Synthetic Vision Systems CONOPS Workshop

Dialog Transcriptions

Disclaimer

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SVS CONOPS Workshop

Breakout Team Summary Reports on

Arrival and **Ground Operations** Flight Phases

Thursday Morning, February 24, 2000

Orange Team (Red and Yellow combined)

Ray Comstock, NASA LaRC - One of the statements that came out early by our group leader was sort of a philosophy for the group. One of the things that we were talking about is through the separation of what you would like or prefer to have in an SVS display versus what kind of information cannot be obtained in any other way. That was one of the ways we were thinking about this because we early on got into the discussion of a lot of information that is available today on some of the displays that you already have. But, it would be easier or perhaps the format would be better and more situation awareness could be derived if it was in a more integrated format. Therefore, we started thinking about what you could not obtain in any other way. We were all talking about the **Approach** phase and, just as a guess about what that included, we settled on 30 miles from the airport or 10,000 feet and below. Under the example applications for considerations we ranked the following high: self-separation, hazardous weather avoidance, terrain avoidance, parallel approaches, IMC wake avoidance (as in visual approaches), and runway incursions while on approach. The self-separation issue … it was pointed out that the forward view is a really small part of the issue. You need to know something about where the other traffic is and some of that can be accomplished today with TCAS-2 as pointed out. However, the accuracy is probably a lot better if you have ADS-B to determine what kind of in-trail distances you are when you are trying to separate yourself from other traffic. One of the important things was also the map display in trying to separate yourself from other traffic. It is important to be able to see the other traffic, especially if you are on final and trying to maintain in-trail position … the ranging information. It is also important for parallel approaches to see where the traffic is relative to yourself, that is, traffic beside you.

Another issue raised was that it would be nice to be able to identify what runway you are heading to. You have that now on the map display, but it would be nice also to have that shown in another way. Self-separation and terrain avoidance are high importance. One of the questions of course is navigation accuracy and checking of data base. It's probably pretty constant as far as terrain itself but when you add obstacles to that, that is going to require an updating cycle beyond the basic terrain kind of information. Wake avoidance in IMC -- If you have the potential to calculate wake locations aside from the SVS display but there perhaps you could put in some information of where you expect the wake to be based on ground sensors or aircraft based sensors. And there is a little bit of debate over that where you derive the information from. For example, like the

AVOSS Program uses predictions based on ground information but there is also capability that the Langley Research Center is working on in airborne detection of wake information as well. Another issue raised was the possibility of noise abatement procedures being shown on the display in some way so that you could follow a particular profile or something like that. Although it was pointed out that suppose you have this nice little path to follow for noise abatement and then you had an engine out, you might have a problem with the pilot trying to follow the nice path and inappropriately. Another comment was maybe take that away in a case like that. Additional SVS advantages during approach were mentioned. We will get to more on runway incursions later. Station keeping which is maintaining your position relative to parallel traffic - not gaining on them. Altitude deviation was another area. One question was might it help if you have an input error of some sort. You would get this nice little path showing you where to level out. If the data entry was wrong, it might be even more compelling to go to the wrong altitude so that would have to be handled as well. Another question that we are not sure about is if you were basing your synthetic vision picture on the altitude and you had an altitude setting error. For example, if you were an inch off on your barometric setting, would that change the picture that you are seeing on the SVS display? We really did not have an answer to that one. It is something to think about. Another issue was visualizing where the weather is, especially for terrain problem areas. If you have got a combination of places that you do not want to fly because of terrain and weather as well, it might be nice to see where the two of those are.

Dan Baize, NASA LaRC - Ray, I guess I don't understand the comment about inserting your position because GPS position is 3-dimensional.

Comstock - The question was -- Is that a GPS altitude or a barometric-based altitude? If it were a GPS-based altitude, then that would always remain the same.

Another issue we decided to approach later in the enroute session was with regard to preplanning. If you wanted to visualize another airport that you were going to, would that happen on the primary flight display or happen on some other display so as not to take away the active information.

Surface Ops -- Does ADS-B need to include the aircraft type? Especially considering wing-tip to wing-tip spacing to provide alignment so that aircraft do not clip each other in the airport movement area. Also taxiway guidance in low visibility situations, especially with regard to reducing getting lost and blunders being made by not knowing where you are on the taxiway surface. Taxiway excursions or getting the wheels off the hard surface basically could be helped in this way. An ideal system or refined SVS system would have ground path shown and have real-time airport changes, like closed taxiways, so if a particular taxiway was not useable, that would be relayed to the system and shown by the display. Hold short points, things like that, would also be included.

Another issue raised, was would ADS-B have throttle percent power sent? This would help with runway incursion predictors. You would start to see when the aircraft was getting ready to move. Another thought with regard to that is that it could help smaller aircraft tell when a large aircraft ahead of them was going to throttle up. There have been cases where a smaller aircraft has been turned over as a result of that.

Blue Team

Greg Saylor, Delta Airlines - We spent a lot of time talking about questions and issues with synthetic vision rather than applications. We had to rush at the end to come up with some way to use it. Given that we had a lot more of limitations, questions, and things that we did not understand that we discussed. Some of the things that we did talk about that might have some applications are some aids to the specific issue of transition from instrument flight to visual flight. Specifically, in the **Approach** phase, that synthetic vision might facilitate the transition by supplying an artificial world that there is no transition or some other form of aid to smooth that transition. We also talked about the generic potential that with a synthetically- or artificially-derived representation of the world that you could ... We starting talking about the River visual to DC if we could draw a river for a pilot to see to fly over to any airport, that certainly is one application for synthetic vision. But on the other hand, we do not necessarily need a river or a path on the ground to fly over. We really can do the same thing with passed points in space and have most of those capabilities in the more advanced airplanes already. It is just a bit of integration and synthesis work to be done to enable these things. Synthetic vision is one way to crack that; it is not necessarily the only way to do it. And perhaps it is not the least expensive way either. We talked about it also as an overall situational awareness aid in difficult, challenging terrain. Especially in envisioning approaches to mountainous airports, and so on. It can add to the pilot's awareness of the fact that perhaps to my right is high terrain. I cannot go that way in an emergency or if something happens, but to my left is not so high and that is my way out of here. That kind of SA enhancement could be a potential use of synthetic vision.

It is also a separate one, but they are very related that … that really becomes most powerful probably in an emergency situation, where the pilot has an engine out and he is trying to do an engine out go around or he has some other flight control problem where he is perhaps not able to execute any of the published approach or extractions. He has to just work it out. The synthetic vision might build for you to avoid in that case. We also talked about noise abatement procedures. We covered some of the same ground that the Orange Team did. One guy called noise sensitive areas like political terrain area, not to fly over. It certainly could be used to point that out to the pilot. It is not the only way to point out to the pilot the correct path that he is expected to fly. It is just one way to do it. Then the issue is: is political terrain as compelling as actual terrain? It certainly probably should not be. You would have to have a way to distinguish what is really there and what is just a political issue. Those are possible applications.

The last one we had for the approach phase was using it to identify traffic. We started talking about the issues of visual approaches and self-separation and spacing. It got diverted into "Do we want to do this in the first place?" We probably did not dwell long on the specific SVS issues of it. We did discuss that the egocentric point of view, or the pilot looking out seeing the traffic in front of him is probably less useful than just a conventional God's-eye view or TCAS-type view of traffic. It is much easier to determine spacing information and trends and so on than the replication of the visual world. The visual scene is difficult to use to determine spacing, closure and so forth. We felt like there might be tools to do it, but it might not be in an egocentric viewpoint.

In terms of **Ground Ops**, we have a little more enthusiasm about the potential use. I think that is because the NASA team has shown us some very mature applications of that. That allowed us to build our confidence in what might be done. The first we listed was taxi guidance in low-visibility conditions, pointing out when we got done to what should be the priority for its development, and so on, it is not low-visibility very often in most of the world. It depends on where you fly and how often you have that low of a visibility, for instance somewhere between 500 or 600 RVR, that you need taxi guidance. You can go quickly from that into runway incursion prevention. We talked about preventing runway incursions versus runway incursion accidents and preventing accidents. A little bit of a different thing, but certainly synthetic vision applications and preventing runway incursions, especially when you stretch them and include data link communications to the pilot and so on. Then it seems to be some real potential there. By the same token prevention of runway incursion accidents which rather than preventing the incursion, the incursion has happened preventing the airplanes or trucks or whatever to run into each other. We think there are also some very valid application there. We talked about high visibility taxi guidance. This is the electronic replacement for progressive taxi instructions**.** The first time a guy lands at O'Hare, he is probably not going to know what to do. He is going to need some help driving around the airport. The system could also come in to play there. If you have done the low-visibility case, the high-visibility case is in hand and can probably be done with only a subset of the low-visibility symbology and icons. We also talked about what we call speed and/or braking awareness which we felt could be an aid in reducing runway occupancy time. If you gave the pilot some indication of where he will stop and/or reach a safe taxi speed, he could use that as he braked on the runway to bring the plane under control by the next taxiway or next exit. Instead of over-shooting and then taxiing down very slowly to the next exit, in which he has increased his runway occupancy by 20 seconds as he just misses the first one and has to take the second exit. So we thought there could be some applications in those areas.

Green Team

Ken Williams, Alaska Airlines - We got bogged down with general aviation issues a little bit. Then Lynda Kramer kept us on course and we got back onto the direction we needed to head. Archie Dillard made a real important point to the group. He asked, "What is SVS going to do for us in terms of the bean counters at the airline, the FAA, and controllers?" It has to provide us something that we do not already have aboard, either on the aircraft, on the ground, or being developed now. So with that theme in mind and realizing that SVS is to provide situational safety awareness we came up with some priorities. The first one was for added capacity at airports, allowing the airline to benefit from more slots and the controller to benefit with having more traffic per-hour flow rate. So one was curved approaches which is a high priority. I know this theme is in line with the last two groups. Self-contained air-to-air separation was another thing that we put a high priority to in terms of staggered approaches or curved approaches that we would like to have an idea as pilots what kind a separation we also have for confidence. Self-contained parallel approaches. That could be a staggered approach with one runway having a glide path of 3 point whatever degrees and another one a little higher glide path, for instance maybe a 757 on one runway and smaller planes on the higher glide path. Wake vortex awareness was rated as medium.

Required time arrival (RTA) -- We looked at two RTA's. One we discussed was not as important to SVS and that was the enroute RTA to within 100 miles of the airport. The other one that was more important to the controller in terms of getting aircraft into the airport was flying through fixes at prescribed times. That was given a high.

Terrain info to controllers -- They said they would like to have that. Lowering minimums -- This was more of my suggestion where we could use synthetic vision to lower minimums in airports that do not have CAT 1 capability right now because they do not have an ILS, only non-precision approaches. Can we make them CAT 1 without changing existing navigation aids on the surface? Mike Norman came up with VASI self-contained onboard which we could use to provide the flight crews with information that they would not have on the ground. Maybe the airport does not have a VASI**.** I want to make clear, too, that we looked at the integration of both the NAV display as a map for the pilot not flying as the master role monitor and the pilot executing the landing would have this information up in the HUD to a lesser degree.

Flare guidance -- variable glide slope was given a medium. Runway remaining was a high. Simulation training fidelity was given a high. We had to prove the concepts as Archie said were really important to start off in simulation before we put it to real world application. CRM heads-up, heads-down as for as looking at quantity of information was given a high priority.

Expedite -- this is **Ground Ops** now. Expediting taxi in low-visibility. At some airports this would be very important and others do not have this occur hardly at all.

Turn off and hold short was given a high priority. Clearance awareness. My thought on this was after operating at Anchorage Airport we have quite a bit of crews coming to work from the Orient and also Russia. For them to understand a large set of clearances might be difficult. Where if they had that information on a NAV display, this might cut down on the confusion.

Ground vehicle avoidance -- Skeet came up with this, which is important -- SVS on emergency vehicles. So if you are operating at an airport that is down to zero, zero, 300 RVR, and a situation occurs where you need emergency vehicles on site, they might not know where to go, as in the case at Little Rock. Therefore, that was given a high priority. Then the ground equippage for CAT 3C. Deicing was a concern. As a pilot, I am looking at holdover times. If only one runway is cleared at an airport that has multiple runways that have a long route to get there, I would like to have the quickest route to that point and not be pushing the holdover limits on the aircraft deicing. So we decided that would be a priority.

Precision control ground ops was given a medium. Obstacle avoidance was given a high in terms of construction. Larry pointed this out. Currently going on at some of the airports is construction right in the middle of the taxiways. Well, what happens when you go to low visibility? Can you identify that soon enough? And gates was given a low. That was the theme of our meeting.

Purple Team

George Boucek, Boeing - Being the last one in line, I get to say what they said. They pretty well covered most of the things that we talked about. We also had a little bit of difficulty getting started. I guess Marv was taking lessons from Lynda because he cracked the whip on us and got us going. Basically, we looked at the list that was provided and identified those things that were for the **Approach** phase and we added a few. Upset recovery was one that we thought could be a handled by the SVS. And it would cover things like wake vortex upset or other kinds of upsets that might happen on the approach. Bird strike was one that was mentioned. We separated terrain reference navigation from terrain avoidance because there are many cases like Eagle, Colorado, or some of the Alaska routes, especially, into Juneau and others where you would like a system that had accuracy high enough with the terrain to be able to navigate rather than just separate from the terrain. Another one that we also echoed the last group was the reduced minima. I think that, and the group felt that, this was one of the carrots that could get it on the airplane. There is enough operational benefit to be able to allow the aircraft to operate with less dependency on the airport facilities. And if you can provide the visual cues, as well as the approach guidance or approach cues for the airport, you may be able to get into a CAT 1 facility in CAT 3 conditions. And this is a big carrot for the airlines because it opens up runways, especially in places like O'Hare or Denver that have runways that are CAT 1 that go down in IMC and you might be able to get more traffic into them as the weather deteriorates. We also felt that wake avoidance would allow you to … if you had cues for wake avoidance it would allow you to close up the spacing which also facilitate and enhance operations. Not only from an operational benefit point of view, but also from a safety point of view. We talked about the runway incursions. We talked about the curved approaches. And we talked quite a bit about parallel approaches and how the system would try to enhance the operations along with things like CDTI for IMC parallel approach operations.

We then got into the **Ground Operations**. Here we looked at taxi guidance as one of the high operational benefit areas. If we can avoid lengthy taxi mistakes, if you will … if we can speed up the taxi operation by providing information that allows the crews to anticipate the route and to do it more quickly, you will save money for the operator. And it also will enhance the operation of the facility too. Runway incursions were included, both on the ground and in the approach. And like the previous group, on the approach it is more avoidance of runway incursions as far as an accident goes and then on the ground it is more an avoidance of doing the runway incursion. We also had rejected takeoff and the information about rejected takeoff. This also goes along with the runway rollout cues and the braking cues. If you provide a runway or the daylight vision of a runway on SVS, you can get the same kind of benefits that Alaska realized with the takeoff guidance on the HUD and get takeoff at lower minima. And then, also with the braking you get the operational benefits of earlier time off the runway and less time spent on the runway. Plus, I would imagine that you would also get less wear and tear on the equipment because you could plan that in your process. And then we also had separation from obstacles, both fixed and moving obstacles on the ground.

[END OF TEAM SUMMARIES]

D. Williams - Okay, at this point we can do some general comments. We need to use the microphone. Is there anyone from the floor who would like to add anything?

Jeff Cooper, APA, American Airlines - I just wanted to comment that the egocentric/exocentric terms were brought up. From a pilot's standpoint there are times when egocentric is better and there are times when exocentric is better. I want to give you an example, but I could not think of one. For instance, if you are taxiing zero, zero, it is good to see an exocentric, large view of your surroundings. But, if you are in flight and there is an aircraft that you want to avoid and you're IMC, you cannot avoid it unless you see it. And if you see a depiction on a screen, perhaps on a HUD … I know they don't have color HUD'S, not production color HUD's now, … but if you could see on a screen in front of you, even if was heads down, you could still fly heads down. We are not trained that way, but I am sure that we could do it. If you could see that aircraft in its dimension as it approached you, it would be must better than an exocentric view. An egocentric view is what you would want if you were in a micro circumstance. If you are in a much broader circumstance, and you want an exocentric view, that's great. It gives you a planning tool. But if you have to be in the now, sometimes egocentric is the way you want to be. I just wanted to point that out, having participated in those types of tests.

D. Williams - Any other comments? Any more from the panel?

Gary Livack, FAA - One thing we talked about yesterday was the issue of LAHSO, Land and Hold Short Operations on intersecting runways, as opposed to crossing operations or holding of a point. And NASA Ames is working on CD&R, as well as Mark Ballin here at NASA Langley, CD&R being Conflict Detection and Resolution using ADS-B technology. Is there some possibility of combining an airport map and aircraft performance and LAHSO and ADS-B enabled CD&R, you could use it in the tactical sense and therefore address that concern articulated yesterday about the risk of an accident at an intersection. I would raise that as an issue that may tie-in the airport map and some of the things we talked about in the immediate terminal area. But it would be an integrated display with multiple software algorithms doing different stuff. -- Just for your thinking.

