Transcript of the
Joint FAA/Industry Symposium
on

Level B Airplane Simulator Motion Requirements

Part 6 of 9

Transcript of Day 2

Washington Dulles Airport Hilton
June 19 - 20, 1996

Transcript of Day 2

MR. BOOTHE: Good morning. I hope everybody had a restful evening. Secondly, as Frank [Cardullo] reminded me, I hope you did your homework. Frank [Cardullo] did his.

MR. CARDULLO: I wouldn't dare not.

MR. BOOTHE: Yesterday as we wound up we made some plans for today and part of that included the homework and I think we had more or less already said that we were going to look at the takeoff and landing where we think the most critical tasks would occur. But in order to really narrow our direction, I think Tom [Longridge] has had some thoughts about whether we could set a more defined objective; and rather than trying to relay that, I'm going to ask Tom [Longridge] if he could give us his need again and express that so that we can work towards that objective today and see if we can come up with some positive results in that direction. So, Tom?

MR. LONGRIDGE: Okay, thanks, Ed [Boothe]. First of all, I agree we should proceed to look at the motion requirements, map those against a certain subset of what we consider to be critical takeoff and landing tasks. We should continue to do that. My big fear is that at the end of the day we will not have defined a direction that will enable the FAA to achieve its cost objectives and we really are under the gun to do this, so this meeting that we are having is not simply an academic exercise, we are going to have to make some decisions. And those decisions will be targeted at doing something that will increase the accessibility of full flight simulators Level B for the community that I described yesterday.

I certainly enjoyed yesterday's discussion, it sheds a lot of light on why maybe we don't have motion standards to the level of specificity that we would all like to have today, because I think we could continue to talk about these issues for several more days.

One of the critical things that came out of yesterday's discussion in my mind was, well, with regard to critical design parameters, three DOF versus six DOF. It's my perception that the consensus is, if we really want to achieve a significant cost savings for motion platforms, what we ought to do is talk about how we could perhaps come up with a redesign for a six DOF system that is substantially cheaper. That is to say, we could come up with a six DOF system that provides what this group would consider to be the essential motion cues and reduce costs by perhaps reducing the mass on the platform, coming up with ideas on how to do that.

The suggestion has been made that perhaps if we get it small enough and get the weight off the platform, we could actually enable the use of electrics rather than hydraulics and achieve a very significant savings thereby.

What I think I'd like to suggest we do is focus on the notion of a six DOF system in terms of the critical design characteristics that were listed yesterday and get suggestions on how we might proceed to specify the performance characteristics of such a redesigned six DOF system. Particularly in view of the performance characteristics that we feel are essential for the critical takeoff and landing tasks.

Anybody have any thoughts on that?

MR. SMITH: I'd like to comment on that because I've had some discussions with some of the guys and basically I think that's the right direction. But I think inherently the cabin of these regionals is smaller than [of] the large aircraft. By design it's going to be smaller. If you go with innovative designs and material, maybe not just use aircraft parts for the cabin structure and everything, then you are going to wind up with a much lighter weight.

MR. LONGRIDGE: Yes.

MR. ADVANI: As I pointed out yesterday, a major contributor of the inertia is the displaced system, a general rule of thumb for smaller commuter type aircraft where the pilot head position is quite close together, is that you can get away with, say, a nine-foot displaced system that's one indicator but the whole vision system can be smaller if you choose to go that way.

MR. BAKER: You are talking about if you use a dome as opposed to a collimated image?

MR. ADVANI: Beg your pardon?

MR. BAKER: Talking about using a dome as opposed to a collimated [image].

MR. ADVANI: A wide angle collimated [image]?

MR. BAKER: One of the things I think we need to keep in mind, that's not a requirement for this level of simulator. That the requirement for the visual display on this simulator, unless I'm messed up, is relatively simple.

MR. BOOTHE: That's a good point.

MR. LONGRIDGE: That is a good point. But on the other hand, the requirement for this level of simulator at the present time also is three DOF. And here we are talking about six DOF. I personally—the objective is cost. And balanced against effectiveness. It may very well be that because the cost of these visual image generation and display hardware items have come down, that we could also specify a wider field of view. In fact a wider field of view may very well serve our purposes.

MR. BOOTHE: That's exactly what I was going to follow up with. Before a group like this could, I think, be serious about, like he said, design parameters for a motion system, I think they need to know what are going to be the other simulator requirements. If indeed we were going to say that a Level B need have only the current 30 by 45 degree system, then that makes quite a difference to one of our critical parameters, namely mass properties. Well, I think the others would be secondary.

So if we have a notion that we may decide that a wider field of view is going to be necessary, we need to make that known. Because that will make a difference to whether, for example, we could use a hydraulic powered system or possibly an electric powered system simply because of the mass that those systems are capable of handling. So I guess it's the typical design trade-off problem.

MR. BAKER: We are really at this point kind of run up against system design problems, when we try to constrain this to a motion based problem, but we just discovered it's not really just a motion based problem.

MR. BOOTHE: I think we would have to make some design assumptions about the rest of the system before we could really pin down or stick strictly to motion. I think we have to do that.

MR. LONGRIDGE: I think it's reasonable to make a design assumption that we are going to have a wider field of view than the minimally required display system for a Level B. But I don't think it's necessary for us to come to a decision today what the size of the field of vision might be.

MR. BOOTHE: I think to at least know we are discussing the possibility of a larger system, which may introduce the possibility of more mass, I don't think we could accept a dome because I think most of us believe that the separation of the pilots is great enough that we need a virtual image rather than a real image. So that leaves us with some possible comments up there, I think.

MR. LONGRIDGE: We could leave that open because Level B right now does not require a virtual image. That's not a specification, it's a functional specification, not a hardware specification. It may be wise to leave it that way and let industry employ its ingenuity to come up with ways of meeting that functional spec.

MR. BAKER: Well, let me say one thing about that, Tom [Longridge], for just a minute.

One of the things that's going to drive these poor system designers crazy is that they have got more technology than they are sort of allowed to use. You know, if we can't in some way constrain the problem, then they are not going to know when to quit, I mean clearly a large collimated display is better than two CRTs stuck in the window, there is no question about that from a performance standpoint, from a training standpoint, I don't think anybody would argue with that.

But from a cost standpoint two CRTs stuck in the window is a lot cheaper than a large collimated display. It's also got a lower operating cost because the projectors are in some way a little bit of a challenge to keep running all the time. They don't run nearly as long as a CRT. I'm not suggesting that we back off from perhaps changing the requirement to a large collimated display or some other display that has a much wider field of view, but it's going to be hard to—well, first of all, the other comment is that's a very large cost driver, two collimated displays in front of two pilots are relatively expensive, it drives the motion based requirements and it drives the room requirements and all sorts of things. So maybe we need to come to grips with that problem first.

MR. LONGRIDGE: It would be a good idea to do that if we could, but I don't think it's feasible. I would say that, you know, we are having, our strategy is to have a series of these meetings. This is the second one and the next planned meeting will address the visual display and image generation considerations.

So all we can do today is make some general assumptions and perhaps those need to focus on what would be the maximum mass of whatever system is up there that could be tolerated in view of the alternative design that we are talking about for a six DOF system.

MR. BOOTHE: I think to follow up on Bruce's [Baker] comments a bit, the person designing the simulator of course is designing with the objective of getting it qualified for use by a carrier, otherwise they don't have a customer. And it's up to them to work out these trade-offs. If we were to say we have identified some tasks which we think are critical, we think those require this many degrees of freedom, we think those require a certain amount of cuing capability, however we would describe that. Then I think that would serve our purpose and then if the designer decides he wants an extremely large visual system that has massive projectors and other equipment, I think it's then up to the design company—the simulator company and the customer to work those things out and still meet standards that are put forth.

So I know those are all considerations in design of the system, but I think we need to direct our attention to what's the end product in terms of certifying pilots, and if we say it's three, four, five, six degrees of freedom, then we need to write that down. If we say we need a sway acceleration capability of x feet per second squared or centimeters per second squared—

MR. BAKER: Feet per second squared.

MR. BOOTHE: —then if that's possible for us to do, I think that's the only way I would know how to approach this task.

So I'm looking, I think Tom [Longridge], too, on your input there, and I don't know if the homework assignment last night heads us in this direction. But I think those are the things that I would like to see us making some decisions about. If we decide that you only need, let's say we did think you needed a six degree of freedom system but you only needed a plus or minus six-inch stroke, and Thomson comes along and says "yes, but I want to put this huge system on it." Then it's their problem. I prefer to leave it that way. Because I think they would prefer to leave it that way.

MR. HARRIS: I always tend towards not the technology we can use, but the price the customer is capable of paying. The customer wants a certain type of simulator, goes out in the market, what does it cost?

MR. BAKER: Let me ask you a question at this point. Would it be helpful if we could get one of the guys from the major builder companies to put up on the paper over there the cost drivers, the big cost drivers for the system and about what they cost? There are some cost drivers in there—

MR. LONGRIDGE: Didn't we do that yesterday?

MR. BAKER: That's for the motion platform. I'm talking about the whole system. So we can put this problem in perspective in terms—is that useful at all? I'm appalled, for example, what an EFIS system costs.

MR. BOOTHE: I don't know if they want to write down their costs.

MR. LONGRIDGE: We could do percentage, relative percentage of total cost of system, we could do that.

MR. BAKER: I don't think the hardware costs are too big a secret. If you go to Collins and want to buy an EFIS system—

MR. BOOTHE: There are some things happening in that arena. Maybe Don [Irving] can help us a bit, but I keep hearing numbers quoted that aircraft parts are 40 to 50 percent of the total simulator costs. And the latest figure having been 40 percent, and the reason for that is because avionics costs are high and because vendors of the avionics will not support software emulation of their equipment and won't release the data. I think—and there are some changes coming in that area. And something is being addressed.

Now whether or not something will actually get done and the software vendors will actually release that data is another question.

Don [Irving], could you—that's a major cost driver, not one we can fix here.

MR. BAKER: The only reason I was bringing it up was to put the motion based cost into perspective. There is some hard costs in there like the cost of the aircraft parts that were—no matter how we slice this thing up, we are not going to have any impact on that. Unless we work probably with the avionics manufacturers.

MR. BOOTHE: That's true. As Tom [Longridge] said, he is having a series of these discussions and perhaps that will be in one. But this one happens to be addressing just motion. I think motion is not a major cost of the overall simulator, except as how when it gets large enough you have to have a 34-foot bay to put it in. It does become expensive.

MR. BLUTEAU: The cost of simulation—there is a trend in replacing expensive avionics by the use of simulated display, simulated panels, there is definitely a trend. And I think that in the coming years we will see dramatic changes in the cost structure of the simulator.

Secondly, CAE hasn't built small devices, we have done cost studies. The only thing is it's a dramatically different approach design-wise. We don't have the exact figures, it may be a difficult task for us to put on paper what the cost breakdown of a potential Level B simulator would be if we designed it. So it may be difficult to assess that right now. Based on similar estimates that have been done in the past, it turned out that the motion system was a significant part of the overall cost. Especially because in those lower level simulators we tend to save on various things, much cheaper visual systems, structure being simplified, flight control being simplified, display systems, everything else.

One thing that was difficult to make cheaper was the motion system. So I still believe it would be a significant contribution to the overall simulator cost if we could simplify the motion system requirements.

MR. BOOTHE: Do you have an idea of percentage of total simulator cost that would be attributed to the motion system?

MR. BLUTEAU: It varies. I would hate to quote any numbers. Especially because I suspect in the case of a Level B simulator a brand new design would probably be used, so you have that—whatever number I can mention here would probably turn out to be inaccurate.

MR. BOOTHE: I don't mean a raw number but some approximate percentage of the total cost, is it 20 percent or ten percent or 50 percent?

MR. BLUTEAU: I would say in excess of 20 percent.

MR. BOOTHE: Excess of 20 percent. Do you have any comment on that, Geoff [Harris]?

MR. HARRIS: I don't have the figures for small simulators. But for the full flight systems it's way down below that. The small simulators you have a different approach, build different fidelity, individual controls, presumably different instructor stations as well. If all these other factors are coming down in price, then the motion system percentage rises accordingly. It depends a lot on what you compare it against. For a full flight simulator, very small percentage. The smaller system, the price of the motion remains the same.

MR. BOOTHE: For a full Level C or D sim are we talking about five percent, ten percent, fifteen?

MR. HARRIS: I guess between five and ten percent.

MR. BOOTHE: Does that sort of put it in some perspective?

MR. BAKER: Yes. I would certainly agree that as you start to make the rest of the simulator cheaper, if you stick with the traditional six axis 60 inch stroke motion platform, it starts to become a very large percentage of the total cost. If you are trying to get this whole thing down to five million or six million dollars, then have a one million dollar piece of equipment in there, which is somewhere around the right number for the motion platform, is a little absurd.

You don't think it's that much? You think it's more than that?

MR. HARRIS: I think it's less than that.

MR. BAKER: Well, you can buy from McFadden a machine for about 650 thousand dollars. But that's the box of parts. So I was going to include some of the costs of installation and the problem of site, that sort of thing, in the cost.

MR. BOOTHE: Frank [Cardullo]?

MR. CARDULLO: Perhaps a useful estimate to make here is if we reduce the six degrees of freedom, considering the standard hexapod type configuration. But reduce the stroke to on the order of 30 to 36 inches; what impact would that have on cost? Would it cut costs in half or would it cut them more or less? Does anybody have a sense? What is the opinion of you folks that build them.

MR. BOOTHE: I found out that's already been done in some cases that we weren't really aware of because we didn't have any motion standard other than to say you needed six degrees of freedom, people did go to 36-inch systems and we found out after the fact, so I guess the answer is there is no cost impact at this point of going to a 36-inch system because people have already done it. Of course that's a cheaper system than if somebody puts on a 60-inch system. I don't know that differential.

MR. REID: I know what it was 12 years ago. When we bought our three-foot system, it was two-thirds of the price of the 60-inch system. So it wasn't half.

MR. BOOTHE: Six foot or 72-inch system?

MR. REID: Yes. That was 1983, '84. The price costing may have changed since then, it wasn't half.

MR. BOOTHE: So here is one of our SMEs with experience with a 36-inch system.

MR. REID: Yes, we have a 36-inch system.

MR. BOOTHE: Maybe that helps us in deciding whether—what your experience has been with the 36-inch system and whether or not a little bit less would work.

MR. REID: Well, I guess, first of all, we don't train people in it, we use it as a research tool. We have looked at how much degradation we have over a larger system. In particular we have looked at cue duration, acceleration cue duration effects and this sort of thing. And we came to the conclusion that to make a significant improvement in the cues that we were getting for the kind of work that we were doing we would have to go to a large six-foot system because stroke requirement to increase the acceleration cue duration tends to go as Phase squared, with t as length of time duration, and t is so small anyhow you are talking about small absolute number changes, maybe large percentage changes, but small absolute changes.

So we have been using our system really as what we have been saying all along, namely as an onset cue device. And we are under the impression that to make really significant advances in say reducing false lateral cues during turn entry and this sort of thing, you have to get things almost bigger than the VMS to make a real impact.

So we backed off, I guess I didn't have a choice since we are stuck with our particular system, we were fairly happy with the way it's working. And we have had a number of airline personnel through our system who are used to using the full six-foot stroke systems. And we get very favorable responses. We asked them for objective comparison data when they fly our system, both with other simulators they fly normally in their training and the aircraft they fly. And we haven't seen any really big complaints relative to other training simulators with larger strokes. However, we don't do the full gamut of maneuvers that you have been doing here. So we are very restricted.

MR. BOOTHE: What sort of maneuvers were you doing?

MR. REID: Normal takeoff and landings, climb, descent, flight through turbulence, flight through wind shear, what else did we do, Sunjoo [Advani]? Did I miss anything?

MR. ADVANI: Side-step maneuvers, you should mention, usually for a large transport.

MR. REID: Yes. All that experience I'm talking about was basically 747. That's pertinent to this. A lot of our recent work has been on helicopters, so it doesn't really relate too much to regional aircraft.

MR. ADVANI: What about the difference between the washout algorithms which you were comparing, was it similar in both cases?

MR. REID: You never know.

MR. ADVANI: What you did versus what the pilots were used to in their training environments.

MR. REID: We don't know what the algorithms are. I can guess what they are on the training simulators, and I think they are using classical washout.

MR. ADVANI: I think so, too.

MR. REID: We used classical washout during a lot of these trials, too.

MR. BOOTHE: That's interesting. There are people with in-service training simulators, as we call them, that do use or have used 36-inch systems. I don't know that I have ever found one less than that. But if I could put you on the spot.

MR. REID: Just one point. It's a 19-foot ceiling we are working in.

MR. BOOTHE: That's important.

But if the FAA were to say "all right, we have looked at these tasks, we understand the history," and Bob [Foster] has been clear about that. There has been these older systems that have worked but I'm not sure they are really doing anything. As you said yesterday, one cycle per period or something. If the FAA were to say "okay, we are going to look at a six degree of freedom system for Level B, and we are going to say it must have a minimum stroke of plus or minus 12 inches," which would be a 24-inch system, what, in your opinion, would that give us in terms of onset cues that we think are important for critical maneuvers that we really haven't talked about yet but we know are there? Do you think it would be a significant reduction from what you have experienced with a 36-inch system?

MR. REID: It would be a reduction. You can't say there won't be.

MR. BOOTHE: Well, I agree.

MR. REID: But I think we get the onset cue all right. It would be reduced in duration. And we would have a harder time reducing any false cuing that's being generated in the simulator. They make it harder for us to tune the simulator to get the same subjective pilot assessment of the motion quality. We might get around that by reducing the scale factor overall. We tend to run at a scale factor of 0.5, if we can. We might have to back off on that to something lower. Someone yesterday was saying they were using 0.2.

MR. BAKER: Point two we used on a high performance.

MR. REID: So you can obviously get away with lower than 0.5. Point five has never been an official number although it's been used a lot.

MR. BOOTHE: Suppose we don't say anything about the stroke? I, in fact, have suggested this and been shot down before. So it's a familiar position.

MR. BAKER: I think that you may have to require—I'd hate to see this argument go to its logical conclusion, which is you only need a half inch.

MR. BOOTHE: That's right. You get down to vibration.

MR. BAKER: You can certainly say "well, gee, if 36 is good enough, it was only a small reduction from 60, then 24 is probably okay, too. Then maybe 18, then 12."

MR. REID: There is a logical place to stop as you go down. You get to the level of cue you can provide which is below what are called the threshold levels, not really a threshold but down in the region you can't sense it.

MR. LONGRIDGE: We have people proposing 12 and 18 inches right now. I think your point is well taken.

MR. BAKER: I think someone is building one with 24. They can't get anything bigger in the trailer they want to put it in.

MR. RAY: There's been a number of efforts done like that before. Well, selection of the motion base was not done analytically. It was based on what room was available. Can it fit in a room?

MR. BOOTHE: That's because all you say is you have to have a motion system with six DOF.

MR. LONGRIDGE: Maybe we need to specify the minimally required for FAA purposes.

MR. BAKER: The other thing is historically the requirements for motion platforms have been based on essentially what you can do. Lloyd's [Reid] comment really says what you would like to have is something with about 600 feet of travel, okay? Seriously. That's what you would really like to have.

MR. BOOTHE: Sunjoo [Advani] is burning.

MR. ADVANI: Sorry. What it comes down to is how much false cuing are we willing to accept?

MR. BAKER: There is a trade-off in false cuing, it says if I reduce the stroke of the motion platform, I can accommodate that two ways. One is I can reduce the gain. Or I can increase the washout rate or increase the—move the pole for the washout, the zero for the washout, however you want to look at it, up higher in frequency so it washes out faster. And I wish we had a lot of data on the effects of doing that, but I don't think we do. I know I don't have any. I always set mine at one a second. That's a good number. Nobody whined.

MR. BOOTHE: Let me ask a different question. Suppose we were to not say anything about the stroke and say you need to provide accelerations in each of these degrees of freedom for t duration? Is that something that we could do? I mean, is anybody willing to put a number on paper?

MR. CARDULLO: I was going to suggest just that. I think you are better off trying to specify cue duration than to specify stroke length. Because we would be guessing at stroke length. To a certain extent we are going to guess at cue duration. I think we have a better idea of cue magnitude and cue duration, from that you can derive stroke length.

MR. LONGRIDGE: You are going to have to specify the tasks for these.

MR. BAKER: If he specifies the magnitude of acceleration at a time, you can calculate the displacement.

MR. REID: Right.

MR. BAKER: And—

MR. CARDULLO: So from that you could infer displacement. But—you might say "well, why not just define displacement?" But my view is that if the simulator motion system designer has some creative way of providing the cue and the washout, you enable him to do that by this functional specification as opposed to a performance specification.

MR. BOOTHE: Excuse me, I have two down here. But what you also do when you specify stroke is almost lock a design in, and we don't want to do that. Because that—some innovative person might come along and have a completely new and better idea and we would be ruling that out if we specify stroke.

MR. CARDULLO: The other way, just a brief comment, the other way is specifying excursion by degree of freedom as opposed to stroke length. The least desirable is to specify stroke length. The next best would be excursion per degree of freedom. I think a functional specification on cue magnitude and duration is best.

MR. BOOTHE: Bob [Heffley] had a comment.

MR. HEFFLEY: Yes. If we come up with a number for cue duration—yes, for cue duration, we better have a pretty good basis for it, because you know if we say arbitrarily one second cue duration then that could maybe mean a horrendous stroke.

MR. CARDULLO: Oh, yes.

MR. HEFFLEY: That's the sort of thing you really need to think about and do some real analysis on before you come up with a number. In fact, probably it's safer at this point if you want to walk out of here today with a number, let's just say 36-inch stroke or actually, you know, go right—that's at least safer, that at least bounds it to something that's a reasonable cost. Cue duration might wind up costing far too much.

MR. BAKER: Let me comment about that also. When Ed [Martin] talked about his experiment yesterday with that roll machine, and he found that the guys could do the tasks equally well with a large cue or a small cue, but when he took the guys that trained on the small cue and put them in the large cue machine, the training didn't transfer 100 percent. I think that comes from the fact they had the gain in their controller set wrong. They get a little bump in the large amplitude machine and they would over-react to it. The same thing can happen in a simulator if you start to reduce the gain too far on the motion cues, the guy will learn to fly the simulator but the training won't transfer directly. I think in the case of a simulator like this for this application where it's a recurrent qualification simulator rather than training raw recruits, that's not as big a hazard, because I believe—I mean, I'm way out on a limb now, but I really believe that the pilots will very quickly accommodate the change in gain in motion cues in a simulator and equally quickly accommodate when they go back in the real airplane.

MR. ADVANI: But still in recurrent training you are going to go through maneuvers you normally wouldn't encounter, so you are doing training.

MR. BAKER: That's true. That's the argument that says we ought to go to 100 percent gain all the time.

MR. ADVANI: I'm not saying that.

MR. BAKER: But, you know, we are kind of stuck in a lot of cases without being able to do 100 percent gain no matter what size motion platform you are talking about.

MR. STOCKING: I work almost exclusively with a 60-inch system and our entire motivation for the last 20 years has been trying to optimize the cue envelope, to use as much of it as possible for any particular cuing. And there is a bottom limit when you are performing any maneuver that is acceptable to the pilot. When you drop below that level, you are producing a cue to the pilot that tells him to adapt to the machine that he is flying. It is no longer transferable to the aircraft.

And my opinion on this on the three degree system, is that you are supplying to the pilot a system that helps him learn to fly the simulator. Not the aircraft. It's not transferable.

I tend to look at different cue envelopes. When we start reducing the size of the envelope, we are going to come up with some boundary where we are no longer successfully performing that task. And to say that we are transferring that to the aircraft, I think is subjective. Very subjective. I just don't believe that anything less than a six DOF of a certain magnitude is going to accomplish that task.

MR. MARTIN: I think basically that this is what I was finding with that dynamic seat study.

MR. BAKER: If you went down to a two-inch stroke, for example, like our old motion seat, I think all we are going to get is—we are certainly not going to get the cues of the caliber and the accuracy that you get with 60 inch stroke with a two-inch stroke, you can't do it. I think what we are going to get is a situation where the pilots like it as an improvement over no motion at all.

MR. STOCKING: Right. You are helping him learn to fly the device. For that particular part there won't be a transfer of training to the aircraft.

MR. BAKER: Our objective on this one really is recurrent training of qualified Apache pilots. We are not trying to teach him how to fly the bird. We are trying to help him fly the simulator better than he can do with no motion at all. I'm still skeptical we are going to be able to do as well as we think with that small a platform.

MR. BOOTHE: That's not the issue for us. Our issue is we bring a pilot out of revenue service, we are going to relicense him, we are going to relicense him to go back into revenue service. We are asking the pilot to demonstrate in this device the behavior that we expect to be able to observe in the airplane. And that's really, as best as I can describe it, our objective. And if it's not possible, then we need to say that. But we are doing something like that, at least we are assuming we are accomplishing that, you know, maybe airplane accidents are very much at a low level because of other reasons. I'd like to think some of it is because of good training. But we don't want to—we don't want to relicense a guy to fly the simulator, we want to relicense him to fly the airplane. That's the cues we need to try to provide while at the same time trying to get the cost down to something that smaller carriers can play with. Frank [Cardullo]?

