

# NASA's Small Aircraft Transportation System

## *Envisioning and Realizing a New Mode of Travel*

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The National Aeronautics and Space Administration (NASA) has a plan to change the state of U.S. general aviation (GA) and create a system that will introduce a new mode of travel.

### Takeoff Points

More than one-half of the almost 200,000 active GA airplanes in the United States are in personal use; of these, 95 percent are single-engine, piston-powered models (1). These aircraft have high accident rates compared with commercial airlines (2), even though the private-use segment of the GA fleet mostly favors good-weather flying.

Except for the recent introduction of some new designs, GA aircraft are generally 20 to 30 years old and rely on technology that could be called post-World War II.<sup>1</sup> Most of these aircraft operate little more than 100 hours per year.

The United States has approximately 600,000 active pilots, 254,000 of whom are private pilots (3). The nonprivate pilots are either students (about 100,000), commercial pilots (about 120,000), or airline transport pilots (about 135,000) (3). Approximately 20 percent of the private pilots hold an instrument rating (3)—that is, they are certified by the Federal Aviation Administration (FAA) to fly aircraft according to instrument flight rules. The average nonprofessional pilot flies approximately 80 hours per year (4).

Most private or nonprofessional pilots cannot or do not choose to fly in bad weather. Either they do not have an instrument rating, are not proficient, or

do not have the appropriate equipment on board the aircraft.

NASA's plan would change all this.

### NASA's Vision

NASA has initiated a broad-based research effort to develop a smart—or small—aircraft transportation system (SATS). The emphasis is on the system. SATS is not a typical NASA research program for aircraft vehicle or component technology; it involves not only new aircraft technology but also technological improvements for pilots, airports, and the air traffic management system. Under SATS, individuals will be able to fly safely in personal aircraft, with technology to ease piloting and to provide air traffic control (ATC), navigation, and landing services at many airports in nearly all weather conditions.<sup>2</sup>

The NASA vision is for door-to-door flying to and from 5,000 U.S. airports located near places passengers want to travel to and from. According to NASA, the unparalleled convenience of SATS will restore a scarce commodity—time. Can the current

<sup>1</sup>During the 1980s, new production of small aircraft in the United States almost vanished. However, new deliveries of small aircraft have resumed recently.

<sup>2</sup>NASA's Langley Research Center has information on SATS at <http://sats.nasa.gov/>. NASA has suggested that the path to SATS might start with shared ownership of professionally flown small aircraft equipped for all-weather operations.

single-engine GA fleet accomplish this goal? The answer is a resounding no.

Most GA aircraft are not equipped for all-weather operations. Many GA pilots are not trained to fly in bad weather and, even if trained, do not retain proficiency. In addition, many of the 5,000 airports are not equipped with the ground-based navigation and landing aids required for flight in inclement weather conditions. Instrument flight is too costly in terms of training and equipment or cannot be done universally with today's aircraft technology, pilots, and airports.

The vision for SATS is to make safe, all-weather air transportation available at thousands of U.S. airports. Enabling the vision are new aircraft with new navigation and information technology equipment such as onboard weather information and other pilot-assistance technology as well as non-ground-based equipment for airports.

### Public-Private Sector Endeavor

A public-private consortium is pursuing the SATS vision—including NASA, FAA, the Department of Transportation, the Department of Commerce, state and local governments, universities, and private companies spanning the range of aircraft, engine, and avionics manufacturers. Ten states have made commitments to support SATS program planning: Virginia, Florida, Nebraska, North Dakota, Oklahoma, Kansas, Illinois, Indiana, Wisconsin, and Washington.

There is some question whether government should fund a SATS-type program. However, SATS may introduce air service to sparsely populated areas that now have none.

In the Advanced General Aviation Transport Experiments (AGATE) Alliance—a NASA GA technology program—70 firms collaborated under NASA's leadership to develop technology for GA aircraft, engines, and systems. SATS is intended, in part, as a follow-on to AGATE. However, SATS extends beyond the typical NASA aircraft-focused technology program.

