ACCESSIBLE GENERAL AVIATION

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Abstract

This project explores the possibility of improving the national transportation system by giving more people increased access to general aviation. Based on the research, a plan to accomplish the objective is proposed. The technologies that are needed and the social impacts that this improvement might have on society are also analyzed.

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1 Introduction

As cities continue to grow, traffic continues to worsen, and airports become more congested, causing travel times to become slower. A US census conducted in November 2001 concluded that average automobile and air travel commute times have been steadily increasing in American cities over the past decade.[1] Furthermore most major airports will not be able to accommodate the predicted increases in air passengers over the next few years, creating huge congestion problems at every major airport.

The current hub and spoke system is nearing the limits of its capacity. There is a limit to the amount of airplanes that can take off and land at a certain airport over a specified time period. As of 2001, twenty-six of the major hub airports have been classified as "saturated", meaning that they are currently working at or close to their maximum capacity. To complicate this problem further, current predictions estimate that airline traffic in the United States will double by the year 2010, with most of the increase occurring in the twenty-eight already busiest airports.[2] In addition, the high price of last minute bookings and changes alongside the routing at major airports, allow the airlines to manage their fleets more efficiently. However, this has taken away some freedom and flexibility for the travelers.

In modern times, the advances of new technologies have made time a very valuable commodity. Within the past decade, the developments of new technologies have caused a trend for on demand products and services that adapt to customers needs and schedules. Today's world is modeled in order to make it easier for customers to

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[1] Bureau of Transportation Statistics: http://www.bts.gov
[2] James Fallows, *Free Flight: From airline Hell to a New Age of Air Travel* (New York: Public Affairs, 2001) 22.

control their time, with the airline industry being one of the few exceptions in this ongoing trend.

Within this now emerging 'information age', a community's joie de vivre highly depends on having access to rapid transportation since time is of the essence. Therefore, early in the 21st century, when speed is at a premium, the nation's doorstep-to-destination travel speeds will be in decline. The growing delays in the hub-and-spoke system will limit the economic expansion, in this information age, to well connected regions and communities.

A proposed solution to this problem is the implementation of a plan in which more people will be able to utilize smaller aircrafts as an alternate means of easily accessible transportation, helping to solve the congestion problems that most airports are facing. It will allow travelers to take full advantage of their time, since prescheduled airline routes and times will no longer restrict them. People will obtain complete control of their traveling needs by becoming their own pilots; there will no longer be a need of accommodating travel itinerary in order to comply with the airlines rules and regulations.

In order for this to be successful people need to make use of the over 5,000 public airports since more then 98% of the U.S. population lives within a 30 minute drive from at least one of these facilities. As a result, the safe and efficient utilization of smaller aircraft and smaller public use landing facilities can provide a revolution in mobility.

In order to accomplish this objective there is a need to have superior aviation systems. The entire aviation system, including on-board computers, traffic management, regulation, and navigation aids needs to be shifted to a new generation structure. Flying should become simpler so that more people will be able to use airplanes as personal transportation tools.

Nevertheless, in order for this idea of accessible aviation for more people to function successfully, it will be necessary that more advanced technologies in the cockpit, airports and support systems to be available. Advanced avionics systems will allow less training for obtaining pilot certifications. Technological assistance would make flying much less stressful and safer for pilots. New materials and advanced propulsion will make airplanes environmentally friendly. Airplanes with less noise and emissions will make aviation even better for society.

In the following pages, the feasibility of this project and the steps needed in order for it to become successful will be examined.

1.1 Current Problems

1.1.1 Airport Congestion

Identifying the problems that most civilians face when dealing with air travel is easy. Everyone has heard stories about bad travel experiences: from the time you missed your plane because you got stuck in traffic, to the time when your luggage got lost, to the time your flight was cancelled leaving you stranded for two days, etc. Nevertheless the most impressive fact is that airline flying experiences are not good even when nothing goes particularly wrong. The traffic jam on the way to the airport, standing in a series of lines as you go through from check-in to security to boarding, just to begin most of the process again once you arrive at your destination. Furthermore this entire scenario is considering the fact you will have a direct flight, but for those not having the luxury of doing this, the amount of time spent waiting accounts for a very large percentage of the total travel time.

In the US there are currently about 5,000 public landing facilities that could be suitable for all but the largest planes.[3] Nevertheless more than 80% of all air traffic takes off from or lands in just 50 of these airports.[4] These larger hubs (O'Hare, Dallas, Cincinnati, etc.) have over the years become more saturated with passengers and airplanes to the point there is not much room for error. In these major airports, a cancelled flight means passengers sitting on the hallways on standby for the next flight; one delay in one of these hubs would affect airports thousands of miles away.

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[3] Appendix A – Major Airport Performance
[4] Bureau of Transportation Statistics: http://www.bts.gov

To further emphasize this point, a time and motion study conducted by NASA in the late nineties can be examined. This study concluded that for trips of 500 miles or less (which includes a grand majority of all airline flights); flying via commercial airline was in fact not any faster than driving by car. Daniel Goldin, the administrator of NASA, said in a speech in 1998: "You are flying through the air at 300 to 500 miles per hour during the part of your trip that is in the commercial airplane. But your average speed from the time you left your home to when you arrived at your destination was between thirty-five to eighty miles per hour".[5]

[5] NASA Small Aircraft Transportation System: http://sats.nasa.gov

1.1.2 Airspace Congestion

Air Traffic Control (ATC) is the slowest developing area in aviation. Traffic Control for aircraft is mostly done by communication among pilots and air traffic controllers on the ground; it is a very crucial part of aviation. This conventional way of air traffic control is highly organized today. However, the current ATC system is approaching its maximum capacity in regard to the number of airplanes it can handle. In order to handle more flights in the air and at the airports, the current ATC system must be improved.

Since the ATC system was introduced in late 1930s, its basic procedures have not changed much. Most of the time, pilots and controllers rely deeply on verbal communication using Very High Frequency (VHF) radio. For cross oceanic flights where VHF radios cannot reach, High Frequency (HF) radio is used for traffic controlling which has even worse sound quality. Language confusion, difficulty in hearing each other, and handling dozens of aircraft in one frequency are causes for many incidents and accidents.

At uncontrolled airports where there is no control tower, pilots avoid accidents by complying with the prescribed rules. They fly at specified altitude and enter traffic patterns as specified for each airport by the FAA. Today, most aircraft are equipped with VHF two way communication radios so that pilots can announce their positions for other pilots to know. Two way communication radios are required for all aircraft that fly in ATC controlled areas. Transponders are equipments that respond to the radar signals from on-ground air traffic radar stations. When Transponder receives radar radio, it transmits altitude and identifying codes to radar station that will appear on radar screen in front of air traffic controllers. Transponders are required equipment for any aircraft receiving radar services and any aircrafts flying in Class B and C airspaces.[6]

Today, the busiest airports around the country have congestion problems not only on the ground but also in the sky. The radio frequencies of departure and approach controls are constantly used. Traffic controllers speak almost twice as fast as normal human beings. Still pilots sometimes have to wait for few minutes before he or she can squeeze in to all other transmissions. If a controller or a pilot makes the mistake of pressing the transmission switch while someone else is transmitting, everyone will hear nothing but ear-hurting noise.

Air traffic controllers have to think about the different types of aircraft in order to adjust for their different airspeeds, performances and wake turbulences. They also have to avoid leading airplanes into areas with unfavorable weather conditions such as thunderstorm clouds and turbulence.

There have been numerous accidents in which ATC mistakes were blamed as the primary cause. Failure of ATC can cause serious accidents such as midair collisions, runway incursions, and controlled-flight into terrain. Improving the current ATC system is essential for aviation safety. ATC is also blamed for commercial scheduled airplane delays all over the United States. Increase in Air traffic is not possible without developing new improved ATC systems.

In order to develop a better ATC system, new technologies have been introduced in some parts of the world but mainly for commercial aircraft that can afford expensive equipment.

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[6] Appendix D – Airspace.

The physical airspaces around major airports are congested also. Air traffic controllers organize aircraft to avoid collision by providing separation. However, the very complicated airspace systems are reaching their capacities in regard to the amount of traffic they can handle. Pilots expect to 'hold' for sometimes more than 20 minutes before they can land or takeoff at busy time of the day in large airports. When ATC asks an aircraft to 'hold' in the air, the pilots must circle around at designated hold waypoint and the altitude until further advice is given from ATC. Everyday, more than 6 airplanes are lined up in front of runway and waiting for their turn for takeoff in large airports such as New York JFK in the afternoon. The delay can easily double when the weather condition is not favorable, or one or more of runways are closed for reasons such as snow plowing, or maintenance.

According to Bureau of Transportation Statistics (BTS), 22 percent of arrival flights, and 20 percent of departing flights are delayed more than 15 minutes. Delays appear to be more common among so-called "hub" airports. (Appendix 'delay statistics')

1.1.3 Environment Problems

Balancing transportation goals with environmental protection is a difficult and ongoing challenge.[7] Currently the two most important environmental concerns surrounding aviation are noise and air pollution. Since airplane traffic is expected to increase by more than a hundred percent over the next decade, it is important to know what kind of environmental effects are occurring today in order for us to be able to estimate the future effects and analyze the necessary actions that need to be taken in order for this problem to be addressed.

[7] Science News Online: http://www.sciencenews.org/sn_arch/7_6_96/bob1.htm

1.1.3.1 Air Pollution

One of the causes for the rising temperatures is linked to the increasing volume of jet airline traffic around the globe. Even though automobiles and other factors produce a greater amount of air contaminants, jet airplanes are the primary contributor to higher concentrations of greenhouse gases in the stratosphere (a region on the atmosphere where most commercial flights take place currently). This specifies that "the increasing volumes of airplane traffic worldwide have serious environmental consequences, perhaps more serious than the ozone hole phenomenon on which the attention of the scientific community is riveted."[8]

1.1.3.1.1 Plane exhaust

Although ground vehicles generate a great amount of greenhouse gases at ground level where the air density is high, there is vegetation at this level which absorbs and eliminates at least some of the carbon dioxide. In contrast, a modern jet airplane burns and releases its exhaust gases in the fragile and rarefied region of the stratosphere where the air density is only 1% of that at ground level.[9]

Air traffic is releases large quantities of greenhouse gases directly into the stratosphere, around the globe and round the clock. This is perhaps the major contributor to the observed global warming.[10] These emissions may remain in the atmosphere for periods ranging from days to centuries, with some climatic effects felt on even longer

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[8] The Volpe National Transportation Systems Center: http://www.volpe.dot.gov/infosrc/journal/30th/human.html
[9] ibid.
[10] ibid.

time scales.[11] A report in Newsweek cited stated that ocean warming is the most menacing threat contributing to the expected total destruction of coral reefs all around the world in the next 50 years. The article examines the serious consequences that global warming poses to human health around the world. And yet, the very serious environmental consequences of increasing airplane traffic have not so far been recognized by the scientific community, or grabbed the attention of the general public.[12]

Carbon dioxide is a major cause of global warming. The carbon dioxide content in the atmosphere exceeded 360 parts per million (ppm) in 1992 and could reach 520 ppm within a century. A rising sea level resulting from global warming would decrease fresh water supplies and speed up erosion of beaches along coastal land.[13]

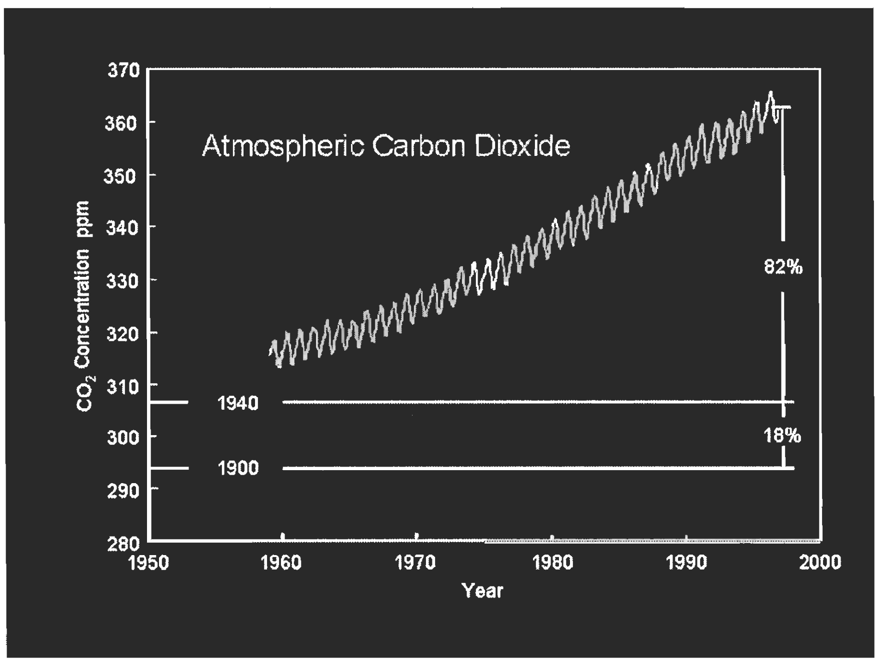

Figure 1 - The CO2 Concentration in ppm [14]

[11] San Diego Earth Times: http://www.sdearthtimes.com/et0896/et0896s13.html
[12] The Volpe National Transportation Systems Center:
http://www.volpe.dot.gov/infosrc/journal/30th/human.html
[13] San Diego Earth Times: http://www.sdearthtimes.com/et0896/et0896s13.html
[14] Oregon Institute of Science and Medicine:
http://www.oism.org/pproject/presentation/sld001.htm

Airplanes flying in the stratosphere probably will not emit enough of carbon dioxide to make a big difference for people living beneath the region, but nitrogen oxides, water vapor, and particles of soot and sulfur in their exhausts might.[15] As the aviation industry grows, so the global warming effects will grow also. Analysts think that within 50 years air pollution from aircraft would account for 10% of all global warming effects.[16] This is significant because aircraft air pollution currently make up just over one percent of the total (automobile emission make up over half of total air pollution).

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[15] American Geophysical Union: http://www.agu.org/sci_soc/prrl/prrl9919.html
[16] University of Michigan:
http://www.personal.engin.umich.edu/~murty/planetravel2/planetravel2.html

1.1.3.1.2 Jet Contrails

The term contrail is a short for the "**con**densation **trail**" that is left behind by a passing jet plane. Contrails form when hot humid air from jet exhaust mixes with environmental air of low vapor pressure and low temperature. Because of the turbulence caused by the engine, the mixing happens directly behind the airplane. The contrail becomes visible when condensation takes place. In order for condensation to occur, only a small amount of liquid is needed. For the flying jets, since the normal byproduct of a combustion engine is water and the air temperature high in the atmosphere is low, condensation is produced.[17]

In comparison to the other factors that are currently triggering the greenhouse effect, the contrails' impact is currently small; although it is expected to be a growing problem. By the year 2050, increased flights by jet airplanes will impact the global climate through the greater number of contrails they will produce. The impact may grow by a factor of six over the next 50 years. In 1992, for example, contrails added an estimated 0.02 watts of warming per square meter globally, which totals to one percent of all manmade greenhouse effects.[18]

For three days following September 11, 2001, when the FAA grounded all commercial flights for three days, meteorological researchers were given a unique opportunity to study the impact of condensation trails on weather. It has been found that the American climate was noticeably different during those three days without air travel

[17] National Weather Service: http://www.wrh.noaa.gov/Flagstaff/science/contrail.htm
[18] Wired News: http://www.wired.com/news/technology/0,1282,52512,00.html

as the researchers have predicted.[19] The temperatures in the United States fluctuated by 1.2 degrees Celsius more when airplanes were grounded than when normal flights were occurring. In another words, planes in the sky lessened the variability between day and nighttime temperatures. According to David J. Travis of the University of Wisconsin, there is much more change in temperature range in areas of the country that used to have jet contrails. This finding is important since it only takes "climatic changes of fractions of a degree Celsius to yield widespread results." For example, cranberry bogs and citrus orchards require a combination of cool nights and warm days for optimum yield. In the spring, sugar maples do not produce sap if daily (diurnal) temperatures do not fluctuate enough.[20]

One of the studies that were conducted in Wyoming has found that airplane exhaust has contributed a substantial number of microscopic particles found at high altitudes. The exhaust possibly helps to provide clouds in the skies, and enhance the growth of cirrus cloud. Although the effect of jets on general cloudiness is not certain, cirrus clouds can warm the Earth's surface. In the US, "preliminary calculations suggest that the increase in cirrus clouds caused by jets since the 1960s could account for a warming of 0.1 to 0.3 degrees Celsius."[21]

NASA's Langley Research Center reported that global air traffic rose by over seven percent per year from 1994 to 1997, in terms of passenger miles flown. Growth is expected to continue. Consequently, contrails will eventually play a larger role in future climates. Taking into account such factors as number of flights per day, fuel

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[19] ibid.
[20] ibid.
[21] Science News:
http://www.findarticles.com/cf_0/m1200/n3_v154/21003402/p1/article.jhtml?term=airplane+pollution

consumption, and altitudes flown, they concluded that by 2050 average contrail coverage will be 2.6 times current levels, or 3.7 percent coverage of the United States continent.[22]

1.1.3.1.3 Effects of Air Pollution on Earth

Jets flying in the upper atmosphere emit 774 million tons of atmosphere-altering gases directly into the stratosphere. "The large amounts of emissions are due to daily flights of more than 52,000 civil and nearly 2,800 military airplanes." And unfortunately, the jet emissions do not disappear quickly for the benefit of the environment.[23]

NOx, which consumes ozone, is the largest aviation emission pollutant by weight in the stratosphere. When the ozone layer thins, more solar radiation seeps through which attacks the immune systems of trees, crops, animals and even humans. Even though the most convenient and obvious way to stop the thinning of ozone layer is for the aircraft to fly lower below the stratosphere, there is a tradeoff for it. Lufthansa estimates a six to eight percent increase in consumption of fuel flying below the stratosphere.[24]

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[22] Wired News: http://www.wired.com/news/technology/0,1282,52512,00.html
[23] Lifeboat News: http://www3.bc.sympatico.ca/Willthomas/invest/investjets.htm
[24] ibid.

