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An Operational Concept for the Smart Landing Facility (SLF)

S.D. Thompson
S.R. Bussolari

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Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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16. Abstract

The purpose of this document is to describe an operational concept for the Smart Landing Facility (SLF). The SLF is proposed as a component of the Small Aircraft Transportation System (SATS) and is envisioned to utilize Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) technologies to support higher-volume air traffic operations in a wider variety of weather conditions than are currently possible at airports without an Air Traffic Control Tower (ATCT) or Terminal Radar Approach Control (TRACON). In order to accomplish this, the SLF will provide aircraft sequencing and separation within its terminal airspace (the SLF traffic area) and on the airport surface. The approach taken in this report is to first define and describe the SLF environment and the type of operations and aircraft that must be supported. Services currently provided by an ATCT and TRACON are reviewed and assembled into a set of high-level operational functions. A description of the applicable CNS/ATM technologies that have been deployed in the NAS or have been demonstrated to be operationally feasible is presented. A candidate SLF system concept that employs the CNS/ATM technologies is described. This is followed by SLF operational scenarios for minimally-equipped aircraft and for aircraft fully-equipped to make full use of SLF services. An assessment is made of the SLF technology and key research issues are identified.

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1. INTRODUCTION

The purpose of this document is to describe an operational concept for the Smart Landing Facility (SLF). The SLF is proposed as a component of the Small Aircraft Transportation System (SATS) and is envisioned to utilize Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) technologies to support higher-volume air traffic operations in a wider variety of weather conditions than are currently possible at airports without an Air Traffic Control Tower (ATCT) or Terminal Radar Approach Control (TRACON).

In order to accomplish this, the SLF will provide aircraft sequencing and separation within its terminal airspace (the SLF traffic area) and on the airport surface. The SLF infrastructure will provide timely and accurate weather and other flight information as well as traffic advisories. The SLF will provide a means to coordinate with nearby TRACONs or Air Route Traffic Control Centers (ARTCCs) to ensure proper integration of its traffic flows with those of adjacent airspace. The SLF services will be extended to all airspace users, but will particularly benefit single pilot operations, since these will be the principal users of the SLF.

The approach taken in this report is to first define and describe the SLF environment and the type of operations and aircraft that must be supported. This is presented in Section 2. In Section 3, those services currently provided by an ATCT and TRACON are reviewed and, in Section 4, assembled into a set of high-level operational functions. A description of the applicable CNS/ATM technologies that have been deployed in the NAS or have been demonstrated to be operationally feasible is presented in Section 5.

A candidate SLF system concept is described in Section 6 that employs the CNS/ATM technologies. This is followed by SLF operational scenarios for minimally-equipped aircraft and for aircraft fully-equipped to make full use of SLF services. In Section 7, an assessment is made of the SLF technology and key research issues are identified.

The SLF system description and operational concept presented herein is intended to meet the high-level requirements derived from current operations at airports with an ATCT and TRACON. No attempt has been made to perform an investment analysis to determine the particular cost/benefit ratio of any particular service or group of services. No safety analysis of the CNS/ATM technologies and their related services has been performed. Detailed safety and investment analyses to determine the appropriate mix of technologies and services for eventual deployment at the SLF will be an important component of the NASA SATS program. While the SLF operational concept assumes that an ATCT is not present, the associated CNS/ATM technology is also applicable to improved operations at towered airports, particularly those currently without terminal surveillance-based separation services.

2. SLF ENVIRONMENT

Candidate SLF airports are those without an operational Air Traffic Control Tower (ATCT) and, in most cases, without radar separation services in the nearby airspace provided by a TRACON or Air Route Traffic Control Center (ARTCC). They include everything from simple airports with a single runway and taxiway and no existing instrument approach, to airports with high operations rates, complicated taxiway layouts, and Instrument Landing System (ILS) approaches. Some of these airports have nearby TRACONs or ARTCCs that provide surveillance-based separation services in the nearby airspace.

The original purpose of the SLF as defined by the NASA SATS program was to provide services at non-towered airports that are now available at airports with an operating Air Traffic Control Tower (ATCT). However, as will be described below, the support of higher-volume operations in adverse weather requires surveillance-based separation services in the surrounding airspace. These services are not currently provided by the ATCT but are provided by the TRACON. Therefore, the purpose of the SLF is more properly defined as providing a combination of those services currently provided by the ATCT and TRACON.

The assumption is made that a SLF airport, like its ATCT/TRACON counterpart must accommodate simultaneous Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) operations and provide some level of service to all aircraft, from those with the minimum required equipment to those fully equipped to benefit from SLF services. For the purposes of this operational concept, the minimum aircraft equipment is assumed to be a VHF communications radio and an operational Air Traffic Control Radar Beacon System (ATCRBS) transponder with encoding altimeter. The rationale for this assumption is that the requirement to provide separation services, particularly in IMC, will necessitate the use of a surveillance system that provides aircraft location, altitude, and positive identification, and a means to communicate with all aircraft. This is supported in the existing aircraft fleet by the VHF voice radio and the ATCRBS transponder.

Additional capabilities over and above the minimum equipment described above may be added to aircraft to further benefit from SLF services. These may include data link communication, a flight management system with sufficient capability to support RNAV precision approaches, Automatic Dependent Surveillance-Broadcast (ADS-B), and a capability to fly approaches with a coupled autopilot, perhaps with an auto-land capability. The cockpit displays of the SATS aircraft may feature integrated displays of the approach path, terrain, weather, and traffic. The aircraft may be capable of adjusting its flight path and time of arrival (by means of fully-automatic, supervisory, or fully-manual control) based on traffic and trajectory estimates of other aircraft in the SLF traffic area.

It may be that some special use airports (e.g., an airport owned by a cargo airline solely for use by their aircraft) will be able to derive benefits by requiring that all aircraft be similarly equipped. However, for this operational concept, it is assumed that the SLF airport will simultaneously serve aircraft with different levels of equipage, with operational benefits provided to individual aircraft according to their equipage.

3. SERVICES PROVIDED BY THE ATCT AND TRACON

This section reviews and categorizes the services provided today by the ATCT and TRACON. The ATCT is generally responsible for the airspace within five nautical miles and 2,500 feet above the airport surface as well as the airport runways and taxiways. Depending upon the size of the particular TRACON, it is generally responsible for the airspace within approximately 20-30 nautical miles of the principal airport and up to approximately 4000 feet above the airport surface (Class C airspace) or 10,000 feet above mean sea level (Class B airspace). The services provided by the ATCT and TRACON may be divided into the following general categories:

3.1 Airport Configuration

The ATCT is responsible for determining the airport configuration. This includes designating the active runways (runways in use for landing and departing), traffic patterns for landing and departing aircraft, and ground traffic flow patterns. The determination of the airport configuration depends on the prevailing surface winds, ceiling, visibility, available instrument approach procedures, and noise abatement procedures. The ATCT can approve requests by pilots to use other than the current active runway.

3.2 Separation

3.2.1 Airport Traffic Area

The ATCT, when operational, is responsible for the airspace within five nautical miles and 2,500 feet above the surface of the airport (Class D Airspace). However, the ATCT does not generally provide separation services except within the airport traffic pattern. Although clearance is required to enter Class D Airspace, VFR aircraft are expected to maintain visual separation, and IFR aircraft are provided separation services by en route or terminal ATC facilities until they are established on an approved instrument approach procedure or the pilot accepts responsibility for visual separation. The en route or terminal ATC facility (ARTCC or TRACON) will coordinate the arrival of IFR traffic with the ATCT. In Instrument Meteorological Conditions (IMC), all aircraft generally operate under IFR and are separated by an en route or terminal ATC facility until they are handed over to the ATCT. The ATCT provides runway separation standards. Under limited circumstances, an ATCT controller may authorize a Special VFR operation when conditions are less than VFR minimums (visibility of one statute mile and clear of clouds), which allows an aircraft to operate VFR within the Class D Airspace.

The capacity of an airport during IMC is dependent on the availability of surveillance data to the controlling ARTCC or TRACON. Without surveillance coverage of the airport and surrounding airspace, procedural separation is required. That is, an entire block of airspace is reserved for an arrival or departure aircraft until the arrival has landed and reported on the airport surface or until the departure is in radar contact. Procedural separation typically limits IFR arrivals to a single runway to approximately 3 per hour compared to the 30 or more IFR arrivals per hour that can be sustained with radar-based separation.

