PANEL DISCUSSION ON WORKSHOPS

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Ron Beard, Naval Research Lab: What I thought we would do is have the people who led the workshops summarize what went on in the different sessions; and after a bit of discussion by the panel, we would open it up to the floor for any other discussion or comments that people would like to make. The first person will be Sam Stein and what went on in the discussion on "Ensemble Management."

Sam Stein, Timing Solutions Corporation: Thank you very much. The session on "Ensemble Management" focused on goals, objectives for both performance and operation; there was also very substantial discussion on what sorts of improvements are needed in technology and software in order to enable people to achieve those performance goals and objectives. I was quite surprised when I saw that those people who attended the session came from organizations that were actively involved in operating clock ensembles. I estimated that more than three–quarters of the people were from those institutions.

The uses of ensembles were varied. Those organizations used the time and/or the frequency internally or delivered it to external customers. Some of them were involved in synchronizing remote sites or providing frequency to remote users. In general, the objectives of operating ensembles were far more to maximize the reliability and availability of the service being delivered to customers than they were to improve the performance characteristics of the time or the frequency. Finally, fairly universally all the people involved were quite interested in delivering UTC and not any other form of time.

In terms of performance objectives, one of the salient comments that was made was that people who are in the delivery business are very, very concerned with no doing harm, to minimize the probability of delivering bad signals; and, for instance, they preferred to deliver no signal for time than to deliver the wrong information.

Frequency stability improvement: it seems to be a rather minor goal for ensemble management. And I think that is quite natural, given that in general the improvement that one gets over one's good clocks is, at best, inversely proportional to the square root of the number of the clocks and the cost increase is proportional to the number of the clocks. So we are all much better off with developing better clocks than buying large numbers of them, for that purpose.

Another thing that came up that I think is important – and we don't often think about it – is that this is an example of a case where the peak errors are far more important than the RMS errors. It doesn't do a lot of good to be exquisitely fine in ones frequency or time capability and be occasionally terrible, if that single instance of being occasionally terrible occurs

during a critical period. I think that has implications on how we need alternative methods for characterizing performance clocks under those circumstances. Given that performance objective, outlirr detection and methods of dêaling with outliers become very important. One thing to point out is that the process of dealing with outliesr is a process of trying to detect without outside information when the measure result does not come from the source that one's normal measurements come from. It is perturbed by something other than what we expect. On the other hand, we don't have a signal line that comes in and says, "Oh by the way, this bad event occurred." So we are guessing. When you reject the measurement in order to preserve the integrity of the system, when the timing receiver says that the time changed by a second, and when cesium clocks say that it didn't, and you reject that measurement, you can do a great deal of good. However, when you reject a measurement that is a few ns out of your expectations – and it was real – you do a minor bit of harm. The resultant in time or frequency that one computes from a group of clocks is a less good reflection of what the clocks actually did than had you included the data. Once again, we prefer not to maximize performance in the RMS sense in order to protect ourselves from the peak errors.

Finally, there was quite a large discussion about the topic of producing real time outputs from clock ensembles and particularly the steering of physical clock signals so that they reflect a computed group ensemble time or frequency. And how big those frequency steers should be, whether or not the users of these real time signals would prefer tight time tracking or smooth frequency. And I think one of the things that we realized was that those questions were answered a long time ago; decisions were made, people operate in a certain way, and there perhaps is a need to revisit the question – we don't know the answer, but at least to revisit the question in the light of great changes that have occurred in the nature of time synchronization. People's operational objectives are pretty simple, like 100 percent automation of systems, with considerable ability for operator oversight. People in general require guru–free operation. Whatever happens, you must be able to deal with the situation without the need for a true expert.

I think I would finally say that at the present time, people are not in general always taking advantage of the capabilities of ensemble systems for the production of real time signals, because right now of fear of what might happen and a fear of delivering very bad signals for extended and noticeable periods of time. For example, people are often not steering, or not steering automatically for that reason. So kinds of improvements are needed. There are actually improvements needed in the available hardware to do this job, particularly in the area of producing real time signals. One of the things that is needed in such a clock system is a low-noise way of steering the clock without perturbing the clock's innards. Today we have cesium standards that can be steered in frequency in this manner, but these frequency standards cannot really be steered in phase without affecting their frequency. Phase steering would be useful and it is desired. We also require highly deterministic steering. And that is the time at which the steer takes place and the exact value, both in phase and frequency, need to be known.