D. Williams - Anything more from the floor?

G. Saylor - On the subject of LAHSO and the application you brought up. I think it is important for everyone to understand before we go out and spend research money on LAHSO that the issues that are addressed in the things that were just discussed, they are only a small piece of the problem of LAHSO, and not the critical piece. From my extremely pilot centered point of view the problem with LAHSO is all wrapped up in the problem that at some point before I make my landing, I make a binding commitment to make that landing. And one of the most fundamental parts of accumulated aviation wisdom is a pilot's option to go around. And it is sacred beyond sacred. It is the 'holiest of holies' that you abandon and do not attempt to save a bad landing. But if the pilot has committed and contracted to make this landing and make this landing and stop short of some particular critical point it becomes the most critical of all landings and he is contracted to do it and safety is specifically dependant on his accomplishing that task. We now eliminate the pilot's reasonable and safe option not to carry on with a bad landing. And that is a problem. Often the pilot does not know it is a bad landing until he is well into it. In fact, it may be when he is on the ground before he knows "I can't stop". And that's the problem with LAHSO. We are removing very important options for the pilot. And if the pilot has to go around, he is potentially in conflict with whatever he was given that 'hold-short' for. If that is a 747 taxiing across the runway with a high tail and I am making a go-around from inches off the runway, I might fly through that tail. If the airplane is taking off on a crossing runway, we might meet at 300 feet above the runways where they cross. That's the problem with LAHSO. It is not particularly technology-rich ground to mine. It is really a fundamental philosophy question. Are we going to ask pilots when they pick up the ATIS at 125 miles from the field and they say "land and hold short operations in progress". Currently, we are required to make a judgment right there, whether they are going to do it or not. And tell them we contact the approach control whether we are going to agree to contract to do a LAHSO or not. And that is the problem with it. The pilot always has to have the option not to land. The conflicts that are created with a 'land and hold-short' operation … Is that ground that can be mined with technology? Well maybe, but there is a lot more to it than just being able to visualize the point I was supposed to stop by. --Just some background information there**.**

G. Livack - By the way, I agree with you, but on the other hand, I was looking at the notion of "ghosting" which is the ? textural projectings and performance and the valid concerns that were raised yesterday and I was again thinking that given this technology and the fact that NASA does the lead thinking …maybe there may be some risk-mitigation strategies using ghosting CD&R and the airport map. Therefore, could create/mitigate some of the issues that you are raising.

G. Saylor - Yeah, I agree and this was one of the most fundamental things put forth by pilots when LAHSO blew up here over the past few years, that if we could just control the sequence at the intersection and assure that no one is going to be there when I am there or that I am not going to be there when someone is there depending on how you look at it, control the sequence in which the different aircraft or vehicles pass through that intersecting point then great, yeah, I think ghosting is a heck of a technology that can be put there. But now we put a requirement on air traffic control that up to now they have been unwilling to accept and that is to control the sequence at the intersection and so we might be in conflict. I am not an air traffic controller so I cannot speak for them. But, maybe that is in conflict with some the accumulated wisdom of years of controlling traffic too that they can't do or don't want to do that. So, I think yes it addresses a very fundamental question that is the sequence of the intersection and if we can do that with technology, then great!

G. Livack - My suggestion was to do it from the cockpit's rather than the controller's perspective.

G. Saylor - I would be dubious of that.

D. Williams - Larry can't resist.

Larry Paschich, FAA - My use of LAHSO takes out my having to control the intersection and if you agree to be able to stop and you can stop, then I don't have to control it. Otherwise, you say "no I can't", then I do have to control it. It speeds up the operation and increases the number of operations and reduces separation. Because if you say "no I can't", then I am going to watch and see is he going to be able to stop and get off at that intersection before I roll the next one, or am I going to hold this one short of the intersection before I cross, reference your aircraft? That is my use of LAHSO. Some of them abuse that, but that is the concept. I fully agree that if I don't give you the option to go around, then throw it out. I don't want to use it because you have to have that option. An example at El Paso, the guy that hit the coyote had to go around because he lost his nose gear and he could not put it down on the nose until we foamed the runway. Those kinds of things happen. And so, if you had been having to LAHSO, you would not have been able to. You would have had an unusual incident.

Ed Rafacz, ALPA - Just a question on LAHSO. It sounds like if I don't accept a LAHSO, I have to go around – no? From a controller standpoint of view, I am not accepting a LAHSO landing. What happens then?

L. Paschich - You land. I just told this one. I'll give you the full runway.

E. Rafacz - Okay, I have to go around and I have a clearance.

L. Paschich - You're talking to Level 3, Level 4 controllers. There are some of those un-nice people at Level 5 that would make you go around.

Tom Doyle, Adsystec - I haven't seen any of those! (laughter)

L. Paschich - No!

D. Williams - Okay, any more comments from the floor? No.

[END OF A.M. SESSION]

SVS CONOPS Workshop

Breakout Team Summary Reports on

<u>Departure</u> and <u>Enroute</u> Flight Phases

Thursday Afternoon, February 24, 2000

Blue Team

<u>Greg Saylor, Delta Airlines</u> - Taking the **<u>Departure</u>** phase first. Our first comment was -- see all applications for the approach phase. We figured they were pretty similar so we did not repeat them. We just said "see approach". The second comment that went along with that was -- and this was a significant amount of discussion -- Is synthetic vision a better and/or cheaper way to do these things than the current guidance and deviation displays we already have? There was considerable discussion on whether it is worth the trouble. With that being aside, we did come up with one idea that we thought had a great deal of usefulness. We didn't know what to call it except Clark's 'Smart Box'. We are thinking about a system that could recognize and instantaneously compute an acceptable single-engine extraction procedure in the case of an engine failure on takeoff. You can certainly take this into the approach phase and apply it to single-engine go around -- sort of a tactical instantaneous computation of the best single engine escape profile for airports with high terrain. Currently, pilots sometimes are forced to brief and theoretically memorize two or three different engine-failure procedures to fly themselves out of airports in and around high terrain. If you had a box, especially if it could recognize the engine failure on its own, instantaneously compute and display the optimum single-engine escape profile, that would be a real help. And we thought that had a lot of application, both to takeoff and to single-engine go around situations. We also discussed the general issue of takeoff guidance and synthesis in display of data that could be useful in the takeoff arena. We discussed ways to show guidance back to centerline in low visibility takeoff. And whether or not that means a synthesized visual display of the runway itself or an iconic display or just guidance. But, we also thought there was some value in having some calculation of rejected-takeoff braking and stop calculations to present to the pilot <u>where</u> on the runway he might stop, or whether he might stop on the runway if it's low-visibility and he can't actually see the runway. So we thought that there were some applications there in the RTO case in the general category of takeoff guidance information. We also had a significant discussion about the general issue of symbology and whether symbology was considered part of synthetic vision. We don't know the answer, but we do know that there are a lot of other applications, current and future uses of symbology and icons to do helpful things for pilots. We didn't actually list them because we couldn't decide whether it fit in this particular box, or not.

Moving to the **<u>Enroute</u>** phase. We also in the enroute phase applied the 'Smart Box' idea to an instantaneous drift down calculation for flying through high terrain, to calculate drift down profiles and escape profiles of that scenario as well. We also discussed using synthetic vision for display of traffic in the enroute phase and/or as a part of the (ASAS) Automatic Separation Assurance System application. There was a lot of discussion again about the general desire to even do these things. But if they were to be done, certainly, synthetic awareness could come up with some displays to assist and be part of the system that did that. We talked about wake turbulence and we talked about it enroute and it also has some applications to the approach and/or departure phase as well. Display of the location of the wake of another airplane or general turbulence locations in the sky around you – if you had data concerning weather data or from whatever source about the location of turbulence, could it be displayed in such a way that was meaningful to the pilot? Some say that's really more of an extension of synthetic vision than core synthetic vision. But either way, we agree that if you had such data there might be valuable ways that it can be displayed whether it's in the form of a top down God's-eye view or an egocentric display, I'm not sure. But that's what research is for - to tell us those things. We discussed some other things, just to bring them up briefly that we talked about, that really didn't qualify as potential applications. We did some quick discussion of issues such as 'highway-in-the-sky' and 'tunnel-in-the-sky' applications. The pilots in the group were not too sure we saw the reason for doing those things and felt like there were some issues with hypnosis with poles and tiles and things flashing by and confusion about ways to use them. There were a lot of unresolved issues there. We talked about using some sort of synthetic vision tool for approach rehearsal and issues associated with that. That was <u>not</u> well-received, figuring that the pilots in flight should be attending to the airplane they have in flight at the moment and not rehearsing some phase of flight that they are not currently engaged in. So that didn't go over real well. We also discussed using something as a briefing tool. We had some agreement that a briefing tool might be a useful thing but that it probably in the end wasn't really synthetic vision. It was just some form of an electronic briefing tool. That's it from the Blue Group!

<u>D. Williams</u> - What is an electronic briefing tool – did you guys define that?

<u>G. Saylor</u> - No – it was on the list, I think. You guys did. Well, maybe not …

Re-route planning, emergency air field deviation and so on. It's just, well, the thought that … something that gives you some sense of, when you get to Birmingham, here's where the hill is and here's where the three towers are out on final and all of the stuff that we always talk about when we brief an arrival. If you had some electronic way to lay out a checklist for approach briefing and so on, you could electronically build a briefing tool. Would I give up any other display space in my cockpit in order to bring this up – no, because I don't really need a briefing tool. We succeed already. But, if you had an extra display that was dedicated to displaying publications or Jepp charts or whatever, that might be a valid application to put into that function, but not probably in your core flight control displays.

Green Team

Ken Williams, Alaska Airlines - Our group broke down the **Departure** and included a go-around also in this phase of flight since they both accomplished roughly the same tactical scenario. The first thing we looked at on the application and description was the VFR separation as a high priority. For instance, San Francisco runway 19-Left departures. Another item, again back in San Francisco … was just a place that we took a look at that everyone felt comfortable with in terms of a picture, … was airspace-constrained versus terrain-constrained departures. Terrain-constrained departures would be where we would make the missed approach and end up with some type of failure, and while we are busy battling the failure, recognizing or knowing where the terrain is and all that we have to deal with there, making it more situationally aware. So we gave it a high for terrain and medium for noise abatement airspace. Another one we were thinking of – this is not for the cockpit application of synthetic vision but for the controller … and that would be airspace visualization … looking at the 'wedding cake', back to the original classified B airspace, C airspace, what have you, and allow them to see aircraft violating that airspace or vectoring aircraft around that a little better situational picture. The one item that I think we all agreed on highly was the T-procedure. For those of you who are not familiar with the T-procedure – it allows airlines and probably general aviation aircraft to use an airport that is specified for a specific weight. We can go greater than that weight if we have a different departure procedure off the airport if we were to lose an engine right at V- 1, the critical speed to make a decision to either abort or carry on. So, that T-procedure is not depicted and can sometimes be very complicated, and unfortunately the controller - either the tower or the departure controller will have no idea what we're doing, and every airline and every aircraft have their own T-procedure for a particular runway. So this would be nice to have displayed as a terrain avoidance procedure while you're battling. Then, a non-standard go-around. An issue would be to come in and, all of a sudden, instead of having a normal go-around you expected to have, either under visual conditions or IFR, the controller, because of traffic, would need to send you somewhere else. Route depiction to prevent altitude deviations – 'tunnel-in-the-sky' was the theory behind that. Larry, looking ahead, was thinking of triple and quad departures off of some airports. Why is that an issue? Allow four aircraft to take off at the same time and, say the center aircraft had a major catastrophe, causing lateral loss of control and winding into another field or departure path of another aircraft. This is more for uncontrolled airports, but as the airspace becomes more crowded and the concrete becomes more competitive, I believe that we are going to have uncontrolled airports becoming more 'feeders'. So you're going to use them as diversion airports or departures without instrument procedures. VFR traffic identification – the thought here is having synthetic vision, including CDTI. And then wake turbulence … taking off behind a heavy and lose performance climb capability -- taking off behind a 757-200 or a 767 and planning to out-climb the path of that aircraft and, all of a sudden lose an engine, now I'm in that path. Can I see that wake turbulence? That would be a very critical phase of flight.

Moving on to the **Enroute** phase. My enthusiasm wasn't as great until … because I couldn't picture what we would use that we didn't already have in the aircraft. As we talked about it, visual separation during a step climb would be a great tool for both the controller and the pilot. Where this would be applicable for myself to not necessarily climb from 31,000 to 37 immediately, but allow me to slowly climb up there and as I slowly burn off fuel I can accomplish that climb and arrive at that altitude safely without pushing the envelope. This would also give a tool to the controller to let us stay in charge of that, while they may be rehearsing some other problem or looking at traffic elsewhere. Something that Greg wasn't too impressed with but I was surprised. It might be interesting to see where the rest of the panel is. I think rehearsal, along with the group, would be a great tool. Especially, if you have time in a diversion. Say, for instance on a long-haul flight, I'll give Los Angeles and Anchorage as an example, and also now you're stuck with very few airports available to you and maybe one that you've never been to before. It sure would be great to pull up that approach and take a look at it, especially if the weather is very close to minimums at that airport. And also knowing what the missed approach would look like. Other factors would go in with that of course. But having a mental picture for a pilot on what you're trying to do is miles ahead of the airplane. If you are 'hanging on to the back of the stab', that is not a place you want to be … or as I call it, 'riding in the jumpseat'. Station Keeping – we gave that a medium. I didn't realize what this term meant until today. It means keeping track of another aircraft in front of you. Do you have that aircraft in front of you for a visual? The next item we have for a high was enroute diversion. An example would be emergency depressurization or an engine loss and turning 90 degrees to the intended track of flight and/or icing concerns on that descent. But also alerting other aircraft with SVS systems which altitude you would be crossing through and what the path would look like. One I was concerned about was low altitude enroute. We use a little bit of this for our structure up in Alaska, but also the general aviation and the smaller commuters are using low altitudes to go back and forth between the airports between 4 and 6,000 feet. If they were to have an emergency, using CFIT as an SVS recovery, this low altitude enroute phase, having SVS for that would be rated as a high priority. Airspace depiction was a medium. And then the last one was lost of control recovery. And you're probably wondering why wouldn't this work for TCAS –enhanced ground prox. warning system or what have you. And we're thinking about … and I think Mike Norman's point on this was – once you're down into the red on enhanced ground prox. warning, what do you have left? And that is where the synthetic vision would take over.

Orange Team

Kim Kaiser, Alaska Airlines - A lot of the same issues and same ideas as the first two groups, of course, reviewing the same runway incursion benefits that we would see for the landing mode. The rejected takeoff mode, the ability to have a better presentation of runway remaining, obstacles down-field, other traffic down-field as the pilot is trying to look at where he might exit the runway. In the non-normal takeoff -- there can be a lot of discussion here of the engine out, but that can be any non-normal which affects control of the airplane - a flight control problem or something like that that takes the aircraft off route or reduces the performance. And of course you have the immediate and the unplanned off procedure situation for whatever reason that situational awareness of where the terrain is. In the case of degraded performance, typically with an engine out, one thing we don't have any other way in the airplane now is projecting the potential flight path of the airplane. The HGS gives it to us in clear conditions, but of course with synthetic vision we would be able to see immediately what that flight path will look out in front of the airplane, under the current conditions. We also included the discussion if you were going to try to do an immediate return to the field, whether you are continuing your takeoff or trying to get right back on the ground right away just that additional situational awareness that you get from the display. The T-procedure, as we mentioned, being able to show that quickly with a button press or two, or even automatic to come up so the pilot does not have to retune radios, recompute where he is going to go in this engine-out condition or even preferrable to that, what would be available for many airports for many operators, although there are individual aircraft differences, it is possible that you could make minor changes to existing procedures, taking into account the navigation capability and visual capability with this system, to have the programmed and planned-for departure match the best possible T-procedure departure. We have done that with the RNP capability in the airplane now. So whether it's engines running or engine out, the airplane is going to go the same place even under more optimal conditions. We talked about enhanced weather - let's say atmospheric capabilities. If we were able to show, in a sort of a more traditional view or format, a convective cell sitting off the end of the runway. Make the minor adjustments to course or be able to plan ahead for making a minor adjustment. If possible, to show down-burst activity, an actual cell really moving right in on the airport, making the decision not to even begin the takeoff roll based on what could be displayed and possibly displaying again the wake vortex of departing aircraft on parallel runways, upwind runways. At the very end, of course, we wanted to make sure we didn't overlook the most significant, economical benefit which is the reduced takeoff minimums on all runways. I almost forgot all about that one.

And the **Enroute** … the first one we came up with was pictorial weather displays – looking for both the strategic in the Nav display and the tactical look-ahead. This could be again considered broadly atmospheric weather, that would be just traditional weather, convective weather or volcanic ash which we currently have no sensor on the aircraft capable of depicting. Again, clear air turbulence - if we could have a way of displaying that … I guess it would tie in, what was a little bit separate but again the air traffic spacing for oceanic or non-radar environment that would get you possible wake turbulence affects that you could be looking for as well as the enroute climb spacing that has been mentioned. The emergency descent situational awareness or engine-out drift down, both with the tactical immediate safety implications. The drift down situation for engine out also has a strategic preflight planning economic impact, in that airlines in many cases now have to preflight plan inefficient routing to allow for drift down engine out requirements. If you had this capability on the airplane, you could then take a benefit for it and maybe reduce or eliminate those inefficient routings. The weather capability might also be able to be used the same way to reduce the number of times that airlines will preflight plan inefficient routings around weather given a better capability of analyzing and reacting enroute. On the flight plan mission rehearsal or 'looking ahead', I also started into that one thinking that possibly that wasn't the greatest benefit there … thinking of a nice, clear day and the fact that these displays would be so intuitive that even if I hadn't been there before, it was just going to be that easy to fly this thing in the missed approach. But then when we talked about being able to put real-time weather onto that and be able to analyze ahead of time maybe two or three different arrivals into an airport based on what the weather is currently looking like on each arrival and step through that, that started to look like some real benefit that could be had there for preflight planning. Unless someone in the group wants to correct me, those are the main things that we covered.

