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Synthetic Vision Systems (SVS)
Description of Candidate Concepts Document, CY 01

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1.0 INTRODUCTION

This document supports work done under NASA Contract NAS1-00106 Task #1002, titled "Synthetic Vision Systems Concept Assessment and Flight Integration Planning". Specifically, efforts herein are intended to satisfy Deliverable Number 1 in the Statement of Work, titled "Description of Candidate Concepts Document". This document describes the current baseline Synthetic Vision Systems (SVS) Concept. This document summarizes the efforts and inputs of a number of individuals on the Synthetic Vision Systems (SVS) Team from a number of industry and government organizations. It is a snapshot of the current concept, with some team member variations, as it exists at the end of Calendar Year 2001. As the Concept is in early stages of development, much of the defining activities and studies are in progress as of the date of this document, or have final reports or analysis pending. As the Concept matures, updated descriptions will be published, with the next update scheduled at the end of Fiscal Year 2002.

1.1 PURPOSE

The purpose of this document is to characterize the current SVS Candidate Concept, including key components of the Concept, and issues associated with selection of technologies and components. The demonstrated or analyzed capability and potential of existing candidate SVS concept components in satisfying Commercial and Business (CaB) Transport Aircraft mission requirements is included.

1.2 BACKGROUND

1.2.1 Aviation Safety Program

In August 1996, following the wake of several high-visibility commercial transport accidents, a White House Commission on Aviation Safety and Security was established to study matters involving aviation safety and security. The Commission findings concluded that although the worldwide commercial aviation major accident rate is low and has been nearly constant over the past two decades, increasing traffic over the years has resulted in the absolute number of accidents increasing. Given the very visible, damaging, and tragic effects of a single major accident, this situation could become an unacceptable blow to the public's confidence in the aviation system. As a result, the anticipated growth of the commercial air-travel market would not reach its full potential. In February 1997, in response to the Commission's recommendations, President Clinton set a national goal to reduce the aviation fatal accident rate by 80% within ten years. NASA's role in civil aeronautics is to develop high risk, high payoff technologies to meet critical national aviation challenges. Currently, a high priority national challenge is to ensure U.S. leadership in aviation in the face of growing air traffic volume, new safety requirements, and increasingly stringent noise and emissions standards. NASA has a successful history of leading the development of aggressive high payoff technology in high-risk areas, ensuring a proactive approach is taken to developing technology that will both be required for meeting anticipated future requirements, and for providing the technical basis to guide policy by determining feasible technical limits. Therefore, NASA has stepped up to the challenge of addressing the President's national aviation safety goal by forming the new, focused Aviation Safety Program. As a first step to establish a focused safety program, NASA sponsored a major program planning effort to gather input from the aviation community regarding the appropriate research to be conducted by the Agency. This activity called the NASA Aviation Safety Investment Strategy Team (ASIST), held four industry- and government-wide workshops to define and recommend research areas, which would have the greatest potential impact for reducing the fatal accident rate. NASA then redirected existing research and technology efforts and formulated new ones to address the safety needs defined by ASIST.

1.2.2 Synthetic Vision Systems Project

One of the significant recommendations from ASIST was to establish a project to eliminate visibility-induced errors for all aircraft through the cost-effective use of synthetic/enhanced vision displays, worldwide terrain databases, and Global Positioning System (GPS) navigation. Therefore, on March 25, 1999 the Associate Administrator for Aerospace Technology, Spence Armstrong, signed the Project Formulation Authorization for the Synthetic Vision Systems Project. The Synthetic Vision Systems Project emphasizes the cost-effective use of synthetic vision displays (both tactical and strategic), worldwide navigation, terrain, obstruction and airport databases, integrity monitoring and forward looking sensors as required, and Global Positioning System-derived navigation to eliminate "visibility-induced" (lack of visibility) accident precursors for all aircraft and rotorcraft.

Studies concerning the SVS Project mission have been framed around, and developed, several candidate concepts (aggregate system and component characterizations) for satisfaction of mission requirements and reduction of technical and certification risk. Studies, simulation experiments, and flight test experiments have been devoted to exploring research issues associated with, and assessment of elements contained within, these concepts. As the SVS Team is composed of representatives from several organizations, some of which are planning on marketing their own SVS concepts eventually, there are variations in concept definition specifics, particularly with respect to display formats and operational philosophy. The current document will summarize the present definition of those concepts and variations, at an upper level. Concept definitions will necessarily change as the Program matures, lessons are learned, and down selects occur. This Concept Definition Document will be updated yearly to document those changes.

1.3 SCOPE

This document is intended to be an upper level summary of concept definition. Detailed descriptions of research hardware, software, and system architecture may be found in the requirements documents for each of the experiments, rather than contained herein.

Component descriptions and characterization are documented as they are known as of the date of this report. Changes resulting from meetings or reports released subsequent to this report date will be incorporated in the next update of this document, planned annually.

1.3.1 Components

For purposes of this task, the SVS Concept is assumed to consist of the following elements (elements will be discussed individually in a later section).

1.3.1.1 SVS Sensors (or sensor equivalents)

- Forward Looking Infrared (FLIR) (potential)
- Weather Radar (Potential SVS Modes)
- Millimeter Wave Radar (potential)
- Onboard SVS Data Base
- Other aircraft navigation sensors and data bases (i.e., TAWS)

1.3.1.2 Displays

- Primary Flight Display, or imbedded display features
- Navigation Display, or display features/pages
- Vertical Situation Display (may be imbedded in Navigation Display)
- Head Up Display (option) with dedicated display features
- Pilot Information Display (potential)
- Head Mounted Display (under study)
- Interface with Other Cockpit Displays, i.e., TAWS, TCAS, Weather

1.3.1.3 Computers/Imbedded Computational Functions

- Format Transformation (i.e., perspective, point of view)
- Image Object Detection and Fusion (potential)
- System Integrity, Verification and Validation
- SVS Dedicated Mission Computations and Symbol Generation

1.3.1.4 Equipment

- Dedicated SVS Support Equipment and Crew Interface
- Interface with Other Aircraft Systems

1.3.1.5 Associated Aircraft Systems

- Differential Global Positioning System (DGPS)
- Inertial Reference Unit/Attitude Heading Reference Set (IRU/AHRS)

- Air Data Computer
- Radio/RADAR/Laser Altimeter (R/A)
- Traffic Collision Avoidance System (TCAS)
- Data Link (aggregate of IFF Mode S, ADS/B, etc.)

2.0 METHODOLOGY

The process of concept selection decided upon by the Industry and Government SVS Team members consisted of the following five steps:

1. Conduct a literature review, concentrating on previous studies, documents and experiments concerning technology availability, human performance, issues identification and resolution, and systems development relating to the Commercial and Business (CaB) aircraft mission.

2. Conduct a review of data and issues with Industry and Government (NASA and FAA) SVS team members, to determine SVS related requirements and issues, select candidate technologies, and list operational considerations and concerns related to the CaB mission.

3. Conduct analysis, trade studies, and experimentation to refine issues and requirements, and develop a list of candidate technologies to resolve them.

4. From the above results, select and develop a Candidate Concept, which has the best potential for satisfying system requirements, as well as providing the best balance in system performance, weight, support requirements, technical risk, certification cost and risk, and manufacturing cost and risk.

5. Refine the definition and functions endemic to the Candidate Concept, as inputs from subject matter experts and results from experiments are obtained.