If the weather at the airport is Visual Meteorological Conditions (VMC), VFR arrival aircraft must obtain a clearance from the ATCT to enter the airport traffic area, but are expected to maintain visual separation from other aircraft. IFR aircraft arriving in VMC are provided separation service by an en route or terminal ATC facility until accepting responsibility for visual separation. The ATCT is responsible for sequencing and separating the VFR and IFR traffic for landing. This includes runway assignment and the merging of traffic into the traffic pattern. This is normally accomplished visually from the ATCT with the assistance of VHF voice position reports from the pilots. In some cases, an ATCT will have remote radar displays from an ATC terminal facility to assist in this operation.

3.2.2 Runways

The ATCT is responsible for ensuring that runway separation standards are met. In general, this means that an arrival aircraft cannot land until the preceding arrival is off of the runway or the preceding departure is past the departure end of the runway. If the air traffic controller in the ATCT can determine distances by reference to suitable landmarks, and the preceding departure is airborne, the departing aircraft need not have crossed the other end of the runway. Separation standards are met if the departing aircraft is airborne and at least 6,000 feet beyond the runway approach threshold when the arriving aircraft crosses the threshold.

Light, single engine and twin-engine piston-powered aircraft are subject to less stringent runway separation standards during daylight hours if the controller can determine distances by reference to suitable landmarks. A light, single-engine piston airplane can land behind an arriving or departing light single or twin-engine piston airplane if the preceding aircraft is at least 3,000 feet down the runway. A light twin can land behind a light single or twin if the preceding aircraft is 4,500 feet down the runway. Note that the separation requirements apply to the landing aircraft as it crosses the runway threshold and that the separation may decrease as the landing aircraft overtakes the preceding arrival or departure aircraft.

The runway separation requirements for takeoff aircraft are similar. The preceding arrival must be clear of the runway or the preceding departure past the end of the runway. Again, there are exceptions if the controller can determine distances and reduced standards for light, single and twin-engine piston powered aircraft.

An aircraft arriving or departing to a runway while there is arriving or departing traffic on an intersecting runway cannot cross the threshold or start the take-off until the traffic on the other runway is through the intersection. The restriction may not apply if special land and hold short operations are approved and in use.

In addition, there are wake vortex separation standards that apply to arrival aircraft at the threshold of the landing runway. These requirements depend on the relative weight classes of the aircraft involved.

Finally, there may be takeoff restrictions based on wake vortex considerations. These are expressed as minimum time limits between the departure of the first aircraft and departure of the next aircraft and are dependent on weight classes.

The ATCT is responsible for coordination of simultaneous use of multiple runways. In some cases, the surface wind and noise abatement procedures may favor one runway while runway length requirements may dictate the use of another runway for some aircraft. In some cases, multiple runways are used to increase airport capacity.

The ATCT coordinates the use of the runway between departures and arrivals. In general, arriving aircraft have priority and departures are cleared for takeoff when the runway is available, but when the demand is heavy, the ATCT will often space arrivals in the traffic pattern to allow for departures. Coordination is also required for departures using a runway that intersects with the arrival runway. Surface winds may dictate that one runway is used as the primary runway for arrivals and departures, but large aircraft may have to use a longer intersecting runway. This requires ATCT coordination.

3.2.3 Surface

The ATCT issues taxi clearances on the Ground Control frequency to implement a conflict free flow of traffic on the surface to and from the active runways. In general, taxiways are not wide enough to accommodate two-way traffic flows.

The ATCT must sequence and separate arrivals and departures so that aircraft on the surface can cross active runways if necessary. The ATCT (Ground Control or Local) provides the clearance to cross the runway assuring that there is no conflicting traffic.

It is the responsibility of the ATCT to coordinate surface movement of emergency and maintenance vehicles.

3.3 Weather

The ATCT provides continuous recorded weather observations to pilots via Automatic Terminal Information Service (ATIS). This recording is updated once an hour. Special observations are entered if there is a significant change in the weather.

The ATCT is responsible for providing hazardous weather warnings to pilots. ATCTs at large airports may have access to Terminal Doppler Weather Radar (TDWR) or Integrated Terminal Weather Service (ITWS). The ATCT has the authority to shut down all operations at the airport due to hazardous weather.

3.4 Information and Coordination

The ATCT is responsible for providing information concerning airport operations or facility outages that are relevant to pilots. This may be in the form of Notices to Airmen (NOTAMs). The ATCT also aids pilots by providing directions to facilities to pilots not familiar with the airport.

The ATCT uses landline communications with en route and terminal ATC facilities to coordinate the arrival and departure of IFR aircraft. The ATC facility must fit a proposed departure in with other traffic in the airspace and so issues an "IFR release" for the aircraft to the ATCT. The ATCT must fit the departure in with traffic using the runway and accommodate any finite time limit issued with the IFR release.

The ATCT is responsible for assisting aircraft in an emergency. This will generally require priority handling of the aircraft in distress and coordination with emergency ground equipment. Aircraft in the traffic pattern may have to be temporarily rerouted or diverted. In some cases, the airport may have to be closed to operations.

The ATCT provides clearances to IFR departure aircraft and verifies the read-back on the Ground Control or Clearance Delivery frequency. At larger airports, the clearance is provided by a data link (via Pre Departure Clearance, PDC) to aircraft equipped with the ACARS data link system supplied by ARINC.

ATCTs are the coordination points for airport maintenance activities and emergency response activities. In addition, the ATCT is a point of contact between the airport and the surrounding neighborhood.

3.5 Current Operations at Airports without an ATCT

It is worth contrasting current operating procedures at airports without an ATCT with the operations at ATCT airports described above. The airport configuration (runways in use) is generally determined by the surface winds and that information is available to pilots by visual reference to a wind sock or wind triangle. This may require that the pilot fly over the airport at an altitude higher than the traffic pattern altitude. Sometimes the pilot can obtain this information from a UNICOM frequency or by listening to other pilot reports on the Common Traffic Advisory Frequency (CTAF). Some airports have automated weather observation and reporting available (see below) on designated VHF frequencies and the surface winds can be obtained from this source. A pilot can infer the preferred runway for landing from the direction of the surface winds, but in the case of light or variable winds, this can be misleading.

Separation is based on visual acquisition of other traffic and self-separation. Designated airport traffic patterns are suppose to be followed and there are "rules of the road" to determine which aircraft have the right of way for VFR traffic. IFR operations are allowed at uncontrolled airports, and this is especially workload-intensive for pilots when the weather is such that VFR traffic is allowed in the traffic pattern. En route traffic must arrive following a designated instrument approach procedure. Generally, the IFR pilots must monitor the CTAF frequency to obtain situational awareness of the VFR traffic in the pattern and announce their position while remaining in radio contact with the en route facility until they can cancel their flight plan. At the same time, the pilot may be flying an instrument approach that, if conducted outside radar coverage, may contain complex maneuvers (e.g., procedure turns) to correctly position the aircraft for the approach. Surface operations are uncontrolled and rely on self-separation.

Some airports are equipped with Automated Surface (or Weather) Observation Systems (ASOS/AWOS) that report the weather over designated frequencies. If not, the pilot must rely on a manned UNICOM frequency or weather reports from nearby airports.

Coordination with en route facilities may be difficult at uncontrolled airports. More airports are being equipped with remote communications systems that allow the pilot to receive clearances and cancel flight plans directly with the controlling en route facility via VHF voice radio while on the ground. Otherwise the pilot must depart VFR or obtain a clearance time and limit over the telephone before departure. If there is no surveillance available, the airport is closed to other IFR operations when an aircraft has been given an approach or departure clearance until the aircraft cancels over the radio or is under radar surveillance. This significantly limits the IFR capacity of the airport. Typical maximum operations rates under these circumstances are approximately 3 per hour (sum of IFR arrivals and departures) or approximately 10% of the IFR operations rate that can be sustained at a single runway airport with an ATCT.

4. HIGH LEVEL OPERATIONAL FUNCTIONS OF AN ATCT

A review of the services provided by an ATCT described in the previous section can be used to generate high-level operational functions. These operational functions may be grouped into four categories: 1) Surveillance, 2) Sequencing and Planning to assure Separation, 3) Communications, and 4) Integrating the Effects of Weather.

4.1 Surveillance

To provide services, the ATCT must have access to surveillance information. In its simplest form this must include:

1. Aircraft location
2. Aircraft identification
3. Aircraft intentions

In practice, this data is often made available to the ATCT controller by a combination of direct visual observation and VHF voice radio communications. In some cases, surveillance data is made available to the ATCT from an Airport Surveillance Radar. However it is provided, surveillance data must be accurate and updated at a rate sufficient to support the sequencing and planning function.

