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Previous Issues

Cover Story: Systems that Permit Everyone to Fly

NASA's SATS program is to shepherd GA technology into the 21st century. It's bold and challenging—though much of the systems technology already exists.

by Kathleen Kocks

When Orville and Wilbur Wright began developing a vehicle that could fly, people no doubt laughed and shook their heads. "Poppycock. Man wasn't meant to fly," they probably proclaimed. But the brothers weren't daunted, and today we fly aircraft rather than ride bicycles from city to city.

Embracing the inventive spirit that drove the Wright brothers, the National Aeronautics and Space Administration (NASA) is embarking on a project so futuristic that many people are again shaking their heads. Called Small Aircraft Transportation System (SATS), the project explores the feasibility of a highly integrated and highly automated aviation transportation network. So automated that virtually anyone could operate an aircraft.

NASA's first challenge was to win funding for the project. The agency wants $69 million to fund the five-year program and asked for $9 million for the first year, FY2001. The U.S. House of Representatives originally denied any funds for FY2001, while the Senate approved the $9 million. After conference work to resolve the differences between the two houses and finalize NASA's budget, SATS ended up with the full $9 million requested.

Meanwhile, some naysayers have churlishly labeled SATS the "George Jetson Plan." The reference is from the 1960-era U.S. cartoon show in which every adult used aircraft as automobiles are used today.

"Well, why not?" NASA wants to know. The agency that put men on the moon is quite serious about propelling general aviation (GA) a giant leap ahead.

"Overall, SATS is considered a personal air transportation mode for small businesses and families, as opposed to mass-transportation modes like commercial airlines. It would give the general population accessibility to the thousands of small airports that already exist," explains James R. Burley II, planning lead for SATS vehicle technologies at NASA Langley Research Center in Hampton, Va.

Transporting the Third Wave

Burley's opening statement is the tip of the iceberg when it comes to explaining SATS. The concept is spurred by a macro view of the transportation needs of a U.S. population rolling full steam on its "third migration wave." The first wave drove the masses from farms to cities; the second wave transplanted them from cities to suburbs; and the third wave is taking them from suburbs to small-town America, euphemistically called the "ex-urbs" by transportation planners. Today, 40% of the U.S. population is ex-urban; the percentage is expected to reach 50% by 2025. This is generating new transportation-demand patterns.

However, studies warn that these demands cannot be satisfied by planned investments in highway systems. The hub-and-spoke commercial airline system isn't the answer either. Ex-urbans need individualized transport: i.e. few passengers, on-demand service and on-demand destinations, like a taxi.

One solution lies in GA and the nation's existing 5,400 GA airports. Eyeballing this, NASA set an aggressive goal as part of its National General Aviation Roadmap: "Enable doorstep-to-destination travel at four times the speed of highways to 25% of the nation's suburban, rural and remote communities in 10 years and more than 90% in 25 years."

To do this, the GA infrastructure requires a technology booster shot. Through SATS, NASA will explore technologies to determine whether the concept can be adopted as a national policy and developed as an alternative to airline and highway systems. So far, NASA's ideas for SATS are riveting.

"We envision SATS as not just considering the air vehicle, but also taking in airspace infrastructure, rules and regulations, to reduce the complexity existing in those systems today. Much of which, incidentally, was derived from and is still based upon 1950s technology," Burley remarks.

SATS proposes to fully leverage new cockpit and aircraft technology to develop aircraft and to fully exploit digital information and communication technologies to develop the airspace infrastructure. The ultimate result would be that aircraft and the airspace could be used with the same ease as automobiles and highways are used today.

The skill sets mandatory for today's GA pilots would no longer be required. Burley, who is also a pilot, says the person flying a SATS aircraft will more appropriately be called an "aircraft operator," because only minimal training will be required. A real-world example is a modern subway system, which is run primarily by computer, with oversight by an operator who no longer requires the skills of a locomotive engineer.

Cross-country via SATS

To illustrate SATS, Burley walks us through a cross-country flight between two GA airports.

Arriving at your local airport, you pick up your plane or rent one at the airplane rental counter. Thanks to standardization in airplane design, you don't need special training or certification to fly a model.

Your aircraft has decoupled digital flight controls, large-format glass cockpits, GPS-based navigation, exquisitely detailed moving maps, and satellite-based, digital data link communications. Safety systems include icing prevention and health monitoring. The key enabling SATS technology is your aircraft's computer system.

"You start your airplane, then touch a cockpit screen or say to the system, 'I want to go to,' say, 'Peoria, Ill.' You only need to know where you want to go. The system does everything else," Burley says.

Your airplane uses intelligent software programs that know what information you need to get to your destination. Once the airplane is turned on, these programs log into another enabling SATS technology—an "airborne Internet" that could be called the ultimate evolution of Free Flight. A satellite-based system using wide-band frequencies, it interconnects all information sources needed to plan and conduct your flight, from takeoff to landing. Information it delivers to your aircraft's computer includes locations of other aircraft, weather along the flight path, and conditions at departure and arrival airports.