### Key Policy Issues

SATS raises several important policy issues:

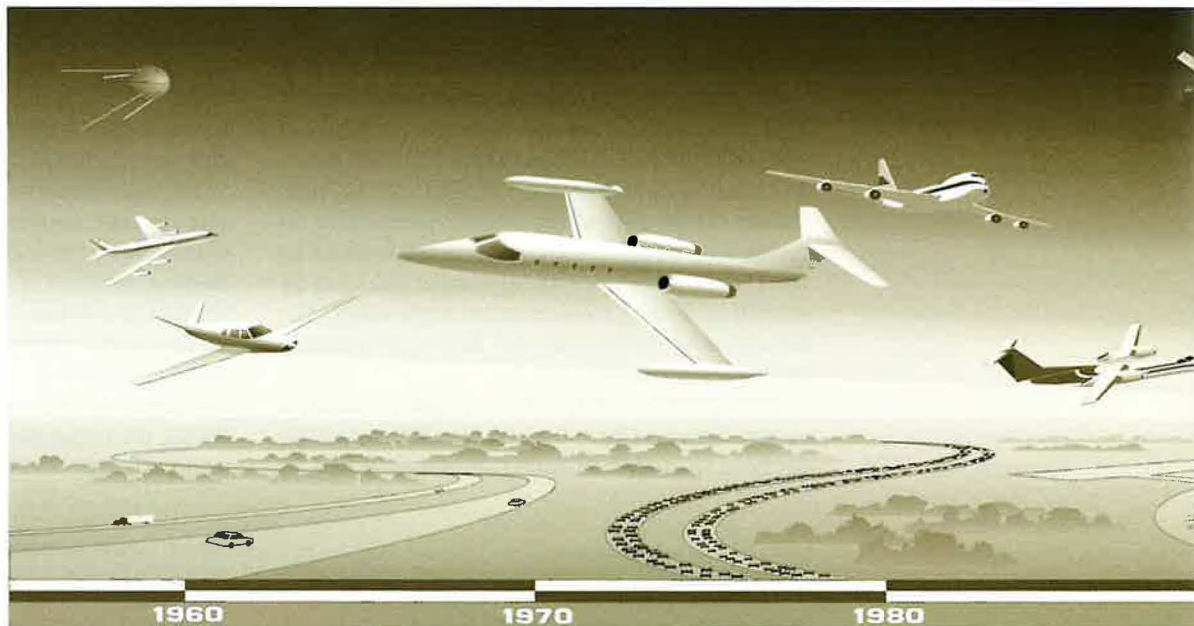
- ◆ Can the unmet demand for air transportation between secondary airports provide a market large enough to support the economic production of SATS aircraft?
- ◆ Should the government invest in an activity that may benefit only a small segment of the population?
- ◆ Will SATS be able to operate without increasing congestion in an overburdened air traffic control system?
- ◆ Will the public accept small aircraft operating with a high degree of automation?

These and other questions must be resolved before proceeding with SATS.

### Technology Issues

SATS is a complete system linking the pilot, the aircraft, and the airport through information technology that makes the job of flying easier and provides weather data to the cockpit. SATS also provides satellite-based navigation and landing aids to

Illustrative timeline of NASA's vision for future of general aviation.



equipment on the aircraft as a substitute for ground-based systems. This extends the capability for all-weather flight to the many thousands of airports that lack ground-based navigation and landing aids.

### **Pilot Training**

For SATS to be successful, the skill level required of the pilot should be equivalent to what it takes to drive a car—or perhaps a bit more. If SATS requires a highly trained or fully proficient, instrument-rated professional pilot, it will not achieve the ubiquity necessary to drive system costs down and provide widespread availability.

The cost and time of training may limit the number of SATS users. Therefore SATS requires technology either to reduce the time and cost of training or to alleviate the need for some types of training.

### **Pilot Assistance**

The technology to allow a relatively unsophisticated pilot to operate in all weather conditions likely will evolve from military work on unpiloted air vehicles (UAVs) and remotely piloted air vehicles. However, the reliability of UAV technology will have to increase by orders of magnitude before a highly automated vehicle can carry passengers at acceptable levels of safety.<sup>3</sup>

Piloting can be less demanding if many of the functions are automated. However, the difficulty of this task should not be underestimated. Designing

and flying a sensor platform with remote piloting or automation is an entirely different task if the vehicle is carrying people. UAV technology must become extremely reliable, small, and low cost, so that incorporating it would be attractive to SATS aircraft. Automating tasks may reduce the skills and the recurrent training required to operate small aircraft safely.<sup>4</sup>

