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Synthetic Vision Systems (SVS) Concept Assessment Report, FY 00

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1.0 INTRODUCTION

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 results and findings from several Project activities, as they exist at the end of Fiscal Year 2000. Some of these activities are in progress as of the date of this document, or have final reports or analysis pending. Some results listed herein may change upon completion of the analysis and publication of final reports. Final results not summarized herein will be incorporated in the Fiscal Year 2001 SVS Concept Assessment Report.

1.1 PURPOSE

The purpose of this document is to summarize experimental and study results, findings, and critical issues concerning the demonstrated or analyzed capability and potential of existing candidate SVS concepts in satisfying Commercial and Business (CAB) Transport Aircraft mission requirements.

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. The current document will summarize results from those studies and experiments, in terms of the demonstrated ability and potential of candidate concepts in meeting mission requirements.

1.3 SCOPE

This document is intended to be an upper level summary of results. Detailed study and test results may be found in the final reports of results for the individual experiments, rather than contained herein. Results are documented as they are known as of the date of this report. Results from 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:

1.3.1.1 Sensors (or sensor equivalents)

- Forward Looking Infrared (FLIR) (potential)
- Weather Radar (Potential SVS Modes)
- Millimeter Wave Radar (potential)
- Global Positioning System
- Onboard SVS Data Base
- System Integrity Monitoring
- Other Onboard Navigation Systems and Data Bases

1.3.1.2 Displays

- Primary Flight Display, or imbedded display features
- Navigation Display, or display features/pages
- Head Up Display (option) with dedicated display features
- Interface with Other Cockpit Displays, i.e., TAWS

1.3.1.3 Equipment

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

2.0 METHODOLOGY

Concept assessment has been conducted in conjunction with experiments and studies planned in CAB sub-elements within SVS. Where formal reports have been submitted, those results, as well as inputs from researchers and study participants are used to obtain assessment data. Where studies are in progress or final reports have not been released, interviews with researchers and study participants, or interim study data submittals are used to obtain assessment data. In the latter case, it should be realized that subsequent completion of data collection and analysis may change overall conclusions concerning concept suitability. In that event, new conclusions will be captured in subsequent updates of this document.

2.1 CRITERIA

As stated in the Synthetic Vision Systems Concept Assessment Plan, top level criteria for overall concept assessment include the following:

- Operational Performance. How does the concept perform in an operational environment, with respect to mission requirements and issues resolution? Metrics in this area will consist of quantitative performance data, and some pilot (test and subject) qualitative opinion.
- Technical Feasibility and Risk. To what extent is the technology in the year 2004 time frame expected to support technical requirements for the concept and its mission? What is the risk of overestimation in technology capability predictions? Metrics in this area primarily qualitative with supporting evidence, though technology readiness scales can be useful.
- Operational Risk. To what extent are limited operational performance results from current studies using concept elements expected to be applicable to a fleet of operational aircraft? What is the risk of error in expected acceptability in concepts and their elements to industry airline managers and flight crew? How susceptible are operational acceptability predictions to error? How well will components be integrated with other cockpit equipment well into the design and implementation cycle? Metrics in this area will consist primarily of qualitative (albeit statistical) data, with supporting evidence.
- Marketing Risk. To what extent are concepts and their elements expected to be acceptable, in an intrinsic sense, to airline managers and passengers? How much more marketable and profitable is the aircraft using this concept and its elements expected to be? How susceptible are market predictions to error? Metrics in this area will consist of quantitative predictions, based on qualitative studies, hardware data, and experience with previous aircraft.
- Certification Risk. To what extent are concepts and their elements expected to be acceptable to airworthiness authorities for the purpose of commercial revenue service certification? How susceptible are predictions of certificability to error? A

Certification Issues Resolution Team has been formed by the SVS Project Team to help with assessments in this area.

2.2 METRICS

Specific metrics for use in each of the above areas include the following. Metrics are included in dedicated or shared studies, and used for assessment of each concept element, and the integrated concept assessment (of all elements and their interactions).

2.2.1 Operational Performance:

2.2.1.1 Flight Path Management

- Ground
  - Integrated Path Error (raw and threshold)
  - Maneuvering Reference (bldg, vehicle, hold short lines, etc) Errors
  - Workload Metrics (MCHR, etc)
  - Handling Qualities Metrics (CHR)
  - Effective Resolution (Color, Monochrome)
  - Situational Awareness (Judgment)
  - Quality Metrics (opinion, information content, clutter, aesthetics, etc.)
  - Physiological Distress and Confusion
- Flight
  - Integrated Path Errors (raw and threshold)
  - Maneuvering Reference Errors (aircraft, terrain, airport features)
  - Flying Qualities Metrics (CHR)
  - Workload Metrics (MCHR, etc.)
  - Effective Resolution (Color and Monochrome)
  - Situational Awareness (Judgment)
  - Physiological Distress and Confusion

2.2.1.2 Hazard Avoidance

- Ground
  - Object Detection thresholds
  - Object Maneuver Detection/Prediction
  - Object Recognition Errors

  - Escape Maneuver Errors
  - Situational Awareness
  - Quality Metrics (opinion)

- Flight

  - Object Detection Thresholds
  - Object Maneuver Detection/Prediction
  - Object Recognition Thresholds/Errors
  - Escape Maneuver Errors
  - Situational Awareness
  - Crew Interaction
  - Quality Metrics (opinion)

2.2.2 Technical Feasibility/Risk:

- Established in the Literature
- Technical Readiness Level (TRL)
- Implementation Readiness Level (IRL)
- Lab Demo
- Vendor Marketing Demo
- Subject Mater Expert Opinion

2.2.3 Operational Risk:

- Pilot Involvement/Opinion
- Potential Customer Involvement/Acceptance (Opinion)
- TRL/IRL
- Workshop Support

2.2.4 Marketing Risk:

- Market Studies
- Surveys
- Subject Matter Expert Opinion

2.2.5 Certification Risk:

- FAR Support
- Workshop Support
- Study Team Support
- Certification Issues Resolution Team (CIRT) Inputs

2.3 READINESS LEVELS

To clarify the overall assessment of a concept element in terms of its suitability for the CAB mission, the following technology and implementation readiness scales are adopted. The Technology Readiness Level refers to the readiness of the SVS component or element to support the CAB mission. The Implementation Readiness Level refers to the maturity of the SVS component or element with respect to operational use in the CAB fleet. These scales will be subsequently applied to concept elements, with respect to the overall criteria listed above in Section 2.1, to establish readiness levels.

