CNS

Computer Networks & Software, Inc.

SATS Operational Concepts

to

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7405 Alban Station Court, Suite B 201, Springfield, VA 22150

SATS Operational Concepts

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1. INTRODUCTION

This document describes operational concepts that will be implemented in National Airspace System (NAS) in the years 2005 and 2025. The purpose and focus of the document is to provide a basis upon which to develop the traffic type and load characteristics to be supported by the Airborne Internet (AI) component of the Small Aircraft Transportation System (SATS).

1.1 Background

The general approach for developing the traffic type and load characteristics of the AI is graphically shown in Figure 1.

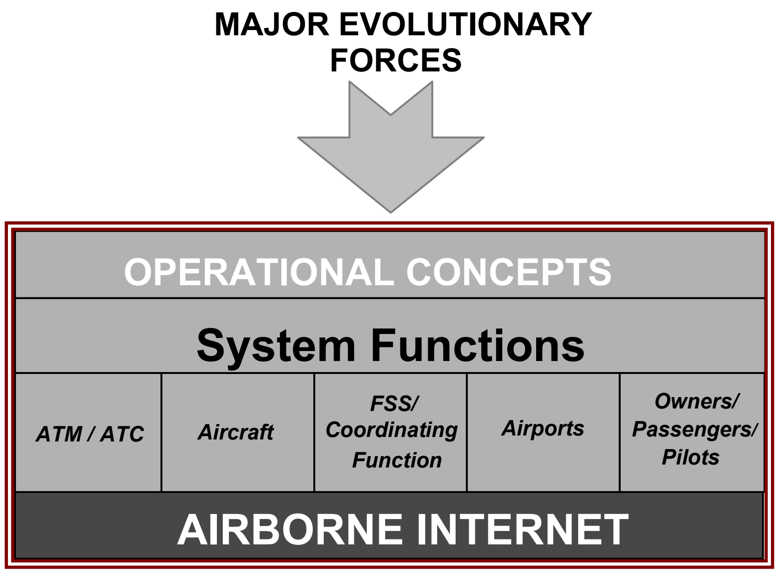

Figure 1. Top-Down Analysis Approach for Defining the Airborne Internet

Industry experts have analyzed evolutionary forces in both the marketplace and aviation industry, and projected them upon former and current work in the SATS arena. Supporting data upon which this document is based includes current (Year 2001) NAS descriptions, RTCA work in SC-186 and other committees, Safe Flight 21, Capstone, and Computer Networks & Software, Inc. reports. Also included is information from various SATS workshops and documents.

For the purposes of this work, the Airborne Internet is considered to be a set of wireless communications that enable an aircraft in the system to achieve its full functionality in a Communications/Navigation/Surveillance (CNS) space, with primary focus on Communications and Surveillance. It is not limited to Internet Protocol (IP) technologies, but is considered to be a web of techniques, methods, and modes designed to allow easy access to and manipulation of data and information. As such, the AI does not include GPS or the Wide Area Augmentation System (WAAS), nor does it include some of the other already existing basic NAVAID transmissions, such as VHF Omnidirectional Range (VOR), ILS, and ADF. On the other hand, the AI will include access to information about these NAVAIDs such as status and figures of merit. It might also include or enable other navigational solutions that new technologies may provide.

To lay a framework to examine the Airborne Internet, this basic operational concept considered three timeframes, but focuses on the closest two. The first SATS capability is a short term "proof of concept" vision (2005), one in which today's technologies, rules, and procedures are used in different ways to achieve new results, not available within today's national transportation system. This "proof of concept" vision specifically supports the requirements of the planned SATS flight demonstrations between 2002 and 2005. The AI will provide the communications connectivity to ensure reliable SATS-to-SATS coordination is effected in support of arrival and departure traffic density evaluations. Using the AI as the primary non-ATC data collection source, SATS aircraft will be capable of demonstrating the ability to operate in the NAS regardless of the complexity of the assigned traffic flow while maintaining full IFR/IMC fidelity with a lone pilot.

"Proof of concept" is followed by the "transition" vision (2025) that features pilots operating with more sophisticated and proven equipment and rules than in the current NAS. SATS technologies have achieved full system certification and acceptability. Additional automation needs have been discovered.

The longest range vision is a "mature" (2050) concept featuring sophisticated vehicles that can either wholly guide themselves or can do so with minimal inputs from the pilot. This period will see the integration of system improvements and the prototyping of follow-on technology development.

1.2 Scope and Intended Use

The purpose of developing the SATS operational concepts is to assist in defining the services to be available to SATS aircraft and from that developing communications characteristic and sizing estimates to be supported by the Airborne Internet. *The document is not intended to be a complete or comprehensive outline for the future direction of the entire SATS concept.* ***This document does describe a SATS operating environment based upon available documentation from which Airborne Internet characteristics and requirements can be derived.***

1.3 Projected Characteristics of the NAS

SATS as a concept will not only *operate within* the NAS, it will also actually *become a part of* the NAS infrastructure during its flight operations. As such, a quick overview of expected NAS operations can help put the SATS operational concepts in perspective.

1.3.1 "Proof of Concept" Airspace Operations - 2005

To quote the FAA's ATS Concept of Operations for the National Airspace System in 2005:

> "2005 sees the completion of the National Airspace Review, the replacement of the "Host" en route automation system, the transition to satellite navigation, and the introduction of new display platforms. It marks the end of the first phase of transition to the technologies and airspace structures required for Free Flight. With some of these technologies fully deployed, and others under limited deployment, subsequent development is under way to complete the transition to a full Free Flight environment in the post-2005 era."

While this 1997 assessment is somewhat optimistic of the actual "deadline," the characterization seems, nonetheless, accurate. It is obvious that SATS is well positioned to integrate certain of these "Free Flight" technologies to provide the General Aviation (GA) community with a systemic approach to improving its transportation opportunities.

In this proof of concept era of the near future, rules are unchanged - but they are being applied somewhat differently. Similarly, technology is not new - just available and beginning to be used.

The increases in the quality and timelines of surveillance information in particular will start to have some effects on the system in general (and SATS in specific) as it starts to become a reality. For instance, limited deployment of Automatic Dependent Surveillance - Broadcast (ADS-B) equipment in the cargo airlines will spark the beginnings of passenger airline deployment. Initially targeting ground applications, ADS-B and Traffic Information Service - Broadcast (TIS-B) surveillance will begin building momentum, with the FAA addressing runway incursions and the airlines addressing departure/arrival operations management. The multilateration capabilities of TIS-B will begin to bring General Aviation (GA) into a web of distributed surveillance. GA is likely to respond by purchasing ADS-B, provided manufacturers integrate Flight Information Service - Broadcast (FIS-B) and TIS-B surveillance into a single, affordable system.

The availability of FIS-B data through the AI will provide NAS status and weather information to assist the pilot in strategic planning. SATS will integrate selected technologies to provide an economic path to increasing operational tempos at uncontrolled airports, as well as giving SATS aircraft the full capability to participate in the complexities of the redesigned NAS.

SATS aircraft will use a Highway in the Skyway (HITS) capability, which will accurately integrate TIS data into the display. This will contribute to safer operations in uncontrolled airspace. The SATS capability to self-organize and self-sequence will enable the use of reduced separation techniques, even when operating during inclement weather. The video graphic nature of the HITS will support final approach spacing. For instance, it will support closer to Visual Meteorological Conditions (VMC) arrival rates under Instrument Meteorological Conditions (IMC) conditions.

Graphical FIS-B will be coming into widespread use by 2005. These services will include a number of marketplace "experiments" with providers and links as groups maneuver to establish a successful balance between business and governmental areas of expertise and provisioning. Graphical weather, NOTAM overlays for airfield and approach diagrams, Special Use Airspace (SUA) status, facility management, etc. will be evolving toward a graphical format with layering and grouping capabilities for rapid display, easy manipulation, and quick, accurate consumption. The use of FIS will help define the nature of the NAS at any given moment, thus affecting strategic and some tactical traffic flow. Strategically, a SATS pilot will use FIS-B data to formulate a flight plan or for replanning requirements en route. Tactically, GPS navigation (used with LAAS where feasible) will enable lowering landing minimae at most uncontrolled airports

New equipment and techniques being phased in over a period of years allow more timely, consistent, NAS-wide information distribution. Due primarily to more accurate, shared, and widespread surveillance, there will be a gradual redistribution of roles and responsibilities. Specifically, traffic separation responsibility will begin to shift to include the cockpit, or SATS aircraft, for certain applications at given times. At uncontrolled airports where multiple SATS aircraft operate, taxi operations will achieve increased safety by the SATS self-separation and self-organizing capabilities.

1.3.2 "Transition" Airspace Operations - 2025

The 2025 timeframe can be view as a transition point for SATS. Within the next quarter century, most of the technologies, procedures, and processes necessary to secure a "free flight" capacity across the nation will be in place, but only beginning to be used in a routine manner. The airspace will be in the final phases of undergoing a transformation, much like the conversion from props to jets that occurred in the major airlines in the 1960s, or in the regional airlines in the 1990s. As ADS, TIS, FIS, and other flight-centric services become widespread, available, and dependable, other passenger-centric services will have already been available for some time.

Electronic Flight Rules (EFR) will have joined Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) as operating modes within the NAS. Full-blown self-separation will have become acceptable for high altitude en route flights, first during oceanic operations, and gradually within denser airspace. SATS self-separation algorithms will ensure that the entire aviation community, including GA, has an equal opportunity at safely improving flight efficiency.

Most notable among airspace changes in this transition timeframe will be the completed move to a performance-based Air Traffic Control (ATC) system within the US. Just as airline deregulation had reverberations over the quarter century that followed that event, so too will the move from a theoretically-based safety system to an empirically-based safety system that also officially values capacity, flexibility, and user requests. As the performance-based mentality infuses the underlying infrastructure, measurements, procedures, and rules, a good deal of the constraints within the NAS will likely become "commodities" that have a demand related value.

This "commoditization of the airspace" will have a significant effect on the evolution of SATS. Given that the airlines will still employ a largely hub-and-spoke system and continue to primarily use the airspace above 30,000 feet during the day. (This is where the demand, the value, and the costs of consuming these commodities will be highest.) It seems likely that a typical SATS flight - a point-to-point operation among off-peak airports in less used airspace will be welcomed, perhaps even encouraged with economic incentives. As currently conceived, much of the motivation for SATS involves using available, integrated technology to leverage effective use of niches within the transportation system. The differences between what a SATS operation costs versus an airline operation may be exacerbated by the commoditization of the NAS and its services.

1.3.3 "Mature" Airspace Operations - 2050

After half a century, the airspace should be characterized by nearly complete global harmonization and free flight capabilities. Although there will still be an important ground infrastructure, aircraft themselves will bring significant infrastructure to the airspace they transit. Surveillance, control, and collaboration techniques used to ensure safety, throughput, and reliability will be distributed in nature, and accessible from many locations, through multiple channels. "Free Flight" will be a mature concept within the US, Europe, and around most of the globe.

1.4 Organization

To convey a set of meaningful operational concepts, this document is organized by the sequence that users follow to plan and conduct a flight through the air traffic system.

- *Section 2* generally describes relevant portions of the SATS vision as well as the potential sizing of the SATS market.
- *Section 3* describes the services that will be required to make SATS a viable concept, with emphasis placed on phases of flight, and the two relevant measurement points, 2005 and 2025.
- *Section 4* describes the expected results of the SATS "proof of concept" and demonstration period, concentrating on describing the emerging Airborne Internet, and its potential beneficial impact on SATS operations.
- *Section 5* details the "transition" of SATS operations from proven (and certificated) aircraft technology through the growth of SATS as a viable, desirable transportation capability.
- *Appendix A* contains a list of acronyms.

2. SATS VISION

2.1 Some Existing SATS Assumptions

2.1.1 Stated Mission

The basic mission of a SATS environment has been stated as: "*To create a personal, rapid transit, air travel system, that utilizes small aircraft for personal and business transportation, for point-to-point direct travel between smaller regional, reliever, GA and other landing facilities, with connections to intermodal forms of transportation.*"

This mission suggests a vision in which SATS becomes part of a "doorstep to destination" transportation system that creates a near seamless travel experience. It is this mature perspective that was used to create the mature, transition and proof of concept visions upon which this work is based.

2.1.2 Short Term Operational Objectives

To focus early work, four core operational objectives of near term SATS work have been expressed. These are:

- High-volume operations at airports without control towers or terminal radar facilities;
- Lower adverse weather landing minimums at minimally equipped landing facilities;
- Integration of SATS aircraft into a higher en route capacity air traffic control system with complex flows and slower aircraft; and
- Improved single-pilot ability to function competently in complex airspace in an evolving NAS

These essential objectives are woven into the concepts stated within this document. They are to be enabled by a number of technologies, including:

- Airborne Internet
- Enhanced Vision
- Highway in the Sky
- Software based flight controls
- Emergency auto-land
- Self-organizing sequencing and separation algorithms

2.2 Framing Relevant Issues

Besides the direct impact of the NAS, there are major forces at work that are shaping the evolution of our society in general, as well as the transportation and communication systems which connect it together. Graphically, that might be viewed as in Figure 2.

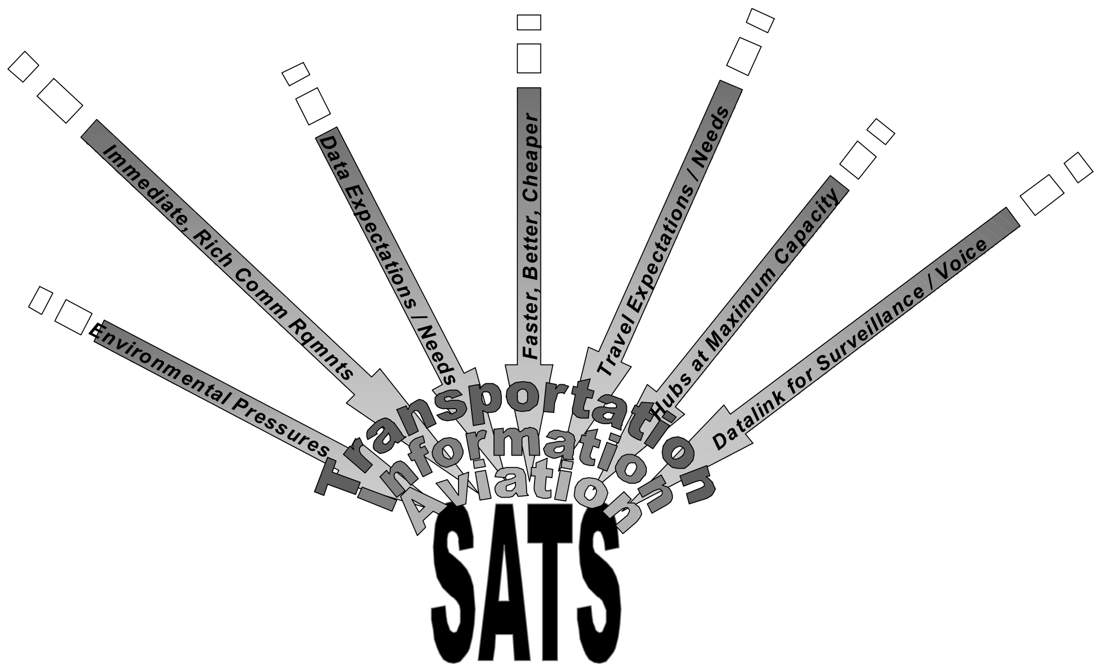

Figure 2. Some Major Evolutionary Forces Shaping the Future of Transportation

2.2.1 Major Evolutionary Forces

2.2.1.1. Faster, Better, Cheaper

The modern world is under increasing pressure to do more with less, and with greater efficiency. Partly due to our success in meeting this desire, expectations are constantly raised in nearly all areas of human endeavor. One of the most prevalent needs is for ever-increasing integration of formerly disparate activities or information sources and collaboration among formerly separated stakeholders. This desire for increasing integration and collaboration permeates nearly every aspect of an evolving system.

