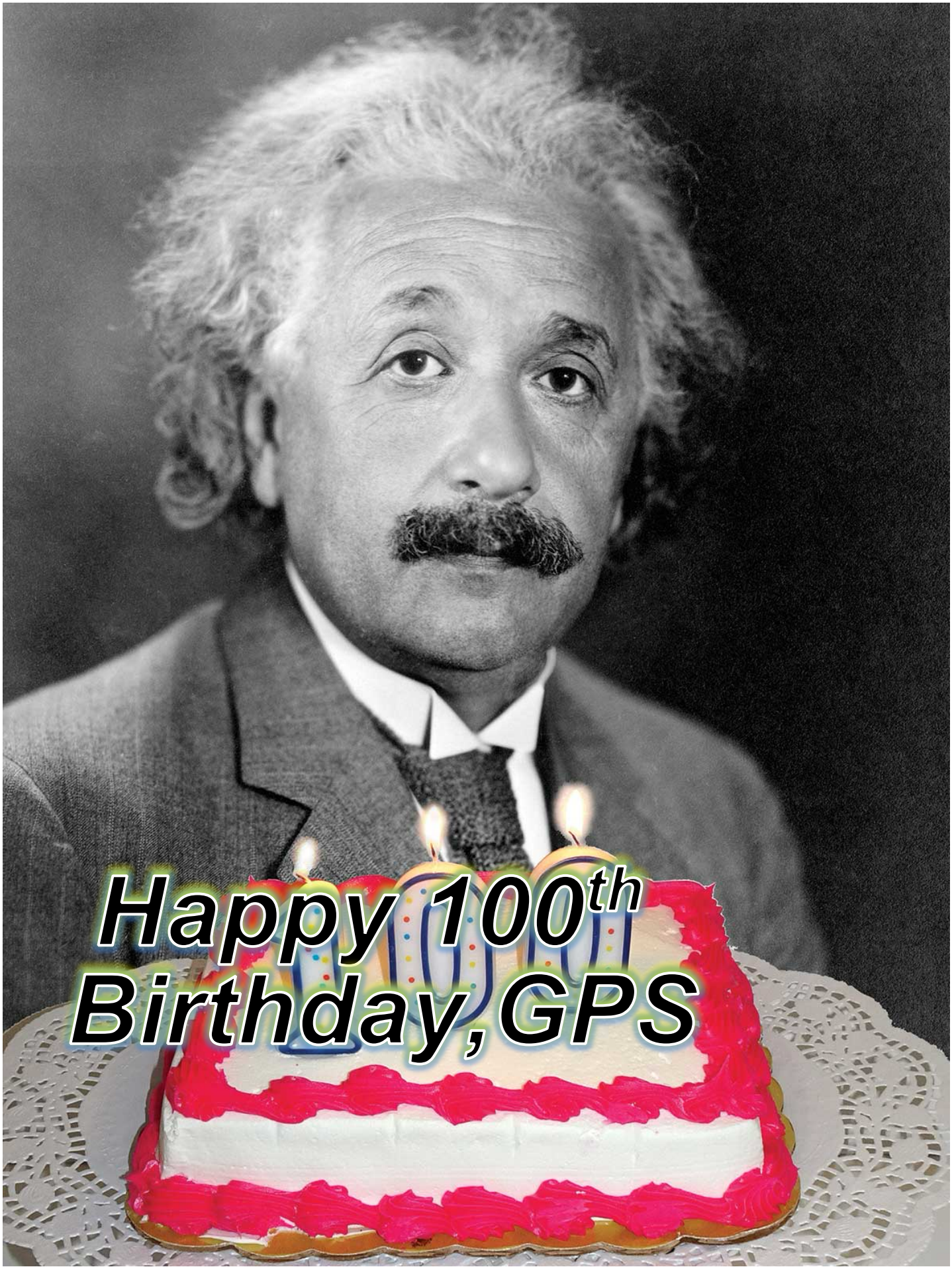
Happy 100th
Birthday, GPS

Einstein's Anniversary and Happy Birthday GPS

By Mike Jones

Cessna Pilots Magazine, originally published: April 2019

I don't very often sing "happy birthday" to my avionics, but this May 29th we all might want to give it a try.