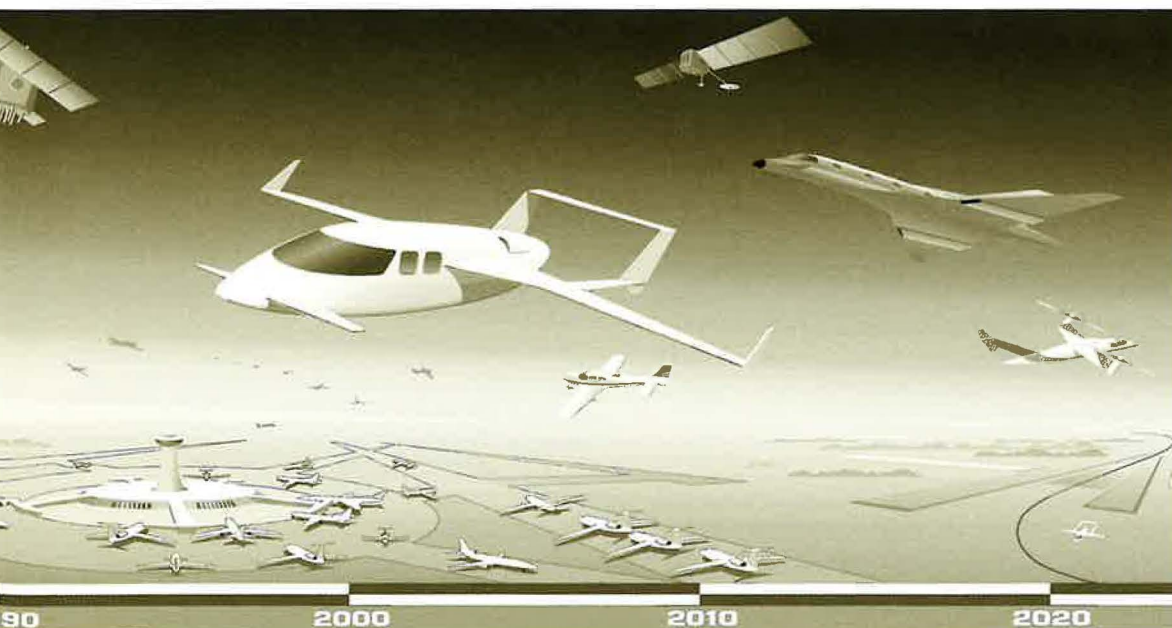
### **Overcoming Barriers**

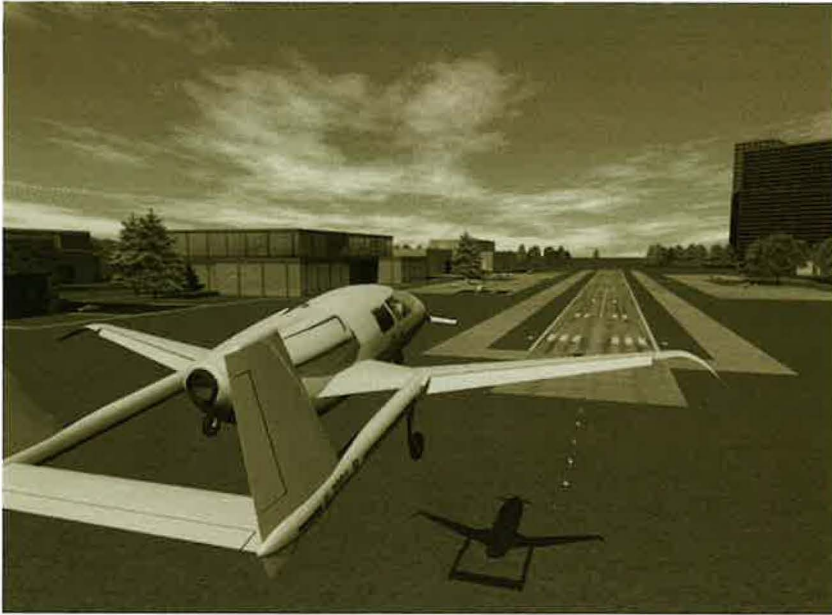
Although advances in conventional aeronautics technologies—including materials, structures and propulsion—could produce a lower-cost and more highly efficient small aircraft, the vehicle control, communications, navigation, and other systems present technological barriers to achieving the vision of the SATS planners.