MR. CARDULLO: I think we should refrain from talking about transfer of training because all we know about transfer of training concretely is that there may be none, from a motion system. We have no real basis to say that any motion cues transfer. We all have opinions about it, but all the experiments that have been done, or a very large percentage of the experiments that have been done say there is none. And albeit that most of those experiments were done on inferior motion systems for one reason or another. The data is really inconclusive. However, we have no proof to the contrary.

So I think we should say nothing about transfer, and since we don't have that, what we have got is that feel that because of intuition and other things that we need a motion system, we should base our sizing or specification on our best engineering analysis of the problem.

And what I think that comes down to is, since you can't provide a full motion cue in a simulator, you have got to provide enough of a cue to advance the vection that you get from the visual system. Since the vection research shows that as long as you don't do anything wrong with the motion, that even a very short duration onset cue provides an advancement of the induction of vection. So now I don't think we can risk taking that to the extreme of just providing a jolt because there is a little bit of research on jolt simulation that jolts just don't seem to work, but nevertheless, I think we can look at things like cue duration.

There are several of us here who have software that could go and say "well, for these—this particular set of maneuvers, what kind of cue duration would you be able to get out of a 30-inch stroke, 24-inch stroke, et cetera?" And you could come up with some bounds analytically by doing something like that relatively quickly. Do you agree?

MR. REID: Yes. The tricky part would be to correlate those numbers with what a human is going to experience. Right? If you wanted to say what percent of the time is a human going to detect some of the lower values, you would have to make some extrapolations on the literature or do some investigative project.

MR. CARDULLO: I think what we know is we need to produce a cue for a couple tenths to three tenths of a second in order to advance the induction of vection.

MR. BAKER: What's the trade-off on cue duration versus cue level? I can trade those two off and I don't have any experience with that at all.

MR. CARDULLO: Well, cue level largely is determined by, I think, the range. By the maximum. You were talking about a fighter, you set it at about—

MR. BAKER: Two-tenths.

MR. CARDULLO: —two-tenths. With transport you are setting it at five-tenths. The reason for that if you set it higher because of the dynamics of the airplane—

MR. BAKER: You run out of stroke.

MR. CARDULLO: —you run out of stroke. That's really set by the dynamics.

MR. BAKER: But see, I could have changed the washout, I could have washed it out faster and I could have also solved the stroke problem that way. I had the washout set at one radian a second. So I never changed it. I never went and—we weren't chartered to run the experiment that says suppose I change the washout to two radians a second. What happens to the false cues? I did query the pilots about false cues and they said well, the only way they could notice them is if they concentrated on looking for them. If they concentrated on their task, which was a high level task, they never noticed the false cues from the motion platform. We don't have a charter to mess with it, we were building avionics equipment.

MR. STOCKING: I wanted to say I didn't disagree with Frank's [Cardullo] premise about transfer of training to the aircraft. But I have been able to observe how quickly a pilot adapts to the simulator. And in my way of thinking that's where we should concentrate. If we are talking about the number of degrees of freedom or the size of the envelope or anything else, that's within the capability of a six DOF system to program it so it restricts its cue to a smaller and smaller envelope. As a matter of fact, it's going to be fairly easy to do. And you can determine subjectively just from taking line pilots into the simulator and observing how quickly they adapt to the simulator, you can determine the quality of that cue.

MR. LONGRIDGE: Yes.

MR. BAKER: I would think so.

MR. CARDULLO: I don't completely understand what you mean by adapting to the simulator.

MR. LONGRIDGE: Backward transfer. So you take somebody that's totally adapted to the aircraft, put him in the simulator and measure the performance in the simulator.

MR. CARDULLO: Until he comes to asymptote in the simulator.

MR. LONGRIDGE: That's a pretty good technique, actually.

MR. STOCKING: Everything we are talking about at this level is just that.

MR. CARDULLO: You could do that in a simulator that has 72-inch or 60-inch stroke, then just gradually reduce it, and that's not a difficult experiment to do.

MR. STOCKING: And the same thing with eliminating degrees of freedom. If you want to find out what the minimum degree of freedom set is to give the pilot an alerting cue and what would be the best situation, you could do the same thing in a six DOF system.

MR. CARDULLO: That would take longer.

MR. ADVANI: You could also have temporal fidelity in that sense.

MR. BOOTHE: I'm just—let me ask Geoff [Harris], go ahead.

MR. HARRIS: Considering the cost of small short stroke actuators, to achieve the same angulation, the same rotational displacements with a smaller actuator, you move the motion feet in on the floor and the pads in on the structure. Obviously you get less translation of cues. If the simulator adopts, what's the word, a nose down or extreme attitude, like 30 degrees of the platform, to recover from that displacement you actually need to put a larger force into the actuators, so for a given mass of simulator you suddenly need larger diameter cylinders. That doesn't mean the cylinders cost more, but your hydraulic requirements go up. The apparent savings are not quite as good as they seem.

MR. BAKER: It also depends on the CG height, which is a function of cabin size and how much stuff you put above your cabin. So it's very CG height dependent.

MR. HARRIS: It comes back down to mass properties again.

MR. BAKER: Funny thing about that.

MR. CARDULLO: But you do save in building size, even if you don't save in the cost of motion system you save in building size, which is probably a more significant cost for the operator because he has to air condition and heat that building.

MR. HARRIS: You mean the physical size of the room?

MR. SUSSMAN: Yes, or the number of simulators you can put in a room.

MR. HARRIS: That's true. Invariably these days we put simulators in existing rooms. Very rarely do people build a new room for us.

MR. BOOTHE: Bob [Foster], help me out, I don't know if the regionals have ever gotten that far into their thinking. I think they are hung up on initial cost and I really don't think they have looked at life cycle costs or buildings. It seems to me they are hung up right now on initial costs.

MR. BOOTHE: Well, you have to get past the first step before you can think of the next step in some cases.

MR. FOSTER: Actually we have gone past that with some of the ones we own.

MR. BOOTHE: But excuse me for saying so, but you are different because you have a different experience from some regionals. So for the ones that you are concerned with, but there are others out there who I think have not—

MR. FOSTER: I agree. There are those operators who don't have simulators and don't have a parent company that does, that haven't looked at that, but that was one of the reasons in fact why with what's now Piedmont, which used to be Henson, that USAir group said we want the USAir simulator department to look at providing simulation because they have the expertise. And immediately the question came up from Henson saying we would like to put this simulator in Salisbury, Maryland, but there is no facility there in Salisbury.

When you start looking at the cost of putting them in new buildings, Geoff [Harris], we are looking at new installations here now, not installing necessarily in the—in an older facility. And the cost of new buildings is extremely expensive. And again then you start looking at life cycle costs and how many people it takes to maintain them. Do they have to add staff? How much staff has to be added? What are the spares requirements? All that sort of stuff.

MR. HARRIS: This touched on something I mentioned last night with Hilton [Smith], does it have to be a building? Suppose the simulator is a portable device.

MR. BOOTHE: Suppose it was what?

MR. HARRIS: A portable device.

MR. BOOTHE: That I can't answer.

MR. BAKER: We are looking at one of those right now. I could make a comment about that. It's a B-1900 that TDI is in the process of building. And space requirements in the van restricted to a 24-inch stroke on the motion base, you can't get anything bigger in there.

MR. HARRIS: Right. What about the certification issues?

MR. BAKER: That fortunately is not my problem. We may have to get our controller certified for it but the motion platform is not our piece of equipment. We are not on the hook for that one.

MR. BOOTHE: Let's follow this one more step. Paul [Ray]?

MR. RAY: We have had some discussions with those folks, it's not going to be an easy hurdle to jump.

MR. BAKER: Right.

MR. RAY: Their incorrect assumption is that systems are certified in the classic sense. In fact, they are not. We have to look at that system every time it moves.

MR. BAKER: Every time it moves?

MR. RAY: From one location to another.

MR. BAKER: You want to recertify every time it's moved?

MR. RAY: Because we don't certify simulators. That term is misapplied. Ed [Boothe] has accurately pointed out before, if we certified simulators, nobody could afford them.

MR. BAKER: I think the concern that I would have prior to that one is the concern about is the 24-inch stroke motion platform going to pass muster? Because they have made an assumption that it will, based on the fact that's the biggest one they can get in the truck. And—

MR. RAY: If their truck was smaller would a six-inch system be acceptable?

MR. BAKER: MIL-STD-1558, if you lay it on the desk, and you get the data off a Link 60-inch motion base, it's surprising how close the numbers match. So MIL[-STD-]1558 I think came after the motion base design and not prior to it.

MR. MARTIN: Actually the Link motion base was designed around those numbers.

MR. BAKER: It's awful close.

MR. CARDULLO: There was a back and forth.

MR. BAKER: It's an awful good match. And I'm not saying there is anything wrong with that. But if I were the guy building that sim, my first concern would be will you guys sign off on the thing with a short stroke motion platform considering there doesn't seem to be a whole lot of data in the industry that says it's all right?

MR. BOOTHE: Paul [Ray] and his staff are in the process, once they do that, perhaps that's—the solution to this whole issue of motion may be your decision on that 24-inch system. And that may set the precedent for Level B. Which is to say maybe what we say here could be overridden by what you do on this particular system.

MR. RAY: I hope not. We're not necessarily looking forward to it, either. It points to another issue. The fact is that we don't currently have any substantive Level C or Level D standards which encompass the issue we are talking about here. We simply say a six DOF system.

Is there any disagreement in this room that the drafted international standards for a Level I or II motion system are acceptable? They unfortunately were not incorporated in the final ICAO standards. I don't have a copy with me, but I believe they require—Bob [Foster], you may know better than I—a 60-inch system?

MR. FOSTER: I honestly don't remember.

MR. RAY: Does anybody have any problem with what the international group came up with for [Levels] C and D, and we can set that aside. That should allow us to address Level B more comfortably.

MR. BOOTHE: I haven't seen the international proposals except in a handbook.

MR. RAY: That's the only place I have seen them.

MR. IRVING: They were done after the work was actually formally finished, it was an extra meeting of a motion working subgroup, I'm not sure that the results were fully incorporated in the final document.

MR. RAY: They were not fully incorporated in the international document, correct.

MR. IRVING: It was to try and handle Ralph Lugent's motion critical airplane maneuvers plus some other metrics for the motion system. The idea of specifying the critical maneuvers was thrown out, the metrics were broadly agreed, I think it was fairly conservative, no manufacturer or regulator or operator was prepared to demand high levels of performance, just minimum standards.

MR. RAY: I'm sorry, Don [Irving], I apologize for interrupting. I want to make the comment there has to be an assumption that in order to address Level[s] A and B we must also establish standards for Level[s] C and D.

MR. IRVING: We must resurrect that work. It's a good starting point.

MR. RAY: Back to the issue. I apologize, I had to get that thought out.

A lot of the discussion we are having here has application to Level[s] C and D systems.

MR. IRVING: I think they were minimum standards to protect us from the crazy man, the two-inch six degrees of freedom, I think we didn't expect people to design down to that level, it was just a floor. I think that's all we can do here, whether we get hung up on whether it's 36 or 37 or

38, perhaps we can say it's 36 or equivalent. That puts the ball back in Paul's [Ray] court when it comes to qualification. Somebody could perhaps design a system which is better than somebody's 36-inch, which has 36 inches in one direction and three inches in another direction, I don't know.

MR. BOOTHE: That's exactly what Appendix H says now for [Levels] C and D, it must provide cues equivalent to those provided by a six degrees of freedom system but it doesn't say what six degree of freedom system. Frank [Cardullo]?

MR. CARDULLO: I think in order to come to some kind of closure here, we need to do something. If we refer to Tom's [Longridge] keynote to us yesterday, the sense I got was that what he is looking for is some interim recommendation, both a short-term and maybe a long-term plan. And so in the long-term we could look at some of the potential research that can be done in order to quantify these various parameters. But in the near term, I think we are faced with, at least without interminable discussion about which we have no concrete data, we are faced with either one of two alternatives, either no standards, and having no protection against the crazy man, as you said, or making some reasonable estimate of a floor as was pointed out. And say for the interim, let's go with that floor. And my opinion is, and it would sort of recant something I said earlier, if you put it somewhere around 36 inches you would probably have a reasonable floor. You would have something that you know would not be a disaster. And perhaps it could be optimized a little bit less or maybe a little bit more. But my opinion is we would be in the ballpark. Maybe we could just get a consensus from people.

MR. BAKER: If I may make another comment, and this is the one I made to you on the phone when you called me up about the meeting, and that is can we potentially scale this problem based on aircraft physical parameters, like the size of the aircraft, one is a 747 or 737, the other is a smaller aircraft, and therefore—in some cases you can say "well, if it's a smaller aircraft, then the problem gets easier." In other cases you say maybe it gets harder. But can we arrive at some set of numbers starting with a 737 or 727 on a 60-inch stroke base and work our way back to a smaller base?

MR. LONGRIDGE: You have to consider the size of the aircraft and the task. We have to go back to critical tasks that we are designing these specifications to as well.

MR. RAY: That's true. Bruce [Baker], we have addressed that with one operator. Their proposal was "an analytical comparison between airplanes and motion base requirements." They tried to equate the size of the aircraft and takeoff pitch attitude to motion excursion requirements, totally discounting aircraft acceleration characteristics. If you compare aircraft you will find, I suspect, that the acceleration characteristics and potentially the motion requirements for a Beech 1900 or a Lear Jet may be significantly greater than that of a 747-400.

MR. ADVANI: Absolutely.

MR. RAY: Perhaps the characteristics of an aircraft in acceleration could be in that matrix, that being more appropriate than the physical size of a system. As this one individual tried.

MR. BAKER: I'm not suggesting you do it based on tape measure data.

MR. CARDULLO: But I think any attempt in trying to do that here is not possible. I just don't think we have time—

MR. BAKER: We don't have time.

MR. CARDULLO: —in the couple hours remaining to do something like that.

MR. RAY: I agree.

MR. CARDULLO: Whereas I think we could come to some consensus on what the floor should be.

MR. BOOTHE: Could we possibly come to a consensus on an interim cuing floor, if you will, in terms of those parameters we mentioned earlier? Acceleration and duration, rather than stroke, do some of us know enough to have some numbers that we would—we know we can't support the data maybe, but just like we have done the rest of simulation to this point in time, it's all been expert opinion, there is no data base, that's well-known. The aerodynamics falls into the same realm, it's based on expert opinion. So why can't we base minimal motion cuing on expert opinion as an interim standard to be followed with research to improve that? And of course those simulators that might be qualified to the interim standard would have to have some strong assurances that grandfather is alive and well and not be subject to requalification with new standards.

MR. ADVANI: What do you do if your final standards are quite different from your interim standards?

MR. BOOTHE: That's why grandfather has to be invoked here.

MR. SUSSMAN: You should look at each function, is this a cuing or alerting function, or does this motion provide direct feedback in a control loop that includes the pilot? We could take a crack at this mentally, but it would be better if we subsequently developed a list of motions and then tested to determine whether a given motion was required simply as an alerting cue or was also required as part of a feedback loop.

MR. ADVANI: We have gone through the whole exercise of motion base design. It turns out that stroke is not really the most relevant factor. It's in fact the maximum length and the minimum length, and the ratio of the two is one. The size is one. The size of the upper gimbal circle, the lower gimbal circle, the space between the gimbals in both cases. You see tremendous variations in the maximum angles and lateral displacements for a given stroke, so you have to be very careful.

MR. SUSSMAN: But what the pilot is seeing or feeling is acceleration and duration.

MR. BOOTHE: Go ahead.

MR. ADVANI: But for a reduced stroke you can still have the same angular parameters, but not at the lateral. So my feeling is it should be based on the lateral displacement, if you want to use displacement and not acceleration, and the maximum angle.

MR. BOOTHE: I think what Sunjoo [Advani] told us, if I interpreted him correctly, if you specify stroke, you almost have to specify system design to go with it.

MR. ADVANI: Correct. That's what I'm saying.

MR. SUSSMAN: What I heard is talking about rotational motion stroke doesn't make much difference. You put a different actuator. If you are talking about lateral it does make a difference.

MR. ADVANI: No, what I'm saying is very small changes in design parameters can have a very large effect—

MR. SUSSMAN: That's why like Frank [Cardullo] said, take a straw man, see how it fits.

MR. BOOTHE: Bob [Heffley] had a comment.

MR. HEFFLEY: I think the point here is that, let's take stroke, it's perhaps just too simplistic. Yes, you can sit down here and on the back of an envelope compute accelerations, displacement, durations, but it winds up not being quite that simple. And I think for a given stroke actuator, there are a lot of different ways to come up with a final solution.

And one other point, I think we are really on thin ice if we want to come up with some numbers on something today, it seems to me we ought to come up with some numbers that at least some of us have had a chance to really think about. It's not the time to invent a new parameter here for getting at simulator amplitude or whatever we are talking about. I think that if numbers are to come out of this, they ought to be numbers that are coming from some previous thought. That's why I guess again it's probably safer to be talking in terms of 24-inch, 36-inch, whatever numbers people have really been accustomed to thinking about here, rather than to try to go off and devise another metric.

MR. BOOTHE: What metric, are you suggesting that we might—

MR. HEFFLEY: Frankly, I guess I've been in recent discussions similar to this and with similar issues being discussed with reference to a 720-inch actuator (the Ames VMS). And so I'm not sure how relevant it is to really pin that down beyond just going back to this idea of just starting to enumerate just exactly what we really want in terms of cuing. I think that's the one thing that probably most of us are most comfortable with, is what are the cuing needs task by task.? It's almost going back to the old list here that you had.

MR. BOOTHE: Maybe we should go to that list.

Frank [Cardullo]? You had a comment?

MR. CARDULLO: I was just going to say that Sunjoo [Advani] is exactly right in what he said. There is no question. If you just specify stroke there are a lot of different configurations that come with a wide range of capabilities.

All I'm saying is that to come up with something within a couple of hours I only think we have two choices, which runs counter to what I said, really, before. In trying to specify cue duration and amplitude and I just don't think we have time to do any of that.

So we have two choices, either just say it's six degrees of freedom with no standards and be unprotected from the so-called crazies, or to come up with some stroke length, which is about the only thing that we could do in a relatively short time, we feel somewhat comfortable with. And that is what drives me to that. I feel uncomfortable with that. And the only reason I'm willing to propose it is we are thinking about it in terms of short-term solution, not a permanent recommendation.

MR. REID: Just a brief addendum. Instead of specifying a stroke, why don't we specify simulator displacement both angular and linear, don't talk about the stroke. You can produce it any way you want. We know a three-foot stroke on a typical hexapod produces plus or minus two feet in this or that direction. Then you aren't nailing them down or creating the problem that Sunjoo [Advani] was describing where a given stroke can produce a whole range of different simulator displacements.

MR. CARDULLO: I would like to be able to do that, I'm not sure we can. I'm having a lot of trouble, I don't have a lot of trouble with angular degrees of freedom but I have a problem—

MR. REID: In the back of your mind when you say three-foot stroke you know the simulators you are used to seeing, typical hexapod setups have plus or minus two feet from a linear degree of freedom from a three-foot actuator.

MR. BAKER: It's actually closer to 40 inches.

MR. REID: Okay. But you know roughly what it is.

MR. BAKER: Sixty-inch stroke size has typically got about 68 inches of stroke on x, y and z.

MR. BOOTHE: But you couldn't take a direct proportion to 36, I don't think it works that way.

MR. BAKER: It can. It just depends on the geometry.

MR. ADVANI: Without unnecessarily complicating the matter, yesterday we talked about the temporal fidelity in phase lag. In fact in the SIMONA simulator our stroke was determined by the natural frequency of the actuators, simply that. That of course determines the total of system fidelity. You shouldn't exclude that. Keep that in mind, please.

MR. BAKER: Let me take Frank's [Cardullo] thoughts and wander off with them just a minute. I suggest that we take a look, see if we can scale the motion base problem somehow and Frank's

[Cardullo] comment was we don't have time to do that. I think I agree with that on a purely analytical basis. Could we take the critical maneuvers, decide what they are in a qualitative way, go through and say "well, I think in the small airplane this is going to get worse, in a small airplane this problem is little better," and at least bound the problem that way?

MR. BOOTHE: Yes, that was the whole purpose here of the table[1] and maybe we ought to do that. Because I want to try to leave here with at least some interim number. I don't think it's possible to leave here with a permanent standard. But because one thing I'm going to leave with is—I'm glad I studied aerodynamics, because it's a lot easier. But I think we need to leave here with at least a recommendation for an interim standard that Tom [Longridge] can use to solve an immediate problem. Understanding that that's to be confirmed or revised by future work. And I don't think it's defined yet how that future work will be accomplished, but certainly there is every intent to do such work. So if we could go to the tables now and look at those critical things or identify what we would say is critical, and maybe we could get something from there.

MR. SUSSMAN: I just had one question. Is it possible when you make the entries in the table to consider the amplitude of the acceleration and the duration for each critical degree of freedom? That will tell you an awful lot about them.

MR. BOOTHE: Well, I don't know, because you notice that I put a_x, v_x and x, because I don't have a number and I think that's the crux of the whole thing here. I don't think anybody here so far has a number to fill in, the suggestions I made are that they have confidence in a safe number that's neither penalizing nor too lenient.

MR. SUSSMAN: I wasn't suggesting you nail it to the ground but at least get an opinion as to what's a reasonable number.

MR. BAKER: Let me ask a question of the guys that build simulators for a living. Is it possible to go through these, what we think are the critical maneuvers, and have you guys tell us where the motion base is a severe limitation? For example, on a normal takeoff I would assume that the lateral acceleration is not a big deal, you are not generating normally enough lateral acceleration cues to limit the travel of the acceleration.

MR. HARRIS: There is also a cue, the pilot goes down the runway you can—

MR. BAKER: There is a little bit of cue there. What I'm thinking of is which particular DOFs in these critical maneuvers are limited by the motion base limitations, by the stroke length limit, or the angular rate, angular position load? I'm thinking during climb-out you normally have the nose of the motion base, the nose of the airplane up, to give a longitudinal acceleration cue. That's going to limit the motion of the motion platform in the other degrees of freedom. Now, you would probably like to have more nose up attitude capability than you can. I'm guessing that you would, not knowing for sure. What I'm trying to do is get a qualitative feel for where is the motion, where are the critical limitations of the motion base in an existing sim right now so we can address those with respect to the new Level B requirements?

MR. STOCKING: Go ahead.

MR. HARRIS: The limitations that I see from outside the simulator; if I watch a training session, it would normally be a fairly clean training session without turbulence or whatever, the strong pitch nose up for takeoff, strong pitch nose down for braking, a bit of heave, not too much, minimum roll, very rarely do I see a significant roll. And yaw in fact only on ground accompanied by sway.

The limitation, if any, would be in the rotational axis. I see very little translation on the simulators. Maybe a touch of surge when you put the brakes on, release brakes. So sustained acceleration, a simulator very gently will surge, really not too much. So the linears I think we can cut back on. The rotational I think we need.

[1] The final set of tables resulting from the Symposium can be found in Appendix 2, 08*apndx2.pdf.*

MR. BAKER: That's a valuable piece of data.

MR. STOCKING: I also disagree with it.

MR. LONGRIDGE: Of course.

MR. BAKER: I think we need to get more than one person's opinion.

MR. BOOTHE: We are coming up on break time. I have seen some indications that we need that. So if we could take one more comment, I'd like to suggest we take our break and come back. And you had a comment?

MR. HEFFLEY: I guess I just wanted to ask Geoff [Harris], it seems to me that you are seeing all of that because number one, you have very limited motion to begin with; and number two, it's been scaled down far enough for the so-called maximum maneuvers that in ordinary operations you really are going to see these fairly mild motions.

MR. HARRIS: It is true they are normal operations. It's on acceleration, it's not wind shear—

MR. IRVING: Bob [Heffley] is right, reverse cuing is devastating to the pilot, so during rotation and takeoff you need all the pitch and heave you can get. With 50 degrees of pitch and 60 inches of heave you can't have both so you scale down heave because you need pitch. It's a major trade-off.

MR. HARRIS: Yes.

MR. IRVING: From the outside looking in you think "oh, that's the way it is." It's not the way it is, it's the way it has to be.

MR. HARRIS: I still don't see the heave from the outside.

MR. IRVING: Because it's not available because you are pitching.

MR. BLUTEAU: It's one of the toughest cues, the rotation cue you have it's a matter of fully pitch up, you want to, on top of maintaining pitch you want to create heave but you don't have—

MR. STOCKING: To optimize the envelope what we have done is, sustaining a longitudinal acceleration is to slowly squat the system so you have more rotation and wash it out once airborne.

MR. BLUTEAU: So heave is critical, we need enough heave to do rotation.

MR. BOOTHE: Let me suggest a 15-minute break. And please hold your thoughts.

(Break taken.)

MR. BOOTHE: I think there must be something to the theory of relativity after all, because it seems like whenever there is a break, time slows. I never have quite figured it out but everybody's watch slows down during a break.

MR. CARDULLO: Ed Martin had a good suggestion, I think, during the break. Where we were talking about perhaps a 36-inch stroke system, if we didn't want to specify it in terms of stroke, but rather in terms of excursions, we could use the numbers from Lloyd's [Reid] system. Because he has been using that. You know that, if we are adopting this defensive posture for the interim. We know that would be a viable system. And it's been manufactured, so you know it's manufactureable and all that sort of thing. I mean, Lloyd [Reid] says he doesn't have the numbers on top of his head. He could give you a call tomorrow or next week.