Another aspect of the steering mechanism that is I think often neglected – it has been pointed out to me before and it was pointed out again at this meeting – is that when one is steering, and in particular when one is steering frequency to remove phase errors, there is a danger that

the system might stop in the middle of the process. And so if we have intentionally offset the frequency standard in a degree in excess of the noise of the ensemble, in order to change a large amount (perhaps 100 ns, or 10 ns, or one ns), and the computer chooses that moment to stop, we would leave in this large offset – perhaps several parts in 10 to the 14 or several parts in 10 to the 12 – and steer off into Never–Never Land unintentionally. So that the intelligence of knowing what the long–term steering target is needs to be built into the steering mechanism in a way of determining that in fact has to return to the nominal steering value; it has to be built into the steering mechanism.

Finally, an important thing that came out of this is the large desire on everybody's part to be able to steer to UTC. That has large implications on the desire for the availability of UTC in real time; so improvements in the time at which we can access UTC – and a great deal is being done now in the way of providing that. There was a paper by Claudine Thomas, a discussion of UTCP and how we will in the future have better access and more timely access to a UTC replica.

Ron Beard: Thank you, Sam. There are some interesting points there that we can follow up on. And I think a lot of what has come out of ensemble management today was a result of some of the good R&D and sales being done by various companies. So why don't we pass on to Jack and see what came out of that session. Jack?

Jack Kusters, Hewlett–Packard Labs: Thanks, Ron. Our workshop was not quite as technical, since we were dealing more with opinions and feelings and observations. In particular, we were looking at a way of improving communications between R&D groups, sales groups, and support groups in an organization. And indeed this is a problem that has been around for a long time; the "Harvard Business Review" articles have termed it the "silo effect." And if you think about it, a silo is a very tall building with no windows in it. And if indeed the various functional areas in the company are in their silos, the communication between silos is virtually nil. They reached a peak at the Ford Motor Company in the late fifties where the R&D people and the marketing people were kept separate. And the only communication allowed between them was through their vice–presidents. You can imagine how effective that was (I think that is when they brought out the Edsel).

So we were looking at several areas. Number one, what were some of the problem areas that we saw that were caused by a lack of communication? And secondly, we spent time looking at some of the suggestions from the group, more of sharing opinions and experiences than good concrete ways of solving the problem. These tend to be highly organizational–dependent. For example, those companies who are engaged as a direct supplier to the U.S. military have an entirely different set of problems and an entirely different set of interactions with their customers than those of us who engage in strictly commercial activities. And so it became very interesting to share opinions as to what we saw were problems in our organizations.

Even though the area that we were asked to concentrate on was strictly internal, the group insisted on talking about customers. And so it sort of flowed into the other workshop area. In particular, they felt that one of the biggest problems in effective communications between sales and R&D was that the customer didn't know what they wanted. And there were several areas that were brought out: customer uncertainty, customer education, costing problems, problems

in funding. And the people especially engaged in military activities pointed out that many programs that are many years in extent become very difficult in dealing with the customer, because the customer is changing personnel while the program is going on. On the commercial side, we tend to face large groups of customers. So the effect of one customer moving on to another area becomes sort of minimal.

In the external focus on customers, some of the suggestions that were made to improve the communication – and again, this is getting communication from the customer all the way down to the engineering support people that are actually responsible for building the final product – by providing customer education through seminars, technical papers, articles, workshops. Anticipate customer needs; learn enough about your customer so that indeed you can determine what the customer's needs really are. This may mean unsolicited proposals; it may mean a lot of other activities.