Purple Team

George Boucek, Boeing - As with this morning just about everything we had was covered by the previous three groups. We also looked at in the **Departure** -- weather off the end of the runway and the ability to make adjustments to that weather. We were looking at the emergencies and engine out. But we covered a lot of the categories with the terrain navigation and the ability to have high-fidelity navigation. Because that function in itself will help in the emergency, with the ability to do the noise abatement and the missed approach. You'll get all of those with that same functionality. And the ability to do precise navigation and terrain avoidance gives you those things. We also noted the reduced takeoff minimums and the ability to get the operational benefits from that reduction, and we looked at the ability to see wake turbulence and the ability to do aircraft separation, not only from threat traffic but also in-trail separation and the parallel runway operation separations. That is pretty much it. We were in agreement with the rest of what was already said on departure.

As far as **Enroute** goes, one of the things that we did look at was 4-D Nav and the ability to do 4-D navigation with a display on an airplane that may not have a map or may not have an FMS. The synthetic vision display with a tunnel may be able to provide you the capability or functionality of doing 4-D navigation. We also had the emergency descent engine-out drift down and emergency decompression the ability to replan very rapidly and be able to see what was happening. The ability to optimize your route with respect to weather by being able to see the three-dimensional weather. The ability to detect and react to turbulence which again is both a safety and an operational benefit if you can reduce the number of injuries due to turbulence, especially with cabin crew. That is a big factor with some companies because of lost work from injuries. We looked at the mission rehearsal and thought it was something that could be beneficial, especially going into unfamiliar airports with low-visibility, the ability to do 'what-if's', - to look at potential switches of runways or potential ATC types of interference with your flight plan. Again we looked at collision avoidance although it is much less of a problem enroute, it is still a problem.

[END OF TEAM SUMMARIES]

D. Williams - This is another one for the panel: basically, I didn't give you any prep, sorry. Through the phases that we have discussed today, if you could prioritize those, maybe that could be something that could be helpful or at least comment on that.

K. Williams - We should ask the group what the consensus was. That would be fair. I would have top say for myself it would be the **Arrival**.

G. Boucek - From my point of view, if I were prioritizing how I would want to do the work based on a strategy of getting the system on the airplane, I would start with the **Ground**. There is nobody doing anything on the ground right now. You can get an immediate benefit from it. And then you get the platform on the airplane and then you show the accrued benefits of the in-flight operations.

K. Kaiser - My first reaction is maybe the biggest safety impact could be in the **Takeoff**. I wouldn't have thought so coming into it, but as we discussed more and more, as far as the criticality of control of the airplane in non-normal situations, that's when terrain is the biggest factor that you can't control. That could be a real high impact from a safety standpoint.

G. Saylor - I think I would agree with George. The **Ground** probably offers the most realistic approach to finding benefits and getting planes equipped. At this point I think I'll have to acknowledge some of NASA's previous work in showing a fairly mature product already, at least a mature approach that really makes achieving benefits seem realistic. I think that is some pretty fertile ground and a good way to go there. I also would like to echo Kim's discussion about **Takeoff**. When I mentioned the 'Smart Box' that could instantaneously figure single engine go around paths and takeoff paths, and so on, I think that has some real potential and that might be an extension of current FMS technology it might be in addition to it. I am not sure what form it would take in the airplane, but there are probably ways with incorporation of that for the airline to realize a takeoff weight increases and other benefits of that nature … and certainly add some safety benefit to the pilot. One of the problems with special terrain-based procedures is that you have to memorize two or three different things during any given takeoff – the normal departure, the single-engine departure from a failure at V-1, the engine failure above 100 feet, the engine failure after the right turn. There could be a number of iterations of this. So if the pilot didn't have to memorize them, it would just automatically detect and compute the correct an advantageous escape path. I think there might be certainly safety benefits and there might even be operational benefits that the airlines might be able to increase take-off weight and stuff like that. I think that has some real applicability too.

D. Williams - Thanks, and if there are any comments on that … specific questions on that?

Ed Rafacz - Just a question – We're talking about synthetic vision and I want to know … we're all talking about maybe a heads-up display, what's in front of us. It slipped my mind … are we talking about maybe looking 130 or 180 degrees around? Because, how will that affect all these things that we want to do. We are talking about wake turbulence: if I'm looking straight ahead and I make a turn and I make a wrong turn into wake turbulence and I have to turn back or something like that we are losing performance. Just as a question to the group "do you think that is going to affect what we are looking at here". Like I said, it seems that we are thinking about a HUD. We are not thinking about full vision.

D. Williams - Russ, would you like to address that?

Russ Parrish, NASA LaRC - I think that most of us aren't thinking just about a HUD. Most of us are thinking about an integrated display system … a PFD, a NAV, and maybe a HUD. Not all of us have conceded that a HUD is necessary, even for retrofit. There are others that think a HUD is the only way to retrofit some of the analog airplanes. Personally to me, it is an integrated display system that gives you the strategic picture, as well as the tactical picture that you need to do whatever operation that you are doing.

G. Saylor - We talked about this issue … if I could extend it a little, Ed, Doug in our group is working on head-mounted displays. We discussed that not in terms of applications, but in terms of areas that research has got to settle some issues before we will know what can and can't be done. The issues of what's available in the real world visual scene and how you can synthesize and present that in compressed formats. There are very fundamental issues that NASA or that someone is going to have to address in terms of size of display. Is a heads-down display or a even a heads-up display, should it be conformal to the real world or not conformal to the real world and what are the issues of perspective display and texture and the impact of texture on the perception and certain display characteristics? There is tremendous ground that is real fundamental research before we can know what we can do. I think every pilot would say, well if you can give me a display of the real world that is exactly equal to what the real world really looks like, well then I can fly it. So if it wraps around from one side to the other where the windows are in my airplane now and it does everything the real world does exactly like the real world does it, it's a 'no-brainer', it's easy. It may be a head mounted display so that whichever way I look it's correct. That may be the only way to actually achieve that. You start from the ideal, a perfect replication. Well, if we can't be there, the question is how far down can we bring it and still use it. It seems to me the answer is unknown. The question is entirely wide open. There is research being done to answer that specific question. It's … any one display looking in any one direction is like flying looking through a knothole, and that's not optimum, and a lot of cues in the visual field the pilots use don't occur directly in front, they're in the peripheral vision. We haven't answered all those questions on how synthetic vision is, you know, how that integrates into the whole question. We talked in our group some about this and just mainly agreed that there's a lot to work on.

D. Williams - Okay if there are any more comments.

Jim Burin, Flight Safety Foundation - In prioritizing, I'm kind of curious of the prioritization when over 60% of the accidents in general commercial and business aviation are approach and landing and CFIT. Runway incursions are a minimal number.

Ground ops the way I've heard it described here will help you get to the gate. I can't see how ground ops could be a priority to get a system like this in an airplane when approach and landing is screaming out for some help because it is such a large number of accidents and such a big killer that ground ops would be a factor, even in the same class as that.

G. Boucek - The way you get systems on airplanes is that they have a return on investment. The companies that put systems onto airplanes want to make their money back. Safety is a factor and safety will always be a factor. And increased safety, we're always looking to do it. But it's easier to get a system on an airplane that makes the company money. Because the system is safe, the system … we're working to make it safer and you can quantize the savings that you get from a system that saves a company money. You can't quantize the savings a company gets, very easily, from safety. Now if we can show monetary savings to the company and allow that to get the system on the airplane and get the safety along with it, that's the best way to go. So if you can get the platform on the airplane from the ground ops point of view and get the safety benefits in the air, then go for the ground ops and achieve the safety too.

K. Kaiser - It's also useful, I think, to break down the category of those accidents: where are they occurring, why are they occurring in the approach phase. And I know the three of us sitting here are all fortunate enough to be in the few airlines that have equipped with inertial flight path HUD's. Many of the approach accidents are landing short in the very near-term, close into the runway, visual phase of flight or in poor path control some way or other poor energy control. The HUD takes care of that. I mean there's no way you're going to put the airplane short if you have even a little bit understanding of what the inertial flight path is telling you and what the inertial acceleration is telling you in the HUD. Another significant accident rate occurs in the non-precision approach phase. And again, HUD gives you better flight path control over that, and in our case with the aggressive implementation of RNP procedures we're working our way out of the non-precision approach, out of the circling approach and giving ourselves precision path guidance to every runway in our system.

G. Saylor - I'd like to ditto what both George and Kim said, absolutely true and both cases and suggest that the CFIT statistics are real enough, but three very significant tools are available and are in fact being implemented by various airlines today that specific address CFIT accidents. Kim covered the heads up display, which I personally feel is probably the most powerful one of the three. We also have enhanced ground prox warning systems, which are also very powerful and useful system and are being almost universally adopted. And to extend the RNP comment of Kim's we're also moving into using our FMS's and their vertical navigation capability in extending that into the non-precision approach to provide us a vertical path guidance on non-precision approaches which is one of the more hazardous things that we do, is non-precision approaches. I think those three things, integration of VNAV for vertical path guidance in non-precision approaches, enhanced ground prox warning systems, and head up displays very capably address the CFIT issues. The statistics we are talking about pre-date any wide spread adaptation of those things. I think if you gave us 5 years to even get a semi-penetration of the industry with these technologies and then 5 years to take data for that, I think you'd show a dramatic decrease in CFIT accidents. I think three valuable steps have, in fact been done and they will pay off.

G. Boucek - Eminent application that a number of companies are working on is the Vertical Situation Awareness Display. Which is going to do for the vertical plane what the map did for the horizontal plane. And that will also cover the area close-in to the airport. It will help in energy management and will help in both CFIT and landing accidents.

K. Kaiser - Lest we rained on the parade too much, let me finish by saying I definitely want SVS in my cockpit. It is a better way of doing much of what we talked about doing, or a better way to integrate various pieces of what we're doing all into one very intuitive display that handles multiple scenarios and situations that best of any of them. (Applause & laughter)

D. Williams - Ok, without further ado, thank you for plodding through the details. It's been a good day and yesterday was a long preparation day, but today was a very good day of collecting a lot of information. We appreciate that, and the interchange is valuable. Tomorrow again, we want to point toward the operational benefit analysis that Pete Kostiuk and Bob Hemm are working on. We're going to again go through the assumptions, and in doing that we're going to focus again on operational benefits, but some specifics to those, and we will enjoy your input there to. If you have any further people that you know that need to be involved in this type of work, send me that information. That's something I need. Not just me, the group. Anecdotal examples where you see synthetic vision being applied, that's stuff that we need, and gives us horsepower for the work that goes on. Are there any other further comments? Russ?

R. Parrish - I have a question. Would you review where we go from here with your efforts.

D. Williams - Okay, we are going to assemble the information that we've gathered through this day, and we will boil that down. We have an outline that we have as the beginnings of our CONOPS document. We're going to put that information into the document as best we can. Then we need to get that back to each of you so that you can have a last crack at it. There have been thoughts of having another workshop. I don't know about that just yet, so we're trying to figure that out as , is there a value in doing that at this point, or is it going attach onto a conference or something further on. So that's my short answer. We have a deliverable that is in June to focus on this.

R. Parrish - You might ask for comments on that approach.

D. Williams - Okay, comments on our approach?

Mike Norman, Boeing at LaRC - Do I need to use the mic?

D. Williams - We're trying to record things.

M. Norman - Yeah, I would suggest if we do this again in a workshop forum that we get a bit more specific next time. There's a precedence for this in how it was done in HSR but I would suggest grouping around a laboratory environment with specific displays showing what can be done with the technology, getting ideas on implementation specifics. Now this was real good for brainstorming the general areas that might be useful, but I think if you do this again it ought to be a year away, 8-10 months away. At that point you're going to be ready to show some specifics and get some ideas on how the specifics might be fine tuned. That would be my suggestion.

D. Williams - Anything else? Gary?

G. Livack - Yeah, I think it would help me immeasurably tomorrow if you could give us a recap from your management perspective overview in your process and where you're focused on deliverables and milestones. I was distressed yesterday, for example, when I saw that not all of the synthetic vision contracts had been completed (finalized), and I was curious to see from a deliverable and from a milestone perspective how we can look forward to what will be coming out of the shuttle mission, maybe some of these other satellite based systems? How will this all be integrated into something? And then the presentation we heard yesterday on the certification needs, I work in the FAA flight standards and of course we have aircraft cert, and I think there needs to be perhaps some sidebar dialogue as to what other things the FAA might do in that certification side. Is there a need for RTCA or SAE-G10 or some other group, AEEC, to do some other enabling technical standards? What does the community think? What role does NASA have in this whole process? So, that would be an interesting discussion. You know, what's next?

D. Williams - Yeah, I do concur in that, and that's not just me.

R. Parrish - Gary, that's a good suggestion. Unfortunately, we've got an agenda tomorrow morning that really… We won't be able to do that tomorrow morning. But Dan and I will get with you individually and get with you as we can. We need have personal discussions with you anyway. But as far as programmatic approaches, we're really not prepared to go into that in this forum.

Peter Howells, Rockwell Collins - We had a lot of discussion in our group about this tool, this synthetic vision tool. And whether it would actually replace some of the things that are already being defined for support of CFIT such as FMC approaches, enhanced ground prox. Is the intent that a synthetic vision system gives you the visual view and would replace some of these things? I think our view was that it would supplement whatever tools are being developed elsewhere, CNS/ATM related stuff. I think that has to be clear in the cost benefits analysis. To operate in a high traffic area where flight management systems are controlling airplanes going around the area, you don't want someone coming in VFR just because they've got this wonderful synthetic vision system. You still have to be able to operate in that environment, and that's a different type of presentation. A comment more than anything else.

D. Williams - Unless there are any other tidbits or comments? George? 30 seconds

G. Boucek - That's all I need. Me, 30 seconds? What I would like to do is make the offer from SAE-G10 to entertain the initiation of any subcommittee you would like to see to develop guidelines for the types of displays or system elements that you think are going into the SVS. We have a perspective display, perspective PFD effort starting in August. We have a multifunction display effort already going. We have a vertical situation awareness display effort going, But I would like to see and I initiated thoughts about it last meeting, an effort on taxi display and ground handling display. And if you all can think of anything else you would like us to do and if you would like to participate in those subcommittees we would be more than happy to have you do that.

D. Williams - Thank you, and I think we're concluded. Tomorrow 8 am.

SVS CONOPS Workshop

LMI Cost Benefits Presentation And Discussion

(1st Session)

Friday Morning, February 25, 2000

Peter Kostiuk, LMI - Not to be too prejudiced but I think we are getting into the most interesting and exciting part of this two- and-a-half day workshop. I was joking with Russ that I am actually surprised that so many people are back here this morning because normally engineers are not real excited about going over the intricacies of cost benefit analysis. I think in this particular program as well as the way that the industry has been evolving over the past couple of years that there is a much clearer understanding on the part of both the research and development community as well as the business advocates that there needs to be a clear understanding of the business case in order to get these technologies out into the market place. That's the objective of our study here. As we discussed during the workshop, synthetic vision is going to be developed by NASA in order to solve some safety problems: CFIT, loss of control, and runway incursions. But they also expect that there could be potential for some significant operational benefits and enhancements to the users, both commercial airlines and as well as the business communities. The objective of our task is to focus in and help them identify what those operational benefits may be and to try and quantify those. And to use those to help them to develop program objectives and the operational concept.

Before we get into some of the details of the analytical approach that we will be covering, I thought it would be helpful to discuss the material that was covered yesterday. There was a lot of discussion about different operational and safety benefits that may come from synthetic vision. So, for purposes of our analysis I was scribbling those down and here are some of the ones that came up, breaking it out by phase of flight, starting with approach first. There was some discussion that there might me a greater ability to fly in on some runways that currently do not provide you with CAT 1 capability. One of the analytical issues is what other equipment or systems or information in addition to the synthetic vision system might you need to need in order to get that type of functionality. We also discussed improved access to airports during CAT 2 and CAT 3 conditions. Bob will go into some detail about how our analysis will be tackling that.