4.2 Sequencing and Planning

Where available, the ATCT uses radar surveillance data to determine both a strategic and tactical plan for aircraft sequencing and spacing. Example components of a strategic plan are arrival acceptance rates, active runways, integration of arrivals and departures, and use of traffic patterns. An example of a tactical plan is the plan for spacing of specific aircraft in right and left traffic patterns to integrate with an IFR arrival and a departure. Both the strategic and tactical plans must be flexible and are updated in response to weather conditions, upstream and downstream traffic flow constraints, and unanticipated actions of the pilots.

4.3 Communications

The ATCT's tactical plan is implemented by communicating individual clearances to specific aircraft. Two-way communications is needed to confirm that the pilot can accept and comply with the clearance and to accept requests from the pilot. Today's communications are, for the most part, by voice over common VHF frequencies. This allows for a party line effect in that all aircraft using that frequency can hear all communications and use that information for situational awareness. The communications load on a common frequency leads to congestion on that frequency. The communications function could be accomplished via data link to the aircraft, but it is necessary to compensate for the loss of party line information.

4.4 Integrating Effects of Weather

The ATCT must have access to current and forecast weather because the weather affects the planning function in several ways. There may be areas of hazardous weather that must be avoided. The weather may require that instrument approaches be used for arrivals or that instrument arrivals be integrated with local VFR operations. The ATCT may have to close down an airport or individual runways due to hazardous weather or surface conditions.

5. SURVEY OF ENABLING TECHNOLOGIES

The following is a list and description of technologies that are candidates for use in the SLF.

5.1 Communications

5.1.1 Voice Systems

VHF voice communications are available at airports with ATCTs. The VHF aeronautical communications band is currently divided into 25 kHz channels that are used for both voice and data communication between aircraft and ground. Voice is used for the ATC portion of Air Traffic Services (ATS) communication and for airline operations. Data transmission is currently used primarily for Aeronautical Operational Control (AOC) communication with airline operations centers. The planned evolution of ATS communications is based on a digital communication network infrastructure, and VHF digital links for ATS use are planned for the near term.

Generally there are at least two separate frequencies available for use by the ATCT. "Local" for runway and air traffic operations and "Ground Control" for the surface movement area. Sometimes there is a separate frequency for Clearance Delivery and Gate Control. Currently at airports without an ATCT, a Common Traffic Advisory Frequency (CTAF) is used as a voice "party line" for pilots to announce their position and intentions. The CTAF may be a UNICOM, Multicom, Flight Service Station (FSS), or ATCT frequency (when the ATCT is not operational). Except for ATCT frequencies, the frequencies available for CTAF are limited and subject to overlapping, i.e., pilots at one airport using the assigned CTAF are likely to hear pilots from another airport with the same assigned CTAF.

A growing number of uncontrolled (no operating control ATCT) airports are equipped with Remote Communications Outlets (RCO) or Remote Transmitter/Receiver (RTR). These are unmanned communications facilities remotely controlled by air traffic personnel. RCO's serve FSS's. RTR's serve terminal ATC facilities. These communications outlets serve to facilitate communications with FSS and terminal ATC facilities while an aircraft is on the ground. This allows the aircraft to file a flight plan, receive weather briefings and receive an ATC clearance prior to departure. These frequencies are not usually subject to overlapping with other uncontrolled airports. An RTR is often the same departure frequency that is used in the air but because of the remote communications equipment at the airport, aircraft on the ground can communicate before departure.

VHF channel availability is becoming a major problem. The need for additional VHF voice channels has become so acute in Europe that a new analog voice system is being introduced this year. This system divides existing 25 kHz analog voice channels into three 8.33 kHz analog voice channels, and will be referred to here as "8.33 kHz voice."

VHF Digital Link Mode 3 (VDL Mode 3 or just VDL-3) is being considered as an alternative to splitting the 25kHz channels. VDL-3 is based on transmission of voice or data in digital form using time division multiple access (TDMA) technology for sharing a single 25 kHz channel among three or four sub-channels. Each sub-channel can be assigned to either voice or data functions, with a ground station managing the assignment of sub-channels.

5.1.2 Data Systems

Air-to-ground data link communication systems are in wide use today. The Aircraft Communications Addressing and Reporting System (ACARS) is used for communications between aircraft and their Airline Operation Center (AOC). The two major ACARS service providers are ARINC (Aeronautical Radio, Inc.) and SITA (Société Internationale de Télécommunications Aéronautiques). Mobile data link communications are provided over VHF data link, Inmarsat satellite links, and High Frequency Data Link (HFDL). The latter modes provide for communication over the oceans and in remote regions. Ten 25 kHz aeronautical VHF channels are allocated worldwide for ACARS, but in no one location are all ten utilized.

ACARS is specified by ARINC standards, but not by ICAO Standards and Recommended Practices (SARPs). Instead, ICAO has developed SARPs for the Aeronautical Telecommunication Network (ATN). This is a bit-oriented set of protocols based on the International Organization for Standardization (ISO) Open System Interconnection (OSI) reference model. The ATN is intended to support both ground-ground and air-ground data communications and allows arbitrary network topology based on packet routing.

The 2400 bps data rate of ACARS is regarded as inadequate for today's AOC needs by many airlines and a replacement link called VHF Digital Link Mode 2 (or VDL-2) is currently being implemented. ICAO has approved and published the VDL-2 SARPs. VDL-2 is a 31,500 bps bit-oriented link that is compatible with ATN, and the intended evolution is from ACARS messages over the ACARS link, to ACARS messages over the VDL-2 link, to ATN messages over the VDL-2 link. VDL-2 is also the basis for the distribution of weather data by two Flight Information System-Broadcast (FIS-B) vendors operating under contract to FAA. The FIS-B system is described in the weather section of this chapter.

Given the rapid evolution of commercial telecommunications, including mobile communications, and the greater success of the TCP/IP protocol suite compared to the ISO/OSI protocol suite, the future of ATN is uncertain. Competitive pressures from future commercial mobile data services may prevent its widespread operational deployment for all but the most critical ATC communication functions.

Neither ACARS nor VDL-2 are capable of guaranteeing short message delays in the presence of high demand. The VDL-3 protocol being developed by the FAA for voice and data communication will be able to support such time-critical messages. It uses the same 31,500 bps modulation as VDL-2, but uses a Time-Division Multiple Access (TDMA) protocol for access to the channel rather than the Carrier-Sense Multiple Access (CSMA) protocol used by ACARS and VDL-2, thus guaranteeing channel access within a defined time. VDL-3 employs a bit-oriented protocol compatible with ATN. An ICAO SARPs for VDL-3 is under development.

Yet another VHF digital link using TDMA technology has been proposed by Swedish ATC authorities, and is referred to as VDL Mode 4 in ICAO. VDL-4 is an outgrowth of earlier work done on a self-organizing TDMA (STDMA) system. Currently, VDL-4 is being considered within ICAO only for Automatic Dependent Surveillance-Broadcast (ADS-B), see Section 5.3 above, although it is potentially capable of supporting general data link functions including the ATN. The "self-organizing" feature of VDL-4 has been designed to allow aircraft to determine their own TDMA slot assignments without the need for channel management by a ground station. This concept would allow VDL-4 operation in areas where ground station support is not available, making the system useful in remote areas of the world and in underdeveloped nations. However, high-density airspace requires a higher reporting rate than does remote airspace, therefore additional channels will be needed in terminal areas, along with ground stations to assign aircraft to channels and to set the rate at which aircraft report their position.

The Mode S secondary radar system is capable of general data link communications. Existing SARPs define the use of the Mode S data link as an ATN-compatible subnetwork.

The Universal Access Transceiver (UAT) is a digital data link with a broadcast protocol that has been proposed to provide Automatic Dependent Surveillance Broadcast (see the Surveillance section below) as well as broadcast traffic and weather services. UAT is currently operating on an experimental basis in Alaska on 966 MHz.

Table 1 shows the alternative communication systems being proposed for implementation and the type of services each is intended to provide. ATS Messages refers to Controller Pilot Data Link Communications (CPDLC), Automatic Dependent Surveillance-Addressed (ADS-A) and Flight Information Services. ACARS users, including AOC communications, are expected to transition to VDL-2. VDL-2 will be used for ATS data communication in Europe and the U.S., although the U.S. plans to migrate to VDL-3 when it becomes available. European voice traffic will migrate from 25 kHz voice to 8.33 kHz voice, while the U.S. expects to migrate to VDL-3. Currently there are no plans to use VDL-3 for AOC communication, although that is technically possible. VDL-4, and UAT are capable of providing broadcast flight information services.