1.1.3.2 Noise Pollution

Airports are considered to be one of the two largest sources of noise pollution, the other being vehicle traffic. Airports are a major source of noise due the number of airplanes and concentrated landings and take-offs in an area. It has been known that people living near airports are affected very much, sacrificing their well-being by aircraft noise. Adding to the noise problems is that the noise sources are growing at a rate of three to five percent annually.[25]

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[25] Emagazine.com: http://www.findarticles.com/cf_0/m1594/n2_v9/20492806/p1/article.jhtml

1.1.3.2.1 Effects of Noise Pollution on Humans

Noise pollution greatly affects people who live in big towns and cities. Twenty million or more US residents are estimated to be "exposed on a regular basis to hazardous noise levels that could result in hearing loss" (National Institutes of Health).[26]

One observation of noise effects on animals is that birds desert their nests and young. Like the animals, humans are adversely affected by the noise. A single unprotected short-range exposure such as a gunshot or explosion can leave a person with permanent hearing loss, but most of the time the cause is due to long-term exposure of less intense sounds. From the Noise Center at the League for the Hard of Hearing, Nancy Nadler says, "In general, sustained exposure to noise above 85 decibels, over time, will cause permanent hearing loss and the louder the sound, the less time before hearing damage can occur."[27]

Some of the hazards that are caused by noise pollution that are serious to humans are not only of hearing loss. Researchers have concluded that noise causes physiological changes in sleep, blood pressure, and digestion.[28] According to the report by the American Academy of Pediatrics in October of 1997, "(1) exposure to excessive noise during pregnancy may result in high-frequency hearing loss in newborns and may be associated with prematurely and intrauterine growth retardation, (2) exposure to noise in the neonatal intensive care unit (NICU) may result in cochlear [inner ear] damage, and

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[26] Earth News: http://www.consciouschoice.com/note/note1206.html
[27] ibid
[28] Emagazine.com:
http://www.findarticles.com/cf_0/m4PRN/2001_Nov_27/80559773/p1/article.jhtml?term=airplane+pollution

(3) exposure to noise and other environmental factors in the NICU may disrupt the normal growth and development of premature infants."[29]

Gary W. Evans of Cornell University and his coworkers have found that long term exposure to aircraft noise can raise blood pressure and stress levels and hinder reading abilities and long-term memory, according to a series of studies published since 1995. An article by Arline L. Bronzaft and colleagues published early in 1998 found that almost 70 percent of respondents to a questionnaire who lived within the flight routes of a major airport were bothered by the noise. Also, "subjects who were bothered by aircraft noise were more likely to complain of sleep difficulties and more likely to perceive themselves to be in poorer health."[30]

David Staudacher of Vancouver's Right to Quiet Society says, "By any standard of health, from infant mortality to life expectancy, statistics will show that people are healthier in quiet areas than in noisy ones (all else being equal). The reason, I believe, is that noise destroys the sense of public peace and tranquility that nourishes healthy social interaction."

1.1.3.2.1.1 Noise measurement

In considering the effects of noise on human health and quality of life, intensity duration, time, and place at which it is heard have to be characterized. Measurement of sound intensity is in the logarithmic decibel (dB).[31] A noise that is 10 dB more intense than another is twice as loud. Here are some of the samples of average intensities in logarithmic decibel:

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[29] Earth News: http://www.consciouschoice.com/note/note1206.html
[30] ibid.
[31] ibid.

Source of Noise	Noise Intensity (dB)
Threshold of hearing	0
Normal conversation	55-60
Gas-powered lawn mower	90
Threshold of pain	120-130
Airplane takeoff, 100 feet	130-150
Shotgun	170

Table 1 – Sample sound intensities

As shown on the table, airplanes produce considerable amounts of noise around their surrounding area. Airplanes can be up to 30 decibels above the threshold of pain at 100 feet away, which is about three times as loud as what human ears can endure noise. Even if a person were to be in a position more than 1000 feet away from the airplane taking off, it would be a considerable amount of noise to bear for him for a long period of time. The noise would be like a shotgun going off at some distance continually.

With so many loud airplanes landing and taking off, airports are considered the single largest sources of noise. The noise from the airport, especially from the large airports, can be troublesome for more than 15 miles away from them.[32] Newer and quieter airplanes are being introduced and being used, but "air traffic is increasing at such a rapid rate," – according to the Federal Aviation Administration (FAA), "there will be at least 36 percent more flight in 2007 than today, therefore airport noise pollution will increase even with the use of quieter planes."

[32] ibid.

2 Proposed Solutions

2.1 Small Airport Transportation System (SATS)

Due to emerging technologies and past research investments through NASA, the congestion in the air, as well as on the ground will be solved thorough alternative concepts for air transportation systems. These innovations have the potential to give Americans new choices in traveling, product delivery, and transport services in the 21st Century. NASA and various other organizations are currently working on a joint project, which is intended to solve the current problems, called the SATS program. Once SATS is implemented, the nation will be able to have on-demand, point-to-point, high-speed personal air transportation between suburban, rural, and remote communities served by over 5, 000 public-use landing facilities distributed throughout the nation.

The vision for SATS is to provide the nation with an alternative to road trips and commercial airlines. The SATS technologies will make it possible for entrepreneurs in the transportation industry to create access to more destinations in less transportation time. More than 98 percent of the U.S. population currently lives within a 30-minute drive of over 5,000 public-use landing facilities.[33] This infrastructure is an unused national resource for national mobility. As a result, NASA has set the goal of "reducing public travel times by half in 10 years and two-thirds in 25 years.[4]" This travel alternative must also be relatively cheap with existing choices and meet the public expectations for safety and accessibility.

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[33] NASA Small Aircraft Transportation System: http://sats.nasa.gov/

NASA expects that the SATS will enable an advanced generation of "smart" aircraft and "smart airports." These technologies will enable access to any runway or helipad in the nation.

The SATS will be capable for upgrade to provide near-all-weather utility and minimize error. The aircraft would be primarily single-engine configurations and single-pilot-operated in near-all-weather conditions.[34] The aircraft will be equipped with modern advancements in avionics, airframes, engines and pilot training and be capable of operating in free flight within the National Airspace (NAS)[35]. Although the targeted operating environment will be in Classes C, D, E, and G airspace and facilities serving suburban, rural, and remote communities, the aircraft will be capable of flights also in Classes A and B airspace.[36]

Continued technology investments for SATS are planned for both vehicles and infrastructure. Vehicle technology objectives are planned that will advance affordability, safety, ease-of-use, airport utility, and intermodal connectivity. These technology investments will be prioritized using existing NASA and FAA advisory processes, and includes the following according to *A Small Aircraft Transportation System Concept*[37]:

- Simplified and intuitive flight controls, including decoupling as well as envelope limiting and ride smoothing concepts
- Next generation propulsion systems, including non-hydrocarbon and hybrid concepts
- Advanced pilot vehicle interface systems, including artificial/synthetic vision for "electronic" visual meteorological conditions
- Affordable software certification for application of commercial-off-the-shelf components and operating systems

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[34] ibid.
[35] Appendix D - Airspace
[36] NASA Small Aircraft Transportation System: http://sats.nasa.gov/
[37] University of Nebraska: http://www.unomaha.edu/~unoai/sats/SATS_Definition.html

- Automotive synergies in manufacturing, including automation in integrated composite structures
- Integrated training, including Internet-based training, unified instrument-private curricula, lower-cost simulation, and public school roles for "fliers' education"
- Satellite-based communications, navigation, and surveillance for ubiquitous flight and destination information systems
- SATS "Smart" airports incorporating satellite navigation approaches to all landing areas, without requirements for control towers and radar, and fully digital flight, traffic, and destination information systems
- Free Flight in the National Airspace System architecture for SATS airports;
- On-board access to travel information for seamless air/ground and mass/personal transportation intermodal connectivity

In summary, the nation is now in a position to create a major innovation in consumer choices available for personal and business air transportation, shipment of goods, and delivery of services. This opportunity to innovate comes at a time when existing air and ground infrastructures are maturing and reaching saturation. Without alternatives to existing systems, the economic opportunities of the Information Age will be limited to existing transportation infrastructures. With alternatives, new patterns of economic opportunity are enabled that need not be constrained to the 20th century hub-and-spoke airport and interstate highway infrastructures.

2.2 Ground transportation upgrade

The ground transportation system in the United States is very different than those of other developed countries. The interstate highway system has overtaken the railroad system; as a result the American railroad system is currently very poor.[38] In Europe or Japan the train is not only an option for inner city travel, but is also a very viable method for long distance traveling. High-speed train systems in those countries provide very reliable and affordable transportation for people and cargo.

Railroad systems are usually more reliable than air transportation because it is less vulnerable to weather and do not require airports, which can be problematic. Furthermore since trains are quieter than airplanes it is possible to build train stations in the middle of cities, making them more convenient. In addition trains are more flexible than airplanes and are able to make more stops since airplanes require takeoffs, landings, climb, descends maintenances, re-fueling, and weight & balance calculations each time they depart.

As a result an improved railroad system in the United States would solve many of its current transportation problems. Then again this is very difficult to accomplish since the United States is very large, possesses almost no railroad infrastructure, and its railroad companies are financially weak. Consequently it will take a long time and substantial money to develop a superior railroad system in the US.

In comparison making use of the over 5,000 already existing public accessible airports will be faster and financially efficient.

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[38] Appendix G - System Mileage within the United States

3 What is needed to make SATS possible

Avionics for commercial aviation has been evolving continuously through generations of aircraft. This evolution is required to increase the functionality of airborne systems in relation with the growth of air traffic.

In order for a greater number of small airplanes to be able to safely and efficiently occupy the same airspace at the same time, they need to be equipped with more advanced avionics. While some of these avionics are still in development, many of them are currently being used by larger commercial airplanes.

Today, most of the systems for modern aircraft are controlled electronically by computers. Unlike Cessna 152, which just has basic flying instruments (Altimeter, airspeed indicator, attitude direct indicator, turn coordinator, vertical speed indicator, and directional gyro), radio, and single engine, the system became large and complex as a result of developing airplanes to fly faster, higher and safer. Aircraft systems can be categorized into the following areas and each of the system have avionics computers to control them:

- Primary and secondary control surfaces
- Landing gear
- Ice and rain protection
- Static discharger
- Hydraulic systems
- Oil systems
- Fuel schedule and distribution
- Air-conditioning systems
- Pneumatic systems
- Oxygen distribution
- Lighting systems
- Warning systems
- Emergency equipment
- Cockpit voice recording/ flight data recording

- Radios
- Airplane condition monitoring system
- Radar
- Cockpit instruments
- Cockpit control panels
- Communication equipment
- Navigation system
- Auto flight control system
- Flight Management system
- Engine monitoring and control system

Because of these complicated systems, conventional large complex aircraft such as DC-8 or Boeing 707 used to have 5 flight crews in the cockpit; Captain, co-pilot, Flight Engineer, Navigator, and radio operator. Technological advances to increase reliability and performance reduced chance of aircraft system malfunction dramatically. The development of computers made it possible to automate management and monitoring for most of the aircraft systems. Today's advanced cockpit systems do not show most of the system information such as hydraulic pressure or engine vibration. Instead, the pilot will see a message on the display only when the condition of any system goes beyond the defined limits. Pilots can turn switches to "auto" position at pre-flight check, and leave them alone for the entire flight. While those automatic systems ease flight crews' workload dramatically, each pilots' workload has not changed or might even have increased due to the reduction of numbers of crew members in the cockpit. Increasing air traffic is also a significant concern for pilots during flights. Air traffic control and monitoring of enroute weather are also of only few areas in aviation which are slow to adopt automation. Changes to air traffic control system and weather forecasting system are essential for SATS idea to become realistic.

3.1 Necessary systems for SATS

- Global Positioning system (GPS)
- Satellite Based Augmentation System (SBAS)
- Flight Management System (FMS)
- Automatic Dependent Surveillance – Broadcast (ADS-B)
- Airborne Separation Assurance Systems (ASAS)
- Data-Link system

3.1.1 Global Positioning system (GPS)

GPS is a satellite-based radio navigational, positioning, and time transfer system developed and operated by the Department of Defense (DOD). This system is already being widely used by pilots as well as sailors on the ocean and drivers on the road.

"GPS provides highly accurate position and velocity information and precise time on a continuous global basis to an unlimited number of properly equipped users. The system is unaffected by weather and provides a worldwide common grid reference system based on the earth-fixed coordinate system."[39]

GPS receivers verify the integrity of the signals received from the GPS constellation through Receiver Autonomous Integrity Monitoring (RAIM) to determine if a satellite is providing corrupted information. At least one satellite in addition to those satellites needed for the navigation must be in the view from a GPS receiver in order for RAIM to function. A GPS receiver needs minimum of 5 satellites or 4 with barometric altimeter aid, to detect a satellite with corrupt signal. If the GPS has more than 6 satellites in view, it is capable of isolating the corrupt satellite.

Before GPS was available, the methods for navigation were the following:

- Visual Flight Rule (VFR)

[39] AIM 2002, AIM 1-1-21: Jeppesen Sanderson, Inc., 2001

- Radio Navigation aids
- Self contained navigation systems

VFR simply relies on pilots' skills to recognize the current location by comparing observations to the VFR charts that include depictions of major scenery objects. Radio Navigation includes, VHF Omni Range/ Distance measurement Equipment (VOR/DME), Non-directional Beacon/Automatic Direction Finder (NDB/ADF) and Long-Range Radio Navigation (LORAN). They are based on radio stations installed around the country. On-board radio receivers use the signals form those stations to help determine current location. Satellite based navigation systems eliminate the need of those ground based navigation aids. FAA is planning on phasing those ground-based-navaids starting 2008.[40] Another method of navigation widely used by many larger aircraft is self-contained navigation systems such as Inertial Navigation system (INS) and Inertial Reference Unit (IRU.) These self contained navigation systems have mechanical or laser gyros that detect roll, pitch, and yaw angular changes to track the position of the aircraft and determine ground speed.

VFR will still be the basic skill for pilots for a while because it is fundamental for flying and also the last backup system when everything else fails. On the other hand, radio navigation aids are highly cost inefficient because each radio stations must be transmitting radio signals continuously and require maintenance. Self contained navigation systems are very reliable tools while they are very expensive that it is also cost inefficient compared to GPS.

Because GPS was developed by DOD for defense purposes, it had a function to intentionally give errors to receivers called Selective Activity (SA.) On May 2nd, 2000,

[40] Federal Radionavigation Plan: http://www.faa.gov/asd/international/TSO_FAR_AC/frp_021900.pdf

United States removed SA, making GPS as reliable navigational tool for all public.[41] European Union decided to build their original satellite navigation system for commercial purpose only. Russian Global Orbiting Navigation Satellite Systems (GLONASS) is also available for satellite navigation.

Compared to the conventional navigation methods, GPS system is very efficient navigation method for aviation because there is no need for installing and maintaining thousands of ground stations and its inherent accuracy.

[41] INTERAGENCY GPS EXECUTIVE BOARD : http://www.igeb.gov/sa/diagram.shtml

3.1.2 Satellite Based Augmentation System (SBAS)

Satellite Based Augmentation System (SBAS) is a name of different navigation systems that give accurate navigation aid based on the position data acquired from satellites.

There are currently two kinds of SBAS being developed in the USA: Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS). Using very simple ground based stations; these systems enhance accuracy of satellite based navigation by error correction.

Augmentation technologies to the basic GPS service such as Wide and Local Area Augmentation Systems (WAAS and LAAS) will further increase the capabilities of Satellite based navigation technology for all phases of flight from take-off through precision approaches and landings.

3.1.2.1 Wide Area Augmentation System (WAAS)

WAAS is a GPS-based navigation and landing system that will provide precision guidance to aircraft at thousands of airports and airstrips where there is currently no precision landing capability. WAAS consists of precisely surveyed ground reference stations positioned across the United States that monitor GPS satellite data. Two master stations, located on each coast, collect data from the reference stations and create a GPS correction message. This correction accounts for GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere. The corrected differential data are then broadcast through one of two geostationary satellites, or satellites with a fixed position over the equator. The information is compatible with the basic GPS signal structure, which means any WAAS-enabled GPS receiver can read the signal. The WAAS broadcast message improves the GPS 95 percent signal accuracy from 100 meters to approximately 7 meters.[42]

SBAS are regional systems, meaning that it being developed solely in the United States. However, there is a commonly recognized need to establish adequate cooperation and coordination among SBAS providers so their implementation becomes more effective and part of a seamless worldwide navigation system. It is hoped that cooperative efforts among SBAS providers will lead to improved service outside and between the nominal service volumes of each SBAS provider. Outside the US, Japan has designed the Multi-function transportation Satellite-based Augmentation System (MSAS) and three organizations within Europe (European Union, European Space Agency and EUROCONTROL) have combined to develop the European Geostationary Navigation Overlay System (EGNOS). NAV CANADA has also participated in the development of a Global Navigation Satellite System (GNSS) by proposing a Canadian WAAS (CWAAS) that supplements the US WAAS by adding additional reference stations within Canada in order to increase coverage within North America. [43]

3.1.2.2 Local Area Augmentation System (LAAS)

The Local Area Augmentation System (LAAS,) sometimes called Special Category One Differential GPS (SCAT-I DGPS) is an augmentation to GPS that focuses its service on the airport area (approximately a 20-30 mile radius). It broadcasts its correction message via a very high frequency (VHF) radio data link from a ground-based

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[42] AIM 2002, AIM 1-1-22-b.
[43] SBAS Technical Interoperability Working Group (IWG): http://www.faa.gov/asd/international/sbas.htm

transmitter. LAAS will yield the extremely high accuracy, availability, and integrity necessary for current instrument landing systems, and will provide the ability for more flexible, curved approach paths. Having one LAAS error correction antenna would cover all the runways from each direction in most airports because the system is satellite based. This will reduce an immense amount of cost compared to current precision landing systems such as Instrument Landing System (ILS) and Microwave Landing System (MLS).

ILS, the most widely used precision landing system, is designed to provide an approach path for exact alignment and descent of an aircraft on final approach to a runway. ILS usually consists of three parts: Guidance information, Range information, and Visual information. The Guidance information is given by VHF radio signal transmitted from end of the runways. Localizer signals give exact alignment for horizontal approach path, and the Glide slope signals give exact alignment to vertical approach path. Range information is usually given by marker beacons and Distance measurement Equipment (DME.) Marker beacons are located under the horizontal approach path. Cockpit lighting tells pilots the distance to the touch down point when aircraft antenna receives marker beacon signals transmitted vertically upwards. ILS signal reaches about 18nautical miles from the touchdown point in 20degrees sector around the approach path.

