NASA/GAMA/FAA Synthetic Vision Workshop
March 16 – 18, 2004
Feedback Form

All questions are specific to SVS research for GA applications, and can be in terms of general research, implementation, certification issues, operational benefits, etc.:

1. In your opinion, what are the current synthetic vision research areas that are already strong (i.e., enough research has been completed)?

   Summary of response 1: *The research on SVS terrain depiction is mature with the relative benefits of various forms of terrain portrayal established. Some comments regarding guidance symbology concepts were also well defined for applications with SVS.*

   Response 1: The research on which type of SVS terrain depiction is mature enough that NASA no longer needs to spend government money. Also, what type of tunnel symbology is best is now defined well enough that the government no longer needs to spend money here.

   Response 2: We know that terrain portrayal techniques beyond the constant-color fishnet are acceptable and do not contribute to pilot disorientation due to lack of a blue-over-brown attitude indicator.

   Response 3:
   a. HITS
   b. Database development/optimization (need to focus on processing requirements)
   c. Situation Awareness as a research rationale (need to focus on measurable benefits, such as risk mitigation, pathway definition (lateral and vertical limits))

   Response 4: Terrain rendering, guidance symbology.

   Response 5: Displays, Field of View, Images; Integrity of SVS displayed image and method to ensure SVS provides up-to-date information to the pilot.

   Response 6: Use of photo-realistic terrain. There are too many holes in the database, the rendering and storage is a problem, and there are not many clear operational human performance benefits to rendering the terrain in that manner.

   Response 7:
   a. Resolution and update rate.
   b. PR versus synthetic.

Response 8: Terrain depiction (texture, color, photo realism) (NASA has done a thorough job in this area)

Response 9: Terrain depiction

Response 10: Terrain depiction comparisons

Response 11: Synthetic vision texturing/coloring – some feel that photo-realistic rendering may actually be counter productive

2. In your opinion, what are the current synthetic vision research areas that are weak (i.e., need more research)?

Summary of response 2: *Input in this area was wide-ranging and sometimes contradictory. However, addressing potential users' needs was indicated in several responses. Users needs include a further definition of operational use and benefits of SVS as well as training needs. Developing database integrity, closely related to resulting operational capabilities, was also stressed as an important area for future research activity.*

Response 1: The types of flight guidance evaluated were good. But there was a major omission in the research. That is how do any of the new guidance symbologies (ghost airplane, tunnels, etc.) compare in flight technical error and workload to the standard state of the art that you automatically get in any GA airplane with a flight director? That is, how does the new symbology compare to a single cue (not pitch/roll) flight director? For reference, your C206, SR20 and Columbia should all have this type of flight director if they have any at all.

Response 2: I would like to see additional research on egocentric vs. exocentric attitude display.

Response 3:
a. Tools and methods for validating software meets minimum requirements
b. Training requirements to meet performance metrics with SVS, HITS, TPC displays.
c. Database integrity monitoring in real time (i.e., smart automation in cockpit associate sense)
d. Operational use, too much basic research without considering the end user needs

Response 4: Inherent errors in the SVS as a primary flight system or display. Currently SVS buys no credit from FAA and lower landing minimums at SATS-type airports because of built in error bounds in current IFR system. Therefore, SVS research should address existing error bounds and ways to eliminate SVS error sources with the goal of finding ways to lead the FAA to the conclusion that

SVS can buy something lower than current IFR, especially at non-precision airports.

Response 5: Data base integrity and validation; Data that supports operational approval for use of SVS for following intended functions: 1) terrain avoidance, 2) Pilotage over air traffic service roles and approaches and departures to airports using SVS as only means of navigation.