TABLE 1

Communication Functions Associated with Current and Future Data Systems

	25 kHz Voice	8.33 kHz Voice	ACARS	VDL-2	Mode S	VDL-3	VDL-4	UAT
Voice	✔	✔				✓		
AOC Msgs			✔	✔				
ATS Msgs			✔	✔	✓	✓	✓	
FIS			✔	✔	✓	✓	✓	✓

✔ - Current communication functions

✓ - Potential communications functions

In addition to the links discussed above and listed in Table 1, commercially-available satellite services are being introduced. Echo Flight expects to receive certification this year on a data link transceiver that uses ORBCOMM's constellation of 35 low-earth orbit satellites operating in the VHF band to provide bi-directional data and messaging. Real time weather will be available to compatible cockpit displays. Avidyne's Flight Max Flight Situation Displays (FSDs), when interfaced with Echo Flight's data link transceiver, will display radar weather data, storm cell vectors, and satellite imagery as well as data on icing and turbulence and text messages.

5.2 Navigation

The ATCT does not currently provide navigation services, but the use of precision navigation is essential to the SLF operational concept and so a brief description is included here. Navigation in the NAS is supported by an infrastructure of VHF OmniDirectional Range (VOR) transmitters with Distance Measuring Equipment (DME). Low altitude and high altitude airways connect these VOR "nodes". Most ATM separation functions are based on aircraft following these airways. Area navigation or RNAV equipment that allows direct point to point (great circle route) navigation is widely available. Most commercial airliners use VOR/DME based RNAV equipment in the U.S. Oceanic flight requires Inertial Navigation Systems (INS). Global Positioning System (GPS) has gained wide acceptance in general aviation and business aircraft. The relatively limited use of direct routing in the NAS is not due to lack of equipment on the aircraft, it is due to lack of capability of the ATM system to accept widespread direct routing

Most commercial flights use the Instrument Landing System (ILS) for precision approaches. Non-precision approaches are not widely used except by commuter airlines at smaller airports and general aviation aircraft. Non-precision GPS approaches are now widely available. Frequency limitations will not support a large increase in additional ILS approaches although most airports served by commercial aircraft now have adequate ILS approaches. Precision approaches using the Instrument Landing System (ILS) are available at major airports for multiple runways. Some candidate SLF airports are expected to have ILS currently operational. It is not expected that new ILSs will be required at SLF airports. It is assumed that this will be accomplished with precision GPS approaches.

The Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) are designed to extend GPS capability to support precision approaches from the existing 625 airports to approximately 3,300 airports. Problems with the programs have led to a review by the General Accounting Office that questions the cost benefit and technical feasibility of these programs. Additionally, there have been some concerns raised over susceptibility of GPS and WAAS/LAAS to jamming. However, the FAA recently made the WAAS system available for VFR use after testing the system for stability and reliability. WAAS improves the accuracy of GPS to 2 meters horizontally and 3 meters vertically throughout the contiguous U.S. The WAAS system will not be approved for IFR use until the FAA completes more testing.

The technology to allow vertical guidance on non-precision GPS approaches is now being introduced. Modern GPS avionics have the capability now of flying vertical guidance approaches. There should be no technical problem with the introduction of vertical guidance utilizing curved initial approach paths to precision approach procedures.

Some modern small aircraft today have sophisticated autopilot systems that track programmed flight plans, accept direct routing and reroutes, accommodate holds, and provide vertical rate selection to pre-set altitudes. Most modern airline aircraft, in addition to the Flight Management Systems that can accomplish the tasks described above, also have auto-throttle capability and auto-land capability. It should be technically feasible to incorporate this technology into smaller aircraft that will enable them to make full use of SLF facilities. Certification and its associated costs are likely to present the most significant barrier to this process.

Instrument approach procedures for all airports in the US are currently available in digital form from a commercial provider. There are commercial products and services currently available that provide graphic displays of the digitized approach procedures. All instrument approved GPS navigation systems have provisions for updating the navigation data from commercial sources using data supplied by the FAA.

Terrain mapping databases are required for terrain avoidance and to display a "VFR"-like environment to the pilot in IMC. Terrain databases are not required to design an obstacle free instrument approach and missed approach procedure. Color moving map navigation displays integrated with user input flight plans are commercially available. These displays include aircraft position, navaids, flight plan route, airports, holding patterns, and instrument approach transitions and procedures. Displays that provide "virtual" VFR display of terrain, approach "tunnels", the airport environment and runway, and traffic have been demonstrated in the laboratory.

5.3 Surveillance

5.3.1 Airport Surveillance Radar (ASR)

For the foreseeable future, surveillance in the majority of the NAS will consist of ground-based primary and secondary radar and will support aircraft equipped with either Mode S or Air Traffic Control Radar Beacon System (ATCRBS) transponders.

The terminal area at major airports is covered by primary and secondary Airport Surveillance Radar (ASR) that provides coverage to aircraft within approximately sixty nautical miles of the airport. SLF airports that fall within this coverage area may be able to receive a remote data feed from this radar depending on the coverage it provides in the SLF traffic area.

5.3.2 ADS-B

Automatic Dependent Surveillance-Broadcast (ADS-B) is a technique whereby the aircraft broadcasts its self-determined position to other aircraft and the ground. It is often assumed that the source of position determination is GPS although other systems or combination of systems that meet Required Navigational Performance (RNP) such as INS, LORAN, or VOR/DME RNAV may be acceptable.

ADS-B receivers located on the ground (e.g., at the SLF) or on aircraft can receive the ADS-B broadcasts and thereby obtain the surveillance information required for ATCT functions.

There is currently no schedule for the implementation of ADS-B. There has been no FAA decision on the technology that will be employed for the ADS-B data link. There are three data link candidates for ADS-B candidates: Mode S Extended Squitter, VDL Mode 4, and Universal Access Transceiver (UAT).

Because of the requirement to support mixed aircraft equipage, ADS-B alone cannot meet the surveillance requirements for SLF.

5.3.3 Small Terminal Sensor Options

There are several options available to perform cooperative aircraft surveillance that exploit the capabilities of the existing equipage base of ATCRBS and Mode S transponders.

A short-range secondary radar, which could use a small rotating antenna or simple phased array, would provide surveillance on all transponder-equipped aircraft in the SLF traffic area. The complexity of such a sensor is directly related to the coverage volume, accuracy, and update rate desired. FAA currently uses stand-alone secondary radars to fill gaps in the en route environment.

Transponder multilateration is being considered by the FAA for surveillance on the airport surface and could provide surveillance in the vicinity of an SLF. To perform this function, several multilateration ground stations would be required. The number and location of the ground stations is dependent upon the desired accuracy and coverage area.

The existing airborne Traffic Alert and Collision Avoidance System (TCAS) uses active interrogations of target aircraft to elicit replies from both Mode C and Mode S equipped transponders. It is essentially an airborne secondary radar. The FAA-sponsored Small Terminal Sensor (STS) project [1] demonstrated that a ground-based TCAS unit could be used as a surveillance sensor in the airport traffic area. The prototype STS updated tracks once per second with demonstrated accuracies of better than 100 feet (1σ) in range and better than 1° (1σ) in azimuth. STS demonstrated interrogation of near-co-altitude, minimum transponder capability aircraft at a range of 14 nmi (3dB link margin). For nominally-equipped aircraft, this range was extended to 20 nmi (3dB link margin).

The Transponder Landing System uses a technique similar to TCAS but employs a much larger antenna array to provide very accurate azimuth information to support precision approach. A similar technique could be used to improve the surveillance performance of the TCAS-based STS described above.

5.3.4 Airport Surface Surveillance

Airport Surface Detection Equipment (ASDE)-3 radars are installed at major airports for surface surveillance. Lower-cost X-band radar has been demonstrated as an effective substitute that may be suitable for smaller airports. Airport Movement Area Safety System (AMASS) is a collection of algorithms designed to track the movement of surface aircraft and landing aircraft and warn controllers of possible conflicts. The use of runway status lights, automatically operated by software receiving data from airborne and surface surveillance systems, has been demonstrated as an effective method of preventing runway incursions [2,3,4]. Transponder multilateration has been demonstrated and is being deployed by FAA at major airports to complement the non-cooperative surveillance provided by the ASDE primary radars.