Steps One through Four are ongoing, and preliminary results delivered in previous documents. This document addresses step four in the concept selection process and provides the current characterization of the baseline SVS system design. Step Five is an ongoing task to monitor efforts to further define or validate SVS design requirements and to evaluate technology demonstrations. This step continually evaluates the current baseline SVS concept in light of these requirement and technology refinements, resulting in changes to the concept, to be documented in periodic updates to this document.

The majority of the evaluation comments presented herein are based on the engineering judgment and experiences of researchers and other subject matter experts associated with, or having worked on, the various technologies on this (SVS) project, the High Speed Research (HSR) Program, and other Synthetic Vision programs.

3.0 CONCEPT CHARACTERIZATION

3.1 GENERAL

The following is a description of the present SVS Candidate Concept and a general overview for the Commercial and Business (CaB) aircraft SVS Mission. It represents a summary of what has been written and discussed to date by the SVS Group relating to the concept and mission, gleaned from analysis, lab tests, ground simulation, and flight test. The concept will be framed in terms of overall flight mission description, mission functional decomposition, concept implementation categories, and upper level architectures.

3.2 COMMERCIAL AND BUSINESS SVS MISSION DESCRIPTION

3.2.1 General Mission Description

SVS will enable enhanced safe and consistent gate-to-gate aircraft operations in normal and low visibility conditions. The CaB Aviation Industry believes it is presently safe, and is unlikely to purchase SVS solely for safety's sake, but will purchase SVS for a better capability to accomplish the mission of moving people from Airport A to Airport B. Therefore, the CaB SVS must be focused on operational benefits through mission accomplishment for aviation industry acceptance. SVS will support safe aircraft operations gate-to-gate (taxi, departure, en route, arrival/missed approach, landing, taxi, shutdown). It may be feasible to apply SVS technology in zero visibility. However, Category IIIc or "zero/zero" operations are not an approved operation at this time, the weather minimums that would require Category IIIc use are rare, and operational benefits of such operations to the CaB Industry have not been clearly established. For example, conducting "zero/zero" operations will likely require enhanced navigation and/or visual systems equipage on emergency response vehicles at airports. Consequently, the focus of the CaB SVS Mission will be on facilitating operations in normal and "low visibility" or Category IIIb or better visibility conditions. For departure and ground operations, the SVS goal is to enable head-down operations with an RVR of 300 feet. SVS will potentially allow greater operational flexibility, such as permitting aircraft to taxi, depart, and arrive in Category IIIb visibility while using Category I equipped airports and runways. Therefore, the potential operational benefits are also a major area of consideration.

Safe operations in the various mission phases involves two primary areas – acceptable manual or autopilot path control, and hazard avoidance. Acceptable path control implies the ability to manually or automatically configure navigation and control systems to fly a cleared or desired path, and the ability to stay on that path, to required navigational performance requirements, given the aggregate of system and crew capabilities. Acceptable hazard avoidance implies the ability to detect potential hazards, identify and categorize them with respect to threat level and expected future actions, make decisions regarding necessary avoidance maneuvers, and assess the effectiveness of those maneuvers, if required.

3.2.2 Path Control

Successful path control pre-supposes the ability of the crew or system to identify the cleared or desired path, and configure aircraft systems to display and/or fly that path. Systems configuration will involve strategic and tactical display elements. Strategic elements are those indicating in an aggregate sense where the aircraft is going (ideally in a four dimensional manner), and the relationship of that path or position with respect to other important navigational features, such as in a Navigation Display. Tactical elements typically indicate more direct path control requirements, such as required pitch or bank angle changes to maintain desired path, as in a Flight Director on a Primary Flight Display. The SVS Concept involves enhancements in both of these areas.

3.2.3 Hazard Avoidance

3.2.3.1 Elements

Successful hazard avoidance involves the following elements:

- **Detection**. Sensing that a specific potential hazard exists in a position to be a present or future threat. Detection may be through direct visual contact (optical windows), raw presentation of imaged sensor data (as in Forward Looking Infrared imagery), or display of data interpreted or filtered through processing sub-systems (as in symbolic or iconic representation of objects). SVS Concept components potentially involve enhanced detection of hazards, through dedicated sensors (i.e., FLIR, MMWR), or enhanced features in existing sensors (Weather RADAR, Radar Altimeter).
- **Identification**. This Element involves categorization of potential external threat by its phase of flight for aircraft (ground or airborne), vehicle type (i.e., aircraft, ground vehicle, terrain, animal life), and vehicle subclass (large, medium or small, or specific type). SVS Concept components potentially involve enhanced identification of hazards, through dedicated Image Object Detection and Fusion computation equipment, or advanced communication equipment (air-to-air and air-to-ground datalink).
- **Geometry Awareness**. Determination of relative range, relative altitude, object aspect angle (i.e., nose-on, tail-on, right or left side), and expected motion (closure and angular drift). SVS Concept components potentially involve enhanced geometry awareness, through dedicated Image Object Detection and Fusion computation equipment, and enhanced display features (iconic perspective representation of hazardous traffic, and symbology elements).
- **Prioritization**. Determination of the significance of the anticipated threat, immediacy and proximity of closest point of approach, based on anticipated motion of object and own aircraft. This element is generally either accomplished by the crew, or augmented with mission computation subsystems such as TCAS, or RIPS. SVS Concept components additionally (potentially) involve enhanced prioritization

of hazards, through dedicated Image Object Detection and Fusion computation equipment.

- **Action Decision**. The decision as to which action, if any, is appropriate, with regard to aircraft maneuvering or communication, to maintain safe separation with the potential threat object. Generally either accomplished by the crew or augmented with mission computation subsystems such as TCAS, or RIPS. SVS and associated advanced displays may afford the advantage of further augmenting the capability for appropriate action decision by allowing multiple hazards (i.e., aircraft collision, terrain clearance, hazardous weather, etc) to be integrated into the decision process.
- **Action Assessment**. Sensing of sufficient information relating to the relative success of the maneuver decided upon (including the potential decision not to maneuver) in achieving the desired goal of hazard avoidance. May include further iteration of action decision and feedback. Generally accomplished by the crew or augmented with mission computation subsystems such as TCAS, or RIPS. SVS and associated advanced displays may again afford the advantage of further augmenting the capability for appropriate action assessment by allowing multiple hazards to be integrated into the assessment process.
- **Overall Situation Awareness**. Maintenance of a clear mental picture, among all aircraft crew members, relating to the presence and potential future threat of airborne and ground external hazards, including the ability to weigh the consequences of future path control decisions based on this mental picture. SVS Concept components potentially involve enhanced overall hazard situation awareness, through enhanced display features (iconic perspective representation of hazardous traffic, for example), and, potentially, dedicated Image Object Detection and Information Fusion computation equipment

3.2.3.2 Specific Hazards

The hazard avoidance mission will include the above functions relating to potentially hazardous objects. SVS Concept elements providing hazard avoidance augmentation will, of necessity, have to consider several categories of hazards (or at least make assumptions concerning coverage). To present a clear path to a runway stop, for instance, on an SVS display when one of the below categories of hazards exist, could be construed as misleading information. Objects of interest will include the following.

- **Cooperative traffic**. Those ground or airborne objects obeying known clearances and equipped with IFF and accurate navigational equipment. ADS/B, ASDE, and TCAS, as examples, may be used to detect and display this category of hazard. The presence of cooperative traffic, and the infrastructure necessary to sense and display it, affords both an advantage and a disadvantage. The advantage lies primarily in expanded capability (long range, increased numbers, etc.) to display the traffic. The disadvantage lies primarily in the potential, if sufficient care is not given to the design of aircraft and infrastructure, in misleading crews with respect to the absence of traffic, when no traffic is displayed, but uncooperative traffic exists.