MR. REID: Norm [Bluteau] may have them. It's a series 300.

MR. BLUTEAU: I was just on the phone to get the numbers.

MR. CARDULLO: Let me offer that as a suggestion. We use those numbers, then we don't specify stroke, we specify excursions, we may be more comfortable with that.

MR. BOOTHE: I think excursion is a good start. If somebody has the numbers we can write them down.

MR. BLUTEAU: I've got numbers, they are rounded out but I can always follow up with more accurate numbers.

MR. BOOTHE: I will give you my fax machine number.

MR. BLUTEAU: They are roughly in the x axis plus 27 and minus 31 inches. In y plus/minus 26 inches. In z plus 22, minus 25 inches. In pitch plus 25 degrees, minus 23 degrees. In roll, plus/minus 24 degrees. And yaw plus/minus 27.

MR. REID: Just one comment on the last three numbers. Those numbers are the numbers for the absolute angular displacement. If you drive it to those numbers, the CG moves. If you want the numbers that represent pure rotation, I was about to say the centroid of the platform, they are slightly reduced from those angular numbers.

MR. BLUTEAU: Yes. Those numbers are maximum numbers. Also they are nonpure axis. So you are driving each actuator to its mechanical limit and see how much displacement you get.

MR. BOOTHE: But this is single degree of freedom numbers.

MR. BLUTEAU: No, they are not.

MR. BOOTHE: They are not. We have to say what they are.

MR. REID: You can get the numbers. They are approximately plus or minus 21, 22 degrees. The pure motion about the centroid. You can get the exact numbers. Or I can look them up.

MR. BOOTHE: What I'm trying to get at is, how would I say under what conditions these numbers are attainable?

MR. MARTIN: I would suggest, number one, rather than plus or minus just specify total excursions so they can optimize the plus and minuses for the specific design.

Number two, specify that those total excursions may be about one neutral point so they don't play games moving the neutral point around. That way at least you have got some consistency.

Number three, that it's not required that these motions be simultaneous.

MR. BAKER: You better believe that.

MR. HARRIS: Zero cross-coupling between the axes? Is that implicit?

MR. MARTIN: I'm not sure what you mean by zero cross-coupling.

MR. HARRIS: It's sway without any—

MR. REID: Yes, I think that's what it was.

MR. MARTIN: I think that's what I meant by saying establish a single neutral point from which you make the measurements.

MR. BOOTHE: So that's redundant to say—

MR. MARTIN: That should be redundant.

MR. BOOTHE: So Ed [Martin], should we say x of 30 inches? Would that—

MR. MARTIN: I'm saying that you should specify a total excursion in x of 60 inches, or whatever. The 60 inches may be plus and minus 30, or it may be plus 33 and minus 27, but leave that up to the specific designer.

MR. BOOTHE: What size system are these taken from?

MR. BLUTEAU: It's a 36-inch.

MR. BOOTHE: It is a 36-inch.

MR. REID: It's the one I've got.

MR. BOOTHE: How can we get an x of 60 inches?

MR. STOCKING: That would be a unique single degree of freedom number. These are not single, right?

MR. BLUTEAU: No, those are coupled. The figures were derived, derived from the platform, move it as far back as you can, including pitching it over.

MR. BOOTHE: That really amounts to all legs extended in one direction and essentially laying them down as flat as they will go.

MR. BLUTEAU: Absolutely. Then go the other direction would be the same. Those are extreme numbers. I'm not sure they are really meaningful for training purposes. Because for training scenarios you only use a fraction of the whole stroke, you tend to drive using pure x.

MR. MARTIN: This is beyond the operational limits.

MR. BLUTEAU: Oh, yes.

MR. REID: I've got the numbers which are the pure motions for the same system. We use the real numbers, the ones that are pure motions.

MR. BLUTEAU: Do you subscribe cushion legs as well?

MR. REID: We use the stroke just to before the microswitching and we use pure motion. In other words, we don't allow any coupling of the motion when we specify what performance we are getting. These are smaller than what you are quoting.

MR. STOCKING: These are from mid stroke.

MR. REID: Yes, from mid stroke.

MR. BLUTEAU: Perhaps those numbers should go in a final version as being pure.

MR. REID: These are a little bit larger than the numbers I would quote.

MR. BOOTHE: Can you round them down to a—

MR. REID: I can send you a fax with the page with all the data on it tomorrow.

MR. BOOTHE: Okay.

MR. ADVANI: I can do the same.

MR. BOOTHE: Okay.

MR. STOCKING: What you are doing is reverse specifying a 36-inch system.

MR. REID: In effect. That may not be what you want to do.

MR. CARDULLO: The only reason I suggested this approach is that it gives us an ability to specify excursions rather than stroke. And that gives the potential manufacturers a little bit more flexibility.

MR. BOOTHE: Okay. Before Bob [Heffley] breaks his arm here, give him a chance.

MR. HEFFLEY: I guess this appeals to me because, number one, we bring in some experience base here that's attached to some numbers.

Number two, if you are going to express these numbers in terms of this pure axis by axis motion you are talking about, Lloyd [Reid], then that makes it not explicit in terms of how you may achieve these and I think that's neat, because it doesn't say you have to use a hexapod, it doesn't say you have to use anything, it leaves it up to the designer to satisfy this. So, you know, if you have everything that's gone on here, and all of the circles that we have been around, you know, it seems to me this really starts to get to something. If you really need a number today, this really comes close.

MR. STOCKING: You do want to specify in here you want to do it in neutral. You can optimize the envelope by setting your operational point to different positions.

MR. REID: Oh, yes. You can cheat.

MR. BOOTHE: Well, Lloyd [Reid], in the fax you will send me, will it specify also the basis for measurement that—

MR. REID: I will make sure it's in there.

MR. ADVANI: Ed [Boothe], my colleague from Thomson had a paper of mine which specifies our system, if you are interested in that.

MR. BOOTHE: Of course I'm interested. Thank you very much.

MR. ADVANI: That's for a 1.25 meter stroke.

MR. BOOTHE: Can we get this copied? Don [Eldredge] is not here.

MR. ADVANI: As I mentioned earlier, I should warn you it doesn't state—oh, yes, it does state the gimbal circle diameters.

MR. BOOTHE: I'll get this copied and back to you, Sunjoo [Advani].

MR. ADVANI: To him.

MR. BOOTHE: Thank you.

MR. WILLMOTT: There are six more pages there, Ed [Boothe].

MR. BOOTHE: I also have here a copy of a table from Jane's, is it called "All The World's Simulators?"

MR. IRVING: Simulation and Training Systems.

MR. BOOTHE: By our good friend I. W. Strachan, who is now the editor of Jane's Simulation Documents, which is quite an impressive document. But this lists various motion platforms around the world and who made them, what country they are in, but it does give pitch, roll, yaw, heave, sway and surge, throws he calls them here, or excursions, as we call them, for each of those systems. I don't know that that's of any particular help, it's just a document that has the world's motion systems in it. But unless I could find out which is a 24- or 36-inch system, I don't know that I can use it. But I would—I will take a look and see if I can get some useful information from it.

But now having put—thank you, Stu [Willmott], for bringing this along, I appreciate it.

Having put some numbers now on the paper in terms of excursion, my next concern is the one Bob [Foster] brought up yesterday, we could do this at one cycle a training period. So we have to say something, I believe, about one more parameter, like an acceleration.

MR. CARDULLO: I was going to suggest, I talked with Ed [Martin] during a break about this, I was going to suggest for acceleration we adopt the [MIL-STD-]1558 standards for acceleration. They have been around for a long time, people have built motion systems to them, we know it works reasonably well, as well as anything else. We know manufacturers can meet them, so for an interim standard it seems to be a very reasonable set of numbers.

Now, Ed [Martin] suggested a modification. The heave number in [MIL-STD-]1558 is, I think eight-tenths of a g, and the other translational degrees of freedom are six-tenths of a g. He is suggesting make them all six-tenths of a g. While everybody can make larger numbers with hydraulic systems, making them all six-tenths of a g in translation will open the door for some electric systems to meet this standard.

MR. BAKER: The reason they are the way they are has to do with geometry of the base. You are going to get more acceleration vertically than laterally. You have more actuators working for you.

MR. CARDULLO: You have a mechanical advantage. I guess all I'm suggesting is if we have to come up with some numbers, these are numbers that have worked in the past, they are achievable for an interim standard, why not go with it? I think we can defend the position.

MR. BOOTHE: All right. I don't happen to have a copy of [MIL-STD-]1558, I'm sure—

MR. CARDULLO: The translation numbers are plus or minus six-tenths of a g. And Ed [Martin] is recommending that for all three translation degrees of freedom. Do you remember the angular numbers?

MR. MARTIN: I think they were something like a hundred radians per second squared.

MR. BAKER: Degrees per second squared.

MR. MARTIN: Degrees per second squared.

MR. BOOTHE: Slight difference.

MR. BAKER: I could get a copy faxed up here.

MR. STOCKING: They are a function of the—

MR. MARTIN: If you could meet the translation—

MR. CARDULLO: You can do a lot more. The systems are capable of much more than 100 degrees per second squared.

MR. BAKER: It's not that much more. I have run tests on them.

MR. CARDULLO: We can argue about them but we are trying to set numbers.

MR. STOCKING: In a regulatory environment every number we put down is going to add hours and hours of testing requirements to certify the simulator. That's engineering hours. We are talking cost drivers every time we put a number down.

MR. CARDULLO: The other thing is, don't put any numbers and let them do what they want to do.

MR. BOOTHE: That seems to be the choices.

MR. STOCKING: You can achieve a compromise, you can put one thing down like 0.6 g for translational, that way you don't have to test rotational.

MR. BAKER: The only thing is you need to test the—specify the translational velocity. You basically constrain the rotational velocity and acceleration by specifying the rotational angles and by specifying the linear velocities and accelerations.

MR. BOOTHE: Let me ask one question. Are you saying rather than acceleration we use translational velocity?

MR. BAKER: You also have to specify velocity, the velocity and acceleration are essentially independent of each other. I can get you a momentary acceleration with a very low velocity and you will be—based on cue duration, you will be relatively disappointed with the motion platform performance. You know, I think [MIL-STD-]1558 has about 20 inches per second.

MR. MARTIN: I think it's about 20 inches per second.

MR. BAKER: Somebody's comment yesterday was that actually on sustained cues you run out of velocity before you run out of position. But in terms of cost, raising that 20 inches per second number up raises the price up in a hurry. It's all related to oil flow. Valves get bigger, oil lines get bigger, and the pump is going to get a whole lot bigger if you want to start raising that number.

MR. BOOTHE: Let Bob [Heffley] make his statement and then I have a question for you.

MR. HEFFLEY: Well, I guess I have a question. So far the numbers that we are talking about are only system potential and we have not even come close to getting to the point of what do you have to provide relative to the aircraft and pilot and task that you happen to be doing? And somebody could in effect turn down the gain to nearly nothing on this thing that we have come up with thus far and make it real easy to engineer and have totally inadequate cuing. I mean, we haven't come that close to getting to the task-related stuff.

MR. BOOTHE: Well, I hope to do that. I think what we have now is an engineering envelope in which to contain ourselves and then we can look at these tasks and try to make some decisions within that envelope. But if we were to just go down the task and say what we need, then we might come up with a system that's totally unacceptable in terms of size and expense, so I think we have contained it. Now we should perhaps look at task.

MR. CARDULLO: Let me suggest, to satisfy Bob's [Heffley] concern, [MIL-STD-]1558 and other specs have sort of addressed that problem without actually going and specifying a specific cue for each maneuver. It lists a number of maneuvers which are necessary and states that the system must be capable of providing a perceptible cue for all of these maneuvers.

MR. HEFFLEY: Does it say how much you must exploit that?

MR. CARDULLO: No. It just says it has to be perceptible. Since we don't know how much you should exploit it, it seems something like that would be a reasonable compromise.

MR. FOSTER: The last IATA group that worked on this came to the conclusion, they were talking about conventional six degrees of freedom, that the best thing to do was still require what we were saying was the manufacturers' specifications for acceptance. Then the concern was, how do we then ensure that this system continues to operate the way it was approved?

So the approach they took was to say "well, each maneuver should be subjectively evaluated and tuned during an initial evaluation by the regulators and the—working along with the operator. And at the conclusion of that, then the operator must provide a method to, in the computer, inject aircraft accelerations into each axis prior to coming out of the equations of motion, prior to the motion drive algorithms, and record the output of the motion platform accelerations that were produced by that." And then that became the standard that you retested to for recurrent evaluations. And that was felt, at least all the operators that participated in that, felt that that left their pilots that were responsible for the training, the ability to subjectively evaluate a system that had some given performance capabilities. It was either going to be a Thomson or CAE six degree of freedom, 60-inch stroke, so they could tune the motion system to match their training requirement and their airplane type but still give the regulators something in addition to that to make sure that now in recurring evaluations, we can show the simulator hardware and software is still performing the way it did when it was evaluated.

MR. BLUTEAU: Something that isn't in AC120-63 but it is a cost driver.

MR. BOOTHE: It is in [AC]120-63. And I think the person that designed that is right over there. But we felt we needed something like that to assure continuing performance to the original acceptance. And I think that's a good idea, but there is still nothing to say that initially providing the cues other than the subjective—

MR. FOSTER: Subjective, right.

MR. BOOTHE: —evaluation.

MR. MARTIN: In my experience, if you try to nail things down too much objectively you find you tune the simulator to satisfy the objective specifications and then you retune it to satisfy the subjective evaluations. It might be better not to say too much objectively.

MR. CARDULLO: I think Bob's [Foster] suggestion is a reasonable one. It's a little more comprehensive than what I suggested. The only negative thing would be from Norm's [Bluteau] perspective of the engineering time required to run that test. And I'm not sure it would be any more than what I was suggesting. So probably they are equal cost drivers. But I think your language specifies things much better than what I was suggesting.

MR. STOCKING: It's an accepted process, too, using [AC120-]45A to establish what the criteria was when it was accepted.

MR. CARDULLO: I have a question. Did we have a consensus on a velocity of 20 inches per second in translation?

MR. REID: It's all part of the same standard.

MR. STOCKING: As long as that's what's in [MIL-STD-]1558, I'm comfortable with that.

MR. CARDULLO: I agree, it's in [MIL-STD-]1558. Did we come to consensus?

MR. BOOTHE: I don't think so. I think I might have written it down if we did, and I didn't. I have written down a lot of numbers.

MR. CARDULLO: I would suggest that we adopt that. Unless some folks could think why we shouldn't.

MR. MARTIN: As long as you just specify the velocity in terms of translational degrees of freedom. You start getting into some—

MR. CARDULLO: Right.

MR. MARTIN: —geometric considerations when you start talking about pitch and some interactions.

MR. BAKER: The spec in [MIL-STD-]1558 is for actuator velocity. So with that in mind the actual x, y, z velocity will be a little bit higher, okay? Because the actuator velocity is less than platform velocity in every case that I'm aware of. Due to geometry.

MR. BOOTHE: What was the number, Frank [Cardullo]?

MR. CARDULLO: Twenty inches per second.

MR. BAKER: Twenty.

MR. MARTIN: Actually in [MIL-STD-]1558, we had to do some tuning for pitch. We had to back off on the pitch velocity requirement because—with the geometry used—pitch velocity was driving actuator velocity requirements.

MR. BAKER: Right now based on—I just looked at this test data a few days ago. I ran some tests on an AH-1W motion platform a couple years ago and compared that with spec requirement [MIL-STD-]1558, and with a couple of exceptions meeting the spec was not too much of a challenge. There wasn't a lot of margin but there was I think quite a bit more roll, pitch and yaw velocity than the spec required. That came from the fact you had translational velocity requirements. There was more pitch, roll and acceleration than the spec requirement. The requirement in x, y and z drove you to that position. You know, I don't know the history of that spec, so I don't know if it got backed off a little bit in the process, it may have.

MR. MARTIN: We didn't typically stick by all the numbers in MIL-STD-1558. We had some modifications in the Air Force that we typically used. Unfortunately, we were never able to complete an update for the standard before it eventually was canceled.

MR. BOOTHE: Okay. Let me record a couple of IOUs here. Lloyd [Reid] has said he will fax me your system performance.

MR. REID: Right.

MR. BOOTHE: And was somebody going to provide some pages from [MIL-STD-]1558?

MR. BAKER: I can supply you with [MIL-STD-]1558, I have a copy of it.

MR. ADVANI: I can provide you my latest paper where I show these trade-offs.

MR. BOOTHE: That's not this, that's Geoff's [Harris] paper. I will run a copy of that. I think that covers the IOUs. Frank [Cardullo]?

MR. CARDULLO: Yes. I suggest we might want to specify bandwidth. And as Ed [Martin] recommended yesterday, we should do it in terms of phase angle. And I would offer 45 degrees of phase lag at four hertz.

MR. BAKER: That's a lot more than [MIL-STD-]1558 requires.

MR. CARDULLO: Yes indeed, it's a lot more than [MIL-STD-]1558. But I think that's one area, that's probably one of the most important areas in my opinion, and [MIL-STD-]1558 was written against what the state of the art was in 1968 or so. Also, these numbers are relatively easily achievable, especially with a lighter payload.

So if 45 degrees at four hertz, and if you are talking about 150 milliseconds of transport delay, which was mentioned yesterday, that's going to give you about 110 degrees of phase lag, so you add the 110 and the 45 and you are up to 155 degrees of phase lag, which is not giving you too much phase margin. So I don't think we can do much less.

Now, it is true, most of the operating we are doing is going to be down under four hertz, it's going to be around two to three hertz. And some even below that. But in the extreme maneuvers it's going to be around two to three. So we could fudge these numbers a little bit, but it's something to shoot for, anyway.

MR. BOOTHE: If we use 45 degrees at four hertz, do we forget about the 150 millisecond transport delay?

MR. CARDULLO: That's for the whole simulator, 150 ms. Well, and also it includes the motion. But it's from when you get a stick input until the end.

MR. ADVANI: Is that above the aircraft dynamics?

MR. CARDULLO: Yes.

MR. BAKER: The thing about the motion base that's a little peculiar is the motion base time delay, if you measure with a step function, doesn't depend very much on the bandwidth of the servo because essentially what you are doing is putting a step command in the valve, and the valve is essentially at that point running an open loop.

MR. CARDULLO: Right.

MR. BAKER: Those are a lot—let me make another comment about the four hertz number.

First of all, I think it's imperative that we constrain or somehow encourage the manufacturers to push the motion base bandwidth up above what it in some cases may have classically been. I've seen them down around a hertz and a half, and that's a little bit slow. But you don't have to get there by pushing the position bandwidth up. Okay? The actuators are very good integrators. And you can set the bandwidth as low as a sixth of a hertz and still gets ten hertz equivalent bandwidth out of the system. I have test data to show that off of several different motion platforms.

Recently I took an old Link base that the Coast Guard owned that has about 2.7 hertz actuators on it, as I recall. And we pushed that up well above five hertz in most axes, on all the axes and I think some of them were closer to ten, so you don't necessarily have to do it by forcing the designer or the builder to position the loop bandwidth of the hardware. Maybe Frank [Cardullo] wants to comment on that, he may have different data than I have got. I admittedly don't have a totally thorough set of test data on this stuff. I would be interested to know people's comments.

MR. CARDULLO: Well, how would you suggest specifying it, then?

MR. BAKER: Well, when we talked about this for the helicopter Advisory Circular, we suggested one way to do it was to measure from the acceleration input to the motion and washout equations to acceleration measured over on the platform on the accelerometer. And actually, if that, you know, if you run a Bode plot of that, you get a very clear picture of exactly what the motion base is going to do when the aircraft does some maneuver. And I don't think we came around to specify what that had to be, but I think we did suggest in the circular that people use that measurement technique to determine what the motion platform was doing. We didn't get to the point of telling the guy how good it had to be, we just got to the point of suggesting that was a valid measurement technique and he probably ought to look at it.

MR. BOOTHE: Maybe Paul [Ray] has that. That's been so long, Bruce [Baker], I don't remember. We put in a method and it seems to me an alternative would be acceptable.

MR. RAY: I don't have it with me.

MR. BAKER: There was two alternatives, the older one said to basically make it acceptable to the operator or to the pilot. And I didn't think that was quite analytical enough or scientific enough.

MR. BOOTHE: Okay. Are there any other numbers we should consider in a general way on the engineering aspects or engineering envelope of the motion system independent of any specific cuing that we might want to look at?

MR. CARDULLO: Have we come to closure on this one?

MR. BOOTHE: I don't know. Which one?

MR. CARDULLO: You are asking for additional ones and I don't know if we have come to closure on bandwidth.

MR. BOOTHE: I'm still thinking of phase lag, I'm sorry.

MR. CARDULLO: Bandwidth based on phase lag. I don't think we have come to a consensus, necessarily. One thing about it, I was just asking Lloyd [Reid] what his system is capable of and it's a little bit less, he thinks, than what I was suggesting. And I think we can live with that. He was also saying it is considered in terms of acceleration transfer function, which is really what's important, I think. And he thinks that maybe it's about 60 degrees phase lag at four hertz.

MR. REID: Don't quote me. What do you think, Norm [Bluteau]?

MR. BLUTEAU: It all depends on the controller. The controller can be made to match or exceed those numbers. Even with a 45 thousand pound payload. It depends. Frank [Cardullo]?

MR. CARDULLO: So if we were in that ballpark that shouldn't be a problem.

MR. BLUTEAU: This 45 degree phase lag at four hertz, would it be tested on all six axes?

MR. CARDULLO: Yes. In terms of acceleration transfer function.

MR. BAKER: You want to test it in x, y, z space, not leg space.

MR. CARDULLO: That's correct. It's meaningless in leg space, in my view.

MR. BAKER: It's harder to make it work in x, y, z space.

MR. CARDULLO: It's harder to drive the simulator.

MR. BOOTHE: Are you suggesting 60 degrees?

MR. BAKER: I have measured data on it, I could send it to you on several different motion bases.

MR. CARDULLO: What I'm saying, 45 degrees, degrees, it doesn't matter much. Norm [Bluteau] seems confident that their system with a lower payload would have no trouble meeting 45 degrees. And I think most people don't have any problems now with these kinds of numbers. So 45, 60 is not that much, as far as I'm concerned, for an interim spec.

MR. BOOTHE: Well 60 appears more relieving whether it is or not.

MR. CARDULLO: Yes.

MR. BOOTHE: So if it appears more relieving we probably should use it.

MR. CARDULLO: It's all right with me if everybody else agrees.

MR. ADVANI: I don't see 45 as being any problem, from my experience.

MR. STOCKING: Yes, that's wide open.

MR. MARTIN: I would like to make sure it's clear as to what transfer function you are talking about. Are you talking about from the input to the motion drive laws to—? I'm wondering.

MR. CARDULLO: Exclusive of the drive.

MR. ADVANI: To the servo valve, input to the servo valve, correct?

MR. CARDULLO: No, because we are going to do it in degree of freedom space, it has to be input to the kinematic transformations. So that's just one step before. And the only additional problem there since—the only additional problem there is D[igital] to A[nalog].

MR. MARTIN: Yes. If you start bringing the D to A into it, that changes the picture.

MR. CARDULLO: It's going to change the picture.

MR. MARTIN: You might have some filtering hung out there.

MR. STOCKING: You want to find those, too.

MR. CARDULLO: Good point. So I think from the input to the kinematic transformations to the acceleration of the platform.

MR. BAKER: You are not going to include the washout now?

MR. CARDULLO: No.

MR. REID: No.

MR. HEFFLEY: Just to clarify, so we are talking about like an x double-dot to x double-dot command transfer function. Right?

MR. CARDULLO: Yes.

MR. BOOTHE: I feel like an auctioneer here. 45 once? Should we say 45 sold? I don't have a problem with 60, and apparently you don't think it's that important, that that's an acceptable range, actually. But I think we would like to use a number that appears to be less stringent if it doesn't make, especially if it doesn't make any difference.

MR. HARRIS: If the number is less stringent you may find other manufacturers are now capable of achieving it. This may be a good thing.

MR. BOOTHE: So should we say 60 once?

MR. CARDULLO: I don't object to 60.

MR. RAY: Sold.

MR. REID: Sold.

MR. BOOTHE: We use 60 degrees at four hertz.

MR. CARDULLO: And when someone says "where did the 60 degrees come from?"

MR. ADVANI: And four hertz.

MR. CARDULLO: We cast dice.

MR. BOOTHE: About the same place where plus or minus three pounds came from.

MR. HEFFLEY: To maybe state this slightly different, if we are talking about 45 degrees, you know, you are in effect saying normally that's going to determine a bandwidth, so you would say "this has a four hertz bandwidth." If you take an effective time constant to that 45 degrees, four hertz, that's about 40 milliseconds for a time constant. 60 degrees you come along, fine, that will give you some slightly different numbers there, but it's kind of—it's a slightly nonconventional way of stating bandwidth.

MR. CARDULLO: Yes, it is.

MR. HEFFLEY: So 45 degrees from the standpoint of being a universal way of—

MR. BAKER: Some of us use 90 degrees, too.

MR. BOOTHE: Okay, 45 makes it appear that we know a little bit more about what we are doing.

MR. SMITH: I like the word "appear."