There was a lot of discussion in the breakout groups as well as in the broader group discussions about what you may gain with improved station-keeping ability through the SVS system and that would improve the efficiency of the spacing. Additionally, there is some possibility of reducing separations on final approach if you were to couple in some of the wake vortex detection and prediction systems. These are two separate issues:

improving the efficiency under current separation standards and reducing minimum separation standards. Another issue would be to try and improve the throughput or capacity on closely-spaced parallel runways whether you are increasing the frequency by which you can continue independent operations or by doing some staggered arrival procedures. Continuing through the approach phase some of the benefits might be: greater availability of visual approaches during marginal visual meteorological conditions, also discussion about what the potential would be for doing more curved approaches during IMC if you had SVS. During the departure phase of flight the one that stood out was reduced departure minima on all runways if you had the SVS system. During ground operations you could have a strong potential for reducing your taxi times during periods of low visibility and would also include nighttime operations, as well. En route, there was more grasping for potential benefits there from the operational side, not the safety side. Two of the items that I picked up on were doing smooth climbs versus the step climbs that you do now as you gradually lose fuel just slowly rise up to your optimal altitude. Also, a possibility through SVS of providing a 4-D navigational capability for aircraft that currently do not have FMS systems. Therefore, you would have a retrofit capability. We hope to identify your understanding of how an operator may capture some of these benefits. There are important analytical issues that we are wrestling with and have been discussing. A lot of technologies out there that are chasing after these common benefits, certainly on the arrival minimums, heads up guidance displays, autoland systems and SVS. Also, SVS provides additional functionality when have enabling technologies if you bring in an ADS-B through a CDTI into the SVS system it provides you with additional operational functionality. Discussion whether it will be a heads up or heads down display. So, it depends on how the integration process works, that could be another confounding factor. That's my quick overview to describe what we are trying to do to identify and quantify some of the operational benefits. Bob will go through and describe in detail the analysis approach that we have developed to capture some of these benefits, not all of them, we are still working on a few of those. He will describe some of the capacity and delay models that we have worked with over the last several years in evaluating some of the NASA programs.

Archie Dillard, FAA - Before we get into that, what exactly is your definition of SVS? We've talked about enhanced vision and synthetic vision and all these things over the years. I would like to understand what you guys are calling SVS. I think it's all of the above.

Bob Hemm and Peter Kostiuk, LMI - It's a multiple definition. It's a movable feast.

Russ Parrish, LaRC - What do you want it to be, Archie?

Kostiuk - That's actually the point of our study. What are the high-payoff capabilities that the operators are looking for? We'll try to quantify those and bring the results back to NASA as they develop their operational concept, and then we'll help lay out some milestones and objectives.

Bob Hemm, LMI - The way I look at SVS, studying it and everyone's definitions, it's basically when you are putting up an image of something that is not there but it is not just symbology of speed, and so on, it is a representation of something that is out there that really is artificial. EVS would have a sensor, it may be a manipulated image like you have enhanced it or false colored, but it is coming from a sensor while SVS is coming from a database.

??? - What do you call it when you merge the two?

Hemm - I don't have a name. I like 'hybrid'. You'll see when I'm talking about things; I make it clear when I'm adding the two systems. When I talk about SVS plus this or that, I will usually say 'SVS database' to make it clear. Heads up guidance system is presenting symbology. If you take data from a heads up guidance system and put up an artificial 'thing', like an artificial horizon that's not really there, but people fly to it. That is really kind of an SVS system, but we just don't consider that SVS because everybody has one.

The options that we're looking at right now come into these major sets: the baseline is autoland, there are planes that do not have this. The baseline of a technology that will operate in low-visibility conditions is autoland. Then we have heads-up guidance systems, a significant fraction of them available, SVS database, head-down, head-up (head-up display when don't have any room for display so put up a dumb guidance system with imagery on it or it could be a full head-up guidance system a la Flight Dynamics or Marconi or Sextant that links with navigation and other information), and a runway incursion system a la LVLASO. Since there is no head-up guidance system, it is hard to do the runway-incursion program. It is open to discussion and has not been determined from data that was taken in simulations, whether … how much you can do head-down versus what you need a head-up guidance system to do as far as low-visibility taxi, hold short, etc. For our assumptions right now, you get RIPS when you go head-up. You can add your enhanced vision sensor to the head-up guidance system. Now there are two items that I've made independent: pathway-in-the-sky, head-down and: pathway-in-the-sky, head-up with HGS and RIPS. They are also, in some way, a type of synthetic vision. I'm putting something out there for you to follow, but it's more like guidance than displaying terrain or displaying the world in some fashion. So I segregate these partly because they're being developed independently.

The big question is: what is the difference in performance between these two sets? Finally, there is an ultimate with head-up guidance, SVS and RIPS. With the other feature in the ultimate SVS that we have gotten enough confidence and have enough information that the pilots can be responsible for separations in IMC conditions as they are now in visual conditions on approaches.

Lynda Kramer, LaRC - I'm sorry, but frankly I don't see the difference between that and the SVS database.

Hemm - Technically, there is probably not a lot of difference in what is on the airplane. The difference here is in performance, if this has reached a level that pilots are responsible for separations on visual approaches. The pilots go to whatever they think is appropriate, they have enough information, see the traffic, airport, setup, and the controller is not controlling them to his numbers for separation. He is just monitoring. Under IMC, it's the other way around. He is always watching the dots and has big separations. Historically, visual separations are closer than IMC separations or radar-controlled separations. In this case, you are making a transfer of responsibility that should, and was already discussed Wednesday, still an open question: if he gives the guy more information, will he get closer or farther? Fundamentally, there are two limitations on separation of aircraft coming into an airport: one aircraft on the runway at a time (making sure the runway is clear), and the other is miles in-trail for wake vortex. Depending on conditions, mostly in IMC, the miles in-trail separation dominates. But in visual the other one dominates.

George Boucek, Boeing - If you're going to talk about separation, everything up there with database is static information. Somehow you have to put a technology up there that provides you with information about the dynamic situation.

Hemm - Yes. It is assumed, particularly kind of added onto RIPS, in the set of stuff you're getting when you put on RIPS. It includes ADS-B, CDTI, that kind of information that can give you a dynamic picture of what is happening in the airport, traffic and any other dynamic information. People talk about electronic NOTAMS to tell you if there are new obstacles in your database.

Boucek - You may do RIPS differently than airspace dynamics.

Hemm - True, but you will still have data links and technology will be there. The assumption is whatever is needed, this is assumed to have that dynamic update of traffic. This is assumed to have, as a basic assumption, TCAS-type level of information.

Kostiuk - I think with the ultimate SVS, that's where you bring in the datalink technology where SVS could be coupled with the CDTI and perhaps a wake vortex detection and prediction system that would allow you to do that type of dynamic adjustments to the airspace.

Boucek - I'd just like to see some of the assumptions that you're making about what you have and what you don't have.

Kramer - Yesterday when Russ was talking, his feeling was that we want an integrated system. That's how our whole group feels, at least the NASA side. I really don't see that represented here. It's either head-up or head-down. Is there a reason for doing that? Can we add that category?

Hemm - The reason is that right now we are looking at benefits, but ultimately it is cost benefits.

Kramer - Well, the RIPS system, for instance, has a head-up and a head-down part of it, so I don't know if you could take just part of it and still get the same benefits.

Hemm - I talked to Denise Jones about that, whether you need your head-up guidance system or whether you could do it head-down. I don't know if you need a head-down display. That's a question for the house. I presumed that you would have a head-down display. My assumption is that you would have a head-down display in the first implementation, then you would translate to a head-up display. This one, hardware-wise, is close to the integrated system.

??? - Just to further confuse the issue here, may I suggest that the ultimate SVS includes the EVS sensor display, whereas the one above does not?

Hemm - I would be glad to do that. In the models, by the resolution we have, it will not make much difference. We can define it that way and if there is another benefit to pick up, but when talking about operating with minimums and other parameters, we are thinking that SVS will give lower minima than EVS. So, adding the EVS to it will not improve things. That could be changed.

Paul Leckman, Boeing - It seems like one of the heavy hitters in economics that's not on there is LNAV, RNP, VNAV type approaches, allowing lower minimums and making the system more efficient. This is exactly what Alaska has been doing and they've made some real gains on minimums. That probably should be on your list.

Hemm - It would be a cost item.

Kostiuk - Would some type of capability like that be required to be coupled into the SVS system, or would it be a competing way of getting lower minima?

Leckman - SVS supplements that type of operation.

Hemm - OK. Supplements or enables?

Leckman - Supplements.

Hemm - OK.

Dillard - You don't mention FLIR anywhere up there.

Hemm - Well, FLIR is in here [EVS sensor]. This could be a millimeter wave, or FLIR or night vision goggles, whatever enhanced vision sensor items you might add.

Leckman - So, FLIR by itself is not carrying a lot of weight as far as enabling technology is concerned?

Hemm - No, it's kind of a separate discussion. Do you need millimeter wave, do you need FLIR, do you need both? With a whole set of questions…

Leckman - On Wednesday I heard quite a bit of comment about FLIR. I haven't heard that in this discussion.

Hemm - No, partly because we're tasked to do SVS, and what you're doing these for is to see alternatives that you have to consider. Either as other things that are available to do the same kind of job or as things that you want to combine if combining them gives you enhanced performance. I didn't understand, coming back to the question about RNP performance. Does that give you something by itself or is it a part of HGS-coupled features?

Leckman - Basically you're reusing LNAV, a varied navigation to create new approaches to airports independent of ground-based navaids and to permit straight-in approaches to any runway heading. The other item that plays into that is whether or not you use differential GPS. It would further improve your minimums. I don't see differential GPS in there.

Russ Parrish, LaRC - Well, you can't do SVS database without differential GPS.

Dan Williams, LaRC - To address a little bit of what Archie was saying is we have classes of technology, that is what EVS is. That's why the granularity of distributing the FLIR and millimeter wave model. The gist of where he's trying to define EVS will give a certain general performance enhancement.

Kostiuk - What we're really trying to identify in this analysis here is different levels of capability or functionality as opposed to looking at specific engineering implementations that will provide you that.

Greg Saylor, Delta Airlines - I'd like to take you back to what Paul said about RNP and VNAV and so on. Another way to look at it is that industry is footing the actual operating cost. We're well down the road towards implementing these things. Based largely on relatively conventional, well-understood FMS and other technologies, it gives you a way to address the same issues that SVS proposes to address without SVS. As such, it would probably have to be viewed as competing technology. In a lot of cases the actual baseline system on the airplane is autoland. Any benefits that can be accumulated for SVS have to be in addition to what you can do without it. And the world of what we can do with LNAV, VNAV, RNP type concepts is just being exploited. Frankly, in all this discussion, there have been a lot of the same things that SVS has been trying to claim that we already have ways to do, or plans to do. And some people are actually doing them.

Williams - You hit the crux of the matter, Greg. That's really what we're trying to dig into.

Kostiuk - Regarding yesterday's discussion, we're looking for some specific benefit or operational improvement that would not necessarily be provided by some of these other technologies which would probably get fielded a little bit sooner than SVS would. There's a lot of discussion about that. It's still up in the air.

Hemm - Let me ask questions for my education. On the enhanced RNP capability, will it allow CAT 2 operations on a CAT 1 runway?

Kim Kaiser, Alaska Airlines - That doesn't use the ILS.

Hemm - Ok. So, it allows CAT 1 operations on visual runways, basically.

Kaiser - Yes, it does that near CAT 1 right now, without differential. With differential you have a real potential to go for CAT 2 from CAT 1.

Hemm - Now, does it require just basic enhanced autoland, no heads-up guidance system?

Kaiser - Not necessarily, I think CAT 2 into a CAT 1 runway may require the HUD.

Saylor - CAT 2 or CAT 1 either requires HUD or autoland. The issue is really about runway lights and what you can and can't see and what the autoland and the HUD can carry you through in lieu of having those visual cues.

Kaiser - In the extreme cases we're now doing near CAT 1 to what has been a visual runway in. Based on that, we are THE carrier for the capital, Juneau. We are now putting in approach light systems for that runway. Which there was not a need for before. So again all of this is the work-around; not having the SVS you can get there. Get pretty darn close.

Leckman - Using SVS could be conceivably, to be determined, but it could be used for identifying the area around the airport or things associated with the airport using virtual lead-in lights to the runway, getting you close to the point where you use say a HUD for the final stages.

Kaiser - The economics for SVS is I can put my airplane on a two-mile final to every runway in our route system right now. Getting it from there down to the runway has all the variables of the, what's the capability of that airport, do I have the HUD operational or don't I? SVS would allow me to go from that two-mile point down to the runway.

Hemm - Regardless of what the citizens of Juneau want to pay for.

Larry Paschich, Crown Communications (FAA) - Let me tell you from a control standpoint what I see the ultimate SVS is. That they're getting the systems in there that are going to be able to individually get them to my runway without my assistance probably. But ultimate SVS is going to allow them to follow the guy ahead of them or the guy behind them to follow them. And I won't have to be interjecting my opinions into that separation. So that means they can go below the data base separation, because they have the ability, they know how far they are, they know how much turbulence there is, allowing them to close in to the aircraft they're following knowing that aircraft is going to be off their runway by the time they get there. It's taking the IFR portion to almost be VFR with the aids. So that's from the control standpoint.

Hemm - Good. That's what I was thinking.

Saylor - As a pilot that routinely flies into airports we do a lot of visual approaches in very high traffic in long streams, I think there's a lot of unsupported contentions about the use of artificial devices to control longitudinal spacing on final. And the possibility is very real that is might get bigger and not smaller if you leave it up to pilots. Right now, the truth of it is, a great majority of the time pilots do not control spacing or accept the clearance for visual approach based on seeing other traffic. They may or may not see it. What they really want to see is the runway. A vast majority of the time the controller in the crowded airspace, we're talking about, Atlanta, Dallas, Chicago, or wherever you happen to be, he's already issued you an airspeed and you're just flying that speed. He issues that same speed to everybody. Once he sets that spacing that spacing works, and when I'm looking at the traffic in front of me on final I'm not really trying to narrow that down. If he sets me up at 5 miles, I'm just happy as a clam at 5 miles and I make no attempt to get closer than that. I might accept it if it just happens to occur. I might use TCAS to help me avoid some inner limit where I know it's not going to work anymore, but I'm not controlling to that, I'm not trying to put the aircraft in some specific spacing. I take the spacing I'm issued that just works out from when the controller gives it. I see the airport, I fly my plane on a visual approach to the airport, and I trust that the controller has set that spacing so it's going to work, and he usually does. Although, I think in Atlanta currently, in visual conditions, last thing I heard, we run around six go-arounds a day for botched spacing. Too close spacing.

Hemm - Too close for what reason? For runway incursion?

Saylor - No, one airplane is still on the runway when the other one has to make the decision to go around.

Hemm - That's pretty close.

Saylor - So, as a pilot, well believe me that happens constantly, and in fact there's a lot of pilots that think below 300 ft. or so it's not even a reasonable thing for the pilot to be worried about, whether or not the runway is going to be clear. That's absolutely routine in current airspace. That is one of the key things the pilot is still looking at below three hundred feet in the last mile of final, he's still wondering is that runway really going to be clear and should I really land on it by the time I get there. Many, many times the pilot flying he asked this other guy, just tell me is the traffic clear, I've just got to fly. I can't worry about him anymore and you have to divvy up the responsibility because it can be down to a hundred feet or 50 feet before you really know whether you're going to land or not. And that's why you hear a lot about visual spacing.

Hemm - That's in visual or instrument…?

Saylor - Visual. But any way, I think the basic contention that this is to allow tighter spacing on final whether in visual or instrument conditions, that basically is an unsupported contention. Nobody has ever gone out and done it in a rigorous simulation to prove that it is going to produce that result or not produce that result. So claiming that benefit is a conjectural benefit, and we can conjecture it and throw it out there, but as an airline that would consider purchasing it I wouldn't go looking to claim that until I could see some proof that it even works. There are a lot of reasons, question marks flying around in that. We just don't know if that works or not.

Hemm - I'll come back to that because at the very end I'll show the separation spacings we use. That is, in the model. That's a big issue because of what's being used for visual. The separation spacings we use for when the controller is controlling are easy because they're in the book. We know what he is shooting for. The other is exactly what you say. The only data taken, the only reported data, in this area that anybody stands up to as a separation matrix is 1976 which precluded any one having information on good distance information. On being able to tell how far you are behind somebody. That's a new phenomenon that could work, as someone mentioned, two ways. If because the plane looks so big and I can't tell my distance you creep up closer than you think. You can't tell 3½ miles from 2½ miles. Now we can. So that can be an issue.

Leckman - I don't think you necessarily need a forward perspective view to space yourself to know what the distance is between the person in front of you. We have TCAS now with targets, and all you really need is a distance, and a closure rate or some information to hold the distance, whatever that distance is. But it isn't vital to have synthetic vision in order to do that.

Hemm - That's correct, one of the places we need to take data, and I don't know if anybody, I haven't seen the data come up, and I've asked for it a lot, is visual condition separations. Things like TCAS are now in the fleet. A guy can put himself on his range and say okay, that's four miles, I'd better not get inside this.

Leckman - By the time you roll out on the final you have very little control over how far the airplane is ahead of you. You're stable, you're becoming very close to the point where you've got to stabilize at your own speed, required for your weight. The big variable in spacing is how the controller turns you on final behind somebody else.

Paul Abramson, TITAN (SRC) - Just a comment about the lack of data for spacing. Both the NASA and FAA Wake Vortex programs have been running tests for centuries on aircraft on final approach in all weather conditions and have a lot of data about inter-arrival spacing because that's the key thing they do.

Hemm - Oh yeah, AWIN has taken a lot. I've looked at it hard. What you get is, you get radar tracks in VFR.

Abramson - No, these are sensors that measure vortices. They also have data when the aircraft goes over.