SATS also raises issues about the airport and ATC infrastructure needed to accommodate the new mode of transportation under all weather conditions. Today, onboard equipment and ground-based navigation aids such as VOR/DME, ILS, and radar accomplish these tasks. SATS implies a well-developed and well-equipped aviation system with thousands of aircraft operating into and out of thousands of airports in all weather conditions. GPS navigation and landing aids could be developed to provide the technology base. In addition, SATS aircraft will need up-to-date weather information.

<sup>3</sup>The military uses UAVs as sensor platforms, as in the war in Bosnia. Advanced military research is developing UAVs and remotely piloted vehicles that are less than 1 ft long or wide.

<sup>4</sup>The SATS airplane must be fully automated even in the failure recovery mode. Today's highly automated airline aircraft still require the pilot to take control to recover from a failure. A NASA program seeks to demonstrate "reliable, autonomous" control of any vehicles with technology developed in the space program (*Flight International*, 16–22 May, 2000, p. 29).





SATS aircraft landing.

Pilot skills will have to be upgraded or, as already noted, automation will have to substitute for these skills. This raises questions about public acceptance of a technology that does not allow the pilot to operate the aircraft independently of automatic aids.

#### **Air Traffic Control Challenges**

SATS also offers challenges to the ATC system. Many foresee a gridlock with the number of flights increasing faster than the ATC system can handle (6). To maintain safety, the ATC system imposes delays to balance demands with available capacity. In the SATS vision, the added aircraft may not operate to and from the major air transportation hubs but still will have to be separated safely from each other as well as from commercial flights.

SATS therefore implies either a large growth in the ATC system or new ways of separating aircraft in flight. Will self-separation using a free-flight<sup>5</sup> paradigm be acceptable? Will cockpit displays of surrounding aircraft allow a pilot to fly a conflict-free path?

One knowledgeable observer suggests that ATC for SATS will have to be “cooperative robotic control” to keep infrastructure costs low and yet maintain safety. If feasible, this would obviate the need for air traffic controllers when SATS aircraft operate in airspace without commercial aircraft.<sup>6</sup>

<sup>5</sup>Free flight is an FAA program allowing aircraft to operate from origin to destination along an optimum four-dimensional trajectory without ATC intervention except to resolve potential conflicts.

<sup>6</sup>Personal interview with George Donohue of George Mason University.

NASA envisions tens of thousands of additional aircraft operating in the United States in the mature SATS. No data or analyses yet have suggested a significant unmet demand for flights between secondary airports. If SATS leads to more flights from secondary airports to major airports, it could exacerbate the already problematic airport congestion and delays.

NASA proposes that the first SATS aircraft should be small jets operated by professional pilots. These aircraft would have an effect on the ATC system by operating at the altitudes of commercial aircraft. In addition, a metropolitan area is the likely origin or destination of the trip even if the other end of the flight is rural.

### **Economic and Policy Issues**

SATS raises several important economic and policy questions. First, should SATS be viewed as a new mode of transportation? If SATS works according to plan, it promises near door-to-door transportation at competitive travel time and travel costs. The system may substitute for air and automotive trips and also may stimulate new travel patterns and lifestyles. SATS also could reduce congestion by diverting some trips away from hub airports. At NASA’s request, the Transportation Research Board (TRB) has undertaken a major study of SATS (see sidebar, page 27).

Second, what will SATS do for society as a whole? It offers the potential of significantly enhanced mobility, allowing people to live and work in areas that would not be feasible due to travel time and other constraints. SATS also promises to bring safe, reliable, and efficient transportation to many more communities than the commercial airlines can serve, providing a boon to small community air service.

In the classical economic framework, travel demand responds to the following:

1. Travel time,
2. Travel cost,
3. Schedule availability, and
4. Other attributes such as safety and comfort.

The first two are simple to consider: How long does it take to get somewhere? What is the cost, either out of pocket for airfare or in operating and owning a vehicle? Proponents argue that SATS will be competitive on these two fronts.

#### **Schedule Availability**

SATS particularly targets the third point—schedule availability. Where does the trip start or end and how frequent is the service? Everyone is familiar

with the long trip to the airport and the time spent in passenger processing through parking, security, and check-in before the flight. In addition, air service may be available in certain markets only a few times a day from a nearby airport. These may or may not be the times people want to travel. The

choice is either to fly through a hub airport on a connecting flight or to use ground transportation to a larger airport with more frequent service.

