The past, present, and future of airborne weather radar

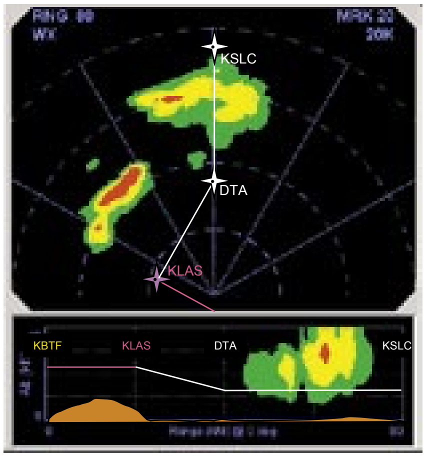
B Y D A L E S M I T H

Once upon a time, not too very long ago (at least I hope not, considering that's when I started my career at Bendix Avionics), airborne weather radar was at the very forefront of avionics technology development. Operators and aircraft manufacturers even went so far as to put "Radar Equipped" on the sides of their aircraft so passengers could see that their airplane carried the latest in "safety technology."

But, like an older brother when a new baby comes into the house, the day the first 'glass cockpits' began appearing in airliners and business jets, the front and center of the instrument panel went from the exclusive domain of the radar indicator to a space where manufacturers put something called the "multifunction display." Alas, the once mighty radar became just another display mode.

The ironic thing is that at the same time the dedicated radar display indicator—at least in airliners and business jets—was going the way of the Dodo, the three major radar manufacturers were making some of their biggest technological advancements. Even though many pilots at the time didn't agree.

One of the advancements that took a while to catch on, with pilots anyway, was the change from the old magnetrons to the new solid-state systems. Sure the magnetron radars did the job,



Honeywell weather radar

but they suffered from a short lifespan. "The early evolution of radars was based on the need for greater reliability," explained Dan Woodell, principal systems engineer, Radar Products for Rockwell Collins. "The original magnetron systems would deliver about 300- to 500-hours of tube life and they would be done. When you had piston engine airliners that were getting a new engine every month or so, that didn't seem like a problem.

"But now when you have jets that go thousands of hours [between major maintenance], having something you had to change every couple of hundred hours would stick out like a sore thumb," he continued. "That meant switching from magnetrons to solid-state systems. Those were not without tradeoffs, but the real issue was to force reliability."

"I think that it is true that if you look at the older analog radars they do have more penetrating power," Bruce Dawson, Honeywell's business and product manager for radar, added. "However, that could lead you into a false belief of where the storm is located. The analog radars could look a little further into the storm than the new solid-state radars can and that may be why some of them [pilots] thought it was a better thing." The reason was the early solid-state radars didn't have the same sort of loop gain that the more powerful magnetrons had, so they couldn't see as "deeply" into storm cells.

"The magnetron systems could often give you a false impression of what was really there," he said. "In reality though, the digital versions paint a better picture of the actual weather that is in front of you. Again, we've always touted this as a 'weather avoidance' system. Not a weather penetration system."

Things that go bump in the flight...

Of course there was more to the switch from analog to solid-state than just a tremendous increase in reliability. Technicians had discovered that, while the solid-state systems couldn't see as far into storm cells, they did have the ability to more clearly display areas of possible turbulence using Doppler. And after all, while rain can be a problem, the thing you really, really want to avoid is turbulence. Especially if you are carrying passengers.

"Noteworthy along with solid-state was the introduction of Doppler turbulence detection in around 1982," Woodell said. "About that same time we also introduced path attenuation compensation and alerting—if the radar has so much rain in front of it, it can't be trustworthy, the system now tells you about it."

Avoid the heavy rain. Avoid the heavy turbulence. And between Doppler and Path Attenuation Compensation, the early-generation digital radars—digital just sounds so much cooler than solid-state—did an excellent job of helping pilots do just that. But, the engineers knew there was so much more capability hidden in those digital boxes, and in the early '90s they took the next great step by introducing the first wind shear detection systems.

"We [Collins] certified our first forward-looking wind shear system in 1995," Woodell added. "If you've noticed, there have been no more wind shear related fatalities in the air transport [industry] since then. We've pretty much gotten rid of it, but it's been a number of systems, both ground and airborne, working together to make it happen."

Wind shear detection capabilities have come quite a way in the past decade. "We [Honeywell] build both predictive and reactive wind shear detection systems today," Dawson said. "We have reactive wind shear in our EPGWS system and then predictive in our RDR-4B and RDR-4000 systems."

As Dawson explained it, reactive wind shear detection senses when the aircraft is in a shear zone. "The pilot has to be experiencing some kind of degradation in aircraft performance. It can be an increasing speed and lift or a decreasing speed and lift. Decreasing is obviously the back-end and the most threatening. But you are actually in the shear," he said.

"The predictive is actually looking out in front of the airplane, up to five-miles, to see where there may be wind shear," Dawson continued. "What it is doing is looking at a Doppler shift in the individual particles—typically rain, and then it is measuring that shift. When it [shift velocity] crosses a given threshold it says, 'Hey, wait a minute. We have a problem here.' There is a wind shear ahead and the radar announces 'Go Around, Wind Shear Ahead.'"