"Your airplane remains in contact with the airborne Internet throughout the flight, providing real-time information. It constantly talks with other aircraft, with air traffic control, and with airport flight services," Burley explains. "The other aircraft are in Free Flight too, so everyone knows where everyone else is.

"The aircraft's computer, rather than the human, monitors all the activity. If anything deviates from normal, it alerts you of the problem."

In the cockpit, you look at a large screen that has a moving simulation of the outside world, even in zero visibility. This 3-dimensional "synthetic vision," similar to that in high-fidelity simulators, is generated by using your flight-path information, high-resolution terrain databases, and graphics technology.

(Of note, another NASA project, the Shuttle Radar Topography Mission, used the Space Shuttle in early 2000 to collect 3-dimensional measurements of nearly 80% of the Earth's land surface. With an accuracy of better than 53 feet [16 meters], the measurements will be used to generate digital elevation models for terrain databases needed for synthetic vision. NASA anticipates a synthetic vision system will be available in five years. Displays will show terrain, ground obstacles, air traffic, landing and approach patterns, runway surfaces, and other relevant flight data.)

Highway in the Sky

Overlaid on the cockpit display's synthetic vision is a skeletal corridor showing your upcoming flight path. Called the Highway in the Sky (HITS), this corridor is constructed from your flight plan, current weather, air traffic, terrain and airspace information to generate a 360° "lane" of safe airspace surrounding your aircraft.

"That's where you can fly the airplane. You simply follow it," Burley says of the HITS corridor. "You press cruise control and let the aircraft fly the airplane. Or you put the aircraft in manual mode and fly the path yourself.

"But the aircraft won't let you get into trouble in manual mode. Say you drift to the edge of the lane; the flight control system nudges you back to the middle." If you want to alter your flight path, the simplest way is to tell the computer, which consults the airborne Internet and then generates a new HITS corridor. Another way is to push the flight control far enough to deviate from the HITS corridor; possible because you retain the capability to override the aircraft system.

However, the safest move is to let the airplane change the flight path, because it knows about other aircraft traffic in your vicinity. You won't get that information from an air traffic controller. "There is no reason for any ATC controller involvement," Burley says. "Air traffic control will have evolved into air traffic management. All the aircraft can talk to one another, the system manages traffic, and the man on the ground is gone.

"Say another plane wants to go to Peoria, too. That's no problem, because the airborne Internet tells your plane to speed up and the other plane to slow down so you don't arrive at the same time."

Airports are also tied into the airborne Internet and provide to your aircraft such information as local weather, runway conditions, and the airport's terrain data. Your airplane uses this information to land itself, if in cruise control mode. Or, you switch the plane to manual mode and land it yourself, following the HITS corridor.

"Admittedly, this scenario is way out in the future," Burley states. "It's impossible to predict when these developments would occur. Not next year certainly, but probably more like 15 years ahead and beyond.

"Technologically, the SATS concepts could be available sooner, but you have to also consider matters of national policy and integration of the products at a reasonable cost. We have many evolutions of the system ahead...but we'll eventually get there," Burley states.

SATS has generated much interest from manufacturers of smaller GA aircraft. Among them is Eclipse Aviation Corp., which says it is working alongside FAA and business "to develop the technologies necessary for the production of an inexpensive, small aircraft that operates at unparalleled levels of safety." Eclipse says its new Eclipse 500 is first in a line of such advanced aircraft (see www.eclipseaviation.com).

AGATE Opens Doors

Wet blankets who believe SATS is impossible should look at NASA's Advanced General Aviation Transport Experiments (AGATE) program. Launched in 1994 to revitalize GA, it draws strength from a distinguished alliance (70-plus members) from government, industry and academia. Culminating in September 2001, AGATE already has invested more than $30 million for GA advances, achieving extraordinary success within 10 work packages covering airplane, infrastructure, certification and training issues. Henry Jarrett, AGATE deputy program manager, says the program's budget exceeds $200 million.

"AGATE was a necessary step to make SATS possible," Burley avows. True, many AGATE-bred products validate the feasibility of SATS. For example, real-time weather in the cockpit is a reality. AGATE was pivotal to the Federal Aviation Administration's (FAA's) award of its Flight Information Services-Broadcast data link to ARNAV Systems and Honeywell. The technology made its operational debut during AirVenture 2000 in Oshkosh, Wis.

Thanks to AGATE, an attitude heading reference system (AHRS) for GA aircraft should be certified before the year’s end. Made by Seagull Technologies and Vision Micro, it uses solid-state accelerometers and GPS corrections, rather than mechanical gyroscopes, making it more accurate and lower cost.