5.4 Air Traffic Management: Sequencing and Separation

5.4.1 Situational Awareness / Collision Avoidance

The airborne TCAS system is in widespread use in air carrier and larger GA aircraft to provide aircrews with situational awareness and collision avoidance. Several lower-cost derivatives of TCAS are currently offered by manufacturers for smaller GA aircraft.

The Traffic Information Service (TIS) [5] is a Mode S specific service that uses the surveillance information gathered by a ground-based FAA Mode S sensor and uplinks that information using the Mode S data link to client aircraft.

The Traffic Information Service-Broadcast (TIS-B) is a concept for a service similar to TIS but uses the ADS-B data link to broadcast surveillance information from ground-based radars. Either TIS or TIS-B can be supported by any of the surveillance options discussed in Section 5.3.

5.4.2 CTAS (TMA)

The Center Tracon Automation System (CTAS) comprises the Traffic Management Advisor (TMA), the Descent Advisor (DA), and the Final Approach Spacing Tool (FAST). The Traffic Management Advisor is designed to optimally schedule and sequence aircraft arriving at major airports. CTAS has been demonstrated at Dallas and Denver and is designed as an automation tool to assist Traffic Management Coordinators and Air Traffic Controllers with the runway assignments, metering and scheduling of arrivals. The CTAS automation includes a real time trajectory synthesizer. The Descent Advisor uses the trajectory synthesizer to provide conflict-free, fuel-efficient descents that are consistent with TMA arrival scheduling. Trajectory prediction techniques similar to those used by CTAS (but considerably simpler than those necessary at a major airport) may be applicable to scheduling arrivals at the SLF.

5.4.3 URET

User Request and Evaluation Tool (URET) is a tool designed to assist en route controllers at Air Route Traffic Control Centers (ARTCC) in predicting and resolving future conflicts. URET combines real-time flight plan and radar track data with site adaptation, aircraft performance characteristics, and winds and temperatures aloft to construct four-dimensional flight profiles, or trajectories, for pre-departure and active flight plans. For active flights, URET also adapts itself to the observed behavior of the aircraft and dynamically adjusts predicted speeds, climb rates, and descent rates based on the performance of each individual flight tracked through en route airspace. URET uses its predicted trajectories to continuously detect potential aircraft conflicts up to 20 minutes into the future and to provide strategic notification to the appropriate sector. Trajectories also form the basis for the system's trial planning capability. Trail planning allows the controller to check a desired flight plan amendment that resolves conflicts before a clearance is issued. The controller can then construct the flight plan amendment from that trial plan with the click of a button. URET is currently in use as a prototype in two en route centers. The trajectory generator and conflict prediction algorithms of this tool may be adaptable to SLF arrival traffic and integrated with the "smart" ground-based separation and sequencing algorithms. In any case, the automated functions of the SLF must integrate with URET where required to provide a smooth transition to and from the en route domain.

5.4.4 DSP

The Departure Sequencing Program is designed to integrate departures from multiple airports into the en route air traffic system. Limited en route departure gates require coordination among departures from nearby multiple airports. This could be adapted to SLF airports with synthesized voice advisories or through RCOs. As with URET, it will be necessary for the SLF functions to integrate with DSP where required to coordinate traffic flows with nearby DSP airports.

5.5 Weather

Accurate timely hazardous weather data from Terminal Doppler Weather Radar (TDWR) and Integrated Terminal Weather System (ITWS) is available at the largest airports, but the same fidelity of weather information is not available at most small airports. However, the FAA has begun to expand the availability of NEXRAD graphical precipitation weather data to medium size airports located within the coverage area as part of the Medium Intensity Airport Weather System (MIAWS). MIAWS or a derivative could be used to extend this service to SLF airports.

Commercial aircraft and high-end general aviation aircraft have reliable on-board weather radar but lower-end general aviation aircraft generally have only lightning strike detectors or must depend on air traffic control advisories. New controller displays allow display of weather as an overlay but the older radar displays have only rudimentary weather depiction.

Flight Information System-Broadcast (FIS-B) is being designed to be an automated data link system to provide non-control, advisory data, including graphical hazardous weather to pilots. The goal of FIS-B data link systems is to provide weather and other flight advisory information to pilots in a way that will enhance their awareness of the flight situation and enable better strategic decision-making. The information provided through FIS-B will be advisory in nature, and considered non-binding advice and information provided to assist in the safe conduct of a flight. The FAA has made two VHF frequencies utilizing a VDL-2 protocol for FIS-B available nationwide.

The future SLF operational concept requires that all users have access to the best weather information available to ensure agreement on how to best avoid hazardous weather. This will require a data link of the weather available on the ground to all aircraft.

There are commercially-available satellite services for receiving and displaying graphical weather data in the cockpit. Data includes radar reflectivity data for precipitation and lightning strike data. As described above, Echo Flight expects to receive certification this year on a data link transceiver that uses ORBCOMM's constellation of 35 low-earth orbit satellites operating in the VHF band to provide bi-directional data and messaging. Real time weather will be available to compatible cockpit displays.

5.6 Avionics

This section contains descriptions of demonstrated avionics capabilities that would be applicable to make best use of SLF capabilities.

Cockpit display technology has made great strides in recent years. There are now commercially available color multifunction displays designed for general aviation aircraft that combine navigation information with available traffic, weather, and terrain data. Navigation data includes moving map displays with stored routes and available navaids. Holding procedures, instrument approach procedures, and standard terminal arrival and departure procedures can be appended to the flight plan information and displayed. Traffic from the Traffic Information Service (TIS) or TCAS can be displayed on the same unit. Weather from weather radar or from commercially available satellite services can be overlaid on the display. Lightning strike data available from on-board units can also be displayed. A topographical data base can be accessed based on GPS supplied position to provide warnings or to provide three-dimensional visual displays of the terrain.

Examples of units available now include the Bendix/King KMD 850 Multifunction Display and IHAS 1000, 5000 and 8000 Integrated Hazard Avoidance Systems. Honeywell has received the FAA's TSO (technical standard order) approval and a Supplemental Type Certificate (STC) for the Bendix/King KGP 560. The KGP 560 includes its own GPS receiver and a worldwide database of terrain features and manmade objects. The KGP 560 provides a color display of terrain and obstacles within ranges up to 320 nm on the Bendix/King 550/850 multi-function displays. Other units available include the BFGoodrich SmartDeck Integrated Flight Displays and Control System utilizing a Primary Flight Display and a Multi-Function/Instrument and Crew Advisory System Display, the Universal Avionics Systems Corporation Terrain Awareness and Warning System, the UPS Aviation Technologies MX20 Multi-Function Display which is being demonstrated in the Alaska Capstone program, and the Avidyne FlightMax series of Multi-Function Displays which includes data link capability. The Garmin integrated nav/com/GPS moving map units also interface with traffic displays from TIS and weather from lightning detection systems. Sandel offers an Electronic Flight Information System (EFIS) for general aviation that replaces the Horizontal Situation Indicator (HSI), Directional Gyro (DG) and Remote Magnetic Indicator (RMI). A moving map of the flight plan, airspace, approaches, runway diagrams, lightning detection data, marker beacon lights, GPS annunciators and DME readouts are integrated into the normal display of heading, course and glideslope data.

Rockwell Collins is working with NASA to develop a synthetic vision system that will give pilots terrain views and intuitive guidance in any weather.

Traffic Alert and Collision Avoidance System (TCAS) incorporates a display that shows relative position of target aircraft with the relative altitude and climb or descent information printed next to the target. Large air carrier aircraft and some business aircraft carry a TCAS-2 system that will actively interrogate other aircraft and provide coordinated resolution advisories in the vertical direction. The TCAS-1 carried by commuter aircraft and some business aircraft also actively interrogates the transponders of nearby aircraft but do not provide resolution advisories. Ryan International Corp. introduced a lower cost Traffic Collision Alert Device (TCAD) that displays traffic based on replies from target aircraft but does not provide active interrogation. Newer units from Ryan (9900BX) and BFGoodrich (Skywatch) do provide active interrogation and display traffic with TCAS symbology. The newer units provide more sophisticated conflict alerts but not resolution advisories.

A display format identical to TCAS can be incorporated into existing storm scope displays or moving map displays. One commercially available unit for light aircraft provides voice warnings of conflicting traffic and in the event of a conflict duplicates the TCAS display as a postage stamp icon on the moving map display. The user can click on the icon for a large-scale full color display of the traffic. If ADS-B becomes available, traffic information can be displayed based on known own ship position and reported ADS-B traffic positions.