2.2.1.2. Environmental Pressures

The growing scarcity of fossil fuels, sensitivity to the effects of emissions, intolerance of noise, and desire to sensibly manage the human impact on the planet have raised environmental concerns to increasing levels. Pushing for an integrated, efficient, intermodal transportation system is therefore quite attractive from both the environmental point of view, as well as from the traveler's. Increased costs involved with regulation and control of environmental issues will be a driving factor in future transportation development – efficiency is paramount.

2.2.1.3. Data Fusion & Information Management

It is said that we truly live in the "information age." There is an almost exponential need to gather, manipulate, and share data of all kinds in every aspect of our lives. Addressing this force in particular, is essential in order to meet the four core SATS objectives. The drive to command data, convert data into information, and synthesize information into knowledge is at the core of SATS, as well as almost any business activity and our personal lives.

2.2.1.4. Requirement for Immediate, Reliable Communications

Manipulating data, information, and knowledge have little effect without the ability to communicate what one has learned or wants accomplished. People in general society, and especially those engaged in business, are growing increasingly less tolerant of being disconnected from their usual information networks while traveling. Even as of this writing, the transportation industry is beginning to respond with the first attempts to keep airborne passengers connected to their business, entertainment and educational channels while traveling in the air, on the land, or on the oceans. The SATS AI concept will provide an infrastructure-independent communications capability that improves operational communications while providing key personal and business communications for pilots and passengers. Simply managing basic daily activities in a world that increasingly demands integration and collaboration is impossible without immediate, reliable communications channels.

2.2.1.5. Service Expectations/Needs

As elements of the economy become increasingly interdependent, the demand for "service" has increased significantly. That "service" takes many forms including knowing who the traveler is and what his/her preferences are, managing luggage and other personal effects, connectivity to business and pleasure outlets such as Internet and television, personal work and social space, etc. The business traveler in specific often focuses on productivity; most cannot afford long periods of "down" time while traveling or waiting for a connection to the next leg/mode in a business journey. Security service needs, including traveler's personal and property safety, aircraft and flight operations security, and externally driven security requirements, will all have an impact on SATS operations. Though providing a service can require physical presence, it almost always depends upon the effective management of information to ensure the quality and timelines of that service.

2.2.1.6. Hubs at Maximum Capacity

SATS was conceived as a viable alternative to the ever increasing amount of time a traveler needs to move between the doorstep and the destination. For air travel in specific, one major factor affecting the future is that our major hub airports are operating at capacity during much of the day. In order to accommodate increasing demand for air travel and still use the infrastructure in which airlines operate on a near-exclusive basis, a number of trends will emerge. Traffic will likely be redistributed with economic incentives. Off-peak traffic will increase, and the average size of aircraft moving through hubs will likely increase. As the aircraft size goes up, other aircraft, including SATS aircraft, will be under increasing pressure to stay out of major hubs during peak hours. This pressure may well give rise to “satellite” or “regional” feeder-hubs as well as an increasing number of point-to-point operations over “long and thin” markets. Ultimately, the major airlines may soon relate to the regional airlines, as the regionals relate to fractionally owned business jets. Eventually, all the aviation community will relate to the SATS capability, either as an asset in promulgating seamless transportation connections, or by use of SATS-proven technologies.

2.2.1.7. Travel Expectations/Needs

Increasing dependence on integration and collaboration has increased the desire for business travel, despite advances in remote collaborative technology such as webcasting and video conferencing. In fact, some have argued that the e-commerce activity of the last decade has accelerated the need for personal interactions in business due in part to increasing decentralization. Busy, sophisticated business travelers are demanding travel schedules that feature timelines, integrity, and easy access while minimizing discomfort and “down” or non-productive waiting time. SATS aircraft will contribute significantly to improvements in meeting traveler expectations as a primary means of dedicated travel, or as an efficient alternative to connecting airlines.

2.2.1.8. Datalink for Surveillance/Voice

Wireless communications of all types have become ubiquitous in our society, and are rapidly saturating the aviation industry as well. Just a few years ago, a simple, slow, character-based Aircraft Communication Addressing and Reporting System (ACARS) capability on an aircraft was considered novel, whereas now nothing less than full, speedy Internet access is being requested for both cabin and cockpit. SATS AI development will optimize various datalink capabilities for surveillance and other operational needs. Increasingly, datalink will supplant voice communications of various kinds for weather reports, flight plan changes, clearances, etc.

2.2.1.9. Summary of Evolutionary Forces

SATS is a measured response to an identified need for significant improvements to the nation’s transportation system that answers the airborne portion of the “doorstep to destination” concept. Integrating available air- and ground-based aviation technologies, SATS will enable fast, safe, efficient travel to and from airports that are currently un-served (or underserved) by either the airlines or by positive ATC, or both. The SATS will evolve by demonstrations that prove the four goals for SATS. The AI’s growth will parallel SATS growth.

2.2.2 Evolutionary Forces General Effect

2.2.2.1. Communications

All of the forces that have been driving the revolutionary creation of SATS capacity and the subsequent evolutionary progress of SATS will also drive our communications infrastructure and functionality. The Internet, cell phones, and laptop computers are all evidence of an accelerating drive to connect with the world's information, and to keep access to it wherever we are.

In the increasingly intersecting arenas of cell and Internet technologies, many of the problems facing an AI have already been being solved. Message integrity, system scalability, packet security, and acceptable delays were all issues that only a decade ago looked formidable in many areas, yet the solutions have become almost commonplace in COTS hardware and software.

There is a well known, growing drive to use these technologies in the aviation industry, as they are already being used in the surface transportation sectors. There will be some resistance to using COTS products in the aeronautical information arena. Years ago, the international aviation community agreed to the development and use of the Aeronautical Telecommunications Network (ATN). This protocol has been designed to replace the current analog communications with digital capabilities. There are advocates of COTS solutions, available now, who contend that ATN is too cumbersome and will complete development too late to take advantage of existing protocols (i.e., TCP/IP). Of course, the ATN advocates use the protocol's security features and its custom design and its message accountability capabilities to continue to support ATN implementation.

2.2.2.2. Transportation

Many years ago, our surface transportation system (rail and highway) underwent an evolution similar to that which the NAS is now experiencing. The first roads and railroads were built basically point-to-point. As rail transportation grew, a hub-and-spoke system appeared. Finally, with the advent of the modern car and highway system, true point-to-point surface transportation became the standard. As road transportation offered complete, fast, efficient, flexible service from doorstop to destination (and with the advent of a meaningful long-haul aviation capacity), passenger rail service withered - almost to the point of death.

NAS designers must accommodate the entire aviation community, and General Aviation, including SATS, will have access to equitable use of the NAS. The forces driving the revolutionary creation of a SATS capability and the subsequent evolutionary progress of SATS must also influence the needed changes to our current transportation infrastructure and functionality. Airports, passenger (and cargo) rail facilities, roads, and where feasible, waterways and ports must be interconnected to improve transportation opportunities. Future transportation systems must be effectively and efficiently integrated to ensure doorstep to destination services, and that all people have equitable access to economical, convenient travel resources.

2.2.2.3. Aviation

GA operations are increasingly discouraged, or prevented, from using the larger airports and hubs by equipage, pilot training and certification requirements, and landing fee costs. At most small airports, all-weather facilities are extremely rare. Even if an owner can afford the aircraft's equipment, lack of convenient, accessible ground facilities makes it difficult to obtain the training necessary for private pilots to achieve the qualifications needed to fly into the larger airports. This lack of resources also impacts the owner/operator who cannot fly from one small airport to another during inclement weather.

The aviation community must integrate its capabilities to ensure seamless air transportation for all users. Additionally, community transportation planning must ensure that aviation operations are integrated onto the general transportation planning and implementation process.

2.2.2.4. SATS

The mid-sized business jet provides on-demand travel to upper-level business executives. The logical extension for the common man is an affordable aircraft with full SATS capability. In actuality, both capabilities will benefit from SATS technologies. The small SATS aircraft can satisfy both personal and business travel via direct flights, or connection to regional or major airports. The business fleet will benefit from the increase in travel options gained by using SATS separation, surveillance, and take-off and landing technologies.

Currently, air travel is not well integrated with other modes of transportation, especially within the United States. Moreover, aircraft are still more complicated and expensive to operate than is perhaps necessary. After applying the SATS technologies mentioned previously, flight operations will be simpler to perform, and contribute to a more efficient, distributed transportation capability. SATS is aviation's key link to increasing the fusion of well-coordinated and integrated transportation and communications capabilities that our society is increasingly demanding.

2.3 General SATS Vision

2.3.1 "Proof of Concept" SATS - 2005

The SATS "revolution" is just starting, fueled in large part by the major forces previously discussed. The attention focused on the difficulties associated with air travel is coming to a head with many looking for unique solutions. The FAA will come under increasing pressure for common-sense solutions that strike a balance between theoretical safety numbers and practical transportation, enabling a shift in the certification of processes and some avionics, especially those devoted to information management, situational awareness, and collaboration. Eclipse has been certified and is breaking production and sales records in what is generally regarded as a "prototypical-SATS" aircraft. The first 12 experimental "SATS" airplanes are in place for a variety of tests and demonstrations, and Eclipse as well as others has announced its intentions to build these promising technologies into future aircraft already under design.

Traveling is still decidedly vehicle-focused with a keenly felt separation between the “travel” and “communications” arenas that will not allow travelers a seamless experience. Though it is gradually improving, there are still significant barriers to combining airborne travel and communications connectivity, and the interfaces among the various airborne and surface modes of travel are significantly limited. Pressure is building to unite the travel experience through integrating and coordinating traveler transportation needs with reliable communications.

Pilots, their certifications, and training have changed little in the recent past, with the exception of the creation of a “Sport Pilot” category of aircraft and license. The precedent that this sets can be employed in future arguments for the creation of a SATS-specific license as simple-to-operate SATS aircraft are perceived to be just around the corner. Initially, a SATS certificate will be a “type-certification” for commercial pilots, but could eventually be extended to lesser qualified pilots as SATS and the NAS implement new designs and operations.

The airspace is changed little from today, other than the already mentioned limited uses of on-board surveillance to help incrementally increase throughput at major hubs. Nevertheless, the process of creating a tactical tool (such as Center-TRACON Automation System (CTAS)) to address a specific problem in a non-integrated manner will have nearly reached its maximum potential. As a result, the extreme pressure on the hub-and-spoke system will have accelerated the call for a performance-based ATC system within the US and a fundamental change in the way we operate the NAS in specific, and transportation in general. In short, the air travel situation will be ripe for SATS to evolve and thrive.

Travel alliances will become increasingly important as a number of market experiments are carried out. Some alliances will be based around major US carriers such as they are now. It is likely that others will appear with a focus on regional, governmental, or political lines. Still others may form that are not based on companies, but on virtual services. These outgrowths of travel agencies and web companies will not have to own any portions of an airline, cruise line, or limo service outright, but will contract for services, then re-sell them to the public at large as increasingly coordinated packages. As SATS becomes a dawning reality, it will attract the attention of these “virtual” alliances first.

In 2005, we will be even more awash in data than we are now, but much of it will be processed into an increasingly coordinated web of information. Readily accessible and easy to manipulate in a wired paradigm, information will be used in a dynamic, just-in-time fashion even more than it is today. In that vein wireless voice communications will continue its heavy growth as people increasingly choose it as their primary voice service. Wireless data communications, however will continue to lag as the system runs out of bandwidth. Airborne wireless communications, especially for data, will come under even more severe pressure to both match terrestrial performance and release under-utilized bandwidth perceived as “available” in classic aeronautical spectrum bands. As a result of this range of pressures, multiple solutions will yield an increasingly wide variety of links, schemes, and methods through which both voice and data will be sent to and from aircraft in the air and on the ground.

2.3.2 "Transition" SATS - 2025

To achieve the mature vision that NASA and various industry partners have laid out, the 2006 to 2025 timeframe will be a critical one. If it is going to be successful, the SATS evolution will be in full swing. Many of the enabling factors for the mature SATS vision will have been proven during the demonstration period. Others will be near a critical juncture that will determine the level and timing to which the SATS program will eventually succeed.

Transportation in general will not yet have achieved a fully traveler-centered orientation, but it will be definitely transforming in that direction in a variety of ways. The required interconnectivity among various modes of transportation and communication will be enjoying pockets of success. Surface transportation and services will become more integrated as ground-based communications and service infrastructure merge and mature. IP-based coordination among various wireless devices and customer databases will provide a personalized, traveler-centered approach to much of what we do, especially in major metropolitan areas. Those areas and communities that have invested in related SATS infrastructure will be reaping the benefits of those investments - serving as an example for other communities. The business world will actively seek to invest in communities that fully support a nimbly mobile personal and business lifestyle. Integrated transportation and communications services that provide nationwide connectivity, and the potential for planet-wide connectivity, will thrive.

Pilots, including the rising number of SATS-qualified pilots, will still be very much a part of air transportation during this era. The use of Unmanned Aerial Vehicles (UAVs) and Remotely Piloted Vehicles (RPVs) will become common, especially at night or in remote skies. Due to their sophisticated avionics and automation, most 2025 SATS aircraft will probably be RPV/UAV capable, enabling them to be pre-propositioned for next day operations, deliver night/remote cargo, or both.

Airspace, as described earlier, will be changing significantly, thus further enabling SATS to achieve its promise. Though we will not have complete "Free Flight" within this country, there will be significant pockets of self-separation activity. Increasingly "IFR" operations will be enhanced by EFR which will specifically address and enhance SATS operations, although pilots will likely need more than a basic "SATS type-rating" to operate EFR.

