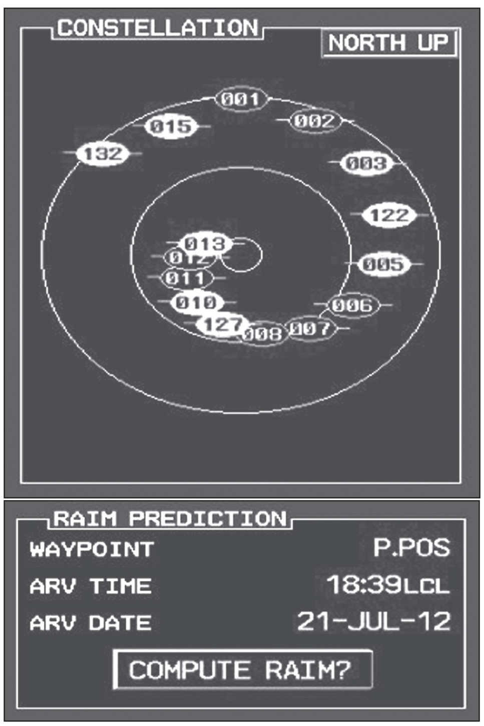
RAIM, RAIM, DON'T GO AWAY

GPS is generally so reliable that we don't think much about situations that can cause accuracy to be degraded. That's why RAIM is important.

by Fred Simonds

GPS reliability and accuracy has generally been so phenomenal that users of all stripes have come to take it for granted. However, the demands of precision and reliability for IFR operations means we can't go whistling along fat, dumb and happy.

The accuracy of GPS is compromised by human or natural interference, poor satellite geometry, signal-warping atmospheric effects and many more hazards to navigation.



A G1000 satellite constellation (top); those near the horizon are in the outer ring, near a 45-degree angle in the middle ring and overhead in the smallest ring. The G1000 RAIM Prediction Utility (above)—waypoint, arrival time and arrival date may each be edited with the cursor; put the cursor on the button and press enter to compute RAIM.

Sanity Checking Software

Since many of these hazards cannot be fully mitigated, aviation GPS receivers invoke sanity checking software in an effort to warn pilots when safety limits are exceeded. That software is called the Receiver Autonomous Integrity Monitor or RAIM.

RAIM is necessary since delays of up to two hours can occur before an erroneous satellite transmission can be detected and corrected by satellite controllers.

Many handheld and portable GPS units exclude RAIM software, creating the specter of an undetected error. That is one reason why these devices are illegal for IFR use beyond general "situational awareness". Systematic cross-checking with other navigation systems is essential.

RAIM is specific to non-WAAS GPS systems which, according to TSO-C129/C129a, are not considered standalone systems. This is why the AIM calls for an alternative form of navigation, in effect VORs, should RAIM capability be lost.

In contrast, WAASs built to TSO-C146a *are* standalone systems. WAAS machines incorporate an advanced form of RAIM that not only detects faults but excludes them from use. This software is called WAAS Fault Detection and Exclusion.

How RAIM Works

RAIM or Fault Detection [FD] requires at least five satellites in view of the GPS with satisfactory geometry – spread well apart is best. One RAIM implementation is to have it derive position solutions using visible satellites not needed to provide a position fix.

Inconsistent solutions called "outliers" trigger a RAIM warning. RAIM availability itself is therefore not to be taken for granted since satellite positions can be poor (clustered together), satellites can be down for maintenance, environmental/atmospheric interference can raise its own havoc, as can, per a study at Carnegie Mellon University, forgetting to shut off your cell phone. RAIM availability itself is a prerequisite for safe GPS navigation.

In G1000 systems, loss of RAIM availability triggers an assortment of warnings, the most general of which is an **LOI** or Loss of Integrity advisory. This is where that VOR redundancy comes to the fore. The letters LOI will also appear in the center of the HSI. In the G1000, bad satellites are excluded from the navigation computation, turning its version of RAIM into FDE – Fault Detection and Exclusion.

For this to work, at least six satellites must be visible allowing a single corrupted satellite to be excluded while still offering the needed five for RAIM. The GPS satellite constellation is designed so that at least five are always visible anywhere on earth. Typically, 7-12 satellites are in view. Few receivers are designed to accommodate more than twelve.

The **GPS NAV LOST** advisory can mean that there are insufficient satellites, a simple on-board GPS failure, or excessive position error. RAIM protection limits are ± 2.0 nm for oceanic or en route flight phases; ± one nm for the 30 nm radius terminal area, and ± 0.3 nm for non-precision approaches.