Air carrier aircraft display airborne radar weather on a dedicated display. Weather radars are now available and common on some of the larger general aviation aircraft including single-engine aircraft but the systems are still expensive. As pointed out above, there are commercially available Flight Information Service data link systems that receive weather data and allow the pilot to superimpose weather data over the moving map display.

6. OPERATIONAL CONCEPT

The following is a description of an SLF operational concept that makes use of the technologies described above to provide services to minimally-equipped aircraft as well as advanced services to fully-equipped aircraft. This operational concept assumes that the minimum equipage requirement is an ATCRBS Mode C transponder and a VHF voice radio. All services currently provided by the ATCT are treated below. It should be emphasized here that no analysis of the cost/benefit of any particular service or combination of services has been included in the development of this operational concept. The objective was simply to describe how all of the services provided by the ATCT today could be provided by SLF and what technologies could be employed. Determining the proper mix of technologies and services to achieve a favorable cost/benefit ratio for the SLF should be addressed by the SATS Program and should be used to modify the operational concept presented here. Figure 1 is a block diagram of the information flow in SLF and Figure 2 is an illustration of the SLF sequencing and separation services.

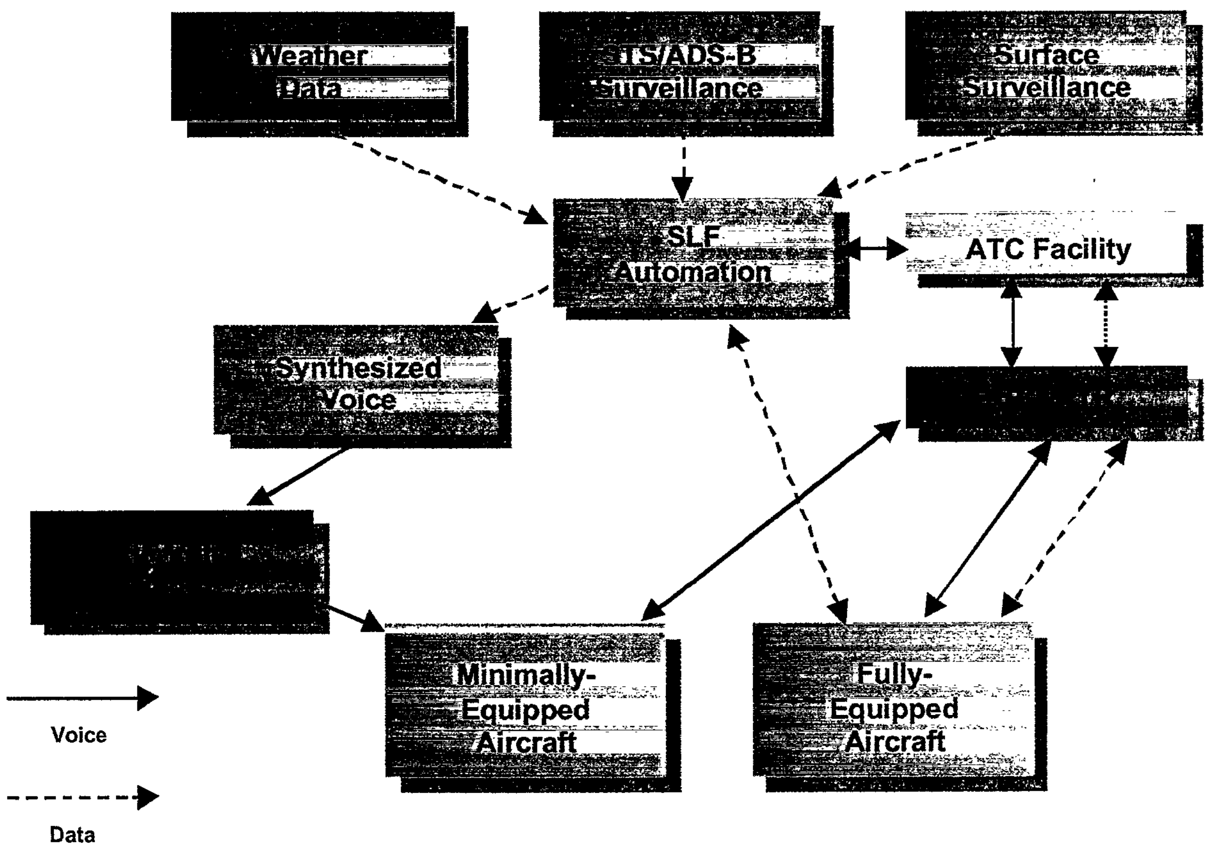

Figure 1. SLF Automation Block Diagram. Data sources (shown in blue) provide the SLF automation with information on weather conditions, and the locations of all aircraft and surface vehicles within the SLF traffic area. The SLF automation performs planning for traffic sequencing and separation and implements the plan by means of synthesized voice on the VHF voice radio and via data link. An interface with the adjacent ATC facility is provided to allow manipulation of the SLF strategic plan and coordination.

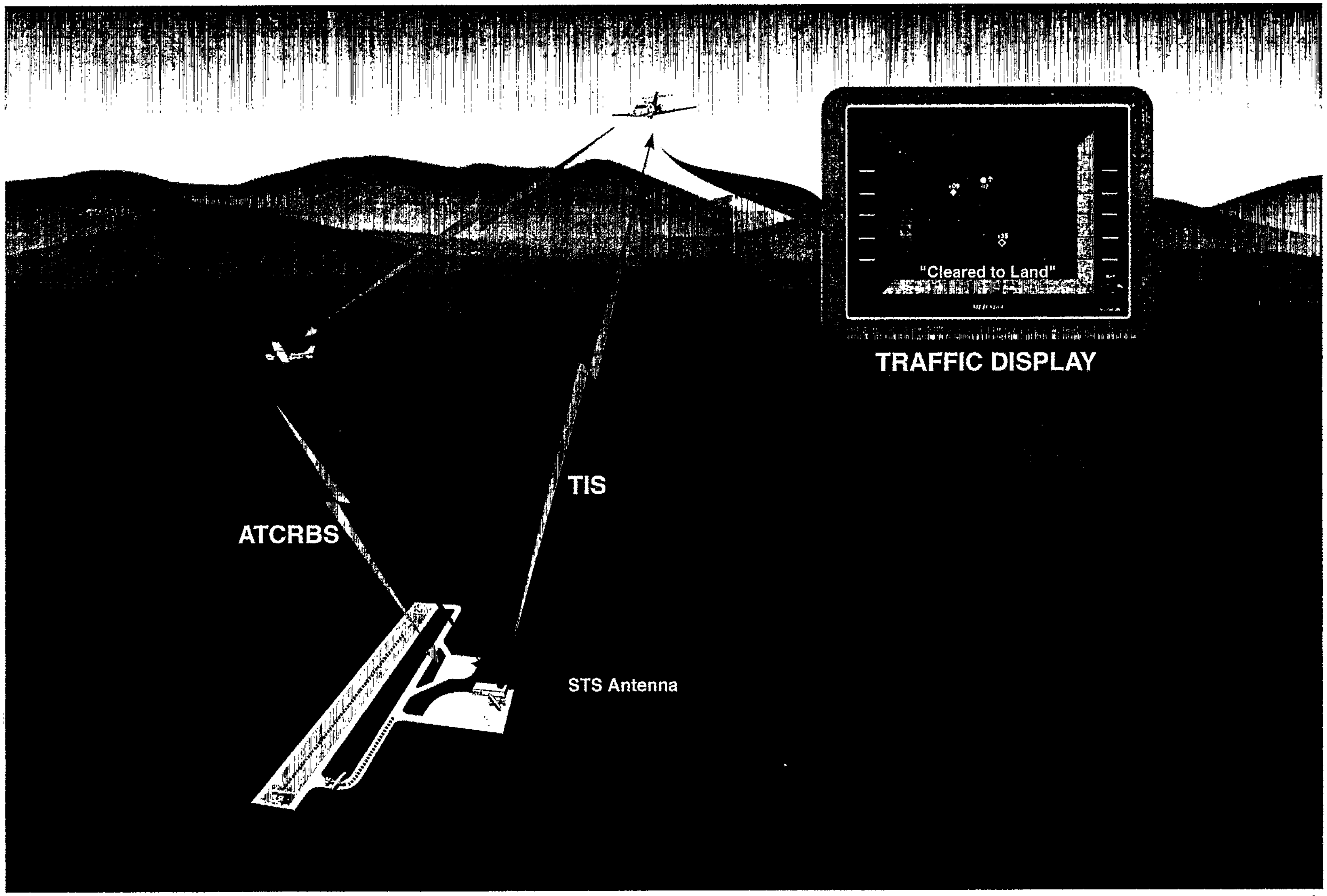

Figure 2. Smart Landing Facility (SLF) Aircraft Separation Services. Traffic sequencing and separation services are provided to minimally-equipped aircraft via synthesized voice on a VHF communication frequency. Situational awareness is provided to SATS aircraft by means of a combination of self-contained surveillance (e.g., TCAS derivative or ADS-B) and TIS uplink from the Small Terminal Sensor. Clearances from the SLF are transmitted to SATS aircraft via data link.