The airline alliances we see in today's world will have evolved into multiple planet-wide travel alliances, enabling more coordination among selected transportation modes and lodging locations. The major airlines will fly larger aircraft across the country and throughout the world, while forming tight alliances with smaller, "regional" partners, rather than choosing outright ownership. The "regionals" will fly smaller aircraft, mostly within the country; however, they will be far from "regional" in their service. Hubs at, or above capacity will force the major carriers to increase the average size of the aircraft flowing through their major hubs, thus increasing pressure for the regional carriers to develop regional or satellite hubs. A significant amount of SATS activity will respond to avoiding the major airline hubs, and could focus on coordinating and cooperating with the regional hubs. (At the same time, a few airlines and hubs may try to create airspace and ground infrastructure that will support SATS operations at major hubs where airliner arrivals and departures are not impacted.) SATS operations could often bear the same relationship with regional airlines as the regionals do with the majors, meaning that many commercial SATS flights will be associated with a travel alliance and their increasingly integrated operations.

Enabling much of this activity will be an increasingly seamless communications infrastructure on the ground. Databases and interconnectivity will enhance almost every service we can currently imagine, and create others we cannot yet predict. However, wireless communications will be essentially out of bandwidth; we will be at the peak of a frequency crisis. Competing technologies and techniques will offer the promise of more efficient use of available bandwidth. Aviation users, with higher certification costs, significant safety issues, and expensive legacy systems will become one of the primary forces in the battle to manage bandwidth rather than frequency. These growth pains will disproportionately affect SATS operations, which depends on the wireless coordination of transportation and communications. The length and outcome of the battle will likely have a noticeable effect on the growth of SATS in this time frame.

2.3.3 "Mature" SATS - 2050

A functional, mature, end-state SATS concept is outlined in various places in the literature. A full description is outside the scope of this document, other than to point out some characteristics of the mature system as currently envisioned. Keeping the ultimate SATS goals in mind helps to predict the transition vision, which in turn helps fix the stepping stone state where the true work of creating a SATS capability actually starts. In the mature SATS vision:

- The SATS "revolution" is complete. Nearly all air vehicles incorporate some level of SATS-like technologies and procedures. A direct, on-demand, global SATS is blended with other modes of transportation.

- Traveling is *traveler-centered* - integrating transportation and communication into a seamless experience that is no longer focused on vehicles, methods, or modes.

- The NAS has been completely evolved to make airborne self-separation a reality, and distributed surveillance systems the norm. "IFR" is nearing the end of its meaningful existence, being replaced by "EFR" as the common and useful set of rules that air carriers, business aviation, IFR-capable GA, and SATS operators usually employ. "VFR" operations have begun to decrease due to the availability and affordability of SATS and SATS-like CNS capabilities.

- Wireless communications are ubiquitous and the world has learned to dynamically manage bandwidth rather than statically assign frequencies.

3. SATS OPERATIONAL SERVICE REQUIREMENTS

To arrive at a full understanding of the support an Airborne Internet will have to provide to a SATS operation, looking at NAS-related services is in order. The SATS operation will be unique in the NAS, and will use current and projected NAS service components to gather and disseminate flight related data. As the NAS has begun transitioning to the future airspace and air traffic management capabilities, it has already implemented a cooperative decision-making process. The basic tenets of the NASA Distributed Air Ground Traffic Management (DAG-TM) concept or the FAA's recently implemented Collaborative Decision Making (CDM) programs, combined with an inspection of the communications services required to support this type of cooperative decision management concept element in a SATS environment helps to place the four, short-term SATS enhancement goals in perspective. These short-term goals are:

- High-volume operations at airports without control towers or terminal radar facilities;
- Lower adverse weather landing minimums at minimally equipped landing facilities;
- Integration of SATS aircraft into a higher en route capacity air traffic control system with complex flows and slower aircraft; and
- Improved single-pilot ability to function competently in complex airspace in an evolving NAS.

Certain components of the NAS, both current capabilities and future implementations, will be required to ensure SATS operations are allowed the freedom needed to operate efficiently without jeopardizing safety. These NAS elements are described below.

3.1 DAG-TM

NASA's development of the DAG-TM concept appears to be an important step toward a concerted growth path to Free Flight. The concept embodies a "gate to gate" approach to developing a robust, future, air traffic system that can provide the flexibility, capacity, and safety for which industry is searching. Although DAG-TM as expressed is necessarily airline centric, it does contain valuable concepts that will affect SATS operations. Thus, a short review is included.

3.1.1 DAG-TM Constituents

In characterizing an airline-centric "gate-to-gate" vision of an air traffic system, the DAG-TM concept recognizes a basic triad of constituents that share in managing the process. These constituents are fundamental to the concept. Notionally represented in Figure 3, these three are the Flight Deck, Air Operations Center (AOC), and Air Traffic Service Provider (ATSP).

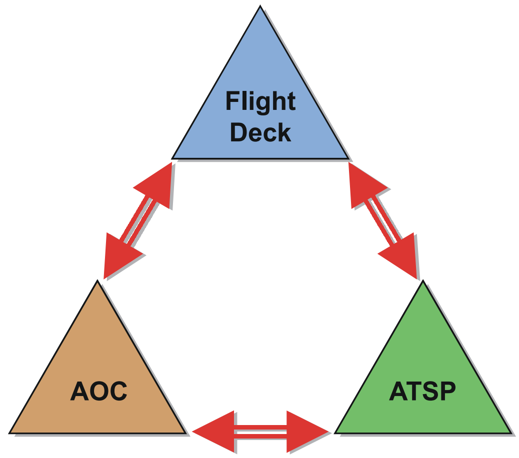

Figure 3. The Classic DAG-TM Triad

It is critical to note that the arrows between each of the constituents represent a communications capability; therefore, the upper two arrows represent a major portion of the "Airborne Internet."

With these specific constituents in mind, it can be said that a SATS operation will generalize the DAG-TM concept. In this model, the three constituents generalize in this manner:

- The "Flight Deck" becomes the ***Aircraft*** as a whole.
- The "Air Traffic Service Provider" becomes the ***Air Traffic Management System*** as a whole.
- The "AOC" becomes the ***Airline*** as a whole.

These constituents will apply to SATS as well as airline operations; however, the AOC function may differ somewhat according to usage. Please note that in the SATS case, the AOC function is a more general Coordination Capability that provides information to and from the aircraft, and the entity that the aircraft is supporting (e.g., owner, commercial operator, fractional operation, business, or personal group). For instance, a commercial SATS operator may employ a full-fledged internal or contracted AOC service. Private business or community owned SATS operations might use contracted AOC services, Flight Service Stations or even the company's administrative assistants. Finally, purely private operations will also want some level of coordinating functionality. For them, a Flight Service Station may suffice, although this kind of coordination may ultimately rest with the pilots. Thus, a SATS-specific DAG-TM triad might be represented as in Figure 4.

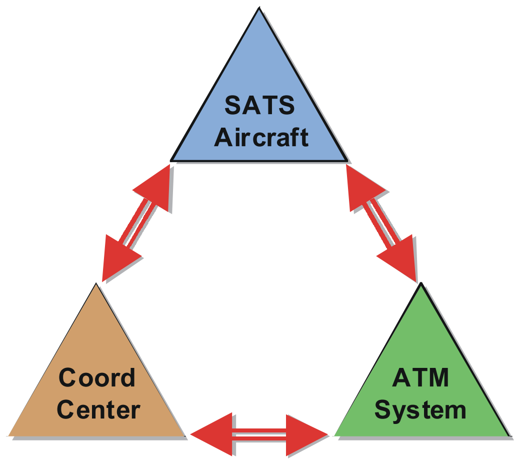

Figure 4. A Generalized SATS DAG-TM Triad

3.1.2 Concept Elements

To give the DAG-TM concept depth and direction, a set of "Concept Elements" (CEs) were identified. Each Concept Element is designed to be a "coherent set of solutions to a series of key ATM problems (or inefficiencies) in the gate-to-gate operations of the current NAS."

Table 1 lists the concept elements that comprise the DAG-TM solutions set. The first has been numbered "CE 0" to indicate its over-arching nature. The other concept elements are numbered "CE 1" through "CE 14," their sequence corresponding to the progression of a typical flight and named according to operational domain, phase of flight, and description. For example, the DAG-TM concept would refer to the second item as "CE #1 - Pre-Flight Planning: NAS-Constraint Considerations for Schedule/Flight Operations."

Table 1. Concept Elements of DAG-TM

CE #	Operational Domain & Phase of Flight	Description	SATS Service(s)
0	Gate-to-Gate	Information Access/Exchange for Enhanced Decision Support	Flight Service / Emergency and Alerting Service
1	Pre-Flight Planning	NAS-Constraint Considerations for Schedule/Flight Optimization	Flight Service / Emergency and Alerting Service
2	Surface Departure	Intelligent Routing for Efficient Pushback Times and Taxi	Air Traffic Service / Self-Separation & Self-Sequencing
3	Terminal Departure	Free Maneuvering for User-Preferred Departures	Self-Separation & Self-Sequencing
4	Terminal Departure	Trajectory Negotiation for User-Preferred Departures	Self-Separation & Self-Sequencing

CE #	Operational Domain & Phase of Flight	Description	SATS Service(s)
5	En route (Departure, Cruise, Arrival)	Free Maneuvering for: (a) User-preferred Separation Assurance, and (a) (b) User-preferred Local TFM Conformance	Air Traffic Service / Self-Separation & Self-Sequencing
6	En route (Departure, Cruise, Arrival)	Trajectory Negotiation for: (a) User-preferred Separation Assurance, and (b) (b) User-preferred Local TFM Conformance	Air Traffic Service / Self-Separation & Self-Sequencing
7	En route (Departure, Cruise, Arrival)	Collaboration for Mitigating Local TFM Constraints due to Weather, SUA and Complexity	Air Traffic Service / Self-Separation & Self-Sequencing
8	En route / Terminal Arrival	Collaboration for User-Preferred Arrival Metering	Air Traffic Service / Self-Separation & Self-Sequencing
9	Terminal Arrival	Free Maneuvering for Weather Avoidance	Pilot Information Exchange / Self-Separation & Self-Sequencing
10	Terminal Arrival	Trajectory Negotiation for Weather Avoidance	Pilot Information Exchange / Self-Separation & Self-Sequencing
11	Terminal Arrival	Self Spacing for Merging and In-Trail Separation	Self-Separation & Self-Sequencing
12	Terminal Arrival	Trajectory Exchange for Merging and In-Trail Separation	Self-Separation & Self-Sequencing
13	Terminal Approach	Airborne Conflict Detection and Resolution for Closely Spaced Approaches	Self-Separation & Self-Sequencing
14	Surface Arrival	Intelligent Routing for Efficient Active-Runway Crossings and Taxi	Self-Separation & Self-Sequencing / Flight Service

The key point to note from this list is the implicit call for greater collaboration and integration to make the NAS in general more efficient. These notions become even more important for SATS aircraft as they will primarily frequent airports with less or no ground infrastructure. This means the SATS aircraft must be properly equipped, and SATS pilots must be capable of using the DAG-TM concepts. The SATS aircraft system will be able to prompt pilot collaboration with ATSPs, non-SATS aircraft, and among themselves when and as required to create these conceptual elements within the NAS.

3.2 Evolving NAS Services

Taking the DAG-TM concept into account, a NASA study performed by SAIC provided a high level grouping of services offered within the NAS. The Computer Networks & Software, Inc. Technology "Gap" Analysis took a more in-depth look at these services from a "classic aviation" (non-SATS) perspective. Additionally, these "classic aviation" works focuses primarily on an air carrier perspective. They were listed as they are expected to evolve over the next 25 years in three stages. A summary of the differences expected to occur in the classic aviation world includes features that will tend to:

- Acknowledge and leverage an increasingly distributed surveillance architecture that knows more and more about the state and intent of the objects that comprise it.
- Integrate more easily as lines between tactical and strategic start to blur.
- Move toward a contract model as the airspace "commoditizes".
- Increasingly enable user desires.

3.3 NAS Services Use by SATS

From this perspective, using the NAS is often a constraint-bound effort. SATS on the other hand, focuses by nature on the areas that are *not* bound by classic constraints such as traffic density, hubs at capacity, too few published approaches, etc. Thus, many of the "services" that are provided to classic users may be of somewhat lesser interest to a SATS operation.

From a SATS perspective, services tend to become important because they focus on:

- Surveillance of relevant "objects" (state and intent) within the SATS sphere of interest.
- Coordination and integration of "object" related services.
- Self-organized service rather than externally provided service.
- Collaboration among users and providers of services.

3.3.1 SATS CNS Service Groups

Furthermore from a SATS perspective, CNS services might be organized into three basic groups. The Communications group is SATS-specific, springing from the need to self-manage in an environment that demands successful collaboration among users and the system at large. The Navigation group, in this case is represented by the portion of the NAS that provides status of the navigational capability. The Surveillance group, in the SATS paradigm relies on distributed known traffic. Both Navigation and Surveillance groups are classic outgrowths of pilots co-managing a flight along with the ATSP and AOC/Coordination functions.

- Communications Information Services (CIS) - Information about the state and intent of information itself and the links that provide it.
- [Navigation]Flight Information Services (FIS) - Information about weather, SUA, NOTAMs, state and intent. (FIS includes status of navigation aids, facilities, and services through which the SATS processes its flight trajectory).
- [Surveillance}Traffic Information Services (TIS) - Information about traffic state and intent.

3.3.2 SATS Top Level CNS/ATM Services and Functions

SATS flight operations will require essentially the same basic services as listed in Table 1, DAG-TM Concept Elements. However, the use of those services will be significantly altered by the nature of the SATS self-organizing, -sequencing, and –separation capabilities. For the most part, informational requirements will be gathered from the same source as other, conventional flight operations. The SATS automation will then distribute individual elements of information to the appropriate service user process to perform the required functional capability. For the service and functional requirements, SATS operational needs have been distributed to eight (8) user service categories which best define the baseline requirements. The services are summarized in the Table 2 below.

Table 2. SATS User Services and Functions

Ref #	SATS User Services	Functional Capability
1	Flight Service	File flight plans and amendments. Process flight plans and amendments. Provide information for flight plans. Obtain in-flight or pre-flight weather and NAS status (NOTAMs) advisories. (*Near real time and forecast, tactical and strategic*) Obtain in-flight or pre-flight traffic advisories. (*Existing tactical and strategic*) Obtain in-flight NAS status advisories – current and scheduled.
2	Air Traffic Service	Provide separation of aircraft during ground operations. Provide separation of in-flight IFR aircraft. Avoid potential hazards and collisions. Maintain minimum distance from Special Use Airspace (SUA). Monitor flight progress. Enable in-flight sequencing, spacing, and flow management for SATS aircraft. Obtain pre-flight runway, taxi sequence, and movement restrictions. Project aircraft in-flight position and identify potential conflicts. Provide data to support managing use of SUA.