MR. REID: If you want to use 45 and keep the same characteristic, you could always back off on four hertz. You could say 45 and whatever it works out to be, three and a half hertz.

MR. HEFFLEY: True.

MR. BOOTHE: So Bob [Heffley] says a more conventional way of specifying, 45, 90, 135, 180. So maybe we should stick with 45 for that appearance.

MR. CARDULLO: Yes, I agree.

MR. BOOTHE: And maybe, I don't know what the frequency would be for an equivalent, but three and a half hertz?

MR. HEFFLEY: You can figure that out.

MR. CARDULLO: Why don't we just stay with 45 degrees and four hertz?

MR. ADVANI: It's a very easy computation.

MR. BOOTHE: 45 degrees and four hertz. And that's measured from an input to the kinematic transformation equations—transformations to platform—

MR. CARDULLO: Acceleration. In each degree of freedom.

MR. BOOTHE: Any further comment on that?

MR. BAKER: One of the interesting things about this is the method of measurements, which I think is a very proper way to do it. It's going to include some of the transport delay in the computer. In the output of the computer. And I think that's good, I think that part of that should be in that measurement.

MR. CARDULLO: Do we want to specify looking at our list of critical parameters, cost drivers, do we want to specify a cross-talk or smoothness?

MR. BLUTEAU: Before we go to that, I would like to possibly finish with displacement, velocity and acceleration.

MR. CARDULLO: I thought we did.

MR. BLUTEAU: I want to make sure. Have we specified rotational velocity at all?

MR. CARDULLO: No. We specified actuator velocity. Right?

MR. MARTIN: No, translational.

MR. CARDULLO: Okay. We are saying the rotational falls out from that?

MR. BLUTEAU: I'm not sure.

MR. MARTIN: Rotational becomes somewhat complicated by the specific geometry of the design.

MR. REID: It may be true of a hexapod system. What you are saying here will hold. Specifying linear may specify angular. It may not.

MR. BLUTEAU: To be sure, we should specify linear and rotational displacements, velocity and accelerations.

MR. BOOTHE: We only have translational velocity and accelerations, we have six-tenths g for translation. We have one—wait a minute. We have angular of 100 degrees per second, we don't have a velocity.

MR. CARDULLO: We don't have angular velocity.

MR. MARTIN: I think the mind set was "synergistic." You could come in with a cascaded system, so that's a good point.

MR. BOOTHE: Well, Norm [Bluteau], now that you have put yourself on the spot.

MR. CARDULLO: Give us some numbers.

MR. BLUTEAU: AC120-63 for Level C and D, I think, has plus or minus 20 degrees per second for pitch and roll. I think it has 25 for yaw. I'm not sure whether we should back off a little bit from those numbers.

MR. BAKER: Those numbers are small. Those numbers are quite small. And probably something above that, I think [MIL-STD-]1558 has them as 30 degrees per second. And I think the bases are actually achieving something closer to 50.

MR. BLUTEAU: Do we have to be consistent with Level C and D? Should Level B be below Level C and D in terms of performance requirements?

MR. BOOTHE: Well, should it be? The perception is yes, it should be, Level B should be a lesser—a less stringent requirement than [Level] C or D. But since at the present moment there are no such specifications as these for [Levels] C and D, I guess we just pick something that we can propose for a Level B, and Paul [Ray] has to worry about [Levels] C and D some other time.

MR. BLUTEAU: There is something—

MR. BOOTHE: Pardon?

MR. BLUTEAU: There is something specified for helicopter performance in AC120-63 on both Levels C and D.

MR. BOOTHE: We didn't do anything on [Level] B, did we?

MR. BLUTEAU: No. There is a concern to be consistent between what we do now and what is presented with helicopter. But I agree those numbers are not unreasonable, I'm just addressing the consistency.

MR. BOOTHE: Yes.

MR. BAKER: Well, let me say first of all I don't think the numbers in [MIL-STD-]1558 are that hard to achieve.

And secondly, let me say if somebody comes in with a cascaded system, what you expect goes out the window. In a cascaded system if you are forced to go to plus or minus 20 degrees of pitch, roll, yaw. Most of the cascaded systems I see do that simultaneously. You do that in all three axes at once. Which you can't do with the synergistic systems.

It's not a bad assumption to press on and assume that we are talking about a synergistic system, and if somebody wants to design something else they can come back to Paul [Ray] and say "hey, here is a rationale why this is an equivalent system, we would like to do it this way because of these engineering reasons." And he will call this body back together again and we will have a few days of nice meetings and say "yes, that's okay." Maybe it will be simpler than that. I don't know.

MR. BOOTHE: Let me get that number written down that you were proposing.

MR. BLUTEAU: I was proposing possibly the same numbers as being used, presently used on AC120-63 Levels C and D, and the numbers are, for pitch and roll, plus minus 20 degrees per second.

MR. BOOTHE: Okay.

MR. BLUTEAU: For yaw it's 25, I think.

MR. MARTIN: MIL-STD-1558, at least what I have written down here, specified 20 degrees for roll, pitch and yaw. For the geometry that [MIL-STD-]1558 was written around, I recall we had to back off to about 18 and a half degrees per second pitch to be consistent with the two feet per second translational velocity. This was due to the geometry.

If a vendor doesn't come in with a cascaded system you may be driving it with some of the angular rates. It all doesn't scale down very neatly.

MR. BAKER: I wish I had a calculator. That would—wish I had a copy of that, that would eliminate a lot of discussion.

MR. STOCKING: I was going to say for [MIL-STD-]1558 testing we segregate the testing in two areas. One is testing the capability of the hardware, and we do those tests without the platform being populated, we do a dummy load on it. And once the maximums are tested, we never test them again. We only have maintenance testing from that point on. But once it's populated, both with expensive electronics and people, with expensive visual systems, these accelerations can be potentially damaging.

You have visual systems that are located a long way from the CG and whatnot that are starting to magnify things considerably. We are approaching these problems with this type of regulation.

MR. IRVING: So why bother with them?

MR. STOCKING: Instinctively I feel we are maybe doing something that we want to specify when it's a manufacturer's type of motion system. And in another place have it tested when it's fully populated with some other type of test system then indeed we've got a system, right? That has that capability but not test explicitly once that platform is populated.

MR. BOOTHE: I'm not sure I followed all that, Chuck [Stocking]. There's silence in the room.

MR. STOCKING: Once you populate the platform, a lot of the numbers we are talking about are potentially damaging or reduce the life cycle of the equipment on the platform.

MR. IRVING: Therefore we shouldn't specify something we can't use. Or am I missing something?

MR. BAKER: I think the biggest problem is you kill the projector for the visual system.

MR. STOCKING: Tear off screws and bolts and all kinds of things.

MR. BLUTEAU: What number are you concerned with?

MR. STOCKING: The acceleration testing. As soon as we get into acceleration testing for translational, it isn't too bad. Rotational stuff really starts taking off when you start testing.

MR. BLUTEAU: So the 100 degrees per second or 20 degrees per second that you take, which number is a threat to simulator integrity?

MR. STOCKING: I don't have a good feel for that.

MR. BAKER: You know, I basically agree with what Chuck [Stocking] said. When I ran a test on an AH-1 they put a projection dome and a bunch of high quality projectors in it. I said "are you sure you want me to do this? Because it's going to thump the equipment pretty hard." They said "go ahead."

But we also did damage some projectors on a CH-46 sim by having the computer program overflow and wrap around once and give a full scale, full amplitude motion input into the platform. We didn't get cursed real bad, but the guys weren't real pleased with that.

MR. BLUTEAU: [MIL-STD-]1558 requires that the simulator can sustain—well, the simulator typically can sustain up to 2.5 g or something along those lines.

MR. STOCKING: That's an unpopulated platform.

MR. HARRIS: No.

MR. MARTIN: No, that the worst case emergency shutdown is 2.5 g.

MR. HARRIS: Under no circumstances must it exceed. It's not shutdown.

MR. MARTIN: That's a "not to exceed number."

MR. BAKER: I think very few people test to that number. Particularly with it populated, you would be foolish.

MR. CARDULLO: If we are talking about 100 degrees per second squared and if the equipment is about 15 feet from the center of rotation, you are only talking about 26 feet per second squared tangentially. It's less than a g. This stuff ought to be able to hack a g.

MR. BAKER: It doesn't always hack a g real good.

MR. CARDULLO: Well, then I have to agree with Don [Irving]. Why are we specifying it if you can't use it? It seems to me it ought to handle a g.

MR. BOOTHE: That brings up a question. We are talking about what [MIL-STD-]1558 says and what other specifications say, what we have done in Advisory Circular 120-63. Those are system specifications. The question is, is anybody using a motion base that even approaches that performance level?

MR. MARTIN: Yes.

MR. BAKER: The motion bases do, the performance that's in [MIL-STD-]1558, some do a lot more than that.

MR. BOOTHE: They get tested to that but in daily operation are they doing that, is my question?

MR. HARRIS: Certainly we achieve [MIL-STD-]1558. One of the requirements, one of our customers in this country wants to take the simulator ready for acceptance and drive it as hard as he can till it stops.

MR. BOOTHE: Drive it until it stops?

MR. HARRIS: Drive it worst case and check that the simulator itself is safe and what are the g[-value]s, and this we have to do.

MR. BOOTHE: That's testing. My question is now, what's going on in operations? Do military simulators actually use the values to which the motion base was tested in flight training operations? Or do they decide we don't want to damage our equipment and for a number of other reasons attenuate it subjectively and we are hitting ourselves with these numbers?

MR. MARTIN: Let me make a couple comments. Based on what I have on the table here from the short-course notes—and I think I have copied this accurately out of [MIL-STD-]1558—what we specified for peak acceleration in rotation was 60 degrees per second squared. Not 100. I have tested the systems to these limits with the operational equipment on board. I have done it with sine waves, not steps. That may make a difference.

Now, whether we use it, whether the washout ever commands this size acceleration, I don't know. I've never monitored for that—only whether the capability was there in the basic equipment.

MR. HEFFLEY: Seems to me that's an awful relevant question, though. I mean, if we are designing something that is far in excess of what is really being used—

MR. BAKER: Well, it turns out that the—

MR. BOOTHE: Frank [Cardullo] has been up here raising his hand.

MR. BAKER: I'm sorry.

MR. BOOTHE: Sorry.

MR. CARDULLO: Part of the reason I don't think it is used, at least not in all cases, but part of the reason for that is the types of cuing algorithms that are being used. If you use a linear cuing algorithm, you scale so that the washout is imperceptible. And in a linear cuing algorithm, the washout is proportional to the onset. So this drives you to scale factors like 50 percent or 20 percent.

If you use nonlinear cuing algorithms, then you can take advantage of that capability and you really want to be able to do that. I don't think the capability that we are specifying is anything less than what we could use and should use, but it isn't often used because of the types of cuing algorithms. But cuing algorithms are getting better, people are improving them, they are using nonlinear adaptive algorithms, and so in that case I think you will find that they are using much more of the capability of the hardware.

MR. STOCKING: On a case-by-case basis, right? You will find uses to use the things that we are testing to. And somebody is going to make a decision. I've got this expensive electronics in there, and it's more important to me that I don't break the electronics every six months than it is for whatever training it achieves. And you have that potential to make that decision at any time down the road if you have these limits. But you don't have to test for them all the time if it's a design criteria and not maintenance criteria.

MR. BAKER: One thing I was going to say, if you design a 60-inch stroke base with the payloads they are designed for, you are going to end up with three kinds of acceleration numbers based on the way the rest of the engineering comes out. You are not going to want to reduce the system pressure much below 1200 psi because of problems with the valves if you do that. You are not going to want to make the actuator smaller in diameter, because of the problems of holding a static load and problems of stiffness of the actuators in the bending direction. So I don't think we have put an unnecessary burden on anybody by keeping those numbers, those g acceleration numbers where they are in [MIL-STD-]1558.

MR. BOOTHE: Well, another question I would have about these numbers, then, is whether or not they could be met by an electrically driven system, within its own payload capability, of course. I guess Fokker says they can handle seven thousand or eight thousand pounds, which really simulator-wise is not a lot. But are we out—are we overruling electrically driven systems with these numbers?

MR. BAKER: I don't think so.

MR. MARTIN: I don't think so.

MR. CARDULLO: One of the reasons I reduced the eight-tenths accelerations to six-tenths, was to accommodate electric motion systems.

MR. BOOTHE: I do want to make sure we are not just ignoring that capability. Because I think that's a system very much of interest to people in this environment.

MR. WILLMOTT: I'm not familiar with [MIL-STD-]1558. I would take it to be a military specification?

MR. MARTIN: Military standard.

MR. WILLMOTT: What was it designed for, what was it produced for? Was it for F-14s? F-18s? Or was it for—

MR. MARTIN: It was produced around the 1974, '75 time frame. Back then it was to be a generic six degree of freedom six post standard for the motion simulators that we would require for the Air Force.

MR. WILLMOTT: So it applies equally to these fast little fighters that need very, very high rates of—

MR. STOCKING: It's an all product spec.

MR. MARTIN: That was the intent. In fact after it got published we found that the frequency response numbers didn't really make a whole lot of sense in some areas. We backed off on the pitch velocity requirement because that turned out to be driving actuator velocity, which in turn starts driving the cushions and devices that are needed to absorb the kinetic energy in the event of a failure, and became a cost driver.

These modifications wound up just being an addendum that we put in specific specifications. So [MIL-STD-]1558 was generally what we used, but there were a few amendments to it that we always applied.

MR. WILLMOTT: The point I'm getting at, I wonder if that is relevant to passenger carrying aircraft.

MR. CARDULLO: This was used for transports, C-130s and B-2s.

MR. WILLMOTT: But it's really designed for all military aircraft and much, much more responsive ones than what we are talking about for regional aircraft.

MR. STOCKING: In the commercial division we used the military hardware but we used it without the specs. In other words, we did not test those specs because they were design specs. That saved us money.

MR. BLUTEAU: Also I would like to say that this spec, being over 20 years old, it is generally accepted that this spec is now very easily met and it's not seen as being a high performance spec to meet at all.

MR. WILLMOTT: But there are quite definitely some systems out there now that do not meet it.

MR. BLUTEAU: They may not meet the safety part of it, which is the toughest part.

MR. WILLMOTT: In terms of performance.

MR. BLUTEAU: Performance is generally recognized to be fairly easily met.

MR. WILLMOTT: There are systems out there that don't.

MR. BLUTEAU: I'm sure there are, yes.

MR. BOOTHE: That brings up the next subject I would like to introduce. We are talking here about a segment of the industry which would much prefer a fixed base device, they would like to get all the credits. So I don't mean that facetiously, but in perspective, we are going with this segment of the aviation industry from nothing to what appears to be a rather stringent specification of performance here. Tom [Longridge] is going to hear about this. So I think the next step we have to do is still look at these tasks and say what cues are necessary to check pilots in these tasks, and put them in the perspective of this engineering envelope that we have now designed. Because I don't think the industry that we are dealing with is going to be very receptive to us, to the FAA just saying here is your motion spec, live with it. There is going to have to be some rationale to convince them why this is an important thing to do.

MR. LONGRIDGE: I think that's certainly true. But I would hope by virtue of some of the decisions we made today we are coming up with a more affordable six degree of freedom motion platform.

MR. BOOTHE: Well, I guess that's the question.

MR. SUSSMAN: I was just going to say the whole concept was to bring the simulators used by the Part 135 airlines to a higher level. What you have done is come up with a meaningful spec, which is more consistent with the "state of the art." I don't think you can say "yes, it's possible that it will be more expensive but the only way you are going to enhance the simulation capabilities available to Part 135 airlines is to make use of the advanced technologies which represent the current state of the art." The goal of this activity, as I understand it, is to elevate safety by providing improved simulation. So you are suggesting what appears to be a reasonable level of improvement.

MR. LONGRIDGE: Yes, that's true. But we have to be pragmatic, we absolutely must come up with a system that is accessible from a cost perspective.

MR. SUSSMAN: I think you are getting there, though.

MR. CARDULLO: I had a question about your question. I didn't really understand what you meant by matching these maneuvers to cues. What did you really mean? Do you want to go and specify what acceleration is necessary for each one of these maneuvers? Is that's what you want? I don't think we can do that.

MR. BOOTHE: Then that's what I want, but your feedback is what I want to find out, too. So if that's not something that's possible for this group to do, we need to know that. Maybe that's one of the longer term things we need to think about.

MR. CARDULLO: I think what we sense, what we kind of know, is that given the engineering specification that we have laid out so far, that we could accomplish all of these maneuvers at a reasonable level of fidelity. I think that's what we are implying in what we are doing.

But to go into each maneuver and specify a cue for each maneuver and magnitude of acceleration or whatever, I don't think we can do that.

MR. BOOTHE: Okay. I think Lloyd [Reid] had his hand up.

MR. REID: What we can do, Frank [Cardullo] and Ed [Boothe], is go over to the next column, motion objective, and go over these items, and say these are the things that must be produced with sufficient fidelity to allow training in the judgment of whoever it is we are going to say has to make these judgments. I assume it's FAA certification pilots or whatever their titles are. I think we could go over that list and see if we are happy with the things that you have listed initially.

MR. CARDULLO: I agree with that.

MR. REID: And modify those based on our experience.

MR. BOOTHE: I would like to look at them because, I mean those are just one person sitting at the computer saying "why do we want to do this?" And there you have it. I think I do need some input there, very much so.

MR. CARDULLO: Before we depart from the engineering specifications to go to this, let me reiterate the question that I asked before. Do we want to have any specifications concerning cross-talk and smoothness? Because I think if we don't, all the rest of the spec kind of becomes meaningless because those can add a lot of false cues.

MR. BOOTHE: Well, I think if we are going to do this we ought to do it completely or else we are wasting our time. I don't mean we should overdo it, but I certainly think we should include all of those things that are important to the appropriate result. And exclude everything that we don't need. Stu [Willmott]?

MR. WILLMOTT: I'd like to suggest that we include a check for the balancing of the lags dynamically. If you say you accept 45 degrees lag at four hertz, I would recommend that each of the six legs be within—I beg your pardon. You are not—I'm off on the wrong tack. You wanted to do that on each axis. I was thinking in terms of the legs.

MR. CARDULLO: What you are suggesting is cross-talk in degree of freedom space.

MR. WILLMOTT: We recently accepted a simulator with a motion system that didn't meet these dynamic characteristics, and you could do a heave motion just checking the system out and you would find a lot of lateral and other spurious movements, and it got down to the characteristics of the individual valves on the legs not being closely matched.

And we had to get those checked.

MR. CARDULLO: You do want cross-talk and spurious movement to be below the level of perception. So you want to specify in terms of acceleration. But what that threshold is varies depending on what the pilot is doing. If he is heavily task loaded, it's much higher. If he is just sitting there testing the simulator, that threshold is much lower. You can feel a lot more.

MR. BAKER: Let me make another comment on that, Frank [Cardullo]. The problem with the synergistic base is that the cross-talk is not a simple thing to specify or test to. And if we, I think—not that I think we should back away from it, if you make some simple tasks, for example running the thing in the lateral direction and measuring cross-talk in roll, then if you change the attitude of the base or you change something about the base, then the cross-talk is going to change. And I think we need to at least be aware of the fact that people may try and design a simplified controller to take some of the cross-talk out, which will work for the test but won't work in general.

MR. CARDULLO: Well, that's a problem. Although I think that if you run these tests out of neutral, which is where you would probably do it most of the time, or a high percentage of the time, you are operating the simulator out of neutral. So you may run into some situations where you get into that problem. But it's usually the dynamic effect of the mass that causes that problem in unusual attitudes. Since we are talking about a smaller payload with smaller mass properties, that problem will not be as great as it is in a Level C or D device.

MR. BAKER: That's an assumption, I think, be careful with that. Because you know if you go back to the specs that we have got for acceleration, for example, that's going to size the actuators for the payloads on there. The real question is not—the real question is driven by the—determination of cross-talk is driven by the natural frequency of the actuators, the natural frequency of the oil spring, that's what causes the phenomena. If the oil spring wasn't there you wouldn't have cross-talk.

MR. CARDULLO: Right, that's a function of the virtual mass that exists at various attitudes.

MR. BAKER: It's dependent on that, it's also dependent on that if you reduce the acceleration requirement, then the designer can reduce the diameter of the cylinder, which makes the spring softer, so I think the whole thing washes out. If he designs to a particular acceleration level.

MR. CARDULLO: Well, would we be comfortable in specifying cross-talk and smoothness simply as in terms of, rather than numbers, words, to the effect that cross-talk should be imperceptible as opposed to saying it should be less than 0.01 g or something like that? The problem is that it leaves it sort of open, but it leaves it up to the examiner to say—well, I'm not sure that's the right term for the person doing the checking.

MR. RAY: Right.

MR. CARDULLO: But it leaves it up to them to say "yes, it's acceptable" or "it's not acceptable." You have to remember this is an interim specification that we are talking about. And if we get more knowledge later on, we can change it.

MR. WILLMOTT: The sort of test that I was envisioning to check that out, in fact, goes to drive all six legs, so it's essentially moving up and down, which I guess is the z axis test at zero pitch, and to put an accelerometer on board that measures the lateral and the longitudinal accelerations, and those should be below certain threshold levels. I thought the threshold value was about 0.05 g.

MR. CARDULLO: If I may answer that. That's sort of the absolute threshold. But it's higher if you are task loaded. So when you are flying the airplane that threshold moves up. We don't want to be too stringent because the guy is going to be flying the airplane, or flying the simulator. I mean, since we don't really know what those numbers are, I'm not comfortable with putting one in.

MR. MARTIN: Well—

MR. HARRIS: Go ahead. Okay. Currently in [AC]120-40 we have frequency response, which we normally take as being platform response. [Item] 3.b. is leg balance. Now, here you are talking about driving the platform, either all legs together or else in heave, which are similar but not the same. And checking the symmetry of the legs to each other. Any asymmetry and the thing will rotate as opposed to—

MR. WILLMOTT: But it is done at a relatively low frequency. When you do things faster depending on the frequency response of your system, you get something totally different.

MR. HARRIS: It will buck and twist.

MR. WILLMOTT: I think we did ours, I forget the frequency, at half a hertz or something like that, but still when you were doing this sort of thing *(indicating a fast push/pull control column motion)* you get all this lateral movement.

MR. HARRIS: Are you expecting that a Level B simulator will have a tighter specification than [Levels] C and D?

MR. WILLMOTT: I think what we are specifying here is a requirement for a Level D sim, but I'm going along with the general consensus which is to make the system as complicated and sophisticated as we possibly can. This is something that I have found and experienced but there is no requirement to test that, I think it should be included.

MR. BAKER: Let me comment on that a minute. First of all, it's my opinion—

MR. BOOTHE: Go ahead. We had a couple other comments.

MR. BAKER: Getting the leg servos to balance pretty well is not hard to do. I'm more concerned about the dynamics of the oil spring. And the effect of putting a large input, a fast input in x or y than having the base react in pitch or roll. Those things are inherent in the design of a base and they are somewhat difficult to correct. I don't think making the leg servos match is as difficult as that problem is.

MR. HARRIS: It's inherent. The specification is in [Levels] C and D.

MR. BOOTHE: Ed [Martin] is trying his best.

MR. MARTIN: Just some comments. One of the first problems that I got involved with in motion simulation was a problem where an Air Force pilot in an F-4 simulator complained about a problem involving cross-talk. It was pretty subjective, he said "when I roll it feels like I bump my wing on a cloud." I don't believe there was any cross-talk spec on the simulator at that time. Nonetheless, there was an intensive effort to try to correct the problem. I think it was due to the oil spring problem. It never did get corrected satisfactorily, to my knowledge, in that particular simulator. Link developed another motion simulator to supercede it. It was a major change.

What I'm thinking for purposes here, is that the FAA has a much larger hammer than the Air Force does—and the Air Force was able to get the vendor to address the problem. Leg balance is one critical parameter. If you don't get that right you have a lot of problems. It's a fairly straightforward test.

If we start getting into trying to test other aspects of cross-talk, we might start driving cost just on the basis of some of these complicated tests. It might be best just to have some words in there about subjective evaluation of cross-talk.

MR. CARDULLO: That's what I was going to suggest, I was going to suggest some straw man wording.

MR. MARTIN: By the way, since the question came up earlier, the magnitude of this cross-talk was about a tenth of a g.

MR. BAKER: I would like to get an input from—

MR. BOOTHE: You said to say it's imperceptible, which sounds okay to me.

MR. CARDULLO: I was going to say imperceptible during normal flight maneuvers or imperceptible while flying a simulator during normal flight maneuvers. I don't think you should simply say imperceptible because someone can then sit in the simulator and concentrate on the motion cues and they will be subject to this 0.015 or 0.008 g threshold if he or she has a really fine-tuned otolith.

MR. BOOTHE: Like staring at a visual system.

MR. CARDULLO: Exactly. I would put it in the context of normal maneuvering.

MR. RAY: Could I suggest operational use as opposed to normal maneuvering.

MR. CARDULLO: That's fine.

MR. SUSSMAN: If I could suggest modifying that slightly I think it is right to do it in the performance of routine maneuvers or however. I think one way of framing it, cross-talk shall not be objectionable and then that leaves it open to the—

MR. CARDULLO: Maybe "objectionable" is better than "imperceptible."