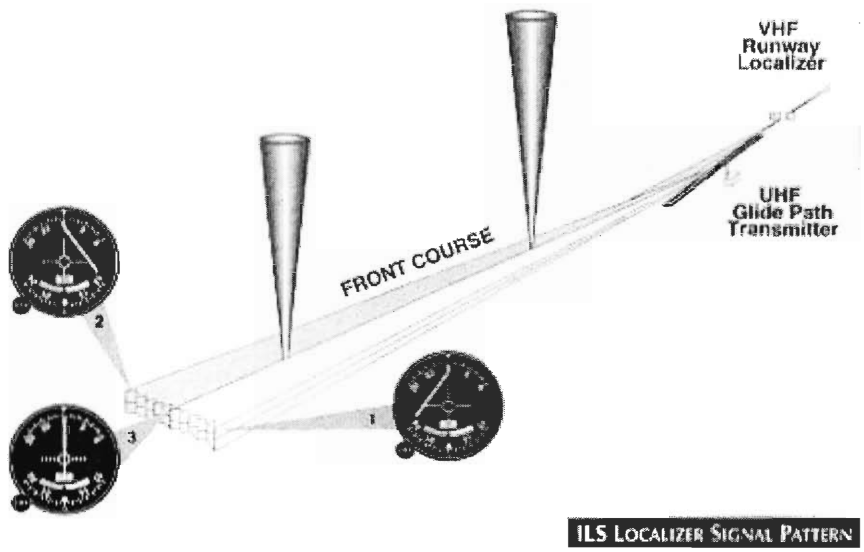

Figure 2 – ILS[44]

Because ILS systems requires several different radio transmitters for each runway, the cost for installation and maintenance is relatively high compared to the satellite based landing aids. Compared to ILS, LAAS system can create more efficient approach courses for any required distance within the range of local LAAS signal. It is possible to set a non-straight line approach courses and departure courses for reasons such as noise abatement. Having smaller as well as less equipment, LAAS landing system could also achieve reduction of the system malfunctions.

[44] Aerospace Learning Laboratory for Science, Technology, And Research. http://www.allstar.fiu.edu/aero/ILS.htm

100 meters:	Accuracy of the original GPS system, which was subject to accuracy degradation under the government-imposed Selective Availability (SA) program.
15 meters:	Typical GPS position accuracy without SA.
3-5 meters:	Typical differential GPS (DGPS) position accuracy.
< 3 meters:	Typical WAAS position accuracy.

Table 2 – Accuracy SBAS[45]

3.1.2.3 Satellite Based Navigation System

GPS is cost efficient because ground based infrastructure is not needed except for error correction stations for WAAS and LAAS. It gives accurate location and velocity information for all the aircraft. GPS receivers are inexpensive and small; they make navigation cheap, easy, and accurate.

Note: Augmentation systems such as WAAS and LAAS augment, meaning they correct the error and make satellite based navigation very accurate.

[45] Garmin, what is WAAS: http://www.garmin.com/aboutGPS/waas.html

3.1.2.4 Flight Management System (FMS) / Auto Flight Systems

More aircraft are being equipped with FMS. FMS manages the entire phase of flight from takeoff to landing. It controls navigation, flight surfaces, and thrust. FMS has all the updated airport data and navigational waypoints in the world on its database, and the system can also download the flight plan by the data-link. Before each flight, the FMS takes in the number of passengers, amount of cargo and fuel, and calculates the most economical altitudes, takeoff speed, and estimated arrival times for all the waypoints and the destination. Once the flight plan is set in the system, lateral navigation (L-NAV) and vertical navigation (V-NAV) information is provided. Once in the air, the FMS communicates with Navigation radios and positioning such as Global Positioning System (GPS) and Inertial Reference Unit (IRU) to determine the exact location of the aircraft and commands autopilot to follow the flight plan in its database. FMS can switch the radio navigation stations by itself. At the same time, performance calculations are done in FMS and options are given for pilots to choose from climbing up to cruising altitude in most economical speed or the fastest way. All throughout the flight, pilots can intervene with the FMS flight plan, and FMS can recalculate any changes needed of the flight plan on case of engine failure or diversion to alternate airports. Control Display Unit (CDU) is a device that pilots input commands to FMS. CDU has input keys for alphabets, numbers, and menu and line select keys on the sides of its display. Although pilots can see all the information on the CDU display, primary information is displayed on Electronic Flight Instrumentation System (EFIS.)

Figure 3 - Example of a CDU for FMS[46]

FMS is essential equipment for modern aircraft to fly without requiring every pilot to have intense workload, skill, and reliability. When Pilots can let FMS do the actual flying and all the necessary calculations and navigation, they can act as managers or supervisors for the whole complex system of modern aircraft to make sure everything is working well, deal with things that computers are yet to do such as looking out for the weather on enroute, and dealing with air traffic control until the day when air traffic system is automated.

FMS is a computer system on-board an aircraft. It stores maps, airport information, and figures out the ideal airspeed and altitude for the flight according to the fuel load, number of passengers, weight of cargo, wind, and temperature.

[46] Project Magenta: http://www.projectmagenta.com/

The auto flight system is connected to the FMS and steers the airplane on the flight plan. Before, pilots had to set magnetic headings and altitude by themselves to keep the aircraft on track. FMS lets airplanes fly economically, relieves pilots from many workload calculations, and makes flying less stressful.

3.1.2.5 Automatic Dependant Surveillance – Broadcast (ADS-B)

ADS-B is a new technology that allows pilots in the cockpit and air traffic controllers on the ground to "see" aircraft traffic with much more precision than there has ever been before. Radar works by bouncing radio waves off of airborne targets and then "interpreting" the reflected signal. ADS-B does not need to interrogate targets to display them. Rather, it relies on the satellite-based global positioning system. Each ADS-B equipped aircraft broadcasts its precise position in space via a digital data-link along with other data, including airspeed, altitude and, whether the aircraft is turning, climbing, or descending. This provides anyone with ADS-B equipment a much more accurate depiction of air traffic than radar can provide. Since the equipment is so small and light, it can be made a standard part of the equipment on board for any aircraft, allowing pilots to see an accurate depiction of real-time air traffic, along with controllers.

Unlike conventional radar, ADS-B works at low altitudes and on the ground, so that it can be used to monitor traffic on the taxiways and runways of an airport. It is also effective in remote areas or in mountainous terrain where there is no radar coverage, or where radar coverage is limited.

One of the greatest benefits of ADS-B is its ability to provide the same real-time information to pilots in aircraft cockpits and to ground controllers, so that for the first time, they can both "see" the same data. [47]

ADS-B relies on the satellite-based global positioning system to determine an aircraft's precise location in space. The system then converts the position into a digital code, which is combined with other information such as the type of aircraft, its speed, its

[47] ADS-B Web Site: http://www.ads-b.com

flight number, and whether it is turning or climbing or descending. The digital code, containing all of this information is updated several times a second and broadcast from the aircraft on a discreet frequency, called a data-link.

Other aircraft and ground stations within approximately 150 miles receive the data-link broadcasts and display the information in user-friendly format on a computer screen. Pilots in the cockpit see the traffic on a Cockpit Display of Traffic Information (CDTI). Controllers on the ground can see the ADS-B targets on their regular traffic display screen along with other radar targets.

Since ADS-B uses digital computer technology, it can be scaled for use in smaller, general aviation aircraft. ADS-B provides an opportunity for smaller single-engine or twin-engine aircraft to have cockpit displays similar to the ones installed in airliners. This accessibility to smaller aircraft gives ADS-B the potential to dramatically improve aviation safety in skies that are increasingly crowded.

ADS-B is currently being demonstrated in 150 small commercial aircraft operating in the Yukon Kuskokwim Peninsula of Alaska. Air Traffic Controllers in Anchorage will be able to "see" ADS-B traffic along with radar traffic on one display. Ultimately, controllers will be able to provide air traffic control services to the ADS-B equipped aircraft, even in areas where they are not visible by radar.

ADS-B data-links potentially can be used to display weather radar data or flight clearances in the cockpits of general aviation aircraft. Using affordable multi-function displays, smaller aircraft for the first time will have practical access to weather radar displays and other linked data.

Airborne Separation Assurance System (ASAS) is a part of ADS-B system that can replace TCAS[48]. In this system, aircraft are expected to automatically maintain their safety separation.

ADS-B will allow pilots and controllers to see all the traffic in the area without requiring radar or expensive equipment. Each airplane will broadcast their location and altitude information they acquire from GPS.

ADS-B will make it easier for pilots, controller, and most importantly for computer to see all the traffic and their exact location, airspeed, and altitude. This will help develop advanced collision avoidance system.

[48] Appendix C – Traffic Alert and Collision Avoidance System (TCAS)

3.1.2.6 Data Link

Automatic Communication Addressing and Reporting System (ACARS) are usually used by airlines. This air-ground data-link using VHF radio sends information at 2400bit/sec. Airlines use this system to send various messages between pilots and the operation centers. Information includes destination, departures points, estimated time, onboard fuel, flight numbers, weather forecasts, and maintenance reports. Pilots can print the received data from the printer in the cockpit panel.

ACARS has been the mainstay of air/ground data communications for over twenty years. However, ACARS capacity is very limited that capacity is now being exhausted and, the ACARS system is not suitable for critical ATC data link communications. International Civil Aviation Organization (ICAO) has thus specified the VHF Digital Link (VDL) family of air/ground communications systems for both ACARS replacement and to support the next generation of ATC data-link services.

VDL Mode 1 is a low risk but low capability option. It uses existing ACARS radio technology and this ensures that the Standard and Recommended Practices (SARPs) can be readily validated and would enable straightforward product availability. However, the data rate is low (600 bps is the channel rate shared among all using aircraft), and the Carrier Sense Multiple Access (CSMA) procedures used to arbitrate access to the channel give rise to non-deterministic channel access times and hence transit delay. Its performance is unlikely to be satisfactory for CNS/ATM[49] Applications and the

[49] Appendix B – Future Air Network Systems Communication Navigation Surveillance/Air Traffic Management (FANS CNS/ATM).

expectation is that with more preferment VDL modes available, Mode 1 is unlikely to be used operationally.

VDL Mode 2 is an onwards development of Mode 1. It uses the same frequency bands, while using a better data encoding modem. This applies Differentially Encoded 8-Phase Shift Keying (D8PSK) to give a channel data rate of 31.5kbps. However, CSMA is still used as the channel access procedure and, while Mode 2 may give acceptable performance at low utilization levels, as the applied load on the network gets higher, the access time will increase exponentially and the transit delay will no longer meet operational requirements. Therefore it is doubtful that VDL Mode 2 will be in operational use.

VDL Mode 3 is a significant improvement over Mode 2 using Time Division Multiple Access (TDMA) procedure for channel access, at the same time as operating at the same channel data rate as Mode 2. It also supports voice communications in the same channels. The use of TDMA permits a deterministic transit delay to be offered and bandwidth utilization is much improved over Mode 2. Operationally, it has significant advantages over Mode 2. However, the support of voice by VDL has added a significant technical risk. Currently, no voice encoders are available that meet VDL Mode 3 requirements.

VDL Mode 4 is in many ways very different to the other VDL modes. It uses the same frequency bands as the other VDL modes, and encodes its data using D8PSK at 31.5kbps. It also uses TDMA. However, while Mode 3 relies on a ground station to provide the channel synchronizing signal for TDMA, Mode 4 is self-synchronizing and hence permits air to air communication in the absence of ground stations. The channel reservation protocol used includes and demands position information, and thus support for ADS-B is built in. The data link procedures provide a simple acknowledged connectionless service. This is the most efficient data link service for Aeronautical telecommunication network (ATN) use. There is no need to implement ISO 8208[50] services for ATN use and VDL Mode 4 thus integrates readily into the ATN without the complexity of providing ISO 8208 access.

VDL Modes 1 and 2 may have difficulty in meeting the operational requirements for CNS/ATM[51], due to their reliance on CSMA and the consequential non-deterministic transit time. On the other hand, VDL Modes 3 and 4 can provide deterministic transit delays due to their use of TDMA access procedures. There are complementary aspects to these modes, with VDL Mode 3 providing voice communications and data where ground stations are available, and Mode 4 providing ADS-B and operating even in the absence of ground stations. Mode 4, in particular, integrates well with the ATN. By providing the ADS-B information believed to be needed to support acceptable use of CPDLC (will be discussed next) , Mode 4 could be very important for pilot acceptance of the use of data-link.

Data link systems let aircraft exchange information with ground control. Mostly done via satellite communication, the digital data link today is even capable of voice communication. Pilots can obtain updated flight plans, weather info, airport info, or anything necessary. Pilots can also send messages if there are problems on board.

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[50] International Organization for Standardization - X.25 Packet Layer Protocol for Data Terminal Equipment

[51] Appendix B – Future Air Network Systems Communication Navigation Surveillance/Air Traffic Management (FANS CNS/ATM).

Data link allows pilots and computers to be updated at all times. Voice communication capability allows pilots to be able to talk to any necessary people at any time regardless of where they fly. A SATS aircraft needs data link so that their computers will have updated route, traffic, and weather information as well as pilots.

3.1.2.7 Controller Pilot Data Link Communication (CPDLC)

CPDLC is a part of CNS/ATM system. CPDLC is already in use in some parts of the world. It uses either VHF radio or satellite links to allow pilots and traffic controllers communicate using data-links instead of aural communication. Data-link communications are better when pilots have to send a lot of information such as reroute, weather, fuel, altitude, and location. Controllers can send commands without danger of the command being misinterpreted. When using satellite link for this, aural communication is always available as a backup with better sound quality compare to VHF communication. Currently, CPDLC system is installed into CDU on those airplanes. Pilots can press one of four keys for basic communication, "Wilco" (Will Comply with request), "Unable," "Negative," and "Roger" (understand the message.) By using these keys in CPDLC, pilots and controllers will no longer required to repeat the message received. CPDLC also is expected to increase safety by eliminating some human errors such as pilots forgetting what was said, and difficulty understanding different dialects and accents.

Devices specially designed for CPDLC communication can widen use of the system. This system should include audio and visual alert that notify pilots of receiving messages. Communications between ATC and other aircraft should also be included in the CPDLC display for situational awareness.

At 07:38 on October 7th, 2002, the first CPDLC communication in the USA was operated in Miami center.[52] This is a year long experiment on effective use of CPDLC. This is an effort by FAA and its partners; American Airlines, Rockwell Collins, ARINC,

[52] *Aviation Week & Space Technology* (McGraw-Hill Companies, Oct 14, 2002) 40.

and Computer Sciences Corp. American Airlines expects to have about 20 of its aircraft to be installed with CPDLC system. 10 of B757s have been installed with the system, and four of B767 are working on the certification. Other airlines are expected to join this experiment soon.

CPDLC will eliminate miscommunication and relief frequency congestion by using data link for routine communication (altitude change, course change, and landing clearance) instead of voice communication. Voice communication can be reserved for more critical communications such as traffic avoidance or emergencies.

3.2 Control systems

Single engine airplanes with two or four seats are the first trainers for most pilots. All control surfaces are directly connected to control yoke and rudder pedals mechanically by wires or rods. Pilots can "feel" the air acting on control surfaces. When airplane is flying at low speed, pilots can sense a "mushy" feeling as they move the control yoke in order to maneuver. When airplane is too slow and about to stall, pilots can feel how heavy the controls feel as they attempt to maintain the attitude of the airplane. Many pilots enjoy the feeling of "flying." That feeling is not only part of the fun of flying, it is also very important information pilots can obtain besides instrument readings.

When aircraft became bigger and faster, pilots' muscles were no longer strong enough to control them. Hydraulic systems were introduced to aid pilots moving control surfaces. Artificial feeling systems are usually installed on control yokes to prevent pilots from over controlling. For most airplanes, there are at least 2 separated hydraulic systems for redundancy.

Fly by Wire (FBW) is a name given to the system when control yoke in the cockpit is no longer mechanically connected to control surfaces but signals are transferred by electric wires. Concorde was the first commercial aircraft to use such a system. Concorde, as a supersonic aircraft, it was extremely important to make the airplane as light as possible so more engine thrust could be used to accelerate and climb the airplane. Engineers realized that the size of aircraft would expand significantly because of the temperature generated by air friction. The nose of the airplane can heat up to 127 degrees C during supersonic flight. FBW was suitable for Concorde because it reduced significant amount of weight, and fully electric control systems were less vulnerable for the extreme differences in temperature. A Mechanical link was still on Concorde's control system as a backup.

The F-16 was the first airplane to have full FBW. In the F-16, the control yoke was replaced by a side stick, which is not much different from joysticks for computer games. There is a computer between the side stick and control surface that augment stability of the airplane. By having such computers, there is no need to have well-experienced veteran pilots to fly airplanes with unusual characteristics. Such stability augmenting computers can make any airplanes fly like the most stable airplanes.

Airbus Industry was the first company to install full FBW into commercial airplanes. In fact, several companies that were involved in Airbus were part of the Concorde program. By installing FBW, they successfully and significantly reduced the weight of those airplanes. Airbus currently has 3 different kinds of aircraft with FBW, A320, 330 and 340. In the cockpit, the traditional control yoke was replaced by small side sticks next to each pilot. The two sticks are not even mechanically connected so that left-seat pilot can be steering the airplane to hard left when right-seat pilot is trying to steer the airplane to the right. In such case, the average of two inputs becomes the command. One of pilot can also take complete control by pressing "priority" button on the side stick. When the airplane is flying on auto-pilot, the sticks are in neutral position and locked. If a pilot forces the stick to move, the auto-pilot would be disconnected after loud warning. Engine control is also fully automated. In normal flights, pilots can place the thrust lever in T/O G/A (take off/ go around) position for take off, cruise power position for cruising. The powers of the engines do not reflect on the position of levers.

Aside from the different appearance in the cockpit, FBW made those Airbus planes very unique compared to previous airplanes. There is computer protection system called "alpha-floor" that that keeps airplane at a safe attitude. When a pilot pulls and holds the side stick at the up position, the airplane will start to nose up just like conventional aircraft. However, when the angle of attack becomes too large or the airspeed becomes too slow, the computer will stop bringing the nose up. Pilots can never put these airplanes into a stall whether intentionally or unintentionally. All input commands that brings airplane into unusual attitude are ignored by the computer. When pilots release their hands from control yokes on conventional aircraft, the straight and level position is eventually achieved. In contrast, releasing pressure from side sticks for airbus FBW planes means "keep current attitude." Once the side stick is in neutral position, the airplane will keep the bank angle and pitch attitude.