There were some revolutionary comments: sharing data with customers, even proprietary data, if necessary, to really teach the customer what the customer needs to put in his specifications. As one individual pointed out, it is very helpful to help the customer write the final specification, because that way you would know exactly what to bid. Make the customer part of the solution through a joint definition of the specifications and joint product development, if that becomes necessary. And, encourage customer visits, both from the field – people from the factory going to see the customer – and customers coming to the factory. In that same area, there was quite a bit of comment on staff education. Too often the sales people are the only people directly contacting the customer. But also in many companies, the sales people don't necessarily have the in–depth technical knowledge to ask the right question of the customer. And indeed if that is the only contact, there is a possibility of the communications chain internal to the company ending up with some very interesting interpretation of what the sales people thought the customer really wanted. So there was a fairly good consensus that direct contact with the customer by the R&D and engineering folks would be important to really understand and to really communicate properly what needed to be done.

Strong encouragement of staff rotation. Let the R&D guys go out and talk to the customer; let the engineering people get involved in a lot of these activities. QFD – that stands for "Quality Functional Deployment" – is a technology that is starting to show up in companies. It is a methodology whereby you gather tremendous amounts of information on a customer's viewpoints. It tends to be more appropriate either in interfacing on very large programs or on developing products that go to a wide variety of customers. Because you are dealing with one individual for one particular product, the types of questions that you have to ask in the in–depth interview that you have to do are just not appropriate. I can strongly recommend QFD in terms of trying to find out what customers may wish and to build that into your product.

A very strong emphasis came from a number of people on core teams. Involve more than just the sales people in calling on a customer. Set up a team that involves not only the sales people, but the R&D people, the manufacturing people, the QA people, the systems people, the test people; so that indeed the program operates without any misunderstanding or any surprises as it goes down the chain and into production.

We spent a lot of time talking about the internal problems. What are some of the things

that we saw internally between Sales, Marketing and Engineering? Several areas that were identified were cultural differences – we don't have a common language, in general; the people that are associated with sales or marketing tend to talk in different terms than the people in engineering. There is a joke that has been going around my company that a engineer and a marketing person is asked "How much is one and one?" The engineer says "two" and the marketing guy says "What do you want it to be?" I think that there is a slight change in the cultural emphasis in the two areas.

Quite often there is no control on the final specs. Things are not properly defined. There is no ownership of a particular program or a particular product. And there is no product champion. Some of the areas that were identified as possibly improving these were, number one, to abolish the silos. I tend to look at them as bunkers, because at times we are far more defensive of our functional areas. Some of the solutions, again, establish core teams; combine meetings – again, as an extension of core team; concurrent engineering – get the manufacturing people involved in the R&D program; make sure that as the product comes out into the manufacturing floor that the engineering people who have to support have been a part of the problem and have been a part of the solution. One thing that we found very effective is colocation; make all those guys sit together. It is strange how much communication can improve if indeed the R&D and the sales people are sitting next to each other. It is amazing how much you overhear when your peer in the next cubicle talks to a customer and makes comments that you know full well are wrong. It helps improve the communications there. Self–elected planning groups: make open environments such that people can indeed move from one area to another. Self–empowerment of the engineers to help make those decisions early. Interactive brainstorming in all aspects of sales, engineering and R&D. Combine unstructured brainstorm sessions, but with a very carefully–defined goal.

Some of the other ideas that people came up with were not directly related to problem solving, but are areas of concern. These are testing, human engineering, reaching the right person, TQM ("Total Quality Management"), which immediately segued out into a long discussion on ISO–9000; that faces a lot of us now in terms of trying to understand our own internal processes. Certainly in my company the interaction between the various engineering groups regarding ISO–9000 has been a real experience for all of us trying to understand what we are really doing.

The final area that we talked about was brought up by one the individuals in the workshop. He said, "Why is it that when I order something, I don't get something that just meets my requirements, I get something that is a total overkill that I have to pay too much for?" It is a question of "perfect versus good enough." And some of the problems and comments we received on that: number one, it is a perfect example of product of evolution, or creeping futurism. The problem is that we don't really know what the customer wants. And again, we have not communicated with the customer on options. We have not verified with the customer our impression of what he asked. And, we have not communicated that customer preference down through our structure. It is partially also a problem of not having adequate specifications. It is also a problem in commercial companies of designing for multiple customers. If you are designing for one customer, that's a lot easier; if you are designing for multiple customers, the temptation is to be all things to all people. And indeed, we end up putting in so many

different hooks and options that we lose sight of what the real direction is. What happens is that the product ends up costing too much and has too low of a customer value.