Hemm - I haven't seen any, actually I have seen some.

Abramson - It's just another data source if you have in mind, it does have data on inter-arrival spacing.

Hemm - Their data was done in support of similar programs. It will tell you VFR conditions. What it doesn't tell you is when you are operating under clear visual approaches. Nobody has noted that.

Saylor - That's a key point, you have tons of data about any given day about how far apart the planes were on final. Seconds, miles, whatever you want. What you don't know is why they are that far apart. Is that because there was no more feed than that so they were three minutes apart because that's just how far apart they got there? Or was that because they were controlled to fit that pattern? You have no clue about what drove that spacing. You don't know. There are a whole lot of other issues that might have been driving that spacing. So your historical data, if all you've got is spacing, you just don't have real insight into actual issues that have to be addressed in order for this to build a benefit. It's just not about how far apart they were on these days.

Hemm - There are certainly critical criteria. It's a tough job to do, because you want get it at a busy time so you're pushing. You'd like to know what people are doing when you're maxing the system. Then you have to have data like, was he cleared for visual or not? And they'll give you data. There's lots of good data for people have done their analysis. Here's the 2½-mile limit, the 2-mile limit. Here's how many were above it. A lot of statistical, above it, below it. Well, when he was below it, was that a bust because the controller let him get inside of 4 miles behind a heavy or 5 miles behind a 75, or was he on visual and he just did it. It's not a bust on a controller, it's just how he flew in, because he couldn't tell 5 miles or he thought he was up and behind or something like that. That isn't in a lot of data to know and pull that out. There's a lot of data when it's sparse so that doesn't, when you've got 8 miles separation, does that mean the guy was flying at 8 miles or just there wasn't a plane there to bring in? That's fraught with problems but it's fun.

Anything else, to try to illuminate to these choices?

Mamad Takallu, Lockheed Martin, LaRC - What about the ground equipment and technology for lowering the requirements for CAT 3B to CAT 3C?

Hemm - Okay, the question is on ground equipment. That if you're going from surface movement guidance control plan and states or other things. Right now when we taxi under low-vis conditions, it is controlled by both the airplanes and what you can do on the ground. This kind of stuff helps a lot. If you've got synthetic vision operating on the ground. In most of our systems, well in all of our assumptions, and this is another thing, the models we have are for major airports, major HUBS. There is a lot of movement. They were all chosen to be the top ten busiest airports way back, to get a significant fraction of the air carrier fleet. So, they all have, most of them have, low taxi operation runways down to 600 feet. Seattle, there are about four airports and five runways that will give you 300 feet. Portland is not in ours.

Takallu - They are all CAT 3B, not 3C.

Hemm - There are no CAT 3C runways in the United States, in the world. There are no zero/zero operations.

Takallu - Why not? As far as the requirements for 3C, there is no difference as far as time of training and equipment. The only difference is ground equipment.

Hemm - Yes. As part of coming up with some of these requirements I called the battalion chief at Dulles on the fire department, asking how well he could respond, what he did in bad weather and in special rules. They are one of the airports with a 300' runway. The answers from the memo, they do their three minute response which is the requirement. They're tested in good weather. They do a test, where they put a hood over the driver and he drives with instructions from the tower. I guess he's looking at ASDE-3? I don't know if that's done in bad weather. It might be done with binoculars, which is kind of questionable. It might be done off ASDE-3, which they have there. Which could be done, but they don't get any 3 minute response, their farthest runway 3 minute response has them up to 70 mph. Consequently, their experiences in bad weather, they pre-position, and surface movement guidance plans call for that. If you operate in low visibility, one of the things is your guys have to be out there closer. The, "problem wise", and the guys also in a lot of cases in emergencies, when a guy declares an emergency is out there, he gives you time to pre-position in whatever weather. The cases that kill you as far as timing and other reasons really end up with people dying, are when you have a surprise. Which is like what American Airlines had down a few times ago, because they were on visual approach, no declared emergency, hit the runway, crashed off the end. It took 19 minutes to get to them. I don't know, there are some details, someone maybe turned wrong and they were off the end of the runway, whatever. It might not have just been bad weather in that case. But surprise cases, a crash on takeoff when you think things are normal or a crash on landing when you think things are normal that is going to get you on that response time. If you're pre-positioned you can do it. That is the limit and one of my little notes was NASA might want to look into this kind of stuff for emergency vehicles. I think that was mentioned in the group.

Takallu - What I'm saying is, if you have that kind of equipment for the ground the aircraft could taxi to the ramp. You wouldn't need that kind of ground equipment if the aircraft could taxi to the gate.

Hemm - Oh, you wouldn't need things like lighting and stuff like that, but if you want to get a fire truck to the airplanes and can't see anything in 3 minutes, then the fire truck has got to have something on it, too. That's the limit.

Takallu - But that's the emergency part.

Hemm - Yes, that's the emergency part.

Takallu - But the other part is that after you land, you would like to be able to taxi to the ramp/gate.

Hemm - Yes, the RIPS actually is probably at zero/zero capability.

Boucek - There are other reasons why they don't operate 3C. Like the people can't get to the airport. Connecting flights don't get in. So they just don't operate 3C.

Hemm - Plus, there is quite frankly, not a lot of it. It kind of gets exponentially more expensive to do it. I think when you're going to see it is, if for other reasons you've got this kind of equipment, and this kind of equipment on the aircraft, then marginal cost of going to 3C might just be the cost of putting it on the emergency vehicles. So, you get the benefit without a big marginal cost. That's kind of the incremental buildup approach. To go sell your program to get to 3C is probably a loser, because there's just not that big of a market.

Saylor - You know Bob, currently with the CAT 2, CAT 3 conditions, a lot of the ATC spacing requirements are based on the technical characteristics of the ILS beam and the importance of not interfering with the critical ILS areas. So we, with the CAT 2 they have one requirement and with CAT 3 an even tougher requirement. So if you posit a LAAS system to, a differential GPS system, flying to CAT 2 or 3, now you don't have the physical characteristics of a beam in space that drives the spacing. And you're really going to become constrained by the landing pilot's ability just to get out of the way. And so the use of a system in some form of synthetic vision or other presentation of data, whether it's iconic or whatever, to help the pilot get off the runway at the appropriate exit and not spend 30 seconds or a minute groping around finding an exit so the next guy can land, we may be talking more about improving arrival rates in CAT 2 and 3 conditions over all, rather than going to the very tail end of the curve to pick up the microscopic 3C weather condition. There are other ways to see system improvements, if you have widespread equipage that might produce system wide benefits.

Boucek - There are reports from British Airways when we were doing the High Speed Research program and the ESAS [Enhanced Situation Awareness System] program before it, is that they have autoland on every airplane, but they don't use it as efficiently as they would like because in low visibility the taxi rates and the exit from the runways make them separate more than they need to with the autoland system. So the whole system doesn't run efficiently because of the slowness on the ground.

Leckman - Even though you're landing with CAT 3B you've got sensors that tell you what the visibility is along the runway but only maybe 3. For those conditions the visibility can really change drastically, taxiing with some visibility one minute and no visibility the next. So, having, even though the airplane is equipped for safe CAT 3B it may be very difficult to taxi unless you have 3C taxi capability.

Hemm - Yes, and that's why, well we see what the limits are, these are held to like 700 or 600 foot, while if you have something like him or this or this and particularly this you can taxi at 300 on SMGCS [Surface Movement Guidance and Control System, pronounced ‘SMIGS’] runways and even on other runways. The Terminal Area Productivity program, which was the founding father of this, there were programs in that here at NASA. The low visibility surface landing operations included roll out and turn off, producing the dynamic runway occupancy measurement was using, could've used any that the tests at Atlanta were done to support that. They used multi-lateration where you'd be tracking the airplane so that you're seeing what their actual runway occupancy time was, so you've got current updated measurements on, if you have wet runways, dry runways you can tell what your expected runway occupancy time was, and that can be fed to controllers and fed back to the pilots, both. There was also low visibility taxiing, which is a lot of what the RIPS is. So what you saw in the movie from RIPS was actually hardware development in that LVLASO area and it was addressing all of those parts of getting off the runway. At the same time, the reduced spacing operations was dealing with wake vortex determination and how to tell how close you could be there, whether you can be 5 miles, or you can be 4 miles, or whether the 3-mile limit was fine. When you get to 3 or 2½ miles you're up against the ATC fellow's ability to control people using a screen. There is also ATM, I guess Air Traffic Management. That was dealing with enhanced versions of CTAS, where you had interaction between the FMS and the CTAS computer so that you could give the controller more information on his scope, so he can control things better, including intent if you get stuff from the FMS in 3D or 4D, then you can plan your spacing better because the guy says, "I'm going to be here at this time" with some confidence. With a fully integrated program, with all parts of it, a lot of what you have here is residual out of it that's showing up in things like this. AILS was an Airborne Information for Lateral Spacing system and also was part of that.

Kostiuk - I think we've milked this chart pretty thoroughly.

Hemm - This is one you saw and I won't delve too much. We have the capacity model and we have the delay model, and particular inputs. There's a list of input parameters we need here, and there's a list of input parameters, the runway minima feed in here. That's enough of that. So, that's what we'll be talking about. First, the capacity model parameters, and here's a long unreadable list, things that, and this shows some of the coarseness you know this is what you're going to get. This is an analytic model. It is not a tail number simulation model, or a Monte Carlo thing you go over and over. This takes a mix, takes stuff, uses probability analysis and comes out with a set of capacity curves. So the aircraft mix can be just one. We've got small, large, 757's, and heavies in our mix, 4-by-4 matrix. Sometimes that's adjusted, can be adjusted, if during some hours or if you need another capacity curve for a period when you're heavy, a lot of heavies, or something like that. Also, in the capacity model on a lot of occasions you redo the mix because you've got some turbo-prop only runways. So, a mix for that runway becomes all turbo-props, and a mix for the other runway now becomes a lower fraction of turbo-props. So, subtleties like that, and these models, there's two sets. They're both, there's the set of detailed airport models which are for the twelve airports we have, where we've really gone in and tried to model the exact configurations of the airport, controller's preferences, and operational rules. Sometimes two sets of runways could have on concrete the same kind of capacity but they're generally operated one direction or another. Seattle's that way. South is good. North is bad. Same amount of concrete, they could operate both ways, but they operate them South. And it's not just wind, if you let the wind go they'd flip back and forth a lot more often. When we're talking about mixed equipage we can deal… Here it results in an 8-by-8 matrix. So, you've got small, large, heavy, 757's, and mediums, with and without. 8-by-8, analytically, is about as big as we can go right now because some of the analysis, particularly when we're dealing with staggered runways, closely-spaced where you're in stagger, and you have to count maybe ten aircraft because you have a plane here approaching this runway. You've got a plane out there, you've got another plane approaching this one, a plane out there, and together they all control each other's separations. So there's a lot of analysis goes on, and how many planes you put in that history which can be up to ten. You do a lot of crunching, and you end up with an 8x8x8x8 analysis problem. 4x4x4x4 is okay, but when you start getting up to 16, 12x12x12x12 we starting running into memory problems, rather than, and speed problems. So, for here, that's how we can handle mixed equipage here, and for some things like curved approach, that's probably where we would take care of it. Some of these guys, some fraction, would be allowed to have a, one of the things here is a common path. I defined that before, could have a shorter common path if they were brought in that way. Anything… minimal separation, we have a matrix, approach and departure speeds, standard deviations of those. I'll say at this point, long ago when we started this there were models extant, there was the FAA capacity model, which uses much the same approach as an analytic model, there are some of the other simulation models. We looked at those, we actually ran several of those, but then we developed this model for two reasons. One is, we knew what was in it, some of the others were written in Fortran, and you just didn't know what was going on in the algorithms, and if you have to stand up and argue the answers you'd sure like to know how they came to be. The other was, there were parameters that TAP was trying to model that were not available in the other models. You just couldn't get a handle on them. They were piled into, inter-arrival time uncertainties is an input parameter rather than an output parameter based on velocities and position uncertainties. The other aspect, this is a controller-oriented model. You look at the controller sitting here and deciding what kind of spacing to set up when he lets the planes go, which is at the head of the common path, when he can no longer provide inputs. So, the uncertainties in position, uncertainties in speed, and where he lets them go, the standard deviation of wind speed, for example, is actually the difference in wind the two planes will experience, he sends one in and three minutes later the other plane comes in, he may have a different wind, and how well do you know that? That all goes into his judgement of how far he sets them up out here to make sure he doesn't violate his minimum separations over the threshold, and that's done to where he doesn't violate them with a 95% confidence. So, when you look at a separation number like 3 miles, the actual model, if you fly that or see what it comes out in the model, is longer than 3 miles, because he's got a 95% confidence that he doesn't break that. Similarly, on runway occupancy time, he's got how much time you're expecting to see and how much uncertainty is that, and he has a 97½% confidence that you don't violate that. Looking at both those times, miles in-trail, what is controlling miles in-trail separation is, what separation he needs to prevent runway occupancy time, the model chooses the greater of the two, and that's what's applied. On the departure side you've got some minimum distance to departure turns, which is important, for a certain runway, well for a lot of configurations. In Atlanta it's 5 and 5, 5 miles out, 5 thousand feet. You aren't peeling off at 3½ miles. That kind of adds distance between departures. This one down here, max history is just the analytic one I told of how many planes you actually keep track of when you're doing staggered's. Communications delay is used right now only for the time difference between, the guys told "you're cleared for departure" and the guy actually begins to roll, and it's not very long. In one case, in Seattle, we had to change that because of the CAT 2 protection. The CAT 2 protection bars are way back and you say you're cleared for departure, he's got to trundle quite a ways to get to the runway, which adds time, and that's where we add it. If you have AVOSS, wake vortex, Aircraft VOrtex Spacing System, and it tells the controller that, and AVOSS tells the controller and can tell the pilot that under the wind conditions prevailing now, and the thermal conditions, wakes are dissipating, or they're transporting, and you don't have to have a 6-mile spacing between a heavy, you can get down to 4-mile spacing, or actually you can get all the way down to 3-mile spacing, because we're saying that they're dissipating in a mile. You have another separation matrix appropriate to that based on what the AVOSS people tell us here. We don't use that all of the time, and the criteria in the model to use that is based on some FAA wind rules that were developed for their vortex advisory system back in the 70's, which says that if you have a headwind of twelve knots, a crosswind of 5½ knots, if the wind is bigger than that and you get an ellipse from that, that it's outside that ellipse the vortices will blow away within 80 seconds, 3 miles. Now that's considered conservative by the people here, it was good enough to certify VAS system in Chicago, as soon as it was certified it was shut down for reasons that are very contentious, but that's what we use as a criteria. We look at the wind each time and decide if you're outside those VAS limits and you're not VMC1, where you've got shorter separations anyway, then you can use those separations, so each time the delay model does that. So there's a separate set of curves for AVOSS. Numbers, I apologize for this, I tried ten times this morning to load this spread sheet into this model with getting the left end or the right end, but I couldn't get both ends. These are basically the cases. This is the HUD GPS, or HGS. These are all the basic Autolands, SVS without a HGS, with, EVS, pathway-in-the-sky without and with, and ultimate. This was based on Dallas, what we use for Dallas; it's a 7-mile common path. These are the uncertainty numbers for speed of an aircraft. He's concerned with the airplane in the last 7 minutes, the average speed of the aircraft in the last 7 miles. That includes all his transition to approach, and there's uncertainty depending on the airplane's weight, and since we're talking about 'heavies' as one class, they've actually determined in simulations here that can vary by 20 knots for heavy aircraft coming into approach. So, the standard deviation for that's about 5. That's what the controller has to deal with when he's got two airplanes to separate. Out there he can have a 5-knot uncertainty so he has to basically make sure, even with that uncertainty, he doesn't violate his separations. Position uncertainty is about what he's got now with his radar, and one of the problems in TAP was, "I've got GPS. I can do 100 feet." The problem is on his scope, which he's controlling from, he doesn't have a clue, you know he can tell them 100 feet but his dots still look the same size, and he doesn't have any better information on that. So, you really can't take advantage of it unless you have something like Active Final Approach Spacing Tools under CTAS, which give him actually "turn here" commands or speed commands based on the fact that the computer knows his position more accurately. Eye-balling it, it's hard for him to decide to take advantage of that kind of information. This should be 7½, I forgot to change those this morning. There are some technologies that allow that to be smaller. That's the wind uncertainty between two airplanes flying 3, 4, or 5 miles apart. What kind of wind do they experience on that final path? One guy hits gusts and the other guy doesn't, it affects how fast he flies. So, that has to be built in. This one here, one over lambda, is a buffer to accommodate the fact that the guy sets up, he's says okay here's this guy, I want the other guy behind him, but there's no guy because of errors in the TRACON, errors from the Center, other buffers that say I wanted him but they didn't get the whole string there on time. From Ballin's [Mark Ballin, LaRC] data at Dallas, quarter-mile is about what they were looking at. Pulling that out of there. Some of the things like Passive Final Approach Spacing Tool with CTAS, when we were doing TAP, couldn't get that to be smaller because it helps the controller in the TRACON and the Centers load guys in better, get them on the better runways. Ultimately, FMS CTAS coupled could get that much smaller. I only have dug this out for the Dallas data, and one of the uncertainties, and probably doesn't make much difference because it's not going to change for any of the technologies, but just as a basic accuracy issue is when you have an airport, Dallas is a particularly difficult airport because a lot of runways and the posts are far away, and there are a lot of options to deal with, and you're bringing guys into a complicated airspace. When you have something like San Francisco, where you either shoot this way and you catch this way and everybody comes in on a line. I would think you might be able to, just this may be smaller at places like that, where the approach is simpler, or at Los Angeles, where they can line them up for a long time, they bring guys in to fill those gaps. So, that parameter can be different. The runway occupancy time, like I mentioned in, the conventional wisdom of the runway occupancy time gurus over time, is that when things are really low visibility, you get a 20% penalty, and that's applied. Except, now if you have something like RIPS which does have that, inherently has the roll out and turn off features to it, we believe that can turn into a, you can get that down to about 100, to the normal dry runway ROT'S. Now, we're not considering ice, things like that, that are really going to affect you. But it's presuming that in most heavy weather conditions it's water. Now people have talked about sand and blowing snow, and things like that, rubber, light rain raising up oil and rubber versus heavy rain, but the airports we have are all the major airports with crowned and grooved runways and stuff like that. So, that's what we're using here. That's true for anybody that's got RIPS. Down here, the last one, are the separations that you use under different conditions, and like I say, at the end we'll talk about what these are. This is basically FAA 3.0, is the FAA regular 3, 4, 5, and 6-mile spacing matrix, where I use 3.0 because that's the minimum. Under some conditions if you can demonstrate less than 50% average runway occupancy time, and if you've got 2-mile visibility you can see the exits, the minimum drops to 2½. Which is why you will see FAA 2½. That means, in the matrix where you have a 3-mile separation, like large behind large, they can do 2½ miles, and they do 2½ miles large behind large. That's what their minimum separation is. If they can certify, which they have at Dallas, that the average runway occupancy time is less than 50 seconds and you can see the exits, and there's a couple of other parameters, certain things are functional. If you can, and this is one of the features, as soon as the runway is wet, as they can see water on the runway, right now they revert to 3.