Figure 4 - Captain side in cockpit of Airbus A320-232[53]

***Note that the control yoke is gone. The side stick is seen on the left side of the picture.**

[53] Photo by Manuel Marine: http://www.airliners.net

Figure 5 - Similar picture for Airbus A300-600R[54]

The last airbus airplane with control yokes.

Boeing also installed FBW in its new aircraft, B777 but decided to use neither side stick nor the protection system that can override pilots. Instead of ignoring unsafe input from pilots, the protection system for the B777 will make the control yokes heavier. B777 still has conventional control yoke, and pilots have full authority over the controls.

Fly by Light (FBL) is an advanced FBW. Instead of electric wire, FBL system would use optical cables. Optical cables are less likely to be affected by EMS and more signals can be transmitted in shorter time.

In Airbus airplanes, pilots do not "fly" the airplane in the traditional sense. They have system administrator responsibilities and input the route, altitude, and speeds, then the computers fly the airplane. Pilots can aid computers using little side sticks' input only when computers are not certified to do certain things such as taxi, take off, and executing non-precision landings.

There are still emergency situations where pilots' inputs are necessary. For avoiding unexpected traffic, pilots must act very quickly to change the direction of the airplane. When pilots detect extreme weather condition such as downburst when

[54] Photo by Carlos de Anda: http://www.airliners.net

approaching to land, they must act very quickly to increase speed and climb up. However, should such control systems be installed to GA aircraft, it is possible to have pilots with less experience to fly safely.

FBW allows engineers to design aircraft that can be very difficult to fly but have other benefits such as economy. The FBW computers will receive auto pilot or pilot commands from input devices (i.e. side stick) and move the control surfaces. It also prevents pilots from putting the airplane in dangerous situations, for example: unusual attitude, or flying into terrain.

SATS airplanes with advanced auto pilot and FMS will be able to let the computers do most of the flying. Although pilots are able to take control of the plane using input devices in case of emergencies.

3.3 Airspace organization

Even with advanced technology, it is not realistic for one to expect that all flight will be automated in short time. Acceptance from aviation industry, frequent users, and the broader society are essential for fully automated aviation to become practical. The only way for societal acceptance for such thing is slow transition.

Smaller aircraft, private or business size aircraft, can be appropriate for introduction of automated aircraft to the aviation.

By creating new classes[55] that are specially designated for automated flights can manage aircraft with different flying rules in the same sky.

3.3.1 Infrastructure

When navigation and control systems become largely dependant on GPS and satellite communications, less ground based infrastructure will be required. VHF radio communication will no longer be required when satellite communication become available. SBAS will eliminate needs for ground based radio navigation system such as, VOR/DME, ADF, VORTAC and ILS. ADS-B should take over primary radars and surface radars. LAAS will provide precision approach capability for any airports just by installing one antenna and a system. LAAS will also eradicate need for ILS system, which require large antennas for each runway. These SBAS will make infrastructure greatly smaller in size, cost, and energy usage. Less equipment should also result in less failure therefore easier and less maintenance.

[55] Appendix D – Airspace

3.4 Safety

3.4.1 Parachute

Flying on a commercial airplane has been proven to be very low. Due to the fact that crashes on airliners have been greatly reduced, today's crashes seem terrifying because of their uncommonness. As the predictable airline failure has been identified and eliminated, what remains are incidents that are not explainable.

However, the situation in general aviation is not as good. Accidents for smaller airplanes occur on an average of one per day and the reasons are more obvious compared to the commercial airplanes.[56] Since their crashes are more obvious, the disasters are more preventable.

There are two main causes of general aviation accidents: weather problems and low-level maneuvering. There were a total of 341 fatal general aviation accidents in 1998 and 54 were weather related.[57] Out of the 54 incidents, 39 were due to pilots flying in zero-visibility areas.[58] The other 15 were from severe weather, such as thunderstorms and freezing cold weather.[59]

The other primary cause is low level maneuvering flight. This is when the pilot is flying under 1000 feet above the ground Out of the 341 crashes in 1998, 63 were due to the low level maneuvering.[60]

These major causes of general airplane fatalities would be solved by a parachute equipped airplanes. Currently the SR20 designed by Cirrus Design Corporation carries a

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[56] National Transportation of Safety Board - http://www.ntsb.gov/aviation/aviation.htm
[57] James Fallows, 67-69.
[58] James Fallows, 71.
[59] ibid.
[60] James Fallows, 70.

parachute or a Ballistic Recovery Device (BRD). The Cirrus Airframe Parachute System (CAPS) is a BRD that will lower the entire airplane to the ground when all alternatives to land have been eliminated. After deploying the parachute, the canopy will position itself over the center of gravity of the aircraft, and make the aircraft descend at a constant 26.7 ft/sec.[61] (If an airplane loses control at 800 ft, and freefalls till it hits the ground, the airplane will be going about 200 ft/s before hitting the ground). When the airplane hits the ground, the roll cage and the seats will absorb large amounts of energy, resulting in a livable landing. The CAPS will decrease the fatality in both low level maneuvering and weather related accidents.

[61] Cirrus Design: http://www.cirrusdesign.com/

3.5 Eclipse

Modern turbine engines are highly desirable aircraft propulsion systems because they are lighter and environmentally cleaner compared to the conventional aircraft. They are characterized by high reliability, smooth operation, use of readily available jet A fuel, and low noise emissions. Their smoothness contributes greatly to aircraft safety and comfort. Until now, the use of turbine engines in the light aircraft market has been limited by its high cost.

In order to achieve SATS' future goals, there is a need to develop a type of airplane that is fuel efficient, has reasonable operating cost, and has advanced avionics systems that enhance the safety and ease of operation.

Currently Eclipse Aviation is in the process of mass producing an affordable jet aircraft that many revolutionize the transportation market. By applying new propulsion, manufacturing, and electronic systems into the production of the Eclipse 500, Eclipse aviation will be able to offer an aircraft that would cost less than a quarter of the average business jets. Eclipse Aviation says that the Eclipse 500 will be commercially available by January, 2004.[62]

One of the main reason Eclipse Aviation was founded was because Daniel Goldin, the NASA Administrator; promoted a futuristic vision. He believed that it would be possible to achieve a goal of "safe, affordable, jet-powered small aircraft travel" where it is "available to anyone, anytime, anywhere." His vision is similar to that of Bill Gates', who envisioned a "computer on every desktop." This is a way of distributing efficiency and convenience to all the people.

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[62] Eclipse Aviation: http://www.eclipseaviation.com/howtobuy/price.htm

Eclipse Aviation is developing the Eclipse 500 which is different from conventional jet airplanes. It would utilize the state-of-the-art technologies at a third of the price of current jet airplanes. Also the pilots would find the Eclipse 500 easier to fly than most piston powered aircrafts with the use of digital and computer systems. Technologies that are worth noting are integrated GPS-based flight management systems, digital flight control systems, dual full authority digital engine control system, and aircraft utility control system.

In 1996 Williams International started work on a joint project with NASA called the General Aviation Propulsion (GAP) Program, and was intended to stimulate the light aircraft industry.[63] In this program, Williams International was able to develop a turbofan engine, FJX-2, which will serve the next generation of four to six passenger general aviation airplanes. With turbofan powered engines, the new generation of light airplanes will help the SATS program achieve its goals of making airplanes more accessible. The light airplanes will fly faster, have a longer range, and be more comfortable and quiet, setting a new standard for the general aviation industry.

The EJ22 production engine, which will be used on the Eclipse 500, is a result of the FJX-2 technology. The Eclipse 500 will be a twin-jet airplane and will carry up to six passengers. The engine will be able to produce over 770 lbs of thrust and weigh less than 85 lbs. The thrust to weight ratio of the EJ22 is 9.05 while the BRR710 used in the Gulfstream V Global Express has thrust to weight ratio of 4.71. This thrust to weight ratio is the best compared to any commercial turbo fan engine currently produced.[64]

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[63] Williams International : http://www.williams-int.com/index.htm
[64] Eclipse Aviation: http//www.eclipseaviation.com/500jet/performance.htm

Turbo fan engines with high thrust to weight ratios will have higher acceleration and have a faster rate of climb.[65] As shown in Table 3 the thrust of the Eclipse 500 compared to the Golfstream V Global Express is minimal. However the Eclipse 500 has a greater thrust-to-weight ratio, and therefore will have a better acceleration.

EJ22 Performance Comparison				
	Eclipse500[66]	Gulfstream V[67]	B747-400[68]	Cirrus SR20[69]
Engine Model	EJ22	BRR710	CF6-80C2B1F	IO-360-ES
Thrust (lbf)	770	16500	57900	600
Bypass Ratio	4.60	5.30	5.00	N/A
Weight (lb)	85	3500	9570	305
Thrust/Weight Ratio	9.05	4.71	6.05	1.96

Table 3 – Engine Comparison

The Eclipse will be capable of flying 385 knots for nearly 1,500 nautical miles and flying at altitudes of up to 41,000 feet.[70] Due to its high thrust-to-weight ratio the Eclipse 500 will be able to land and takeoff at any small airport in the U.S.

Eclipse 500 is equipped with highly sophisticated avionics and delivers more reliability and safety compared to any business jet. The system will be able to display the current status of the plane, instead of the conventional aircrafts that have several displays for the pilots to obtain the present status of the aircraft.[71]

The Eclipse 500 is equipped with three large Electronic Flight Instrument System (EFIS) which consists of two primary flight displays (PFD) and one multi-function display (MFD). Both display information of primary flight information (airspeed,

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[65] NASA Glenn Research Center: http://grc.nasa.gov/WWW/K-12/BGP/Donnat_w_ratio_acitivty.htm
[66] Eclipse Aviation: http://www.eclipseaviation.com/500jet/performance.htm
[67] ibid.
[68] Boeing: http://boeing.com/flash.html
[69] Continental Motors - http://www.tcmlink.com/EngSpecSheetDocs/IO360ES.PDF
[70] Eclipse Aviation: http://www.eclipseaviation.com/500jet/performance.htm
[71] Eclipse Aviation: http://www.eclipseaviation.com/500jet/avio.htm

altitude, airspeed, attitude, etc,), navigation information, weather radar image, traffic information, terrain avoidance information, autopilot modes, and aircraft performance information. These functions are comparable to business jets that cost millions of dollars more.

Avionics						
	Eclipse Aviation Eclipse 500	Beech Baron	Cessna CJ1	Bombardier Continental	Gulfstream GV	Boeing 777
	$837,500	$1,153,910	$3,986,000	$16,290,000	$43,243,000	$140,000,000
Dual PFD, MFD with EICAS	Available	N/A	2nd PFD is Optional	Available	Available	Available
Fully Integrated Systems Control	Available	N/A	N/A	N/A	N/A	N/A
Flight Management System	Available	N/A	Available	Available	Available	Available
RVSM Capable	Available	N/A	Optional	Available	Available	Available
On-board Performance Computer	Available	N/A	N/A	Optional	Available	Available
Auto-throttle	Available	N/A			Available	Available
Integrated Communications Management	Available	N/A	N/A	N/A	N/A	N/A

Table 4 - Avionics[72]

The Eclipse 500 will not only be fast and easy to operate but will also be cheaper than the competition. The cost of the Eclipse 500 will be $837,500.[73] As a comparison, the cheapest business jet Cessna offers is the Citation CJ-1, which has a base price of about $4 million. Raytheon's entry-level business jet, the Premier I, carries a price tag of $5.4 million and the Bombardier's Continental costs over $16 million.[74] The Eclipse 500 will not only be cheaper than the typical twin turbo fan jet aircraft, but will also be

[72] "Some people play by the rules. We're about to shatter them," Eclipse Aviation (July 2002).
[73] Eclipse Aviation: http://www.eclipseaviation.com/inthenews/detail_02.htm?content_id=371
[74] "Some people play by the rules. We're about to shatter them," Eclipse Aviation (July 2002).

cheaper to maintain and operate. For every nautical mile of flight the Eclipse will cost approximately 56 cents.[75] According to Eclipse Aviation, that is a quarter of the operating cost of the KingAir C90B and one half of the operating cost of the Baron 58 which have similar performance specs.

Estimated Direct Operating Cost of the Eclipse 500

Fuel ($2.00/gallon)	$89.21
Maintenance Labor ($60.00/manhour)	$15.79
Parts, Airframe, Engine, Avionics	$63.52
Engine Reserve	$36.00
Total DOC per Flight Hour	$204.52
Total DOC/statute mile	$0.56
Notes: *1. Costs based on 500 nm stage length.*	

Table 5 – Operating Cost[76]

Safire Aircraft Company is also another venture on the verge of developing an affordable jet aircraft similarly matched to the Eclipse 500. Like the Eclipse 500, Safire's S-26 will be powered by two small turbo fan engines and will be sold for under a million dollars. As shown in Table 5 the two aircraft have similar specs. However, unlike the Eclipse 500 there is no specific schedule for initial production.

[75] Eclipse Aviation: http://www.eclipseaviation.com/500jet/performance.htm
[76] ibid.

Eclipse 500 vs. Safire S-26		
	Eclipse 500[77]	Safire S-26[78]
# flight crew	1	1
MAX occupancy w/ crew	6	6
MAX Take off weight	4,700	5,900
max cruise speed (kts)	355	340
stall speed, flaps down (kts)	62	69
approach speed (kts)	85	90
MAX range IFR (nm)	1,300	1,020
MAX cruise altitude (ft)	41,000	37,000
landing distance (ft)	2,060	2,500
takeoff distance (ft)	2,050	2,500
Projected first delivery	January 2004	Unknown

Table 6 - Eclipse 500 vs. Safire S-26

[77] Eclipse Aviation: http://www.eclipseaviation.com/inex.htm
[78] Safire Aircraft Company: http://www.safireaircraft.com/index.html

3.6 For the future

The idea of totally automated flight might seem impractical today especially because, for the commercial transportation industry, there are more than enough commercial pilots so there seems to be no point of choosing airplane with no human in the cockpit. Also, people in the aviation industry including pilots, air traffic controllers, FAA officials, and even engineers who design avionics are all very conservative when it comes to new technology. However, the technology does exist and it is being improved everyday for fully automated flights.

3.6.1 Technology from military

Many technologies were first developed for military use. Fly-By-Wire (FBW) technology was first introduced to fighter aircraft because it is essential for fighter planes to have high maneuverability and light weight. GPS was initially developed for military use. There are several other existing military technologies that can be transferred to civil aviation. Such technologies can help improve small airplane transportation and make it more accessible to general public with enhanced safety, reliability, and less difficulty.

3.6.1.1 Head Up Display (HUD)

HUD has been widely used in military aircraft for long time. It allows pilots to look outside and see various instrument data at the same time. Pilots can obtain attitude, altitude, speed, course target, traffic, and various other information that are necessary while looking through the wind screen. HUD can also assist pilots to land the airplane safely in low visibility.

3.6.1.2 Unmanned Aerial Vehicle (UAV)

Recently (2002,) the US Air Force has successfully done a flight test of X-45A Unmanned Combat Air Vehicle (UCAV). This aircraft can taxi, take off, and land with no outside commands. According to UCAV official web site[79], it is capable of accomplishing various strike missions.

Global Hawk is a surveillance unmanned aerial vehicle used by US Air Force. Once mission parameters are programmed into Global Hawk, the UAV can autonomously taxi, take off, fly, remain on station capturing imagery, return and land. Ground-based operators monitor UAV health and status, with the ability to change navigation and sensor plans during flight as necessary.[80] It is under testing at Edwards Air Force Base, Calif., and it has already had more than 1700 hours successfully.[81]

RQ-1 Predator is already in use by air force and Navy. It is a medium-altitude, long-endurance unmanned aerial vehicle system. Armed with two Hellfire missiles, it is being used currently over Afghanistan.[82]

Proteus is a test UAV built in Mojave. It has been used to test a collision-avoidance system for UAVs. On March 13, 2002, Proteus was had been tested for collision avoidance capability with various other UAV. Based on its onboard sensors detecting a collision potential, it relayed information of collision courses to ground controller, who picked a safe new course.[83]

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[79] Defense Advanced Research Projects Agency: http://www.darpa.mil/ucav/index.htm
[80] Aeronautical Systems Center U.S. AIR FORCE FACT SHEET: http://www.af.mil/news/factsheets/global.html
[81] ibid.
[82] U.S. Air Force Fact Sheet: http://www.af.mil/news/factsheets/RQ_1_Predator_Unmanned_Aerial.html
[83] NASA news releases : http://www.dfrc.nasa.gov/PAO/PressReleases/2002/02-15.html

Once the technology of military UAV is transferred to GA industry, it can be used to make auto-flight or assisted flight possible.

3.7 Environmental Solutions

3.7.1 Fuel Cell

Although currently the environmental effects caused by airplanes are not substantial at the time, nevertheless, with increase in flights, there usage would increase to levels that would be harmful. In order to reduce the pollution, fuel cells could be utilized to resolve most environmental concerns.

In principle, a fuel cell operates like a battery. But unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.

A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water, and heat.

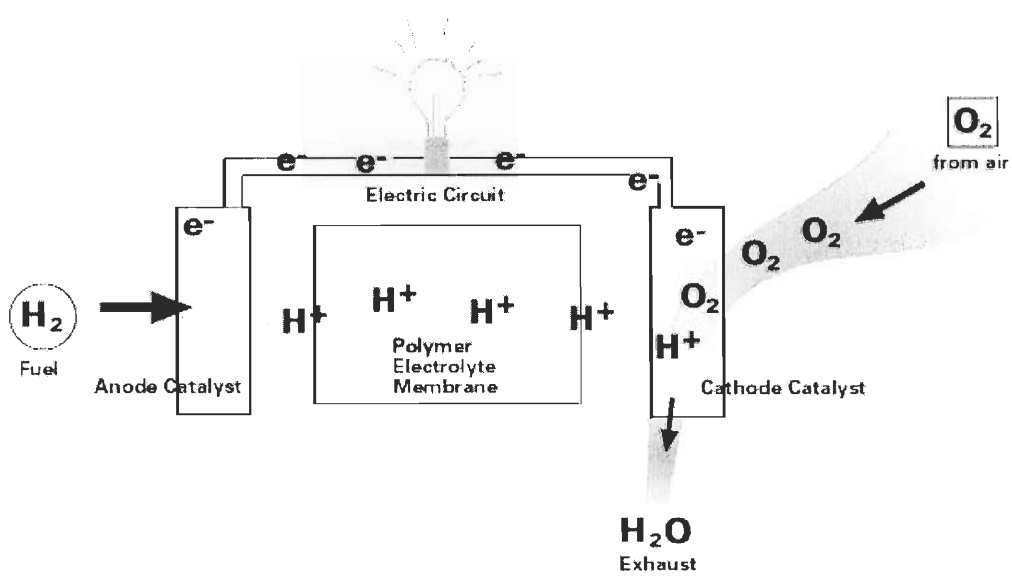

Figure 6 – How fuel cells generate energy[84]

[84] Fuel Cell: http://www.fuelcell.org

Hydrogen fuel is fed into the anode of the fuel cell. Oxygen (or air) enters the fuel cell through the cathode. The hydrogen atoms are encouraged by a catalyst and splits into a proton and an electron, which take different paths to the cathode. The protons pass through the electrolyte. The electrons create a separate electric current that can be utilized before they return to the cathode, to be reunited with the hydrogen and oxygen in a molecule of water.