MR. HEFFLEY: You know, that's going to get you—

MR. CARDULLO: That's sort of a number.

MR. HEFFLEY: That's a number.

MR. CARDULLO: People look for numbers.

MR. HEFFLEY: What you really want is something that's not going to get in the way of doing the job.

MR. WILLMOTT: But how do you check for it? What is it that you do to check for your cross-talk?

MR. BOOTHE: You don't notice it. Then it's not there. Right?

MR. HARRIS: Intrusive.

MR. BOOTHE: Seriously, that's what we are saying.

MR. WILLMOTT: Subjective evaluation, that I thought was what we were trying to get away from.

MR. RAY: I personally prefer, everyone has a different word they like to use in the English language, I prefer the word "imperceptible." To me that's an objective term, "objectionable" is a subjective term. That being different to any two pilots. However, they should be able to clearly identify whether or not they can perceive that cross-talk.

MR. HEFFLEY: I understand, you are certainly right about that. But not perceptible can be awfully small. And awfully tough.

MR. SUSSMAN: What we do when we have to work with a basically subjective judgment, we tend to specify the maneuver and the conditions and the people who certify it need to develop a repertoire of what they think is perceptible within that maneuver, that's the only way you can do it, you can't get away from subjective all the time. After a while the guys develop a repertoire of what they expect.

MR. BAKER: One of the things that has probably kept us out of trouble in this area is the fact when a guy is doing a normal maneuver, he is not pushing the motion base too hard and the cross-talk levels are very, very small. And when you get a wind shear situation where you expect higher frequency inputs into the platform, the cross-talk levels come up. But the guy doesn't really know what to expect anyway, so he doesn't know if that's a real computer generated cue or it's a false cue, and furthermore, it doesn't make any difference because you are basically trying to let him know he is in a turbulent situation, how the turbulence got there is kind of subjective anyway. So I don't think the problem is a real issue except to keep the legs balanced. I don't think we are going to force people to change the design of the motion platforms to reduce the cross-talk that's inherent due to the oil spring. Okay?

MR. BOOTHE: Well, if we use words like not objectionable or imperceptible, I think we could come up with something that satisfies the group.

MR. SUSSMAN: You know what you want to use the simulator for, concentrating on the following maneuvers it should be imperceptible, not objectionable, and specify the maneuver.

MR. CARDULLO: We specify this list of maneuvers.

MR. HARRIS: That does become aircraft dependent as opposed to motion systems dependent. If you want to quantify a particular attitude, a particular amount of cross-coupling, then these are the numbers. That's the objective. If that's what you want to do.

MR. CARDULLO: I have to take a cue from Ed [Martin]. There is an objective way of doing it which is rather expensive because it's very time-consuming. You could simply do leg balance tests, but I don't think that tells you really everything you want to know.

So given that compromise I think the subjective approach is acceptable, especially in an interim spec. Since we don't really know what numbers to put on it.

MR. BOOTHE: That's the cross-talk issue. What about—

MR. CARDULLO: I would put smoothness in the same category.

MR. BOOTHE: Okay, that was my—

MR. CARDULLO: Would you—

MR. REID: Yes.

MR. BOOTHE: We can use similar words for smoothness.

MR. BLUTEAU: Smoothness can be easily tested.

MR. CARDULLO: What's the number?

MR. BLUTEAU: Not a number but in terms of process, in terms of test procedure it's a lot easier.

MR. CARDULLO: I agree, but the number is tough to determine.

MR. REID: The other point is that smoothness is more than turn-around bump. There could be systems, maybe not our nice hydraulic systems we have now, but there could be systems, some of the electrical ones where just the actual movement, not turn-around, but actual travel has ripple, and you measure that. You have to do a big series of tests just like you do for the cross-talk tests if you want to cover every condition.

MR. BLUTEAU: I just wonder if subjective assessments will be able to pinpoint problems.

MR. CARDULLO: But that's up to the manufacturer to do, not the FAA or the user. The manufacturer can use his own tests to pinpoint problems.

MR. BLUTEAU: I mean whether the FAA will be able to say with a certain level of confidence that this simulator is actually acceptable if all that is used is a number of subjective assessments.

MR. CARDULLO: I think so. From my perspective what we are concerned about with smoothness and cross-talk is that it gives a false cue. Really the only thing we care about, is whether these are false cues. These are two things that can give rise to false cues. If it's imperceptible, that's all we care about. If it turns out it is perceptible and someone is going to try to fix it, maybe you have to run additional tests to find the problem, but I don't think the FAA should care about that. That's up to the manufacturer to go fix it.

MR. BLUTEAU: I'm trying to imagine the words to be put in the circular to tell an FAA inspector, which may or may not understand motion systems very much, what maneuvers he has to do, what to look for and how to judge whether a level is acceptable or not. I'm sure we can all do it because we know what to expect, how to trigger those problems. I just wonder—

MR. BOOTHE: I think these kinds of subjective evaluations are more within the day-to-day practice of people in the FAA who are evaluating simulators. With some exceptions, they are not engineers, they don't maybe understand the stuff we have been talking about here. But they certainly can tell whether or not there is something strange going on with the motion system when they perform a certain maneuver. So I think in that case some subjective guidance is probably better for the continuing evaluation part. So I personally don't have a problem, and particularly as Frank [Cardullo] has said, for an interim solution. If in the final solution that's found to be insufficient, then we can discuss it.

One thing I would like to do, we are coming up on lunchtime, some of us have to check out during lunch and take care of some other things, some people have to leave shortly after lunch. I know Frank [Cardullo] does. But we have sat here and I think made great progress this morning, but I don't want to put Bob Foster on the spot, but I'm kind of forced to. I wonder if I can hear a little now, if I may, the operator's perspective or your perspective as an operator, Bob [Foster], about what we have done or what we are in the midst of doing. If you don't want to do that—

MR. FOSTER: I don't mind saying that. I'm concerned we have built in excess of what Stu [Willmott] implied. I think we have built a Level E motion system. Especially if we were to put these testing requirements in any sort of recurring evaluations, I don't know what we have done to fulfill these requirements. But it—I don't think we have done much of anything towards making a Level B simulator more affordable.

MR. BOOTHE: I thought you might say that.

MR. HEFFLEY: But I think—

MR. BOOTHE: Go ahead.

MR. HEFFLEY: I think there is another side. I think it's wrong to—I don't disagree with what you say, Bob [Foster]. But I think it's also fair to recognize that we are looking at this whole business today, we are not looking at it ten years ago or 20 years ago. We are looking at it in the context of a lot of things that have been learned over a long period of time. And it's legitimate to recognize that there are a lot of factors that really do need to be brought to the table when you are talking about the design of a simulator, even though you are trying to make it a cheap, inexpensive simulator. You know?

MR. FOSTER: I don't like the term cheap. I think what we want is an effective simulator for Level B recurrent training and checking. And to some extent it will of course be used for initial checking, initial training as well. I just—and from a pragmatic standpoint, where we are at now is these guys are not trained in simulators. They are tooling around in the middle of the night simulating engine out conditions at whatever condition an instructor feels is safe handling. They are not getting the opportunity to practice things like, you know, feather pump failures and things where they actually go in and push the buttons and cancel the bells and do all those sorts of things.

And it's just my personal feeling that we would be much further ahead to have a truly affordable Level B simulator that can be very effective for training and checking, and I don't personally see the need for anything in excess of the existing motion system to do that. The existing three axis motion systems. You might want to make it, I was talking to Paul [Ray] a little at the break, you might want to eliminate heave axis and go with pitch, roll and sway or something like that.

But to me the initial step is we have to get these guys into simulators, they should be in simulators and getting the advantage of all that repetitive training and really looking at a guy, doing demonstrations of V_{MCA}, showing what happens when that engine doesn't feather, and you better be quick and jump on that thing, and have gone through that drill. Which you can't do very effectively in the airplane.

So to me that's the first step. You look at saying I have to get these guys out of the airplane and into a simulator, and if I can keep them in a reasonable facility with a maintainable piece of equipment that doesn't drive the airplane operator out of business, then you want to go to the highest level you can.

Especially for an interim type of situation, I think we are building kind of a—like I said, a Level E with this, and I also question because of not having a wider angle visual and the other thing you are looking at is trying to convince these, especially the independent operators, to take this step. It's going to be difficult.

MR. CARDULLO: Well, we were given a ground rule at the outset that no motion was unacceptable.

MR. FOSTER: Right.

MR. CARDULLO: So we are faced then with either current level of motion or what you call the current level of motion, which I assume is three degree of freedom systems and six degree of freedom, and we argued that quite a bit yesterday and I thought we came to a consensus that you might as well not have any if you are going to have three.

MR. WILLMOTT: No.

MR. HEFFLEY: Bob [Foster] suggests another set of three, okay? It's a different set of three.

MR. CARDULLO: I understand. I understand. It's a different set of three but it's three. And, you know, we never discussed the homework assignment, but I know when I went through the maneuvers, I really couldn't find three degrees of freedom that would satisfy all these requirements. And if you are going to get false cues out of the motion system you might as well not have it. I hold that bad motion is worse than no motion. And I would rather see us throw away the motion system than put a motion system on there that's going to be bad. Unless it was just a vibration system. That, in my view, would be a preferable option to a three degree of freedom system.

MR. BOOTHE: Maybe we could before you have to leave, do some of that homework assignment quickly. You have to leave at?

MR. CARDULLO: I've got to get the 1:30 bus to the airport. I have a 2:20 airplane.

MR. BOOTHE: So immediately after lunch we could at least look at part of that.

MR. CARDULLO: We can eat and talk.

MR. BOOTHE: Would you mind a shorter lunch period?

Instead of an hour we could take, like I said, for example, I have to check out and stuff like that. So maybe 45 minutes would give us at least 15 more minutes, or say be back at quarter to 1:00 from now. Is that all right?

MR. RAY: I just want to capture one thought. Did we capture Bob's [Foster] comments from the IATA group as far as testing? The intention was to embed it in there. Did we get a consensus that the language is reasonable to embed or did we not?

MR. BOOTHE: I don't think there was any discussion to the contrary. I wrote down as much as I could, understanding that she is [The Reporter] writing down all of it. But I didn't hear that anybody objected to that kind of language. Did you, Bob [Foster]?

MR. FOSTER: I didn't, it goes along the lines of what was Chuck [Stocking] was talking about in testing these things. If we have to go in once a year and do velocity and acceleration testing and stuff it's going to take about a week to get the simulator ready for it and do the testing and then unbolt everything afterwards. It really tears it up. It really does.

MR. RAY: The reason I raise the issue, it seems like something reasonable to use regardless of what motion system you are talking about, whether a three DOF or four DOF or six DOF or a Level A or a Level D.

MR. BOOTHE: Well, I don't—I didn't hear any objection. And it is very similar to what was written in the helicopter Advisory Circular, which has not been used to any great extent, but it's there. So I think it's not precedent setting at this point.

MR. RAY: I just wanted to close that issue.

MR. BOOTHE: Okay. Lunch and return at quarter of.

(Lunch break taken.)

MR. BOOTHE: While we continue dessert, those of us who are, I want to take maximum advantage of some people's time here and probably it's a good time to begin looking at the table. I would suggest we begin by looking at takeoff. Not at the exclusion of others, but simply to get what we might think is more critical and see if we can better describe the task or motion objective for those tasks.

And so if we can read through those and if there are questions on the table, please bring them up. You notice under takeoff those objectives are really for each of the components of the task, like for acceleration along the runway, steering and crosswind, each have a motion objective written. And I'm open to correction.

MR. HEFFLEY: I have a question. Takeoff is a good example of where you can see that there—it's clear that there is motion involved on takeoff. But to what extent is motion at all essential from the standpoint of training during normal takeoff? Forget all other tasks, but if you were to design a simulator to just train for a normal takeoff, what is it that you—that would drive you to say I need to provide a motion cue in that particular task?

MR. ADVANI: Because sometimes you will have an abnormal takeoff. There is a lot of lateral, longitudinal forces.

MR. HEFFLEY: Okay. I guess I was trying to put aside the abnormal takeoff point. Clearly there are some things that come in there.

MR. ADVANI: Since it's part of training you cannot say "okay, we are going to normal takeoffs with no motion," so to speak.

MR. STOCKING: Rejected takeoff, when to make a rejected takeoff.

MR. HEFFLEY: Let's say rejected takeoff, is there cuing in that?

MR. RAY: Yes.

MR. HEFFLEY: Motion cuing.

MR. RAY: And for crosswind takeoffs.

MR. CARDULLO: This is also a workload consideration.

MR. RAY: That's correct.

MR. CARDULLO: In some respects during a takeoff, motion reduces the workload because it gives you an indication of when you've lifted off, for example. The other case, it increases a workload because if you have some vibration on the runway and that sort of stuff, so it's giving you a little bit of increase in workload. Therefore, we have to remember, as I understand our charge, this is not to be used just for training but for evaluation. And so in a way to be fair to the pilot whom you are evaluating, you have got to give him as much of the information that he would have in the airplane as possible. Although we can't give him everything.

MR. RAY: That's the genesis of it. To limit the issue to training can be a false road. There are many very effective training mediums that contribute to the ultimate proficiency in the aircraft. However, the device we are talking about is an assessment vehicle. It's that vehicle at which we are either going to recertificate or requalify a pilot for operation without another evaluation in the aircraft.

MR. HEFFLEY: Right.

MR. RAY: Many of the studies I have reviewed tend to point towards training value, which tends to become very subjective. Particularly when you start selectively including or excluding the myriad of cuing that occurs inflight. If we maintain our focus on pilot assessment, it makes the need for the respective cuing much clearer. And the reason for its need.

Imagine that you are taking a driving test in simulation. You're going to be recertified or requalified every year to drive your car on the highways. What do you need in order to assess a person's ability to safely do that? You have to include all the cues that you possibly can, that you know they will be exposed to in the real world.

MR. BOOTHE: Does that answer your question, Bob [Heffley]?

MR. HEFFLEY: Yes. I mean, there are some things in there I was looking at differently.

MR. BOOTHE: Well, I wasn't totally listening, obviously, but I think there are some secondary intrinsic things here that provide cues that we maybe unconsciously use but miss them when they aren't there. I think it's just speed cues that occur because of roughness of the runway being modeled. If you do a takeoff with no motion or even with a motion system in which there is no runway roughness modeled and there are no "bumpetty-bumps" that get faster as you accelerate, you notice that it's missing. And you have to shift your emphasis from things that you normally do and substitute other things. Like more concentration on the air speed indicator rather than if you make a couple takeoffs in an airplane, you know when it's time to look at the air speed indicator at 60 knots, whatever the speed check is. If you don't have the bumpetty-bumps collected, you have to stare at it and take your attention away from where it ought to be. I think there are a lot of subtle cues that motion provides that we really don't give a lot of thought to.

MR. BAKER: I think there is some surprises. I know I have been surprised at least twice on motion cues in air vehicles. It turns out pilots were using them as a primary cue and I thought it was kind of a "who cares." One of them is the transitional vibration in a helicopter when it transitions to forward flight. The guy sometimes will fly a descent down the 25 knot air speed using that as a primary cue to air speed, not looking at air speed. I would have never guessed they did that.

MR. BOOTHE: Having an extremely limited helicopter experience, but having gotten a license, my instructor taught me to use that to recognize transition. So I'm not surprised.

MR. BAKER: It's like every heli sim that I have looked at, the high quality sim has a seat shaker in it for that reason. It's a seat shaker instead of shaking the whole motion platform, to keep Charles's [Stocking] visual systems from going belly up.

MR. BOOTHE: So for normal acceleration—I'm sorry, wrong terminology. For acceleration along a runway in a normal takeoff, which is what that really means, are there any objections to what's written there or should there be additions?

MR. RAY: Ed [Boothe], have we selectively excluded sounds in there? I can't help but believe high frequency, low amplitude sound in a turbo prop is so important. It's a separate issue but you can almost put it into, because of the vibration created, put it in the motion category. I don't know how that plays or how to integrate that into this table or a separate table.

MR. BOOTHE: I don't know, Paul [Ray]. I think it's important. But I wasn't thinking about it when I did this.

MR. RAY: I'm raising the issue because having flown a couple of turbo props, the seat of the pants, if you want to call it, vibrations created by the turbo prop itself are significant. The vibration through the aircraft is extremely important to me, or was.

MR. CARDULLO: I remember at Sunjoo's [Advani] conference in the Netherlands this fall one of the KLM pilots was talking about how he flew a landing profile listening to the sounds of the engines on a 737. Just by the sound of the engines he could hold the glide slope to within some small deviation. Then he said one day he was making a landing and he just couldn't hold the air speed and the glide slope angle correctly and he suddenly realized that the problem was he had windshield wipers on and the windshield wipers were masking the sound of the engine to some extent adding another sound.

MR. BAKER: Wow.

MR. CARDULLO: And it became a problem for him.

MR. ADVANI: Did he mention by any chance what fidelity the sound was in the simulator?

MR. CARDULLO: This was in the airplane.

MR. BOOTHE: In the airplane. It was 100 percent.

MR. CARDULLO: That gave me a totally different perspective about sounds.

MR. RAY: That's similar to the story I believe I have relayed to you before of my own personal experience. I promise this is the last time I tell the story. Bob [Foster] has heard it at least twice, where just the headset change—

MR. CARDULLO: Oh, yes.

MR. RAY: —made a major difference in my ability to control air speed and pitch attitude on the approach, particularly in the landing flare. It had a major impact on my ability to make a smooth landing. It was sound change.

MR. BOOTHE: This whole business of sound is not new. The aviation pioneers used the whistling of the wind around the structure wires, the fly wires and the ground wires to judge their speed. And half the time they didn't have an air speed indicator that was of really decent accuracy, some little flipper thing out in the wind. But they, according to my readings of aviation history, anyway, they used the sound of the wires. So we still use sounds, it's not flying wires anymore, but certainly other sounds that airplanes—

MR. BAKER: Is that what you call fly by wire?

MR. CARDULLO: Very good.

MR. BOOTHE: With that I will move on to the next.

MR. FOSTER: Ed [Boothe]? I think for the terms of Level B recurrent training and checking particularly, I don't think you really need surge and yaw for takeoff. For any of the modes of takeoff. You can do a decent job—

MR. BOOTHE: You don't?

MR. FOSTER: It's nice to have. It would be nice, but in terms of providing the essential cues, the accelerations I think can be done pretty effectively with pitch and deceleration, the runway roughness comes out of heave, the roll and sway I think—sway would be nice because you need to coordinate the roll and sway in order to provide good steering cues. But the yaw is so small.

MR. CARDULLO: I agree with Bob [Foster] on yaw, but I disagree on the surge because if you don't have that onset of acceleration on the takeoff roll, then you don't have anything with which to transition to the gravity align. So that means you have got to rotate and the guy is going to sense that rotation.

MR. ADVANI: Right away.

MR. CARDULLO: That's going to be a false cue because he feels like he is rotating when he has just begun to accelerate.

MR. FOSTER: I honestly believe if you wash that in pretty slowly, and remember for recurrent training and checking we are talking about a guy that knows the airplane, initial training I think it's a different deal. The guy, how he pumps the power to it, what to expect out of it is a different thing. But when we are talking about recurrent training and checking, I just don't think there is a requirement for that type of a cue. The guy knows what the airplane does. I don't know of any sort of abnormal emergency thing that we do where we are trying to cue him starting from no air speed, basically.

MR. CARDULLO: I agree. The only thing for longitudinal is the acceleration.

MR. FOSTER: Sure it's nice to have. But I think we are trying to say here, "what do you need to have?" at least that's what I'm trying to say.

MR. BOOTHE: I think that's what we should be saying.

MR. CARDULLO: Yes.

MR. BOOTHE: I put it in for the reason Frank [Cardullo] described. In fact keep in mind that doesn't just address normal takeoffs, it addresses rejected takeoff, engine failure and so on.

MR. CARDULLO: On rejected takeoff you might need it.

MR. BOOTHE: So it addresses this whole column of events.

MR. FOSTER: Yes.

MR. BOOTHE: One of the things I've noticed that people sometimes do, especially in turbo prop airplanes, you do it in most all airplanes, you extend the throttle up somewhere, you don't release the brake until the engines accelerate to that power setting. And then when you do release the brakes you get that surge, and if that isn't there, I had the same thought, how do you initiate the feeling of the takeoff and then how do you transition from that to a continuous—

MR. FOSTER: I think the cues come out, primarily come out of sound, especially on turbo prop as you come in and the prop governors are sorting themselves out. Then I just think you have to, you can't jerk the pitch to simulator but you wash it in. It may not be 100 percent fidelity cuing, but this guy is now rolling down the runway and everything perceives to him to be pretty normal. Maybe I didn't—I see the opposite of that, too, where a guy will do this and this *(indicating)* and then it will pitch.

MR. MARTIN: It would take about 30 seconds or so to get up to any sensible surge if the platform is rotated below perceptible rates.

MR. CARDULLO: He is off the ground.

MR. BOOTHE: Then you are airborne.

MR. CARDULLO: Yes.

MR. BOOTHE: Wait a minute, say that again.

MR. MARTIN: I said it would take 30 seconds or more to tilt the platform.

MR. BOOTHE: To get to tilt.

MR. CARDULLO: If you rotate it at a subliminal angular acceleration, is basically what he is saying. By the time you got to the right angle.

MR. MARTIN: Or sensible angle.

MR. CARDULLO: Even sensible angle.

MR. MARTIN: Threshold.

MR. BAKER: When I sit in a commercial airliner on takeoff, what I think I'm feeling is pitch and not longitudinal acceleration.

MR. CARDULLO: You know why? There is a visual illusion that's going on, it's called the oculographic illusion, but pilots are not susceptible to that illusion because they are looking out the window.

MR. ADVANI: Looking forward.

MR. CARDULLO: The illusion is the oculographic illusion. If you are sitting in the passenger cabin and the aircraft is accelerating down the runway, and you look forward, it looks like the forward bulkhead is elevated, right? So that's what you are experiencing.

MR. BAKER: Even if I look out the window that sensation doesn't go away.

MR. CARDULLO: There may be some latency in it going away. I don't know anything about that. But if you are looking out the front window driving the airplane, you won't get that sensation. You get a different sensation. Because you can't get the oculographic illusion when looking at the horizon remaining at the same level.

MR. BAKER: I don't get nearly as much in a car. You are the pilot in that case. It's an interesting—

MR. CARDULLO: It is interesting.

MR. BOOTHE: Actually sometimes frightening to me, because if I'm on a relatively light airplane like a DC-9-80 series and we rotate for takeoff, of course I've got the perspective inside the cabin, the airplane is both pitching up and accelerating. And I feel like it's doing this *(indicating)* and it scares the daylights out of me.

MR. BAKER: Because it's going to stall, right?

MR. BOOTHE: Yes. So it is a very perceptible feeling.

MR. BAKER: Taking Bob's [Foster] inputs, which I think are extremely important, I don't know exactly how to factor those into the rest of the discussion, but I keep kind of getting led back and thinking about the problem of motion base geometry and thinking maybe we can do this with a three or four axis base based on roll, pitch and yaw base, that's got the cab sitting well ahead of the pivot point. Now when you put, for example, yaw into the base, it gives you a lot of lateral motion, which is what you want to do to achieve some of these effects.

Runway you can do with pitch, because pitch at low amplitude is a vertical motion, the pitch angle is insignificantly small. Roll looks like what roll would normally.

The thing I'm trying to decide is, could we in this discussion come to any conclusion that says "well, if you did three or four degrees of freedom and did them right, that would be so close to a six axis base that it would be totally satisfactory?" I'm kind of inclined to think it would be if it was done right. But I don't know if we can make that conclusion here. I don't know if we have enough data.

MR. BOOTHE: One reason yaw was included in these, my thoughts included airplanes as small as ten passengers and as large as turbo prop airplanes to 50 passengers. And I think somewhere there must be a crossover between sway and yaw and maybe a ten passenger airplane is still above that, so it's mostly sway. I don't know, Bob [Foster], I didn't have any basis for making that decision. But if we consider basically large airplanes, with the exception of possibly wind shear, I would agree with you on yaw.

MR. FOSTER: Again I'm just coming from this position of trying to establish these interim guidelines. And trying to keep the device affordable. And give people options. I was talking a little bit to Tom [Longridge] during lunch, you can make some logical progression out of the fact if we have a Level A device as far as motion requirements and training and checking, you can't do any landings and takeoffs in it, basically. There is no aerodynamic ground effect package in it.

If you move to a Level B package, we are trying to encourage people to build Level B which is a little different than we were trying to do when we did the advanced simulation at the beginning. If we are trying to encourage people to do Level Bs because they can do all of their recurrent training and checking in it, a side effect of that is that since they now buy this device and have it, they are also going to use it for engine out takeoffs, since the rules permit that. Because of that, I think it makes a lot of sense to say, "since we are encouraging you to now buy these devices and you are going to use it for engine out work, we feel as an expert group it's very important that you give that pilot engine out cues in excess of what's available in the old style three axis machines. Then the logical progression is you get—and in addition to that we are giving you an aerodynamic package that will more correctly model the flight of this airplane."

Then you move to the next level, you get a Level C, and it gives you the ability with the addition of six axes now to do transition and upgrade training as well as the recurrent training. And then the price you pay for that is the additional realism with a wide visual system and a six degrees of freedom motion. You can now move from one model airplane to the other. We have to show you the differences in these in training.