2.3.1 Technology Readiness Level (TRL)

1: Basic Principles Observed and Reported
2: Technology Concept and/or Application Formulated
3: Analytical and Experimental Critical Function and/or Characteristic Proof-of-Concept
4: Component and/or Breadboard Validation in Laboratory Environment
5: Component and/or Breadboard Validation in Relevant Environment
6: System/Subsystem Model or Prototype Demonstration in Relevant Environment
7: System Prototype Demonstration in Operational Environment
8: Actual System Flight Qualified by Demonstration
9: Actual System Flight Proven in Operation

2.3.2 Implementation Readiness Level (IRL)

1: Technology Transfer Initiated
2: Industry R&D Funding Committed
3: Commercial Product Development Initiated
4: Application for Certification
5: RTCA/SAE or Equivalent Convened
6: Draft Certification Standard Developed
7: Certification Standard Established
8: Certification Approved
9: Operation of Certified System

3.0 STUDIES

Table 3.1 below, list studies and experiments commenced as of Fiscal Year 2000, which are pertinent to the present Concept Assessment task. A summary of the study title, the type of study, and notes concerning status are included.

Table 3.1 SVS Related Studies and Experiments

Study	Type	Notes/Status
Tactical Terrain Awareness Concept Flight Evaluation (TIFS) - 09/99	Flight	Complete. Technical Highlight released
Initial Assessment of Size/FOV effects on Head-Down Tactical Retrofit Concept	Simulation	Initial tests complete for DFW. Planning for EGE related tests ongoing
Flight simulation evaluation of Tactical Terrain Awareness Concepts – 09/00	Flight and Simulation	Ongoing
Flight Evaluation of Limited Tactical HUD Concept for Flight Ops – 09/00	Flight	DFW testing complete. EGE test planning ongoing
SA Tools for Retrofit Assessment – 09/00	Study	Complete. Report released
Advanced Display Media Technology Assessments – 10/00 to 03/03	Study	In planning. Chief Scientist has summary. Pursuing procurement vehicles for several technology assessments.
Simulation evaluations of Strategic EFIS Concepts – 10/00 to 09/01	Simulation	In planning, Spring 2001.
SVS in Challenging Airport Operational Environments - High Traffic, busy terminal area/airspace (DFW)	Flight	Complete. Technical Highlight in work. Subjective and objective data analysis ongoing.
SVS in Challenging Airport Operational Environments - Difficult Terrain (Eagle Vail)	Flight	In planning. Spring 2001.
SVS Ground Operations Study	Simulation	In planning. April 2001
Integration of SVS/TAWS	Study/Flight	In planning
Concept of Operations Study	Study	Final Draft in work
LMI Operations Benefits Study	Study	Initial study complete. Follow-on in work
Runway Incursion Prevention	Simulation/ Flight	Complete.

Study	Type	Notes/Status
Hold Short and Landing Technology	Simulation/ Flight	Complete
RADAR EVS Data Collection	Flight	Initial data collection complete
EVS FLIR Tests	Flight	In planning, Spring 2001

4.0 STUDY SUMMARIES

The following are summaries of significant findings for each of the studies which were completed or are in progress this Fiscal Year, which relate to concept assessment.

4.1 Tactical Terrain Awareness Concept Flight Evaluation (TIFS) - 09/99

- The purpose of the research was to conduct flight evaluations of a state-of-the-art photo-realistic terrain database and NASA LaRC Synthetic Vision Tactical Concept display
- Evaluations were conducted from the "terrain impacted" Asheville airport on October 11-15, and November 2-4, 1999, in 16 flights, with over 60 various types of approaches.
- Flight demonstrations featured image comparisons of external video from an High-Definition Television (HDTV) camera with overlaid flight symbology displayed head-up on a 13" x 18" projection system to a synthetic vision scene, with overlaid symbology displayed both head-down on a 8" x 10" LCD and head-up on a 10" x 18" projection system in various size renditions (size A, D, and full screen size).
- For each display size, 4 minification levels -unity, 30° horizontal field of view (HFOV), 40° HFOV and 60° HFOV- were available for presentation on the tactical display.
- The tactical synthetic vision scene incorporated terrain, obstacles, flight symbology, airport features (runway, taxiways, tower, FBO, etc.), and air traffic icons.
- A Navigation Display (ND) was also employed to assist flight test maneuver execution.
- Forty people attending the Aviation Safety Program (AvSP) Synthetic Vision (SV) kickoff meeting participated in ten demonstration flights.
- In addition to the flight demonstrations, the AvSP SV held a two-day meeting in Asheville, NC, to kickoff eight unique SV project cooperative agreements with industry and academia. There were more than seventy meeting attendees from over twenty-five diverse organizations including DOD, FAA, NIMA, and Airline representation.
- NASA personnel provided a summary of the five-year, $100 M Synthetic Vision Project plan and each NASA Research Announcement cooperative agreement team provided an overview of their proposed effort.

4.2 Initial Assessment Of Size/FOV Effects On Head-Down Tactical Retrofit Concept – 06/00

- The purpose of this simulation experiment was to determine whether useful and effective Synthetic Vision System (SVS) displays could be implemented on limited size display spaces as would be required to implement this technology on older aircraft with physically smaller instrument spaces.
- Prototype SVS displays were put on the following display sizes: (a) size "A" (e.g. 757 EADI), (b) form factor "D" (e.g. 777 PFD), and (c) new size "X" (Rectangular flat-panel, approximately 20 x 25 cm).
- Testing was conducted in a high-resolution graphics simulation facility (VISTAS I) at NASA Langley Research Center.
- Specific issues under test included the display size as noted above, the field-of-view (FOV) to be shown on the display and directly related to FOV is the degree of minification of the displayed image or picture.
- Simulated approaches to runways at Asheville, NC, (mountainous terrain) and at Dallas-Fort Worth airports were used.
- Variables assessed included precision of handling piloting task, errors, and nature of errors, answers to Situation Awareness probes, workload and ease of handling piloting tasks, effect of disruptive events (changes, communications), pilot ratings and rankings of display concepts, and pilot comments
- Results indicated:

    Pilot preferences for optimal Field-of-View were varied and phase-of-flight dependent

    Two most preferred FOVs were Unity and 30 deg

- Selected Pilot Comments:

    "Unity is too sensitive to heading changes in turn, 30 deg is best overall."

