PANEL DISCUSSION

THE FUTURE OF MILITARY RECEIVERS

Chairman: Joseph D. White, Naval Research Laboratory

JOE WHITE (NRL): Good afternoon. This session is about the future of military GPS receivers, and when we say "military GPS receivers" in this context, of course, we're talking about timing GPS receivers.

So what we're going to try to do in the next hour or two is fill you in on what the new technology is, what some of the administrative issues are, and a lot of what the panel is going to discuss here shortly will deal with that. And, just in general, give you an overview of where the program is going.

So with that, I'd like to go ahead and start this panel. It's Mihran Miranian from the Naval Observatory, Steven Hutsell from the Naval Observatory Alternate Master Clock, and Don Mitchell from TrueTime. And we kind of picked this group to give a representative sample of the user community, the high-precision users and the manufacturers. So, Mihran.

MIHRAN MIRANIAN (USNO): I'd like to kind of give you a little bit of a history of, at least, the military type receivers at the Naval Observatory. And then we can continue on.

GPS-ICD 200, or what I call the "Bible According to St. JPO," is the one that kind of dictates that the GPS time is referenced to UTC (USNO). And it should be within about 1,000 nanoseconds of UTC (USNO). Of course, you've seen yesterday that it's much better than that, it's down to within about 10 nanoseconds.

That's the Old Testament. The New Testament is ICD 202, which kind of defines how we're supposed to monitor GPS time. It's an ICD between the Naval Observatory and JPO. And anyway, in the present version of that document it says that our error budget is about 12 nanoseconds. Well again, from what you can see from yesterday, we're down around between 6 and 7 nanoseconds. So we're doing very well.

And so I think that everything is kind of falling into place and things are working much better than anyone ever expected. Of course, this means that if the Naval Observatory is responsible for monitoring GPS time, that means that the Naval Observatory is a very unique type of monitor station for GPS, as is the Naval Observatory Alternate Master Clock at Shriever Air Force Base. And we're monitoring time disseminated from each of the GPS satellites.

Now, just to go over a little bit of history, I think we got our first GPS monitor receiver back in about 1978 or '79. And it was a prototype receiver built for us by STel. And then soon after that, along came the STel-502 receiver, which everyone – it's been around for a number years – knows about. Not only was it our monitor receiver, starting about 1982, but it was also a time-transfer receiver. It was our means of transferring our clock data to the BIPM. These, of course, were all CA-code receivers; they weren't P-code receivers.

And then came 1985, and we were preparing for the launch of the Block II satellites and it was time to go to the next level. And that was the P-code dual-frequency receivers. And again, we contracted with STel to take a monitor station receiver and make it into a timing receiver. And they built two of them for us. One was supposed to be in Washington, DC, and the

other one was going to be at our backup Master Clock, which was at that time in Richmond, Florida. Those receivers were delivered around 1987, they were tested, and we were ready to start monitoring GPS time with authorized receivers.

Then a few years after that, we contracted again with STel and with AOA to build some smaller versions of a monitor station receiver. If you saw the old ones, they were about 7 feet high and 19 inches wide and nothing but equipment. Well, the small versions, of course, were rack-mountable and the STel version was called the 5401. I think a number of you are probably using the 5401 if you're a military user. And the other version, of course, was the AOA TTR-4P. Well, the TTR-4P, of course, didn't seem to pan out too well, so we now are using the 5401.

All of these receivers that I've talked about are all single-channel receivers; they only track one satellite at a time. And so we have to put a schedule in the receiver so that it can move from satellite to the other as they pass overhead. Of course, that's old-fashioned. You know, you don't even think about a single-channel receiver anymore. Today, it's a multi-channel receiver.

And the Naval Observatory's goal has always been to be ahead of the requirements, or ahead of the needs and requirements of the user. And so therefore, the time has come now to move to, as I said, the next level and that would be for a multi-channel receiver. So we have contracted with AOA to build a prototype multi-channel receiver which we call the TTR-12. Now, there are two versions of the TTR-12. There's going to be a classified version, or authorized version, and an unauthorized version. They're both dual-frequency receivers, but one can be keyed, the other cannot. I think you heard Skip Osborne talk about that receiver yesterday.

The TTR-12 we had at the Observatory had some tests done with it. We did some additional tests at AOA, and we expect delivery sometime by the end of this year. They're very close to finishing it. And I'm not going to go into a lot of details because Ed Powers will be presenting a paper on it and the test results of that receiver.