- **Uncooperative traffic**. Those ground or airborne man-made objects not obeying or in receipt of a known clearance and/or not equipped with standard navigation and IFF equipment. Detection of these hazards must be made through own-aircraft sensors, through the use of ground sensors and a communication path (radio or data link) to own aircraft, or by separating non-equipped from equipped aircraft procedurally.
- **Terrain**. Natural (presumably charted) ground features of significance to ground or airborne navigation and safety. This category of hazard may be "sensed" through the presence of an onboard data base, however, integrity and reliability of that data base are potential operational constraints which must be addressed. Given the stringent reliability requirements for equipment critical to safe Commercial and Business aircraft operations, it is likely that use of a data base must be augmented with equipment and infrastructure intended to assure the accuracy, reliability, and availability of presented information.
- **Cultural Features**. Man-made structures (i.e., towers, buildings, wires, etc.) of significance to ground or airborne navigation and safety. Given the stringent reliability requirements for equipment critical to safe Commercial and Business aircraft operations, as well as data base maintenance requirements (to display a newly constructed tower, for example), it is likely that use of a data base must be augmented with equipment intended to assure the accuracy, reliability, and availability of presented information.
- **Wildlife**. Ground and airborne animals of significance to ground or airborne safety. Typically, these are sensed and controlled visually, either by the crew, or by Air Traffic Control personnel, or both.
- **Weather**. Typically, hazardous weather phenomena are sensed and avoided either visually by the crew, through the use of onboard weather sensors (Weather Radar, potentially LIDAR) by Air Traffic Control personnel (through forecast information, or current sensor information), or a combination of all of these.

3.3 SYNTHETIC VISION SYSTEM COMPONENTS.

The following is a description of the components, which define the present SVS Concepts, for purposes of this document.

3.3.1 General.

Several Workshops, discussion with researchers and other Subject Matter Experts, literature review, analysis, and laboratory, simulation, and flight test experiments have resulted in an evolving baseline concept, which may be reasonably expected to meet the above mission requirements. The baseline concept is intended to frame mission requirements and potential solutions in the context of defined technology, rather than to represent a specific design solution. Specific components used in flight test and simulation experiments are described in the requirements documents relating to those experiments. Figure 3.1, below, presents an overview of concept architecture and functional relationships. The following briefly discusses each of the components, including variations within the team concerning configuration and/or use of the components.

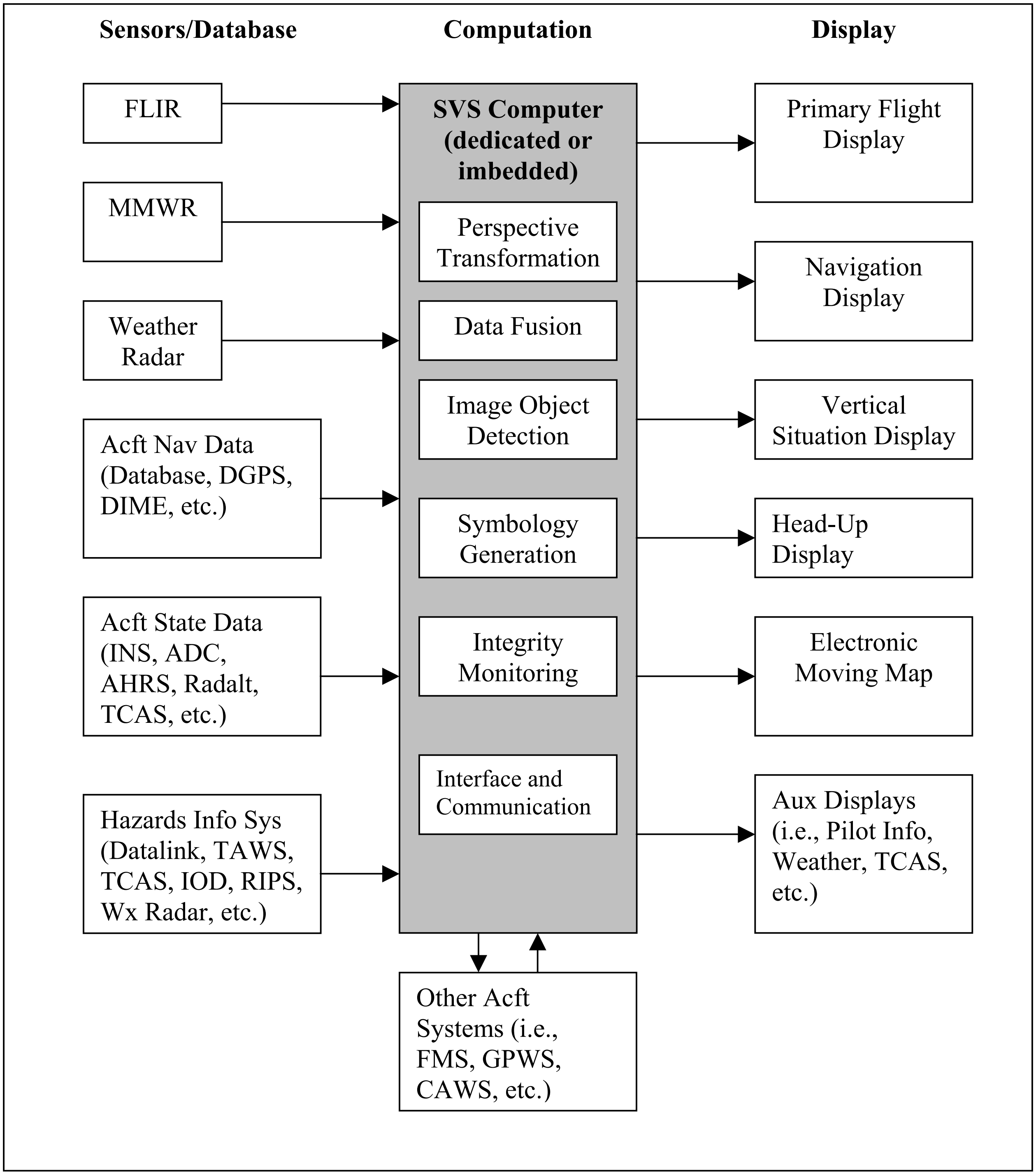

Figure 3.1
SVS Concept Architecture Overview

3.3.2 Sensors

The following is a functional description of the primary sensors (or sensor equivalents) listed in Figure 3.1, which characterize the SVS Concept. Sensors are included herein which are dedicated to SVS Mission accomplishment, as well as other aircraft system sensors.

3.3.2.1 Differential Global Position System (DGPS)

DGPS (in concert with IRU) is the primary SVS navigational source. This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. DGPS provides primary position solution data for SVS Computations and Symbol Generation, as well as System Integrity, Verification and Validation function.

3.3.2.2 Inertial Reference Unit/Attitude/Heading Reference Set (IRU/AHRS)

This is the primary source for attitude, heading (true and magnetic), track, and wind information for SVS Mission accomplishment. This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation function.

3.3.2.3 Air Data Computer (ADC)

This is the primary source for Calibrated Airspeed, Pressure Altitude, Mach, Outside Air Temperature, and Vertical Speed (rate of change of Pressure Altitude). This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation function.

3.3.2.4 Radio/RADAR/Laser Altimeter (R/A)

This subsystem is the primary source for Altitude above ground information. R/A is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation, and Integrity Monitoring functions.

3.3.2.5 Traffic Collision Avoidance System (TCAS)

This subsystem provides position data with respect to other aircraft equipped with TCAS, and generates advisories and warnings with respect to aircraft significant to collision avoidance. This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation, as well as potentially for Image Object Detection and Fusion functions.