    "I would use 90 deg for VMC conditions and unity for IMC approaches."

"Unity has most precise detail for approach, good FOV with the big display. 90 FOV gives widest look as you begin turns. Have a better feel for the overall terrain."

"I can see a tremendous benefit to a larger FOV during the en-route phases of flight especially in mountainous terrain.

"Great concept—looking to see it soon."

- Performance data are currently being processed

4.3 Flight Simulation Evaluations Of Tactical Terrain Awareness Concepts – 09/00 To 12/01

- The purpose of the study is to assess effective Synthetic Vision Presentation on Tactical Displays (PFD/HUD) using flight test research and simulation facilities.
- Issues include varying display sizes, optimum field of view (FOV) for small displays, size A and D, in retrofit aircraft, optimum FOV for larger formats in forward-fit aircraft, FOV/minification tradeoffs, display size and pixel count (resolution) issues, effect on pilot workload as compared to conventional PFD, operational benefits of having elevation/obstacle database, safety benefits/limitations, integration with out-the-window scene – transition / training issues, clutter.
- Test desirable FOVs for converging approaches and parallel approaches/departures, circling approaches.

4.4 Flight Evaluation Of Limited Tactical HUD Concept For Flight Ops – 09/00

- The purpose of the study is to assess effective Synthetic Vision Presentation on Tactical Head-Up Displays using flight test research facilities.
- Testing Considerations include how to display information – opaque SV scene/wireframe, minification utility, operational benefits of using HUD with database, safety benefits/limitation, declutter techniques – manual or automatic, how to avoid clutter, increases in SA – look at different facets of SA, including spatial, systems, etc; effect on pilot workload, integration with out-the-window scene, and transition / training issues
- Tests at DFW complete

- Tests at EGE in planning for Spring 2001

4.5 SA Tools For Retrofit Assessment – 09/00

- The purpose of the study was to develop a set of tools to use in situation awareness measurement of retrofit display media Synthetic Vision concepts.
- Under contract to NASA Langley, Dr. Mica Endsley completed review of relevant SA measures for SVS and documented these in report SATECH-00-11, June 2000, entitled: Evaluation of Situation Awareness in Flight Operations Employing Synthetic Vision Systems. Report includes details on each methodology and candidate questions or probes for simulator and flight experiments.
- Scenarios developed and utilized for Size and Field-of-View laboratory experiments.
- Future Work: Tools, techniques, procedures, and scenarios developed will be employed in future simulator and flight experiments. Additional assistance by Dr. Endsley anticipated.

4.6 Advanced Display Media Technology Assessments – 10/00 To 03/03

- Contracted study to assess presently available and potential future technology with applications to SVS display media.
- Study is in planning.

4.7 Simulation Evaluations Of Strategic EFIS Concepts – 10/00 To 09/01

- The purpose of this simulation experiment is an assessment of Synthetic Vision System elements associated with strategic displays (i.e., Navigation Display) or strategic elements of tactical displays (i.e., PFD).
- Issues include display control issues for PFD-SVS and/or ND, location of controls for SVS / enhanced ND, integration with tactical displays (SV PFD and/or HUD), integration with out-the-window scene – transition / training issues, increases in SA – look at different facets of SA, including spatial, systems, etc; effect on pilot workload as compared to conventional ND, operational benefits, safety benefits/limitations, and clutter.

- This experiment is in the planning stage, with evaluations planned in the Spring of 2001.

4.8 SVS In Challenging Airport Operational Environments - High Traffic, Busy Terminal Area/Airspace (DFW)

- The purpose of this flight test research experiment was to evaluate NASA concepts to address retrofit issues and explore display parameters, and evaluate a Rockwell-Collins head-down concept (aimed at near-term implementation using current avionics)
- Display parameters evaluated included HUD terrain database texture types (generic, photo-realistic), Head-Down Display (HDD) sizes (A/B, D, X), terrain database texture types (generic, photo-realistic), and selectable Field of View (FOV)
- HUD tests evaluated an unconventional use of a HUD for both VMC and IMC operations
- HUD imagery provided an opaque, computer-generated terrain scene, overlaid on the real world scene
- A declutter switch was evaluated and used to view the real world (when desired or at decision height)
- Certification issues about obscuration of real world are a recognized concern
- The SVS Research Display (SVSRD) for this test was a large, 18.1" High-Brite LCD display with touch screen and brightness control, capable of displaying A/B, D, X formats, and SXGA resolution.
- The display was designed for easy (10 second) inflight removal
- The SVS Graphics Engine consisted of two Intergraph Zx1 PCs, with dual 800-MHz processors, 1 Gig of RAM, and Wildcat 4110 Video boards with 268 MB of Texture memory
- Less than $10,000 per PC!
- The scope of tests included six evaluation pilots, 17.5 hours of research time, with 76 total approaches
- Pilot comments indicated that the opaque terrain image on HUD was widely accepted for night operations
- Judging distance and closure rates seemed better with Photo-realistic terrain
- Larger FOV of HUD and being head-up were positively reflected in pilot's comments when compared to HDDs
- Collimation aspect of HUD enhanced 3-D effect of terrain image

- All pilots preferred using selectable Head Down Display FOVs
- Larger FOVs prior to final (~60 degrees)
- ~25-45 deg FOV used for runway change
- Smaller FOVs close-in on final approach (~30 deg or less)
- Larger displays preferred over small
- NASA Opaque image on HUD appears viable for retrofit (at least for night operations)
- Synthetic vision appears to be effective on all display types evaluated (Size-A/B, D, X, and HUD)
- Rockwell-Collins concept considered effective & fairly mature
- All pilots preferred availability of multiple FOV selection
- All pilots acknowledged the enhanced situational awareness provided by synthetic vision, regardless of the SVDC size/type

4.9 SVS In Challenging Airport Operational Environments - Difficult Terrain (Eagle Vail)

- In planning for Spring 2001
- The goals and objectives of the SVDC-EGE flight test were generated by the SVDC flight test team in response to the SVS project and established project plan and milestones.
- In general, EGE testing will extend assessment of the SVS retrofit approach to operations in a realistic terrain-challenged operational environment
- Testing will assess the potential of NASA Opaque HUD / Clear Sky Concept as a retrofit solution for display of SVS concepts in non-glass cockpits, and determine potential in both day VMC and day, low-visibility operational environments.
- Testing will attempt to confirm results from piloted simulation experiments and SVS-DFW flight test for operational utility and acceptability of various sized (size A/B, D, X) synthetic vision displays for retrofit into existing glass cockpits.
- Testing will compare the operational utility and acceptability of photo-textured with conventionally-textured terrain database SVS concepts within NASA SV concepts (HUD; head-down size A/B, D, X).
- Testing will investigate the operational utility and acceptability of enhanced terrain awareness of SV display concepts to RNP approach procedures in a terrain-challenged operational environment.
- Testing will assess pilot path control performance during manually flown landing approach and go-around maneuvers in a terrain-challenged operational environment, with and without SVS display concepts, and

determine the effect on that performance of the presence of SVS components.