The bottom line from the group: the strong consensus was number one, consider customer costs when you are putting out a product. And the last comment from one of the manufacturing people there was "make sure that everything is designed for manufacturing." "One of the fundamental ways of lowering cost is to make sure that the manufacturing process is taken into account." And, "Make sure the manufacturing engineers are a part of the core teams." That about sums about an hour and 40 minutes of very active discussion. My compliments to the group and my thanks to those of you who participated. It turned out to be a very interesting afternoon.

Ron Beard: Thank you, Jack. Well from what I learned from visiting the various groups, it sounds like many of things that you brought up in your session, Jack, were also raised in the other session on communication itself, in trying to work with the vendor to determine what his requirements really are; and arrive at a price that was commensurate with what he was doing. And that is a difficult problem in today's environment with the people who are putting together these systems and trying to develop some new capabilities, really defining what they need to do that; and then effectively working with the vendors to get what he needs, and at an affordable price. And communications is a difficult problem.

A number of points came up out of these other groups, and I would like to open it up to the floor now. Does anyone one want to comment or elaborate, or do you have any questions on what we've discussed so far?

John Gehrhard, Rockwell: I have a question regarding that session on customer interface. The future of time and frequency equipment, are they going to go VXI for that equipment? And are you going to have modular boxes where you buy a console and then you plug in like a counter or plug in a volt meter so you don't buy an instrument that has excessive range capability, etc?

Jack Kusters: Well there certainly is a trend in that. We didn't actually cover that in the workshop because we were not looking products, just at just specific items. But out in the exhibit area certainly several of the manufacturers are heavily engaged in doing just that, providing VXI, VME, MMS modules to go into predefined chassis. Again, it depends on what you are trying to do. If you are looking for a single counter or a single product, it may not be as cost–effective; but if you are building a system, there are somewhere around 170 companies (the last time I looked) involved in providing VXI solutions. And certainly there is a tremendous amount of products out there right now. I don't know if that answered your question, but I certainly see that as a path that many people are taking in the future.

Ron Beard: I'll ask Martin now to summarize what went on in his session and bring you up to date a little bit. In the other session on R&D, it appears that communications was one of the larger subjects they talked about, essentially between the vendors. So I think that is a problem area that everyone is concerned about.

Martin Bloch, Frequency Electronics, Inc.: I think communication was the main topic in my workshop. It was basically the idea of the need to understand and to communicate between

the user and the supplier, and also to identify the non–value added functions that happen in hardware and in testing. There was a lot of discussion about telemetry needs and getting data from spacecraft on hardware that we launched. And, of course, the scientists need to get data for future improvement from knowledge and, of course, the cost associated with having all this data available; I think everybody's conclusion on that was that we need telemetry, but we have to really thoughtful in what we record because the reams of data, in many cases, really mask the actual knowledge that we need.

I think one of the other important items is the concept (this may be mine more than the participants) is that in the next decade in order to be successful, we have to be able to do things smarter; and we need a lot of cooperation between industry, government and the universities to really meet the challenge of new hardware, to make it cost–effective and the quality and reaction time. I think one of the other key points that came out is that it is imperative for the system designer to get together with a hardware supplier early in the game in order to be able to specify the magic bullet for a solution; because otherwise a lot of non–value added specification and testing comes, significantly increasing the cost of the hardware.

Ron Beard: Thank you, Martin. Well it appears as though communications is certainly a key in a lot of these things; plus, the developer really being able to determine what he needs. And I think a large part of that function is being able to determine the requirements of his system. And in time and frequency, that has been a difficult area over the years. We'll open it up again to discussion.