No doubt you've heard of Albert Einstein, the patent office clerk who practically invented thinking outside the box with his equation, $E=MC^2$. That bit of math ultimately led to the atom bomb, quantum mechanics, LED lights, iPhones, Miley Cyrus videos, and other dubious accomplishments. Einstein's writings generally were extremely brief — the original document describing matter and energy is only three pages long — and were not best-sellers. For more than a decade nobody paid much attention.

But Einstein wasn't done. After a decade of hard thinking, he expanded his model into a "general theory" of relativity. He linked our three dimensions — length, width and height — with the fourth dimension, time. Einstein's "space-time" universe was dynamic and changing, like an elastic rubber sheet. When objects move through Einstein's space-time the very fabric of the universe is warped, bent and twisted by the mass and energy of those objects.

Pretty heady stuff. It ignited a flurry of esoteric controversies because Einstein's wacky ideas challenged the conclusions of the preeminent scientist of modern times: Isaac Newton.

Remember Newton? Getting whacked by an apple and inventing gravity? He was the gold-standard of science. He wrote the greatest scientific book of all time. He invented calculus. He ran the Royal Mint. Must have been pretty clever. And Newton stated the universe was static, inflexible, and unchanging.

300 years go by. Along comes this young pup from Württemberg, who says the Big Dog has it wrong. When Einstein's papers were published you almost could hear the grey-haired professors in Düsseldorf and Oxford choking on their false teeth, asking "Who is this young whippersnapper?" But the theories were mutually exclusive and only one could be right.

Two clever guys in the UK were convinced by Einstein's numbers and figured out a way to test his assertions. Frank Dyson was the British Astronomer Royal, which sounds quaint today but it was a heady position in a time when navigation was performed with sextants and chronometers.

He teamed up with Arthur Eddington, a leading astronomer in Cambridge. Together — with a trivial bit of funding from the UK government — they dispatched two teams to observe the total solar eclipse on May 29, 1919. One team went to an island off the coast of West Africa while the other team found clear skies in Sobral, Brazil. In the middle of a World War, no less.

While the teams were small the obstacles were not. Using the best techniques of the time, they were trying to measure the gravitational deflection of star light as it passed the darkened disk of the sun. The effect would be tiny: about 1/60th of a millimeter on their photographic plates. Travel during the war obviously was a challenge, and logistics and the weather compounded the problems. Heat distorted their telescopes and warped their photographic plates. Developing film in tropic conditions was a sweltering task in tightly-sealed black tents.

Amazingly, Dyson and Eddington were able to confirm Einstein's numbers. The scientific community was thrilled but confounded because the

cosmological implications were so baffling. Which brings us back to modern times, our plucky Cessnas, and your GPS.

The Global Positioning System is an engineering marvel. Did you know that a GPS timing error of one-millionth of a second puts you 100 feet off-course? If you're aiming at a runway only 75 feet wide, that's a big miss.

Did I mention the Global Positioning System is an engineering marvel? It cost over $10 billion and twenty years to build. The system uses 24 satellites and super-precise atomic clocks to geo-reference your Cessna on short-final. But telling time in space isn't simple because satellites move fast.

Einstein taught us that time is not a constant; a clock can be accelerated or slowed by gravity and speed. Orbiting GPS clocks tick more slowly than clocks on the earth, losing about seven millionths of a second per day.

But gravity in orbit is weaker than on the surface of the Earth so the clocks tick slightly faster. Net-net, GPS clocks gain about 38 microseconds per day. Because of Einstein, Dyson, and Eddington, the GPS network was designed to adjust for these relativistic effects electronically and mathematically. Without those adjustments the GPS system would become unreliable in about two minutes. Think about that when you fly over another decommissioned VOR or power-up your LORAN.

Since 1919 Einstein's work has been confirmed, again and again, ever more precisely. But it all started with two diligent, disciplined teams of sweaty astronomers, working under impossible conditions with primitive tools, on May 29, 1919.

Happy 100th birthday, GPS.

About the Author

With about 40 hours of tailwheel time, Mike Jones is not quite ready for his bush-pilot rating. He's based in Pinehurst, NC and is eagerly looking forward to testing his RNAV approaches at airports across the southeast USA. You always can reach him at PilotMike2012@gmail.com.