- Testing will assess autopilot monitoring utility and operational acceptability of SVS display concepts in a terrain-challenged operational environment.
- Testing will assess the operational utility and maturity of Rockwell/Collins and British Aerospace SVS concepts in a terrain-challenged operational environment.

4.10 SVS Ground Operations Study

- The purpose of this study is an investigation of issues associated with integration of Surface Operations Display Concepts with Airborne Display Concepts
- Testing Considerations will include integration of both tactical (PFD/HUD) and strategic (ND) displays, and the development of tactical and strategic display switching strategies (gradual, instantaneous, certain altitude) from surface to air (departure) and from air to surface (landing) display concepts.
- Efforts here will build upon display work developed under AvSP's Runway Incursion Prevention Systems and TAP's LVLASO program.
- The study will investigate industry surface operations display concepts and incorporate into ND/PFD/HUD SVS concepts where appropriate
- The study will investigate surface operations display concepts associated with the FAA's SafeFlight 21 and Runway Safety Programs
- This study is in planning

4.11 Integration Of SVS/Terrain Awareness System (TAWS)

- The purpose of this study and flight test experiment will be to investigate issues associated with integration of SVS with TAWS
- Testing Considerations include the best use of low res TAWS, Weather RADAR, and high resolution SVS, obstacle presentation in TAWS, and terrain awareness comparisons between TAWS and SVS, and safety and operational benefit comparisons between TAWS and SVS.
- The study and experiment will consider approach, takeoff, missed approach.
- Scenarios will include a Cali-like CFIT accident (descent)

4.12 Concept Of Operations Study

- The purpose of the study and workshop held on February 23-25, at the NASA Langley Research Center, was to bring together 65 industry, FAA, and NASA representatives for discussion and development of concept of operations (CONOPS).
- Provided feedback to support the creation of a CaB and GA SVS CONOPS document, (milestones 6/30/00, 4/30/00).
- Attendees worked toward defining the CONOPS elements, applications, benefits, capabilities, and a list of areas for SVS research.
- The workshops succeeded in initiating open discussions of the operational applications of synthetic vision technology. New concepts and perspectives were discussed and will be used to guide the Synthetic Vision team's focused research and shared research with our Cooperative Agreement Partners.
- These workshops are critical in forming solid industry/government exchanges and collegiate relationships. This kind of team activity will help to ensure the success in the achievement of the Aviation Safety Program Goals.
- Future Plans: The NASA CONOPS team will write an preliminary CONOPS document from the discussions from the CaB workshop. This CONOPS will be circulated throughout the industry and government for comment.

4.13 LMI Operations Benefits Study

- The purpose of the study was to estimate the economic impact of the SVS capabilities to provide input to the NASA SVS Concept of Operations (CONOPS) document.
- Synthetic vision systems should provide several improvements in airport terminal area operations. Among these are reduced arrival and departure minimums, use of additional multi-runway configurations, independent operations on closely spaced parallel runways, and reduced arrival spacing.
- Using modified versions of airport capacity and delay models previously developed to analyze other NASA technologies, the study estimated how much these improvements would reduce arrival and departure delays.

- The analysis results indicate that SVS technologies should provide large economic benefits, but that different capabilities are important at different airports.
- The results indicate that the ability to conduct circling and converging approaches will provide major benefits at two key airports (Chicago, Newark).
- Reduced arrival separations are essential at two other key airports (Atlanta, Los Angeles).
- The remainder of the capabilities provide significant, but lesser, benefits. The ability to conduct low visibility ground operations at normal visual tempo is an essential enabling capability for all benefits
- Recommendations for future SVS testing included converging and circling operations in IFR Cat IIIb conditions, autonomous aircraft approach positioning with respect to leading aircraft, arrival and departure operations under conditions of zero foot ceiling and 300-foot runway visual range (RVR) with a goal of demonstrating operations at zero foot RVR, ground operations at visual flight rule tempos with visibility as low as 300 feet.
- Tests and analysis should include determining the minimum operational hardware requirements for each of the capabilities above, specifically, whether a head-up display is technically required for each capability, and the minimum hardware suite necessary to provide FAA-required system performance and reliability.

4.14 Runway Incursion Prevention

- The purpose of this simulation and flight test research experiment was to assess and validate technology performance for preventing runway incursion accidents, and collect data to assess the performance of the emerging incursion alerting algorithms, data link, GPS, and surveillance technologies.
- Included was a validation of system performance data against evolving RTCA standards for data links, LAAS/WAAS, surveillance, and databases
- An attendant goal of the flight test efforts was to demonstrate the system in an operational environment, both during tests, and in a separate effort for industry and regulatory representative observers.
- The flight test associated with this experiment integrated with the FAA Runway Incursion Reduction Program's (RIRP) DFW surface surveillance infrastructure

- Three methods of generating runway incursion alerts were used – an aircraft based alerting algorithms developed by Rannoch (RIAAS), an aircraft based alerting algorithms developed by NASA (IDS), and an algorithm using alerts generated by FAA surveillance system and transmitted to aircraft (GBS). Each method evaluated simultaneously, and one source chosen for display in cockpit
- Tested scenarios involved real incursions by ground intruder vehicles (van and truck).
- 4 airline captains were used as subject pilots. 51 RIPS test runs were conducted (in addition to checkout runs).
- Results indicate that pilots felt safer with RIPS onboard, felt RIPS alerting was timely. Pilots were impressed with Electronic Moving Map for surface situational awareness.
- This flight test demonstrated the feasibility of providing aircraft based runway incursion alerting.
- Final data analysis and report are pending