As I said, the requirements – right now, the Naval Observatory is monitoring GPS time to an accuracy of between 6 and 7 nanoseconds. Hopefully with this new receiver, as I said, we're trying to stay ahead of the needs and requirements of the user, and we should be able to bring that down to between 1 and 3 nanoseconds.

Of course, the next generation of this receiver will be a SAASM receiver. Now, I'm told by AOA, as Skip mentioned yesterday, that they can build the same receiver as a SAASM receiver. And just in case anyone doesn't know this, there is a requirement by the Joint Chiefs of Staff, an instruction that says that by January 1, 2000, all new procurements of military type GPS receivers must be SAASM receivers. That's fine, except there aren't any SAASM receivers available. So what you could do, of course, is get a waiver. And that's what we've done. But again, as I said, the next generation of the TTR-12 will be a SAASM receiver.

We've discovered that building a GPS military-type receiver for timing is not that easy, because the vendors are not going to go out and build these things for us, because there's no market for them other than maybe building a couple of a hundred or a thousand. So we found that to help the vendors, we've had to work with them. We have engineers, like Ed Powers, that really know GPS timing and how to build GPS timing. And we work with the vendors to help us to build the receivers to meet our requirements.

STEVEN HUTSELL (USNO AMC): There's been several obstacles in the development of PPS or authorized keyed timing receivers over the years. I think Francine Vannicola and Ed Powers and my other co-worker, Lara Schmidt, who is running the show this week, probably appreciate this even better than I do.

The comparison I'd like to make, if I have my facts in order in terms of what I remember, the first Precision Lightweight GPS Receiver (PLGR) purchase was for 14,000 copies back in '92 or around that time. And I remember when I was in 2SOPS, we wanted to have a half dozen copies strictly for demonstration and for giving tours, et cetera, getting people oriented with how the work they do at 2SOPS is actually used in practical application. So we ordered six, and at the time, all we had to do was send a letter from our squadron commander to the Requirements Office. Eventually, it made its way to the Program Office and they shipped a half dozen out to us. That was nice for us, because not only did it save money in the sense that we didn't have to spend six grand on another vendor's model, but it was only $1,400 a copy; and not only that, 2SOPS didn't have to pay for it.

Well, we haven't really seen a similar parallel for that in the purchase of timing equipment from the Program Office. And like I mentioned yesterday, it's all about communication and getting the word to both sides; getting the word to the JPO about who all is out there, and that's what we try to do by showing the presentation that we showed yesterday as well as about a month ago, and with our meeting yesterday; but also, getting the users educated in the fact that it really makes sense that there be a central office to go through to obtain equipment. But it's one of those cycles where with the PLGR, not only did they purchase 14,000 copies, but also they went on to later purchases. And I think the Program Office has been involved with the acquisition of hundreds of thousands of PLGRs. They're also going to be acquiring 250,000 copies of the follow-on, which is called the Defense Advanced GPS Receiver (DAGR). And because that's going, more and more users are getting used to the fact that the JPO is heavily involved in it, and that there's a process in that users can obtain something that's been proven and used universally.

We really haven't had that kick-start for timing receivers. And, of course, one contributing reason is the quantity. Like you said, there are not nearly as many DoD users, at least that we're aware of, that require a huge quantity of timing receivers. And so that kick-start is going to require an effort of just a lot of pressure and a lot of communication. I think it's definitely legitimate. I talked with Don yesterday, and we're finding out that there are users that show up and would like so many hundred keyed copies; and ones that I've never heard of before; and it's not common knowledge just who all is out there.

For the Observatory, probably the biggest issue with us is we need a different type of receiver. We need receivers that output individual satellite data. And quite frankly, there are not a whole lot of labs that need that. And so it's really not cost-effective to make a low-cost version of that if we're just going to buy a half a dozen; and if NIST would like to buy some copies and if other labs would like to buy copies of keyed timing receivers, we're still talking quantities in the tens, if that. And so there's not a lot of motivation for competition within the manufacturing arena to build those. With users out in the field using unkeyed equipment, that's one problem, but we even have probably a more frustrating challenge at the Observatory, because we want something even more unique than that.

DON MITCHELL (TrueTime): Well, from the manufacturer's side, we have to anticipate what the customer wants, and we have to give the customer what he needs to do his job. And if we look back at the history we've got of timing and the aspect of the manufacturer supplying a P(Y)-code receiver to cover the needs of the community, it's almost an impossible task. In the first place, there has been no real valid DoD procurement of timing receivers that are keyed P(Y)-code receivers.