A fuel cell system that includes a fuel reformer can utilize the hydrogen from any hydrocarbon fuel - from natural gas to methanol, and even gasoline. Since the fuel cell relies on chemistry and not combustion, emissions from this type of a system would still be much smaller than emissions from the cleanest fuel combustion processes.

3.7.1.1 Problems

Although fuel cells are efficient for use in stationary sites, they are considered to be less efficient for mobile vehicles because the unit for generating electricity is heavier than competing power sources such as gasoline engine.

The process of producing fuel cell's energy source, hydrogen, is very energy consuming, which is at least twice that needed to produce petrol from crude oil. There is a high loss of energy in the entire fuel cell cycle because of the fuel production requirements. Although an electric aircraft may be more environmentally friendly the cycle of producing the fuel cell may impact the environment.

Fuel cell will be less dangerous to the environment if moving vehicles are efficient enough to make up the losses during the production of hydrogen. A fuel cell must at least be 30 to 35 % more efficient than a gasoline or natural gas engine. This efficiency would be hard to be achieved in the immediate future since currently, diesel engines are more advanced and efficient in design, and the hypothetical use of the fuel cell in the next millennium is 20 or, at most 25% below that of diesel engines.

For automobiles, it is concluded that it is less expensive to make diesel engines more efficient than fuel cell-powered ones. However, for airplanes there may be advantages for fuel-cell electric power systems in terms of reduced noise and less emission.

3.7.1.2 Types of Fuel Cell

3.7.1.2.1 Proton Exchange Membrane (PEM)

PEM is a type of fuel cell that operates at fairly low temperatures (about 175 degrees F or 80 degrees C), has high power density, can vary its output quickly to meet shifts in power demand, and is appropriate for applications where quick startup is required.[85] According to Department of Energy (DOE), they are the primary candidates for light-duty vehicles, for buildings, and potentially for much smaller applications such as replacements for rechargeable batteries.[86] The proton exchange membrane is a thin plastic sheet that allows hydrogen ions to pass through it. The membrane is coated on both sides with highly isolated metal alloy particles that are active catalysts.[87]

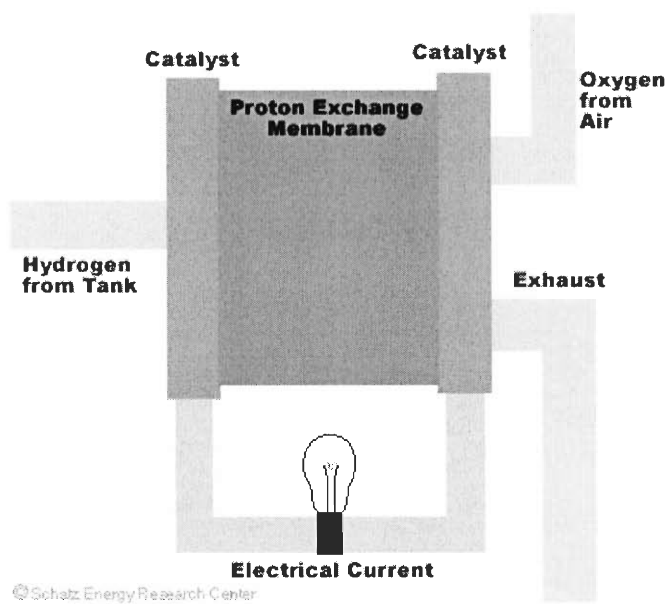

Figure 7 – How energy is generated by fuel cell by using PEM[88]

[85] SAE: http://fuelcells.sae.org/
[86] U.S. Department of Energy: http://www.energy.gov/
[87] SAE: http://fuelcells.sae.org/
[88] Humboldt State University: http://www.humboldt.edu/~serc/animation.html

The electrolyte used is a solid organic polymer which is an advantage because it reduces corrosion and in results reduces maintenance of the plane. Hydrogen is fed to the anode side of the fuel cell where the catalyst encourages the hydrogen atoms to release electrons and become hydrogen ions (protons). The electrons travel in the form of an electric current that can be utilized before it returns to the cathode side of the fuel cell where oxygen has been fed. At the same time, the protons diffuse through the membrane (electrolyte) to the cathode, where the hydrogen atom is recombined and reacted with oxygen to produce water, thus completing the overall process. This type of fuel cell is, however, sensitive to fuel impurities. Cell outputs generally range from 50 to 250 kW which will be enough energy to operate a GA airplane.[89]

3.7.1.2.2 Hydrogen Carriers

3.7.1.2.2.1 Ammonia

In addition to storing hydrogen itself, there are several liquids and gases that are readily available as hydrogen carriers. Examples are liquid hydrogen, methane, methanol, and ammonia. In Oshkosh, 2002 Dunn proposed to use ammonia as their primary source of hydrogen carrier in a demonstration of a fuel cell electric powered aircraft.[90]

Ammonia is the cheapest and safest way to carry hydrogen. It is nonflammable and liquid at atmospheric temperature and pressure, and therefore does not require any type of transformation in order to be stored. The high hydrogen density in ammonia results in the ease of energy storage as a liquid. In comparison, liquid hydrogen, unlike

[89] ibid.
[90] "E-Plane Presentation," by Jim Dunn (Oshkosh 2002)

ammonia, requires a lot of energy and cost to transform it to a storable state. Also, for a given volume, ammonia holds 1.7 times the amount of hydrogen than liquid hydrogen.[91]

Another advantage of ammonia lies in the process at which the hydrogen is cracked. When the ammonia is cracked: as shown in this equation $2NH_3 = 3\ H_2 + N_2$ it only produces nitrogen as its byproduct.[92] Nitrogen which makes up 78.1% of the air will not have any significant environmental impact.[93]

[91] Apollo Energy System: http://www.electricauto.com/HighDensity_STOR.htm
[92] ibid.
[93] Los Alamos National Laboratory: http://pearl1.lanl.gov/periodic/elements/7.html

3.7.2 E-Plane

One possible way of solving current issues of environmental pollution and future alternate fuel usage is the use of electric planes, or E-planes. Dunn and his partner Ekstrom, Advanced Technology Products, are developing a prototype of a fuel cell powered E-plane.

According to Dunn, the use of electric motor driven planes has advantages over the gas-powered ones for several reasons. One of them is the longer interval for overhaul. Gas powered engines, namely 80 hp Rotax engines that power small airplanes must be overhauled every 800-900 hours. Larger engines from companies such as Lycoming and Textron are overhauled at 2000 hours.[94] By changing the engine to an electric drive motor, the overhaul period can be increased to 10,000 hours without a problem. This means that electric drive motor is much more reliable than gas-powered ones.[95]

The main reason that Dunn uses a fuel cell for powering this airplane is that solely relying on batteries would not provide enough endurance. Gasoline is rated at 13,000 watt-hours per kilogram, whereas some of the best lithium batteries only rate at 150-200 watt-hours per kilogram.[96] Therefore Dunn chose a plane that will use Proton Exchange Membrane (PEM) fuel cell for its main source of power. It will be used to provide cruising power for the E-plane.

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[94] Lycoming and Textron - http://www.lycoming.textron.com/main.jsp?bodyPage=/support/publications/keyReprints/general/lowTimeEngine.html
[95] EV World: http://evworld.com/databases/storybuilder.cfm?storyid=252
[96] ibid.

Dunn's ultimate goal of the E-plane is to make an airplane so it performs equally to the reciprocating engine airplanes. American Ghiles Lafayette, a gasoline powered airplane, is one of the most efficient light aircraft ever built, which can carry two adults at more than 160 mph with only an 80hp engine, and will be used as the frame for the prototype of the E-plane.

One of many challenges making the E-plane is to provide enough electric power for the on-board avionics.[97] Minimal electrical power to provide electricity to the E-plane's avionics is available due to the fact that fuel cells cannot generate more than 300 volts and 600 amps. However this will not be much of a concern with adequate shielding, according to Dunn. Moreover, since the developing E-plane is a prototype, it will have few electronics to be operated. It could be an issue later on to provide enough electricity to fully function an E-plane.

Dunn sees an eventual use of fuel cell in the future where its use will become practical, a result of billions of dollars being spent on research.[98] He thinks that instead of PEM, which he is currently working with, either solid oxide or direct methanol fuel cell may be used.

[97] ibid.
[98] ibid.

3.8 Target Market

Public perception has always played a key role in the adoption of new technologies. This poses a great problem for the adoption of SATS by the general public.

It is a commonly known fact that small airplanes have a worse safety record than big airliners. This reality that is further emphasized by the countless stories constantly heard on the news about deadly small airplane crashes. Thus, a certain amount of uncertainty exists concerning the safety of small aircraft in the general public, who are not very familiar with the world of aviation. The airlines on the other hand have an outstanding safety record; in 1998, not one person died on a scheduled flight on a US airline, compared to about 20 people a day dying in car crashes.

Therefore the general population has been exposed to the fact that small airplanes are not and can not be as reliable as the big airliners; as if to say, bigger is safer. Since people have been exposed to this idea for the past few decades it will be hard to get rid of this preconceived notion. That is, even if small airplanes are made as safe as the big airliners the general public will still perceive that there is a higher risk involved by traveling on a small airplane.

Therefore in the foreseeable future, in order for small planes to make a difference and grab the attention of the masses, they will have to be reorganized as an operating fleet, seen as a new national system of air taxis. A supply of inexpensive, safe, comfortable small planes, flown by hired pilots and available at rates comparable to today's coach air fares, could bring freedom and convenience to a broader share of the traveling public. At the same time presenting this new technology to the general public in a safe viable way will promote its usefulness to the risk taking population and eventually create confidence in the minds of skeptic civilians.

People tend to fear what they do not understand. In addition society has guided human nature to be very conservative, unwilling to take risks. If one goes back to the time of the Wright brothers and asked the average person if they would travel on an airplane, the answer would have been: "You have to be kidding." Over time that changed as airlines became safer, cheaper, routine, and omnipresent. The same could happen to general aviation if it becomes safer, cheaper, routine, and ubiquitous. Therefore, if history gives any indication of how fast people's perceptions might change, one can be certain that it won't happen overnight.

From a marketing perspective the implementation of SATS is considered to be a discontinuous innovation since it forces people to modify their current travel behaviors in order to adapt to SATS. Hence, its success will be based upon the attitudes that people will assume towards the adoption of this new technology.[99]

As a result, the Technology Adoption Life Cycle model which "describes the market penetration of any technology product in terms of a progression in the types of consumers it attracts throughout its life."[100] As can be seen below this model is represented by a bell curve with different groups that are distinguished from each other by their characteristic response to discontinuous innovation. In addition, since each group represents a unique psychographic profile, understanding each group and its relation with its predecessor is an essential part of high-tech marketing.[101]

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[99] Geoffrey Moore, *Crossing the chasm: marketing and selling high-tech products to mainstream customers* (New York, Harper Business, 1999) 78.
[100] Geoffrey Moore, 71-73
[101] ibid.

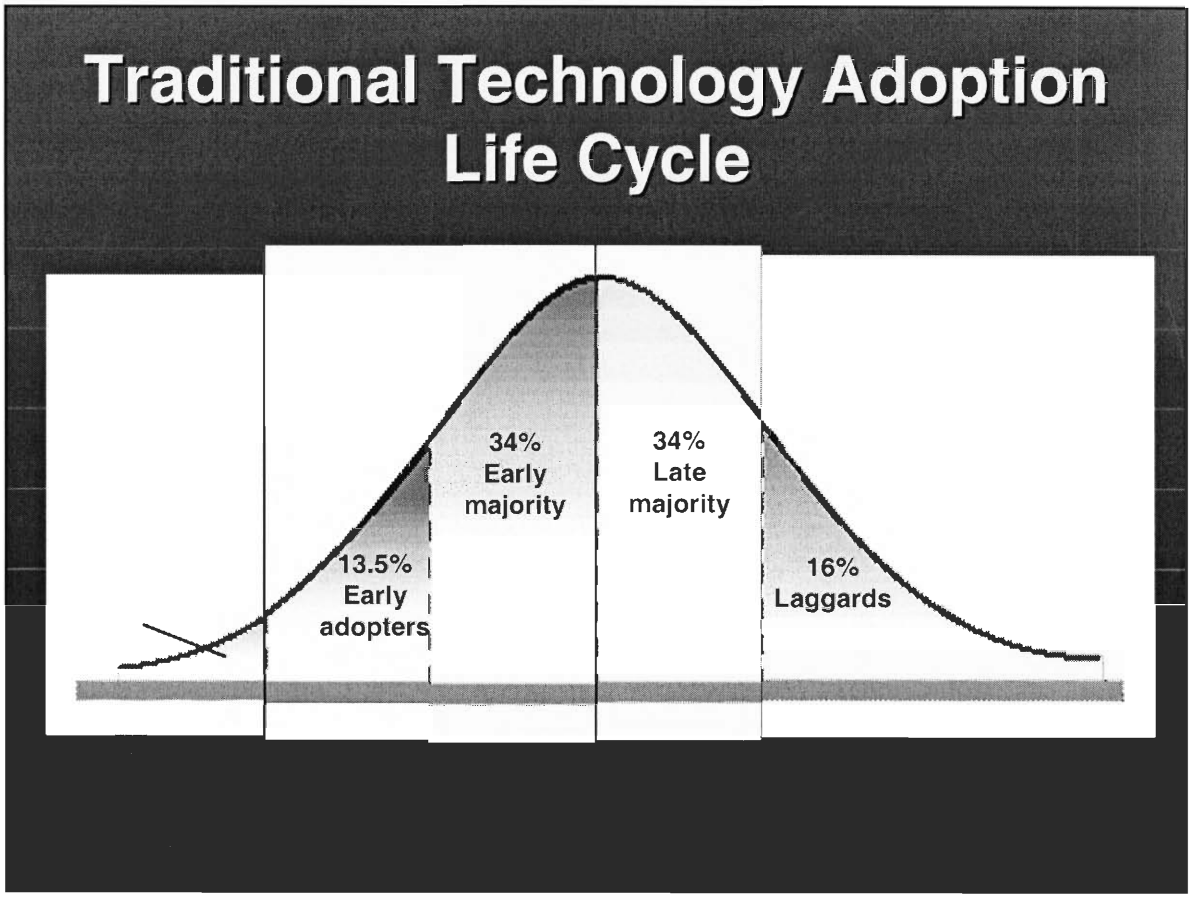

Figure 8 – Traditional Technology Adoption Life Cycle[102]

Innovators are those who aggressively pursue new product technologies.[103] They have developed a need for the product and therefore are the few that seek the product out before it has even been introduced into the market. For SATS this group will consist of the current users of air taxis since these people have developed the need for flexibility of travel which is of more concern than the high price associated to meet this need. As a result, these innovators should quickly adapt to SATS since it brings the freedom of mobility that they are currently experiencing with the added benefit of low costs. The

[102] University of Alabama in Huntsville:
http://cas.uah.edu/simpsonj/powerpoint/mkt_606/mainstreammarkets.ppt
[103] ibid.

innovators support of SATS will be of great importance since their adoption will serve as an example for other consumers by creating confidence in the minds of later adopters.

From here one moves into the early adopters which will be represented by the current businessmen who are forced to travel by commercial airliners due to the high price of the current air taxis. This group will be able to easily understand and appreciate the advantages that SATS will bring into their current lives given that they can easily relate these benefits to an improvement in their lifestyles.

The successful action of the early adopters will open the door to the early majority which represents a much larger market segment. This group is driven by a strong sense of practicality and is not conducive to risk taking; therefore they wait until the technology has been proven before plunging in, usually following the lead of the early adopters. Furthermore since the early majority usually represent about 1/3 of the whole adoption life cycle, winning their business is crucial to obtaining substantial profits and growth.[104]

Following are the late majority which believes more in tradition than progress. They are uncomfortable with technology and as a result wait until something has become a standard before buying into it.[105] This means that these people will not be willing to fly SATS airplanes until it becomes really inconvenient to travel by other means.

Finally there are the laggards. These are people who do not want anything to do with new technology, either because of personal or economic reasons. As a result, they are usually regarded as a group that is not worth pursuing.[106]

The hope is that business people will lead the way since it is for them that time is most valuable. One can not put a price on what it means for an executive to spend a night

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[104] ibid.
[105] ibid.
[106] ibid.

at home with his family instead of in another hotel. After the volume of flights increase, due to the regular use of business men, the price will go down and open the door for the average person to be able to experience the advantages of on demand air travel. Eventually as more and more people are able to confide about the safety and advantages of SATS its expected popularity and successfulness will be achieved.

4 Evaluation

4.1 Difficulty of Implementation

4.1.1 Social Acceptance – A Brief History of Transportation

The history of civilization is characterized by humans learning to interact with each other. At first humans were cavemen that lived among animals spending their lives as nomads traveling in search of food. They had no formal way of communicating and behaved, in many ways, like wild animals do today. Little by little the human race started to put their creativity into use and developed many instruments that improved living conditions.

Many generations later the human race finally became a civilized society. They were able to develop an alphabet which enabled us to amass information about our experiences, ideas, innovations, fears, knowledge, etc. Furthermore people stopped wandering aimlessly around the earth in search of food and started to settle down, thus giving rise to cities. Consequently, in an effort to bring harmony to the cities, humans eventually developed governments, an economy, laws, social classes, etc. Here is where humans give rise to what modern society is today.