4.15 Hold Short And Landing Technology

- The purpose of this flight test and simulation experiment was to assess and demonstrate the utility and acceptability of hold short and landing technology during approaches and landings in a representative transport class aircraft.
- Symbology was provided before landing to provide the pilot with information on the HUD & ND for judging the difficulty of stopping at hold short location; information was provided in the form of a Stopping Factor (SF), and a runway planview with exits & hold short location on ND
- Symbology was provided after Landing on the HUD to provide the pilot deceleration information/guidance for stopping at hold-short location or decelerating to turnoff speed of earlier exit, and provide the pilot continual situational awareness on criticality of stopping the aircraft at the hold-short
- All of the four subject pilots indicated that there was no problem stopping at the hold-short location with SF = 1
- Pilot comments indicated that decel guidance very useful & not difficult to use
- Pilots also expressed that HSALT has applications well beyond land and hold short (LAHSO) operations, including rollout & turnoff for reduced

runway occupancy time, contaminated/wet runway operations, and rejected takeoff

4.16 RADAR/FLIR EVS Data Collection

- Objective at DFW was to collect RADAR data relevant to Runway Incursions using an experimental X-band weather radar.
- Twelve days of Runway Incursion data were collected on 60 CDs.
- These data will be useful in the testing of existing detection and tracking algorithms and should provide significant insight for future algorithm development.
- Further data acquisition in planning for Eagle-Vail Spring 2001
- The Eagle-Vail flight tests will permit the acquisition of actual RF sensor data for direct application to potential hazard detection algorithms.
- Experimental X-band weather radar data, dual band FLIR data and CCD derived visual data are expected to be collected.
- Testing will collect RADAR data and FLIR/visible-band imagery during terrain-challenged operations to enable object detection and terrain feature extraction algorithm development and refinement for independent integrity monitoring applications.

4.17 EVS FLIR Tests

- In planning for Eagle-Vail Spring 2001
- Testing will assess landing approach operational utility and acceptability of enhanced vision system concept (FLIR sensors) in a realistic operational environment. Note, this objective does require a supporting terrain database, and as such is site independent.

5.0 CONCEPT ASSESSMENT METRICS

5.1 RISK

Based on results to date, Table 5.1 indicates preliminary risk assigned to each of the concept elements and assessment criteria listed in Section 1. Risks were assigned by this document author, and do not yet represent a group consensus. Such a consensus will be obtained for future releases. A discussion follows in Section 6.

Table 5.1 Concept Risk Assessment

Element	Technical Risk	Ops Risk	Market Risk	Cert. Risk
Forward Looking Infrared (FLIR)	**Low**	**High**	**Med**	**Med**
Weather Radar (Potential SVS Modes)	**Med**	**Med**	**Med**	**Med**
Millimeter Wave Radar	**High**	**High**	**High**	**High**
Global Positioning System	**Low**	**Low**	**Low**	**Low**
Onboard SVS Data Base	**Med**	**Med**	**Low**	**Med**
System Integrity Monitoring	**High**	**High**	**Med**	**Med**
Other Onboard Navigation Systems and Data Bases	**Low**	**Low**	**Low**	**Low**
Primary Flight Display, or imbedded display features	**Low**	**Low**	**Low**	**Med**
Navigation Display, or display features/pages	**Low**	**Low**	**Low**	**Med**
Head Up Display (option) with dedicated display features	**Med**	**Med**	**Med**	**Med**
Interface with Other Cockpit Displays, i.e., TAWS	**Low**	**Low**	**Low**	**Low**
Dedicated SVS Support Equipment and Crew Interface	**Low**	**Low**	**Low**	**Low**
Interface with Other Aircraft Systems	**Low**	**Low**	**Low**	**Low**

5.2 READINESS

Based on results to date, Table 5.2 indicates preliminary technology and implementation readiness levels assigned to each of the concept elements and assessment criteria listed in Section 1. Readiness levels were assigned by this document author, and do not yet represent a group consensus. Such a consensus will be obtained for future releases. A discussion follows in Section 6.

Table 5.2 Concept Readiness Assessment

Element	TRL	IRL
Forward Looking Infrared (FLIR)	6	4
Weather Radar (Potential SVS Modes)	2	2
Millimeter Wave Radar	3	2
Global Positioning System	9	9
Onboard SVS Data Base	5	3
System Integrity Monitoring	1	1
Other Onboard Navigation Systems and Data Bases	9	9
Primary Flight Display, or imbedded display features	5	3
Navigation Display, or display features/pages	5	3
Head Up Display (option) with dedicated display features	5	2
Interface with Other Cockpit Displays, i.e., TAWS	2	1
Dedicated SVS Support Equipment and Crew Interface	5	3
Interface with Other Aircraft Systems	5	3

6.0 CONCEPT ASSESSMENT DISCUSSION

The following are assessments of significance to each of the SVS Concept element areas, gleaned from results of experiments, and analytical studies to date.

6.1 GENERAL

The experiment and demonstration at Asheville near the beginning of the Fiscal Year afforded an excellent early look at the potential for SVS in augmenting path control and situation awareness in mountainous terrain. This experiment also provided significant material for the issues list in Section 7, as potential problem areas were identified in a real world operational environment and with relevant mission scenarios.

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 study conducted on specific tools for situation awareness in SVS experiments provided a catalog of measurement tools for use in subsequent experiments, and will serve the team well in the future.

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, much 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. Pilot control of the field of view on the PFD proved a useful tool in providing situation awareness during maneuvering or crosswind approaches. Larger display sizes were preferred, although each size was able, with appropriate fields of view, to perform the given tasks in the mission phases evaluated.

Future efforts will now be devoted to continued development of the SVS Concept, with an evaluation of the concept in a mountainous terrain environment at Eagle-Vail, several simulation experiments and studies, and a further refinement of operational issues and concepts.

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

6.2 FORWARD LOOKING INFRARED (FLIR)

Efforts this Fiscal Year have been devoted predominantly to design and installation issues associated with the planned installation of a FLIR sensor package in the NASA 757 test vehicle this Winter, to support Spring flight tests at Eagle/Vail.

The technical risk for FLIR is considered low – the technology is relatively mature. The methodology for operational employment of FLIR in a commercial and business aircraft environment is largely untried or unproven, however, and operational risk is therefore considered high. Assuming operational issues can be overcome, certification methodology will have to be developed, and operations benefits assessed to develop a marketing plan. These areas, then, are assigned medium risk.

Future plans include flight testing of a FLIR package in the NASA 757 test vehicle next Spring, and an investigation of a British Aerospace (BaE) concept involving fused FLIR and MMW images on a Head Up Display, for low visibility approach and landing path control.