Shiela Faulkner, USNO: I have a question for Jack. He said something about writing specifications for the customer. I am under the impression that is a fine line there. I think recommending what the specifications be – while I don't purchase the type of equipment you do, I do work in the field; and when I have purchased other related equipment, I have been told that that's not really acceptable; you can tell me what the specifications are, but writing them would be kind of hazy. Am I correct or incorrect?

/bf Jack Kusters: Not being in the military business, I am not exactly sure, and I may have used incorrect terminology there. But certainly in providing the customer with specifications.

Ron Beard: The intent, of course, is to get the correct specifications; from the government point of view, that is not really permitted, at least not in my agency.

Dr. Winkler, USNO: Jack mentioned – and, in fact, in some conversation with Marty Bloch – the big problem came up of phasing out of the defense business to almost entirely commercial business. And I wanted to add that even those parts of the defense business which remain will be under a very high pressure to buy off–the–shelf line items, instead of custom engineering, instead of making specific specifications for specific purposes. The push is on and it will be assisted by the change which is coming in the procurement regulations. That will make it very easy to procure an off-the-shelf item, particularly if it is under $100,000, as compared to specifying something which has to be custom made. And I think this will increase the pressure on the manufacturer to come up with items which will be more generally useful, and to lower the burden of developing such items will be much greater I think.

Martin Bloch: Dr. Winkler, I think that that is a necessity for the future. And there are

risks and rewards. If John Vig were here, he would tell his favorite Dutch Navy story where they went out and bought a commercial light bulb for a dollar instead of $10; and the first time they fired all the guns, all the lights on the ship went out. So they replaced all the bulbs and then fired all the guns again. All the bulbs went out and they returned to port. So the use of off-the-shelf hardware, I think, is the thing of the future and it is very economical and necessary. And we have to fight the bureaucracy on it every step of the way. I think what is important, though, for military use is to make sure that the environmental requirements of the hardware is tested properly and it does meet. And there is no conflict of interest. You can have commercial off-the-shelf hardware that will exceed the environments, but we cannot overlook, by buying something without making sure that the end user is protected in the environment that he is going to have to live in. And I think that is a risk factor.

Ron Beard: Doesn't this get back to the point that it will give the user exactly what he needs?

Dr. Winkler: That is exactly the point. I think there has been some gap of communication between the two of us. I think in that example of these light bulbs, it would be up to the manufacturer to understand that they will need bulbs which will be able to withstand that, and have that as a line item. That is the problem.

Martin Bloch: There is education on both parts. The manufacturer must understand the user's need and his environment. And the user has to protect himself in some way to make sure that he gets what he needs.

Ron Beard: In many of the military applications, they are operating in environments and stations and things like that that are very comparable to commercial operations. And many of the off-the-shelf items that he needs is perfectly adequate.

Marc Weiss, NIST: Mr. Kusters and Mr. Bloch both have talked about getting the customer what he needs. I think that concept is a little oversimplified; because, as people develop new technology, the in-house engineers and staff work with their own creativity to come up with new technology, new ways to do things. And then customers are out there coming up with systems trying to find ways to solve problems. It is really an interactive problem. The system designer may know what he needs in terms of old capability, but if there is new technology being developed that didn't even exist before that solves problems or actually creates new capabilities, there is a whole communication and a synergy between the customer and the developer and the salesperson, if you will.

Martin Bloch: I think we all agree – I'm sure Jack and I do on a hardware basis – that communication between the end user and the equipment designer is imperative and very cost-effective. From my personal experience, if we can get in early enough in system requirements, then we can come up with a magic bullet at approximately half to 70 percent of the cost. And if you unilaterally design what you need for your system and come to us and impose on our boundaries – which to you is simple, and to us are major cost drivers, and to Jack makes it almost if not being available since he is more of a catalog-type of sales, we are more custom; so to him, you don't deliver; to us, you increase the cost.

Ron Beard: I think this is a good point. It kind of presumes that the customer knows exactly what he wants. And the fact that there are many things that may exceed or actually augment

the capability that he needs that he simply doesn't know about.