Ref #	SATS User Services	Functional Capability
3	Emergency and Alerting Service	Provide emergency assistance and alerts. *(For downed or troubled aircraft)* Support search and rescue.
4	Self-Separation and Sequencing Service	Provide data to ensure proper separation to avoid potential hazards and collisions. Provide data to support VFR and IFR traffic separation. Provide data to monitor flight progress. Provide self-separation in NAS.
5	Navigation Service	Provide airborne navigation guidance. Provide surface navigation guidance.
6	Pilot/Aircraft Information Service	Provide information concerning the flight. Enable separation of in-flight IFR aircraft. Enable in-flight sequencing and spacing for SATS aircraft. Provide aircraft in-flight position and identify potential conflicts.
7	Aircraft and Travel Service	Provide information about airport services. Notification to owner/operator about change in aircraft availability. Notification to owner/operator about aircraft maintenance issues. Provide other travel related information.
8	Public Information Exchange Service	Provide in-flight entertainment Provide public communications including email and web browsing.

3.4 The Airborne Internet

The Airborne Internet is a set of wireless communications that enable an aircraft in the system to achieve its full functionality in a CNS space, with primary focus on Communications and Surveillance. The AI is designed to allow easy access to flight-related operational data and information. The AI does not include GPS or WAAS, nor does it include some of the other already existing basic NAVAID transmissions such as VOR, ILS, and ADF. On the other hand, the AI will include status information about these NAVAIDs. It might also include or enable other navigational solutions that new technologies may provide.

3.4.1 AI Flight Operations and Services

With the above baselines in mind, describing desired SATS-specific operations and services throughout a typical flight allows a fuller understanding of the AI's potential, as well as the requirements an AI will have to meet. To characterize these operations and services, they can be considered in terms of:

- Phase of flight (Planning, surface operations, departure/arrival, en route)

- Functionality of operations and services (Purpose, Pilot-ATSP-operational support interactions, Highway in the Sky (HITS) and other graphic displays use, etc.)
- Environment in which the operation is conducted or service provided/consumed (Ground/Air, IMC/VMC, IFR/VFR/EFR, provider/user, rules and regulations, link characterization, etc.)
- Other operational factors (Training, skill,, safety issues, airspace use, etc.)

3.4.2 AI Non-Flight Operations Service

The AI must provide full SATS service to the pilot and passengers, as envisioned in the SATS Concept. To ensure that “doorstep to destination” services are available, a part of the AI will provide a capability to access the World Wide Web to support aircraft, business, and personal needs. This aspect of the AI will need to address security issues of sharing bandwidth with aviation communications, point of access, and funding and payment issues associated with AI data provided by government or contractor resources.

This aspect of the AI <u>is not</u> addressed in this concept.

3.4.3 AI – Growth Potential

Likely growth paths and divergence points of the AI will emerge as other airspace users determine that the AI’s purpose will best suit their operational needs. AI users will likely be active participants in refining and expanding the capability. AI service providers will also play a significant role in the AI’s capabilities, especially in network and bandwidth management, user interactions, network security, etc.

4. SATS PROOF OF CONCEPT OPERATIONS – 2005

4.1 Flight Planning - 2005

Flight planning between today and 2005 will not significantly change, but some new functionality will begin to appear. In contrast to today's static information about *planned* or *historical* status, NOTAMs, SUA, strategic traffic flow, and other NAS information will become dynamically available in near real time. Collaborative tools that respond to users current requests and plans will begin to appear, regulations that will allow EFR have been finalized, and flight plans will provide a fuller *flight profile* that includes references to flight *objects*, even though the airspace management has not yet advanced enough to have been transferred to a completely object oriented system. Flight planning information will be available through multiple outlets, including many Internet aware devices such as cell phones, laptops, Personal Digital Assistants (PDAs), and on-board electronic flight bag applications. Flight planning can be done from nearly anywhere.

4.1.1 Functionality

The purpose of the "Proof of Concept" SATS flight planning operation is much the same as today; i.e., it helps the pilot understand the environment and restrictions under which the flight will be made, and will continue to allow the system to mount effective search and rescue efforts if an aircraft does not reach its stated destination. The interactions within this operation, however, will begin to transform by 2005.

For instance, in order to meet user requirements, the static and repetitive current flight plan process is enhanced to provide a collaborative interaction with the planner. This interaction will create dynamic, event driven user-preferred trajectories for individual flights. Flight planning operations will be characterized by the following:

- Elements of the NAS-wide information system will be used to obtain and distribute flight-specific data and aeronautical information, including flight trajectory content.
- Real-time trajectory updates will reflect more realistic departure times, resulting in more accurate traffic load predictions, and increased flexibility due to the imposition of fewer restrictions.
- Interactive applications will facilitate a more collaborative role for users in obtaining NAS information in order to improve their ability to execute the flight plan. Examples of this information will include current and predicted status of SUAs, infrastructure status, traffic density, and prevailing traffic flow initiatives.
- Standardized domestic (and international) trajectory information will improve the interaction between the NAS, NAS users, and service providers.

These functional capabilities will begin to become available, but will not be universally so, as specifics elements of the NAS become more automated in their status reporting capabilities. As the individual NAS elements become more able to share their "state and intent" data. These elements will become one of many flight related "objects" in an increasingly object-oriented system. For instance, the scope of available information will be expanded to include items such as:

- Real-time information on the status of SUAs.
- Real-time status of the NAS infrastructure.
- Predictions of traffic density based on current flight trajectories, both filed and active.
- Current and planned dynamic route structure and associated transition points.

As a result of these improved planning capabilities, the flight plan could become more of a *flight profile*, especially in a SATS operation. This profile could be as simple as the user's preferred track, or as detailed as a time-based trajectory that includes the user's "chock-to-chock" four dimensional preferred path along with associated supplemental information.

The flight profile will become a part of a larger data set called the *flight object*. This data set will be available throughout the duration of the flight to the aircraft, the Coordination Center (if any), and Air Traffic Service Providers across the NAS. For an appropriately equipped aircraft operating under VFR, the flight object will contain the flight path, a discrete identification code that provides precise location and identity information, and all necessary information to initiate search and rescue. For a flight operating under IFR, the flight object will be a much larger data set, including user-preferred trajectories, and supplemental information such as the aircraft's current weight, position, or runway preference. Flight object information will be updated by automation capabilities on the aircraft, coordination center, or ATSP at appropriate junctures throughout the flight.

4.1.2 Environment

Flight planning will be conducted in a variety of locations - from home, at an airport operations center, from a remote third-party provider, or on-board the aircraft either in flight or on the ground. For a SATS operation, much of the planning will be done in an interactive manner with the NAS and will include a continuously updated, best estimate of en route and terminal traffic predictions for a scheduled arrival. Better surveillance of the NAS status as a whole will yield increasingly better information upon which to plan flights, resulting in more efficiency, greater throughput potential, and better schedule integrity.

The regulatory environment will remain essentially unchanged in 2005, although the FAA should be seriously addressing an EFR capability that will increasingly be directed toward SATS capabilities. Planning will be done, as today, over multiple links (including the Internet) and with multiple display options, including voice, data, graphics, and text. Similarly, submitting IFR or VFR flight plans will be largely unchanged from today with a single notable exception: *a SATS* *capable aircraft will have the capability to do nearly seamless on-board planning and submissions either on the ground or in the air.*

4.1.3 Growth Paths

As the Proof of Concept period ends, 2005 becomes a critical "Stepping Stone." The flight planning operation will have to support the capability to grow. Nearly every aspect of the NAS will be able to offer state and intent data - enabling them to become flight related objects. Constant updating of own-ship and other flight profiles, integrating ADS-B and other related surveillance information, will become a source of future Airborne Internet traffic, and will have to be sized in advance.

4.2 Airport Surface Operations - 2005

SATS aircraft will be able to use cooperative surveillance data for surface movements, but will be somewhat limited by the airport's capability. By 2005, surface movements in major hub locations will be somewhat more efficient than today. This efficiency will be enabled through various controller tools employing surveillance techniques including Automatic Surface Detection Equipment - X Band (ASDE-X) multilateration, ADS-B and TIS-B, some of which also allow traffic state and intent to be displayed in the cockpit. At more SATS-specific, lower use airports there will be only limited capabilities, or need, for these kinds of surface movement applications. The ability of SATS aircraft to perform taxi operations with other SATS aircraft will provide the requisite levels of separation and safety using the SATS Separation Algorithms. However, SATS taxi operations with non-SATS aircraft will be accomplished as they are today and only limited benefit will be realized.

Sequencing traffic from the ground into the air, however, will continue to be a challenge, particularly in terminal areas that include a major hub airport. Reliever airport terminal air and ground operational constraints will begin to be addressed through real-time surveillance among various aspects of the NAS infrastructure, users, and providers. This more comprehensive surveillance enables greater efficiency through collaboratively managing capacity and demand, particularly in busier terminal areas serving multiple airports.

SATS navigational and surveillance capabilities will enhance the opportunities for a SATS aircraft to be sequenced into the departure flows of terminal areas that contain multiple airports. Those terminal areas with regional or major hub operations can rely on the SATS aircraft to be capable of independent, non-interfering routing, that will allow the departure controller to release SATS aircraft closer to their requested departure time. At uncontrolled airports, the self-organizing SATS aircraft can use its surveillance and separation capabilities to sequence the aircraft into both arriving and departing SATS aircraft flows. The SATS aircraft would automatically notify the other SATS aircraft of its intentions.

4.2.1 Functionality

The primary purpose of surface movement operations in 2005 will be the same as today - transition between a parking location and the airspace. A secondary purpose of airport surface operations and services is to coordinate non-flight, support surface traffic.

Surface movement is both the first and last step in the progress of a flight through the NAS. With no expected increase in the number of available runways or taxiways, removing constraints on flights moving from initial movement to the runway, and from the runway to parking will be essential. Coordinating these movements and their integration into the terminal and center airspace will help minimize average ground delays of arrivals and departures. This will be done by implementing the following system enhancements:

- Expansion of surveillance capabilities will be improved to include more objects' state and intent data and information availability.

- Expansion of datalink capabilities to more users at more airports will improve information exchanges and coordination activities.

- Increased collaboration and information sharing among GA aircraft, coordination centers, and the air traffic system will create a more realistic picture of airport departure and arrival demand.

- Automation aids for dynamic collaboration among ground, tower, approach/departure, and center controllers will enable more efficient operations by balancing system demand with surface capacity.

- Runway and taxiway assignments will be based on projected arrival/departure runway loading and surface congestion, user runway preference and gate assignment, and environmental considerations such as noise abatement. Runway and taxiway assignments will be planned as part of the filed flight profile, and will be dynamically updated.

- Improved planning will allow flights to depart immediately after de-icing, improving both efficiency and safety. ATSP automation to monitor and predict the movement of ground vehicles will provide further safety enhancements through improved conflict advisories.

2005 will see the beginnings of greater integration of surface movements with airborne traffic issues as the transition from parking to flight becomes smoother. Toward this end, three basic functionalities will be evolving between 2001 and 2005 at larger hub airports: aviation information, separation assurance, and traffic management. SATS aircraft will be capable of using these evolving airport capabilities at major airports, and will enjoy some advantage over non-SATS aircraft at uncontrolled airports. (As mentioned earlier, SATS technological advantages will only be fully realized when performing taxi operations with other SATS aircraft.)

4.2.1.1. Aviation Information

By 2005, changes in surface operations information have occurred in three areas: aeronautical information, departure clearance, and surface management information.

Aeronautical information such as NOTAMs and meteorological information for the airport vicinity will continue to be acquired by service providers and disseminated to users to aid in their planning and conduct of flight operations. However, this acquisition and dissemination is expedited by the NAS-wide information system. The Automated Terminal Information Service (ATIS) will remain similar to the system of today. But through the use of voice synthesis technology, ATIS messages will no longer be manually recorded by service providers. Datalink will allow most of these messages to be transmitted digitally rather than over voice communications channels. Weather advisories will be handled in a similar fashion. SATS aircraft will be capable of receiving this information via the AI.

Departure clearances will be issued via datalink at more airports and to more users than is feasible today. In addition, automation functions will use these departure clearances (along with aircraft location and aircraft type) to generate taxi schedules. Thus, departures will be spaced more efficiently than they are today, resulting in reduced taxi times and improved airborne departure traffic flows. SATS aircraft will receive departure clearances via the AI, and will self-announce taxi at uncontrolled airports.

A surface management information system will be fielded at some airports to facilitate coordination between decision-makers at all levels of the airport operation. This system's processes and displays will provide complete data connectivity between the service provider, aircraft systems, pilot(s), operations center, ramp, airport operator, and airport emergency centers. The system will provide access to airport environmental information, arrival, departure, and taxi schedules, airborne and surface surveillance information, flight information, ATIS and other weather information, and traffic management initiatives. These data will be shared with the NAS-wide information system. At sites where the surface management information system is not fielded, ad-hoc site adaptations will provide basic intra-airport connectivity through the NAS-wide information system.

4.2.1.2. Separation Assurance

Separation assurance on the airport surface in 2005 will benefit from increased information to improve situation awareness, cockpit displays of this information, support taxi planning, and improved ramp control to match surface movement with the departure and arrival phases of flight. Distributing awareness among ground controllers and pilots will support increased throughput in poor weather conditions.

In today's environment, the pilot is responsible for meeting departure-time constraints, for maneuvering the aircraft to the appropriate taxiway, and for maintaining separation while in transit to the airport movement area. Ramp service providers (either FAA or airline personnel) manage the movement of aircraft across ramp areas to parking. In 2005, ramp service providers, where used, will sequence and meter aircraft movement at parking and on ramps, using situation displays that interface with decision support systems and personnel in the control tower. Safety will be enhanced by these situation displays which include airborne and surface traffic as well as information from the surface management information system. This information aids in sequencing arrivals and departures in concert with the taxi planning system.

SATS aircraft will be capable of participating fully at major, controlled airports. At smaller controlled airports, the SATS aircraft can contribute to the ground controller's endeavors by reporting and using the self-sequencing and self-separation features for taxi operations. At uncontrolled airports SATS operational capabilities and benefits will only be fully realized when operating simultaneously with other SATS aircraft.

4.2.1.3. Traffic Management Services

By 2005, traffic flow service providers will continue to oversee the surface automation by analyzing the operational situation and establishing initial parameters for surface movement planning. In this process, these service providers will establish initial taxi-times based on weather and airport configurations, and establish aircraft movement times required to accomplish deicing with minimal delay from station to departure. The ATSP will evaluate results and adjust parameters as needed. Both the initial values and subsequent adjustments will be incorporated into the surface management information system to ensure consistency and an integrated approach across systems. SATS' self-organizing capabilities will support both controlled and uncontrolled airport surface operations.

4.2.2 Environment

Communications and coordination will consume most of the ground operations and service provider's time. Therefore, ground operations at major hub locations will emphasize increasingly sophisticated and interconnected Decision Support Tools (DSTs) communicated through datalink messages from ATC, and possibly ramp controllers, to the cockpit. In contrast, SATS operations at little-used airports will be largely the same in 2005 since traffic will still be scarce and coordination mostly unnecessary.