6.3 WEATHER RADAR (POTENTIAL SVS MODES)

Efforts this Fiscal Year have been devoted predominantly to data collection and analysis. 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 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. Technical, operational, marketing, and certification risk of this component, therefore, is listed as medium.

6.4 MILLIMETER WAVE RADAR

No significant testing efforts involving Millimeter Wave (MMW) RADAR have occurred this Fiscal Year, other than limited discussions on potential future flight test opportunities. The technical risk for MMW is considered high – the technology has never, to the author's knowledge, demonstrated an operationally acceptable scheme for augmenting strategic path control in the commercial and business aircraft mission environment. The methodology for operational employment of MMW in a commercial and business aircraft environment is largely untried or unproven, as well, and operational risk is therefore considered high. Assuming operational issues can be overcome, certification methodology will have to be developed, and operations benefits assessed to develop a marketing plan. Given the likely high cost of manufacture, test, and certification of an operationally feasible MMW system, these areas are assigned high risk. Future plans include an investigation of a British Aerospace (BaE) concept involving fused FLIR and MMW images on a Head Up Display, for low visibility approach and landing path control.

6.5 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 mature enough that low risk categories have been assigned for technical, operational, marketing, and certification risk.

6.6 ONBOARD SVS DATA BASE

Significant efforts have occurred this Fiscal Year in learning how to obtain 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 are currently being addressed, and so technical, operational, and certification risks are considered medium. Assuming the resulting infrastructure requirements won't result in prohibitive product costs, and that world-wide terrain elevation data will become readily available, marketing risk for this component is considered low.

6.7 SYSTEM INTEGRITY MONITORING

Given that certain conceivable failures of the data base could cause loss of an aircraft, 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 an 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). Technical and operational risks, therefore, are considered high. Efforts this year have identified two sensor sources to support this function – Weather RADAR and RADAR or LASER altimeter. No significant testing, however, has been accomplished to date. Assuming costs for new required hardware and software to support implementation of the yet unidentified technology can be kept relatively low, marketing and certification risk for this area is considered medium.

6.8 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, and technical, operational, marketing, and certification risks are considered low in this area.

6.9 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, and so technical, marketing, and operational risks are considered low in this area. Certification efforts associated with major changes in a Primary Flight Display are traditionally extensive, however, such that certification risk is considered medium here.

6.10 NAVIGATION DISPLAY, OR DISPLAY FEATURES/PAGES

Flight and simulation testing this year have used a Navigation Display format which is 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. It is likely that SVS components can be implemented which will augment mission performance without adverse impact, both on new and retrofit installations, and so technical, marketing, and operational risks are considered low in this area. Certification efforts associated with major changes in this display are traditionally extensive, however, such that certification risk is considered medium here. Future efforts will investigate development and optimization of this component for SVS implementation.

6.11 HEAD UP DISPLAY (OPTION) WITH DEDICATED DISPLAY FEATURES

Flight and simulation testing this year have used a Head-Up Display tailored and configured for SVS testing, with both raster image and symbolic elements. HUD implementation is also a candidate for SVS implementation in analog based cockpits. 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. The use of an image on a HUD in this role, however, is largely untried previous to the present experiments (albeit well accepted by pilots to date). Therefore technical, marketing, operational, and certification risks are considered medium in this area.

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

Generally, efforts in this area have been limited to studies, or work that is in planning. No significant results exist to date, but are planned for early Fiscal Year 2001. Implementation details are envisioned to be workable for retrofit or new aircraft installations, and technical, operational, marketing, and certification risks are considered low in this area.

6.13 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. Implementation details for support equipment and crew interfaces are envisioned to be workable for retrofit or new aircraft installations, and technical, operational, marketing, and certification risks are considered low in this area.

6.14 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, and technical, operational, marketing, and certification risks are considered low in this area.

7.0 CRITICAL ISSUES

The following is a preliminary list of issues which have been identified as those which are appropriate to address in simulation, flight test, or laboratory studies in the SVS Project. These issues are prioritized as High (H) Medium (M) or Low (L) to indicate their relative criticality, assessed qualitatively, with respect to SVS goals and mission satisfaction. An initial priority has been assigned, to indicate the relative urgency of satisfying the issue, based on a balance of criticality and appropriate application of limited program resources. The list of issues, criticality, and priority should be reviewed by SVS Team members, and a consensus established as to the weighting assigned. This list will be updated at the end of the next Fiscal Year to reflect Project decisions.

Pri	Issue / Question Title	Status/Comments
	Display Issues, General	
H	Flight Symbology – color, scaling, guidance cues, monitoring vs. flying symbology optimization, situation awareness cues, rollout guidance	Efforts ongoing
M	Highway-in-the-sky optimization	Efforts ongoing
M	Latency	
M	Luminance	
M	Contrast	
H	Clutter	Efforts ongoing
H	Magnification	Efforts ongoing
H	Image Issues - brightness/contrast, clutter, color, registration, resolution, scaling/sensor/image FOV	Efforts ongoing
M	Low Cost HUD	
M	Prevention of spatial disorientation:	
M	Ambient displays: suitable for retrofit	
M	Unusual attitude displays	
	Tactical Displays - PFD	
H	Optimum field of view (FOV) for small displays, size A and D, in retrofit aircraft.	Efforts ongoing
H	Optimum FOV for larger formats in forward-fit aircraft.	Efforts ongoing
H	FOV/minification tradeoffs. Test desirable FOVs for converging approaches and parallel approaches/departures, circling approaches.	Efforts ongoing

Pri	Issue / Question Title	Status/Comments
H	Display size and pixel count (resolution) issues.	Efforts ongoing
H	Varying FOVs based on flight segment or pilot selectability	Efforts ongoing
H	Manual or automatic control of FOV selection	Efforts ongoing
H	Flight path vector - format and interaction with FOV	In Planning
H	Increases in SA – look at different facets of SA, including spatial, systems, etc;	Efforts ongoing
H	Effect on pilot workload as compared to conventional PFD	Efforts ongoing
H	Operational benefits of having elevation/obstacle database	Efforts ongoing
H	Safety benefits/limitations	Efforts ongoing
M	Integration with out-the-window scene – transition / training issues	In Planning
H	Clutter	Efforts ongoing
M	Unusual attitude recovery - due to turbulence, wake vortex encounter, hardware failure, asymmetries, icing; sloped skyline adopted as horizon? How is pitch and horizon (sky/ ground) information shown?	
M	Escape Guidance Techniques, Conventional vs. SVS Displays	
H	Curved Path Techniques, Conventional vs. SVS Displays	
H	Integration of Ground Ops Information (covered in separate research issue)	
	Tactical Displays – Head Up Displays	
H	How to display information – opaque SV scene/wireframe	Efforts ongoing
H	Investigate if Minification < 1 useable during some phase of flight	
H	Operational benefits of using HUD with database	
H	Safety benefits/limitation	Efforts ongoing
H	Declutter techniques – manual or automatic	
H	How to avoid clutter	
H	Increases in SA – look at different facets of SA, including spatial, systems, etc;	Efforts ongoing