Jack Kusters: Yes, from my viewpoint, the way to make money is to have a customer who is willing to buy and has a problem; and indeed that the problem you are trying to build solves this problem. But that doesn't happen accidentally. The world isn't perfect, and indeed there tends to be – or there should be – a tremendous amount of interaction so that the manufacturer has an idea of what the customer really needs, perhaps before the customer knows he needs it. How do you lead the technology? How do you understand what is really going to be needed down the line? That is a problem that we all face.

Martin Bloch: I think an example of probably the highest cost driver item that we came across in procurement – we specialize in oscillators that work under dynamic conditions on aircraft and ships for lower 'G' sensitivity. And that is one of our products. And we find that nine out of ten customers will specify aesthetic phase noise which is basically pushing the state of the art with their concept that under vibration and shock that there is going to be a deterioration from the static phase noise to what it does under dynamic conditions. And that is enormous cost drivers. You are talking about, in many cases, doubling the cost of the product. And in reality, it is amazing in the industry how few very sophisticated engineers and scientists understand that the two behaviors are totally unrelated. And what a clock does under environmental conditions is their 'G' sensitivity; and what it does under phase noise is the cue of the resonator on how long it annoys the circuitry.

So if we could just communicate on that level we could do a better job in reaction time and really be more competitive. I feel that both user and supplier have to be on the same side. The 1990s are going to put enormous pressure that we have to be competitive and cost–effective in order to really stay in business and be able to compete with the rest of the world. So we are looking to communicate; we are not looking for an adversarial relationship. It has to be almost like a partnership.

Ron Beard: I think that is a really good point in being able to communicate to the customer. Some of the things that are available today I think what has brought ensembling more into light these days is that the users traditionally have thought of reliability and maintainability in systems by having hot spares and what not that they simply switch in when they have failures that they somehow detect. And ensembling provides a means of maintaining a continuous reliable signal to the user, which he had never really thought of before. And now it is becoming more available.

How do we effectively communicate what is being developed in these areas to the user such that he can define his requirements better? Or, have a bigger appreciation of what is available to build into his system, perhaps at a much lower cost than he would have thought through traditional thinking? That is a difficult problem. Does anyone have any thoughts on that?

Martin Bloch: It is difficult, but you have to start someplace. And I think these interactive workshops would be very effective if we could get the system designer to attend and participate. And that is about the best way that I know of communicating, if you do it on a one–to–one basis; with about 1000 users, especially during this time when there is an enormous transition from the experienced individual that is being phased out of industry to the newcomer who is coming in. And how to get the information to him is going to be a challenge, but we must.

Dr. Hellwig, AF Office of Scientific Research: I am going to help you on this issue of how you communicate. And I think this relates what Gernot said about commercial practices. I think when you develop new hardware or customize existing hardware, specs have to concentrate on the interface specs, on the black box specs, and not on how you build it or how you achieve those performances. I think that is crucial. And that does relate to procurement reform. But quite frankly, a lot can be done (from my experience) without procurement reform. And I don't see enough effort in that direction, personally. That is what I recommend as a tool to help communications.

Dr. Winkler, USNO: I think it is an extremely important item, so we should not stop here. Because, I think the customer is not always right. The customer is not right when it comes to these internal specifications or internal requirements which define the equipment as such. The customer is right, however, in the applications, in the needs of the applications, and so on. So there is a very sharp demarcation. And it is necessary that of course the communication exists between that thing. But it is also extremely dangerous if a manufacturer would go out and build just exactly what the customer wants. Usually this is very bad and very expensive.

Dr. Van Melle, Rockwell: A couple of points. One that Shiela brought up, a lot of unsolicited proposals come to, in our case, the Air Force. I don't know who started GPS, whether it was the Air Force or Rockwell – well whoever started it, they planted the seed. Like all the secondary payloads, I think Rockwell tried to get that and that helped salvage GPS contracts.