By connecting a large number of small airports and providing personal transportation, SATS offers unrivaled schedule availability. Individuals could

## TRB Study Examines SATS Initiative

The National Aeronautics and Space Administration (NASA) foresees greater use of small aircraft and general aviation (GA) airports for personal and business travel in the next decades. Advances in aircraft design, automated traffic control (ATC), avionics, communications, and pilot training are making small piston and turbine aircraft more affordable, safer, and easier to operate. NASA's Small Aircraft Transportation System (SATS) program, begun in 1999, seeks to encourage these advances by collaborating with industry, state and local governments, and the Federal Aviation Administration (FAA).

NASA has asked the Transportation Research Board (TRB) to convene a committee to review the SATS plan and to offer expert guidance on issues critical to the program and concept. In particular, NASA has posed two key questions to the committee:

◆ Do the relative merits of the SATS concept, in whole or in part, contribute to addressing travel demand in coming decades, and is the net benefit sufficient to warrant public investment in infrastructure development and deployment?

◆ What are the most important steps that should be taken at the national, state, and local levels to support SATS development and deployment?

The 16-member TRB committee, led by H. Norman Abramson, Executive Vice President Emeritus of the Southwest Research Institute, consists of experts in transportation planning, travel demand, aviation safety, environmental policy, ATC, and aircraft engineering and production (see accompanying list). The committee has met three times since June 2000 for extensive discussions with NASA program staff and with experts in aircraft manufacturing, air transportation, airports, ATC, human factors, safety, and travel demand. Additional meetings are planned for early 2001 with a final report scheduled for the summer.

Information on the TRB study committee and its work is posted on the web. Click on <http://www4.nationalacademies.org/cp.nsf> and follow the prompts.

### Committee for a Study of Public Sector Requirements for a Small Aircraft Transportation System (SATS)

H. Norman Abramson, Chairman, Executive Vice President Emeritus, Southwest Research Institute

Donald W. Bahr, Manager (retired), GE Aircraft Engines

Marlin Beckwith, Manager (retired), Aeronautics Program, California Department of Transportation

Max E. Bleck, President (retired), Raytheon Corporation

Daniel Brand, Vice President, Charles River Associates, Inc.

Walter S. Coleman, President (retired), Regional Airline Association

James W. Danaher, Chief (retired), Operational Factors, National Transportation Safety Board

John J. Fearnside, Professor of Public Policy, George Mason University

Richard Florida, H. John Heinz Professor of Regional Economic Development, Carnegie Mellon University

John D. Kasarda, Professor, Kenan-Flagler Business School, University of North Carolina

Charles A. Lave, Professor of Economics, University of California, Irvine

Robert G. Loewy, William R.T. Oakes, Jr. Professor and Chair, School of Aerospace Engineering, Georgia Institute of Technology

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Herbert H. Richardson, Director, Texas Transportation Institute and Associate Vice Chancellor for Engineering, The Texas A&M University System

Daniel T. Wormhoudt, Vice President, Airports and Ports Facilities Group Environmental Science Associates (ESA)

travel when and where they want. Moreover, the system offers unrivaled access. In addition to the approximately 700 airports with commercial airline service in the United States, 5,000 smaller airports can become convenient origins or destinations for air transportation<sup>7</sup>—assuming ground transportation facilities such as taxis and rental cars are available.

### **Delivering on All Fronts**

The key points in analyzing a new transportation mode are travel time, travel cost, schedule availability, and other attributes, such as vehicle comfort, the actual and perceived level of safety, and service attributes. SATS will have to deliver on all these fronts to meet its ambitious goals. It will have to be available at a competitive cost; usable by large parts of the population without much specialized training (probably no more difficult than learning to drive a car); and offer a level of safety to operate reliably under nearly all weather conditions.

These technology issues are the principal focus of the NASA research for SATS. However, they venture beyond vehicle technology into air traffic management system technology, weather information and warning systems technology, airport technology, and the technology of training pilots. In some areas, SATS may need to push the frontiers of technology, as well as the public acceptance of technology—particularly automation—that plays a vital role in vehicle operations and safety.

### **Anticipating Public Concerns**

Besides economic questions about SATS technology, environmental concerns about noise and emissions, safety, and the potential for increased ATC congestion will have to be resolved. Will the general public be concerned if tens of thousands of new small airplanes take to the skies, as SATS planners envision?

There is little public disquiet about the more than 100,000 small airplanes in personal use today. Problems generally are localized around a specific airport or are associated with aircraft operations near a particular attraction such as a national park. If SATS reaches its goal of tens of thousands of additional aircraft, many airports will be much more

active and perhaps more intrusive. There may well be public complaints about aircraft noise.