Pri	Issue / Question Title	Status/Comments
H	Effect on pilot workload	Efforts ongoing
H	Integration of Ground Ops Information (covered in separate research issue)	Efforts ongoing
H	EVS vs. SVS HUD Safety and Operational Benefit Comparison	
M	Integration with out-the-window scene – transition / training issues	
	Strategic Displays (Navigation Display)	
H	Display control issues for PFD-SVS and/or ND	In Planning
H	location of controls for SVS / enhanced ND	In Planning
H	Integration with tactical displays (SV PFD and/or HUD)	In Planning
M	Integration with out-the-window scene – transition / training issues	
H	Increases in SA – look at different facets of SA, including spatial, systems, etc;	In Planning
M	Effect on pilot workload as compared to conventional ND	
H	Operational benefits	In Planning
H	Safety benefits/limitations	Efforts ongoing
H	Clutter	In Planning
M	Integration of ground operations information (covered in separate research issue)	Efforts ongoing
	Pictorial Scene Information	
H	Establish which scene cues are most important	
H	Generic terrain vs. generic with distance cue enhancements (e.g. "fishnet", known introduced scene features or elements)	Efforts ongoing
H	Photorealism – where needed, problems of misleading distance/depth cueing	Efforts ongoing
H	Establishing depth cues (distance and range)	
H	Terrain and object color, lighting, and shadow issues	
H	Obstacle depiction	Efforts ongoing
H	Issues of how to show enhanced sensor info and blending of database and sensor information	In Planning

Pri	Issue / Question Title	Status/Comments
H	Integration with Out-the-Window Scene - sun angle conflicts between real / synthetic scenes, sun angle for night flying (?)	
	Limited Visibility Operations	
H	Testing how SVS can support lowering minima	In Planning
H	Test how SVS can provide sufficient centerline guidance to takeoff in 300ft RVR or less (to improve upon HUD concepts that need guidance from a Type II/III localizer)	In Planning
H	Explore departure pathway guidance to a waypoint where you can enter a tunnel (also missed approach)	In Planning
H	Test how the database can substitute for visual acquisition of approach decision height criteria elements (approach light system, threshold, threshold markings, threshold lights, runway end identifier lights, VASI, touchdown zone or touchdown zone markings, runway or runway markings, runway lights)	In Planning
H	Test implications of how SVS is used to conduct non-ILS approaches.	In Planning
H	Precision navigation for departures and approaches (integrating guidance formats and the terrain and obstacle database). Incorporate RNP, VNAV, LNAV.	In Planning
	Airborne/Surface Display Concept Integration	
H	Integration will include both tactical (PFD/HUD) and strategic (ND) displays	Efforts ongoing
H	Build upon display work developed under AvSP's Runway Incursion Prevention Systems and TAP's LVLASO program	In Planning
H	Investigate industry surface operations display concepts and incorporate into ND/PFD/HUD where appropriate	Efforts ongoing
H	Investigate surface operations display concepts in FAA's SafeFlight 21 Program and FAA's Runway Safety Program	Efforts ongoing

Pri	Issue / Question Title	Status/Comments
H	Develop tactical and strategic display switching strategies (gradual, instantaneous, certain altitude) from surface to air (departure) and from air to surface (landing) display concepts	Efforts ongoing
	Situation Awareness	
H	Display compellingness issues when discrepant information is present	
H	Attention switching – major issue, just because much information is present, can pilot switch to needed information – (several simulator pilots have missed seeing decreasing airspeed with SVS-like displays) – what about when tunnels, scenes, and traffic are displayed	In Planning
H	Can a set of overall requirements be established for the display system that includes the minimum requirements needed for both enhanced SA and performance.	
	Integration of SVS with Terrain Awareness Systems (TAWS)	
H	Best use of low res TAWS, wx radar, and high res SVS	In Planning
H	Obstacle presentation in TAWS	In Planning
H	Terrain awareness comparisons between TAWS and SVS. Consider approach, takeoff, missed approach. Use a Cali-like CFIT accident (descent)	In Planning
H	Safety and operational benefit comparisons between TAWS and SVS.	In Planning
	SVS Integration with Enhanced Vision Sensors	
H	Sensor image vs. Symbolic representation of sensor (FLIR, Millimeter wave radar, etc.) detected objects (runway, traffic, etc.) within the database	In Planning
H	Use of HUD (if available)	In Planning
H	Safety and operational benefit comparison between EVS, SVS, and EVS/SVS concepts.	In Planning
H	Flight Symbology, Latency, Image Issues, Integration Issues, Operational Issues, Evaluation Issues	In Planning

Pri	Issue / Question Title	Status/Comments
H	Automatic Declutter	
H	Degraded Visual Environment	In Planning
H	Display Registration Requirements	In Planning
H	Head-Down Display Issues	In Planning
	Human factors Issues for Flight Data integration with SV scene	
H	How do operational requirements by procedure being flown (SID, missed approach, runway change, RNP, emergency), or flight phase (approach, departure, ground ops, enroute) dictate where information needs to be presented? Answering this question with quantitative data is needed for a good design of SVS NDs, PFDs, and HUDs.	Efforts ongoing
H	Placement and format of airspeed information - mins, max, flap range, accel, decel info, scaling	Efforts ongoing
H	Placement and format of altitude information – format, baro info, decision alt, transition alt, ground	Efforts ongoing
H	Vertical Rate info – format, placement	Efforts ongoing
H	Roll info – format, readability	Efforts ongoing
H	Pitch info – relevant scaling, readability	Efforts ongoing
H	Precision nav and landing guidance info (e.g. RNP)	Efforts ongoing
H	Flight path vector – format to minimize obscuring scene	Efforts ongoing
H	Pathway issues - (yes, no, selectable) – major format issues	Efforts ongoing
H	How represent path reacquisition	Efforts ongoing
H	Waypoints - other Nav Info?	Efforts ongoing
H	Traffic/weather - when to show? Format? (covered in separate research issue)	In Planning
H	Ground Ops information – what info to show, format to show (covered in separate research issue)	Efforts ongoing
H	Depicting clearance changes in SV displays (runway change accompanied by a datalink of the command that results in a symbology shift; tunnel changes)	Efforts ongoing