Response 6:

a. There are several documented human factors issues that are still unresolved with HITS: storing 3-D flightplan, poor off-path guidance, cognitive tunneling, clutter, complacency. (e.g., See van Houten, 1999; Ververs & Wickens, 2000; Williams, 2001). The current NASA research is not addressing, identifying, or working to mitigate these documented issues. Additional issues of best tunnel size, appropriate tunnel spacing, tunnel look-ahead distance, and visualization applicable for RVSM or RNP would all be appropriate.
b. Field of view still requires additional investigation. There are certification issues with pilot selectable field of view. Why not 45 degree field-of-view? Investigation of the minification of conformal terrain and symbology and pilot propensity to fly too low needs to be addressed.
c. Integration of EGPWS caution and warning colorings on terrain. Integration of TCAS targets. Integration of weather and terrain on lateral and vertical maps. What are the benefits?
d. Research issues of automation complexity of autopilots in GA in SVS cockpit. How does one best input a 3D or 4D flightplan? How do we make the display compelling if planned path intercepts terrain.
e. How do we get a better sense of range and distance of perspective terrain rendering? How do we improve ground rush cues that are available in VMC but not compelling with current SVS implementations?
f. What terrain database decimation or other techniques for rendering terrain graphically are acceptable for certification?
g. I have additional concerns on the methods that are being used in experimental design by NASA. Variables are not being controlled (e.g., tunnel size) and conclusions are being drawn (crows' feet tunnel outperform other concepts) with out enough description, lessons learned, or caveats to make the results useful with conviction from a development point of view.
h. Will AVS reduce CFIT in EGPWS-equipped aircraft? Because of experiment design of most recent NASA study, this not only reinforced poor behavior in pilots (desensitization to red and yellow alerts), it was an unrealistic scenario. Designing scenarios based upon real accidents or incidents or "real" potential pitfalls of current operations would be useful and meaningful to make a business case for SVS. How/why is perspective ego-centric terrain superior to top-down with vertical terrain profile display is another research question worthy of further investigation.

i. Some of the scenarios for testing should be part of an integrated cockpit glass solution (and more represented of full-envelope of flight) – should include moving map and representative tasks where a pilot is interacting with other non-SVS displays.
j. Design guidelines from FAA on color usage are being violated in taxi display design work that would adversely affect certification if someone attempted to duplicate concept displays. Research into when top down, north up, exocentric, etc frame of reference is most useful for ground operations would be helpful.
k. Continued work on data integrity issues is critical for Part 25 certification issues.
l. Continued investigation in SVS-EVS image fusion/collaboration/merging concepts.

Response 7:
a. Terrain database certification.
b. Low cost airborne integrity monitoring of terrain database.
c. Solving the chicken and egg: Development of techniques and tools for reducing the cost of digital terrain databases in order to bring the user product cost down, to expand the set of databases for CONUS GA airports, and to proliferate the use of SVS among GA operators.

Response 8:
a. Establishing credit for lower landing minimums
b. Use of exocentric view on MFD to complement PFD.

Response 9: Need more work on optimal pathway depiction and dimensions. Also should perform human factors studies on best method of inputting HITS parameters (waypoints, altitude constraints, etc.)

Response 10: Methods for database integrity validation that can be combined with SVS and lead to lower landing minimums at minimally equipped airports (i.e., SVS fused data with EVS systems (low-cost FLIR) or radar altimeter).

Response 11: External sensing, ground-based signals, etc., that can be used to verify the SV imagery (overcome database integrity issues)

3. If you could prioritize, what do you feel are the top three issues that need to be explored when it comes to synthetic vision research?

Summary of response 3: *Input in this area was also wide-ranging and sometimes contradictory. Database integrity research was again listed in several responses. In addition, operational approval for use of SVS, and minimum performance requirements for certification (certification should be performance based) was also emphasized.*

Response 1: Work with the FAA to develop rules (FARS 23, 61, 91 and 135) that encourage manufacturers to incorporate these new technologies (or at least eliminate the barriers). The technologies are understood well enough that NASA does not need to do much more research on the technologies (with the exception of comparing a standard single queue GA flight director to the new guidance systems). However, this research does absolutely no good if there are government imposed barriers to getting it to the market. NASA can help eliminate these barriers.