"It's an integral part of the weather radar," he added. "What it does is actually give the pilot time to accelerate and climb to miss the shear. If that's not possible, at least he can be in a configuration so he is already climbing and accelerating before he gets into it. And that makes it, of course, a much safer condition for the aircraft."

Of course, the intent of the "predictive" technology is to avoid the shear areas so you never have the "reactive" system go off. "The potential of actually having a shear hit right on top of an airplane is extremely remote," Dawson said. "But, it does provide that extra level of safety to have both systems on board."

TILT is a four-letter word

Operation of the tilt control may seem like a proverbial "no brainer" but it's not. In fact, that little knob has been a big thorn in the backside of way too many pilots. So much so, that Honeywell and Rockwell Collins have both introduced new-generation radars that make tilt management "automatic."

"There is a lot of pilot skill and pilot judgment involved and a lot of workload because you are climbing and descending in terminal areas and the correct tilt setting changes rapidly during the time when you are busiest trying to fly the airplane, "explained Roy Robertson, principal systems engineer, radar systems for Rockwell Collins. "We have introduced our WXR-2100 MultiScan radar system. It's a move toward a fully-automatic radar system.

"It's quite a revolutionary radar system. It's design goal, and it is very close to this, is to just push the 'Auto' button and go fly the airplane," he continued. "The unit takes care of the tilt, gain, automatically runs the antenna, and it automatically decides what [return] is ground and what is weather. It uses the data from the various sweeps to provide an optimal picture off the nose of the airplane all the way out to 320-miles."

"You know the early radars had very few computing elements in them," Woodell added. "Now they are a rival of high-end desktop computers when you look at memory and processing speed. So it is able to both use and recall that information and combine and compare it, which allows this capability to happen."

Dawson explained that Honeywell has not only added "automatic tilt control" to its popular RDR-4B radar system, they also went the extra step and integrated the radar with their EGPWS. "What we do is take the terrain data from the EGPWS to tell the radar where the terrain elevations are at every selected range and that determines where the antenna should point to remove the ground clutter." He added that with the development of the new RDR-4000, they are going a step further and electronically subtracting the terrain information from the radar display.

According to Dawson, the RDR-4000 introduces a revolutionary, fully automated radar system. The radar receives the FMS flight plan and uses that information to "look" for weather along the route of flight. The RDR-4000 also provides a vertical view of the weather to bring another level of situational awareness to the cockpit.

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The availability of real-time positioning has also permitted the manufacturers to improve radar performance in other ways. Rockwell Collins' MultiScan system can actually compensate for changes in altitude and temperature. "The system will automatically turn the radar gain up as the altitude increases and temperature decreases to try and normalize the way weather looks," Woodell said. "If you're on the ground and see a hideous thunderstorm that's all red on the display, we want you to have the same characteristics when you are cruising at 35,000 feet.

"The normalization we do now has a strong geographic question to it," he continued. "Things over the ocean are different than over land. Storms over the equator are different than those over the mid- or high-latitudes, like over Canada. So you have to know where you are in order to make good decisions about weather performance and interpretation."

Seeing radar's future

Good news for us radar fans, the technology hasn't been treated like the proverbial second son. In fact it has become an integral part of a modern avionics suite. "Years ago it was just a dumb box that only did what you told it to do. Today it is a proactive part of a complete avionics system," Dawson said. "The intent for the new-generation radars is two-fold: One is to reduce constant workload across the board for flight crews. And two, is to create a system that looks at the intended flight path to determine what the airplane is currently doing and projects what it will be doing in the future to help crews determine the best possible route to improve overall ride quality."

"We have been involved with an advanced turbulence detection technology program that was funded by NASA and was a cooperative effort with ATR and Delta Airlines," Robertson added. "We put an enhanced turbulence radar on a next-generation 737. This new radar actually makes measurements about the turbulence ahead and it also knows the weight of the airplane, its speed and altitude, and it backs out the airplane's physics to give you G-loading on the airplane for that situation.

"This improves the turbulence detection algorithm for that aircraft in that situation," he continued. "It's not just radar spectral width, meters-per-second, which is the way the current-generation radar does it. It's sort of an esoteric parameter—it may say there is probably turbulence, but what does it mean to the aircraft? This new system will actually tell the pilots how severe the turbulence will be in relation to that aircraft and it's current flight condition."

"Is the turbulence a ride-quality issue or a true safety hazard?" Woodell added. "It can help the flight crew tell the difference between the two."

Along with helping pilots 'see' smoother routes, the next generation radars will possibly help crews see in reduced visibility conditions. "Radars today really aren't obstacle detection systems," Dawson said. "We're looking at something in the radar realm that may help with that. A system with multiple transmitters using the same antenna possibly.

"Another step will be in the area of clear air turbulence detection capabilities," he added. "It's much more difficult to detect than the turbulence around storms, but we're doing some work on it. We went up to 45,000 feet where the air gets thin and the particles get very small to see if we could spot anything. The initial response was, 'Yes we can.' So now we are looking to refine that."

Advanced turbulence algorithms, obstacle detection, and clear air turbulence detection, what's next for weather radar? Who knows. But when asked, Rockwell Collins' Woodell said, "I can't say what I can't say, but what I can say is the next three years are going to be very exciting. Stay tuned..." ❑