Jeff Cooper, American Airlines (APA) - I know what the plan is; I know what reality is. For my 10,000 hours, secure is 3 miles, 2¾ miles is my minimum even behind a small jet, because I may have to go around them, and that's what is in the forefront of a pilot's mind. He may not, he makes one mistake, the guy on the runway in front of you makes one mistake, misses his high-speed turn off or miscalculates in any way he will stay on the runway an extra 15 seconds, and I will go around. So, 2¾ miles is my minimum for me and my aircraft, my approach speed. What I'm looking at there is 3.0, 3 nautical miles and 2.5 nautical miles, I just want to bring about, or inform you, that those are extremely tight and extremely conservative if you're trying to prove throughput on a runway, any runway. The distances are greater in the real world.

Hemm - The distances actually measured will be greater, because this is the minimum that you're shooting for guaranteed that 95% of the time you do not violate that distance. So, when you add these uncertainties over this distance.

Then you go with standard.

Hemm - Exactly. These are the rules that he has to follow. And it was a big breakthrough, I don't know how many years ago, when a big move to get 2½- mile versus 3- mile separations. I have not seen, by the way, part of the data I haven't seen, I'm sure it exists just I haven't seen it, is data showing how things how they really migrate when you switch this. It's not clear that controllers really change their behavior much. Some places like Chicago, the Chicago "Three", you're 1½ miles from him and he's 1½ miles from you. So they've got 3-mile separation! Not to doubt anybody that flies to Chicago. Or the other one is, I can give you 6 miles behind the 747, but there's a DC10 between you and him. Next, those are the capacity model input parameters. Next are these, and this is where it gets interesting. It's a break time.

BREAK

SVS CONOPS Workshop

LMI Cost Benefits Presentation And Discussion

(2nd Session – After Break)

Friday Morning, February 25, 2000

Kostiuk - I commented earlier that we really milked this chart. I don't think we actually zeroed in on exactly what it is that we want to do with this operational benefits analysis. Listening here, a lot of these different technologies, and I think it would be useful to go back and re-address this issue to try and clarify what you think is in the current baseline within the fleet. What would be in the 2005 baseline, such as the RNAV capabilities, and so on. And then, discuss what functionality that those capabilities would give you, and then see what, in addition, you would get from an SVS system. Sort of running on the fly here, but we were thinking about in terms of the current state-of-the-art baseline. You sort of have your analog aircraft capable of doing CAT 1 approaches using the ILS. A lot of aircraft out there without the flight management system and without GPS. [Slide modified to show CAT 2 ILS capability.] It's sort of a gross characterization of the current fleet. Now looking ahead to about 2005 with the systems that are in some of the more advanced aircraft now, the new ones that are coming on line. It is that you're going to have DGPS, Autoland systems, flight management systems, and you'll have improved navigational capabilities. This would roughly get you to about CAT 3B is our guess on that. Should there be any additional capabilities in here, some additions or subtractions?

??? - Enhanced ground prox. [Other background comments.]

Saylor - Frankly, 2005 is probably too soon for differential GPS, but is a positive navigational requirement for SVS. It’s got to be there. I think we should probably put something in there, some way to acknowledge the FMS/VNAV approach capabilities. It's not all a lateral NAV issues; some are vertical NAV issues. I don't know too much about Airbus, but in Boeing products if you look at FMS capabilities on the order of Pegasus FMS or V10.3 or V10.4 as a reasonable state-of-the-art in delivered equipment, that's kind of what we can do now. So if you went back and actually dug through, what is Pegasus and what can it do and what is 10.3 or 10.4 and what can it do? That’s probably about what you need to assume.

Leckman - I think you're… adding to that a little bit. I think you're looking at almost eliminating non-precision approaches and having straight-ins to most of the runway ends, supplemented with GPS, and so you're getting near CAT 1 minimums with just LNAV/VNAV using RNP concept. If your differential is added to that, that's going to bring the minimums down because the RNP can go an order of magnitude lower. There is also the possibility that, where an airline chooses to do it, you could have GLS merged with the RNP concept.

Dillard - What's GLS?

Leckman - That's GPS Landing System.

Kaiser - Again for baseline, Paul, a lot of them when you're eliminating non-precision's they'll just be using overlays. So they'll still be a little bit above CAT 1. Because it's still… there will still only be a few of us out there designing our own procedures and really taking the airplane capability to its limit.

Dillard - And they're putting out new non-precision approaches, which would be constant angle non-precision's. They're coming out on the plates right now, so they will be standard operations soon.

Simon Lawrence, ALPA - But the Airbus, the brand new Airbuses now, they only do ILS's and VNAV's, that's all they do. They do not do non-precision approaches at this time.

Leckman - Boeing's moving the same way.

Saylor - You'd probably benefit in that discussion sitting down with AFS-410 discussing where they're going with their plans for RNAV RNP and VNAV approaches and non-precision approaches and incorporation of RNP concepts in advanced area navigation and local navigation concepts into the public domain, where it exists in the private domain mostly today. There are efforts underway to go public and make that available to everybody that chooses to properly equip for it, and that's going to define the, between 5-to-10 year term state of the art.

Leckman - Those are fairly easy but a lot of airlines have that equipment already and are getting that on all their new airplanes right now.

Dillard - Since you made a comment earlier that you weren't considering data sources like the ADS-B or Data Link or Database or whatever you aren't putting a value on whether those are available or not. Is that correct? Traffic Information, TIS, those things?

Hemm - Yes, yes and no, yes.

Kostiuk - If that would be some database or information that would be fed through an SVS system to provide you with some functionality.

Hemm - It's in there. Where it shows up is what minimums can you fly? If I'm getting TCAS data which comes in at the data rate that we're getting it from … the data rate and accuracy if you're getting it from your own little secondary radar at whatever scan rate you've got, versus ADS-B which is getting it from DGPS accuracy data, broadcast very frequently. How does that affect what category, what precision, what separations you apply? That's in there. So, particularly in the head-down case, right now as it sits on that piece of paper in our thinking, that's got TCAS, while once you get HGS and you've got GPS and you assume everybody else has ADS-B you've got some higher level which would justify you've got more accuracy about other traffic. So, you will do things when you have less visibility.

Abramson - But I think you need to put those in your baseline, CDTI and ADS-B, somewhere between 'B' and 'C'. Those are you're competitors, if you will, for some of the self-spacing ideas.

Leckman - Somebody needs to take a good guess at how many airplanes are going to be ADS-B. Whether an airline might choose to solve a problem at, say a critical airport like San Francisco, by equipping their whole fleet with ADS-B. An educated guess, at least.

Kostiuk - At least at this stage in the analysis, I think we'd like to avoid getting into some of those mixed equipage issues so you can sort of do a… step one is let's do a side-by-side comparison. So, the proposal on the floor right now for your approval/disagreement is, for this 2005 baseline, is this a reasonable depiction of what we should assume that the state-of-the-art aircraft would be? Then we would use that as a baseline to compare an SVS-equipped aircraft to this.

Captain Skeet Gifford, United Airlines (retired), Lockheed Martin, LaRC - I don't understand how, where category 3B falls into this because almost 20 years ago the state-of-the-art included airplanes that were certified in category 3B, and so this is not new stuff. Lockheed L-1011 was a full CAT 3B certified airplane. I don't see CAT 3B up there as 'state-of-the-art'. I don't know why it was changed to 'A' up there.

Kaiser - Well, I suggested that because the very top of the chart is based on it. The idea is, so what's the bulk of the fleet?

Hemm - If you don't have autoland you aren't state-of-the-art.

Kaiser - For me, 'state-of-the-art' baseline, there is a little bit of a disagreement there. I mean, because it's like, there's a couple of the airlines that are 'B' right now for most of their fleet. Not many of us though.

Abramson - But would you change that with an SVS or is that a business decision?

Saylor - It's all a business decision.

Kaiser - No, I understand that we're really talking about 'state-of-the-art'. What you're really… maybe take 'state-of-the-art' out of there. Just say the typical fleet is what you're talking about.

Saylor - So change 'A' from 'state-of-the-art' to 'start-of-the-art'.

Hemm - The problem I'm dealing with is, today I've got a state-of-the-art airplane that is an Autoland-equipped airplane that can do CAT 3B. I thought, my guess was 25% of the fleet had them. Talking to some people, or Dan queried some of his folks, he says he would have guessed 30% because some airplanes have half, some airplanes have nearly all, some airplanes have 10%, and it's airlines, not airplanes, sorry. So, that's one. Now the baseline, what's the rest and what can they do, and how many of those are there going to be in 2005? If you assume there's going to be a lot of those in the future when this is coming in and want to do the analysis, then you have to add those guys and you have add these guys, and you have your guys. It's much easier to presume in the future everybody's going to be 'state-of-the-art' and it's only 'state-of-the-art' and your guys. I'll be glad to do that. But that's the problem we've been trying to wrestle with.

Gary Livack, FAA - You know, it's interesting you're focusing on certain functionalities of the displays. I'd be interested in your data bus and it's functionality aboard the airplane and what the throughput of the different data buses would be.

Hemm - My assumption is that the technology will have the adequate data buses. I have no other way, I'm not getting into 1553 or whatever data bus you're using - fiber optics... I don't know. NASA's going to have to deal with that as to what's inquired. Is it a major retrofit? Good question.

Kostiuk - That's a research and engineering issue. What we're trying to do here is identify some benefits and perhaps that gives you a cost OB or whatever type of retrofit of forward fit objective in order that you have to meet to make a business case.

Dan Baize, LaRC - Okay, I think we're close on ‘B’. Now is ‘C’ worth doing?

Saylor - You've got a major thing on ‘C’ you need to change. ‘C’ shouldn't be ‘B’+ HUD it should be ‘A’+ HUD.

Hemm - I don't know that.

Kaiser - You have ‘A’+ HUD right now out there. I think if you're looking farther down in the future we are talking about ‘B’+ HUD, the highest HUD capability.

Saylor - Well, there might be airplanes, I hope there will be airplanes that are ‘B’ configuration plus a head up display, but whether or not there will be additional capability there we're very hopeful, but certainly you've got to acknowledge that just adding a head-up HGS to ‘A’ takes you to Category 3A. So, you've got to acknowledge that there is already technology to go to 3A with an ‘A’+ HUD.

Baize - We've already got your 3A case, what we're trying to do is run baseline cases where we can look at deltas. We already have a case that covers all of 3A capability fully. So, we'll pair SVS equipped to that, so if adding the HUD to ‘A’ only gets you back to 3A which is case ‘B’, then we don't need a new case. There are a lot of intermediate cases we could run. The question is, does adding a HUD to the 2nd baseline give you additional capabilities that we need to then compare back SVS which also be pointing to SVS plus a HUD which gives you an EVS or some different capabilities. So, we're trying to think ahead, what are the deltas at the end of the study that are important.

Hemm - Oh, let me ask this question: folks that have equipped with these things, have you equipped with, and I apologize using HGS because it's different than dumb HUD, smart HUD, have you equipped with your smart, capable HUD, on planes that have Autoland already and the rest of the capability?

Kaiser - And the additional capability there is takeoff.

Hemm - Is that the experience at Delta too?

Saylor - At Delta where we… because the product was already built with the CAT 3A capability (not autoland) and monitors, and so on, to do it. So, for the 3A airplane is going to be equipped with an additional parallel, if you will, 3A HGS system. However, I think we're the only airline that I know of that's aggressively pursuing head-up displays today for 3B airplanes for fail-operational 3B airplanes. Our current position is that, if we buy that HUD, it will not be a CAT 3, independently CAT 3-capable HUD. We won't spend the extra to put CAT 3 in the HUD if we already have 3B fail-op. system head-down. We see HUD primarily as a safety issue, not a minimums or planning issue, so in 3B airplane it may not be independently capable of a CAT 3 approach. It probably won't be.

Kaiser - And to further confuse the issue, we have program goals using a hybrid 3A HUD + 3A Autoland to go to 3B.

Baize - So, it sounds like you take a third case which has at least 3B and has lower takeoff minima, is that what I'm hearing?

Kaiser - Well, your 'C' is a 'B'+ HUD. We're the guys pushing the envelope, but you know, as we like to say, we never met a technology we didn't like. Put it on and try to get something from it.

Livack - Comment: in the Task Force 3 final report from RTCA, there's a section called "the well-equipped cockpit in the year 2000", and maybe cross out '2000' and say '2005'. That gives you a little bit of insightfulness as to what 242 people had a consensus position on three years ago.

Kramer - Could you repeat that paper name, what was that from?

Livack - Yeah, it's from the RTCA Task Force 3 called the "Free Flight Report", and it's dated October 26, 1996.

Leckman - When your looking at deltas down there on your 'B' state-of-the-art, you have differential GPS. There are no, well very few, differential stations. One of the things that will directly affect the minimums, by way of directly affecting RNP, could be whether or not you're using differential and how much is it worth in terms of dollars to the airlines to have differential? That could be a valuable outcome of your analysis. In other words, using differential you get lower minimums, you can taxi around on the airport under low-vis conditions. How much is it worth? Would it be worth putting in a differential station at that airport?

Baize - Well, but that's not the purpose of this study, fortunately. We know we have to have differential for SVS so we're trying to do…

Leckman - Not necessarily, we have enhanced ground prox right now that shows terrain on a map display without differential.

Kramer - Synthetic vision includes ground operations.

Hemm - It's database driven.

Livack - We just, we're in the process of operationally approving in Alaska the MX20. It's received its STC for Terrain Situation Awareness, which is SVS in a conceptual sense, and we do not have differential with that.

Dillard - But in the application you guys are talking about, you're going to need it.

Livack - Oh yeah, for the level of accuracy and functionality here we'll need… in fact for two of the Safe Flight 21 surface movements they've tentatively concluded GPS/WAAS is sufficient. But for the low-RVR SMGCS Flight operation or A-SMGCS … you will need differential GNSS with LAAS functionality.

Baize - We're trying to be fair. We're not trying to get the benefits of differential caught up into the benefits of SVS. We'd love to, but we know the benefits are there.

Abramson - Do you also need a baseline definition for what's on the ground? Either for air traffic control or maybe RIPS or something?

Hemm - Yes, well we do. A couple of things we need. One is whether you've got today's air traffic control system, whether you've got passive FAST, CTAS Passive FAST or CTAS Active FAST. Those will affect those parameters in the capacity model. So, we've chosen one: current technology. So we could presume that you're going to have PFAST or AFAST. But for this analysis comparing these things it's probably just as well to use it, as we aren't dealing with parameters that change those much. It will give you more capacity, but the relative change is not much.

Saylor - Outside of the capacity problem, I think he brings up a good point, because we talk about some type of difference between the availability of CAT 1, 2 or 3 approaches, is the approach lighting system and runway lighting system and the SMGCS system, and to the extent that some of these concepts apparently, especially on the ground, could replace, or render SMGCS irrelevant, or other portions of the total airport lighting…

Hemm - Well, that's exactly right.

Saylor - You may have to factor those in. That might be where SVS starts to pay off, because it doesn't matter what the airport does if the airplane compensates for it in some respect.

Leckman - Yeah, that's a good point.