The final level, when you go to Level D we now have to provide all the more sophisticated aerodynamic effects and also have to toss in buffets and that sort of stuff. I think if we came to some sort of interim thing I think you can make some sense out of saying if we, from the motion standpoint say "okay, following my logic you now need for a purpose built Level B machine you need roll, pitch, heave and sway." I think you could make a pretty good case for that.

Then we recommend some additional work to see if we are missing anything with that. Is that missing—is it asking too much or not enough to be corrected in the future if required? But hopefully giving people the economic incentive to design these machines, specific purpose built for this, and also buy the machines, hopefully, and get them out of the airplanes and into a real training environment.

MR. CARDULLO: Bob [Foster], do you think there is any reason in any of these other maneuvers for surge?

MR. FOSTER: In every case in my mind I put it as a "nice to have but not essential."

MR. CARDULLO: How about on-ground handling and braking?

MR. FOSTER: I just don't see it. Because the guy is flying the airplane already. He knows what this particular airplane type brakes like and steers like and everything else. We are not going to take him—

MR. CARDULLO: But remember we are testing him, not necessarily just training him.

MR. FOSTER: But in what we are testing him in I don't see it as a problem. Because we don't see that as a problem now.

MR. STOCKING: It's a reinforcing cue, it's not a primary alerting or control device. That's where Bob [Heffley] is coming from.

MR. BOOTHE: Bob [Heffley] has been holding his hand up.

MR. HEFFLEY: Two points. One is this matter of surge versus pitch, if you really do need surge, it's because of the necessity for very high rate of onset, and that may very well be specific airplane dependent and maybe that's what you want to be, let the real driver do that. Otherwise I think that pitch really ought to satisfy the surge. Particularly where you have the visual that's also furnishing strong cues to distinguish between surge and pitch.

Number two, yaw and sway. One thing that the NASA Ames people really pinned down pretty well here, is that it's pretty hard to distinguish yaw and sway motion and they are pretty redundant. But if you want to keep one, the one to keep is sway. Again the visual fills in the yaw motion cue. So I think, you know, I think there is a real case here to be made for trying to minimize the need for yaw and surge and those I think are the things to be looking for as you continue through the list here. Where is the real driver that says "yes, I really do have to have yaw" or "I really do have to have surge." Those are hopefully maybe the two that you will let go.

MR. FOSTER: I'm not saying you can build it any less expensively without them, but I would like to give somebody the opportunity to try.

MR. BAKER: Everything that I hear keeps me going back to the direction of building a roll, pitch, yaw motion base, perhaps with surge on it. You could add surge to it without a lot of hassle. It would be a nonstandard motion base, it wouldn't look anything like a standard six axis motion base. And just thinking about—

MR. CARDULLO: No heave?

MR. WILLMOTT: From the pitch.

MR. BAKER: You are sitting ten feet from the pivot point. You can do heave with pitch.

MR. ADVANI: No.

MR. BAKER: You are shaking your head.

MR. CARDULLO: The reason I'm shaking my head is I don't agree. Because you know you get different size airplanes where the pilot is sitting substantially at different distances from the center of rotation. So you need that heave to be able to deal with that.

MR. BAKER: Beyond some point you can't tell the difference between heave and pitch. I don't know how far ahead of the CG you have to be, that's the whole argument that Bob [Heffley] just made about yaw and sway, was if you are going to give one up you might as well give yaw up because you really almost can't tell the difference. Admittedly if it's a helicopter and you are only six feet ahead of the CG, that's one problem. In all these airplanes you are probably at least 15 feet ahead of the CG, it's very hard to distinguish motion-wise when you get a lateral motion that it's sway or yaw or in the case of—

MR. CARDULLO: I can buy the sway—yaw part. I have trouble with the pitch surge part.

MR. BAKER: Not surge, pitch and heave.

MR. CARDULLO: I'm sorry, pitch and heave or pitch and surge. Either one of them.

MR. ADVANI: I have to agree with Frank [Cardullo].

MR. BAKER: For a runway situation where you have got high frequency, small amplitude inputs, I guarantee you if you put them in as pitch or heave you can't tell the deference. The real question I think comes in with things like transitioning when the nose comes up for takeoff and that sort of thing. Is that going to be a satisfactory cue for that part of the scenario?

MR. CARDULLO: I think if you use pitch for surge and the takeoff roll, there is going to be an ambiguity that you cannot resolve. You are going to perceive that as pitch. It's going to take some time before the person integrates the visual information to come to the fact that it's not pitch that he is accelerating down the runway. What effect that ambiguity has on performing the tasks, I can't say. But there is that theoretical ambiguity.

MR. BOOTHE: Three comments on that.

MR. HEFFLEY: I really disagree, Frank [Cardullo]. I mean, the visual is right there right now. The visual cuing is immediate. That's what fills in these ambiguities.

MR. CARDULLO: The visual cuing is not immediate, Bob [Heffley]. It's slow.

MR. HEFFLEY: If you start your takeoff roll, and with pitching motion furnishing the surge cue, but visual is still saying I'm level, I'm nose level, there is a strong sense that you are nose level, and you are just being accelerated—

MR. CARDULLO: But it takes a little bit of time for that ambiguity to be resolved. I agree, you do resolve the ambiguity with the visual, but there is latency in the process.

MR. HEFFLEY: I think we are arguing a minor degree of foundation—

MR. CARDULLO: Could be.

MR. HEFFLEY: —as opposed to the cost of another axis.

MR. RAY: If I could throw in another comment as far as visual. A large percentage, if not a majority of training and checking we are talking about, is done under low visibility conditions. Not ten miles visibility, but with as little as 300 foot forward visibility. How visual and motion fit together there, I don't have the answer to it.

MR. BOOTHE: Norm [Bluteau]?

MR. BLUTEAU: Yes. Three comments. In my experience tuning motion systems with a number of customers, number of pilots, there were times when some of the axes weren't tuned properly. So effectively some axes were missing. As a result of that we examined what problems the lack of specific axes caused in pilot performance.

In terms of pitch and yaw and x, in some cases especially around landing and takeoff, when the surge was not sufficient, and when the pitch was used to generate longitudinal accelerations, many pilots, as Frank [Cardullo] indicated, perceived an acceleration as a pitch of the aircraft. Because we tilted the simulator. In many cases the pilot corrected or the pilot reaction to this acceleration was to provide a column input. Believing that the aircraft was actually tilting. And many pilots crashed the simulator because of the lack of discerning.

I remember one case, it was actually (*American Airlines)*, the pilot crashed on the go-around because he applied power, he felt a pitch up so he just automatically reacted with a column input. Even before the visual cue was recognized. He just had the reflex of reacting to it. So he just crashed into the ground.

Another case for having surge is on rejected takeoff. When a pilot suddenly decides to stop the aircraft, applies the brake, but doesn't get the surge to indicate that he has gotten a deceleration, so those pilots tend to panic, they don't get the reaction they expect because the pitch takes a little while to build in.

The last point is with respect to the mechanism using long drag lengths trying to combine heave and pitch. One of the difficulties there might be to attain enough pitch angle and takeoff gravity alignment, long runway length makes it difficult to tie in 10 or 20 degrees of pitch.

MR. BAKER: I was only suggesting as a compromise, I really wanted some discussion, some negative.

MR. CARDULLO: Ed [Boothe], excuse me. I have to leave.

MR. BOOTHE: I wish you could stay. I understand. Thank you very much for joining us.

MR. CARDULLO: You are welcome. Good-bye everybody. I'm happy for the interchange. I stir up a pot and leave.

MR. BAKER: Okay. Now we get to work, right?

MR. STOCKING: I was going to reiterate much the same thing. For instance the pitch. The synchronization of the angle of the platform with the longitudinal surge is very critical. That's the difference between providing a true cue from the aircraft and supplying something else. If you are going to go to say eliminate surge, I would not tune the pitch to give the same cue. What you are doing then from that point on is you are trying to provide a cue that enhances his controllability of the device. You are not providing an aircraft cue without that synchronization of the pitch and surge, or in the case of roll and sway of the gravity align. As far as what's the most important or the least important degree of motion, the yaw angle is the least used in the simulator. But that's the only one that I could eliminate right off the bat and say, you know, for the type of training we do in airline simulators we could eliminate one degree of axis. That's only sometimes. I would still find a case or two where I would like to have it.

MR. BAKER: Eliminating one axis doesn't buy you anything.

MR. BOOTHE: Maybe not. It may not buy anything, it may not change the final design, but still if it adds nothing then we shouldn't say it should be there. So.

MR. STOCKING: It's the least desirable.

MR. BOOTHE: We may still end up with six degrees of freedom because that's the most sensible and economic way to do it. But still, if it's not necessary to have that degree of freedom, then it shouldn't be part of the performance specification. And if somebody decides they are going to have it anyway, that's fine. I could live without yaw here. I have trouble considering living without surge.

MR. FOSTER: I just go back to remember what this device is for. It's for recurrent training and checking. And before this guy, he is going to go out and have to fly the airplane with an instructor before—has to get his three landings and takeoffs, right?

MR. BOOTHE: In a Level B it's a landing qualified simulator—

MR. FOSTER: Right.

MR. BOOTHE: The total, correct me if I'm wrong, rules are changing faster than I can read, a Level B is a total recurrent check.

MR. FOSTER: Recurrent.

MR. BOOTHE: Recurrent. And I think Norm [Bluteau] brought something up, Bob [Foster], that I think is real important. And that is a rejected takeoff. There is a—surge and pitch I think are pretty important there, because one of the problems, I don't know if it's been a problem so much with regionals because a lot of them have propellers and a lot of them in a rejected takeoff would use reverse propeller thrust, which will throw you out of the seat if you use it correctly. But we have a very poor record of successful rejected takeoffs, especially in larger airplanes. And I think largely it's because people, pilots, were not familiar with what it means to use maximum braking, so they didn't use maximum braking unless it happened to be autobrakes, and then they would get on the brakes and dump that. I think for that kind of maneuver, if we are going to do that in a recurrent check, it may not occur in every recurrent check, I think those degrees of freedom are important to demonstrating how a rejected takeoff should feel with maximum braking and reverse thrust. I don't think surge is important there.

MR. FOSTER: I don't think you can come close to it with surge, it's hardly anything on a rejected takeoff.

MR. BOOTHE: When you first put the brakes on.

MR. FOSTER: Maybe when you first touch them. You can't maintain that surge. Really what you get, the banging of the airplane is what you get on rejected takeoff. There is tremendous deceleration there. The thing that pulls the pilots off is the fact that the airplane shudders and shakes so bad it scares them. I think you can reproduce that without surge. It's a pretty violent maneuver.

MR. WILLMOTT: I thought we heard Frank [Cardullo] say earlier in the day that the acceleration cue duration should be the order of 0.2 to 0.3 of a second. Aren't we talking, as far as this surge is concerned, like a quarter of a second, I'll call it jerk? And it is later followed by pitch gravity align that gives you the sustained braking feel, and this is one area where the FAA is quite concerned to make sure that you do get the hang-on-the-straps feeling when you are decelerating hard. It really comes from the gravity align, it doesn't come from surge.

MR. HEFFLEY: That's right.

MR. STOCKING: In a six DOF system that's the one place where we run out of longitudinal surge. I end up with a cue that's less than ideal because I have run out of longitudinal. I don't have enough room to supply that longitudinal trade-off to where he gets to the pitch attitude, which is making me a little apprehensive about a smaller system because I can see that same thing begin to happen in other areas.

MR. BOOTHE: So would no surge at all be better in your opinion?

MR. STOCKING: Well, right now on a 60-inch system I need everything that I can get to give them a proper cue that he is getting on the brakes properly.

MR. BOOTHE: Well, if we are talking about the system we described this morning, maybe Bob [Foster] has a point, maybe you couldn't get enough surge to make a difference anyway, so why require it?

MR. STOCKING: We are going to end up with less surge and it's going to be a more washed-out cue but it will be stronger than not having it at all. I can't make any judgment about which is correct, whether it's better to have some or not at all.

MR. HEFFLEY: Again, the real answer to this question is that it depends. It depends on the aircraft. It depends on the specific aircraft and task that you are trying to simulate here. If there is not a rapid onset of, I guess with braking of course that's—that's inherently a quick onset. But you know that as Chuck [Stocking] actually points out, with any reasonable amount of surge motion, you still can't sustain it. You have to very quickly fill that in with the pitch.

MR. BAKER: Not only can't you sustain it but in pitch you can't get anywhere as much acceleration, you are limited to two-tenths of a g probably.

MR. HEFFLEY: Granted. That's always going to be scaled down by a fair amount.

MR. BAKER: You can give the guy a pretty good jolt initially, but sustain, why even 20 degrees, that's like a four-tenths of a g at the most. Then you have used up all the motion base just to give that one cue.

MR. STOCKING: That is one area though where a pilot will accept feeling the pitch rotation because he knows it can't be happening. He is on the ground, he knows he is not rotating. And even though he feels a pitch rotation to get immediately to that location, he will accept something above his threshold. I routinely put it there.

MR. FOSTER: This issue of rejected takeoffs, though, if you look at the takeoff safety training aid, there is a lot of issues involved besides just the deceleration cues. I mean, the other things that are important is the brake pedal forces have to be correct in the simulator, there have been some cases on that where people were misled.

The other thing is the demonstration in the simulator should show, it should someplace show them what happens on a balanced runway takeoff when you reject at V_1, you do indeed stop right at the end if you use full braking, et cetera. You show the facts of reverse thrust and why you can't depend on it, all those sorts of things.

I contend from the simulations, from having done these in the airplane, I was amazed at how—I don't want to call it violent or how exciting the maneuver, a real RTO is. My experience was out at Boeing on test flights for airplane acceptance. What amazed me, when you are going to buy the airplane, before you buy it they have carpet runners down the aisle so you can't get it dirty. They were demonstrating to one of our captains what the RTO function did. And we did it. The carpet slid up the aisle, that's how hard you are stopping. To me admittedly the deceleration is very strong, but just as strong is the banging and shaking that goes on. Because you have that strut compressed so hard every little crack in the runway is felt. And admittedly, it's a nice little cue when you start it, surge, but it's that sustained.

MR. BOOTHE: What about an anti-skid cycle, is surge—

MR. FOSTER: That's going to vary. The whole airplane is shaking.

MR. BOOTHE: So you can't distinguish from an anti-skid?

MR. FOSTER: I couldn't tell but I don't have a lot of experience on it.

MR. STOCKING: On the older systems that go to full release you can tell. But on the newer ones they are nice and smooth. If you have commuter class, what kind of anti-skid systems do they have?

MR. BOOTHE: I have no idea.

MR. STOCKING: You are talking about system differences.

MR. FOSTER: Where I have seen surge being a nice effect is where you have a condition where you've got patchy ice and stuff and you have feedback from the visual and that can go into the—that can—but you don't need that for recurrent range and checking, it's a nice effect, but again, given the mission don't hang any drop tanks on this we don't need.

MR. BOOTHE: Especially those that can fall off and burn.

MR. FOSTER: Or have to be maintained or cost me a couple bucks extra.

MR. BOOTHE: Tom [Longridge], Paul [Ray], what do you think you have heard in the last half hour?

MR. LONGRIDGE: I think we have gone around in a circle.

MR. RAY: I think Bob's [Foster] comment is exactly on. The violence of rejected takeoff, particularly as you point out up at V_1 where you are making the maximum effort stop, it almost makes the case for heave needs to be back in there, because how do you do—

MR. BOOTHE: We have heave.

MR. RAY: I thought somebody struck heave. Surge is certainly a player with anti-skid, as you can feel it cycling. If you want to call it the seat of your pants, you do in fact feel the anti-skid system—all aircraft I'm familiar with.

MR. BOOTHE: If it's as great a conglomeration of shaking as Bob [Foster] is describing, can you distinguish that from the other shaking? If you shake the thing and heave rather than surge, are you going to know the difference?

MR. RAY: I'm only pointing out you can distinguish from all that shake, rattle and roll that's going on, that change in deceleration through surge. You can detect it. That's why we put the question on the table.

MR. STOCKING: For—

MR. RAY: I know my own personal preference but I'm holding it back.

MR. BOOTHE: I don't want you to hold it back.

MR. STOCKING: For this type of maneuver to leave out surge you can use smoke and mirrors to cover it up with the accelerations, the violence of the maneuver and whatnot, the pilot will be able to tell the difference but he may not react to the difference.

MR. RAY: Right.

MR. STOCKING: Again, you are talking about what he can get away with or what you can get away with to meet your training objectives. That's a decision that maybe has to be made somewhere else.

MR. BOOTHE: Lloyd [Reid]?.

MR. REID: What about what Norm [Bluteau] was saying? The crashes they experienced, it wasn't a full brake maneuver that was causing it, it was putting the power on.

MR. BLUTEAU: It was a go-around situation.

MR. REID: There is no shaking going on there.

MR. WILLMOTT: What if you had reduced the rate of inputs of the gravity align? You normally input the gravity align at a rate that the pilot will not feel.

MR. MARTIN: Then it's going to take you 30 seconds to make any sensible input.

MR. ADVANI: It will take a long time.

MR. STOCKING: You are talking about very specific programming to get it in one place where you want it, and another place where you don't want it. To me, going to the lesser degrees of freedom is much more rigorous a task in programming to try to get your cues back or some semblance of cue for any specific maneuver. It really becomes a problem.

MR. BLUTEAU: There is another aspect of this, which may be motion sickness. If you see something and you don't get the corresponding motion cue, you may cause sickness problems and the longitudinal versus pitch is sometimes a factor in sickness where people feel the pitching but don't actually see it. After a while they are dizzy.

MR. BOOTHE: That is a good point, because I think cue, lack of cue correlation certainly does promote some sort of sickness or so-called simulator sickness, I guess. But I still, I have sympathy for your issue because I do think if we just run out to the regionals and say okay, guys, just get a six degree of freedom system with these specs, we may have less than a totally successful experience here. On the other hand, we do need to provide the cues that are necessary and sufficient, I guess, for the task.

And the third thing there is if this is to be an interim Level B standard, can it be written in such a way that we can recover later? Normally if we do something it's awfully hard to increase it, it's always easy to back off, but it's pretty hard to increase the stringency of a performance standard unless we are very careful the way we write it in the first place. So I can't answer those questions.

I don't have a problem with yaw, I think nobody in the room has a problem with eliminating yaw. So it's just a surge thing, and if we were to eliminate it, can we do our work in such a way that we can recover it later if we found it doesn't work? Is that a possibility?

MR. HEFFLEY: Well, Ed [Boothe], again this is—it's one of these "it depends" things. It depends on the abruptness of the specific case. In discussing math models for these we talked about the need to go out and obtain flight records. You are going to have documentation of what actual motion there is in some tasks and conditions and something like surge could be in there only if it's needed based on flight records.

And again you have to come up with some sort of recovery factor, some number that we don't know. And we aren't going to get it here.

MR. BOOTHE: So we can say if the airplane is severely underpowered you don't need surge?

MR. REID: And the brakes are real mushy.

MR. HEFFLEY: But it does seem like the right thing to do to try to give some benefit to reduce the number of axes or reduce level of complexity, and we are—it seems to me we are debating this surge thing pretty well on both sides. I mean, it's not an easily decided thing, I think.

MR. HARRIS: It seems the main thing about surge, the braking, it's onset, the thing about surge, it's an onset cue. You have to time stamp from there, you expect certain things to happen to decelerate at a certain cue. But the onset surely is important. Because you expect things to happen in certain times after it.

MR. HEFFLEY: Actually I suspect it's important from the standpoint of actually closing the loop on the brake pedal force.

MR. HARRIS: Normand [Bluteau] mentioned if you don't get the breaking cue, the onset cue for braking, you think there is no brakes.

MR. HEFFLEY: That actually seems pretty compelling right there, I suppose.

MR. BOOTHE: Paul [Ray]?

MR. RAY: If I could weigh that with the feedback I'm getting in the brake pedals themselves I may know what's needed. If I have a manually controlled brake system the responses are different than with anti-skid. A 757 or 767, for example, where you clearly experience anti-skid system cycling, that's where I feel the surge, personally. But I should also feel the correct feedback in the brake pedals.

My tendency to believe that we might be able to do away with surge on a Level B, rationally, is dependent upon the performance characteristics of the aircraft. There may be some aircraft that need additional motion cuing based upon the specific characteristics of that aircraft.

Particularly, in what is essentially a failure mode. Rejected takeoff means something failed. Now you are into abnormals. Baseline is that there is reasonable logic to exclude the need for surge, but potential performance characteristics of a given aircraft may necessitate surge.

MR. BOOTHE: So how are you going to know?

MR. RAY: It's up to the operator to figure out.

MR. BOOTHE: No, it's up to you to figure out later. He is going to throw the monkey in your lap.

MR. RAY: That's true.

MR. SMITH: Any abrupt throttle movements on a prop jet it seems consistent with what you are saying, even on a turbo you would need surge to get the right cue.

MR. BOOTHE: Stu [Willmott]?

MR. WILLMOTT: I guess it's a comment. Twenty percent of the simulators that are out there now are Level B, which means there are a hundred simulators out there now that are Level B that are being used for this type of training without surge and without sway (*Mr. Willmott later determined that there are 35 Level B FAA approved simulators*). We are suggesting that we add sway and that is the one thing that actually is a motion that triggers the pilot to respond. And that to me is the key in this takeoff and engine failure situation, you must have the cue that triggers a response that he must give. That's a part of the training that he needs to have. But, you know, I really don't see that we are making it easier for the regionals by asking them to put in surge as well.

MR. RAY: Those numbers, 20 percent, that's more or less [Levels] A and B combined, is it not, Stu [Willmott]?

MR. WILLMOTT: I think I counted [Level] B.

MR. RAY: I can't recall the specific numbers. But in fact the vast majority of the commuter simulators that have been brought on line in the last ten years are the [Levels] C and D, where in fact they do have all the motion cuing we're talking about. Over the last ten years, only five or so commuter Level B simulators have been brought into the marketplace.

MR. WILLMOTT: I mean, you know, the surge is something nice to add but it's not triggering the pilot to do something. It is, as you say, it's what he expects to feel when he does that. But he knows what he feels in the airplane when he does that.

MR. BOOTHE: It's not stimulating him to respond but feeding back information. Is that fair?

MR. WILLMOTT: But the key thing is adding the sway that is actually triggering him to do something.

MR. HARRIS: Just a quick one. Onset cues don't necessarily need to be large amplitude. So for employing the brakes you get a small kick forward, small amplitude.

MR. BOOTHE: Well, let me ask a question about that. If your pilot brakes you are going to get a little pitch, too.

MR. HARRIS: Sure.

MR. ADVANI: Very small.

MR. BOOTHE: Why can't we substitute that small pitch change, can I tell the difference between that and a surge anyway?

MR. HARRIS: Yes.

MR. ADVANI: You can tell.

MR. FOSTER: On an RTO the big difference you get with that nose strut compressed you get a lot more runway rumble. That comes back through even pitch.

MR. BOOTHE: Okay. I'm leaning towards—it's not my decision. I'm leaning towards scratching surge with the condition that Paul [Ray] might want to keep it if it's needed for the airplane. I have no clue right now how you might make that determination.

MR. RAY: I don't know, either.

MR. BAKER: So we are getting down to leaving two degrees of freedom out and the other four in?

MR. BOOTHE: I don't know what the consensus here is.

MR. LONGRIDGE: Let's go back to the original cost discussion. I thought we decided this morning that it might be as expensive to try to build a four degree of freedom system that still minimizes false cues as it would be to go ahead and build a six degree of freedom system. Are we throwing that argument out now and deciding "yes, there is a significant cost saving with going with a four DOF?"

MR. BAKER: Here is the situation with respect to motion based designs. As far as I know, there aren't any designs in the inventory right now that match what we are deciding right now, that's something, four axis lacking surge and yaw. There isn't a device out there like that. Certainly you could design one. A clever mechanic will design it, and will make something that does that. It's the position of the guys that build simulators that that's not going to be a cheap thing to do. And I tend to agree with that.

It also isn't clear how many simulators you have to build with this abbreviated motion base to cover your nonrecurring costs. So it's not real clear anybody is going to want to belly up to the bar and say we are going to build a cheaper motion base on the basis we are going to sell a hundred simulators a year. I don't think the market is a hundred simulators a year. If you could build a hundred or a thousand of them, it would be a moot point. You would go ahead and do that. But there are a lot of designs around for six axis bases, even if you don't have a 36-inch stroke, six axis base design in inventory, you can take the 60-inch design and scale it down, it scales down easily, you know the numbers are going to come out right. You don't have to do a lot of nonrecurring engineering to arrive at a 36-inch stroke base.

So I think if you deviate from an existing three axis design of which, you know, there is some on the Level B sims right now, you say I want a new three axis design, the practicality of it is that until I think the motion, the simulator manufacturers are convinced there is enough market there, they are not going to spend the nonrecurring engineering costs to do it. There isn't any cost savings in the ten you build. It costs even more to build the first few than it is to use an existing design.

Right now I would suggest that there isn't a marketing plan or a business plan for this particular device that says with any kind of accuracy how many we are going to sell, as an industry. How many we are going to sell to the regional airlines. I'm sure that people expect to sell some, clearly the FAA expects there will be some built or we wouldn't be going through this exercise. I think there isn't any question that there is a requirement that exists that has to be satisfied in some way or other.