Pri	Issue / Question Title	Status/Comments
M	Unusual attitude recovery.	
M	Unusual attitudes due to: turbulence, wake vortex encounter, hardware failure, asymmetries, icing	
H	will sloped skyline (e.g. mountains) be adopted as horizon?	
M	Pitch ladder must handle – guidelines exist	
M	Scene features in attitude recovery ? Turn off?, provide terrain grid info?	
M	Guidance info?	
Failure of information; Backup instrumentation/Reversionary modes)		
M	failure flags / removal of info issues	
M	disagreement / erroneous information – is it misleading, is it detectable	
M	Failure of display - migration strategy	
M	When it fails, can I revert to something else?	
Utilization of Advanced Display Media		
H	Off-axis information presentation	
H	HUD (collimated/non-collimated, color, wide FOV, stereo)	
M	Head-mounted displays (glasses, mounted onto David-Clark headset, etc.)	
Format of Traffic and Weather on Tactical and Strategic Displays		
H	CDTI symbols on ND and possibly on PFD/HUD	In Planning
H	TCAS symbols on ND and possibly on PFD/HUD	In Planning
H	Icon vs. symbol portrayal of traffic on PFD/HUD. In other words, do you draw an icon of a plane or show CDTI symbol on PFD/HUD	In Planning
M	Investigate AWIN tactical and strategic display concepts for weather presentation	
M	Investigate how to present info on ND with weather radar mode and TAWS mode	
M	Investigate how to present weather info on PFD/HUD	
M	Investigate including information on runway conditions, wind shear, rime icing zones, hazards, etc.	

Pri	Issue / Question Title	Status/Comments
Other Issues		
M	Mixed Equipage problems - For an Airline; with ATC	
M	Maintenance / updates to database - obstruction updating; updating a/c system database, database integrity	
H	Runway Incursion Prevention, Conventional vs. SVS Displays	In Planning
H	EVS vs. SVS Head-down Safety and Operational Benefit Comparison	Efforts ongoing
H	SVS HUD vs. SVS Head-down	Efforts ongoing
H	DEM Density Requirements - What's Required Where ? Transitions between DEM Levels	Efforts ongoing
H	Range/Altitude Judgement Techniques (Landolt C Wireframe Overlays, etc.)	Efforts ongoing
H	Airborne Traffic Symbology - TCAS vs. CDTI; Icon vs. Symbol vs. Both	In Planning
H	Ground Traffic Symbology (Icon vs. Symbol vs. LVLASO Tag)	Efforts ongoing
H	Sensor Image vs. Icon - Runway (Image vs. Wireframe); Detected Object (Image vs. Icon vs. Symbol)	In Planning
M	Pathway (yes, no, selectable) - format issues	Efforts ongoing
M	How represent path reacquisition when cannot see path / re-routing issues	Efforts ongoing
M	Maintenance of enhanced sensors - Cleaning, alignment, deicing, etc.	
M	Integration Issues - cockpit integration, display integration, image/symbology integration	
M	Operational Issues - two pilot operations	
H	Evaluation Issues - test techniques, test scenarios, simulation of degraded visual conditions, simulator considerations, flight simulating instrument conditions, flight simulating degraded visual environments, flight in actual conditions	Efforts ongoing

8.0 SUMMARY

This Fiscal Year has 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.

A substantial number of studies and experiments have been conducted this year, which have provided a significant quantity of data addressing existing SVS issues, and generating many new ones. Much follow-on effort is scheduled for Fiscal Year 2001. A catalog of these studies and their significance has been presented in this document.

A list of prioritized issues has been presented in this document, to help guide future studies and experiments. This list is expected to be modified and expanded by the Project team, as results from experiments, studies, and discussions become available.

A list of SVS component risk and readiness has been presented here, to help guide the focus of future efforts. Results indicate that FLIR, Millimeter RADAR, and System Integrity Monitoring are high risk areas, given the presented metrics. Technical and Implementation Readiness Levels of SVS components indicate a wide range of readiness, with Weather RADAR modes, System Integrity Monitoring, and TAWS Interface listed as particularly low in both.

An update to this document will be prepared at the end of Fiscal Year 2001, which will present updates to experiments and studies, issues, and metrics.

9.0 ACRONYMS

ASIST	Aviation Safety Investment Strategy Team
ATC	Air Traffic Control
AvSP	Aviation Safety Program
AWIN	Aviation Weather Information
CAB	Commercial and Business
CCD	Charge Coupled Device
CDTI	Cockpit Display of Traffic Information
CFIT	Controlled Flight Into Terrain
CHR	Cooper Harper Rating
CIRT	Certification Issues Resolution Team
CONOPS	Concept of Operations
DFW	Dallas/Fort Worth Airport
DGPS	Differential Global Positioning System
DoD	Department of Defense
EGE	Eagle/Vail Airport
EFIS	Electronic Flight Information System
EVS	Enhanced Vision Systems
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FBO	Fixed Base Operator
FLIR	Forward Looking Infrared
FOV	Field of View
FY	Fiscal Year
GB	Gigabytes
GBS	Ground Based System
GPS	Global Positioning System
HDD	Head Down Display
HDTV	High Definition Television
HFOV	Horizontal Field of View
HSALT	Hold Short and Landing Technology
HUD	Head Up Display
IDS	Integrated Display System
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IRL	Implementation Readiness Level
LAAS	Local Area Augmentation System
LAHSO	Land and Hold Short Operations
LaRC	Langley Research Center
LCD	Liquid Crystal Display
LMI	Logistics Management Institute
LVLASO	Low Visibility Landing and Surface Operations

MB	Megabytes
MCHR	Modified Cooper Harper Rating
MHZ	Megahertz
MMW	Millimeter Wave RADAR
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NIMA	National Imagery and Mapping Agency
PFD	Primary Flight Display
R&D	Research and Development
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
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
TRL	Technology Readiness Level
VMC	Visual Meteorological Conditions
WAAS	Wide Area Augmentation System

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