As the years went by and a greater amount of people became civilized, cities became larger and started to appear in virtually every corner of the world. This eventually gave rise to a greater need for transportation. During these times the horse represented the only means of mobility other than walking. Further complicating this dilemma was the fact that horses were not very abundant; it was considered a privilege to be fortunate enough to own one. Even in the 13th century less than 5% of the population actually owned a horse.

As a result, most people spent their whole life without ever riding a horse, having to deal with all their mobility needs by foot. Therefore it was not uncommon for a peasant to live 50 years in the same house without ever wandering more than 10 miles away from his residence. This lack of mobility hampered the growth of cities since it limited the amount of social contact (and therefore trade) between cities. Just try to imagine the social and economic impacts of a modern society that has a very limited contact with not only other countries, but its neighboring cities. To get an idea people can presently look at Cuba and see the effects that the US trade embargo has had on the country; but keep in mind that the situation could be much worse since Cuba still has the ability to move from place to place and practice commerce within the country thanks to the technology that has created mobility.

As the years passed, horses became abundant and available to many, but they only resolved mobility problems in and around each community, what is today a couple of hours on a car were then a few days away on a horse.

Then in the 19th century the emergence of railroads revolutionized the way that society traveled. The railroad was the first human invention that enabled relatively high speed long distance travel, what used to be a two weeks journey by horse could be accomplished in a little over a day on a train. The railroads also posed more advantages than just an increase in travel speed. Since a train is able to transport a large amount of goods or people on a single trip, it opened the doors to a new economic revolution. Cities were now able to easily trade goods with cities that were thousands of miles away.

Therefore the train united countries in ways that were not possible before its invention; it created a sense of unity, of a country joined together by trails of steel.

Despite the great impact of the railroads, transportation around and inside the cities remained a problem. A problem that was resolved with the invention and mass production of the automobile.

The car when it was first introduced was looked upon as a toy for the rich. However, in just a few years it became very popular among the general population as more people became aware of the advantages it brought into their lives.[107] The automobile brought a sense of freedom to the travelers, something they had not experienced until then. The travelers could now travel on their own terms; they could go where they wanted, when they wanted. In effect, the car was able to combine the some of the speed and range of a train with the flexibility that personal transportation such as the horse or bicycle provided.[108]

As cars became popular they were able to free the "common people from the limitations of their geography".[109] Just a few years ago, in the days of the horse drawn transportation, the practical distance of wagon travel was just 10 to 15 miles. That meant that any community or farm that was isolated by more than 15 miles from either a waterway, a railroad or a city was isolated from practically all economic opportunity and social life.[110] As a result the car created mobility on a scale never imagined before, by narrowing the gap between rural and urban life.

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[107] University of Colorado: http://www.cs.colorado.edu/~l3d/systems/agentsheets/New-Vista/automobile/history.html

[108] The Growth of Automotive Transportation: http://www.klhess.com/car_essy.html

[109] University of Colorado: http://www.cs.colorado.edu/~l3d/systems/agentsheets/New-Vista/automobile/history.html

[110] ibid

In the city, the effect of the car was even more prominent than on the farms as complex innovations such as the supermarkets were made possible by the existence of the automobile. On the other hand, their growth (by replacing the corner grocery store) along with the rapid growth of the suburbs transformed the automobile more into a necessity than a luxury. [111]

For the reasons mentioned earlier, cars quickly replaced the primary source of transportation, which at the time were horse drawn vehicles. This change in travel is reflected in the following graph.

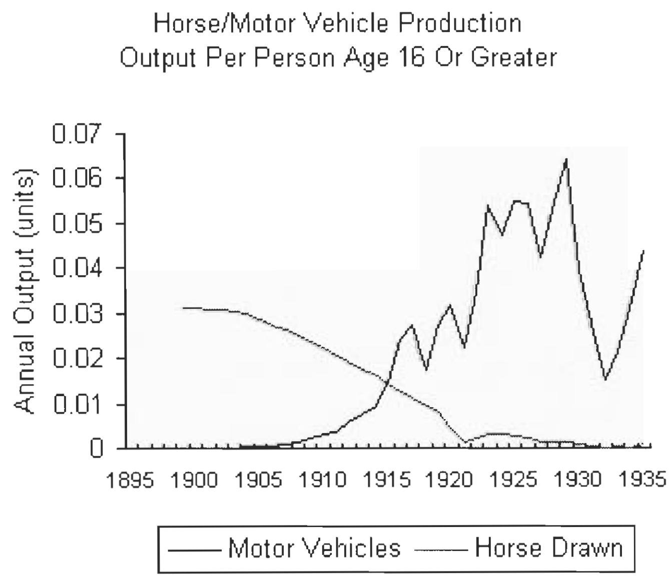

Figure 9 – Horse/Motor Vehicle Production[112]

Railroad passenger traffic was also greatly affected by the growth and adoption of the automobile as rail passenger miles per capita began to steadily decline as can be seen in the graph below. People began choosing cars over railroads since the car allowed travelers to create their own schedule and because cars had the advantage of being able to

[111] The Growth of Automotive Transportation: http://www.klhess.com/car_essy.html
[112] ibid.

arrive at their exact location instead of a railway station. The automobile created the opportunity for travelers to go wherever they wanted whenever they wanted.

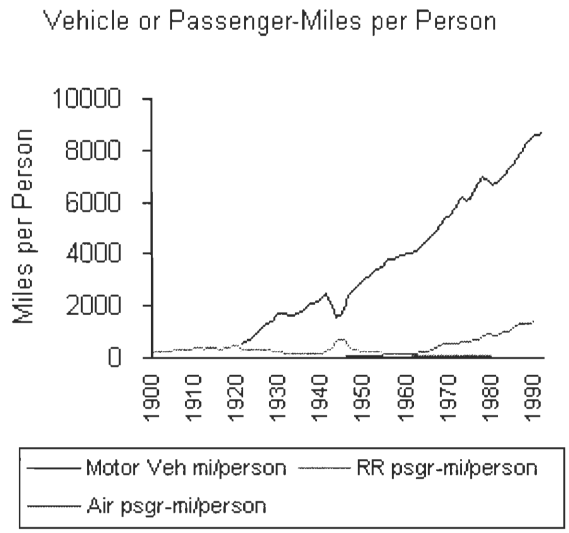

Figure 10 – Vehicle or Passenger M[113]

On a national level, the construction of better roads further increased travel throughout the nation.[114] Today there are over 265 million yearly intrastate trips and over 241 million interstate trips being made in personal use vehicles. This means that over 59% of all intrastate and 56% of all interstate trips are using personally owned vehicles for transportation.[115]

In the 1950's, with the introduction of the airplane as a means of commercial transportation the airlines were replacing the railroads and ocean liners as the primary means of long distance travel. This created a social revolution in which for the first time in history people were able to connect every corner of the globe. The economic, social, and political consequences of this included the creation of global markets, opportunities

[113] ibid.
[114] ibid.
[115] Department of Transportation: http://www.dot.gov

for global travel undreamed of just a few decades ago, and increased cultural homogeneity.[116]

4.1.1.1 Private Travel vs. Public Transportation

In the past decade, the development of new technologies have started an ongoing trend for on demand products and services that adapt to the customers' needs and schedules instead of vice versa. People can get their money from an ATM anytime, do banking from a PC at 3am, order any product on line 24hrs a day, etc. Practically all the services today are geared towards making it easier for the customers to control their time, instead of the customers having to adapt to the services availability. This, in conjunction with the fact that the Americans mentality believes that they are entitled to privacy, independence, power, and control, reinforces the need for personalized travel.

As services evolved in an attempt to meet the customers' every needs, Americans have been instilled with the desire to be in charge of their privacy and control. The car allowed travelers to perceive their trips as private since they could be alone in the privacy of their cars, even though they would never be alone on the road.[117] Cars also encompassed the need for independence and control as drivers feel more confident feeling that they are in charge of their fate when they are at the wheel, instead of giving up control to someone they do not know or trust.

[116] American Institute of Aeronautics and Astronautics: http://www.flight100.org/history/us.html
[117] Brown University: http://envstudies.brown.edu/classes/ES201/2000/energy/transportation/behavior.htm

4.1.1.2 Societal Effect

With the emergence of new technologies and the development of virtual travel and telecommunication, a threat is being posed to the travel industry. It is becoming easier for people to stay at home instead of traveling in both their personal lives and business lives, which raises the question of why travel will be increasingly important in the future. The internet is allowing people to chat, email, shop, and conduct business meetings all from the privacy of their own homes. This new trend towards technology means that no one will have to leave their homes, and all commerce will be able to be transacted by use of the internet.

With this threat of technology facing the travel industry, it is important to understand the importance of personal communications in both the business world and the human social structure. Once these issues are understood, it is clear to see that telecommunication will never be able to take the place of travel and personal contacts. The social structure of the modern world does not allow for a replacement of human contact, and human beings, as social animals desire "co-presence within social life".[118] "Co-present interaction is fundamental to social intercourse; virtual travel will not significantly replace physical travel. The modern world produces no reduction in the degree to which co-present interaction is preferred and necessary across a wide range of tasks"[119]; a few of reasons that humans simply can not do without travel or personal communications include:

> *Legal, economic and familial obligations either to a specific person or generic types of people*: to have to go to work and conduct meetings, to attend important

[118]John Urry "Mobility and Proximity" (Lancaster University, Sociology Department).
[119] ibid

family events (weddings, christening, funerals, holidays, and so on), to meet legal obligations or to have to visit a public institutions (schools, hospitals etc.) These will mostly be impossible to stimulate with virtual travel, allowing corporeal travel to thrive.

Social Obligations: to see specific people 'face to face'. To note their body language, to hear what they say, to meet their demands, to sense people directly, to develop extended relations of trust with others, to converse as a side-effect of other obligations. Co-presence is required in these situations; virtual travel may reduce this amount of co-presence but will not replace it.

Time Obligations: to spend moments of quality time with family, partners or friends. It is impossible to simulate through virtual travel.

Place Obligations: to sense a place or kind of place directly, such as walking within a city, visiting a specific building, being by the 'seaside', climbing a mountain, strolling along a valley bottom. Increased visual and VR information about different places and their unique characteristics will probably heighten the desire to be corporally present at the place in question and hence to travel there.

Live Obligations: to experience a particular 'live' and not a 'mediated' event (political events, concerts, theatres, celebrations. With the emergence of technology the notion of what is considered 'live' will change, allowing an increasingly large amount of events to be mediated instead of attended.

Object Obligations: to sign contracts or to work on or see various objects, technologies or texts that have a specific physical location.[120]

All these factors will help maintain the popularity of travel, and will not erode the human need for physical proximity. Humans simply do not feel comfortable being transformed into virtual communications and 'bits' of them over the internet, people prefer to touch, smell and taste than just to see and hear. With the increased emergence and steadily increasing advances offered by virtual travel this will only "promote more extensive local ties and hence more corporeal travel"[121]. This will lead to an increased demand for fast, personal travel, which will be achieved with the introduction of SATS.

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[120] ibid.
[121] ibid.

People have been taught that humans have the right to travel and that they should travel, they should visit other places such as their family living far away from them. The ability to physically explore new places and learn more about the world can only be done in pure physical surroundings, not through telecommunication.

Even with all the good intentions and excellent reasons that traveling is far more advantageous than telecommunications in order to maintain a social world it is also important to realize that in the world today time is a luxury and it is sometimes harder to find the time to travel rather than the money to travel. In a society of fast food, customer service designed to revolve around customer needs and the ability to do almost anything online at whatever time of day people choose, people have learned that time is a luxury and that they don't want to waste any time doing anything, this leads to the choosing of telecommunications over personal travel. Thanks to SATS travel time will be greatly reduced allowing travelers to create their own schedules, travel at their own leisure and not waste time driving endless miles to arrive at their destination; all this will be available with the added bonus of American right to privacy and control over their own aircraft. The ability to cut down on large amounts of time is one of the greatest strengths of the SATS as customers will feel the same importance they do from customer service, the ability to make travel time revolve around their lives and their schedules instead of vice-versa.

It is likely that because of the value of time to Americans, a greater number of people will choose SATS over cars, or at least as a complement to driving. SATS offers, in essence, the same advantages that are offered by cars, and therefore a shift from cars to SATS can be expected as a shift from horse drawn carriages to cars was seen in the past.

SATS will offer the convenience of personalized travel, individual mobility, privacy, and a sense of control; these are the same fundamental offerings as the automobile, offerings that the American culture has become innately attached to and now considers these their fundamental right. The most pronounced difference between cars and SATS (besides the fact that driving is done on the ground and SATS makes use of the sky) is the advantage of faster travel; therefore more time would be saved by flying rather than by driving.

As the emergence of cars brought on the ability to increase intra and interstate commerce thanks to newfound contacts between cities and towns it can be expected that SATS will be able to produce this same effect on an even larger scale. Having already seen how air travel has increased commerce, but SATS will allow personal commerce, and even small business will be given the opportunity to foster new relationships with other small businesses across the state or country, a phenomenon that has been held back by lack of time to drive cross-state.

Technology is a threat to the social world which people have grown accustomed to, and "declining social capital within the US is already reflected in far less frequent face-to-face conversations." It is viable to be concerned about the possibility of more advanced technologies becoming a threat to more than just social life. As the development of the car helped aid the expansion of cities and created the existence of suburbs more land has been used, creating an increase in commercial interests which "have found it profitable lo locate housing (gated communities), (gated) workplaces, retailing (gated shopping centers), leisure (gated) theme parks, and so in separated zones."[122] The emergence of these zones will rely greatly on personal mobility, without which they will not be able to exist.

SATS will allow faster travel and relocation from place to place, allowing these new developments to become popularized and thrive, aiding the economy and increasing the availability of commerce, creating commerce in places where presently it does not exist. This increase in mobility will also allow for the creation of new communities, new towns will emerge from the usage of rural land that once was not used because even with cars these places seemed too far away from the 'real world' in the future, with the help of SATS these rural communities will only be minutes away from the 'real world'. The real 'live' contacts that will be enhanced by co-presence will aid in generating trust among people in both the social and economic world. This trust that comes from live contact can not be replicated in the virtual world. Most importantly with personal contacts people have the ability to make eye contact with each other, a big factor upon which humans chose whether or not to place our trust in certain people. "Eye contact enables the establishment of intimacy and trust, as well as insincerity and fear, power and control".[123] Eye contact has been termed as "the most direct and 'purest' form of social interaction".[124] As the need for personal communication has been explored it is obvious to see that the emergence of SATS will become a necessity in the future and will aid the development of human life in all ways.

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[122] ibid.
[123] ibid.
[124] ibid

4.1.2 New technology, FAA, and Industry

The general public tends to believe that the aviation industry is always on the leading edge of technology; that airliners are flying with the most sophisticated computers and mechanics. Therefore, they would be surprised to know that their home PCs are faster than the computers used for ATC and the computer responsible for controlling the Flight Management System (FMS) of the widely used Boeing 747 model 400 airplane. Today's commercial aviation is actually one of the most conservative industries since pilots, air traffic controllers, FAA officials, and engineers recognize safety as their primary concern.

Pilots and air traffic controllers are very skeptical about accepting new technologies. When the new generation Boeing 747-400 came out in 1985, the majority of pilots were opposed to the idea of not having a flight engineer. Many pilot unions made their companies require a flight engineer in the cockpit even though there was no panel for the flight engineer in the cockpit of a B747-400 airplane. When airbus industry launched the first Fly-by-wire (FBW) airplane, the A320, every commercial pilot opted never to fly FBW airplanes.

Today's enroute air traffic controllers have displays that show information such as flight number, aircraft type, speed, direction, altitude, weather, wind direction, and conflict alert. However, many controllers like to keep their displays as primitive as possible. As an example, avionics companies still produce circular shaped radar displays for enroute controllers even though better alternatives are available.

Since pilots and controllers, the primary users of these systems, tend to be conservative, engineers in the aviation industry must also become conservative in order to be able to sell their products. On the other hand, new technologies can only become reliable after being used in real situations for an extended amount of time as there is no way for engineers to perfectly simulate real situations.

The main reason for the conservativeness surrounding the aviation industry is that new systems and interfaces are more likely to cause human errors. For an industry in which a single error can have catastrophic consequences, it is understandable why new technologies are hard to be accepted.

4.2 Environmental Evaluation

Three different kinds of airplanes are considered in order to compare their emissions of NOx. Each of these planes is used as a sample to represent their class of airplanes.

The Boeing 757 is primarily used for commercial traveling purposes, carrying over 200 passengers. Bombardier Learjet 31A is used as private business jets which seats seven passengers. The Eclipse 500 is a new type of small jet airplane which is an innovation for its smaller engines, relatively cheaper price, and lower operating cost comparing to the other jet airplanes in its class.