IMC and VMC IFR operations at medium sized, busier airports in more major metropolitan areas will have the greatest need for coordination with the ATC system. Operational enhancements in this environment will come from:

- *Airport authorities* - Well equipped crew and passenger staging areas, intermodal transportation access, wireless network/Internet connectivity, wireless service request and response capacity (fuel, catering, parking, etc.), modern Fixed Base Operator (FBO) services, etc.

- *ATC System* - Updated traffic surveillance and surveillance reporting equipment (such as ASDE-X, TIS-B and/or ADS-B receivers), LAAS, vehicle surveillance tracking. Ability to use advanced surveillance techniques (weather, air traffic, airport surface vehicle traffic, facility status, etc.) to enhance safety and capacity on busy airports, ability to fuse airport, terminal, and en route data to enable better traffic flow among runways, parking, and servicing (fuel, deicing, catering, etc.) areas.

2005 will have an increasingly integrated environment as the system is beginning to automatically transmit surface, terminal, and en route information into the NAS-wide information system. Upon commencement of taxi by a SATS aircraft, supported by appropriate DSTs, a flight's departure and arrival times will be automatically updated based on current or average airport conditions. At wheels-up, these times will be updated again. This continuous updating will improve user and provider planning, execution, traffic management initiatives and collaborative decision making. Additionally, at supported locations, runway assignments in the departure and arrival automation will be based not only on the location of the assigned gate/parking spot, but also on the surface automation's prediction of congestion and the related taxi plan.

The ground regulatory environment in 2005 will not be significantly different than today, with the exception of specific ADS-B application approvals. Purely cockpit-based separation will not yet be present, but a variety of applications based on the work of Safe Flight 21 will have recently been approved. For instance, basic surface situational awareness and FAROA (Final Approach and Runway Occupancy Awareness) will drastically decrease all four levels of runway incursions. These will be based on the capability to fuse and display surface surveillance data in the cockpit.

ADS-B and other surveillance *data* will come over dedicated and defined surveillance links; however, the resulting *information* will be shared in a variety of ways. The links for sharing this information will range from high integrity low latency, limited frequency to the opposite end of the requirements spectrum.

4.2.3 Safety and Other Issues

With increasingly distributed awareness at major hub locations, safety will be enhanced - especially as it related to runway incursions. There will be increasing pressures to offer similarly integrated services at medium and smaller sized airports, services that enhances levels of safety as well as efficiency.

4.2.4 Growth Paths

Initially, most SATS surface applications will be relevant at controlled airports in major metropolitan areas with a decent ground infrastructure in place. As SATS moves forward, however, with its enhanced capabilities and increasing numbers of airplanes, growth will lie in the uncontrolled airports in smaller cities outside the more major areas. This kind of growth will depend more and more on the self-organizing capability of SATS aircraft. Here, the AI capacity of a SATS must be robust enough to support an increasingly sophisticated interface that coordinates with other SATS aircraft, the ATC system, and supports coordination with other surface transportation.

4.3 Departure and Arrival Operations - 2005

Departures and arrivals in 2005 will become somewhat more efficient than today's as a result of better surveillance and tools for both controllers and pilots. Additionally, beginning with night cargo operators, there will be a limited amount of self-separation among similarly equipped aircraft under tightly controlled circumstances. Terminal airspace will remain highly structured in most locations, although many of the major metropolitan areas are being equipped with ASDE-X radar, multilateration capability and ADS-B receivers. As en route, terminal, and surface surveillance data is fused, traffic management techniques will improve. Some major hub areas will have the beginnings of flexible airspace boundaries, fewer speed and heading changes, and less voice radio traffic than today. Increased situational awareness in the cockpits of SATS and other similarly equipped aircraft will begin to show promise in helping to enable integrated surface, terminal, and en route traffic management.

4.3.1 Functionality

The purpose of departure and arrival operations between 2001 and 2005 is the same as today: to transition airborne traffic back and forth between the ground and the en route segment of flight - or directly to another terminal area on short flights. Operations in the terminal area are usually the single biggest factor in achieving (or failing to achieve) planned flight times; therefore, terminal area operations are critical to efficient flights.

By 2005, SATS tactical operations in the terminal area will focus primarily on coordination between aircraft, while strategic/planning operations will focus on coordination between the ATC system and the SATS coordination function. In general, departure and arrival operations will be characterized by the following:

- ATC DSTs at controlled airfields will increase the efficiency by planning taxi sequences and spacing that lead to runway assignments, which in turn make transitions through terminal airspace and into the en route structure more efficiently than today's "first come first served" mentality. SATS aircraft will participate fully based on the type of flight plan.

- At major airports, departure and arrival route structures will begin to expand, within environmental constraints, to allow increased usage of area navigation (RNAV), satellite navigation, time/fuel efficient routes, and SATS operations, all of which can be flown automatically by the onboard Flight Management System (FMS).

- Improved procedures will begin to eliminate the need for many speed and altitude restrictions, including an expanded program to eliminate the 250 knot speed restriction below 10,000 feet at many locations. This will make final approach and runway occupancy even more keenly felt as the major traffic limitation at busy airports.

- Automatic exchange of information between SATS/equipped aircraft and ground-based DSTs will improve the accuracy and coordination of arrival trajectories. This exchange will include the aircraft's wind and weather information, which is shared with the service provider and other SATS/equipped aircraft.

- Increasingly accurate weather displays (forecasts, now-casts, current conditions) will be automatically made available to service providers. In addition, automatic broadcast of hazardous weather alerts for wind shear, micro-bursts, gust fronts, etc., can be delivered simultaneously to the flight deck and service provider.

- Shared access to NAS-wide information will allow exchanges of parking/gate and runway preference data among the pilot, the coordination capability, and the ATSP.

- Status and intent information concerning the NAS infrastructure components that support arrival and departure operations will be shared with the pilot, the coordination capability, and the ATSP nearly simultaneously.

- The inception of the NAS-Wide Information System (NWIS) will begin to have a positive affect on aviation information distribution within the NAS.

The activities associated with the departure and arrival phases of flight will continue to include separation assurance, traffic management, navigation/landing services, and airspace management.

4.3.1.1. Separation Assurance

By 2005, DSTs will begin to help arrival and departure ATSPs maintain situation awareness, identify and resolve conflicts, and provide sequencing and spacing of arrival traffic. As a result, separation assurance will have undergone changes in the following separation areas: aircraft-to-aircraft, aircraft-to-airspace, aircraft-to terrain/ obstruction. Departure and arrival planning services will leverage these changes to improve aircraft movement and flow.

Aircraft-to-aircraft separation will remain the responsibility of service providers for IFR operations in 2005, and, in most traffic situations, it remains *solely* their responsibility. However, today's practice of visual separation by pilots in terminal areas will expand by 2005 to allow all-weather aircraft-to-aircraft separation when deemed appropriate by the service provider, such as self-spacing on final approach. Furthermore, ADS-B equipped aircraft will have the on-board capacity to monitor and maintain safe separation on the ground and in the air. The increased use of this shared responsibility will be made feasible through improved traffic displays for the pilot. Rules, procedures, and training programs will have modified the roles and responsibilities of users and service providers. SATS aircraft will be capable of self-separation from other SATS aircraft and from TIS-B and ADS-B reported aircraft, and ATSPs can transfer separation responsibilities to SATS pilots as necessary (or desired).

To assure aircraft separation, ATSPs as well as pilots will use improved tools and displays. Today's situation displays and conflict alert functions will have evolved to provide more information, based on expanded data acquisition capabilities and improved trajectory state and intent in equipped aircraft. Expanded NAS information system data acquisition results from inputs by the aircraft's automation (or pilot), coordination center, ATSP, and interfacing NAS systems. These NAS information system inputs will provide more information concerning traffic status and predictions, status of individual flights, pilot intent, user preferences, and traffic plans generated by upstream and downstream ATSP automation systems. The distribution of this information by improved displays assists in ensuring situation awareness and in traffic planning. With these data, improved trajectory models and analyses will benefit the ATSP through highly accurate conflict detection and resolution functions that maximize safety while minimizing traffic disruption. These conflict detection and resolution functions will consider arrival and departure traffic throughout terminal airspace, separation at the intersection of converging runways, separation between parallel runways, and separation from ground vehicular traffic on the airport movement areas.

Aircraft-to-airspace and aircraft-to-terrain separation will also remain the service provider's responsibility in 2005 under IFR operations. In this regard, the ATSP will continue to maintain separation between controlled aircraft and active SUA, and between controlled aircraft and terrain/obstructions. An automated safe-altitude warning function will enable the ATSP to keep aircraft safely above terrain and obstructions. For airspace separation, accurate information on SUA status and intent will be disseminated by NAS information system, and updated with more automation than today. This will eliminate a growing number of coordination calls currently required among facilities, and will improve the timeliness and accuracy of the information. In addition to airspace and terrain/obstruction avoidance, both the ATSP and pilots will have improved tools to assist in avoiding hazardous weather. Enhanced weather data and weather alerts will be simultaneously downlinked by NAS information system to ATSP and coordination center displays, and uplinked to the flight deck. This distributed situational awareness will be key to early, efficient collaboration.

Departure and arrival planning services involve the sequencing and spacing of IFR arrivals, and the integration of departures into the airborne traffic environment. By 2005, SATS aircraft operating at controlled airports will operate using improved departure flows that will be achieved through tools that provide more efficient airport surface operations, improved real time assessment of traffic activity in departure and en route airspace, and expanded usage of flexible routes based on RNAV, satellite navigation, and FMS. Arrival operations will also benefit from these tools. However the ATSP's primary task in this phase (after safe separation) will continue to be planning to achieve optimum spacing and sequencing of the arrival flow. The runway assignment, which provides the basis for this activity, will be made early in the arrival phase of flight. The user's runway assignment preference will be made available through the flight object within the NAS information system, and will be used in conjunction with departure and arrival DSTs, and the integrated surface management tool to coordinate an optimal assignment. In the final approach portion of the arrival phase, DSTs will use time-based metering to maximize airspace and airport capacity. Other tools will generate advisories to the ATSP that will aid in maneuvering flights onto the final approach course in accordance with the planned traffic sequence. On final approach, the ATSP will have the option of giving the pilot responsibility for in-trail spacing to maintain the required sequence and spacing to the runway.

At uncontrolled airports, SATS aircraft will enjoy the distinct advantage of their CNS automation capabilities by being able to operate simultaneously with other SATS aircraft in IMC conditions in the vicinity of the airport. Using the SATS surveillance and self-separation capabilities, coupled with the SATS self-organizing functionality, traffic flow into and out of uncontrolled airports will allow safe, multiple SATS aircraft operations simultaneously.

4.3.1.2. Traffic Management Services

By 2005, the ATSP traffic flow management function will receive increased assistance from decision support systems for managing arrivals and departures. Today, these ATSPs make the plans that will guide arrival and departure activities. But with the increased use of decision support tools in 2005, these ATSPs will focus on establishing the parameters to be used by the support tools, and the tools will develop the plan. In this process, service providers will use the decision support systems to monitor traffic flows, NAS performance, and weather. They also will use these tools to report on departure/arrival resources, and to identify airspace and airport congestion problems. This will be facilitated by the commonality of information used by tower, arrival/departure, and en route ATSPs, who have access to identical tools and information regardless of facility.

Improved weather tools and displays will be used to assess the effect of weather on departure and arrival airspace capacity. Through the NAS information system, ATSPs will remain informed on distant weather conditions in order to anticipate changes to the daily traffic flow, and requests from other facilities. Data from the NAS information system will allow ATSPs to monitor infrastructure status, staffing, and other conditions in order to anticipate traffic demand and workload, both at their own facility and at others. This is especially important when working with tower ATSPs to manage runway configuration changes. Arrival flows and departure queues will be planned around projected times for configuration changes that cause the least traffic disruption. The arrival and departure ATSPs will also update the NAS system information about the capacity of airport and surrounding airspace resources and current status of the area's SUAs.

When traffic management initiatives are required, ATSPs will collaborate with users to resolve congestion problems through adjustment of user state and intent. If these adjustments do not adequately resolve the problem, the service providers will work with the national traffic management function to solicit user input concerning flow constraints, and these constraints will be entered into the NAS information system as planned or current operational requirements.

The SATS aircraft's capability to receive, process, and re-distribute NAS status information, including traffic management initiatives, will place SATS in the unique position of not only being a collaborative user, but of becoming an integral part of the NAS infrastructure during the flight. A SATS aircraft will be a collaborative user of ATSP services while operating in the NAS, and will be able to integrate itself into the traffic flow of uncontrolled airports using its self-separation and self-organizing capabilities.

4.3.1.3. Navigation/Landing Services

In 2005, the current ground-based navigation systems will have begun transitioning to satellite-based systems with space and ground based augmentation. The resulting extremely accurate navigation will allow aircraft to fly more flexible routes, resulting in savings to the user. Approach guidance, currently provided by ground-based systems, will be supplemented by satellite-based approaches by 2005. Augmentation systems will have the accuracy, availability, integrity, and continuity necessary for precision approaches.

Separation standards are established in accordance with the accuracy of the resulting surveillance information, which is based on the corresponding accuracy of the navigational solution. The use of satellite-based systems with space and ground based augmentation results in accuracies that ensure precision approaches can be made available at more airports, increasing all-weather access to an increasing number of airports.

4.3.1.4. Airspace Management

ATSPs currently use predetermined routes to manage departure flows. By 2005, more flexible departure routes will be gaining acceptance, within environmental constraints, as more aircraft become equipped with advanced navigation systems, and the service provider has automated support to verify adherence to the selected profile. These flexible paths will comprise a large set of profiles from which the user may choose. However, individually coordinated, user-preferred trajectories may also be used. Advance coordination of planned departure routes during the pre-flight phase make more flexible routing possible. SATS aircraft capabilities ensure that ATSP originated departure flows can be readily used by the SATS flight manager. At uncontrolled airports, SATS automation will generate recommended departure routing that will be included in the SATS flight object. The ATSP and SATS pilot will collaborate and decide any necessary changes to the SATS flight object.

4.3.2 Environment

In 2005, SATS departure and arrival operations will conducted in both IMC and VMC under IFR in the vicinity of major hubs - since this will be where the required DSTs and personnel reside, as well as where traffic will be most constrained. IFR operations, particularly under IMC conditions near regional and smaller airports will use the SATS to SATS distributed architecture to provide self-separation assurance. Under VFR, however, most SATS operations will be unchanged from current GA operations. The largest exception to this will be the potential ability of a SATS aircraft to depart a small, uncontrolled airport in VMC without speaking to an ATSP, but still have a full IFR clearance and the knowledge that the aircraft is already accepted into the IFR ATC system.

The aviation automation systems, both ground and air, will benefit from significant improvements that will contribute to more efficient operational capabilities. Systemic changes will also include the rules, procedures and regulatory environments that will begin to allow for and enable runway assignments and in merging and sequencing traffic, based on accurate traffic projections and user preferences. Eliminating today’s comparatively rigid routing and airspace constraints will become more of a priority as surveillance and situational awareness are distributed throughout the skies as well as ground. Tools such as CDM, FMS, datalink, and satellite navigation will allow route flexibility by reducing voice communications and increasing navigational and surveillance precision. Satellite-based position data, broadcast by properly equipped aircraft, are used in cockpit traffic displays to increase the pilots' situation awareness for aircraft-to-aircraft separation. SATS self-separation algorithms will ensure the separation from other SATS traffic, and will contribute to the pilot's situation awareness.