Another thing, the Air Force has a tendency to over–spec – like in the clocks, for example. We have got minus 54 degrees to survive, we have turn–on at minus 19 degrees C. The clock has never, ever seen in its whole lifetime anything below plus 5 degrees C. But you have to talk about margins – you know, how much margin do you want to put in specs? So that drives up the cost. There were a lot of vibration specs we didn't need, and we could go on and on down the line. But who comes up with these specs? Should we have told them that these payloads will never reach the requirements that you are trying to tell us to do?

Martin Bloch: Van, I think there is a misunderstanding on what is margin. Sometimes people extend the temperature range or increase the vibration levels, increase the temperature cycling; and they think that this gives margin. And that has to be very carefully analyzed. Our experience is, for the most part, that it adds cost on this without really giving the necessary margin. I can cite an example: recently someone came up with the requirements for fighter aircraft that a precision crystal oscillator has to build up in approximately 100 millisecond start–up time. If you had a five–megacycle three–million Q crystal, you immediately have to deteriorate the Q considerably in order to meet these requirements. This was like a "do or die" spec. And it is in three major programs. I took it as a personal challenge to find out what the requirements were, because I know the warm–up of the system is a couple of minutes; and I found that a guy in the power supply decided that he wants to have a status of "get well" on this within the first 100 ms; and he needed a clock reference in order to be able to drive his chip over there. That drove the spec and it literally tripled the cost of the clock and the complexity.

So these are items that you need to fight. You can't find the universal solution. I think what

is important is to communicate and express. And the supplier has been very remiss; in our enthusiasm to make the sale, we really are afraid to challenge the customer in what is difficult and what is expensive. And I think we need to do that.

Jerry Norton, Johns Hopkins Applied Physics Lab: We frequently see multiple margins built in. The systems engineer will add three dB to cover his tail, if you will. The systems people, the test people, everybody wants three dB, just in case, and frequently those three–dBs more than double the cost every time, when it is not necessary at all.

Ron Beard: Aren't they really striving for reliability, trying to get the most out of what they are getting? That is really what they are attempting to do, aren't they?

Jerry Norton: There are points of diminishing return though. I mean, the first dB may be pretty easy; the second dB is going to be much more difficult; and the third one may be impossible. And the cost may be tripled or quadrupled while you are doing that.

Martin Bloch: Our experience, Jerry, is the same. We had a major system that put a four–dB margin on phase noise and the specification was 170 dB floor because of the error in the measuring instruments. And that basically decreased the yield by 50 percent. So yes, I don't think it added reliability. Maybe it made it convenient for somebody on a data review. But the cost was just overwhelming.

Jerry Norton: Frequently, you know, as things get tough down the line, people start relaxing those things. And if they had just been honest and up–front about it, it would have saved everybody a tremendous amount of trouble and cost.

Philip Talley, Aerospace: My experience has been over quite a few years that the problem is people are forced into specifying military standards. And military standards called for these particular limits and it takes an act of Congress to get it changed. And this is a big factor in the cost; and I think it is something that needs to be worked on. But everybody wants to have standards; and if you have standards, then everybody has to comply to them. But still there appears to be a logical work–around by having the designer say, "Okay, that is the standard. But for this application, you need to do so–and–so and take exception to that standard and logically defend it." I think that is the only solution that ever came about.

Ron Beard: Aren't a lot of these standards actually tailored when you get right down to it? And it gets back to a point I think that Jack made on generic solutions, trying to generically solve it for all applications; and that is very difficult.

Marc Weiss, NIST: Mr. Kusters, you used the word "leadership." And I think that is primarily the issue; I think that is at the heart of what we are talking about; who provides leadership for developing new technology? Who provides a leadership for trimming things that have been over–specified? I think we need not to be afraid to say that they are specifying too much, that we don't think you need this much. As a supplier you can say to a user that it is a risk. You need to step out and say "I think this; I have some expertise and this is what I think." At NIST, in the other direction, we come up with services before people need them. We need to anticipate people's needs and say that this is a primary frequency standard that nobody needs and we're going to start building it today; because by the time we build it,

people are going to need it. Here is a timing service that nobody needs, and we come out with it; and then suddenly people need ten times better than what we are supplying. So there is a leadership there, also, where you come out and say here's a product that we think will be useful but that nobody needs right now. And there is a risk in that.