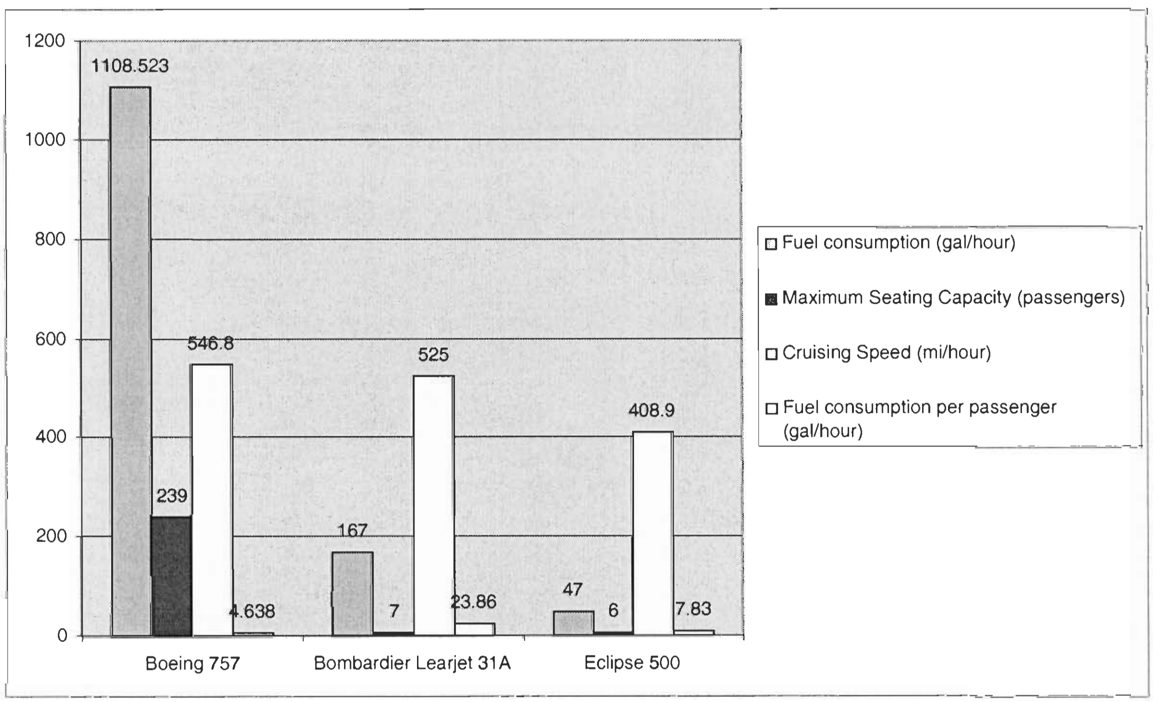

Table 7 – Fuel Consumption, Maximum Seating Capacity, and Fuel consumption per passenger[125]

[125] Boeing : http://www.boeing.com/commercial/757family/flash.html
Bombardier Learjet 31A: http://www.bombardier.com/en/3_0/3_2/pdf/Learjet_31A_Fact_Sheet_en.pdf
Eclipse Aviation: http://www.eclipseaviation.com

The Boeing 757 has an advantage over other planes in terms of its fuel consumption per passenger and speed because the large airplane can seat many passengers at once. The Bombardier Learjet 31A is almost as fast as the Boeing 757 but it lacks the fuel consumption per passenger mile. The Eclipse 500 is slow but its fuel consumption is efficient almost enough to match that of Boeing's 757.

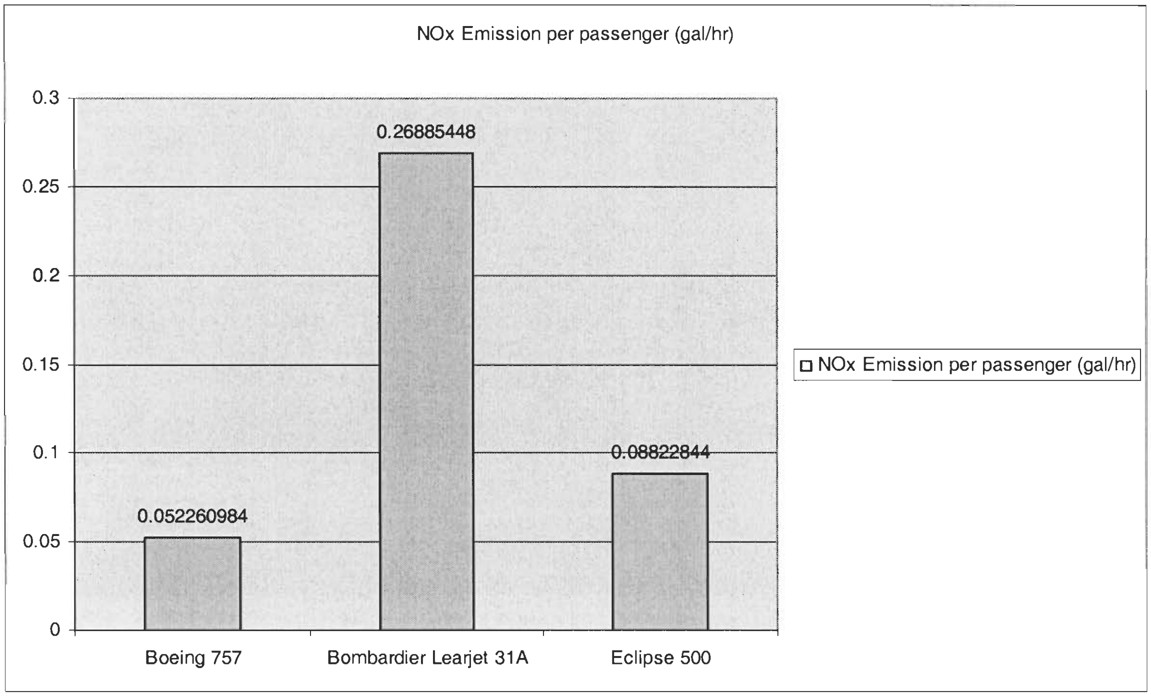

Table 8 – NOx Emission per passenger

The NOx emission is calculated by multiplying the average percentage of NOx emitted in jet airplanes in a gallon of fuel, which is 1.1268 %. After having done the calculation, it is easy to see that the Boeing 757 emits the least amount of NOx per passenger mile.

The Eclipse has considerable advantage over Bombardier Learjet 31A for emitting less NOx pollutant. However, this is almost the double the amount that of

Boeing 757. If people were to replace their traveling on Boeing to Eclipse, there is no doubt that the emission of NOx will increase in the air.

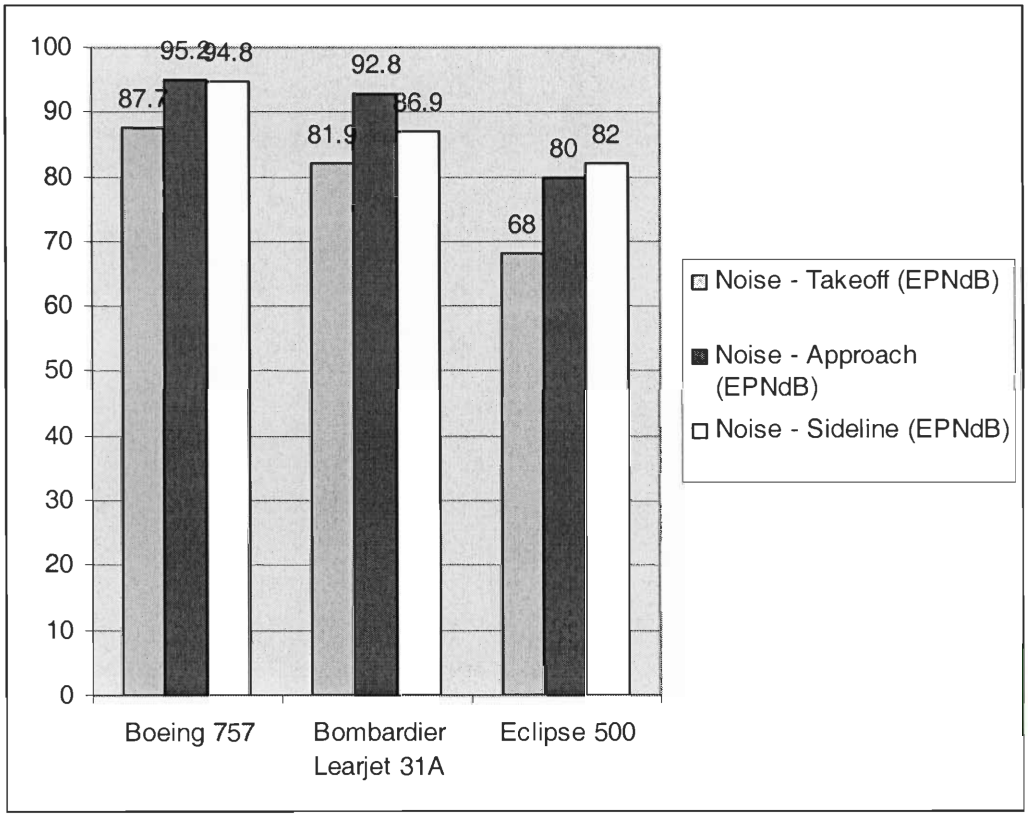

Table 9 – Noise emission for each airplane[126]

As for noise emission, the Eclipse 500 has advantage over Boeing 757 and Bombardier Learjet 31A for its low noise due to its efficient EJ22 turbofan engines. However it is noted that the Eclipse 500 carries the least passenger while the Boeing 757 can carry as many as 40 times or more.

[126] Boeing : http://www.boeing.com/commercial/value/quieter.html
Bombardier Learjet 31A: http://www.bombardier.com/en/3_0/3_2/pdf/Learjet_31A_Fact_Sheet_en.pdf
Eclipse Aviation: http://www.eclipseaviation.com

5 Conclusion

The current hub and spoke system forces approximately 80% of all commercial air passengers to pass through at least one of the major hubs regardless of their departure and destination points. This has allowed commercial airlines to manage their fleets more efficiently and offer cheaper travel, but at the same time it has taken a lot of the freedom and flexibility of travel away from the passengers.

In addition, it is a widely known fact that the current hub and spoke system is reaching the limits of its capacity. Furthermore, it is predicted that airline traffic in the United States will double by the year 2010 with most of the increase occurring in the twenty eight already busiest airports. This represents a serious challenge for the current hub and spoke system since most major airports and their surrounding airspaces are already working at or very close to their maximum capacity.

As a result, if a new transportation system that will help alleviate congestion at the major hubs is not implemented in the near future, travel times will be exponentially increasing in proportion to the level of overcrowding experienced at these major airports. Therefore, in the upcoming information age when time will become the most valuable commodity and speed is at a premium, the nation's doorstep-to-destination travel speeds will be declining overtime; thus limiting most economic expansion to well connected regions and communities.

A possible aid to the problems affecting the hub and spoke system will be the implementation of a national system of air taxis. Under this new system a passenger would be able to make a reservation and within a couple of hours have an airplane and a pilot waiting for them at their local airport. Further into the future the air taxi system will be replaced by fully automated planes that would allow civilians to become their own pilots and obtain total control of their traveling needs.

The first step is to implement a national system of air taxis that will bring flexibility and decreased travel times to its users by permitting near-all-weather direct access to over 5000 publicly accessible airports that are not currently being used by commercial airlines. The implementation of this system would be made possible due to cheaper, faster, safer, more reliable airplanes such as the upcoming Eclipse 500 and the Safire S-26.

This system will begin its implementation around 2010 when a good amount of planes like the Eclipse will be available. However in order for this system to be economically feasible there needs to be a considerable market that will constantly keep the airplanes in the air. A quick societal adoption is the key since the amount of time needed to fully implement this system will depend upon the number of planes that are readily available and the level of existing customer demand.

The air taxi system is expected to be fully implemented within ten to fifteen years after its launch. Within this time frame there would be enough technological advancement for the Eclipse like jet planes to be made safer, more reliable, and ubiquitous, and therefore will gain social acceptance from the majority of the population.

Although the air taxi system would be fully implemented there would still be a need for airlines. They would still represent the best alternative for long distance travel between major hubs. The increase in the air traffic would be handled by the Communication Navigation Surveillance/Air Traffic Management (CNS/ATM) system.

Further into the future, with more airplanes in the air, additional pollution would be expected. While, it is true that new technologies are being researched, and may perhaps be introduced, the increasing number of planes would result in pollution rates equal to or greater than those experienced today.

Fuel cell technology could efficiently address this problem. Although the process of making fuel cells produces some polluting emissions, airplanes using fuel cell technology do not emit harmful pollutants directly into the sensitive high atmosphere. Currently, fuel cells can not power large, heavy aircraft. Using present technology, they can only be used for small planes. Nevertheless, they offer a preliminary alternative to fossil fueled energies in terms of reduced emission.

Currently fuel cell technology is the most viable source of energy that has the potential to solve the ongoing environmental problems caused by high altitude emissions. In order for humans to inhabit earth far into the future, they will need to change their life styles to be more sustainable with the environment by using such environmentally friendly technologies.

6 Appendices

Appendix A - Major Airport Performance

Appendix B - Air Traffic Management

Appendix C - Traffic Alert and Collision Avoidance System (TCAS)

Appendix D – Airspace

Appendix E - Number of U.S. Airports

Appendix F - Number of Air Carriers, Railroads, Interstate Motor Carriers, Marine Vessel Operators, and Pipeline Operators

Appendix G - System Mileage within the United States (Statute miles)

Appendix A – Major Airport Performance

Annual Flight Delay Averages: 2000-2001
Major Airlines at All Airports
Source: Bureau of Transportation Statistics

All U.S. Airports

Year	Arrivals			Departures					
	Average Delay (minutes)	Percent On-Time Arrivals	Percent Delayed 15 minutes or more	Average Delay (minutes)	Percent Delayed 15 minutes or more	Cancelled	Percent Cancelled	Total Number of Flights	Number of Airports
2000	10.4	69.04	27.41	11.3	23.21	187,490	3.30	5,683,047	203
2001	5.5	73.40	22.51	8.2	19.78	231,198	3.87	5,967,780	229

Top 32 Airports

Year	Arrivals			Departures					
	Average Delay (minutes)	Percent On-Time Arrivals	Percent Delayed 15 minutes or more	Average Delay (minutes)	Percent Delayed 15 minutes or more	Cancelled	Percent Cancelled	Total Number of Flights	Number of Airports
2000	10.6	67.99	28.06	12.3	24.70	142,709	3.63	3,934,520	32
2001	5.4	72.62	22.94	9.0	21.05	166,118	4.11	4,039,315	32

NOTE: The Top 32 Airports are Atlanta (ATL), Baltimore (BWI), Boston (BOS), Charlotte (CLT), Chicago Midway (MDW), Chicago O'Hare (ORD), Cincinnati (CVG), Dallas/Ft. Worth (DFW), Denver (DEN), Detroit (DTW), Dulles (IAD), Fort Lauderdale (FLL), Houston (IAH), Las Vegas (LAS), Los Angeles (LAX), Miami (MIA), Minn-St. Paul (MSP), Newark (EWR), NY Kennedy (JFK), NY LaGuardia (LGA), Orlando (MCO), Philadelphia (PHL), Phoenix (PHX), Pittsburgh (PIT), Portland (PDX), Reagan National (DCA), Salt Lake City (SLC), and San Diego (SAN).

Table 9 – Annual flight delay average

Summary of Airline On-time Performance, 1995-2001

Source: Bureau of Transportation Statistics
Data as of February 13, 2001

Year	Number of				
	Operations	Late Arrivals	Cancelled	Late Departures	Diverted
1995	5,327,435	1,141,647	91,905	919,839	10,492
1996	5,351,983	1,362,702	128,536	1,102,484	14,121
1997	5,411,843	1,193,678	97,763	944,633	12,081
1998	5,384,721	1,227,741	144,509	1,014,904	13,161
1999	5,527,884	1,320,591	154,311	1,091,584	13,555
2000	5,683,047	1,557,784	187,490	1,319,153	14,254
2001	5,967,780	1,343,608	231,198	1,180,673	12,909

Year	Percent On Time Arrivals	Percent Late Arrivals	Percent Cancelled	Percent Late Departures	Percent Diverted
1995	76.65	21.43	1.73	17.27	0.20
1996	71.87	25.46	2.40	20.60	0.26
1997	75.91	22.06	1.81	17.45	0.22
1998	74.27	22.80	2.68	18.85	0.24
1999	73.07	23.89	2.79	19.75	0.25
2000	69.04	27.41	3.30	23.21	0.25
2001	73.40	22.51	3.87	19.78	0.22

Table 10 - Summary of airline on-time performance

Major Airports: Percent Of Late Arrivals

15 minutes or more behind schedule

Source: Bureau of Transportation Statistics

January - December, 2000		January - December, 2001	
Airport	**Percent**	**Airport**	**Percent**
NY LaGuardia (LGA)	42.95	NY Kennedy (JFK)	30.99
San Francisco (SFO)	39.22	Seattle (SEA)	30.67
Chicago O'Hare (ORD)	36.78	NY LaGuardia (LGA)	29.38
Boston (BOS)	34.46	San Francisco (SFO)	28.62
Los Angeles (LAX)	33.44	Boston (BOS)	28.25
Philadelphia (PHL)	33.28	Philadelphia (PHL)	27.59
Seattle (SEA)	32.31	Chicago O'Hare (ORD)	27.03
Denver (DEN)	31.80	Los Angeles (LAX)	26.08
Newark (EWR)	30.76	Newark (EWR)	25.24
Dulles (IAD)	30.22	Miami (MIA)	24.46
Las Vegas (LAS)	29.55	Reagan National (DCA)	24.04
San Diego (SAN)	29.19	San Diego (SAN)	23.74
Phoenix (PHX)	28.76	Fort Lauderdale (FLL)	23.69
Portland (PDX)	28.13	Portland (PDX)	23.25
NY Kennedy (JFK)	28.07	Dulles (IAD)	22.61
Fort Lauderdale (FLL)	27.20	Denver (DEN)	22.46
Tampa (TPA)	26.57	Atlanta (ATL)	22.41
Miami (MIA)	26.13	Tampa (TPA)	22.40
Orlando (MCO)	26.01	Orlando (MCO)	21.51
Baltimore (BWI)	25.11	Las Vegas (LAS)	21.43
Atlanta (ATL)	25.06	Phoenix (PHX)	21.13
Chicago Midway (MDW)	23.87	Baltimore (BWI)	20.61
Reagan National (DCA)	23.84	Dallas/Ft. Worth (DFW)	20.11
Pittsburgh (PIT)	23.61	Salt Lake City (SLC)	19.48
Salt Lake City (SLC)	23.16	Pittsburgh (PIT)	19.26
St. Louis (STL)	22.42	Minn-St. Paul (MSP)	18.68
Dallas/Ft. Worth (DFW)	21.97	Houston (IAH)	18.56
Charlotte (CLT)	21.86	St. Louis (STL)	18.53
Detroit (DTW)	21.00	Charlotte (CLT)	17.95
Houston (IAH)	20.72	Detroit (DTW)	17.83
Minn-St. Paul (MSP)	20.55	Cincinnati (CVG)	16.98
Cincinnati (CVG)	20.23	Chicago Midway (MDW)	16.92

Table 11 – Percent of late arrivals

Appendix B - Air Traffic Management

Area Navigation (RNAV)

Area Navigation provides enhanced navigational capacity to the pilot. RNAV equipment can compute the airplane position, actual track, and groundspeed and then provide meaningful information relative to a route of flight selected waypoints and the selected route. Several navigation systems with deferent navigational performance characteristics are capable of providing area navigational functions. Present day RNAV includes INS, LORAN, VOR/DME, and GPS systems. Modern multi-sensor systems can integrate one or more of the above systems to provide a more accurate and reliable navigational system. Due to the different levels of performance, area navigational capabilities can satisfy different levels of required navigation performance (RNP.)[127]

Reduced Vertical Separation Minimum (RVSM)

RVSM airspace will allow certified aircrafts piloted by certified pilots and equipments to fly in minimum of 1000ft vertical separation between flight lever 29000ft and 41000 ft. This rule enables more airplanes to fly in same airspace by reducing vertical separation between airplanes. Aircraft involving in the RVSM must have auto flight system with altitude hold function, and also the altimeters must be certified for their accuracy.

