AN OPERATIONAL CONCEPT FOR THE SMART LANDING FACILITY (SLF)*

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Introduction

This paper describes 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 of 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.

A candidate SLF system concept is described that employs current and near term CNS/ATM technologies. An assessment is made of the SLF technology and key research issues are identified.

SLF Environment

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.

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High Level Operational Functions of an Act

A review of the services provided by an ATCT 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.

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.

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.

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.

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.

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.

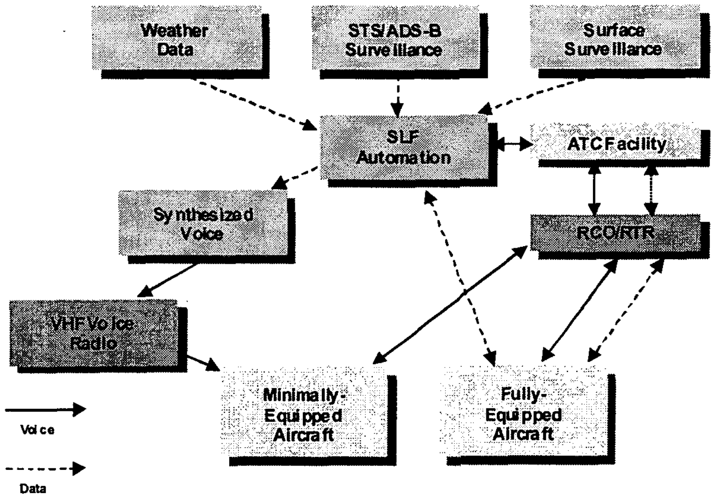

Figure 1. SLF Automation Block Diagram. Data Sources (Shown In Blue) Provide The SLF Automation With Information On Weather Conditions, And The Locations Of All Aircraft And Surface Vehicles Within The SLF Traffic Area. The SLF Automation Performs Planning For Traffic Sequencing And Separation And Implements 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.

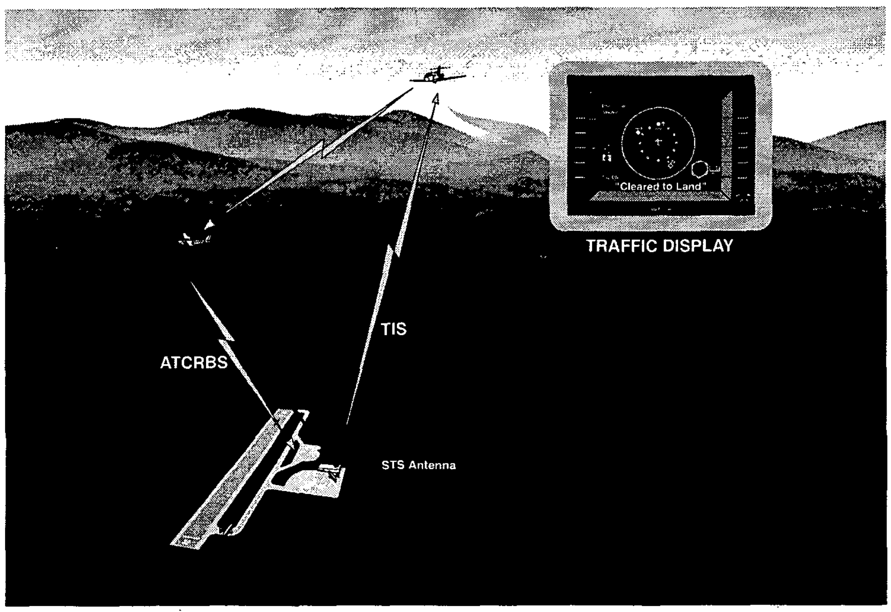

Figure 2. Smart Landing Facility (SLF) Aircraft Separation Services. Traffic Sequencing And Separation Services Are Provided To Minimally-Equipped Aircraft Via Synthesized Voice On A VHF Communication Frequency. Situational Awareness Is Provided To SATS Aircraft By Means Of A Combination Of Self-Contained 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.

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 sercvice (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 [1,2]). 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.

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.

Operations Description for Minimally-Equipped Aircraft

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.

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 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.

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.

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

[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.

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.

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.

SLF Technology Assessment

The operational concept described 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.

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.

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.

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. 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.

Air Traffic Management (ATM)

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 there exist no mature sequencing and separation algorithms that are directly applicable to SLF operations. Surveillance information has been used previously [1,2] 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.

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.

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.

References

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