Loss On the Approach

On an approach, a **RAIM UNAVAIL** message declares that there is insufficient satellite coverage to perform RAIM between the Final and Missed Approach waypoints. A similar message, **ABORT APR** indicates that GPS navigation has been lost between FAWP and MAWP. Either message calls for a miss.

If RAIM is not available, you will not be offered GPS approaches when you attempt to load a procedure. If you loaded a procedure when RAIM was available and then it became unavailable, the procedure will not activate.

RAIM can even be necessary in WAAS-equipped GPS receivers if the receiver is outside the WAAS coverage area. On long trips, AIM suggests periodic destination RAIM checks since conditions can change en route.

All this sounds pretty scary, but Garmin says that RAIM is available nearly 100% of the time regardless of phase of flight. RAIM outages are usually very short – under five minutes.

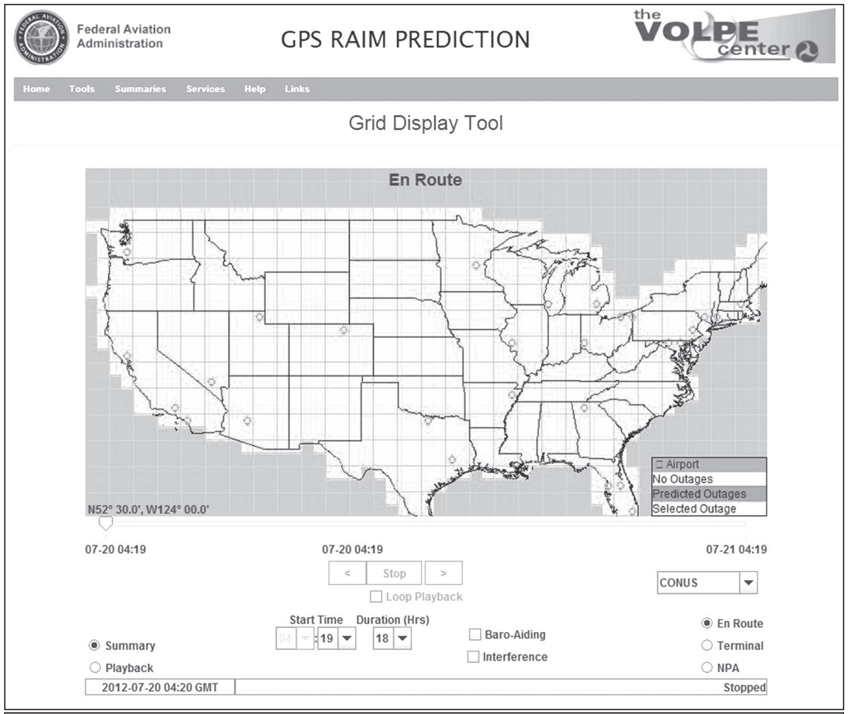
PREDICTING AVAILABILITY

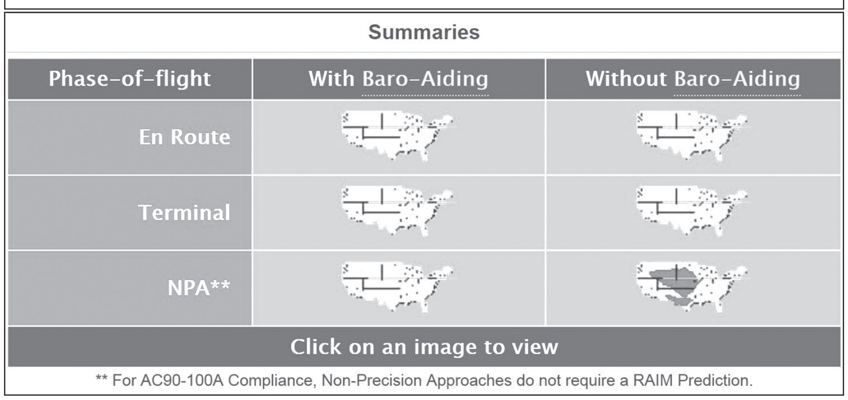
RAIM prediction tools indicate whether RAIM will be available at a specified date, location and time. Many boxes including the Bendix-King KLN-89B/90A/94 units along with the GNS 430/530 and G1000 have a RAIM prediction tool.

The G1000 version appears on the AUX-GPS Status page as shown. Enter the information and the G1000 will hopefully return a **RAIM AVAILABLE** message which is valid ± 15 minutes of the specified arrival date and time. It is possible to have a **RAIM AVAILABLE** message for an en route waypoint and **RAIM NOT AVAILABLE** for an approach since the latter's protection limits are more stringent.