Pre-defined data link messages, such as altitude clearances and frequency changes, will be uplinked to an increasing number of equipped aircraft. Voice communications among ATSPs, coordination centers, and the pilot will be reduced, allowing extra time for planning functions that help accommodate increased traffic demand. ATSPs will be further assisted by enhanced ground-to-ground communications systems (both digital and voice) that allow seamless coordination within and between facilities. As a result, coordination between tower, departure/arrival, and en route ATSPs will become virtually indistinguishable from intra-facility coordination. Finally, disruption in departure and arrival traffic will be minimized by improved weather data and displays. Available to both ATSPs and all users, these data and displays will enhance safety and efficiency by disclosing weather severity and location.

4.3.3 Safety and Other Issues

Safety will be enhanced by 2005 primarily by redundant and distributed situational awareness in crowded terminal areas. In less crowded locations, adding self-aware SATS aircraft will contribute somewhat to an overall increase in situational awareness in both IFR and VFR operations.

Ground infrastructure in crowded terminal areas will have been upgraded, although not for SATS reasons. In lesser used areas no increase in ground infrastructure can be anticipated by 2005 for arrival and departure operations, which will give SATS aircraft a distinct advantage in these areas.

4.3.4 Growth Paths

In 2005, a SATS capable aircraft be will nearly alone in its ability to provide and accept surveillance, but not totally so. Airliners, notably the cargo carriers, will begin to equip with ADS-B while the first of over 50 airports in the country will be equipping with multilateration TIS-B capability. As SATS aircraft become more common, and the usage of under-utilized airports and airspace increases, the need for coordinating services and operations in outlying airports will increase. If airports themselves are not to take the burden of infrastructure upgrades, SATS capable aircraft will have to focus on robust wireless connectivity that provides acceptable, reliable service on the ground or in the air, at remote or congested locations. As SATS approaches a second or third generation in 2025, arrival and departure operations will begin to be coordinated more extensively with ground transportation and communications services to approach a seamless, hassle-free travel experience. The AI, especially in the busy coordination of a terminal area, will have to be capable of processing a growing number of links, messages, formats, and methods to provide the desired levels of service.

4.4 En Route - 2005

The two fundamental advantages of SATS aircraft are that they are not constrained by 1) published route or intermediate waypoints, or 2) a time schedule. Thus, with some ATSP constraints, a SATS aircraft may transit 4-dimensional space on a coordinated, self-determined and reprogrammable basis. This would mean dynamic rerouting of scheduled and/or intermediate destinations en route that could reduce the overall flight time or increase business operational opportunities. It is in the en route phase of flight that these fundamental differences have their greatest impact on the SATS concept of operations.

4.4.1 Functionality

To accommodate the flexibility required for an en route SATS flight will require increased communication and coordination of en route procedures and technology to maintain a smooth and efficient flow of aircraft "objects" through the NAS. With better technology aboard the SATS aircraft, self-separation will become an all- or near all-weather capability. With self-separation capabilities, the aircraft may assume responsibilities on-board the aircraft for separation, and be assisted by controllers versus the opposite in today's NAS.

4.4.1.1. Purpose

The purpose of the en route phase of a SATS flight will be to navigate 4-dimensional space while using new technologies that support the capability to vary any of the 4 dimensions. This capability will allow the SATS aircraft to maintain separation from 1) other SATS aircraft, 2) aircraft whose position and trajectory are reported via the TIS, and 3) airspace boundaries to achieve the SATS doorstep to destination flight mission.

4.4.1.2. Interactions among DAG-TM Constituents

Interactions among DAG-TM constituents will depend on equipage. Today, there would most likely be surveillance via MODE C transponders. By 2005, new technologies using space-based navigation facilities like GPS and WAAS/LAAS and data link using ADS-B technologies will provide for more accurate navigation and tracking of the aircraft. This could result in reduced separation of aircraft for transit through airspace otherwise unavailable or constrained due to altitude or other restrictions.

4.4.1.3. NAS Element Interactions

Today we have forms of visual self-separation. In 2005, we will begin to see broadened use of electronic self-separation with "hand-offs" from the controller to the aircraft. For example: "N1234, do you have electronic acquisition of aircraft at 12 O'clock, 5 Nautical miles and 500 feel below you?" "Approach, N1234 had the aircraft 12 O'clock, 5 Nautical miles and 500 feet below." "N1234 follow target aircraft and maintain 3 miles separation, you are cleared direct XYZ." "Approach, N1234 maintaining 3 miles separation and cleared direct XYZ." SATS aircraft will participate in this type of electronic separation based on traffic information available via the AI. SATS to SATS separation will use the separation and automated SATS information exchange capabilities.

4.4.2 Environment

Generally, the environment for 2005 will be similar to what exists in 2001. There will be some expansion of "direct to" flights for both VMC and IMC conditions made possible by Mode C transponders, global navigation and datalink capabilities. To the FAA, a SATS aircraft will be a "hybrid" IFR-capable aircraft. SATS pilots will be required to meet and adhere to all existing FAA regulations and rules governing the operation of the aircraft under IFR. The technological advances in the cockpit that allow SATS operations in IMC will allow the pilot to file flight plans that use direct routing, as well as instrument departures and arrivals at uncontrolled airports. In sparsely populated airspace, the FAA is likely to grant approval to such flight plans. However, as air traffic density increases, the first SATS flights will probably be subject to more restrictive routing.

SATS use of NAS airspace will include operations in all types and categories. Some SATS flights will originate in uncontrolled airspace, and transition into the NAS at flight plan coordinated fixes and times. SATS aircraft may transit the NAS at virtually any altitude, but initially the projected altitudes will likely be between the Minimum En Route Altitude and FL 220. SATS flights in controlled airspace will comply with the operational requirements of the airspace in use. Arrival and landing operations will be conducted at all levels of control, from TRACON airspace to uncontrolled. Most SATS flights will be conducted during daylight (± 80%), about 15% will be early morning or early evening operations, and the remaining 5% of the flights will be operated at night.

4.4.2.1. Location

SATS will be relatively unaffected by geography, except where aircraft performance is a factor. The CNS capability of SATS aircraft will initially use the existing communications networks for flight operations. For navigation, SATS will use a combination of GPS and ground-based navigational aids, and the use of surveillance capabilities will be the responsibility of ATC. As ADS-B and TIS near implementation, SATS will be a fully capable, early participant. As the NAS improves its CNS/ATM infrastructure, the locations of CNS facilities will become less dependent upon geographic locations.

4.4.2.2. IFR/VFR

For SATS aircraft, the most significant difference from similar IFR-capable aircraft, will be the SATS technologies that support near all weather operations. The number of GA aircraft departures and arrivals from uncontrolled airports will increase significantly and exponentially after 2005 as more GA owners take advantage of SATS technologies to enhance their business and leisure travel. SATS IFR operations at controlled airports, and in controlled airspace will adhere to ATSP procedures and instructions, However, the SATS pilot will enjoy a cockpit display set that is easier to use, and reduces the number of instruments from those currently needed for IFR flight.

VFR operations by SATS aircraft will not differ much from current VFR flights. The SATS aircraft will be able to detect, track, and maintain separation from other SATS aircraft in the area. Otherwise, SATS will operate as any other VFR aircraft.

4.4.2.3. IMC/VMC

SATS pilots operating in IMC will have a distinct advantage over their non-SATS counterparts. The advanced display and communications capabilities of SATS will greatly enhance the safe conduct of IMC operations. SATS' HITS display provides the pilot distinct advantages in flying "in the soup" because it displays the route of flight in three-dimensional pictographic video that displays terrain data which is helpful in maintaining spatial orientation, and can be used as a quick reference attitude indicator. The HITS display also depicts other SATS traffic (and ADS-B/TIS-B traffic when available). SATS communications capabilities will reduce the amount of time currently used to establish and maintain communications with ATSPs, FSSs, airport operators, and other supporting functionalities.

VMC operations will be conducted under the requirements of the type of flight plan, and as indicated in the section above.

4.4.2.4. Provider & User

In 2005, the ATSP of en route traffic services will continue to be the FAA. However, the Flight Information Services (FIS) will be available from private providers such as ARNAV, Honeywell, and ViGYAN. Other communications service providers may also be using satellite and other means to communicate. These agents may provide services to include flight plans and planning, weather, business services and personal communications.

4.4.2.5. Regulations and Rules

In 2005, SATS flights will use contemporary regulations and rules, and SATS operations will be conducted without extensive modifications of the rules and regulations. Initially, some SATS issues will arise based on the significant improvements SATS capabilities have, and some new procedures will be required, but for the most part, SATS operations will be conducted under contemporary operational constraints that only require local clarification. For example, SATS capabilities will support takeoffs and landings from uncontrolled airports, and transitions to and from controlled airspace under much worse weather conditions than currently allowed. Some ATSPs could authorize such operations based on the ATSP's operational situation. Other ATSPs may have to redesign their airspace to accommodate transition areas to handle these cases.

SATS will not have, or require, a series of its own amendments to existing rules and regulations, but will probably begin initial operations using SATS capabilities after a comprehensive orientation for both ATSP and flight support personnel.

4.4.2.6. Data Link Characterization

The implementation of SATS requires the use of the many new data link technologies currently being developed and tested. While SATS use of any one of these technologies may work in narrow bandwidth implementations, full realization of the SATS goals will require broadband implementation to accommodate the volume and extent of the services used by SATS aircraft.

4.4.3 Safety and Other Issues

4.4.3.1. Safety

Safety will continue to be the primary concern of all technologies applied to SATS. All SATS automation, airframe, and communications will be subject to gaining the appropriate certification prior to being implemented. SATS will be required to integrate with the NAS without interference or disruption to the NAS just as any other user does. FAA's Air Traffic Services department will need to examine, in depth, the self-sequencing, self-separation, and self organizing capabilities of SATS to gain the confidence in the SATS required for full operational implementation.

4.4.3.2. Certification Issues

The technologies being used represent innovative approaches to ATC and ATM. As such, organizations like NASA will be helpful in working with agencies such as the FAA Small Aircraft Directorate, and the FAA's Air Traffic Services department to provide a certification path for the new technologies. The SATS communications and automation technologies will require new certification guidelines on the use of spread spectrum technologies, bandwidth management, and other communications means.

4.4.3.3. Airport Interactions

4.4.3.3.1. Uncontrolled Airports

SATS aircraft transitions from departure to en route to approach will have minimal interactions at uncontrolled airports. Departure operations will be conducted as other IFR flight plan departures at uncontrolled airports, but with much lower weather minimae. During en route operations, a SATS flight will be able to access information about airports and be able to communicate with them to ascertain availability of services and to arrange for needed services such as car rental or repairs. SATS arrival operations will be conducted at much lower landing minimae due the technologies on board the aircraft.

4.4.3.3.2. Controlled Airports

SATS operations at controlled airports will be subject to the same rules, regulations, and procedures as other IFR operations, but the SATS technologies will support operations at much lower minimae as indicated above. Non-operational communications will be available to support coordinating services and personal support.

4.4.3.3.3. Air Traffic Control

SATS technology will require no additional qualification training for the ATC community. The implementation of new transition areas that could be implemented as a result of SATS will require inclusion into routine familiarization and currency training conducted at the area manager/supervisor level.

4.4.4 Growth Paths

In 2005 and beyond, the CNS/ATM capabilities will be become more automated. Interaction with the communications equipment will be such that it can be used by minimally trained operators. Likewise the ground infrastructure will accommodate the automation and support its operations with the required services and information.

5. SATS TRANSITION OPERATIONS – 2025

5.1 Flight Planning Operations - 2025

SATS flight planning between 2006 and 2025 will undergo significant transformation, becoming largely a matter of defining origin and destination along with any other user-centric preferences. Then SATS interactive tools will be capable of coordinating necessary operations and services to support the flight. Intelligent applications will take into account the current and projected status of all service elements, as well as the stated user preferences. Any incompatibilities between the stated desire and the capacity of the NAS to support that desire will be brought to the attention of the flight planner who will be given a range of options prior to securing a “flight contract” for services. This more traveler-centric approach will begin to extend beyond the NAS as users begin to manifest their destination desires to locations beyond the airport or gate. In this vein, a SATS flight planning exercise will begin to approach a “transportation contract” for destination to doorstop service.

5.1.1 Functionality

The changes in the flight planning process between 2006 and 2025 will ensure that a pilot can secure a given level of service, in both the NAS physical traffic and communications traffic arenas. Additionally, the flight plan will provide “hooks” into the surface transportation and communications space in order to provide predictable doorstop to destination service levels. To provide this level of integration, there will have been fundamental change within both the NAS and ground transportation communications service functions. For instance:

- SATS aircraft will be capable of gathering and distributing real-time surveillance data of the NAS, including traffic, weather, infrastructure, etc. on both the surface and the ground. This information will be available in real and near-real time as both state and intent of all participating objects.

- Dynamic traffic loading, sequencing, and separation will be transitioned into a smoothing spectrum of events. Traversing areas that are constricted in some manner will be more expensive than traversing areas that are not constricted. This “commoditization” of the airspace will become a favorable growth factor for SATS operations - especially if they are rewarded for bringing surveillance architecture to areas with little to no ground infrastructure.

- Highly intelligent and interactive planning automation elements will be capable of negotiating a “flight contract” that will balance user desires with resource availability. Many resources will be self-aware and self-reporting. Those that are not can be queried by and reported to the NAS by intelligent SATS aircraft.

- The airspace will be transitioning to a Free Flight environment with designated areas of Free Space available to equipped aircraft. In these areas, there will be no flight levels or routes, but a collection of dynamically reported and self-deconflicted four-dimensional routes. SATS flight operations in this airspace will provide the same reporting and self-separating capabilities as other aircraft.

- User profiles of pilots, passengers, cargo, and operators will become "objects" within the system, taking into account training and experience levels, standard desires such as speed over fuel consumption, actual destination locations, etc. These pilot and operator profiles will be used to provide dynamic assistance when necessary.

- Surface transportation "objects" will interact with the SATS AI to provide real-time updates that affect doorstop to destination travel, such as road commute times, taxi availability, rental car availability, and bus and train status.

Interactions between the SATS Aircraft and ATSPs are highly automatic and integrated - trading and updating information about the various "objects" within the NAS. Adding to these interactions are the surface coordination centers that will help arrange "doorstop to destination" movement of people and cargo. Surface "objects" will make a SATS 2025 "flight contract" quite similar to a "*transportation* contract."

5.1.2 Environment

Flight planning will be conducted even more seamlessly from nearly anywhere with minimal input from the planner. User profiles will reside as "objects" within the system, taking into account training levels and preferences (such as speed over fuel consumption). Thus, intelligent, SATS flight planning modules will be able to make most choices for a flight contract, allowing dynamic input and collaboration from the planner as desired. Furthermore, constant surveillance of most objects of interest will make flight planning more accurate, providing better schedule integrity.