But I still think that, especially based on historical data, the regionals are not going to step up and order these things by the hundreds. It would be a real surprise if that happened. So that's the practicality of building a new special motion base just for this application. And I'm not going to say it wouldn't happen, I'm not going to say we ought not to allow for that in the Advisory Circular, but we could go through an awful lot of exercise in trying to discover how to design a motion base that had only four axes and it would all come to nothing because the practicalities of designing it didn't ever yield a design.

We could exercise the psychologists and they could go off and run studies and they could say "yes, you could sort of do it if you leave these axes out and it doesn't make a difference." Two years from now we may have an answer, two years from now doesn't get a solution to the problem. And, you know, somebody wants a four axis base, sure we can put one on paper, that's not a problem. It's just a question of whether or not there is enough market there to make it a reasonable thing to do.

MR. BOOTHE: I have a slightly different philosophical answer from that. I don't think we are violating anything we said about six degrees of freedom standard system might be the cheapest way to go. That could very well be. But I do think we owe the industry a minimum requirement. If they choose to exceed that, it's wonderful. But if we in this room were to say only four degrees of freedom are necessary for the takeoff task with the various kind of events listed here, then I think that's what we should say. If they choose to meet that by the most economical means, which may be a six degree of freedom system that already exists, then that's their decision, I think, and that may be the cheapest way for them to go.

But if we include things in a requirement that are not necessary, then I think we have exceeded the—I think we have exceeded the performance, minimum performance requirement concept.

So I don't think it violates anything, Tom [Longridge], I'm just saying we ought to say what is least required to get the job done. And leave the design to the folks that want to build it, and then if it meets those least requirements to get the job done, it passes. That's just my philosophy. And that's what I was trying to get at when I was saying "well, what is the consensus on surge?" Paul [Ray]?

MR. RAY: I agree with that philosophy. Particularly in light of where we are currently looking. In our discussion of a Level B simulator, we must recognize that in initial training pilots are still going to the aircraft for certain maneuvers. However, they are not going to do V_1 cuts in the aircraft. They are going to do them in simulation, in Level B. But we can't extrapolate or take our comments regarding surge and yaw to the Level C and D environment. In that case, with [Level] C or D, we are talking about all initial training, all takeoffs and landings, with zero airplane time. I'm confining my comments just to Level B, knowing what that environment means.

MR. BOOTHE: I confine my thoughts to a Level B for recurrent training. Now if a Level B is going to be used for initial training, which we have to consider, there would be a follow-up either in a higher level simulator or in an airplane. But if we try to maintain that application of recurrent training, then I think we ought to specify the minimum to do that.

MR. RAY: Right.

MR. BOOTHE: And if surge is not important in that concept, then we shouldn't specify it. Even though I think the chances are ninety-nine and a half percent we are going to get it anyway, because I think to build a four degree of freedom system, as we have heard for two days, is probably not very practical unless something unexpected happens to the market. That doesn't look likely.

MR. FOSTER: I think you have to throw out there that it's not a four degree of freedom motion system, it's saying a Level B purpose built simulator. It's just one piece of the package.

MR. BOOTHE: That's true.

MR. FOSTER: Which that is going—from the people I talked to, that's going to get some attention of some manufacturers to try to do some innovative things.

MR. LONGRIDGE: Are we all saying some of the specifications that we recommended this morning would now apply to this four degree of freedom system even though the discussion was in the context of a six DOF system?

MR. BOOTHE: Well, it was, but I don't think that we would change what we said this morning. It would apply to the degrees of freedom that are left, if you will. Some of you that are more familiar with building motion systems might help me out.

MR. BAKER: I don't see any reason to change the numbers.

MR. BOOTHE: I don't think what we are saying now in any way violates or diminishes what we said this morning.

MR. SMITH: Ed [Boothe], it was kind of interesting, something Paul [Ray] said, you said and maybe Tom [Longridge] has a lot of insight on this, but I was talking with someone in the training industry who is pretty knowledgeable, and they seem to think the real training requirement is initial as much as recurrent because of the turn-over.

MR. BOOTHE: Yes, I think that's true.

MR. LONGRIDGE: I think that's true, but the feedback we get is they are not complaining about having to use Level C and D for initial. They are willing to eat that cost, wherever they need to go to get it. The issue is recurrent training.

MR. BOOTHE: I think if we could get a couple more tasks done in a simulator, their attitude will change about using the airplane. A few years ago it was absolutely "no, if I've got to use the airplane, if I've got to use the airplane for anything, I will use it for everything." I have seen a shift in attitude of people I have talked with. If we could do 80 percent or 85 percent of an initial certification in a simulator, including such things as engine failures, if we have to go out and do some normal procedures in the airplane, which is what would be required is acceptable, I see a shift there. I think this may serve initial enough in that respect.

MR. FOSTER: I agree with that, yes.

MR. BOOTHE: So the requirement is there, no doubt about it. I think this will do as I said, 80 or 85 percent, something like that.

So to go back to my question, trying to get from you a consensus or at least a majority opinion, do we strike surge here?

MR. HARRIS: Well, don't you think aircraft results—we can't strike surge?

MR. BOOTHE: Aircraft results?

Bob [Foster] can say for one commuter airplane—

MR. FOSTER: I'm not basing it so much on airplane results as to a lot of what Stu [Willmott] was saying about the fact that you are looking at cuing in the case of, I don't know what you call it, causal cuing versus feedback cuing or something like that. I'm not sure what the right terms are. Where we are saying or what I'm saying is that the surge effect is a nice effect and reinforces the pilot's behavior, but it's not what made him start to do the rejected takeoff or it's not what—I don't think it's what tells him necessarily that the anti-skid cycling, I agree with Paul [Ray], especially with the older systems you feel the pedals cycling is what you feel more than the airplane. But sway, its two primary purposes that I see is for runway alignment steering, it's a causal cue, it causes him to use the rudders to keep straight on the runway; and the other thing is to recognize the onset of that engine failure.

MR. HARRIS: You mentioned different types of cue that are known among psychologists as maneuver cue, which is pilot induced. And disturbance cue, which is somebody else shifting the aircraft, the pilot has to react. The disturbance cues are the ones that require attention.

Judith [Burki-Cohen] is going to agree or disagree, did I make sense, maneuver cues and disturbance cues?

MS. BÜRKI-COHEN: Can you repeat?

MR. HARRIS: I talked about maneuver cuing being pilot, and disturbance cues as external cues, as outside induced.

MR. BOOTHE: That's either God did it or you did it.

MR. RAY: That raises a good point, Ed [Boothe], that you may not have addressed. At least I don't think you did. The issue being random disturbance motion cuing during the simulated flights. Flights don't always occur in smooth air. Typically in simulation, instructors have a button that turns turbulence on or off. If it's off, you know it's off, it never occurs. Smooth air is present all the time. It's maybe a rhetorical question, should there be some random turbulence of varying levels occurring during the entire flight?

MR. HARRIS: Well, a lot of instructors that we have put the turbulence on like the lowest level, if it goes from one to nine they often put it on one and do flying like that. But there are other people who don't. Those tools are there for them to use.

MR. RAY: My question, Stu [Willmott], I appreciate your comment, is that continuous or is it random?

MR. WILLMOTT: I'm sure it's random with the instructors.

MR. RAY: It's random continuous versus random—

MR. WILLMOTT: Oh, the turbulence itself is random. Of course. Yes. We use the Dryden spectrum with "patchiness" on top.

MR. BOOTHE: Poor choice of words, maybe you are picking on my "continuous." What I could say in general and on all the time atmospheric disturbance, but I didn't mean to imply that the turbulence model would be changed. The patchy model with random disturbance, the continuous simply meant on all the time.

MR. RAY: I was referring to systems I have observed, the selection of turbulence is constant, it's not random in nature. I have seen more than one sim that have that type of turbulence embedded. That's the only turbulence they have. You can selectively pick one, two, three, four, perhaps even through ten levels. But if it's on, it's on all the time. It's not in fact a random disturbance.

MR. BOOTHE: Well, I don't want to spend time on that right now.

MR. RAY: I agree.

MR. BOOTHE: Stu [Willmott]?

MR. WILLMOTT: I was just going to comment if you intend to leave all of those things in the specification for the simulator that we were talking about, the phase margins, the 110 degrees per second squared, things like that, that's great as far as specifying the hardware that you need to be used for the motion. But we have still not specified what it is that we want it to do. It's rather like defining the control loading system in great detail but not ever doing any checks on the forces that are on the controls, as I see it.

MR. BOOTHE: No, I don't see it that way. Because you have an objective reference against which to check your control loading in. And here we have no objective reference against which to say we need this much sway or that much heave. And we have—you are right. We haven't addressed that. I brought that subject up on several occasions. But we haven't really addressed it, and the alternative was, which we have now drifted away from, the alternative was to just look at the motion objectives and see if we can work on them and we sort of stalled out about to spin in on surge.

So I am for just voting for four degrees of freedom here unless there are violent objections in the room, and write the specification in such a way that if we determine that's a mistake, then we can recover from it. I think since it's interim we ought to have that privilege. What do you think?

MR. BAKER: Isn't that going to create a problem for you if you decide it really doesn't work and you have got a bunch of four axis motion bases built? Is that an acceptable end game? I'm not suggesting what you said is a bad idea, I just want to say that's definitely a thing that could happen.

MR. BOOTHE: It is a thing that could happen, Bruce [Baker]. And I would hope, since we are talking of an interim requirement, that people would cautiously approach that with an existing design and limit it to provide these degrees of freedom somehow. Maybe that's not properly with the synergistic system—

MR. REID: No problem.

MR. BOOTHE: No problem?

MR. REID: Carrying on of extra expense in hardware, some extra.

MR. BAKER: You wouldn't limit a six axis base to four axis.

MR. REID: You could.

MR. BAKER: You wouldn't do it.

MR. BOOTHE: I wouldn't want to see somebody tool up for a four DOF system that's capable of only four degrees of freedom and then change the spec on them later. However, the caveat would be there.

MR. BAKER: Yes.

MR. BOOTHE: I don't know how to answer your question.

MR. BAKER: Is it also acceptable that we could start down this road with a four axis base and there could be two or three simulators under construction when we discover that that wasn't a good idea and change the spec and then you tell those simulator constructors you all are going to have to change your motion platform because you didn't get grandfathered in quite fast enough.

MR. ADVANI: Or the other way around, where someone starts building a six DOF and later on you say "well, you only needed four."

MR. BAKER: Well, yes, but in that case the system can still get certified.

MR. ADVANI: But the investment was made.

MR. BAKER: The investment was made and it's unfortunate. It's a lot more unfortunate to come and tell the guy "by the way, your motion platform is now a hunk of scrap. Go get another one." So I'm not saying what we are suggesting to do here is wrong, I'm just saying that the transition can get to be painful if it's not—if it ever does occur. If we have several machines under construction and some in the inventory—

MR. LONGRIDGE: We have to be careful to assure the industry that this is not going to be a risk. We have to be willing to bite the bullet, otherwise no one will ever build one of these things.

MR. SMITH: Typically when we have a draft interim we allow them to go ahead. However the reality of it has been pointed out, if you cut it off at very few machines, then they will never recover the design cost. And somebody is going to be—

MR. BAKER: Will be upset.

MR. SMITH: But then at the same time they would be almost unwise to even launch upon it considering it's an interim, and be advised this may be changed.

MR. BOOTHE: You had one more thing.

MR. FOSTER: That's the manufacturer and the buyer's decision. I think our purpose here is to say what are the requirements. And you guys put the programs together.

MR. BOOTHE: The same thing for a manufacturer would be if this is an interim thing to go with six degrees of freedom, I guess, the safe thing.

MR. FOSTER: I would approach it by either having some sort of prearranged thing like we have had with interim advisory circulars in the past, our Dash 8 was built on an interim Advisory [Circular 120-]40B. We had a letter to you we were starting that project, it would be okay.

The alternate approach would be if I'm going to take this bite of building this simulator as a user, I would put in the contract to have some sort of what does it mean if I now have to buy a six degree of freedom motion in terms of the manufacturer? What will you, to make that change to the contract and put a six DOF under it, what's it going to cost me if I have to do that? So there wouldn't be anything undefined. There is no risk.

MR. SMITH: Yes, there is. That's covered. That goes without saying you would be grandfathered if it were a draft and you start construction. The problem, the cost that the manufacturer would have, he spent all the up front money to design this which would take umpty-ump—

MR. FOSTER: That's his decision.

MR. SMITH: Are we misleading him?

MR. BAKER: I don't think he is being misled. I don't think you are going to get very many four axis motion base for the first simulators.

MR. BOOTHE: I can't shake we have to specify the minimum and let the industry do its design.

MR. BAKER: The industry guys are here, they should be sensitive to this.

MR. HARRIS: It's up to you to specify the requirements. It's up to us to decide how we fulfill the requirements. I would say rather than build a four degree of freedom motion and design from cold, I would take a scaled down six degree of freedom.

MR. BOOTHE: So if that in the interim, if the final requirement were for more degrees of freedom you would be able to, rather than rehardware you could resoftware to get the additional degrees of freedom?

MR. BAKER: I think he did.

MR. HEFFLEY: You do it for a different reason, you do it just because it is cheaper to start with six.

MR. HARRIS: We have the software, we have the hardware, we have the nuts and bolts to go with it.

MR. BAKER: You wouldn't rewrite software to take out two degrees of freedom.

MR. HARRIS: Sure.

MR. BAKER: It's more work to take them out then leave them alone.

MR. BOOTHE: We are at a point where Allison's [The Reporter] fingers are turning blue. Perhaps since we started 15 minutes early we can take a break for 15 minutes and come back and settle this argument.

(Break taken.)

MR. RAY: I wanted to comment if I could, Ed [Boothe], apologies to everyone. Hilton [Smith] and I have to catch the 4:00 flight. We will be leaving in the next ten or 15 minutes.

On behalf of everyone here, thanks to you for the way you conducted the meeting and also the participation of everyone in the room. While some may not think we have gotten too far in two days, I think we have gotten farther than some may have expected to begin with. Thanks everyone for your outstanding input and freedom of the input. I haven't seen too much parochialism in the comments. It's been an honest discussion of a very serious issue. We are seriously committed to increasing simulation use across the industry. Particularly focusing on the commuter industry. While we are trying to do it as cheaply as we possibly can we can't lose focus of the fact we are certifying pilots in these devices. While everyone may have the dream of getting a Level D sim or a Level E, as some have commented about, for under ten thousand dollars, there is that balance of recognizing what we are doing with these devices and the public trust that's been thrust upon our shoulders to make sure we maintain that safety that's needed, and it's in these devices we are putting together.

Thanks again, for the outstanding job you have done with putting this together, you [Boothe] and Don [Eldredge], Judith [Burki-Cohen] and our lovely group of transcribers [Allison and Dave Hoyman].

MR. BOOTHE: That applies to one.

MR. SMITH: I have enjoyed this, too, renewing old acquaintances, making new ones, I have really learned a lot. Thank you.

MR. BOOTHE: Are you going to leave right now?

MR. RAY: We have ten minutes.

MR. BOOTHE: There is just a couple things. We didn't close the issue on surge. I assume we are going to try without it. Is that concluded?

MR. RAY: I will try to wrap up my thoughts about it, at least. Where I think we are with this. I'm going to go from Level A up. It appears to me we are at a point where we have the obligation to identify those degrees of freedom required from Level A through D. I believe everyone understands what six degrees of freedom consists of. We, the FAA, have never, and erroneously so, identified what three degrees of freedom are satisfactory for a Level A simulator. We have assumed that those three degrees are what was present in the old Link system.

I believe we have the obligation today to clearly identify which three degrees. Based upon this meeting, those three would be pitch, roll and sway, for a Level A simulator.

Level B, from what I'm hearing here, would be the addition of heave, because we are involving a landing maneuver and the resultant necessity of having heave.

MR. BOOTHE: That's the question I've had. We have only talked about takeoff, if we say that for takeoff do we follow through the rest of the book for landing and post landing, four degrees of freedom?

MR. RAY: If that works. If the consensus is that a fifth degree is needed on landing, then it may change what I just said. It doesn't change the fact that I think we need to clearly identify what degrees of freedom we are talking about, not just any three, but a clearly defined three, four, five, whatever it should be.

MR. BOOTHE: We are not going to get all that done, obviously, so I don't know how we will handle completing that task, whether we might revise this and send it to you or perhaps if we could ask some of you to follow through on the thoughts and send them to me. I would appreciate any thoughts I get from you in that respect.

MR. RAY: If I could add another comment, I'm not trying to set aside all of the discussion that went on on the six degree system. That would similarly be a part of the same option available to anyone, if they selected a six degree system in lieu of a three degree defined as pitch, roll and sway for a Level A, or a four degree assuming the definition is pitch, roll, heave and sway. Such a six degree system alternative would be the six degree system as defined this morning.

MR. BOOTHE: I think you can always go to six.

MR. RAY: Sure. A six defined, you don't have to go to a six, a 60-inch six degree system, a six degree system defined as this, to put it very quickly, a 36-inch system that was defined this morning. That also drives the necessity to clearly define in the standards what [Levels] C and D six degree would be. It has to come out at the same time. And the inclination is to go with what the international group, even though it didn't get embedded, is to take a good look at that along with the requirement in [AC]120-63 and see if there are any disconnects. And then come out with [Levels] C and D six degree requirements at the same time. That's the general feeling or thought pattern I'm going through right now.

MR. BOOTHE: Thank you, Paul [Ray]. I had a suggestion, too, it would be nice to hear a little bit more about longer term plans, and not in detail, but just in some summary of what sort of research ideas to have in mind longer term. I don't know quite how to say what kinds of things or what things are to be studied, maybe Bruce [Baker], you have a better description of that.

MR. BAKER: Well, you and I talked about it during the break. And essentially I brought up, do we want to try to make suggestions of particular studies that we would like to see done and/or even make some gross suggestions on the approach that might be used to determine answers to questions that have come up in this meeting that we just don't have answers to.

MR. LONGRIDGE: I think we do. As a matter of fact I think that's on the agenda for the last hour, to get input of the group with regard to what are the most important research ideas that we ought to pursue because there is almost an infinite variety of them, we need to prioritize those.

MR. BAKER: We have 20 or 30 years of research of one type or another that's been looking at this type of problem and yet we don't seem to have any really good answers to the questions that keep coming up in these meetings. This isn't the first time I have sat in a meeting like this and we have said "well, how much motion do we need? How big should it be? What should its characteristics be? How many degrees of freedom?" And some, while I will admit this is a very hard problem, this is not something a couple guys will do in a couple weeks' time.

It would seem as a result of this meeting we have got some significant direction and I will bet you we can get two or three good ideas at least out of this group that says here is how we ought to attack this problem, and at least kind of head off in that direction and provide some feedback to the group and let us as individuals evaluate it and say "yes, I think that's a good result," or how about also looking at this and take another day or something during the test and look at another aspect of it, because the day will come when we are going to get asked how did you arrive at these conclusions, and the day is probably already here. If they didn't want to embarrass us, they would go ahead and ask the questions anyway.

MR. RAY: If I could offer at least one input to that process.

Going back to the comments that I made yesterday morning. We must define the training environment. Training environment being classically plus or minus 45 degrees of bank, plus or minus 30 degrees of pitch. If those aren't the right numbers, then we can modify those somewhat. We are not addressing acrobatic flight. We are talking basically IFR training that we provide typically to the commercial pilot. Any study, in my opinion, needs to focus on an environment. That impacts the visual requirements and how visual rolls into motion. To acquire results as we alluded to earlier with ten miles or 20 miles visibility as the focus, could provide some improper results, where in fact the training and the need for pilot assessment is reduced visibility such as with 150 feet or 300 feet visibility as opposed to 20 miles.

MR. BAKER: I'm reminded of another thing that happened some years ago when I didn't have as much gray hair. We ran a study up at Fort Monmouth in the avionics lab, we only ran one pilot in each aircraft, which of course is an anathema to a good psychologist. The fact is before we ran that pilot we had no data points. We knew we were closer to the answer than before we had any data points at all. I'm not suggesting we have to be totally thorough and run every aircraft type and every flight condition, because we have identified in this meeting flight conditions that we know are more critical than others. Like ground taxi isn't as important as aborted takeoff.

If I was going to spend my money I would spend it on aborted takeoffs as opposed to taxiing around the ramp.

MR. RAY: Proper cues resulting from any control input, whether it be nose wheel steering or braking action, I think are extremely important to pilot acceptance and realism. The need to visually navigate in and about an airfield would depend on the checking requirement.

MR. BAKER: I bet you could get consensus that the hardest problem to solve and the most critical one in terms of training the pilot has to do with emergency procedures in takeoff and landing. If we are going to solve one first, let me suggest we do one of those and not worry about taxiing on the apron over to the jetway. Maybe I'm naive about that.

MR. RAY: I go back to the initial instruction I received in a larger airplane, our instructor would not let us take off until we could taxi the aircraft satisfactorily on the ground with his eyes closed, without him being able to detect the aircraft stopping. It's a lot more important than some may want to give to it.

I have to run.

MR. BOOTHE: Yes, you do. That bus leaves early.

MR. RAY: Thanks again.

MR. BOOTHE: Chuck [Stocking]?

MR. STOCKING: I was going to say as long as we are talking about R&D projects, from the point of view, my point of view, which has been mostly cuing and supplying cues for the Level C and D simulators, plus or minus 30, 60-inch system would be to answer the question "can you take a six DOF, cut the stroke in half, and see what that does to the quality of the cues?" That would be my number one concern if we are going to go to a limited excursion six DOF system.

MR. ADVANI: Or even reduce the degrees of freedom on the six DOF system.

MR. STOCKING: I wouldn't reduce—first I would not reduce the degrees of freedom. First of all I would go to a six DOF system with restricted throw and see what that does to the quality of the simulation on a device that has been certified to Level C or D so you have a point of reference. You have got to—here are the crews that were flying this before, here is the crew flying it again, what is their attitude towards it? Does it have aircrew acceptance? What did it do to their flying? Did it degrade it? No impact at all? Those are the kind of questions you want answered.

From that point on you begin taking away your degrees of freedom. And assess what the impact is on that. You may get down to the point where all you need is heave.

MR. BAKER: I think that's a very reasonable thing to do and I think it's important to do that in a full flight sim.

MR. STOCKING: Yes. Using past experience as your steering course.

MR. BAKER: Essentially what you would like to do is change one parameter at a time and see if you can discover what the effects of the parameter is. Take a guy that flies the airplane, two or three guys to satisfy Judith [Burki-Cohen], and put them in there and take one thing away from them and see what his reaction is, see if he even notices. And look at both stroke and degrees of freedom on the motion platform and probably there is going to be other things people would want to look at unrelated to motion cue.

MR. BOOTHE: I would want to do more than see if he notices it. That doesn't really count to me. I would want to measure any change in his performance and workload, because without those I don't care whether he notices or not. Pilots don't notice things and compensate for them and don't know they compensated until some point at which they can no longer compensate. So asking them whether they noticed it, unless they reached that compensation saturation point, they won't tell you, they won't know.

MR. ADVANI: You do, however, have to be careful in how you measure workload.

MR. BOOTHE: I realize that. I made it sound simple and it's not, but still you have to come up with some sort of measurement, otherwise performance doesn't mean anything, in my opinion. Anyway, I just wanted to kick that in.

MR. BAKER: I agree with your comments, I agree exactly.

MR. ADVANI: Also going back to yesterday's discussion regarding phase lag, that's another very important design related parameter that needs further investigation. Although you need a system that has the response in order to study that and degrade the system qualities and assess then the pilot performance as a result.

MR. BAKER: Of all the parameters that we have discussed in the last two days that one is the one in which I think we can probably analytically get a better grip on than most of the other ones. Furthermore, in terms of getting it to what we agree is a good number we can get there.

MR. ADVANI: Analytically and empirically.

MR. BAKER: And with the hardware. I would like to answer the question how good does it need to be, because the question keeps coming up, particularly with respect to older equipment. We can potentially advise the industry you can get improvement in the handling qualities of the simulator if you go back and fix this one little parameter.

In terms of answering questions for this kind of study or this kind of project, since the industry feels it's not that hard to achieve a good result as far as phase is concerned, that's not as important as deciding how well can you do it if you start leaving out degrees of freedom.

MR. HARRIS: When you are talking about phase are you talking about the motion phase or are you talking motion phase with relation to available—

MR. ADVANI: Both.

MR. BAKER: Today we were talking about the phase on the motion platform.

MR. HARRIS: Motion is very straightforward. But motion with relation to visual is not quite so easy.

MR. BAKER: I agree with that.

MR. WILLMOTT: I think one of the things that would be in question in doing these studies is the drive equations, the model that you are using would suggest that those ought to be clearly understood by all before the study is done to ensure everyone is in agreement with those. If you do a study and there is one set of models and Frank [Cardullo] comes up and says "yes, you should have had nonlinear something or other," that throws all the results away.

MR. BAKER: We don't want the dimension of the parameter space to get too confining.

MR. BOOTHE: Lloyd [Reid] has done work in drive equations.

MR. REID: Many moons ago. You are right. I was going to bring up eventually that we haven't talked about one of the biggest distortions in our motion systems, and that's the washout.

MR. ADVANI: That's perhaps the most detectable variable.