3.3.2.6 Data Link

For purposes of the present SVS Concept characterization, Data Link is a collection of subsystems which receive information from external sources (ground and/or airborne) concerning hazards (traffic, weather, and terrain). For example, Automatic Dependent Surveillance/Broadcast (ADS/B) data would be included here. This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation, as well as Integrity Monitoring, and potentially Image Object Detection and Fusion functions.

3.3.2.7 Weather RADAR (WxR)

This sensor subsystem provides data with respect to other air (and potentially, surface) traffic. The ability of this system to detect ground and airborne hazards (other than weather related ones) is a function unique to SVS, and may potentially involve WxR hardware and/or software changes, in addition to those required for SVS interfaces. This subsystem provides data for Image Object Detection and Fusion; System Integrity, Integrity Monitoring, and SVS Computations and Symbol Generation functions.

3.3.2.8 Forward Looking Infrared (FLIR)

This sensor subsystem provides an infrared spectrum view of a field of regard in the aircraft's forward quarter, and potentially image information useful for system integrity monitoring, object detection, and path control. This system is one unique (as presently envisioned) to SVS. Raw data would be in the form of a video image. This subsystem provides data for Image Object Detection and Fusion; System Integrity, Verification and Validation; and SVS Computations and Symbol Generation functions. Requirements for FLIR, if any, are being assessed by the Project Team.

3.3.2.9 Millimeter Wave RADAR (MMWR)

This sensor subsystem provides a millimeter wave spectrum image of a field of regard in the aircraft's forward quarter, and potentially image related information useful for system integrity monitoring, object detection, and path control. This system is one unique (as presently envisioned) to SVS. Raw data would be in the form of scanned MMWR returns, azimuth versus range, at selected elevations. This subsystem provides data for Image Object Detection and

Fusion; System Integrity, Integrity Monitoring, and SVS Computations and Symbol Generation functions. Requirements for MMWR, if any, are being assessed by the Project Team.

3.3.3 Terrain and Navigation Data Bases

Data bases indicated in Figure 3.1, which characterize the SVS Concept, include those dedicated to SVS Mission accomplishment, as well as other aircraft system data bases (Flight Management System navigational data bases, for example). Databases could be implemented separately by function, or accessed through a central source by multiple functions. This subsystem provides latitude, longitude, and elevation data for terrain and man-made structures of potential significance to navigation and hazard avoidance. The SVS dedicated data base may involve nested components in hardware and/or software, with varying resolution and accuracy, appropriate to the phase of flight anticipated in the represented region. This subsystem provides data for System Integrity, Integrity Monitoring, and SVS Computations and Symbol Generation functions.

3.3.4 Computational Subsystem Components

The following subsystems satisfy requirements for integration and accomplishment of computational functions associated with SVS Mission accomplishment. Computational subsystems may be in the form of dedicated computers, or imbedded hardware and/or software in other computers, either dedicated to SVS, or part of the other aircraft subsystems.

3.3.4.1 Image Object Detection and Fusion Computation Function

This computational subsystem receives data from TCAS, Data Link, Weather RADAR, FLIR, TAWS (unless imbedded in SVS), and Millimeter Wave RADAR subsystems, with regard to potential airborne or ground hazards. It receives data from the SVS Computations and Symbol Generation subsystem with regard to aircraft state and navigation (for use in reasonability tests, for example). This subsystem performs the following functions using these data:

- Data confidence, detection threshold filtering, expected error, source data reasonability and integrity estimation
- Hazard detection
- Data fusion (correlated position of potential hazards)
- Image enhancement and fusion, where appropriate
- Integrity self monitoring and alerting

3.3.4.2 System Integrity Monitoring Computation Function

This computational subsystem potentially receives data from DGPS, RADAR/LASER Altimeter, Weather RADAR, FLIR, Millimeter Wave RADAR subsystems, and Navigation and Terrain Data Bases, with regard to own aircraft position, expected terrain or obstacle height, and actual terrain or obstacle height. It receives data from the SVS Computations and Symbol Generation subsystem with regard to aircraft state and navigation (for use in reasonability tests, for example). This subsystem performs the following functions using these data:

- Data Base reliability, integrity, expected error
- Other source data reasonability and integrity estimation
- Generate appropriate system alert messages
- Integrity self monitoring and alerting

3.3.4.3 SVS Computations and Symbol Generation

This computational subsystem receives data from all the sensors and data bases described above in Sections 3.3.2 and 3.3.3, with respect to aircraft position and state, as well as sensed external position and hazards. It receives data from the System Integrity Monitoring computational subsystem with regard to data base and other systems integrity, and the Image Object Detection and Fusion Subsystem with regard to hazard detection, identification, prioritization, hazard situation, and fused sensor imagery. It receives data from other aircraft systems with respect to cleared path, terrain hazards (TAWS), and system integrity and status. This subsystem performs the following upper level functions using these data:

- Cleared and actual path depiction
- Hazard element display integration and depiction
- Runway Incursion Prevention System algorithm computation and display
- Hold Short and Landing Technology algorithm computation and display
- Navigation and hazard situation awareness enhanced display element generation
- Alert and warning generation and presentation
- Overall display symbol generation and/or SVS integration
- Integrity self monitoring and alerting

3.3.5 Displays

The following is a functional description of the primary displays listed in Figure 3.1, which characterize the SVS Concept. Display configurations may be dedicated to SVS Mission accomplishment, for example, in a dedicated Primary Flight Display. Alternately, they may be integrated into conventional aircraft display subsystems, as in a dedicated page on a multifunction Navigation Display, or imbedded SVS features in a conventional Navigation Display page. Display formats are extremely implementation specific, and variations exist among SVS Team members. Three primary research configurations exist, for example – two developed by NASA, one developed by Rockwell Collins, and one developed by British Aerospace. For each of the display components, representative formats will be shown for each of the groups. It should be kept in mind, however, that display formats are the most volatile of the SVS Concept characterization elements, as they change rapidly for each of the flight test and simulation experiments, and as the Team learns and interacts. Formats, then, are predominantly examples of what might be done in SVS implementation, rather than strict elements of the Concept definition. Furthermore, implementation specifics may be radically different dependent on the category of vehicle involved – existing mechanical cockpit, existing glass cockpit, or future design.

Displays are assumed to receive SVS specific information from the SVS Computations and Symbol Generation computational subsystem. Information paths for other functions in these shared displays may exist separate from SVS components, for example, in FMS status messages, or inputs directly to the Navigation Display.

3.3.5.1 Primary Flight Display (PFD)

The PFD provides primary tactical (and to some extent, strategic) guidance for path control and hazard avoidance. In the present concept, this is a head down (below the glareshield) instrument. Issues of scale, size of the display, the presence and nature of terrain perspective cues, and guidance format are significant research issues which are being (or have been) addressed by the Team. Specific examples of PFD formats used by SVS Team members are presented below. Detailed descriptions of all the formats used for a particular experiment may be found in the requirements documents relating to those experiments.

Figure 3.2 presents an example NASA SVS Research Display PFD format. In experiments to date, the NASA PFD format has been collocated with the ND, on the same research display. For future tests, options are being investigated which will split PFD and ND functions on two, edge-abutted displays. In the NASA PFD, terrain modeling has been either generic texture overlaid on elevation data, or photo-realistic textured data. Past and continuing research will help decide where each might have advantages over the other.