The regulatory environment will become quite different in 2025 than in 2005 with EFR being an option common among SATS operations. By this time, there is likely to be a SATS-specific license for pilots, as well as SATS certification category for aircraft and supporting systems. An EFR contract will likely be the most common type of SATS flight plan scheduled, as these operations will fly into the less stressed airports within the system.

There will likely be a far greater reliance on wireless communications for flight planning, especially as SATS operations spread to increasingly smaller airports with nearly no dedicated, local infrastructure. Flight planning will increasingly be done during transportation to and from the airport while engaged in a destination to doorstep operation.

5.1.3 Growth Paths

As the Transition period progresses, flight planning activity will foreshadow a mature system that will become completely traveler-centered. All "flight objects" will be incorporated into the transportation system as a whole, with their state and intent being reported almost continuously. Travel objects (people and goods) will be easily tracked and reported upon as needed, with appropriate privacy protections. The challenge of the period's flight planning growth path will be to anticipate twofold: 1) be able to transform massive amounts of dynamic state and intent data into relevant information, and 2) anticipate and incorporate the unintended, beneficial uses found for such a dynamic travel planning engine as they develop.

5.2 Airport Surface Operations – 2025

Airport surface operations between 2006 and 2025 will undergo almost revolutionary change. The maturing of multilateration systems, integrated with ADS-B and TIS-B, and the introduction of low-cost vehicular and personal locator/intent squitters will provide both the ATSP and responsible ramp/agency with real time surface situation displays. This will ensure that each moving object, regardless of size or complexity, can be accurately tracked and guided by the responsible agency.

Both air carrier and SATS aircraft will be equipped to take advantage of this capability. The NWIS will provide systemic airport data that will be used in the displays of both air carrier and SATS aircraft as baseline information. SATS surface operations at controlled airports will be able to display the airport's surface taxi situation (via TIS) to support safe, expeditious taxi operations. This data, overlaid on the airport diagram, will be used to support surface routing to and from the runway-in-use. At uncontrolled airports, SATS aircraft will use available sensor data and cooperative data from other SATS/equipped aircraft for self-organizing among equipped aircraft, and to safely transit the surface movement areas.

By 2025 surface movements at busy airports - both with and without legacy infrastructure - will become an efficient, integrated process among ground, terminal, en route, and user desires and requirements. The distributed character of the self-organizing SATS surveillance infrastructure, combined with the increasing numbers of SATS flight operations will support multiple, safe take-off and landing operations at small airports with no ATSP capability. Medium sized airports which do have operating towers should have, or be scheduled to receive the surveillance technology that will allow them to gather and display a wide variety of information (ADS-B, TIS-B, aircraft weather, and infrastructure sensor transmissions, etc.). The NWIS will make a significantly increased amount of information available about the NAS in general, and each airport in specific, and will support the DST capabilities of aircraft and the ATSP. The DST-automated interactions will predict and adjust for any constraints or opportunities in the travel system as they help organize, sequence, and separate ground traffic.

5.2.1 Functionality

The primary purpose of surface movement operations in during this period remains essentially unchanged - transition between a parking location and the airspace. The secondary purpose of coordinating airport surface operations and services is also unchanged. How these functions are managed, however, will have advanced considerably.

The sophistication of operations and services available for SATS aircraft operating with other SATS aircraft at uncontrolled airports will be nearly indistinguishable from those at a major hub. Additionally, SATS activities at a couple major hubs will likely rise as airspace and infrastructure advances allow for increased SATS capacity without losing major airliner capacity.

Specifically, since 2005, the following system enhancements can reasonably be expected:

- The NWIS will be fully operational, offering a significant increase in downloadable flight support information. The data will include airport surface conditions and status, expected taxi operations loading, and expected taxi and departure delay information on specific flights.

- At a major hub, nearly all moving objects will be surveilled passively, actively, or both - including ground operations personnel.

- At a major (towered) airport, most aviation related equipment will provide active state and limited intent data for surveillance and control of the airport surface. SATS aircraft capabilities will enable full participation with these systems, and their procedures.

- At uncontrolled airports, SATS (and equivalently equipped) aircraft cooperatively sense and track each other and collaborate when necessary on movements, allowing for near VMC capacity in IMC conditions. Some operational and support functions will also broadcast status and intent information for optimal coordination.

- All surveillance activity can be displayed and used by on board SATS aircraft DSTs. Furthermore, the aircraft will transmit any object state and intent data that it knows to the system at large for outside consumption. This will include the status of runways, taxiways, parking facilities, local NAVAIDs, etc.

- Maturing collaboration among SATS aircraft, coordination centers, the air traffic system, and the ground transportation system will create an accurate method to balance capacity and demand in individual airports as well as multi-airport regions.

- Four dimensional flight objects will comprise dynamically updated flight profiles. Ground based and on board DSTs will be constantly balancing strategic and tactical aspects of SATS travel in the background, making minor adjustments automatically in routing, timing, altitude, etc. Larger required adjustments will be brought to the attention of the pilot, controller, and/or coordinating function for human collaboration and/or decision making.

By 2025 there will be even greater integration and automation of services. These three functionalities from 2005 will now look something like this:

5.2.1.1. Aviation Information

Aeronautical information (infrastructure status, weather, traffic, etc.) will be regionally and nationally compiled and assessed to determine the state and intent of the NAS as a whole. NWIS will manage and distribute NAS status information, and certain airport and airspace status will be available as a subscriber service, automatically distributed whenever the status or conditions change. The individual pieces comprising the NAS are nearly all equipped to self report, as have portions of the ground-based transportation system. In 2025, the beginnings of an integrated "Travel Information" network will begin to emerge.

Departure clearances will be simply part of the constantly updated, dynamic, object-oriented flight profile.

A surface management information system will share all known surveillance information with SATS aircraft. At smaller fields, this system will be a distributed one that resides among the SATS aircraft currently operating on the ground or in the immediate vicinity of the airport. Furthermore, these SATS craft will act as conduits to the NAS at large where no ground infrastructure exists to do the job. Finally, airport/aircraft/NWIS information has begun being shared with the surface transportation system, again creating the beginnings of a "Travel Information" network.

5.2.1.2. Separation Assurance

Separation assurance on the airport surface by 2025 will be predicated on the information that has improved situation awareness. Distributing awareness among ground controllers, gate controllers, pilots, service vehicles and personnel, etc. will no longer be considered an anomaly, but a requirement for safe, efficient operations. Separation on the ground will be assured by a combination of visual and electronic surveillance using complimentary algorithms among all concerned parties.

5.2.1.3. Traffic Management Services

The 2025 surface traffic flow will be integrated into the systemic (terminal, en route, etc.) flow. Tactical and strategic management of surface traffic will increasingly blend, and for metropolitan areas with multiple airports, will include using all as appropriate. SATS aircraft self-organizing capability will cooperatively determine surface flows on uncontrolled airports.

5.2.2 Environment

After 2005, as SATS aircraft and capabilities become more common, they will gradually affect smaller airports in both major and minor cities. As such, traffic will increase in these (sometimes under-utilized) airports. Operational enhancements in this environment will come from:

- *Airport authorities* - Updated, inexpensive, self-reporting active surveillance technology for appropriate non-aircraft vehicles and equipment. Increased intermodal transportation and communication access, wireless network/Internet connectivity as part of selected community business development.

- *SATS Aircraft* - Aircraft that bring portions of the distributed architecture with them, including next generation surveillance processing/fusing, various auto-reporting sensors (weather, traffic, surface conditions, infrastructure state, bandwidth usage, etc.). The AI will provide a redundant transmission conduit to and from the NAS for all distributed surveillance information gathered and received.

- *ATC System* - Highly integrated services at controlled airports, highly effective information distribution capability using NWIS and well coordinated, self-organizing services among equipped providers and users at smaller airports.

- *SATS Aircraft Owner/Operators* - Pilots trained to tactically employ their tools in variously capable environments; coordinating capabilities familiar with strategic SATS and NAS constraint issues, etc.

The NAS in 2025 will be a well integrated aviation environment at many airports. SATS aircraft will be able to directly exchange surface, terminal, and information with the NWIS. Using this AI feature, nearly all SATS flights' departure and arrival times will be automatically updated based on current airport conditions independent of location.

The ground regulatory environment in 2025 will be somewhat different than today with acceptance of purely cockpit-based taxi and separation in extremely low visibility. Except when associated with dangerous weather (lightning, severe convection, icing, etc.), even zero/zero ceiling and visibility will cause few restrictions for SATS aircraft ground operations connected to arrivals and departures.

It is likely that there will be an explosion of data link frequencies, methods, and technologies competing to carry both operational and supplemental information. By 2025 there will be inexpensive, unobtrusive transmitters that can be attached to nearly every object associated with ground operations - including people and goods. Due to the projected, complete depletion of frequency availability, this transition timeframe will be marked by increasingly sophisticated methods to manage bandwidth, rather than frequencies.

5.2.3 Growth Paths

By 2025, SATS will be a known concept to most of the public within the US. As such, communities will be realizing what an economic benefit a true SATS capability might bring. This, along with other outside environmental pressures, will motivate many communities to build intermodal transportation and communications capabilities into their airports, creating the beginnings of a traveler-centered transportation system.

Beyond 2025, the primary challenge the ground activity of an AI will have to meet will be twofold: 1) adapting to the transition from frequency management to bandwidth management, and 2) developing the capability to dynamically route both surface transportation and NWIS to and from SATS aircraft without regard to their location on the field.

5.3 Departure and Arrival Operations - 2025

IFR departures and arrivals at busy airports - airline hubs and regional/SATS airports alike - will be remarkably more efficient than in 2005. Stand-alone DSTs will have been integrated into nearly seamless tool suites that share a common look and feel across airport, terminal and en route controller stations. All modern aircraft will share intelligent uplink and downlink capabilities that allow for smooth transitions through arrivals and departures with a minimum of path and speed changes and a maximum of user preferences. Less busy airports will have an increasing number of SATS aircraft traffic and will be at their most efficient when multiple SATS aircraft are in the vicinity. Even non-SATS aircraft will begin to be outfitted with SATS-like capabilities, particularly inexpensive, VFR-only surveillance technologies (FIS/TIS) as well as HITS-like capabilities CDTIs.

5.3.1 Functionality

The purpose of arrivals and departures will remain unchanged - to transition traffic to and from the surface and en route arena. Just as today, smooth and efficient transitions will be essential to maintaining schedule integrity. In fact, as the en route segments of flights become more efficient, and since SATS aircraft will use airports with little or no ground congestion, the terminal area will begin to stand out clearly as the arena most responsible for schedule disruptions not due to weather.

By 2025, as mentioned earlier, there will be large areas of self-separation allowed. Having started with simple arrival procedures that were modeled after visual approaches, arrivals will begin to be paired (as in SOIA – Simultaneous Offset Instrument Approach) and then finally grouped into multiple interdependent objects (aircraft in this case) with the same objective (landing at a given runway). Busy airports serving mostly commercial flights are likely to see arrival streams of aircraft flying curvilinear approaches that converge at given locations into larger streams, and finally onto a runway. Being “cleared for the approach” at these more advanced airports will probably include an arrival time “slot” and prescribed four dimensional path. Additionally, “clearance” for the approach is likely to carry with it the responsibility to maintain separation from other participating traffic in the arrival sequencing stream of what is probably going to be ATC/ATM protected airspace.

By and large, SATS aircraft will not participate in these arrival streams, since they will not frequent the busier hubs where these technologies and procedures will first appear. They will in all likelihood, however, be equipped to do so if and when it is needed. More nominally, SATS aircraft will use smaller airports with little or no scheduled service. Even so, a number of relevant SATS-specific trends will be appearing by 2025:

- Major metropolitan areas will begin to realize the economic impact of SATS, and begin to establish some satellite/non-commercial airports as “SATS friendly airports.”

- Due to local economics, traffic to selected airports in smaller cities and towns will also become known as “SATS friendly airports.”

“SATS friendly” airports will be those with a fairly heavy SATS traffic load - something that will likely develop due to local business travel, local demographics, airport intermodal connectivity, airport information and “creature comfort” infrastructure. As the SATS concept becomes more accepted - indeed, more desired - local arrival and departure traffic will likely become a factor at given airports and given times. This trend should just begin to become a factor around the end of the transition period - 2025.

As the commercial hubs have done, the busier a "SATS friendly" airport becomes, the more susceptible it will be to having to develop the capability to efficiently and safely sequence and separate inbound and outbound traffic – i.e., ATC. Success will contribute to the airports upgrade opportunities. At many of the SATS friendly airports however, there will be little to no supporting ground ATC infrastructure available. Thus, the SATS aircraft will rely on its ability to self-organize: providing surveillance, sequencing, and separation services not only for itself, but also among other SATS traffic and traffic of various equipage levels.

In order to provide increasingly integrated SATS arrival/departure service, the cockpit, coordinating function, and ATC will begin to collaborate, something that is currently undergoing significant change with the Collaborative Decision Making application. By 2025, the difficulties collaborating among the cockpit, coordination center, and the ATSP will have been overcome for commercial traffic in terminal airspace. In 2025, the SATS coordinating function or ATSP may have important strategic input that could alter where and how the cockpit, tower, or ground wants to operate through terminal airspace. The aircraft, tower, or ground may have critical tactical input that might also alter prospective terminal operations. Moreover, the arrival and departure itself may be done without a classic approach/departure controller, but directly with a center or tower controller – or, in the case of a SATS aircraft, no controller at all.

5.3.2 Environment

Uncontrolled airports and lesser used airspace will provide the optimal path to allow SATS operations to come into their own by 2025. VFR operations will be flown with SATS aircraft mixing into the GA VFR traffic flow; the major challenge will be a probable slight mismatch in speed and performance. IFR traffic will continue to coordinate with the appropriate ARTCC on the way in and out through the multiple pathways an AI will provide, and also with any other SATS aircraft who may be in the vicinity on the ground or in the air. IFR traffic mixed with VFR traffic in the arrival and departure segments should cause little problem due to low volume. However, as always, good visual scans and radio discipline will be essential, as SATS pilots will remain responsible for ensuring their own visual separation from other SATS and non-SATS aircraft.

5.3.2.1. Controlled Airports

Controlled airports will bring some potentially challenging issues to light. Multiple reliever-type airports around major metropolitan areas, or multiple airports in relatively dense airspace such as the northeast corridor will be sharing arrival and departure streams. As SATS truly comes into being, some of these airports are likely to become known as "SATS-friendly" and frequented much more than others. (A SATS-friendly airport, for instance, might feature a restaurant, lodging, boarding step rental car delivery, a business center, bus service, etc. - all accessible within 5 minutes of arrival.)