Perhaps one of the most important contributions of SATS may be aircraft safety, which has room for improvement. In 1996, there were 421 fatalities in single-engine, piston-powered airplanes in the United States. These aircraft had flown about 17.2 million hours. Using FAA's estimate of \$2.8 million as the societal cost of a fatality (7),<sup>8</sup> these costs amount to approximately \$1.1 billion or about \$69 per flight hour. Average total operations cost \$177 per flight hour; including the estimated insurance costs, the safety cost to society is 46 percent of average total costs (8).

### **SATS Market**

SATS may not target the current base of GA pilots and aircraft. Although some pilots may shift to SATS, the NASA planners view the target market as relatively well-to-do individuals who place a high value on their own time and who may be willing to spend money on lifestyle choices. A key issue is how to allow these people to operate SATS aircraft safely without requiring large blocks of time in initial or recurrent training. Although adventure-some, these people place a premium on their time as well as on their personal safety.

The SATS planners also envision an evolving technology, with professionals flying the first aircraft carrying only six or so passengers. In effect, this would be an on-demand air taxi, using technology to make total trip costs competitive with airlines.<sup>9</sup> As noted previously, however, this type of flight could have significant impacts on the ATC system, exacerbating congestion in an already over-taxed system.

### **Government Involvement**

Should the government be involved in developing SATS? This is an important policy question, but SATS will never be built unless private companies believe it will be an economic success. Government can facilitate the early stages, as it has done for all new transportation modes. The government also

<sup>7</sup>New transportation opportunities can induce new demand through price and service combinations previously unavailable, as the full price of travel falls for some consumers. Some contend there is a large latent demand for SATS services because of the new opportunities for people with high values of time. (Source: B. Holmes, NASA, testimony on the future of aviation before Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, May 16, 2000.)

<sup>8</sup>The value of a statistical fatality avoided is based on willingness to pay for small changes in the risk of a fatality taken from large number of studies of risk in labor and product markets.

<sup>9</sup>Similarly, policy analysts in the United Kingdom maintain that relaxation of the two-engine requirement for air taxis would spawn an industry based on highly reliable single-engine turboprop airplanes (already available and allowed in the United States), greatly expanding the transportation opportunities offered by air taxi operators (Sheppard, *I.Aerial Flypass*, *Aerospace International*, April 2000, pp. 12–14).

can help in assessing feasibility, providing research dollars to develop needed technology, and most importantly by coordinating the diverse groups—manufacturers; operators; infrastructure providers at the federal, state, and local government levels; environmentalists; and others—that either can enable or hinder the realization of SATS.

The government's involvement in SATS entails a value judgment about the need for increased mobility, the provision of transportation choices, the potential to reduce aviation system congestion, and the appropriate bounds for government in technology development. The SATS program envisions substantial cost sharing by industry in cooperative precompetitive research. Government would fund research and provide infrastructure; as noted, some state governments already have signed on as partners with NASA. These roles generally fall within the scope of what many view as acceptable for government.

NASA, however, should be involved in SATS for the safety issues. The annual societal losses from GA accidents are large, and many of the SATS technologies are likely to make GA flying safer. This potential to improve GA safety may be an important justification for government sponsorship of SATS.

NASA has made a public commitment to investigate SATS. The promise of SATS is great, but many technical, economic, and institutional challenges remain.

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## Related Websites

SATS program

<http://sats.nasa.gov>

TRB Study on NASA's Small Aircraft Transportation System (SATS) Initiative

<http://www4.nationalacademies.org/cp.nsf>

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## Hybrid Vehicles

*continued from page 22*

However, unless the customer becomes an integral participant in the process of reducing GHGs, market acceptance of efficient vehicles, such as hybrids, will be limited. Programs that include government and customers, not just industry, are more effective (Figure 9). The industry can provide the pull by offering products desired by the consumer, but cannot push customers to buy vehicles they do not want. Government programs can stimulate demand, provide incentives, and educate the customer, dramatically influencing the acceptance of hybrids.

Without government programs and consumer cooperation, the key is reducing the cost of hybrids and the time that will take. Markets in Japan and Europe are likely to drive the development and spread of hybrids; only after hybrid systems are proved and the costs reduced would there be large-scale penetration of the U.S. market.

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