So leadership is a balance between leading and providing value that is not useful.

R. Michael Garvey, Frequency & Time Systems: I think one way to tie all this together, in my experience it is relatively rare to find a customer who will say that they don't need that if they think they are going to get it and they think they might need it; or if they are ignorant and don't know if they need it, they will remain silent. And a big part of the challenge, I think – and we talked a little bit earlier about communication and educating our customers and so forth – is that there is a fairly common tendency in the industry to bring on a person, let the vendor educate him, and then move him somewhere else. And then you have got a new person and a new education process. I hesitate to say this, but it is a sort of standing joke that if it takes longer than two years to teach it, then the customer may never learn it. And so I think it is particularly important for the customer to realize if there is going to be an education process, he has to dedicate the person or persons, let them be educated and let them make intelligent decisions throughout the process. Because, it is a big load on the vendors to dedicate a high–level person to teaching one customer after another within the same organization, on the same program – be it six months or two years at a shot.

Martin Bloch: Mike, are you resenting that you have nine program managers over a four–year period from a customer? I'll tell you one of the problems – it sounds so simplistic, but we experience it over and over again. And I once wrote a thesis on the generation of a system requirement for a clock. We did the right thing, we got together with the system designers when the study was done, and came up with a two–page requirement for the clock; and it was very simple. It then went to the M&P people, and they added 14 pages. It then went to the EMC people, and they added another 20 pages. And then it went to the components people, and quality control. By the time we were finished – and this was a 100–page document and the basic requirements for the clock – it was basically subservient, compared to all of the other requirements that were put on by this other organization. And I don't know a solution for it; the bureaucracy cuts in on existing organizations that make it very complicated, especially on major weapon systems and satellite clocks.

The commercial people have found a much smarter way of doing it: 'Here is a two–page spec" and everything else is implied. And to the customer it is the supplier's responsibility to make sure that all the implied specs are met.

Ron Beard: I think that is really showing that there are problems on both sides: there are problems on the generation of these things and understanding what the people want, or what they really need in putting their system together; effectively communicating, whether it is with the sales department or directly with the engineering department, such that they can really interpret and give them the product that they want after they wade through the 450,000 pages of the specifications; and citing all the different specs and tailored specifications and other things that they are attempting to add to the procurement in order to get a reliable product that is going to do the job

that they want within the scheme that they have to work on. And in the government, that is applying government standards, military standards and specs.

Ralph Partridge, Los Alamos National Laboratory: I want to take a small amount of exception to something you said, Martin, about implied specs. Our experience has been that you cannot use implied specs. What the vendor states he will supply is exactly what he will supply, and not one bit more. And if you assume that there is more there than there really is, you are going to be in deep trouble.

The other point that I wanted to make is more of a general point, and that is a plea for more QC in off–the–shelf items. We have six GPS receivers in our place – so we are small compared to some of these other people; of those six, exactly one worked properly out of the box the first time. Others would have a hardware trouble that showed up within a month (or something like that). Manufacturers are happy to fix it, of course, under warranty; but that doesn't change the fact that it didn't work. And others, you will find that the software doesn't work, and they will have to fix up the software too. One out of six is a pretty poor result.

Martin Bloch: It is definitely a real problem. And the solution, in my opinion, is quite simple. Don't buy from this supplier again and it won't happen, and he'll improve the quality. And somebody is going to come in its place. That is what the commercial users are doing. There is no tolerance for not delivering a high–quality product in the commercial environment. And the punishment is simple: you don't have lots of specs, lots of QC, and lots of area; the guy is eliminated from being a future supplier. That is a very effective weapon that the customers have in trying to force the quality and force the proper suppliers to stay in line and the marginal ones to really disappear.

Ron Beard: This has been a rather interesting discussion. I hope that you have gotten as much out of it as I have. I think communication has been an age old problem. Hopefully in this current age where we want systems to be more efficient and affordable and to do more reliable things, we are going to need to communicate more between the vendors, the developers, and to really get the systems we will need for the future.