Hemm - The… in the delay model that's exactly what happens. If you can do CAT 2 operations to all existing CAT 1 runways you get the capacity for the CAT 1 set, but if you don't, you only get the capacity for probably the single CAT 2 runway that's operating at the airport. So, in one case the guy's got parallel runways to come into and the other, guy's got one. The presumption there is that there is no additional lighting. If you've got some enhanced vision or some particularly RIPS that allows you to satisfy the FAA that you can navigate without on this CAT 1 runway then under CAT 2 conditions we're presuming your equipment is going to be what does that. We're not presuming they're going to build new lighting to facilitate this for you.

Abramson - You have to look at the cost side. You can save somebody some money by doing this instead of putting additional lights in.

Hemm - It's kind of like Juneau or places like that, that allow you to do even CAT 1 conditions where you just don't have that kind of stuff.

Gifford - I think part of the confusion was in the use of your term 'state-of-the-art', because what you're, if I understand it correctly, what you're describing is the average capability, but you use the term 'state-of-the-art'. So, to clarify this disconnect, would it not be more correct to say an average fleet capability or something like that. Because the 'state-of-the-art', you're not talking start-of-the-art, you're talking throughout the average fleet.

Kostiuk - Basically what we're doing there is defining a current baseline. We want to define a 2005 baseline.

Gifford - I fully understand that, but you use the term 'state-of-the-art', but the discussion is average. Do you not think you should say to change the state-of-the-art to average capability for baseline?

Hemm - I would say 'installed'.

Gifford - Yes, I agree with that, but it’s certainly not ‘state-of-the-art’.

Baize - But it's nowhere near average if you want to be technical. Over two-thirds of the fleet are simply analog, so and that's not going to change a lot.

Hemm - I would be glad to agree, glad to say by 2005 everybody's got autoland. That's the installed baseline. And if it doesn't have any impact on the delta of the parameters…

Kostiuk - We need to move along here…

Kramer - Maybe you have percentages in each one. For now it's 66% and 34% and then maybe in 2005 it's 60% and 40% and then the next one is whatever. Would that help?

Hemm - Yes, but that's kind of what to agree on and the number like you said, the numbers I thought… Half the guys in 2005 are going to be analog and half of them are going to be either technology, you know some technology, or today's…

Kostiuk - But can we conclude that for purposes of the analysis that these would be the two baselines that we would use to go ahead and then evaluate what SVS would give you on top of those.

Abramson - Where are CDTI and ADS-B in this? I think you need that somewhere, because I think it's going to happen.

Kostiuk - I don't think it goes into the 2005 baseline though.

Dillard - It's not going to replace TCAS.

Hemm - Yeah, you're never going to get self-separation.

Abramson - That's right. But other competing solutions are trying to get it.

Kostiuk - What we've got in this baseline, things that are being fielded in the latest generation of aircraft, there's a reasonable expectation that they will be out there in large numbers in the year 2005 or somewhere around there. I don't think that would be the case with the CDTI at this point.

Saylor - It's pretty simple, I think. If you're going to claim a benefit for self-separation concepts, then you've got to put in ADS-B to drive it. And if you're not including that then you don't have to take that cost.

Hemm - Ok, let me, yes exactly, we're presuming, I'm presuming even with the SVS database head-up with a HUD guidance system and RIPS that you've got ADS-B running probably. Certainly the ultimate when you're talking about self-separation…

The question I have is, other than SVS with ADS-B, are there other technologies that will allow self-separation? Does anyone have a self-separation package of other technologies besides this?

Cooper - CDTI?

Hemm - CDTI is necessary but not sufficient. You think you can do self-separation with CDTI?

Cooper - Absolutely.

Hemm - So, I mean, self-separation I'm talking about on approach the controller says the pilot accepts responsibility for separation on approach.

Cooper - Yes, CDTI can do that now, that's what it's for. Gary, what is CDTI using right now?

Kostiuk - Now we want to start taking a look at some of the future SVS technology packages. What capabilities would go into that?

Livack - I have a couple of key comments. One key comment and one detail. There are three sets of emerging technologies that you didn't address in your 'state-of-the-art'. It may not be 'state-of-the-art' with a 50 percentile equipage. But we have the CPDLC for clearance system instructions, and safety services. Number two you have FIS-B which primarily, right now, advisory services, weather, aeronautical data, and I'm not sure whether non-aeronautical data will be advisory or safety. The digital ATIS right now, altimetry - do it twice as a safety maneuver. The last thing is the ADS-B/FIS-B infrastructure. Now, as you list right in this slide… SVS, ADS-B, or whatever… the word I think of is mission creep. I don't know what the consensus of this group is, but when I drove down here two days ago I said, SVS, Synthetic Vision System, that is terrain, it's oriented towards the database. I waffled a little bit because enhanced vision is a sensor, like FLIR or Millimeter-wave Radar. I'm now leaving, it looks like SVS is 'the world', and it includes ADS-B, you have their weather, you have other, AVOSS, I wonder is that really what you mean? AEEC defines this functionality to be a cockpit display system. Archie Dillard over there is working on a multi-function display. What is the scope, and is that consensus position of what the SVS AvSafety Program activities are? I'm uncomfortable as to your scope.

Baize - That's the purpose of this chart is to discuss that. That's the relevant question.

Livack - Where does AWIN fit? Does AWIN now report to SVS?

Baize - (Joking) Of course! No, later in the program we'll be looking at how to integrate AWIN information onto the SVS cockpit display. Again, just like the differential GPS we don't want to get deltas based on non-core SVS technologies. However, if we were to do SVS without a lot of these technologies… It would make no sense to do SVS without CDTI and the others. You have to be very careful; this is why we want your opinion. This then defines the results. This assumption totally drives the eventual benefits or lack thereof.

Abramson - How do you handle those same technologies underneath SVS-‘A’ without SVS? See that's the real dilemma of the baseline… How do you fairly treat… you say "SVS means this", there's another group that does all that without SVS… Is the difference the database and the display?

Livack - And I would see AGATE and SATS as now being part of SVS because the highway-in-the-sky is being developed as a piece of general aviation implementation. So now, AGATE and SATS are part of SVS. Is that what you intended?

Baize - Actually let me clarify with AGATE, they have highway-in-the-sky without terrain. SVS is adding terrain capability to the AGATE highway-in-the-sky. SATS is still a display monitor.

[Lack of sound clarity in original videotape because of tape change]

Hemm - By the way, that was a major part of the discussion in our group yesterday. When we talked about the benefits, the kind of benefits we talked about, what kind of minimums you fly, even some of the enroute stuff... Once you posit a set of benefits for synthetic vision with the equipment… part of the equipment package comes from the experiments that have been done. Somebody demonstrates this is what SVS does, well it's got synthetic vision. But the guy also had a datalink. He also had these other, heads-up display or heads-down display, so your baseline for thinking about it included those things in the package. So that's kind of your point of departure. But the argument was you could get that performance with this, or you can get that performance with pathway-in-the-sky, or you could get the performance with enhanced FMS that we have today. That's a real question for us.

Kramer - The performance, operational performance might be similar or the same. But we're saying SVS is safety and capacity of operations. Maybe that's the difference between SVS and this other capability that you don't get greatly enhanced situational awareness and integration of information all through one or two displays, tactical and strategic.

Hemm - And safety, you're playing, particularly what you playing is what are your odds of getting certified to do these things? And it may be that you need an independent safety feature or the independent features or whatever features that you get with SVS versus doing it the other way.

Livack - Can I comment on that key word before we lose it? What are the odds of getting certified? Somewhere in your process off-line you need to have another work group on certification. Instead of using the word ‘odds’, do a functional hazard assessment and operational safety assessment, some risk mitigation strategies and have a process that would lead to whether or not you need any MOPS or MAPS from RTCA. So, those ‘odds’ of not getting certified are mitigated by a process.

Boucek - What I know I would like to see added to the 2005, there are 2 programs very close to… starting the certification process on the Vertical Situational Awareness Display (VSAD). Both of them are using the same platform as the enhanced ground prox so it would be a fairly smooth technology transfer to get it onto the retrofit airplane.

Dillard - You said two, what was the second one.

Leckman - Two VSAD's.

Kostiuk - All right, let's move on and continue this discussion about what would go into the future SVS system. Just, where we stand here. I mean we had this 2005 baseline which basically gives a CAT 3A landing capability. So, the question becomes then, if you start taking a look at SVS added on top of those systems or perhaps on top of the current baseline what additional capability do you get on top of that? Do you match that? For instance, the 2005 baseline that gives you that CAT 3A capability, but none of those systems give you very good taxiing performance. You still have some safety and operational issues there. Whereas some of the SVS systems, such as RIPS, would improve your ability to taxi safely and efficiently.

Williams - I was going to mention TCAS wasn't on that list, and that's something we would like to add to the list.

Kostiuk - What I think I would like to do, just taking a look at… here… for future technology of the SVS system, we've got the ADS-B listed on here, and being transmitted through the CDTI. You've got a taxi map. I think this is the look-down one here. You have the cockpit weather coming through. Then the last hash mark is AVOSS, which is some type of wake vortex detection and prediction system. So, that would be one candidate set of functionalities that would get fed through the SVS system. The question before you is whether this is a reasonable set to either add or subtract from. Then secondly, what type of additional capability in terms of an operational enhancement would those systems provide you? We had a lot of discussions about that yesterday.

Livack - Instead of using weather, use FIS [Flight Information System] to do weather/aeronautical data. Weather is just weather. Aeronautical data includes NOTAMS, volcanic ash, and radiation hazards…

Kostiuk - It's sort of undefined at this point and there are a lot of things that we could put in there. Exactly what would be presented I'm not sure.

Baize - What I was trying to capture with that one was a tactical icon of windshear or some sort of tactical hazard indication based on the FIS data.

Livack - Well, RTCA includes, has a … MOPS as the air data potentially air-to-ground could be enabled by ADS-B air-to-air exchange of winds, temperature and turbulence. So you could do some computations. So, weather is, you know, a multitude of products. Once again, that's an AWIN activity.

Parrish - It's probably no further off than AVOSS.

Dillard - Why don't you just call it aeronautical data to include weather and all this other stuff?

Abramson - Because I think you needed those automated NOTAMS to come into this so you can update your database. So, closed runways or hazards on the runway will be there. So you need to include it someway.

Kostiuk - Following up on some of the operational enhancements, certainly from the taxi map what you get from here would be improved performance once you get off of the runway when you're allowed to land. Remember some of that lengthy list that we were generating during the workshop breakout sessions yesterday of additional benefits that you get, or potential benefits from SVS.

Dillard - What's the R-O-T-O, is that ROTO…?

Parrish - Roll Out and Turn Off.

Hemm - Reduced Roll Out and Turn Off.

Abramson - I presume you have a datalink for that.

Hemm - If you have a CDTI you've got to have a datalink. Flags are tough.

Kostiuk - Yeah, I'm not sure what would be assumed on data link, or what messages are going to be passed back and forth.

Leckman - An example of datalink would be the cleared taxi route on the taxi map.

Baize - The question I have, does it serve, you know, people that were adding in the rest of those capabilities to get a delta, is that fair to do? Or should we at least have a case with none of those capabilities and then we have a more integrated case on the type of full functionality that we believe will be there? Do we need to pick up the delta for just the perspective terrain and that is the unique feature?

Parrish - But there's no way you would implement just that. You've got to have stuff that's not in the database. You've got to have surveillance information.

Baize - Well, it's true. I think it's true for this category, but for GA maybe? That's all they get. It's not really fair to apply it to this model.

Abramson - Well, in theory it doesn't matter if you pick up the cost of those. To claim the benefits of them, you've got to claim the cost.

Saylor - You can pick up any other technology you think is necessary to implement the functionality you want as long as you include the cost of it. That's fair. In fact that's necessary. It's clear you can't do the taxi without some kind of an ADS-B like functionality. And you can't even do without CPDLC to transmit the taxi clearances. So, if you're going to posit that application and any benefits from that application, then you have to include the cost of adding those other things to make it all come together.

Abramson - Those are not your program costs really, because other programs do rely on ADS-B. It's not clear.

Livack - What this is turning out to be, independent of enabling technologies, is a cockpit display and integration. Russ Parrish is right. You can't do SVS without these other ingredients. The question is, like SAE-G10 working on the multifunctional display on the VSAD display, how best do you integrate and display all of this stuff? NASA Ames is doing beautiful work on conflict detection resolution and the strategic conflict de-confliction at the higher altitudes. Now you've added terrain and obstacles and moving maps and whatever, what are you going to get out of it? How will a pilot… Will we have to interpret? Will you have to use automation? Is that what you mean by SVS? Is that the scope of what you want to do, a totally integrated cockpit the twenty-first through the twenty-second century?

Parrish - Are you asking Dan? If you're asking Dan, he's going to say yes, because as a program manager he's going to encompass everything and absorb everything that he can. As long as the budget holds up.

Baize - It's a matter of when.

Livack - You have to crawl first, then walk, then run. You can't try to do everything at once.

Leckman - You have to picture where you're going to end up, and you need to have this system capable of doing these things. Maybe they won't do everything right away, but at some point when the demand comes they'll be capable of doing these things. The airplanes that are capable of doing them will have more economic return than those who can't.

Abramson - I would think somewhere in your back pocket, maybe never to see the light of day, you need a case where you have all of that technology without SVS, display technology, database and with it, to get that delta. Assuming all those other programs go ahead, and milk them for whatever they can, what's your delta? I think you're going to need that sooner or later.

Kostiuk - You also need something to get it onto the airplane, though. Otherwise you don't get a chance to crawl so you can run later on, that's why we had the panel discussion yesterday. You know, what would be the most likely area of flight to sell SVS onto the airplane? Two out of the four said the ground operations. So, maybe if you pick the terrain database and RIPS or something like that, that gets it onto the airplane. That might be one of the analyses to do.

Saylor - There's another side to the 'crawl, walk, run' theory, and that's that for the airlines it's prohibitively expensive to crawl, walk, and run. In any given modification to the cockpit, half or less of the cost of doing it is the cost of the actual hardware. The rest is down time and NRE [Non-Recoverable Expenses?] and all those other less tangible things just to get the project accomplished. So, typically the airline isn't going to even bother to crawl or walk, they're just going to watch you do it, and when you've got run ready to go, that's when we'll buy in. So, you're probably going to have to crawl and walk in a research airplane and in the simulator, and so on. When the thing's ready to rock-n-roll and deliver big benefits, is when the airline is going to come on. Nobody's going to buy a synthetic vision or artificial vision system, with terrain data just to see it, just because you can. It won't sell. It's going to have to deliver benefits and when we're talking about CAT 3A or B or C and all that, we're way down on the tail of the curve on operations. Benefits don't get all that big too fast. So, the airline's not going to buy in just to see that pretty terrain. They're going to buy in when that pretty terrain does a lot of good tricks and jumps through a lot of different hoops and provides benefits in multiple areas. So, you're going to have to crawl, walk, run but don't expect to see it in the fleet at every stage, because the user can't afford it at every stage. It's going to be so different from each stage to the next.

Cooper - Switching gears, I was unaware of a ROTO system you could use without a HUD. Dick, is there?

Richard Hueschen, LaRC - We haven't done anything on head-down. It's all been head-up so far.

Cooper - Well, I mean, necessarily if you're on the runway the pilot needs to be looking out the windshield. He cannot be looking down. So, I just don't see why ROTO is in a SVS 'A' block when SVS plus HUD is in 'B'.

Hemm - That's the point I've been asking about. Great experiments under the RIPS program, with a HUD, with heads-down displays. We did stuff in Atlantic City in real life with real airplanes. They did a lot of detailed simulator work earlier this year, with heads-up, with heads-down, looking at landing and hold short, looking at taxi symbology. They maintain they can do the taxi with the head down. They believe they certainly can't do the landing and hold short without heads up. They do not know from looking at the data, because analyzing the data, how much of the ROTO they could do head-down.

[Two people talking at once]

Cooper - If you can't do100% of runway operations head-down, then I don't care if it's 50, 20, or 30, you need the HUD. If it's point one-millionth of one-percent head-up, you need the HUD, for runway operations. So I say, ROTO is HUD and they're inseparable.

Hemm - Well, I'd be glad to say that, faced with people who do the simulations. And then you get others who ask what you'd be allowed to do, also, not whether you can do it.

[Everyone's talking at once!]

Parrish - Dick says we haven't ever done it. We've never… all the work he's done used a conventional PFD. We're not talking conventional PFD anymore. We're talking about an image that's better than what you get on your HUD. Now operationally you certainly want a guy head-up, so we would agree with that. But, the symbology on that SVS display head-down would allow you to do it. We've done it with the HSCT program where we had no forward window. Now, you can taxi all over the surface very accurately, and quickly, and safely without being head-up. Would you be allowed to? No.

Cooper - Taxi, I don't have a… I wouldn't be opposed to that. Really my emphasis is because at high speed things happen very quickly. It's so dynamic, that if you're not looking at your actual visual reference, be it 300 RVR, you know. I used to do zero/zero approaches in the service, and I had a window down by my foot, and that's how I saw the runway. I looked at the runway out there. It wasn't out here; it was down there. So, that's just something we did in the military. It doesn't really apply, but I'm just telling you the importance of this [i.e., his eye], because this is my primary balance. You know, my brain and my inner ear are secondary, and very subordinate to my eyes.