Figure 3.3 presents an example Rockwell Collins Research Display PFD format. As in the case with NASA formats, the Rockwell Collins format has to date collocated the PFD and Navigation Displays on the same display, but in future concepts may split PFD and ND functions on two, edge-abutted displays. In the case of terrain depiction, the Rockwell Collins format has used only generic terrain, to facilitate economical and quick implementation.

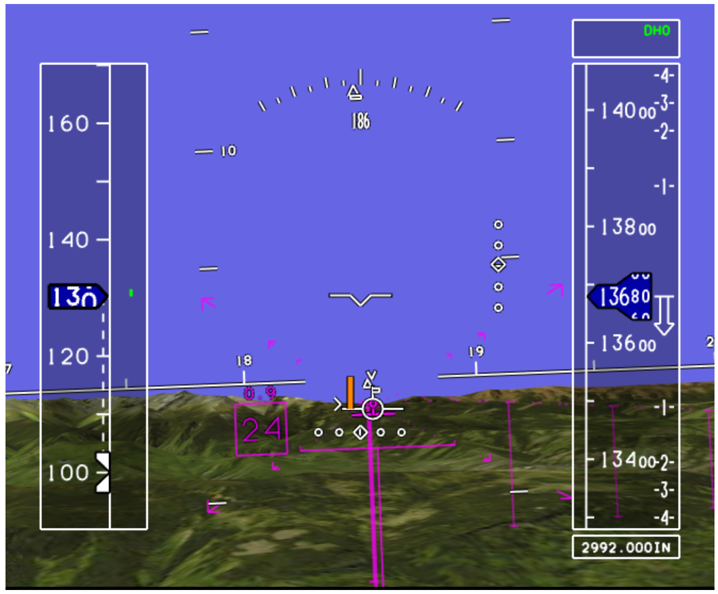

Figure 3.2
Example NASA PFD Format

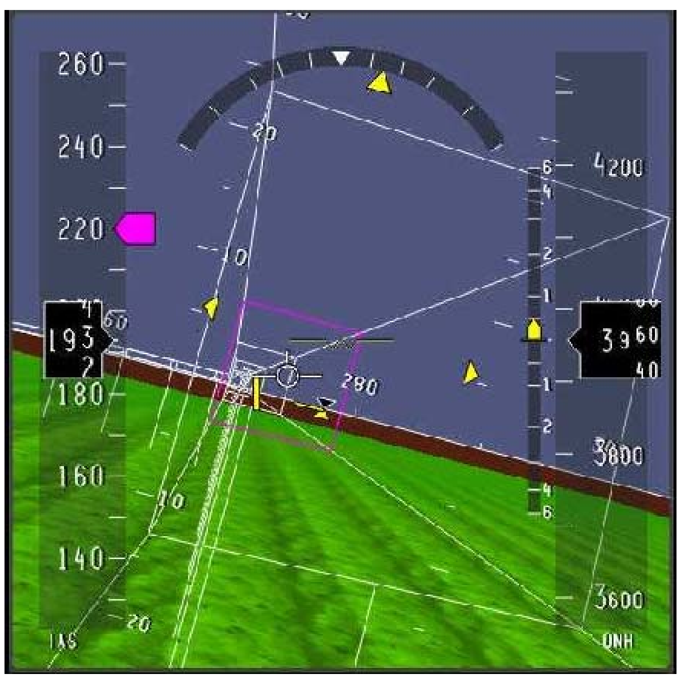

Figure 3.3
Example Rockwell Collins PFD Format

Figure 3.4 presents an example British Aerospace (BAe) Research Display PFD format. As in the case with NASA formats, the BAe format will either collocate the PFD and Navigation

Displays on the same display, or will split functions on edge-abutted displays (testing will commence in Spring 2003).

Graphic Requested, to be Provided

Figure 3.4
Example British Aerospace PFD Format

3.3.5.2 Navigation Display (ND)

The ND provides primary strategic information for path control support, and hazard avoidance. In the present concept, this is a head down (below the glareshield) instrument. Issues of scale, size of the display, display point of view, the presence and nature of traffic hazard cues, and overall format are significant research issues which are being addressed by the Team. Specific examples of ND formats used by SVS Team members are presented below. Detailed descriptions of all the formats used for a particular experiment may be found in the requirements documents relating to those experiments.

Development of a NASA strategic display is scheduled for FY 2002. NASA has used a conventional format Navigational Display to date in conducting airborne research, and is investigating the incorporation of terrain texture cues, a Vertical Situation Display, and 3-D perspective cues, in subsequent research next year. Figure 3.5 presents example NASA SVS airborne research ND formats. In experiments to date, the NASA ND format has been collocated with the PFD, on the same research display, though a configuration which splits the ND and PFD functions in two, edge-abutted displays, is being investigated.

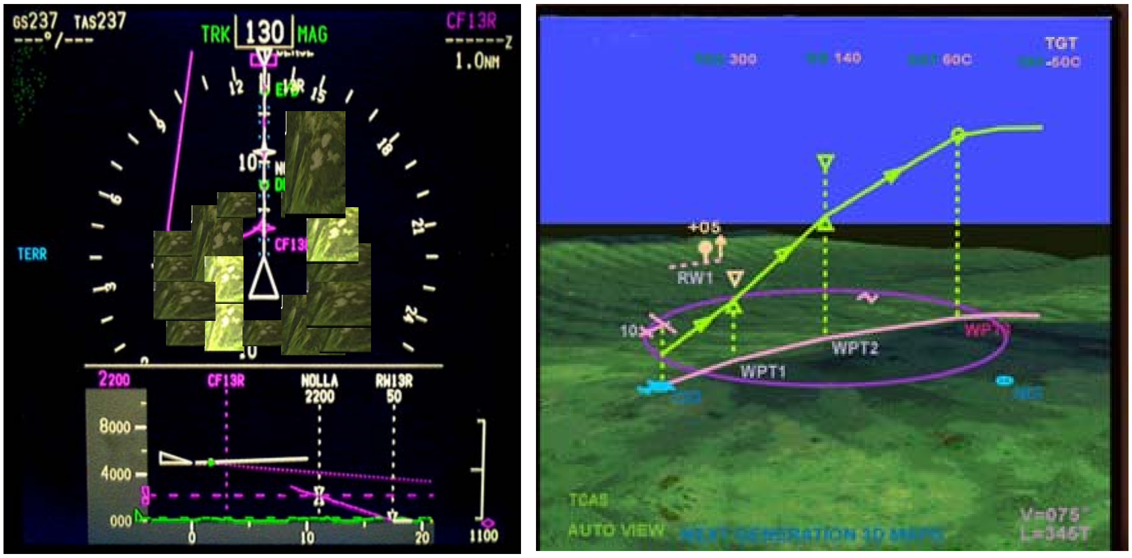

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Figure 3.5
Example NASA ND Formats
(Note: Blocked texture for representational purposes only.)

The NASA SVS Team also tested another ND format, specific to Runway Incursion Prevention System and Hold Short and Landing Technology flight and simulation testing. This format is presented in Figure 3.6. In subsequent tests in 2003, basic SVS, RIPS and HSALT formats are expected to be integrated.

Figure 3.6
Example NASA RIPS ND Formats

Figure 3.7 presents an example Rockwell Collins Research Display ND format. As in the case with NASA formats, the Rockwell Collins format collocated the ND and Primary Flight Displays on the same display.

Figure 3.7
Example Rockwell Collins ND Format

Figure 3.8 presents an example British Aerospace Research Display ND format. As in the case with NASA formats, the BAe format is expected to collocate the ND and Primary Flight Displays on the same display (testing will commence in Spring 2003).