SATS-friendly airports are liable to have locally high arrival and departure rates on given days and times. Multiple SATS-friendly airports in the same vicinity will, then, quite likely produce arrival and departure loads that "spike" on given days and times. Given that some form of ADS-B would probably help all equipped airplanes maintain safe separation (purely tactical), efficient sequencing (somewhat more strategic) should not become an issue in airspace with arrival/departure ATM services.

In airspace that features high frequency of both SATS operations as well as scheduled commercial services, the sequencing and separation issues become even more tangled. As previously noted, by 2025 there will be significant pockets of self-separation allowed, especially at or near final approach or initial departures. In complex airspace with more than one airport, and more than one operating paradigm, a number of options might be pursued to address the issue of safe, efficient sequencing and separation. In fact, it is likely that different solutions may be tried in different locations as the system as a whole evolves.

SATS operations will take place in IMC and VMC alike, although the IMC case is less stressing since operations will be among known aircraft. In mixed IMC/VMC operations, SATS aircraft can coordinate among themselves, but still must contend with non-SATS aircraft. In the vicinity of higher use airports, especially for arrival and departure operations, this could become an important issue.

Depending on the ultimate utility of an AI, it is possible that non-SATS aircraft may not be ADS-B equipped, but might choose to equip with an AI capability. If so, the AI might be used to provide some level of surveillance among participating aircraft. For instance, an aircraft may be equipped with a surveillance solution that is not certified to the level required to provide the basis for tactical self-separation. Nevertheless, the same surveillance solution might well be certifiable to use as the basis of more strategic self-sequencing applications. This would be particularly useful if the AI and associated sequencing collaboration were connected with standard ATC/ATM sequencing DSTs as well - especially in airspace around commercially busy airports.

5.3.3 Safety and Other Issues

Unmanaged or minimally managed airspace in terminal areas will probably be the location of greatest concern for SATS operations. It features the least desirable mix of traffic density, equipage mix, unknown intent, and airspace user complexity. SATS operating procedures will support maintaining safety while integrating SATS into the operational capabilities. During VMC, the SATS aircraft will operate cooperatively within the existing system. SATS aircraft using an IFR flight plan will use instrument procedures similar to those in current use. As the weather deteriorates, the SATS user will begin to realize the distinct advantage of SATS. An EFR flight plan will be used to document the SATS flight, which can be conducted safely in all-weather conditions.

Although airports will not need classic infrastructure to enable arrivals and departures to support a SATS paradigm, the "character" of the airport will in large part determine whether/how much it is used in SATS operations. A destination will not be a popular one, perhaps even in major metropolitan areas, unless it can support full utilization of the AI. During arrival and departure, AI activity will likely peak as this is when aircraft-to-aircraft, aircraft-to-ATSP, and aircraft-to-coordinating function collaboration is liable to be at its peak.

Today's "uncontrolled" arrival and departure airspace require IFR service to levy a "one in and one out" paradigm to ensure separation. By 2025, such managed but uncontrolled airspace will allow multiple ADS-B equipped aircraft to self-separate on an IFR (or EFR) clearance. However, the majority of coordination between the ATSP and participating ADS-B aircraft will require separation assurance be monitored by the ATSP. While there will be some increased benefits to maintaining separation using ADS-B, limitations on releasing that responsibility may continue to be driven by independent surveillance capabilities. The SATS aircraft, with its own separation algorithms will likely be considered better equipped for self-separation outside independent surveillance coverage.

By 2025, SATS aircraft in particular will be easier to operate than any aircraft previously built. ere will be certain demonstrable skill sets and training levels required to gain full SATS functionality. For instance, filing and operating "EFR" may require more than the basic level of proficiency required to operate the aircraft VFR. IFR operations, where the SATS pilot is responsible for the aircraft will remain constant, and require even more training and experience.

5.3.4 Growth Paths

In order for SATS arrivals and departures to achieve their ultimate goal of seamless integration into a larger transportation system, the 2025 AI will have to support robust and automatic

5.4 En Route Operations - 2025

By 2025, the airspace within the US will be in a transition to three basic types: Managed, Unmanaged, and Self-Managed (i.e., Free Flight). The boundaries between "en route, terminal, and airport environments" will be evolving at selected locations, where operations will involve seamless communications transfers and less workload on both controller and pilot. Due to the early Capstone work, this distinction is likely to begin in Alaska and spread to other fairly remote areas in the US where there is little-to-no ground infrastructure available.

There will be little unmanaged airspace in the en route domain, especially in the contiguous (lower) 48 states. Most en route airspace will still be managed, although some self-managed airspace will allow limited delegation of separation authority, and become a fairly common event for suitably equipped aircraft, SATS included. 2025 should see the onset of truly self-managed free flight airspace in the en route domain where SATS and other appropriately equipped planes can fly user-preferred trajectories while within the confines of the space.

Terminal environment operations will have self-managed approaches, and some self-management of departures is possible for aircraft on diverging courses. The airports will continue to improve on the taxi management and control automation installed in the previous transition period. Uncontrolled airports will experience a rapid growth of SATS-capable aircraft, which will use their self-separation, self-sequencing, and self-organizing capabilities to perform safe arrival, departure, and taxi operations

5.4.1 Functionality

The core function of the en route segment will not have changed - it is to cruise at the optimum condition while in transit from one location to another. SATS aircraft, operating at en route altitudes below FL 220 will operate in what is likely to be the first self-managed airspace in the contiguous 48 states. On-board sensors and surveillance data that is received and processed automatically will provide SATS with a self-separation capability. SATS will be able to operate in self-managed and self-organized traffic flows with like-equipped aircraft, and perform its own self-sequencing operations.

5.4.2 Environment

Medium altitude, non-terminal airspace is most likely to be the first self-managed airspace within the continental United States because it is the least occupied in many instances, and because it will be more heavily traveled by SATS aircraft. While in this "free flight" airspace, all aircraft will be equipped to some specified minimum level to provide self-separation. Self-sequencing operations enabled by SATS and other like-equipped aircraft, combined with the DSTs automatically communicating over the AI will support self-managed traffic.

During this period, the FAA (and presumably all ATSPs) will begin the transition from active airspace management and synchronization to stratified self-management that will include automatic cooperative self-organization. The aircraft's automation capabilities will attain certification to automatically coordinate with ground-based ATC DSTs to manage and control traffic within a designated area. The en route ATC services will also begin transitioning to less positive control; allowing the majority of aircraft to self-organize and self-sequence. The controller's role will see a shift to more of a management function, although positive control would remain a full capability in the event of an emergency or incident that cannot be resolved by the ATSP and aircraft automation alone.

In terminal areas, ATC will be closer to positive control, with the controller exercising closer supervision over the arrival and departure operations while DSTs automatically coordinate and assign RTAs for individual aircraft to provide the appropriate separation based on interoperability parameters (i.e., differences in preceding and succeeding type aircraft, speeds, altitude, airport capabilities, etc.). SATS aircraft will be fully capable of participating in the terminal environment.

The airport environment will see incremental improvements in some areas, but the majority of airport operations upgrades will have been completed in the previous period. Implementations of cooperative interactive surveillance, self-organizing taxi/movement operations, and enhanced arrival and departure prediction capabilities will be in place, and function to their full capability.

5.4.2.1. Airspace Transition

SATS, and other self-managed aircraft transitioning from self-managed to managed airspace will not be allowed to do so until the airspace manager/air traffic controller can accommodate it, just as ARTCC controllers today cannot be forced to receive an aircraft from another sector until ready. Although the airspace manager will begin to have a different function than that of today's controller, there will likely be two basic cases of transition out of free flight airspace. SATS aircraft must be capable of dealing with either.

5.4.2.1.1. Low Density Free Flight Entry and Exit Points

Entering or leaving free flight airspace and entering or leaving a low density en route or terminal area should normally provide no problem. As the SATS aircraft approaches the transition point, it will request, probably through the AI, the equivalent of an "IFR pickup," or a release from IFR. Air and ground DSTs will automatically negotiate a time and location for the transition from self-managed to managed airspace (or vice versa). Flight planning will consider the possible rare occurrence of delayed hand-offs.

5.4.2.1.2. High Density Free Flight Entry and Exit Points

Entering or exiting a self-managed environment into a high-density managed one will be more complex. Entering or exiting free flight airspace into high density managed airspace will likely depend on a Required Time of Arrival (RTA) contract. This constrains the SATS aircraft to arrive at a given location and a given time, but in return guarantees a hand-off. Any deviation from the contracted RTA will have to be negotiated - again, through the AI.

5.4.2.2. Conditions and Rules

Below 18,000 feet in managed airspace, both IMC and VMC operations can occur, as can IFR or VFR flight rules. The result is mixed equipage aircraft operating in the same airspace. SATS aircraft will likely encounter areas of traffic density where an inability to self-separate in any way other than specific, controller-assigned, pair-wise encounters will be the acceptable procedure. In this case, the ATM system is helping with sequencing. However, a growing number of sequence aware and sequence sensitive SATS aircraft can collaborate with the system to achieve individual user preferences.

In self-managed airspace (probable "EFR" operations), it will not matter whether aircraft are IMC or VMC because they will be compatibly equipped for self-separation. With this level of sophistication, the meteorological conditions should not significantly impact the capacity, flexibility, or throughput of the system. On the other hand, not all participating aircraft may have AI capability, which would affect optimizing a sequencing solution in free fight airspace if aircraft are competing for the same resources in the sky, such as a gap between thunderstorms.

Even in the most favorable of climates where free flight, EFR, and self-separation are embraced, regular IFR operations will still have to be accommodated due to legacy aircraft. IFR airspace is likely to begin the transition to "highways" near the end of the 2025 period. These "highways" will mark IFR routes through the growing expanse of free flight/EFR airspace in the en route domain. AI equipped airplanes that are NOT self-separation capable, however, might still participate in RTA negotiations, along with SATS and other aircraft.

5.4.3 Flight Safety and Other Issues

One of the largest flight safety challenges for the en route domain in the 2025 - 2050 timeframe will be to deal with the changing mixture of managed and self-managed airspace. In the beginning of this challenging period, "IFR" and controlled airspace will be the rule with "EFR" and free flight airspace available. Toward the end of the period, the reverse will be true. This will require managed/controlled/IFR climb and descent lanes cutting through so-called "free flight" space at many locations and/or times. The dynamic allocation or creation of such managed airspace within delegated self-managed airspace will be required to be coordinated. SATS' self-separation capabilities will support this coordination. In 2025, the majority of this coordination will already be conducted over the AI. During this period, the coordination of climb and descent lanes, transition areas between managed and self-managed airspace, and RTA sequencing will be conducted automatically between airborne and ground systems.

The surveillance of a "free flying" SATS aircraft in most free flight airspace by 2025 will be done by at least two means: ADS-B and ground-based sensor data being displayed via TIS-B. This dual thread system will ensure continuity of non-SATS traffic reports. All SATS and like-equipped aircraft will receive contingency clearances that allow air traffic managers to provide an "escape path" in case equipment failure causes a "free flying" aircraft to lose that capacity. In areas of no radar coverage, SATS aircraft's self-management capability will be capable of using the AI to broadcast an uncertified (or lower-level certified) navigation solution for a nearby aircraft that has lost its free flight capability. In fact, by 2050, most SATS and free flight capable aircraft will be capable of helping both the controller and other nearby aircraft negotiate the affected aircraft's exit from the self-managed arena.

5.4.4 Growth Paths

Apart from managing the en route AT***C*** to AT***M*** paradigm shift, the most challenging growth issue during 2025 – 2050 will be providing for an exponential expansion for collaboration. With the advent of ever-increasing numbers of SATS (and other like-equipped aircraft) occupying free flight airspace comes a near geometric increase in collaborative traffic requirements. Self-sequencing, RTA negotiations, transition requests, etc. will become more complicated as the airspace becomes more crowded and the traffic picture more complex.

The AI will increasingly provide both air/ground and air/air communications to handle the growing volume of system-to-system coordination required in both managed and unmanaged airspace. The AI will also undergo system extensive communications management enhancements during the 2025 – 2050 period. It will be capable of automatically connecting to the appropriate ATSP, acquiring the appropriate traffic information, and establishing air/air coordination with nearby aircraft. The AI will also be capable of independent retransmission of aviation messages as an integral part of the aeronautical information infrastructure. Providing a full AI capacity to handle rapidly building local data traffic will be essential to keeping SATS moving toward the fulfillment of its 2050 vision.

Appendix A – Acronyms

Acronym	Meaning
ACARS	Aircraft Communications and Addressing Reporting System
ADF	Automated Direction Finder
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance – Broadcast
AGATE	Advanced General Aviation Transport Experiments
AI	Airborne Internet
AOC	Aeronautical Operations Control
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ASDE-X	Automatic Surface Detection Equipment - X Band
ATIS	Automated Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Service
ATSP	Air Traffic Service Provider
CDM	Collaborative Decision Making
CE	Concept Element
CIS	Communications Information Services
CNS	Communications, Navigation, and Surveillance
CNS	Computer Networks & Software, Inc.
CNS/ATM	Communications, Navigation, and Surveillance/Air Traffic Management
COTS	Commercial Off-The-Shelf
CTAS	Center-TRACON Automation System
DAG-TM	Distributed Air Ground Traffic Management
DST	Decision Support Tool
EFR	Electronic Flight Rules
FAA	Federal Aviation Administration
FAROA	Final Approach and Runway Occupancy Awareness
FBO	Fixed Base Operator
FCC	Federal Communications Commission
FL	Flight Level
FMS	Flight Management System
FSS	Flight Service Station
GA	General Aviation
GAP	General Aviation Propulsion
GPS	Global Positioning System
GRC	Glenn Research Center

Appendix A – Acronyms

Acronym	Meaning
HITS	Highway in the Sky
IFR	Instrument Flight Rules
ILS	Instrumented Landing System
IMC	Instrument Meteorological Conditions
IP	Internet Protocol
LAAS	Local Area Augmentation System
Mode S	Mode Select
NAS	National Airspace System
NASA	National Aeronautics & Space Administration
NAVAID	Navigational Aid
NEXRAD	Next Generation Weather Radar
NOTAM	Notice to Airmen
NWIS	NAS-Wide Information System
PDA	Personal Digital Assistant
RNAV	Area Navigation
RPV	Remotely Piloted Vehicle
SATCOM	Satellite Communications
SATS	Small Aircraft Transportation System
SC	Special Committee
SOIA	Simultaneous Offset Instrument Approach
SUA	Special Use Airspace
TA	Traffic Advisory
TACAN	Tactical Air Navigation
TCAS	Traffic Alert and Collision Avoidance System
TCP	Transport Control Protocol
TCP/IP	Transport Control Protocol/Internet Protocol
TFM	Traffic Flow Management
TIS	Traffic Information Service
TIS-B	Traffic Information Service – Broadcast
TRACON	Terminal Radar Approach Control
UAT	Universal Access Transceiver
UAV	Unmanned Aerial Vehicle

Acronym	Meaning
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional Range
VORTAC	Combined VOR and TACAN
WAAS	Wide Area Augmentation System