MR. REID: I know we spend a lot of time making the hardware part as perfect as we can, then we throw these tremendous phase distortions and amplitude distortions in with our algorithms and try to minimize the false cues, the various imperfect cues that result, and maximize the good cues that result, and one of the things I was going to mention, it's maybe a little too researchy for this group to consider, but someone, and we might be interested in participating, should provide some subjective correlation between what pilots think and what the false cues are [that] they are facing under a range of conditions.

We have defined ways of specifying hardware properties like the AGARD[-AR-]144 did, the different things you can measure and systematically specify for your hardware. But the follow-on project was supposed to be the subjective ratings of different degrees of imperfection in the simulator by human pilots, so you would be able to have both parts of the picture. And that work was never done, never sponsored and carried out. We have poked away at it over the years but we haven't addressed the problem in any systematic way.

MR. ADVANI: We are gearing up to do that work.

MR. REID: Again, you are a few years away from doing that.

MR. ADVANI: I don't know about that.

MR. BOOTHE: You are talking about the subjective correlation between what pilots think—

MR. REID: When you put a pilot in and he flies a maneuver you ask him how was the motion, he will say "too jerky" or "I felt a bump in the wrong direction as I entered the turn" or whatever. You go back, look at time domain effects, usually, and try to determine what he was sensing and correct that. And quite often you are faced, if you are the tuning man, as I guess Chuck [Stocking] knows, you have trade-offs between different degrees of freedom. Quite often in the same maneuver you can make one thing better by making something else worse. Say tilt coordination during braking.

MR. STOCKING: Magnify the thing—

MR. REID: Get rid of the angular problem by making a linear problem worse, vice versa. That's the art, right? We don't have any documented pilot rating values for different levels of typical imperfect cues. There is a whole range of things, you can call them false cues, missing cues, scale cues, there is a whole range of things. It's a lot of work, someone is going to have to spend a lot of time to complete. And so that was one, it's not the kind of thing you want to put in a regulation, I'm sure.

MR. BOOTHE: There is something else we don't know. We never could get to today because we don't know how, if I wanted to do almost any kind of research in a simulator it seems to me the first thing I ought to know how to do is establish that simulator's known set cuing parameters as a reference base and work from there. For example, if I were to go out to an airline and say I'm going to measure motion effectiveness one way or another, and use their simulator, I'm measuring from a reference basis that they have established, and it may be useless. In fact it often is, because it's for various reasons that were mentioned in the room today, like shake and visual systems and that sort of thing, is attenuated and we don't know what the starting point is. We don't know what the starting point is for setting a simulator up in terms of what are the effective cues that ought to be there for a motion system to be effective. I'm not making myself clear, I guess I really don't know.

MR. REID: You are talking about the good cues, I was talking about the bad.

MR. ADVANI: I think what you are suggesting, Ed [Boothe], is that the simulator on which you do such evaluation should not be polluted by its own natural properties.

MR. BOOTHE: That, too, but I don't know what should the baseline be? What should the thing do to measure?

MR. BAKER: I was going to suggest a solution to that because Sunjoo [Advani] and I talked about that at the break. It's not unreasonable to take a reasonably good [Level] C or D simulator and start with that and make some measurements on that to get a baseline. Then have some of us engineering folks that have got motion experience, and I don't know if I want to put myself in that category compared to what some of these guys seem to know, but improve the system to where there is at least some reasonable consensus that's as good as you can do. And I think that you can do that mostly with software changes, okay? And then try different algorithms and try different things that we have talked about. And at least from that we are going to get some data points, right?

We don't have any data points right now. We don't have an idea except for engineering judgment on a lot of these things. Admittedly probably that device, even after it's been modified, will not be as perfect as you could do if you started from scratch and did the best you know how. At least if we document what's there, and you know we can extrapolate a little bit off of what we measure if we know what it was we were dealing with as far as the device is concerned. If we don't document the device, as we have criticized other people for doing, and if we don't have some engineers look at it and say "yes, I think what's in there is about as good as we can do or as good as we can do with this device," then once again we have taken a lot of data and analyzed the data but we don't know for sure—

MR. BOOTHE: Even more so, if you do research on a simulator and you conclude certain things about the effectiveness of motion, and Lloyd [Reid] does an experiment and concludes certain things about the effectiveness of motion, I can't compare them because you started at different places. And we need a common starting place. What should the thing—

MR. BAKER: That's the reason I said use a training simulator. Something that is certified, Level C or Level D, because it's at least very, very representative of what the training manufacturers are building.

MR. BOOTHE: It's representative of what that airline got set up and approved, I'm sorry, it's not what these guys built.

MR. REID: I think maybe part of the answer to your problem could be that it depends on how basic the research is you are doing. If you are down to the nitty-gritty of saying I want to just study the acceleration cue for a one g step acceleration input, then you can, no matter what simulator you are using, you can document what's coming out in terms of the response using the instrumentation package that's there, and so it may not be what you think is the best or whatever but at least it will tell you what came out exactly. And then you can compare what different simulators did because each of them had a specific force and angular velocity trace for the same input and now you are comparing apples and apples in a sense.

It got to be the way it is of course because of the other things we were worried about but at least you know where it is. That's a real simple test, it's not the complete flying task you were thinking of.

MR. BOOTHE: I was thinking of a flying task, and if you were to set up your simulator and you were to eliminate surge and do tests with and without surge and see the difference, and Bruce [Baker] did the same thing with his simulator, unless you both started with the same set of cue capabilities that's very close, I couldn't use those results comparatively.

MR. LONGRIDGE: I'm not sure that's true.

MR. REID: I'm not sure you couldn't.

MR. LONGRIDGE: I think as long as you know what they are, you have to know what they are in engineering terms. You are certainly going to want to have more than one value of a simulator configuration, so you have some variability to which you can draw relationships.

I think the one thing that's missing in this discussion and that we all recognize, is ultimately we want to know whether this has any impact on how the pilot performs in the aircraft, and also what we need to do in addition to the ideas that we are going to propose is apply some of these engineering measures, like control technique, to how the individual performs in the aircraft, having been exposed to a given measured configuration in the simulator.

And that would be one of the priorities I think that we would like to pursue in this regard. I mean, it's been established that, and we all know, you can affect the performance of the pilot in the simulator by manipulating these various design characteristics of motion, but the claim of the nonbelievers is "so what, you have never established that this has anything to do with how the individual performs in the airplane."

So I would suggest that ought to be perhaps our number one priority in whatever research initiative we end up undertaking.

MR. BAKER: I wanted to make a comment on something Frank [Cardullo] said, I wish he was here to rebut what I say. He made a comment about proving anything about training transfer.

MS. BÜRKI-COHEN: Backward transfer.

MR. BAKER: I realize that may be, there isn't any proof of training transfer specifically for motion but there sure is for simulators in general. I mean, you guys certify people in simulators, now if there wasn't any training transfer I don't think you would do that.

MR. LONGRIDGE: Clearly there isn't extensive literature which documents there is transfer from a simulator to an airplane. What's different I think in this application, we are looking for 100 percent transfer and I don't think it's ever been documented that is in fact what happens when we certify somebody in a simulator.

MR. BAKER: I think you can probably rationally argue you don't need 100 percent transfer. If you get a high percentage of transfer that's sufficient.

What you are trying to do also is not have negative training in a simulator, not where he has to unlearn something to fly the airplane he just has to learn something additional in the airplane, because you can't learn something in the simulator.

There are simulators that I'm aware of that teach negative training real bad to the point where the instructor pilots are apprehensive about taking the student pilots up in the air after they have been in the simulator for two days. It's a military aircraft, so it's not anything he is going to have to face on CNN one of these nights, but that's a really scary thing to me that the simulator would be that bad. I mean, I have talked to several of the instructor pilots, I know some of them personally, it's a real thing.

Clearly that's off on one end of the spectrum in an area where we hope the FAA certified trainers never get. And the, you know, I think that there can be things done that will show positive training transfer and prove that there is training transfer in various areas of the simulator. Frank [Cardullo] said about motion he wasn't sure you could prove it, I'm not quite that negative, I think maybe it just hasn't been attacked from the right direction. And basically I make that statement very simply because we know if you turn the motion off, the guy flies the simulator a lot different than he does the airplane. So if the motion makes the simulator fly more like the airplane, then there is positive training transfer. Then you could almost make a proof just from that.

MR. LONGRIDGE: I think part of the problem is failure to use measures which are sufficiently sensitive to differences. That's why I say when we go to the aircraft we ought to be measuring things like control technique, control input, in addition to some of the other more grosser maneuver-oriented standard considerations.

MR. BAKER: Control input is a very important measure because you can take a PSD of it and you can make an estimate of how hard the guy is working. The PSD has a lot of energy, at two hertz you know the guy is working real hard. If the energy is all down at a half hertz or less you say he is not working very hard. You can make comparative measurements by looking at the power density.

MR. ADVANI: You definitely get a transfer between the aircraft and the simulator in that case. And that will lead you to some—in some direction at least.

MR. BAKER: That's right.

MR. BOOTHE: I think Bob [Heffley] has been looking at formulating some comment.

MR. HEFFLEY: I've been squirming around here. I mean, what all of you have just been saying, there is nothing to disagree with. I think what we see is that there are a lot of things to be answered and defined. We are having an awful time pinning down the requirements for this particular level of simulator that we are talking about with respect to motion. But it's all because we don't have the right engineering data to start with.

And, you know, it's another case here where the technology, simulator technology, in terms of sophistication of the systems being built has just totally outstripped all of the basic rationale and data that you need to get in and rationally design the systems. What people have been talking about in terms of gathering what we need is right on the mark. But the number one thing is to go about it in a way where you do gather data in a very systematic way. It really can't be done by one little group or another. It really needs to be done by whomever can bring something to bear on this. And the idea of a common baseline case that everybody shares in order to relate to one set of data to another, is really important. Except there probably needs to be several of these baseline cases.

MR. LONGRIDGE: Oh, yes.

MR. HEFFLEY: They need to be defined in terms of a very specific training segment or task. You really have to focus on these things in order to really study them properly. I think you really want to take advantage of not only these larger six degree of freedom training simulators that you all are familiar with, but you also want to go to very, very large amplitude simulators like an Ames VMS so you can really back way off in terms of motion limits and you can have rather long washouts. And then move back in. And let me just note that some of that stuff is going on right now. And I showed some of the material to Ed [Boothe] yesterday.

Some of the questions that we have been debating are under way, but they are not in the context of training. They are in the context of perceptual fidelity for research simulators which maybe lead to different answers on what are the system requirements.

And finally, real important, this idea of keeping track of what the pilot is doing when a pilot is in there either flying the simulator or flying the real aircraft. People have invented dozens of ways of looking at how pilots are flying the aircraft in terms of performance or control strategy or power spectral density or other metrics. But that's where I think you have to leave things up to individual research groups, maybe doing whatever they are doing—working the problem however they want to work it. But that is the key way that you start to get a handle on control strategy and whether what the pilot is learning in the simulator is getting carried over to flight. I've got some study results from several years back where we did actually measure control strategy in very direct engineering terms and where we had good control groups between simulator training and in aircraft training for transition training. And you could sure see transfer of training okay, but you could also see the fact that when the pilots were learning how to—in this case—land an airplane, that what they were learning on the simulator was not a very good control strategy. And it got carried over in their check rides to the real aircraft. There were clear instances of hard landings and also the identified control strategies were inappropriate to flight.

Yes, they readapted after they made two or three landings in the real aircraft, but there were serious training deficiencies. I think these are the things that somehow you really want to bring all to bear in a systematic way so that the next time this whole issue of how to specify simulator requirements comes up, there is hopefully a more rational approach in answer to all of the things that we have been concerned with.

MR. MARTIN: Just to add some thoughts on that, and maybe to extend it a tad. One thing I was thinking is that you could take a look at some training transfer effects from some of your current simulators and try some transfer studies into a variable stability aircraft—that may not cost you much more than renting time in a VMS or something. You might do some interesting studies there if you can figure out what sort of control strategy measures and workload measures you want to look at.

MR. LONGRIDGE: How come the Air Force has never done this?

MR. MARTIN: Well, there were plans at one time. They got thwarted by cutbacks in funding for this sort of research.

MR. LONGRIDGE: Probably so. They already proved that motion is not necessary, so.

MR. MARTIN: You can make a variable stability aircraft behave pretty much as the aircraft for whatever simulator might be available to do the ground-based portion of the study on.

MR. LONGRIDGE: But you would have to have matching ground—the aircraft that you are simulating in both situations would have to be the same one. Is that not true?

MR. MARTIN: Well, you probably want to take your aero data from the simulator, and put it into your variable stability aircraft and operate in some region where the variable stability aircraft would represent that data. You would be able to control things like turbulence or whatever parameters you wish to look at. You could make that variable stability aircraft behave like the other aircraft for landing and whatever.

MR. STOCKING: We will see you all. Thank you very much. Nice to meet you all. Maybe we will get together again.

MR. LONGRIDGE: I'm sure we will.

MR. HEFFLEY: Following on to what Ed [Martin] is saying here, you don't necessarily even have to be thinking in terms of a variable stability aircraft. Look, if somebody is going to go out and build a simulator, they may be having to instrument an aircraft in order to gather validation data. Perfect opportunity, if you happen to have a little bit of extra engineering resources, to also gather data on how the pilot is flying the particular maneuvers and gather in-flight data that are appropriate, and finally, to bring him back to the simulator.

MR. REID: You could make that part of the process that the companies like Dave Kohlman's company would perform as part of your sim package. Part of the sim package would be pilot flying characteristics or technique. As part of the package.

MR. HEFFLEY: Because it's important to be looking at, in the end to be looking at your simulator in the very same context that you have been looking at that real aircraft. And you have got to have the time history data, or the—you have to have some documentation of where exactly you were flying and how you were flying it. And you just cannot ever go too terribly far, it seems, with just simply subjective or commentary, you have to have the records.

MR. BOOTHE: But it would be really interesting to have an instrumented airplane so we could measure at least pilot control inputs. And do handling quality rating in the airplane using recognized standards, and that's subjective but it's a very structured subjective scale.

MR. HEFFLEY: Absolutely.

MR. BOOTHE: So there is a small standard deviation of answers. If pilots use it correctly. So then you could do that same thing in a simulator using the same pilot rating scale. And I think you would just be surprised at the outcome. I think that would be a most interesting thing to do. It won't tell you what's wrong, it will just tell you there is a difference.

MR. HEFFLEY: And Ed [Boothe], you know, in the last couple of years I guess we have been doing exactly that same thing, and this is in the military helicopter area, but there has been a lot of hours of flying a Chinook around through specific flight tasks and getting careful pilot ratings and careful flight data records and bringing that back to a manned simulator in order to try and validate that, and even though in this case it's a simulator with very, very large motion excursions, same—all the same issues have come up that we have been talking about here. And you have to have the objective engineering data in order to really understand what's going on and understand whether your simulator really is valid, whether it's inducing the same way of flying.

But, you know, I think a lot of the methods are really there. And it's a matter of really bringing it to bear on this sort of a problem in a systematic way, which is something that the FAA could really foster.

MR. LONGRIDGE: I agree.

MR. HEFFLEY: Really help everybody focus in a coordinated way.

MR. ADVANI: I think what you are also suggesting is that you need the availability of an aircraft and high enough bandwidth simulators so it's the quality of the simulation facility that you are also—I should emphasize the availability of high bandwidth six DOF system as well as an aircraft and the model of that aircraft in the simulator.

MR. BOOTHE: Tom [Longridge], how much money have you got?

MR. LONGRIDGE: Not enough. I'm sure.

MR. BAKER: He didn't ask you if you had enough, he asked you how much.

MR. BOOTHE: Smart man over there.

MR. BAKER: Then he will decide if it's enough or not.

MR. ADVANI: It doesn't necessarily have to be something unaffordable if it could be tied into existing research plans, such as what we are already undertaking. So it could be very cost effective in the long term.

MR. LONGRIDGE: I think we are never going to do all that needs to be done, but clearly I think we can make a significant inroad in terms of some of the issues that were raised today. I don't see why we can't do that. I'm just amazed it's never been done.

MR. BAKER: What kind of time schedule would you see you are under to get some—

MR. LONGRIDGE: We are under immediate, I don't know, before the end of this calendar year with regard to whatever interim advisory circular revisions are going to be made for Level B, those will have been accomplished. I can absolutely guarantee that.

With regard to the research, we are not under any particular gun, it's really a matter of our own desires to get the answers to these questions as soon as we can. I would anticipate that is something we would like to initiate within the next year. The R&D. But we are not going to wait for the R&D in order to make these changes, we can't do that.

MR. ADVANI: You mean the final changes or preliminary changes?

MR. LONGRIDGE: You know, I was talking to Paul [Ray] about this. It's kind of a matter of semantics, isn't it? Everything is always subject to revision.

MR. ADVANI: Yes.

MR. LONGRIDGE: Whether we want to call these interim or whatever we want to call them, there is going to be a certain element of risk involved for someone that wants to build a four DOF system.

MR. BOOTHE: Yes. Everything is subject to revision, I think how you aim it in the first place gives sort of signals to the industry as to what your intent might be. If you don't say it's interim then they might think this is it.

MR. LONGRIDGE: That might be a reason not to call it interim. So that we don't raise fears unnecessarily. It's probably not going to be interim. You know, at least until the R&D is done.

MR. BOOTHE: If that's the case then I would agree we shouldn't say interim, and people that can go do their thing with the assurance whatever they do has some remaining rights and use after the next revision, which is the way we have always done it, that's, as you know, that's good and bad because Bob [Foster] can sit there and honestly say all those old [Level] B, three degree of freedom B systems, those that are still working we don't really know what they are doing, but they are working and pilots are flying airplanes.

MR. LONGRIDGE: That's true. We are talking about Level B for the commuter community and there aren't a whole lot of ones out there that we need to worry about.

MR. BOOTHE: That is a question that maybe some people have, and I have myself, is the intention to revise the Advisory Circular to add a category that's called Level B regional or something like that? Or will we simply revise the existing Level B?

MR. LONGRIDGE: That's up to Paul [Ray]. My recommendation would be that we are just going to revise Level B. Clearly whatever we do for the regionals ought to be available to the entire industry.

MR. BAKER: The other side of it is people are not building new Level B sims in any quantity at all, it's not cost effective—

MR. LONGRIDGE: That's right.

MR. BAKER: —the way the regs are written right now. I don't think you are going to penalize anybody by revising Level B aiming it towards the commuter aircraft operators. And ignoring the fact that somebody sometime might want to design a new Level B to the old standard. You could still allow them to do that if you wanted to, you could put a caveat or not in there you could go back and use [AC]120-40B the way it is for a Level B sim. I don't think you are going to have a lot of takers on that.

MR. LONGRIDGE: I wouldn't think so. And no one is going to build to the new standard, either, unless it's cost effective and unless those regional airlines that are presently contemplating trying to convince the FAA to allow them to use FTDs can buy these Level Bs for about the same amount of money as they would have spent on those FTDs.

MR. BOOTHE: I think the only way we can do that is twist the FTD manufacturers' arms to raise their prices.

MR. REID: That's one approach. You can always add a surtax.

MR. BOOTHE: I just don't think a Level B can be produced for that amount of money. I know there are people who say they can do it, and I hope they can. But I just can't put it together in my own mind that that can be done. So I hope they are innovative enough to follow through and to be able to produce a Level B for the numbers I've heard quoted.

MR. LONGRIDGE: All we can do is create the conditions.

MR. BOOTHE: Absolutely. So—

MR. BAKER: Have you all looked at the problem of the economics of this new Level B definition? I assume that you have looked at the training scenario that would be allowed under this category Level B.

MR. LONGRIDGE: Sure.

MR. BAKER: Have you run that by a few of the airlines to get their comment on it to say "yes, we would buy a Level B as opposed to Level C because it provides"—well, you can't ask them that question, you have to say what price would a Level B be desirable versus Level C because it gives you enough training value that you don't get in an FTD but it's enough cheaper than a Level C to make it worthwhile to buy it instead of going on and buying a Level C.

MR. LONGRIDGE: We have had these two discussions, we have had two meetings with the Regional Airline Association specifically on this subject. We have indicated, I mean we have indicated that we are looking for something in the neighborhood of a three million to four million dollar price range, which we think is significantly cheaper than a Level C or D.

MR. BAKER: Yes.

MR. BOOTHE: But hasn't the regional airline industry also established a target price that they say beyond this we can't play the game?

MR. LONGRIDGE: It depends on who you talk to. There is quite a diversity of opinion even among those airlines. Some of the regionals are very safety conscious, they are willing to spend the money, and there are others that aren't. It's hard to get a consensus. They are not as organized a group as the Air Transport Association is, for example.

MR. BOOTHE: Do you have any feel for where the more safety consciousness lies, does it lie amongst those who may fly smaller jet airplanes or do you have any feel for how people that fly regional jets, say, compare to those who fly Beech 1900s in terms of—

MR. LONGRIDGE: We have people that fly regional jets and Beech 1900s, so Comair is a good example. I don't know if I want to respond to that.

MR. BOOTHE: All right. What level of safety—as soon as you start naming airplanes you almost start naming airlines. Sorry I asked that.

MR. LONGRIDGE: I think something brought up earlier about having research designs reviewed maybe by this group or somebody like this group is a good idea. Because so much of the research that has been done has been flawed in one way or the other and that may be because the people that are doing it have expertise in a certain area and maybe not in another, and what we need is an interdisciplinary group. Clearly we need to bring the engineering expertise to bear. On the other hand, we need to have the behavioral science expertise there as well because ultimately we are interested in behavior in that aircraft.

What I would propose is the FAA and Volpe, you know, develop their prototype research designs and maybe run it by this group for those people willing to take the time and read what we are proposing to do and make criticisms, so we are probably only going to get one shot at this. We need to try to do as good a job as we can do.

MR. BAKER: You will get more shots if the person is a good one. But if the person doesn't yield anything useful, you will probably have trouble getting money for the second shot.

MR. LONGRIDGE: That's probably true.

MR. BAKER: If something really good, I expect that it's likely that something really good would come out of this research. If something really good comes out of this you can stand on the soap box and say "hey, look right here what we did, we got good answers to tough questions." You go in the next time and you want to pursue that a little further and look at different aircraft or parameters, people would be more inclined to give you the money.

But if you come up with another one of these studies that's inconclusive for the application, then the boss is probably going to say why bother.

MR. LONGRIDGE: I agree.

MS. BÜRKI-COHEN: One thing to keep in mind, the more you want a conclusive answer, the simpler the question has to be. You cannot ask too many questions in one experiment if you want to have a conclusive answer.

MR. LONGRIDGE: The usual conclusion is more research is needed.

MR. BAKER: I don't want that answer.

MR. IRVING: More money.

MR. BOOTHE: Is the JAA pursuing anything such as we have been discussing for the last half hour or so, Don [Irving], that you know about? Are there any ideas of any research in this full flight training or flight simulation?

MR. IRVING: Most definitely not. The JAA has no money to do any such thing. It's a very small umbrella body in Europe, it draws its resources from the various national authorities. There is absolutely nothing.

MR. BOOTHE: What about national authorities such as the CAA?

MR. IRVING: We have a research project, it's mainly air traffic directed, human factors, technical things, whatever. Nothing I'm aware of. But I'm sure that's an area we have to explore. Sunjoo [Advani] is—

MR. ADVANI: There is an interest from the RLD, the Dutch Department of Civil Aviation, in looking at simulator fidelity. They are interested in tying up with other activities such as this, and conducting a multi-disciplinary effort in that sense, so yes, there is an interest from our side and we shall have backing as well as interest. We now have to work together to make this real.

MR. LONGRIDGE: Yes.

MR. BOOTHE: You have a money source, huh?

MR. ADVANI: We are working on that. We are trying to establish a synergistic cooperation and funding source, where airlines, aviation authorities, [and] simulator manufacturers are all involved with research institutes. That's the only way which we feel that something like this can be done. Not only to address the financial issues, but so that the interest of all these groups are addressed simultaneously.

MR. BOOTHE: Are you forming some sort of advisory group amongst those people to monitor and fund research for simulation?

MR. ADVANI: SIMONA has an Advisory Board for Research and Development. The members of this group, including those whom I just mentioned, provide at least an input, and yes, financial support. We have to make the rest of this take shape, because, as you know, it's a fairly new program. It's just becoming operational. And so we would like to see a joint effort with all of you people to carry this through. But yes, the infrastructure is taking shape, to address your concerns effectively.

MR. BOOTHE: Okay, I see Lloyd [Reid] is getting his coat on.

MR. REID: It's cold in here.

MR. BOOTHE: While I still have an opportunity, those of us remaining I would certainly like to thank you for being here. I know it's a big hunk out of your time to come and spend two days with us and give us your advice. And I certainly appreciate it and we have people from Canada and the UK and Netherlands and the UK again, and Canada again, as well as scattered around the USA, and I know you came a long way and if you are like me you notice those trips these days. So I say I appreciate your participation very much, all of you.

MR. LONGRIDGE: I would certainly like to second those remarks, you know, and those that Paul Ray made. This has been a very, very enjoyable experience for me and I believe that the input that we've heard today will indeed have an impact on where we go in the future in flight simulation, especially for the commuters. Thank you all.

MR. IRVING: Thank you very much for the invitation, we look forward to simulated travel in the future. A really useful discussion.