Graphic Requested, to be Provided

Figure 3.8
Example British Aerospace ND Format

3.3.5.3 Head Up Display (HUD)

The HUD provides primary tactical (and to some extent, strategic) guidance for path control and hazard avoidance. In the present concept, depiction of real world cues (symbolic and perspective) is conformal, with respect to location and scale of these cues. Issues of the nature of terrain perspective cues, and specific guidance format, are significant research issues which are being (and have been) addressed by the Team. Specific examples of HUD formats used by SVS Team members are presented below. Detailed descriptions of all the formats used for a particular experiment may be found in the requirements documents relating to those experiments.

Figure 3.9 presents an example NASA SVS Research Display HUD format. In the NASA HUD, terrain modeling has been either generic texture overlaid on elevation data, or photo-realistic textured data. Research will help where each might have advantages over the other.

Figure 3.9
Example NASA HUD Format

The NASA SVS Team also tested two additional HUD formats, specific to Runway Incursion Prevention System and Hold Short and Landing Technology flight and simulation testing. The RIPS HUD Format is presented in Figure 3.10, and the HSALT Format in Figure 3.11. In subsequent tests, basic SVS, RIPS and HSALT formats are expected to be integrated.

Figure 3.10
Example NASA RIPS HUD Format

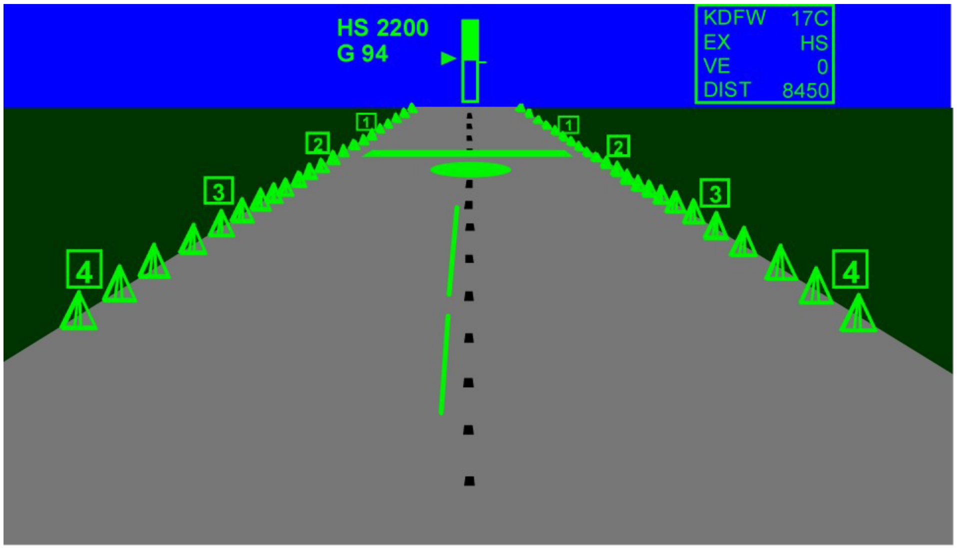

Figure 3.11
Example NASA HSALT HUD Format

4.0 CONCEPT ASSESSMENT DISCUSSION

The following are assessments of significance to the characterization of each of the SVS Concept element areas, gleaned from results of experiments, and analytical studies to date. A detailed discussion of SVS Concept assessment is presented in the Calendar Year 2001 Concept Assessment Document, along with a detailed list of experiments last Calendar Year, and a catalog of critical SVS issues identified by the Team.

4.1 GENERAL

The experiment and demonstration at Asheville near the beginning of Fiscal Year 2000 afforded an excellent early look at the potential for SVS in augmenting path control and situation awareness in mountainous terrain. This experiment showed promise in the ability of displays using synthetic imagery gleaned from onboard data bases, to augment pilot path control and situation awareness functions. This experiment also suggested some tolerance in pilot use of terrain texture cues, leading to subsequent experiments on the nature of those cues, and the terrain modeling options listed in the current Concept.

Initial simulation experiments and concept development helped narrow the scope of test for subsequent flight test, by identifying the likely range of operational acceptability in the extent of Primary Flight Display size and fields of view. The simulator was also very useful in developing flight test scenarios, timing, and procedures. Much of what was learned in the simulator with regard to pilot preference and overall flight operations was verified in the following flight test.

The team conducted an excellent workshop concerning the concept of SVS operations, which brought a significant user community presence into the project. Inputs from manufacturers, airline operators and managers, and regulatory agencies have added considerably to the Concept, by identifying issues and potential benefits in future SVS-equipped operations.

The flight test at Dallas offered an extensive operational look at an early SVS configuration, in a flat terrain, culturally dense environment. A significant amount of quantitative and qualitative data were taken at Dallas, some of which is still being analyzed. Although problems were identified, in general there was widespread acceptance among airline Captains acting as Evaluation Pilots, of the overall SVS philosophy and concept. The presence of database imagery on the HUD and PFD was relatively well received, and pilots felt the information content and display methodology useable. Results from the experiment comparing photo-realistic versus generic terrain depiction indicate that, depending on size of display and nature of image information, each has advantages.

The flight test at Eagle/Vail and Colorado Springs late in the Fiscal Year offered an extensive operational look at an early SVS configuration, in a mountainous terrain, culturally sparse environment. Once again, a significant quantity of quantitative and qualitative data were taken at Eagle/Vail, much of which is still being analyzed. All tactical Synthetic Vision display concepts provided measurable increases in the pilot's subjective terrain awareness over conventional baseline aircraft displays. The head-down display presentations yielded better terrain awareness over the Head-Up display synthetic vision display concepts that were tested. Limitations in the SV-HUD concepts were uncovered from this test, which suggest further research.

A specific discussion of SVS Concept elements and assessment follows, by component.

4.2 FORWARD LOOKING INFRARED (FLIR)

Efforts last Calendar Year have been devoted predominantly to design and installation issues, and correction of those issues, associated with the installation of a FLIR sensor package in the NASA 757 test vehicle, to support flight tests at Eagle/Vail. Further FLIR tests are planned in Fiscal Years 2002 and 2003.

FLIR implementation can potentially support path control through direct presentation of scene imagery to the pilot, object detection (either directly through pilot scene interpretation, or automatically), and data base integrity assurance.

4.3 WEATHER RADAR (POTENTIAL SVS MODES)

Efforts last Calendar Year have been devoted predominantly to data collection and analysis, and object detection algorithm development and improvement. Weather RADAR data based algorithms may potentially provide benefits in two key areas: database integrity monitoring, and ground object hazard avoidance. A key advantage of this scheme is that it uses equipment already present on commercial aircraft (though equipment reliability and availability of this non-critical system is an issue). The operational feasibility of use of existing RADAR data sources, combined with new algorithms, for these purposes, is largely untried in the commercial and business environment. Significant development and test is required to develop and prove utility of this concept prior to industry acceptance.

4.4 MILLIMETER WAVE RADAR

No significant testing efforts involving Millimeter Wave RADAR (MMWR) have occurred last Calendar Year, other than limited discussions on potential future flight test opportunities. The feasibility of incorporating MMWR in FY 2003 flight tests, currently planned at Wallops and Reno, is being investigated.

MMWR implementation can potentially support path control through direct presentation of scene imagery to the pilot in low visibility conditions, object detection (either directly through pilot scene interpretation, or automatically), and data base integrity assurance.

The methodology for operational employment of MMWR in a commercial and business aircraft environment is largely untried or unproven, as well, and operational risk is therefore considered high.