Thanks to AGATE, a digital single-lever power control with FADEC (full authority digital electronic control) is being developed by Aurora Flight Sciences Corp. The company is now incorporating the control into a miniature flight control system it is developing for piston engines. The system will include the single-lever power control, full authority digital electronic control (FADEC) and a three-axis flight control system.

Thanks to AGATE, two new GA aircraft are in production—the Cirrus Design SR20 and the Lancair Columbia 300.

Thanks to AGATE, large-format, glass cockpit, multifunction displays for GA aircraft are available from Avidyne Corp. and AvroTec Inc. The adept screens can display color GPS-driven moving maps, over which traffic or weather can be displayed. Notably, these screens will also display HITS symbology. Avidyne/AvroTec are shooting for full development and certification by AirVenture 2001, in July.

Cockpit evolution is where AGATE really shines. The work has Walter S. Green beaming. Green is NASA’s lead for AGATE’s flight systems work package and also a seasoned GA pilot of 45 years.

"With AGATE, we wanted to get rid of the steam-gauge instrument," he says. "It only provides one bit of information to the pilot, who then has to piece together information from many other instruments before he can increase his situational awareness.

"AGATE’s idea was to display to the pilot an image of where the airplane is, where it’s going, what its attitude and speed vector is. So, we created the HITS display. We complemented that with a multifunction display capable of displaying a moving map, aircraft traffic and real-time weather. With those two panels, the pilot knows his air attitude, position, speed and exactly where he is relative to the rest of the world.

"On a scale of one to 10 for what we set out to do in AGATE, we’ve exceeded the scale. We have the integrated display and it’s being put into airplanes today," Green adds. "The next step is pure HITS, that is, a cockpit with no backup [mechanical] instruments, one using glass to back up glass. We've already talked with the Small Aircraft Certification Directorate and the FAA is ready for it."

Certification is another shining success for AGATE, with two sterling results being new advisory circulars (ACs) for certifying small aircraft systems (AC 23.1309) and electronic displays (AC 23.1311). It was accomplished after AGATE formed a certification team to work with the directorate.

"We showed them how these technologies could cut accidents in half," says Green. "In the end, they wrote new ACs. That was a landmark achievement to get modern technology certified into existing airplanes.

"We already have an open architecture, and we're bringing to the industry a low-cost databus, CAN2B, that features plug-and-play installation for new devices. At the end of the program we will have HITS demonstrated and possibly also have it certified.

"We have also proven the integration of traffic displays and will be testing the concept this year in the AGATE test vehicle, a highly modified Beech Bonanza. One possibility is to use a low-cost squitter, to be available from Rockwell Collins."

Green's group also is using the Bonanza to test decoupled digital flight controls, a sidestick controller, a fly-by-wire system, and emergency auto-landing capability. Its cockpit also has a "pure AGATE" instrument array, flanked on its right by the Bonanza's standard avionics and flight control configuration.

"There are still a lot of things we would like to do," Green says. "For example, [Rockwell] Collins has come up with a low-cost radar altimeter, and the AGATE aircraft was ready to test it, but we've had to pass that project on to SATS."

As AGATE ends its run, Green's group is concentrating on certification methods and publishing standards and design guidelines for the systems. Already written are certification methods for four AGATE technologies: HITS, AHARS, the CAN2B databus, and decoupled flight controls.

"Now the manufacturers have to pick the technology up and do something," Green says. "AGATE is delivering new materials and technology, new ways to fly and new ways to train. The point is: Things we never dreamed about will be true. Small aircraft will be easier to fly."

For more, see http://sats.nasa.gov and http://agate.larc.nasa.gov.

Plans for AGATE

The following are the AGATE program's work packages and goals:

- Flight systems—Develop affordable flight systems that allow near all weather flying and develop intuitive cockpit displays that deliver situational awareness, weather and traffic information.
- Propulsion sensors and controls—Develop design guidelines and certification standards for electronic engine controls and diagnostics that reduce operating costs, emissions and noise.
- Ice protection systems—Develop design guidelines and certification standards for ice protection systems compatible with laminar flow wings, and improve airframe ice formation prediction models.
- Integrated design and manufacturing—Reduce airframe and propeller cost and weight by advancing design and manufacturing methods, nondestructive testing, composite material properties, and crashworthiness.
- AGATE Integration Platforms—Run tests to develop a database for validating mature projects emerging from AGATE and for developing design guidelines and certification standards.
- Flight Training Curriculum—Help create an FAA FAR Part 141 certifiable program by developing training that takes advantage of emerging AGATE technologies and reduces time and costs of IFR training.
- National Airspace Infrastructure—Develop air and ground infrastructure for small airplanes that fits into the FAA's Free Flight airspace plans.
- Program Analysis, Assurance and Systems Assurance—Ensure that AGATE efforts remain on track toward affordable technologies for smalls airplanes.

Back to March 2001 Avionics News and Highlights

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