6.1 SLF System Description

The heart of the SLF is an automation system that receives data from various sources and provides services, including flight information (e.g., airport configuration, weather, etc.), traffic information, ATC clearances, and separation and sequencing of traffic.

The SLF automation system will integrate data on current and forecast surface winds, ceiling and visibility, gust front predictions, hazardous weather, and preferred runway information to determine an airport configuration. The airport configuration includes the active runways, traffic patterns, and instrument approach procedures in use at the airport. The airport configuration would be provided by voice broadcast over the Automated Terminal Information System (ATIS) or Automated (Surface) Weather Observation System (ASOS/AWOS) VHF frequencies as well as on a suitable aviation data link (e.g., VDL-2). The data link will also provide a full set of FIS data that includes graphical and text weather information.

There will be a given surface movement flow pattern for each airport configuration. For airports with simple runway and taxiway layouts, the information will be available over the ATIS or ASOS/AWOS frequencies. For more complicated runway/taxiway layouts, additional guidance will be available in the form of lighted signs indicating the route to and from the active runway. A transponder multilateration system could provide surveillance on the airport surface.

If cost-effective airport surface surveillance is available, an automated runway status light system can be used to reduce runway incursions. The system would indicate when a runway was in use by turning on red lights at the entrances to the runway. These would indicate to pilots and vehicle operators that there is an arriving or departing aircraft using the runway and that it is not safe to enter. Surveillance of airborne aircraft in the SLF traffic area will be provided to the SLF and the adjacent ATC facilities by a Small Terminal Sensor (STS). The STS and the transponder multilateration system for surface surveillance will be compatible with ATCRBS and Mode S transponders as well as ADS-B. Data from nearby terminal radars serving TRACONS for traffic to major airports may be integrated with the STS data, if available.

ATC communications will be supported by both VHF voice and data link. Remote Communications Outlets (RCO) or Remote Transmitter/Receiver (RTR) will be available so that aircraft on the ground can communicate directly with en route and terminal ATC facilities via voice radio. This will allow users to receive clearances, and coordinate departures with the facility. The en route facility will have a data feed of the traffic observed by the STS. Data link clearances will be supported by the same communications outlets. Trajectory modeling and arrival sequencing algorithms within the SLF automation will be used to provide traffic sequencing. Traffic situational awareness will be supported by a combination of synthesized voice messages broadcast on a VHF voice channel and a data link traffic service (TIS or TIS-B). (Note that FAA and NASA demonstrated the use of synthesized voice to provide traffic information at Manassas airport in Virginia in the early 1980s [6,7]). Pilots will use the same VHF frequency to announce their intentions.

Although not a service provided directly by the SLF automation, standardized RNP instrument approaches will be developed that provide a smooth transition from the en route environment into the SLF traffic area, terminating with a precision final approach segment. The SLF will provide sequencing and separation services and will communicate clearances to aircraft via a combination of synthesized voice and data link to ensure proper spacing of traffic on the instrument approaches.

6.2 Operations Description

This section describes typical arrival and departure operations at the SLF for two classes of aircraft, those that are minimally equipped (e.g., have a VHF voice radio and ATCRBS Mode C transponder) and those that are fully equipped (e.g., have the minimal equipage, plus ADS-B, data link, the appropriate RNP navigation equipment, and suitable on-board automation with associated cockpit displays and input devices). For the purposes of this operational concept, only the high level functions on board the aircraft are described. The implementation details of on-board systems are a topic of research in the SATS program.

6.2.1 Operations Description for Minimally-Equipped Aircraft

6.2.1.1 VFR Arrival

Prior to entering the SLF traffic area, the pilot will obtain airport configuration and weather information from the VHF ATIS broadcast. The ATIS broadcast will contain a discrete transponder code for use by VFR aircraft intending to land at the SLF[1]. The pilot will self-announce intentions on the VHF advisory frequency for the SLF. The pilot will monitor the VHF advisory frequency for automated voice broadcasts of other traffic provided by the SLF and for voice broadcasts of intentions by other pilots operating at the SLF. The pilot will maintain visual separation from all other traffic through use of "see and avoid" augmented by the SLF synthesized voice traffic broadcasts. The pilot will enter the VFR traffic pattern in use at the SLF and will land. The pilot will taxi to the parking area, using the guidance provided by the lighting and signage. The pilot will use the runway status lights in addition to normal vigilance to ensure that any runways crossed are not in use by another aircraft at the time.

6.2.1.2 VFR Departure

Prior to taxi, the pilot will obtain airport configuration and weather information from the VHF ATIS broadcast. The ATIS will contain a discrete transponder code for use by VFR aircraft departing the SLF[2]. The pilot will self-announce intentions on the VHF advisory frequency during taxi and when entering the runway for departure. The pilot will taxi to

[1] Note that, depending upon the density of traffic operating at the SLF and constraints of nearby FAA ATC facilities, it may be possible to assign a discrete ATCRBS transponder code unique to each aircraft to permit positive identification of VFR aircraft and allow more precise traffic advisories to be provided by the SLF. The mechanism for this for minimally-equipped aircraft could be through voice communication with a Flight Service Station, or pre-flight through the DUATS service.

[2] A discrete ATCRBS transponder code unique to each aircraft may be used for departures.

the departure runway, using the guidance provided by the lighting and signage. The pilot will use the runway status lights in addition to normal vigilance to ensure that any runways crossed are not in use by another aircraft at the time.

6.2.1.3 IFR Arrival

The pilot will obtain airport configuration and weather information from the VHF ATIS broadcast. The pilot will receive a handoff to the SLF from the adjacent ATC facility and will be instructed to tune to the VHF advisory frequency for the SLF. Upon receiving the handoff from the adjacent ATC facility automation, the SLF will use the discrete transponder code to positively identify the IFR aircraft and will issue sequencing instructions via synthesized voice (e.g., "Twin Cessna 123, proceed direct to GABBE intersection, cleared for the GPS approach to runway 29). The pilot will fly the approach to a landing and the SLF will detect this with its surveillance system and send a confirmation to NAS automation to close the IFR flight plan. During the approach, the pilot will monitor the VHF advisory frequency for automated voice broadcasts of other traffic provided by the SLF and for voice broadcasts of intentions by other pilots operating at the SLF. The SLF will automatically provide the required periodic announcements of the IFR aircraft's progress on the advisory frequency. In the event of a missed approach, the SLF will detect this with its surveillance system and issue instructions to either proceed to an initial approach fix for another approach or proceed to a departure fix and contact an adjacent ATC facility for routing to the appropriate alternate that is in the aircraft's IFR Flight Plan. Upon landing, the pilot will self-announce intentions on the VHF advisory frequency during taxi to the parking area. The pilot will taxi to the parking area, using the guidance provided by the lighting and signage. The pilot will use the runway status lights in addition to normal vigilance to ensure that any runways crossed are not in use by another aircraft at the time.

6.2.1.4 IFR Departure

Prior to boarding the aircraft, the pilot will check in at a computer terminal or telephone to request an IFR clearance from ATC. The pilot will be issued the clearance, including a discrete ATCRBS code unique to the aircraft, and a time window for expected departure. Prior to taxi, the pilot will obtain airport configuration and weather information from the VHF ATIS broadcast. After aircraft start-up, the SLF will detect the aircraft transponder with its unique ATCRBS code and will send an electronic message to the adjacent ATC facility requesting the IFR release. When the IFR release is obtained, the SLF will issue it to the pilot on the VHF advisory frequency. The pilot will self-announce intentions on the VHF advisory frequency during taxi and when entering the runway for departure. The pilot will taxi to the departure runway, using the guidance provided by the lighting and signage. The pilot will use the runway status lights in addition to normal vigilance to ensure that any runways crossed are not in use by another aircraft at the time. The pilot will depart the SLF via the cleared route and will contact the adjacent facility upon reaching the fix specified in the clearance. While operating within the SLF traffic area, the pilot will monitor the VHF advisory frequency for automated voice broadcasts of other traffic provided by the SLF and for voice broadcasts of intentions by other pilots operating at the SLF. The SLF will automatically provide the required periodic announcements of the IFR aircraft's progress on the advisory frequency.