4.5 GLOBAL POSITIONING SYSTEM

Global Positioning System (GPS), even with differential corrections required for precision path control accuracy, is considered a relatively mature technology, with numerous off the shelf systems available, or being tested in their final forms. Though there are integrity, reliability, and criticality issues which remain before GPS is ready to support a fully implemented SVS-equipped airline fleet, the technology is relatively mature.

4.6 ONBOARD SVS DATA BASE

Significant efforts have occurred last Calendar Year in learning how to obtain and develop source data for an SVS data base, and assemble it in simulation and flight test hardware and software. Issues associated with streamlining this process, and with the ability to guarantee accuracy, maintainability, availability, and integrity of the data base have been addressed, and tools for rapid prototyping are being assembled, with some success. The decision to incorporate such a data base in the SVS Concept is supported by assumptions that the resulting infrastructure requirements won't result in prohibitive product costs, and that world-wide terrain elevation data will eventually become readily available. Achievements in both these areas have been realized this year, with the release of new, Space Shuttle based data, and the initial development of database regulatory standards.

4.7 SYSTEM INTEGRITY MONITORING

Given that certain conceivable failures of the data base could cause loss of aircraft and occupants, the team believes this system to be critical to flight safety, and therefore is required to meet commercial critical reliability standards. It is further believed that, given the data collection methodology and the potential for data to change over time (man-made or natural terrain changes, tower construction, etc.), a necessity exists for a separate SVS component to assure data base integrity. The exact nature for this component, and required technology, is at present unknown (though potential candidates have been identified). Efforts this year have identified several sensor sources to support this function – Weather RADAR, RADAR or LASER altimeter, FLIR, and MMWR among them. Testing has been accomplished, predominantly in the area of RADAR Altimeter correlation, which indicates significant promise in successful development of a candidate Database Integrity Monitoring Equipment (DIME) Subsystem. Future testing is planned in FY 2003.

4.8 OTHER ONBOARD NAVIGATION SYSTEMS AND DATA BASES

Though not representing new SVS equipment being added to an existing aircraft concept, SVS will certainly require information from other onboard aircraft systems, like attitude and heading from an Inertial Measurement Unit, altitude and airspeed from an Air Data Computer, cleared and desired path from a Flight Management System, etc. The nature of the interface between SVS and these systems, and the extent to which these associated functions are imbedded within SVS components, will depend on whether the SVS is a retrofit, or a new implementation. In any case, implementation details are envisioned to be workable for retrofit or new aircraft installations.

4.9 PRIMARY FLIGHT DISPLAY, OR IMBEDDED DISPLAY FEATURES

Since the size of the Primary Flight Display, and available display surface for SVS display components will vary depending on whether the installation is in a new aircraft, or a retrofit solution, the SVS Project has investigated size and field of view issues on Primary Flight Displays, both in simulation, and in flight test. Results indicate that mission tasks can be performed across the gamut of anticipated display sizes, though there is a clear preference among pilots for the larger display formats. Certification efforts associated with major changes in a Primary Flight Display are traditionally extensive, however.

4.10 NAVIGATION DISPLAY, OR DISPLAY FEATURES/PAGES

Flight and simulation testing this year have used Navigation Display formats which are relatively mature, and generally well accepted by the evaluation pilots. The elements of this component are likely to be well integrated with existing hardware in the commercial and business aircraft mission environment. SVS elements of the Navigation Display will likely be combined on existing pages in a multi-function display, or be placed on dedicated pages. Future tests in FY 2003 will investigate new (Vertical Situation Display) and largely untried (3-D Perspective Display and Terrain Texture Display) ND formats. Format enhancements, and the benefits of their implementation, will have to be weighed against the fact that certification efforts associated with major changes in this display are traditionally extensive.

4.11 HEAD UP DISPLAY (OPTION) WITH DEDICATED DISPLAY FEATURES

Flight and simulation testing in FY 2001 have used a Head-Up Display tailored and configured for SVS testing, with both raster image and symbolic (stroke and raster) elements. The philosophy to date has been to employ the HUD as an augmentation to path control and situation awareness, rather than as a Primary Flight Display. In retrofit applications, involving analog displays, HUD might be employed as a Primary SVS Tactical Display, but the philosophy would likely still be to consider the existing head down PFD as the Primary Flight Display. The use of an image on a HUD in this role, though largely untried in the commercial community, has been relatively well accepted by pilots to date (with some relatively vocal exceptions). Results to date support its continued presence in the SVS Concept, with both image and symbolic elements.

4.12 INTERFACE WITH OTHER COCKPIT DISPLAYS, I.E., TAWS

Efforts in this area have been limited to previous studies, and testing with an emulated (software) system at Eagle/Vail. Tests indicated reasonably good integration, on the ND, with other data, though no real SVS integration of TAWS functionality has yet been tested. Further tests will occur in association with FY 2003 flight tests. Implementation details are envisioned to be workable for retrofit or new aircraft installations.

4.13 DEDICATED SVS SUPPORT EQUIPMENT AND CREW INTERFACE

This SVS component consists of equipment and controls necessary for crew interface to the SVS, i.e., mode controls, brightness and contrast controls, Flight Guidance interfaces (particularly mode transition and awareness), and flight path control workload alleviation features (autoflight modes). No specific studies were conducted this year in this area, though crew interface provisions were incorporated in all tests (some became rather complex). Future tests will look at some advanced methodology for SVS control, including speaker-independent voice recognition. Implementation details for support equipment and crew interfaces are envisioned to be workable for retrofit or new aircraft installations.

4.14 INTERFACE WITH OTHER AIRCRAFT SYSTEMS

No specific studies were conducted this year in this area, though aircraft system interfaces were required and incorporated in all tests. Implementation details for interfaces with other aircraft systems are envisioned to be workable for retrofit or new aircraft installations.

5.0 IMPLEMENTATION CONSIDERATIONS

The benefits from incorporation of Synthetic Vision Systems components and functionality should not be limited to new aircraft at the early stages of design. The difficulty in implementing SVS in an aircraft type will vary greatly with the maturity of that type, numbers of aircraft in the fleet, and type of cockpit display and computational equipage. These variations will lead to significant variations in SVS concept philosophy dependent on the category of aircraft involved. To discuss these variations, CaB aircraft categories are divided into Forward Fit (new aircraft designs open to SVS incorporation at the basic design phase) and Retrofit (all other types). The Retrofit category is further divided into Mechanical display cockpits (non-electronic analog displays used for PFD and ND), Glass Cockpit/CRT (CRT displays used for the PFD and/or ND), and Glass Cockpit/LCD (LCD's used for the PFD and/or ND).

5.1 Forward Fit Aircraft

For new designs, SVS functionality may be built into the design from Day One, allowing the design to be optimized with respect to cost, functionality, operator acceptability, and certification requirements. Envisioned key components of such an implementation are as follows:

- Wide field of view (30 degrees or greater) Head-Up Display. Potential implementation augmentation ideas being investigated include panoramic glass displays (wrap-around formats), head worn displays, and windscreen (and other window surface) projected displays. Investigation into the feasibility of a Head Mounted Display in this configuration is also underway.
- Enhanced Primary Flight Display, with imbedded perspective ownship, path, terrain, and traffic cues, and variable field of view. Potential enhancements include 4-D path control cues, variable point of reference, and voice recognition control.
- Enhanced Navigation Displays with ownship, path, terrain, and traffic cues. Potential enhancements include 3-D perspective cues, 4-D path control cues, variable point of reference, and voice recognition control.
- Potential augmentation of display information in the form of an auxiliary Pilot Information Display. Displayed information might include clearance and RIPS data, moving maps for surface operations, HUD repeater imagery for single HUD installations, and EVS sensor imagery (FLIR and MMWR, if so equipped).
- Potential augmentation of basic SVS functions include advanced information fusion of Enhanced Vision Systems sensors, for hazard detection and display, and integrity monitoring.