Response 2:
1. Application of color on an elevation-based generic terrain portrayal
2. Attitude depiction techniques (exocentric vs. egocentric)
3. "Follow-me" symbol vs. HITS for guidance

Response 3:
a. Evaluate and define reasonable SVS ConOps somewhere in between VFR in IMC and 1000'/3nm.
b. Begin to develop minimum SVS TPC and GSC requirements to achieve lateral and vertical performance goals.
c. Work with FAA on certification issues (operational and approved)

Response 4: Indirectly – fly-by-wire for small GA aircraft will face a very tough sell to the buying public, therefore some end user surveys should be done to see how strong the resistance is before more research funds are diverted from other ore meaningful research (i.e., SVS).

Response 5:
1. Terrain database integrity and validation
2. Data that supports operational approval to conduct flight and ground operations using SVS in lieu of visual outside the window cues as only means
3. Human factors, training issues

Response 6:
a. Database integrity.
b. Taxi charts.
c. Minification of conformal terrain and symbology and pilot propensity to fly too low.

Response 7:
1. Low cost airborne integrity monitoring of terrain database.
2. Use of SVS as PFD for IFR approaches (how low can you go? VFR-like operation in IMC?)

Response 8:
a. Independent validation of terrain database (e.g., blending external sensor data)

b. Provision/depiction of weather and traffic on SV PFD
c. GA unique runway incursion issues
d. HITS issues (optimization, certification with and without SV)

Response 9:
1. HITS optimization (see Response 9 comment for number 2)
2. Special Use Airspace depiction
3. Addressing major certification issues (database integrity monitoring, for example)
4. Comparison of HITS approaches to traditional approaches (ILS, GPS, etc.)

Response 10:
1. Size requirements for PFD's with SVS and HITS (must be careful with display quality, i.e., size of numbers, HITS portrayal, etc.)
2. SVS database integrity validation methods for use on approaches to lower landing minimums.
3. Integrating PFD and MFD with SVS and HITS displays.

Response 11:
1. Blending sensor data (viz, FLIR) with SV
2. Database integrity
3. Establishing end user preference for SV displays.

4. General comments:

Response 1: I really wish we could have given demo flights in the SVS equipped Bonanza. I hope we can get the system working soon.

Response 2: Great workshop. I think it came at a perfect time considering the current development of a synthetic vision advisory circular. I look forward to the next one.

Response 3:
a. Good, intense content and format
b. Schedule not well controlled. Fewer presentations with prompt start, stop, lunch, and break times.
c. A lot of work was evident, and experimental results very informative.

Response 4: To be sure that Ron Swanda's point is heard, I too feel that research funds from NASA should not go to support any one company or to promote any one product, but should be spent to address issues or technology that the general commercial community can not address on their own nickel.

Response 5: In addition to the excellent presentations presented at this workshop, suggest: presentation by FAA regulation and certification folks (AIR/AFS) that

provides specific regulatory requirements/process for certification of equipment and regulation requirements for operational approval of the installed SVS.

Response 6: Thank you for the opportunity to attend your workshop. SVS is a very exciting field and you are doing some interesting research. I'm the PM/PI for an internally funded program called at my company involving advanced displays. We have conducted several studies in the simulator and completed 2 series of flight testing in our Citation V test aircraft last year. We would be interested in an opportunity to work together on some of the areas noted in #2 above.

Response 7:
a. Excellent workshop. Good choice of presenters and topics.
b. FAA participation was very positive and instructive; should be encouraged to continue.
c. New research should focus on technology concepts that is too costly or risky for industry to pursue alone.

Response 8:
a. FAA participation was very useful.
b. Good conference – excellent exchange of information.

Response 9: No written comments.

Response 10: This workshop was very well done!

Response 11: No written comments.

Response 12:
Near-term -
1. Develop pathway scheme that intuitive by display's lateral and vertical limits
- En route and initial approach are very wide.
- May use secondary (pop-up?) symbology and/or shading for limits.

Longer-term -
2. Develop and/or prove technology that can provide real-time terrain database integrity for use in lowering minimums.
3. Evaluate the errors possible with all technology schemes that provide real-time integrity and define in terms of feet. This error budget can be used to apply towards lower minimums determination.