimed at using the Garmin 92, 195, 295, 196, and 430. It is a U.K. book and many of the examples are based on navigation techniques for the U.K./JAR private pilot license.

   I like my navigation techniques a little better. If you are reading this, then you have seen my techniques. It is certainly worth a look if you are flying in the U.K. Overall, this is one of the better books that I have seen. The examples are not so specific to U.K. flying that it would not be useful to pilots in other countries.

10. ZD Publishing, http://www.zdpublishing.com/
    A source for books on several different panel mounted receivers. I have not had the chance to review any of the texts.

11. GPS Trainer, http://www.asa2fly.com/gpstrainer.htm
    This is a CD-rom training program for learning to use several popular GPS receivers. Since I have already mentioned several ways of gaining proficiency with GPS and I have not seen the program run, I offer the link with no recommendation either pro or con.

12. FAA Capstone Project, http://www.alaska.faa.gov/capstone/
    Capstone is a project in Alaska to use GPS and newer technologies such ADS-B to make flying safer.

13. GPS Techniques DVD by Richard Collins, http://www.sportys.com/courses/dairfacts.cfm
    This is really nothing more than two videos burned onto a DVD. There are no chapter menus or any of the slick features that DVD's allow. Most of the enroute portion appears to be fairly old judging by the example GPS receivers. If you can get by the lack of DVD features and the old GPS receivers in the Enroute portion, I think the overall level of knowledge and philosophy conveyed is good.

➢ WAAS, LAAS, and Differential

14. GPS and Beyond: The SatNav Transition; Ross Bowie, Sat Nav office of Nav Canada
http://www.avweb.com/articles/satnav.html
Good article explaining some of the issues such as WAAS, LAAS, integrity vs. accuracy etc.

15. http://gps.faa.gov/Programs/WAAS/waas.htm

16. http://www.gpsinformation.net/exe/waas.html
WAAS on handheld GPS units.

17. http://joe.mehaffey.com/waaslaas.htm
This is a page of links to more information on WAAS and LAAS.

➢ Soaring

18. http://www.126association.org/gps.htm
It has been over 25 years since I have flown a glider, but this site has good information on using GPS for soaring as well as many links.

➢ CANPA (Constant Angle Non-precision Approach)

19. http://www.aircraftbuyer.com/learn/train03.htm
Flight Safety article by John Wiley outlining CANPA.

20. http://www.avweb.com/news/airman/182402-1.html
The Black Hole Approach: Don't Get Sucked In! by Linda Pendleton

21. http://www.avweb.com/news/columns/182091-1.html
John Deakin of www.avweb.com comments on using CANPA. This is the "con" side.

22. http://www.avweb.com/news/atis/181950-1.html
This is a resonse to John Deakin's article from an SAS captain.

23. http://www.avweb.com/news/columns/182092-1.html
This is a follow up by John Deakin's to his original article.

24. http://www.bluecoat.org/reports/Graham_2001_RawGPS.pdf
Paper by J.D. Andrew Graham of NAV Canada that argues that raw GPS altitude data with appropriate monitoring could be used for vertical profile calculations.

> ➢ **FAA Publications**

25. Aeronautical Information Manual,
http://www.faa.gov/ATPUBS/AIM/index.htm
The GPS section is in Chapter 1, the direct link is:
http://www.faa.gov/ATPUBS/AIM/Chap1/aim0101.html#1-1-21

General GPS information

26. www.gpsinformation.net
Consider this to be a GPS portal. This site is run by two retired engineers,
Joe Mehaffey and Jack Yeazel, and has links to all sorts of GPS
information.

27. GPS Service Interruption NOTAMs,
http://www.navcen.uscg.gov/gpsnotices/

28. Sam Wormley's GPS site,
http://www.edu-observatory.org/gps/

GPS links not necessarily related to aircraft navigation

29. Jet Propulstion Labaoratory, http://sideshow.jpl.nasa.gov/mbh/series.html
JPL is using GPS to track tectonic movement.

30. Geocaching, http://www.geocaching.com/
Geocaching is basically scavenger hunting using GPS. I have not
personally tried geocaching, but it is an interesting application of GPS.

GPS manufactures

31. Garmin, www.garmin.com

32. Magellan, www.magellangps.com

33. UPS Aviation Technologies/ Apollo, www.upsat.com

34. Lowrance, www.lowrance.com

35. Bendix/King, www.bendixking.com

PDA and PC software

36. Nav GPS, www.navgps.net
    Pocket PC and Windows GPS navigation interface.

37. Anywhere Map, www.controlvision.com
    Pocket PC GPS navigation interface.

38. Win Pilot, www.winpilot.com
    Pocket PC GPS navigation interface

39. AirPlan, http://www.razorsedgesoft.com/airplan.htm
    Flight planning software with GPS upload and moving map.

40. NavPlan, www.avedware.com
    Basic and simple Palm software. It can be used to get coordinates for use.

41. CoPilot, www.palmgear.com
    If you are reading this in print, go to the PalmGear site and search for "copilot." Copilot is not as clean, simple, and compact as NavPlan. However, it is free and will do more.

42. Landings.com, http://www.landings.com/_landings/pages/planning-software.html
    If you are reading this in print, go to www.landings.com. Click on the expanded directory and select Flight Planning Software. Many of the flight planning programs have moving map capabilities.