RAIM performs a prediction by two nm before the FAWP, and passing is a condition of entering approach mode. If RAIM is unavailable, do not descend to MDA, but rather continue to the MAWP via the FAWP and contact ATC as soon as practical.

While your receiver operating manual is the governing resource, receivers are allowed to operate without RAIM annunciation for up to five minutes to permit approach completion. If you get a RAIM warning after the FAWP, execute the published missed approach.





GPS RAIM prediction (top), allows RAIM to be predicted up to 24 hours in advance. GPS RAIM Summaries (above), from RAIMPrediction.net. Be sure to check the time stamp when clicking on a map.

PREDICTION REQUIRED?

Performing a *preflight* RAIM prediction is required when flying T or Q RNAV routes below and above 18,000 feet respectively and RNAV SIDs, STARs and ODPs.

RNAV GPS approaches do not require a RAIM check as IFR GPS units do this automatically.

One way to meet this requirement is to ask Flight Service to include GPS NOTAMs and an en route and terminal RAIM check as part of your briefing.

Be sure to tell them if you have baro-aiding or not (see below). FSS provides predictions for ± 1 hour of ETA or a 24 hour time frame at a given airport or as you request, as for an RNAV (GPS) departure. There are also Internet sites such as fltplan.com that will calculate RAIM as part of your flight planning as much as 50 hours preflight. These tools predict outages expected to be longer than five minutes.

The FAA sponsors www.raimprediction.net. The AOPA recommends that if you use the Summary mode, be sure to note the applicable time. It recommends using Playback mode instead which shows outages over time. Check the Interference box to show areas affected as by Department of Defense testing.

Baro-Aiding

If your altimeter can feed altitude information to your IFR GPS, typically through your altitude encoder, it gives your GPS a vertical reference. With this baro-aiding, RAIM requires only four satellites in view rather than five; hence the likelihood of outages is reduced. You can see the difference between with and without on the Summaries page (depicted previous page).

It is yet another reason to have a current altimeter setting. GPS-derived altitudes can be way off and there is no integrity checking. For more information on whether your unit complies with AC 90-100A, search the Internet for the AC 90-100A Compliance Table.

For further information on IFR GPS regulations, see AIM 1-1-9 and my article *IFR GPS Regulations* published in the January 2010 issue of *IFR Refresher*.

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EARTHLY BLACK HOLES

Not the ones in space, the ones on earth that can instantly erase all visual cues, requiring immediate transition to instruments to avoid being sucked in.

by Armand Vilches

The transition from VFR to IMC is more than a little challenging. Pressing on into deteriorating visibilities and ceilings while trying to use visual references is the number one weather-related killer in aviation.

Because about half of the pilots involved in these accidents are instrument rated, it stands to reason that even good pilots have difficulty remaining upright when visual references go away; it takes time to transition to the gauges and react appropriately to the messages they send.

Since we know VFR into IMC is hazardous, we try to make an extra effort to be careful, yet in the process we tend to give little thought to another VFR into IMC situation, one which can occur when the weather is CAVU. We know it as the black hole condition.

Black Holes

Simply defined, a black hole is a dark environmental condition that creates a loss of visual horizon, depth perception and the sensation of speed. The condition can cause the pilot to quickly lose situational and spatial awareness. Black hole conditions can occur during any phase of flight: taxi, take-off, cruise, descent and landing.

In dark conditions, pilots have been known to taxi into other aircraft and buildings or to take a sudden excursion into a ditch alongside a taxiway or runway. Taxiing accidents usually don't involve much in the way of injury, except to the pilot's ego, but they can cause some very expensive property damage. Of course, when the aircraft is in flight, such as after breaking out of the clouds on a night approach, the situation becomes much more serious and the fatality rate of black hole accidents is similar to weather related VFR into IMC accidents.

Drs. Kraft & Elworth Research

In 1969 two Boeing engineers conducted an extensive empirical study to learn why so many pilots were routinely crashing aircraft short of the runway when executing a night approach in good weather with excellent visibility. It wasn't just pilots of little airplanes who were having the accidents. Seasoned aviators flying transport category and military aircraft were not immune.

Early on it was hypothesized, and the study later concluded, that pilots were not varying their descent profiles based on the changing of the runway's visual angle. Instead pilots were descending using a constant visual angle (see diagrams facing page).

In plain language, the visual angle is the angle an object occupies in the eye's field of vision. The larger the visual angle the closer an object appears to the viewer, likewise the smaller the visual angle the farther away an object appears.

In dark conditions, a black hole, when the visual senses of speed and depth of field are diminished or even eliminated, pilots unwittingly keep a constant visual angle as the aircraft flies towards the runway. A little trigonometry would prove that as an air-