5.2 Retrofit Mechanical and Glass/CRT Cockpit Display Aircraft

For designs without advanced computational or display generation equipment, SVS functionality, if incorporated, will likely need to come from new displays installed in the cockpit, due to the prohibitive cost of installation of electronic displays and associated architecture (as well as certification) in such a configuration. The NASA SVS Team envisions SVS functionality in such a configuration to come from a new HUD for tactical information, and an Electronic Flight Bag for strategic information. Envisioned new key components of such an implementation are as follows:

- A conventional Head-Up Display, controlled by an SVS/HUD computer, and incorporating terrain imagery, as well as perspective 3-D path, traffic, and hazard information. Investigation into the feasibility of a Head Mounted Display in this configuration is also underway.
- Precise navigational equipment, to include DGPS and required data bases, to be installed in place of existing Inertial-Only based systems.
- An auxiliary Pilot Information Display, to include moving maps for surface operations, and advanced navigational and terrain information for airborne operations.

5.3 Retrofit Glass/LCD Cockpit Display Aircraft

For designs which include advanced display generation and display equipment, SVS functionality may be realized (it is postulated) using cost effective modifications to existing equipment. The NASA SVS Team envisions SVS functionality in such a configuration to come from modified PFD and ND formats, and optionally, HUD, and Pilot Information Display equipage. Envisioned new key components of such an implementation are as follows:

- A new enhanced head-down Primary Flight Display format, with imbedded perspective ownship, path, terrain, and traffic cues, and variable field of view. Potential enhancements include 4-D path control cues, and variable point of reference.
- A new enhanced Navigation Display format, with ownship, path, terrain, and traffic cues. Potential enhancements include 3-D perspective cues, 4-D path control cues, and variable point of reference.
- Modified or replaced display symbol generators, to perform SVS computational functionality.
- Potential augmentation of display information in the form of a new Head-Up Display installation, controlled by an SVS/HUD computer, and incorporating terrain imagery, as well as perspective 3-D path, traffic, and hazard information. Investigation into the feasibility of a Head Mounted Display in this configuration is also underway.
- Precision navigational equipment modifications, to include DGPS and required data bases, to be installed as required, in place of existing systems, to support SVS requirements.
- Potential augmentation of display information in the form of an auxiliary Pilot Information Display. Displayed information might include clearance and RIPS data (if so equipped for datalink), moving maps for surface operations, HUD repeater imagery

for single HUD installations, and EVS sensor imagery (FLIR and MMWR, if so equipped).

6.0 SUMMARY

Last Calendar Year has once again seen substantial progress in the maturing of an SVS Concept with the potential for meeting the goals of the Gore Commission in the area of Controlled Flight Into Terrain, as well as providing significant operational and marketing benefits to commercial and business aircraft owners and operators.

The architecture of an implementable SVS, capable of meeting significant mission requirements, has been identified. Key components of the Concept have been tested in real-world operational environments, and show promise in meeting identified requirements.

An update to this document will be prepared at the end of Fiscal Year 2002, which will present an update to the SVS Concept, following receipt of results from experiments and studies, issues resolution consensus, and metrics assignment.

7.0 ACRONYMS

ADC	Air Data Computer
ADS/B	Automatic Dependent Surveillance/Broadcast
AHRS	Attitude Heading Reference Set
ARINC	Aeronautical Radio Incorporated
ASDE	Airport Surface Detection Equipment
ASIST	Aviation Safety Investment Strategy Team
ATC	Air Traffic Control
ATM	Air Traffic Management
AvSP	Aviation Safety Program
AWIN	Aviation Weather Information
BaE	British Aerospace
CaB	Commercial and Business
CAWS	Central Alert and Warning System
CCD	Charge Coupled Device
CD	Compact Disc
CDTI	Cockpit Display of Traffic Information
CFIT	Controlled Flight Into Terrain
CHR	Cooper Harper Rating
CIRT	Certification Issues Resolution Team
CONOPS	Concept of Operations
CPDLC	Controller Pilot Datalink Communications
CRT	Cathode Ray Tube
CY	Calendar Year
DEM	Digital Elevation Model
DFW	Dallas/Fort Worth Airport
DGPS	Differential Global Positioning System
DIME	Database Integrity Monitoring Equipment
DoD	Department of Defense
DTED	Digital Terrain Elevation Data
EADI	Electronic Attitude Direction Indicator
EGE	Eagle/Vail Airport (Eagle County Regional Airport)
EFIS	Electronic Flight Information System
EGPWS	Enhanced Ground Proximity Warning System
EHSI	Electronic Horizontal Situation Indicator
EMM	Electronic Moving Map
EVS	Enhanced Vision Systems
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FBO	Fixed Base Operator
FD	Flight Deck
FLIR	Forward Looking Infrared
FMS	Flight Management System

FOV	Field of View
FY	Fiscal Year
GB	Gigabytes
GBS	Ground Based System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HDD	Head Down Display
HDTV	High Definition Television
HFOV	Horizontal Field of View
HMD	Head Mounted Display
HSALT	Hold Short and Landing Technology
HSR	High Speed Research
HUD	Head Up Display
ID	Identify
IDS	Integrated Display System
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
IOD	Image Object Detection
IRL	Implementation Readiness Level
IRU	Inertial Reference Unit
LAAS	Local Area Augmentation System
LAHSO	Land and Hold Short Operations
LaRC	Langley Research Center
LASER	Light Amplification through Stimulated Emission of Radiation
LCD	Liquid Crystal Diode
LIDAR	Light Detection and Ranging
LMI	Logistics Management Institute
LNAV	Lateral Navigation
LVLASO	Low Visibility Landing and Surface Operations
MB	Megabytes
MCHR	Modified Cooper Harper Rating
MHZ	Megahertz
MMWR	Millimeter Wave RADAR
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NGS	National Geodetic Survey
NIMA	National Imagery and Mapping Agency
PC	Personal Computer
PFD	Primary Flight Display
PID	Pilot Information Display
R&D	Research and Development
R/A	RADAR Altimeter
R/C	Rockwell Collins
RADALT	RADAR Altimeter

RADAR	Radio Direction and Ranging
RAM	Random Access Memory
RIAAS	Runway Incursion Advisory and Alerting System
RIPS	Runway Incursion Prevention System
RIRP	Runway Incursion Prevention System
RNP	Required Navigational Performance
RSM	Runway Safety Monitor
RTA	Runway Traffic Alert
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
SA	Situation Awareness
SAE	Society of Automotive Engineers
SF	Stopping Factor
SID	Standard Instrument Departure
SV	Synthetic Vision
SVDC	Synthetic Vision Display Concepts
SVS	Synthetic Vision System
SVSRD	Synthetic Vision System Research Display
SXGA	Pixel Resolution of 1024 by 768
TAP	Terminal Airport Productivity
TAWS	Terrain Awareness System
TCAS	Traffic Collision Avoidance System
TIFS	Total Inflight Simulator
TIS-B	Traffic Information Services - Broadcast
TRL	Technology Readiness Level
USGC	United States Geological Survey
VASI	Vertical Approach Slope Indicator
VFR	Visual Flight Rules
VISTAS	Visual Imaging Simulator for Transport Aircraft Systems
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VSD	Vertical Situation Display
WAAS	Wide Area Augmentation System
Wx	Weather
WxR	Weather RADAR

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