43. Jeppesen, http://www.jeppesen.com/store/prods/flitestar.phtml
    Various products with various degrees of GPS interface.

44. Waypoint+ , http://www.tapr.org/~kh2z/Waypoint/
    Free program for transferring waypoints between a Garmin GPS and computer.

45. Easy GPS, http://www.easygps.com
    Free program for transferring waypoints between several brands of GPS and a PC.

46. G7ToWin , http://www.gpsinformation.org/ronh
    Free program for transferring waypoints between several brands of GPS and a PC. There is also a Windows CE version. Most of the screen shots

in this text used G7ToWin.

47. Links to other third party GPS software, www.gpsinformation.net
There are links to several third party programs on this site.

48. PalmFlying, http://www.palmflying.com/
Palm OS aviation program information.

49. GPS Passion, http://www.gpspassion.com
Pocket PC/ Windows CE GPS information.

50. Dale DePreist's Navigation and GPS Articles
http://www.gpsinformation.org/dale/
Includes information about Palm and Pocket PC navigation.

Waypoints

In addition to the following sites, look under software for Air Plan and NavPlan.

51. **Paul Tomblin's web site**
http://www.navaid.com
This is a site that has data available in several formats. One format allows you to download data that can be read by a free program, EasyGPS, which can then be loaded into a GPS. Another format allows data to be loaded into a free flight planning program for Palm OS called CoPilot.

52. AeroPlanner.com, www.aeroplanner.com

53. SA Aviation POI Set for Magellan GPS 315/315A/320/SportTrak,
http://home.stny.rr.com/bkw/315/
Magellan 315/320 only, U.S. Only
This is a free U.S. database that can be uploaded into a Magellan 315 using the Magellan Data Send software. I discuss this in detail under the discussion of the Magellan 315 in the Which GPS chapter on page 4-30.

54. AirNav.com, http://www.airnav.com.
On this site you can put in an identifier and find the coordinates. Looking up coordinates for many airports or navaids would be tedious. However, there is quite a bit of information for each airport.

Navigation Simulations

I mention some navigation simulators in the text. These simulations are for learning traditional navaids as opposed to GPS.

55. VOR/NDB Simulator from Aviation Tutorials
    http://www.avtutorials.com/

56. Radio Navigation Simulator for Pocket PC
    www.greatsimulations.com
    I have not tried this, but it looks intriguing. The advantage of this software
    would be that you can pull out your PDA and play with it when you have a
    few spare moments.

57. Web simulators.
    There are several Java applet navaid simulators available on the web.
    Ryan Ferguson's Web Site, http://www.fergworld.com/training/ , has a
    couple of nice ones created by Roy Epperson. Another good simulation is
    Tim's Air Navigation Simulator at http://www.visi.com/~mim/nav. You
    might also try a web search to find some others.

Other

These are some personal recommendations that you might not otherwise
possibly come across except for me listing them.

58. A Discussion of Various Measures of Altitude, MJ Mahoney,
    http://mtp.jpl.nasa.gov/notes/altitude/altitude.html
    I would be dishonest if I told you that I did not get lost in the calculus by
    the end of the article. The beginning of the article has a very good
    discussion on various measures of altitude. Before I took on this project, I
    took for terms such as mean sea level.

59. See How it Flies, www.monmouth.com/~jsd/how
    This is an online flying text. I have not read the whole book. But the
    sections that I have read on energy management are excellent.

60. The Bluecoat, http://www.bluecoat.org
    An international e-mailing list on the subject of FMS, EFIS and EICAS
    displays, automated subsystems, flight mode annunciators, flight directors,
    autopilots, and the integration of all avionics equipment in the modern
    cockpit.

61. PC Flight Systems, www.pcflightsystems.com
    I eventually would like to see inertial navigation reach the price level
    where it would make an effective backup for GPS. It is not there yet, but
    PC Flight Systems has a relatively inexpensive system that provides
    attitude reference.

What is in this book

This is a practical guide on how to use GPS in the cockpit. The emphasis is on handheld GPS and includes guidance on using non-aviation GPS as well as some basic navigation techniques that apply to certified receivers such as the Garmin 400 and 500 series.

- Usage Issues
  Issues such as legality of use and what a handheld GPS is appropriate for.

- How it Works
  This is the back of the napkin purposefully over-simplified version. I have references to more detailed explanations if you desire.

- Which GPS
  This chapter deals with what to look for in choosing a GPS. Although I have some specific model information, my main goal is to point out the factors to consider in purchasing a GPS receiver. The discussion is mostly aimed at handheld GPS choices.

- Aviation Waypoint Data
  I have information on where to get this information and how to get it into the GPS if you have a non-aviation GPS.

- GPS Preflight Route Planning
  Special emphasis is given on how a mapping GPS can be used to plan a VFR flight.

- Navigation
  You have to know what the GPS is telling you and how to use it. I have several examples with screen captures from to show you how to navigate with the GPS.

- Miscellaneous
  This is a discussion of some of the extra features and more esoteric details of using GPS.

- IFR use of GPS
  I have some comments and sources of information for using an IFR certified GPS during approach as well as the legality and appropriate manner in with a handheld GPS can be used for IFR operations. Included is a chapter on using GPS for constant angle non-precision approaches, CANPA.