6.2.2 Operations Description for Fully-Equipped Aircraft

The principal operational use for a fully-equipped SATS aircraft will be transportation in a wide variety of weather conditions. It is assumed here, for consistency of operation, that the SATS aircraft is always operating under either an IFR or VFR flight plan. Operations within the SLF traffic area will be VFR or IFR, consistent with the weather.

6.2.2.1 Arrival

The pilot will obtain airport configuration and weather information from a data link broadcast. This information may be obtained automatically by on-board systems as the aircraft approaches within a pre-set range of the SLF. The pilot will receive a handoff to the SLF from the adjacent ATC facility (either by voice or data link) and will be instructed to tune to the VHF advisory frequency (voice) for the SLF. Upon receiving the handoff from the adjacent ATC facility automation, the SLF will use the surveillance information (ADS-B and/or transponder reply) to positively identify the SATS aircraft and will issue sequencing instructions via data link. Automation on board the aircraft will present the clearance to the pilot for approval. Once approved, the clearance will be automatically incorporated into the aircraft flight management system. Sequencing instructions to the SATS aircraft may include a requirement to maintain specific separation distances from other aircraft. With assistance from on-board automation and surveillance information provided by the SLF surveillance system the pilot will comply with the clearance instructions. The pilot will fly the approach to a landing and the SLF will detect this with its surveillance system and send a confirmation to NAS automation to close the flight plan. During the approach, the pilot will monitor the VHF advisory frequency for automated voice broadcasts of other traffic provided by the SLF and for voice broadcasts of intentions by other pilots operating at the SLF. The SLF will automatically provide the required periodic voice announcements of the SATS aircraft's progress on the advisory frequency. In the event of a missed approach, the SLF will detect this with its surveillance system and issue data link instructions to either proceed to an initial approach fix for another approach or proceed to a departure fix and contact an adjacent ATC facility for routing to the appropriate alternate that is in the aircraft's flight plan. Upon landing, the SATS aircraft automation system will self-announce intentions on the VHF advisory frequency during taxi to the parking area. The pilot will taxi to the parking area, using the guidance provided by the lighting and signage and data link instructions provided by SLF automation. The pilot will use the runway status lights and data link runway status information provided by the SLF in addition to normal vigilance to ensure that any runways crossed are not in use by another aircraft at the time.

6.2.2.2 Departure

Prior to boarding the SATS aircraft, the pilot will check in at a computer terminal to request clearance from ATC. The pilot will be issued the clearance, which will be stored on a portable digital media for transport to the aircraft. Prior to taxi, the pilot will obtain airport configuration and weather information from a data link broadcast. On-board automation will communicate automatically with the SLF to obtain any changes to the departure clearance, including any applicable release time from the adjacent ATC facility. The data link clearance information, once approved by the pilot, will be automatically entered into the aircraft flight management system. The SLF automation will use surveillance and data link information from the SATS aircraft to monitor its progress on the airport surface. On-board automation will self-announce intentions on the VHF voice advisory frequency during taxi and when entering the runway for departure. During taxi and departure, the pilot will monitor traffic and runway status information provided by the SLF surveillance and automation systems to maintain situational awareness and, aided by on-board automation, will comply with any specific sequencing and separation instructions provided by the SLF. The pilot will depart the SLF via the cleared route and will contact the adjacent facility (via voice or data link) upon reaching the fix specified in the clearance. While operating within the SLF traffic area, the SLF will automatically provide the required periodic announcements of the aircraft's progress on the voice advisory frequency.

7. SLF TECHNOLOGY ASSESSMENT

The operational concept described in Section 6 above requires several CNS/ATM technologies. The purpose of this section is to assess their technical maturity and identify the key technologies that must be developed.

7.1 Communications

The operational concept can be supported with existing VHF voice (25KHz AM) and data link (VDL-2) technology. Synthesized voice is a relatively mature technology used in conjunction with ASOS / AWOS and Digital ATIS. A ground communication network that supports two-way data link communication for ATC has been developed for Controller Pilot Data Link Communication (CPDLC) and this mature technology can form the basis for the SLF ground data link.

7.2 Navigation

As described earlier, navigation is not a service currently provided by the ATCT. It is not anticipated that SLF operations will require navigation beyond the RNP precision approaches under development by FAA.

7.3 Surveillance

The SLF operational concept requires surveillance in the SLF traffic area and the airport surface that is compatible with existing ATCRBS Mode C transponders as well as ADS-B. As described in Section 5, there are several technical options for this surveillance, each with particular advantages and disadvantages. It will be necessary to derive a set of surveillance performance requirements for the SLF, assess the alternatives against those requirements, and select the appropriate technology for further development and field testing. There is considerable interaction between the performance of the surveillance system and the level of service that can be provided by the SLF automation. Because surveillance is a key enabling technology for the SLF, this assessment must be performed early in the SATS program. It should be noted here that airport surface surveillance, in general, may be quite costly relative to short-range terminal area surveillance. It is included in the operational concept to support the airport surface separation services currently provided by the ATCT.

7.4 Air Traffic Management (ATM)

As described in Section 6, the SLF automation is the enabling technology for the sequencing and separation services that SLF provides. The SLF automation gathers information about the state of the traffic in the SLF traffic area with the SLF surveillance system and communicates with pilots, controllers (in adjacent ATC facilities) and on-board SATS automation systems. One of the two major functions of the SLF automation is to generate the separation and sequencing plan, perform conformance monitoring, and update the plan in response to the information provided by the surveillance and communication systems. The other major function is to generate the voice and data link messages necessary for execution of the plan. While several applicable technologies are described in Section 5, there exist no mature sequencing and separation algorithms that are directly applicable to SLF operations. As described in Section 5, surveillance information has been used previously [6,7] to generate synthesized voice traffic advisories and this work may be used as a starting point for that function. The simultaneous operation of minimally-equipped and fully-equipped aircraft, a combination of voice and data link communication, and the interaction of pilots and controllers with SLF automation raise a considerable number of human factors issues that must be addressed with a combination of analysis and human-in-the-loop simulations. Clearly, the SLF ATM functions will pose one of the greatest technical challenges in the SATS program.

7.5 Failure Detection and Recovery

Air Traffic Controllers in an ATCT or TRACON are capable of detecting failures and adapting their procedures to accommodate them. For example, if an aircraft experiences an on-board equipment failure, the controller can re-route other aircraft and provide expedited services to the affected aircraft. Duplicating this robust flexibility in an automated system will be one of the most significant challenges faced by the SATS program. Advances in hardware and software design will make failures less likely, but the SLF must still be able to detect and handle them. It is likely that some form of intervention by a human controller (perhaps from an adjacent facility) may be necessary in unusual or emergency situations. This will require careful design to ensure that the controller possesses adequate situational awareness and intervention tools to be effective.

8. CONCLUSION

The goal of the SLF is to provide higher-rate operations in a wider variety of weather conditions at airports without control towers or terminal radar facilities. NASA initially defined the SLF to provide the same or nearly the same level of service as that provided by an Air Traffic Control Tower. However, the principal determinant of operations rates in IMC is the presence of surveillance-based separation services in the terminal area. Therefore, the primary function of the SLF should be to provide automated or semi-automated surveillance-based separation services in the airspace near the SLF airport. The SLF will provide communication and coordination with adjacent ATC facilities to ensure smooth transition of operations between the SLF and the en route environment. The SLF will provide traffic, weather, and airport configuration advisories via voice and data link. The combination of SLF services will significantly enhance the safe utility of single-pilot aircraft operations.

This operational concept document has developed the functions of the SLF based on those services provided by the ATCT and TRACON. Many of the services (e.g., data link Flight Information Services and ATC communication) have already been demonstrated and require integration in the SLF. Others, (e.g., automated separation services in the SLF traffic area) will require significant development. In particular, the development of low cost surveillance for the SLF traffic area will be required to achieve the operational goal of SLF, regardless of whether or not the separation services are provided automatically. Some of the services today provided by the ATCT, (e.g., management of airport surface movement) may be costly to implement because of the requirement for airport surface surveillance and a means to depict runway status (e.g., runway status lights) to minimally-equipped aircraft. Clearly, a cost-benefit analysis is required to determine the exact mix of services that the SLF will offer. This operational concept serves as a point of departure for that analysis and the subsequent development of an integrated set of SLF services.

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