[127] AIM 2002: AIM 1-40

Future Air Network Systems Communication Navigation Surveillance/ Air Traffic Management (FANS CNS/ATM)

This system used to be called FANS. However, the word "future" became inappropriate today therefore; it is called CNS/ATM. As the name shows, CNS/ATM is a combination of several onboard systems. In Boeing 747-400, the CNS/ATM includes CPDLC for communication between controller and voice communication capability using satellite networks, enhanced navigation using GPS technology, and FMS sending location and flight information to controllers for ADS-B (Automatic Dependent Surveillance - Broadcast.) The main function for the system is to use satellites to enhance traffic control management. It is being used in cross pacific flights and cross Atlantic flights. By using this technology, more airplanes can fly in same area because of its precise navigation that makes more RVSM possible.

Appendix C - Traffic Alert and Collision Avoidance System (TCAS)

TCAS provide pilot with traffic information using Secondary Surveillance Rader (SSR). SSR transmits airspeed and direction of the aircraft using data-link. SSR is also called transponder.

TCAS I provides proximity warning only, to assist the pilot in the visual acquisition of intruder aircraft. No recommendation will be provided from TCAS I for collision avoidance. TCAS I is intended to be used by small size commercial aircraft and general aviation aircraft.

TCAS II not only provides with traffic information, but also, if necessary, with pitch commands to resolve an upcoming conflict. It provides traffic advisories (TAs) and resolution advisories (RAs). Resolution advisories provide recommended maneuvers in a vertical direction (climb or descend only) to avoid conflicting traffic. Airline aircraft and larger commuter and business aircraft holding more than 31 seats are required to be equipped with TCAS II.[128]

TCAS however has some problems. When giving a resolution advisory, TCAS II cannot provide horizontal avoidance recommendation. Also, TCAS systems do not realize different performance for each aircraft, meaning that TCAS can give heavier and slower aircraft to climb up and lighter aircraft to descend for traffic avoidance.

TCAS systems are expected to be replaced by ADS-B starting year 2006.

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[128] AIM 2002, AIM 4-4-15.

Appendix D – Airspace

Airspace is divided into two categories, regulatory (class A, B, C, D and E airspace areas,) and nonregulatory (military operations areas (MOAs),) warning areas, alert areas, and controlled firing areas.) Within the four categories, there are four different types: controlled, uncontrolled, special use, and other airspace. The categories and types of airspace are dictated by the complexity or density of aircraft movements, the nature of the operations conducted within the airspace, the level of safety required, and the national and public interest.

Airspace Features	**Class A**	**Class B**	**Class C**	**Class D**	**Class E**	**Class G**
Formar Airspace Equivalent	Positive Control Area (PCA)	Terminal Control Area (TCA)	Airport Rader Service Area (ARSA)	Airport Traffic Area (ATA) and Control Zone (CZ)	General Controlled Airspace	Uncontrolled Airspace
Operations permitted	IFR	IFR & VFR	IFR & VFR	IFR & VFR	IFR & VFR	IFR & VFR
Entry Requirements	ATC Clearance	ATC Clearance	ATC Clearance for IFR. All require radio contact	ATC Clearance for IFR. All require radio contact	ATC Clearance for IFR. All require radio contact	None
Minimum Pilot Qualifications	Instrument Rating	Private or student certificate	student certificate	student certificate	student certificate	student certificate
Two-way radio Communications	Yes	Yes	Yes	Yes	Yes for IFR	No
VFR Minimum Visibility	N/A	3 statute miles	3 statute miles	3 statute miles	3 statute miles	1 statute miles
VFR Minimum Distance from clouds	N/A	Clear of Clouds	500' below, 1000' above and 2000' horizontal	500' below, 1000' above and 2000' horizontal	500' below, 1000' above and 2000' horizontal	Clear of clouds
Aircraft Separation	All	All	IFR, SVFR, and runway operations	IFR, SVFR, and runway operations	IFR and SVFR	None
Traffic Advisories	N/A	N/A	Yes	Workload permitting	Workload permitting	Workload permitting
Safety Alerts	Yes	Yes	Yes	Yes	Yes	Yes
Deffers from ICAO	No	Yes	Yes	Yes for VFR	No	Yes for VFR

Table 12 – Airspace Classes

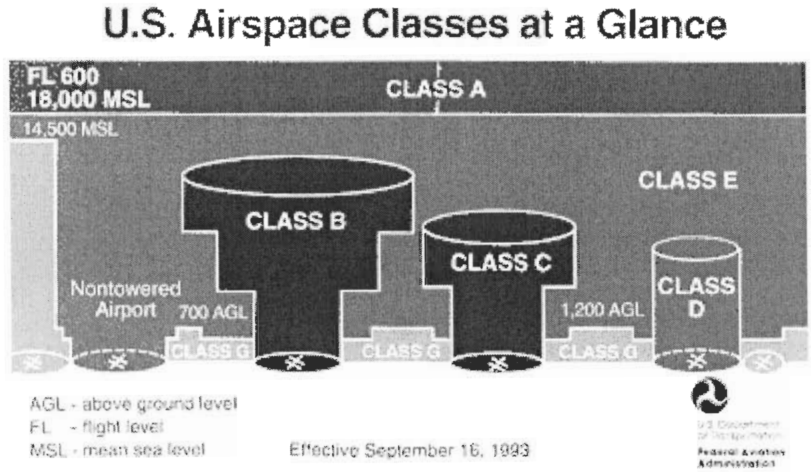

Figure 11 – Airspace Classes

Appendix E - Number of U.S. Airports[a]

	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
TOTAL airports	**15,161**	**16,319**	**17,490**	**17,581**	**17,846**	**18,317**	**18,343**	**18,224**	**18,292**	**18,345**	**18,770**	**19,098**	**19,281**	**19,306**
Public use, total	**4,814**	**5,858**	**5,589**	**5,551**	**5,545**	**5,538**	**5,474**	**5,415**	**5,389**	**5,357**	**5,352**	**R5,324**	**5,317**	5,315
% with lighted runways	66.2	68.1	71.4	71.9	72.3	72.8	73.5	74.3	74.5	74.6	74.8	R76.1	75.9	75.9
% with paved runways	72.3	66.7	70.7	71.5	71.6	72.2	72.9	73.3	73.7	74.0	74.2	74.2	74.3	74.3
Private use, total	**10,347**	**10,461**	**11,901**	**12,030**	**12,301**	**12,779**	**12,869**	**12,809**	**12,903**	**12,988**	**13,418**	**13,774**	**13,964**	**13,990**
% with lighted runways	15.2	9.1	7.0	6.8	6.6	6.3	6.2	6.4	6.4	6.4	6.3	6.7	7.2	7.3
% with paved runways	13.3	17.4	31.5	32.0	32.2	32.7	33.0	33.0	32.9	33.0	33.2	31.8	32.0	32.0
TOTAL airports	**15,161**	**16,319**	**17,490**	**17,581**	**17,846**	**18,317**	**18,343**	**18,224**	**18,292**	**18,345**	**18,770**	**19,098**	**19,281**	**19,306**
Certificated[b], total	**730**	**700**	**680**	**669**	**664**	**670**	**672**	**667**	**671**	**660**	**660**	**655**	**651**	**635**
Civil	N	N	N	N	N	N	577	572	577	566	566	565	563	562
Civil-Military	N	N	N	N	N	N	95	95	94	94	94	90	88	73
General aviation, total	**14,431**	**15,619**	**16,810**	**16,912**	**17,182**	**17,637**	**17,671**	**17,557**	**17,621**	**17,685**	**18,110**	**18,443**	**18,630**	**18,760**

KEY: N = data do not exist; R = revised.

[a] Includes civil and joint-use civil-military airports, heliports, STOL (short takeoff and landing) ports, and seaplane bases in the United States and its territories.
[b] Certificated airports serve air-carrier operations with aircraft seating more than 30 passengers.

SOURCES:
1980-2000: U.S. Department of Transportation, Federal Aviation Administration, Administrator's Fact Book (Washington, DC: Annual issues), Internet site http://www.atctraining.faa.gov/ as of Aug. 1, 2001.
2001: U.S. Department of Transportation, Federal Aviation Administration, personal communication, May 27, 2002.

Table 13 – Number of U.S. Airports[129]

[129] Bureau of Transportation Statistics: http://www.bts.gov

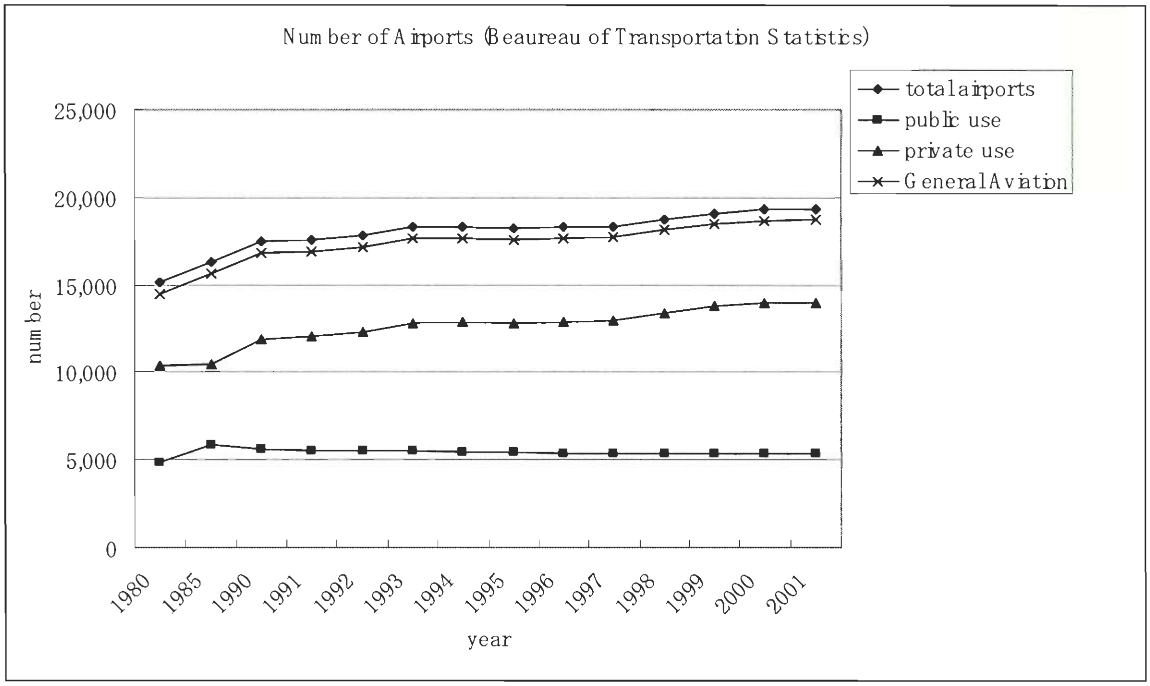

Table 14 - Number of US Airports

Appendix F - Number of Air Carriers, Railroads, Interstate Motor Carriers, Marine Vessel Operators, and Pipeline Operators

	1960	1965	1970	1975	1980	1985	1990	1995	1996	1997	1998	1999	2000
Air carriers[a]	**N**	**N**	**39**	**36**	**63**	**102**	**70**	**96**	**96**	**96**	**96**	**94**	**91**
Major air carriers	N	N	N	N	N	13	14	11	12	13	13	13	15
Other air carriers	N	N	N	N	N	89	56	85	84	83	83	81	76
Railroads	**607**	**568**	**517**	**477**	**480**	**500**	**530**	**541**	**553**	**550**	**559**	**555**	**560**
Class I railroads	106	76	71	73	39	25	14	11	10	9	9	9	8
Other railroads	501	492	446	404	441	[f]475	516	530	543	541	550	546	552
Interstate motor carriers[b]	[e]	[e]	[e]	[e]	**U**	**U**	**216,000**	**346,000**	**379,000**	**417,000**	**477,486**	**517,297**	**560,393**
Marine vessel operators[c]	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**2,519**	**2,505**	**2,494**	**2,534**	**[R]2,391**	**U**
Pipeline operators[d]	**N**	**N**	**1,123**	**1,682**	**2,243**	**2,204**	**2,212**	**2,378**	**2,338**	**2,282**	**2,225**	**2,216**	**2,163**
Hazardous liquid	N	N	N	N	N	[f]222	187	209	215	217	225	216	243
Natural gas transmission	N	N	420	432	474	724	866	974	970	954	880	862	828
Natural gas distribution	N	N	938	[g]1,500	[g]1,932	1,485	1,382	1,444	1,397	1,363	1,366	1,382	1,351

KEY: N = data do not exist; U = data are not available; R = revised

[a] Carrier groups are categorized based on their annual operating revenues as major, national, large regional, and medium regional. The thresholds were last adjusted July 1, 1999, and the threshold for major air carriers is currently $1 billion. The other air carrier category contains all national, large regional, and medium regional air carriers.
[b] Figures are for the fiscal year, October through September. The Federal Motor Carrier Safety Administration deletes motor carriers from the Motor Carrier Management Information System (MCMIS) when they receive an official notice of a change in status. This most often occurs when a safety audit or compliance review is attempted. As a result, many inactive carriers are included in the MCMIS.

[c] The printed source materials do not contain totals for the number of operators and data files from which the figures can be determined are not available prior to 1993.

[d] There is some overlap among the operators for the pipeline modes so the total number of pipeline operators is lower than the sum for the three pipeline modes.
[e] Prior to 1980, the source of motor carrier data was the Interstate Commerce Commission (ICC), which was abolished on Jan. 1, 1996. (Certain functions were transferred to the Surface Transportation Board and the Department of Transportation.) The system used by ICC to collect motor carrier data differs significantly from that used by the Federal Motor Carrier Safety Administration in its Motor Carrier Management Information System (MSMIS), which began operations in 1980. The MCMIS is updated weekly, but archive versions are not retained. Because of differences between the two systems, data are not comparable and thus are not included here.
[f] This value is for 1986. The number of hazardous liquid pipeline operators is not available for prior years.

[g] Includes master meter and mobile home park natural gas distribution operators. A master meter system is a pipeline system for distributing gas within, but not limited to, a definable area, such as a mobile home park, housing project, or apartment complex, where the operator purchases metered gas from an outside source for resale through a gas distribution pipeline system. The gas distribution pipeline system supplies the ultimate consumer who either purchases the gas directly through a meter or by other means, such as by rents.

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Table 15 - Number of Air Carriers, Railroads, Interstate Motor Carriers, Marine Vessel Operators, and Pipeline Operators[130]

[130] Bureau of Transportation Statistics: http://www.bts.gov

Appendix G - System Mileage Within the United States (Statute miles)

	1960	1965	1970	1975	1980	1985	1990	1991	1992
Highway[a]	3,545,693	3,689,666	3,730,082	3,838,146	3,859,837	3,863,912	3,866,926	3,883,920	3,901,081
Class I rail[b,c]	207,334	199,798	196,479	191,520	164,822	145,764	119,758	116,626	113,056
Amtrak[c]	N	N	N	N	24,000	24,000	24,000	25,000	25,000
Transit[d]									
Commuter rail[c]	N	N	N	N	N	3,574	4,132	4,038	4,013
Heavy rail	N	N	N	N	N	1,293	1,351	1,369	1,403
Light rail	N	N	N	N	N	384	483	551	558
Navigable channels[e]	25,000	25,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000
Oil pipeline[f]	190,944	210,867	218,671	225,889	218,393	213,605	208,752	203,828	[R]196,545
Gas pipeline[g]	630,950	767,520	913,267	979,263	1,051,774	1,118,875	1,206,894	1,225,358	1,253,924

	1993	1994	1995	1996	1997	1998	1999	2000
Highway[a]	3,905,211	3,906,595	3,912,226	[R]3,919,652	[R]3,945,872	[R]3,906,290	3,917,243	3,936,229
Class I rail[b,c]	110,425	109,332	108,264	105,779	102,128	100,570	99,430	99,250
Amtrak[c]	25,000	25,000	24,000	25,000	25,000	22,000	23,000	23,000
Transit[d]								
Commuter rail[c]	4,090	4,090	4,160	3,682	4,417	5,172	5,191	U
Heavy rail	1,452	1,455	1,458	1,478	1,527	1,527	1,540	U
Light rail	537	562	568	638	659	676	802	U
Navigable channels[e]	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000
Oil pipeline[f]	[R]193,980	[R]190,350	[R]181,912	177,535	179,873	178,648	177,463	U
Gas pipeline[g]	1,251,095	1,257,971	1,262,152	1,276,315	1,251,199	[R]1,294,262	1,345,381	U

KEY: N = data do not exist; R = revised; U = data are not available.

[a] All public road and street mileage in the 50 states and the District of Columbia. For years prior to 1980, some miles of nonpublic roadways are included. No consistent data on private road mileage are available. Beginning in 1998, approximately 43,000 miles of Bureau of Land Management Roads are excluded.

[b] Data represent miles of road owned (aggregate length of road, excluding yard tracks, sidings, and parallel lines).

[c] Portions of Class I freight railroads, Amtrak, and commuter rail networks share common trackage. Amtrak data represent miles of track operated.

[d] Transit system mileage is measured in directional route-miles. A directional route-mile is the mileage in each direction over which public transportation vehicles travel while in revenue service. Directional route-miles are computed with regard to direction of service, but without regard to the number of traffic lanes or rail tracks existing in the right-of-way.

[e] The St. Lawrence Seaway is not included in this number because 3 of the 5 subsections are solely in Canadian waters, and the others are in international boundary waters. Of the 26,000 miles of navigable waterways, 10,867 miles are commercially significant shallow-draft inland waterways subject to fuel taxes.

[f] Includes trunk and gathering lines for crude-oil pipeline.

[g] Excludes service pipelines. Data not adjusted to common diameter equivalent. Mileage as of the end of each year. Includes field and gathering, transmission, and distribution mains. See table 1-8 for a more detailed breakout of oil and gas pipeline mileage.

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Table 16 - System Mileage within the United States

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