Kaiser - I just wanted to go back a little bit to what Greg said. It's been running around in my brain. I pretty much agree with him. Certainly a bulk of the airlines and certainly dependant on what the cost is likely to be for even fielding just a terrain-only display. But I can't quite go all the way and say an airline will not buy it just to get the terrain display. You have a cockpit that already can support it because you're looking ahead to that. In that it's priced lower than it's likely to be priced, maybe you can sell it. I can't go as far as Greg and say we wouldn't get it just for terrain.

Kostiuk - If there's a request of the avionics manufacturer.

Dillard - When you guys say terrain, what do you mean? Does that include airport maps and things like that? Or is that mountains, gullies and rivers?

Leckman - Terrain and airport maps should be easy to sell.

Kostiuk - Getting back to the chart here. We've got a whole lot of additional enabling technologies that would be included within, you might call this the ultimate SVS system, but maybe we'd also take a look at, you know, sort of like that what the minimal system might be, as well. In the 'B' here we have a SVS plus a HUD which would include the ROTO as we just discussed, and perhaps another package to include would be the SVS with HUD and the enhanced visual system. Any comments on that, or whether it would give you some additional capability that you wouldn't get with either of the first two systems?

Cooper - I think the EVS is really the domain of the military where they don't use the GFMS or GPS based navigation system because of jamming. Well, similarly they love their radar, they love anything autonomous, they love anything sensor, the millimeter wave, and so forth. I'm not sure, it's just my personal opinion that the sensor based is going to be limited once the database and the systems are robust enough and can produce the resolutions that really that sensors are going to go by the wayside in terms of 121.

Kostiuk - Do you need some type of EVS to get you through that transition, or evolutionary path until you have all the other things… everybody's comfortable with it?

Dillard - That's what I think. I think the EVS would be the interim thing that will get you to the database eventually, but you may have to have the enhanced vision.

Kramer - Well, the EVS handles dynamic situations, so that might be the case for it.

Dillard - You're going to have to have that to get into the cockpits.

Kramer - Or even in the low-visibility conditions.

Cooper - I'm just under the personal opinion that it's an impractical avenue to explore, just because of its limitation of technology.

Leckman - I would agree that it's not practical for airline operation based on what I've seen, not likely to be.

Kramer - The weather radar could be considered an EVS with some research we're doing, some modifications to it. So, it wouldn't be new equipment you'd put on there - maybe just added capability. So, that's kind of what would come in there as well.

Leckman - If it, the radar is something that's automatically done as a check in the background and says hey, what you looking at, is not valid and takes it away, then fine. But trying to interpret something that's very ambiguous is not very good for training airline pilots.

Baize - We essentially agree with you. The NASA in-house concepts originally did not include EVS even though some of our industry partner teams did. This year we were blessed with a congressional earmark of $3,000,000 to look at EVS technologies.

Cooper - I know why you're doing it. You have to disprove things sometimes to prove other things, and I just wanted to point out my opinion, that's all.

Abramson - It sounds like you won't be getting additional benefits. You may have to have this to do the SVS with HUD. But, it shouldn't be another level of benefits if you have it or if you don't.

Hemm - Looking at the minimums available, projected for both or talking to people about what they'd do with both, you aren't going to get anything extra.

Abramson - So, as a case you might not need it.

Baize - If there's no delta, we won't run the case. The question is: can the audience think of a delta that makes the case necessary?

Hemm - Your comments are particularly germane, can the audience think of a body of aircraft having just EVS as an alternative to SVS?

Cooper - Not 121. You won't find it… air carriers just aren't… The technology isn't there, integratability isn't there, there are many things that aren't there. Going to database information, it's far in advance of this type of technology.

Williams - What about business jets?

Baize - Maybe it’s important to several types of operations, at least to those who could certify it.

Parrish - Cargo handlers?

Cooper - North/ South polar operations?

Leckman - There are some advantages to EVS in terms of infrared at night, taxiing, seeing airplanes, seeing people, animals. I'm not sure it's something you need to get into.

Baize - The right case to run is EVS alone, I think.

Hemm - If it can give you any… and I don't think we predict any better benefits, we don't expect to see somebody just buying an aircraft with EVS. I'm glad to drop that one off.

Parrish - No, it's expected to get you lower minimums.

Hemm - Right, it will allow lower minimums.

Dillard - I wouldn't drop it off the list.

Kaiser - Yeah, I think it will be there on the fringe, I mean somebody's already got a HUD, and an analog airplane. There's a bunch of those out there still. Now, they can maybe get something for a lot less money than going to a full SVS system.

Boucek - If I can use the weather radar to detect runway edge lights and draw a wire frame of that runway and use a flare cue to get lower minimums, that's EVS.

Cooper - I would agree, I just think that what that gentleman just described, that technology would be obviated by what we seek to produce with the up-linked CDTI, airport map, ROTO and terrain depictions.

Dillard - I think ultimately that's correct. In our low multi-function display discussions invariably, when I talk to pilots, they're looking for something tied to the real world out there, and EVS comes up as a discussion point. They think, intuitively they assume, that there's some basis for this stuff in the real world. The dynamic case is the most dramatic.

Ken Williams, Alaska Airlines - Well, one peek is worth a thousand scans.

Kostiuk - Ok, I think we're coming close to wrapping up here. Bob if you could go back and get my charts from this morning. What I'd like you to do, once again we'll go through some of those potential operational benefits, keeping in mind these different baselines in the SVS system. I'd just like to one last time go through those and get your feedback as to what additional capabilities or benefits you would get from the SVS system that you wouldn't have from either of those baselines.

Livack - The third item from the bottom and the last item sound like, a lot like, ADS-B. [Referring to "Approach Phase" slide]

Kostiuk - Third from the bottom?

Livack - "Improved final approach spacing efficiency due to improved station keeping."

Kostiuk - Do we need some type of CDTI probably fed by ADS-B in order to enable that?

Livack - That gets back to the scope of what SVS is.

Dillard - If you can do it without SVS, with just CDTI.

Livack - The same is true for the last one. [Last slide item: "- greater throughput on closely spaced parallel runways."]

Abramson - The first one is the differential GPS. [Slide item #1: " - greater availability of CAT 1 runways"]

Kostiuk - I think the general pattern of the discussions over the last couple of days, or at least access to the airport during CAT 2 and 3 conditions, that there are some benefits there for SVS but there are other technologies that provide that capability. A lot of them in currently equipped aircraft and it's also relatively low frequency.

Leckman - Taxi on the airport, minimums for departure could be a factor… wrapped up in CAT 3 and CAT 2 operations. You've got to take off as well as land.

Dillard - Didn't you have a 2nd page that has those?

Kostiuk - Yes.

Leckman - I think SVS would help in those last two or assist, or help facilitate those last two, but the third from the bottom, the spacing, SVS is probably not absolutely necessary for it.

Kostiuk - There was some mention on the second bullet [" - Improved access to airports during CAT 2 and CAT 3 conditions."] here that even though under current systems you can obtain, you can do arrivals during CAT 2 and CAT 3 but because of the extra spacing buffers, because of the reduced runway and taxiway performance, that there is some loss there. Presumably with the SVS system integrated with the taxi map displays that you would be able to eliminate that constraint. Turn to the next page, Bob. [Slide, "SVS Operational Benefits"] Okay, they mentioned for the departure phase of flight they were looking at reduced departure minima on all the runways.

Livack - On this curved approach capability in IMC, the curved approach capability, the real benefit is idle thrust from top of descent to make the runway. And in some studies done under FTMI [Flight Operations and Air-Traffic Management Integration] by the FAA said, for example, you don't have to operate a 737/MD80 at 5 - 7- 8000feet for 5-7 minutes an average of 21 nautical miles per trip. And that translated to just a couple hundred million dollars that you could save in fuel costs alone for a curved approach. But it doesn't have to be in IMC. It's just basically the notion of doing a curved approach landing. If you want, I have all those files and all those findings.

Kostiuk - Okay great, I'd love to get that reference from you. I think some of the discussion is that they already do a lot of the curved approaches during VMC conditions certainly but also even during some IMC, but this would allow you to do it more frequently. There was some disagreement about that the other day on using it.

Kaiser - Yeah, your 2005 baseline airplane can do it without this.

Livack - That gets back to your Ops Concept. That isn't what I meant by a curved approach. I mean from top of descent, idle thrust to an extended final approach fix and then stabilized, from coming in from any direction. So, this gets back to we have to have a common ops concept on what you need and then apply your cost benefit analysis.

Kaiser - That's also available on the baseline 2000.

Cooper - The bottom bullet under departure phase and flight, reduced departure minima on all runways, did you want to specify VMC or IMC or, do you think reduced departure minimum are, or do you believe minima can be further reduced under VMC conditions? Do you make that assumption?

Kostiuk - Not during VMC.

Cooper - IMC might have been something to include in that bullet.

Leckman - On your approach phase benefits, I guess there's a question whether synthetic vision could be used to supplement some of the approach aids around the airport such as approach lights, create lead in lights to the runway, artificially, that could be 5 miles away from the airport.

Hemm - We are assuming with SVS, with heads-up guidance wherever you happen to be with SVS you can do your CAT 2, CAT 3 on all ILS runways. That means, there's some lighting on all your ILS runways, but there's not a good enough lighting on all your ILS runways. There's protected ILS capability on your CAT 2's but not on your CAT 1's. Things like that. There are surveys and certifications on your ILS for CAT 2's but not on your CAT 1's. So, we're presuming with SVS you're kind of independent of your ILS capabilities to the degree that between whatever guidance you get from them and what you see out of the system and whatever else you have from your GPS which you have to have for SVS, you can make your CAT 2 and 3 approaches on CAT 1 certified runways.

Boucek - I think what Paul's getting at is it's not just the ILS. The facility has to be certified as far as the markings and lighting, and you can create those markings and lighting to bring the certification up.

Hemm - Enhanced vision could do a similar thing.

Kostiuk - Well, you could, but I think we'll decide not to go into any more detail than our models and how we would actually implement some of these operational enhancements, but for anyone that's interested they can get in touch with us. We probably taxed your patience enough this morning on these slides.

Williams - We would like to give you at least the opportunity, if there are any holes in your data that, I mean, you were mentioning that it would be great to have a database that shows distances, in-trail spacing, that kind of stuff. What are those holes that perhaps our group can give you as well.

Hemm - VFR separations, visual separations are a big hole, and we've gotten a lot of feedback, but it's not enough.

Abramson - I believe that data, … distances are never too high, two-and-a-half that means, under any conditions, you'd never do it with a better system.

Hemm - You say that, but, you know, there are planes landing, as guys are taking off, one guy gets down and he rolls off the end of the runway and the other guy's right behind him. Runway occupancy times are 1 mile, or 60, 40 seconds, 35 seconds, 40 seconds. How far have you actually flown, has this guy flown while he's taken 30 or 40 seconds to get off the runway? It isn't 3 miles. It might be 2 miles, and the old FAA data says they think the average for guys under those conditions is like 1.9 miles. So, and you talk to controllers and I show this is VFR when these guys are in control, this is what the FAA said in these days, we're at 1.9 and 2.3 and they say that doesn't look bad. As I see these guys flying in there.

Cooper - That's fine, and I brought that up when I questioned 3.0 and 2.5. As long as you're going to pad the hell out of it with errors, I don't care.

Hemm - They're talking about actually touching down on the ground. This guy's off, the other guy's down.

Abramson - Is that GA or is that a big 747?

Hemm - Well, if you're talking to controllers in Chicago, it's mostly big guys.

Cooper - That is untrue. 10000 hours of experience back that up, and others in here will tell you that less than 2 miles is a pipe dream. That's very rare.

Hemm - OK, I take that back. It's the FAA 76. `88 is the when they reportedly collected that information.

Cooper - Best case minority, in my opinion.

Hemm - In the model, it actually backs it up. When you use that in the model it comes out to bigger distance, and actually that's always been one of the issues in our modeling, because while they report this as real data, we put that in as the minimum and it backs up.

Cooper - Why does it increase?

Hemm - It increases because the guy behind doesn't have, he's unsure of the guy's position in front of him and the guy's speed in front of him, the wind that he's going to have in front of him, and he's got to make his decision, we're presuming at about the same time as the common path he's setting up for landing and not screwing around with anymore catching up or falling back. So, at that point is when he's setting up his separation. After that, he's flying his plane and somebody's looking to make sure he's off the runway.

Kostiuk - Dan you were going to say?

Williams - I was just going to say, one last thing, the airports that they use, he briefed them the other day, there's only twelve of them that they have good data on, but if there are others that are interesting to you that you have some specific issues with, please let us know on that. Because that can be something we can continue to expand, but 'why' is what we need to know.

Dillard - Are there going to be copies made of the presentations or anything?

Williams - Yes sir, we're going to put them on, we have a web site called <postdoc>, and we'll publish them there. We should be able to distribute them to everybody.

Abramson - What's the full web address?

Baize - What you'll get is an invitation to join, because it is a password protected system. You're going to receive, via email, instructions on how to sign on the first time.

Leckman - Have you looked at the possibility of gathering foreign pertinent airport hubs, types of data? Perhaps they take a different approach to statistics. And have all of this available as well?

Kostiuk - I'd love to do some foreign airports.

Hemm - Yeah, unfortunately, well really, what they don't have is a lot of visual, at least in Europe. They don't do it. They have a lot of information on advanced controlling effects.

Abramson - Are you doing anything specific with the cargo fleet? As a…that's what Safe Flight 21 spends a lot of money doing. Is that set of airports and operators useful as a case, to see if this does it any better? Because they can do things without passengers, they have very different operations.

Kostiuk - That's a good question, but we didn't specifically look at cargo airlines or their hub airports.

Abramson - Memphis, Louisville…

Boucek - They operate at a different time of day.

Abramson - And it's a confined fleet. You'd get 100% equipage if you could sell them this.

Dillard - And they've got money! (Laughter)

Williams - We did invite both UPS and FedEx to this meeting. Both of them couldn't make it.

Abramson - But as a class of operations it might be interesting to see if we could do something about that.

Hemm - They show up as guys that don't have equipment. They are the guys without TCAS.

Leckman - They're the big pushers of ADS-B, which is one of the vital links to enabling technologies for this.

Boucek - I see a lot of emphasis on capacity. We did work on the Enhanced Situation Awareness Program. The delays were the main hook.

Hemm - Delay is what the… delay is the answer that comes out. The capacity model feeds the delay model. The answer that comes out is reduced delay.

Boucek - Okay, because 75% of the delay is 15 minutes or more all-weather, right? And, when you talk about those kinds of delays, as you mentioned yesterday or the day before, you have the ripple effect, 4½ times or whatever the number they're using. Plus you have a baggage effect and getting crews where they want to go effects, and all that.

Kostiuk - Passenger aggravation factor, too. Gary?

Livack - On that last bullet, you use 'departure minima'. Is 'minima' in your terms spacing or weather?

Kostiuk - Weather.

Hemm - And visibility. RVR.

Livack - In Louisville and Memphis, with the ADS-B, we're going to do reduced departure spacing, as aircraft depart. The clearance will be "cleared for takeoff when you have the appropriate departure spacing", and that way we'll be able to tighten up the departures, so we'll get increased capacity. That will be using the CDTI functionality.

Dillard - Well, you've got to remember they're not hauling passengers. They're not worried about comfort or any of that sort of thing in the back of the airplane, and that makes a difference in the way they operate their airplanes.

Hemm - While there are visual arrivals, there are no visual separation departures. They've got 3, 4, and 5 - mile separation requirements, and they either let them behind a heavy when they have minimum separation or 2 minutes. Controllers tell us they usually watch the separations on the radar when they release them.

Leckman - Seems like it would make a lot of sense to try to get these cargo operators participating. In the middle of the night, that's more conducive to fog than at other times. To be able to taxi on an airport in low-vis conditions could be very helpful there.

[Lot's of chatter]…

Kostiuk - We have another 2 or 3 minutes for any more questions or comments…

Livack - Their plan is to put the airport map, at what fidelity or resolution or detail I don't know, but the airport map would be part of their display system because they're going to do surface movement. FAA's going to integrate it with our automation for the controller, for runway incursions in Memphis, and the cockpit will have runway occupancy and then situational awareness on the airport surface in Memphis and Louisville. So, we will have a map on there. It will be a multi-functional display, not a CDTI.

Kostiuk - Last chance? Okay, I'll turn it over to Dan to wrap things up.

Williams - Just, thanks again for making the effort to come and we think this is pretty early, but good discussions on this stuff. The web site again, we'll distribute that invitation out, to get into that. And send us your after-actions. That would help us to compile an overall after-action. If it's something specific to your company you don't want to publish, but you think it would help us, that would be great. We'd like that.

About April we figure we should have a draft of this CONOPS out. Early April, and at that point we can make a determination of whether we'll have another workshop or something at that point. At this point I don't know, and then any other further contacts that you all know who might be interested in this, specific people, that's what we need. Any other further comments?

Baize - Well except that we… we are aware that FedEx and UPS are large users of this technology.

Currently we're setting up a meeting with FedEx in Greensboro, North Carolina, a future hub of FedEx, and we'll be briefing them shortly. Somebody's even kicked around the idea of a first certified use of synthetic vision in `03 in North Carolina, for some obvious reasons. The Centennial of the Wright Brothers.

Williams - Thanks, have safe travels back home.