TrueTime on its own developed a P(Y)-code receiver in conjunction with Trimble Navigation using their Force-4 module. Now we did that with our own money – so to speak, if we build it, they will come. Well, we built it, but they haven't come in large enough volume that we

can get the cost down.

Odetics is now into the field of building a commercial P(Y)-code receiver which will be SAASM-qualified and, of course, so will the TrueTime when SAASM becomes available. The problem is that we are developing these with our own money; in doing so, we have to amortize that over some period of time. And with the volume that we're expecting, the receivers are still fairly high cost.

Another aspect in the timing community is that if you build – I call them a "widget" – that you can build in large volume commercially; the community that we're looking at here is so oriented to using different methods in their timing activities and different signals, that you have to build a receiver that is very flexible in its capability or modularity so that you can meet the customer's changing requirement. Now because it is an improved JPO receiver, every time we make much of a change, we have to go back to JPO and get essentially their blessing on how we've made the change. I noticed, in the Odetics receiver, they used a very modular approach, the same way that TrueTime does, so that they won't have to reinvent the wheel for the customer's changing requirements.

At this time, I'm not aware of any other timing P(Y)-code receivers that are in development, and if they are, they're probably be developed within the private sector and not under a government contract. Am I advocating that there be a government contract for doing a P(Y)-code timing receiver? Well, we have a bad habit of sometimes going out and trying to specify what the timing community wants and what we need; and we don't do an adequate enough job; and then it comes out for procurement; and, in some cases, as in one recent development I know of, it went to a small business set-aside; and so that means that maybe you're not going to get a really qualified vendor who can build a receiver. So there are dangers in how you go about this procurement. And you can always say that, well, I'm going to write in enough safeguards to protect ourselves from the mistakes that are possible to make out there, but you can't do that. What you're going to do is specify close enough to what your requirement is and then you're going to have to stick to your guns on it and make sure that what you get is a vendor delivers what it is that you need to do your job; and not pay the vendor for not doing his job.

In this community, we have – and I've given an invited paper at PTTI about this before – we have a real problem with writing a specification that we can deliver to a manufacturer that a manufacturer can both meet and get there at the price that you need. Because you have a tendency to overspecify your need or put specs in there that are sometimes impossible for the manufacturer to meet. But you still get people that sign up for them. So I think what you need is to consider the specifications that you're writing; really go through a cycle on that and do something in the procurement cycle to make sure that who you select as a vendor is going to deliver your product that meets your requirements and stays modular enough so that you can change. Because we all know that our requirements are changing daily; and if we don't build that modularity into what we're doing, we're not going to be able to address your requirements.

MIRANIAN: As Steven said, most users don't need to be able to look at each individual satellite. All they want is a GPS receiver; like a clock on a wall, it just puts out time, and they have the time. It's essentially like having an atomic clock in your laboratory.

What we need to do, of course, at the Observatory is to define what the needs and requirements are. We have a Requirements Officer at the Observatory who's out there beating the bushes trying to find out who needs the timing and at what level. And so, again, as I said, if he comes up with somebody who needs timing, 1 nanosecond or 10 nano – whatever, we have to be prepared to deliver that. And that's why it's important that we continue improving our

capability of monitoring GPS time.

I know that Steven also said that GPS is not the driver. Well, it may not be the driver, but there are other users out there that are the drivers. And so we have to keep up with that.

I think we can open it up to the floor.

HUTSELL: Any users who want to vent their frustrations about trying to require receivers, et cetera, we'd like to hear about that too. Because we like to take this kind of information back to the Program Office to help them understand what needs work in the future in terms of satisfying the goals of the customer.

Questions and Answers

HUGO FRUEHAUF (Odetics): Why is GPS JPO so paranoid about discussing SAASM, since the entire security architecture was intended to make it less vulnerable to compromise, easier to field because of new keying structure being black keys? That would seem for a manufacturer to be an incentive to assist in the fielding of P(Y), direct-Y, and SAASM receivers. But yet, JPO's reluctance even to show up today and present the overall paper is confusing to me.

DON MITCHELL (TrueTime): Well, I think it goes back to exactly what I termed there in the first place. We go out with the procurement, and we don't adequately specify. JPO actually had gone out with procurement for a timing receiver and it really wasn't adequate. In the first place, they specified it and I believe, if I'm correct, it was a single-channel receiver that only did CA-code and did not do P(Y)-code dual frequency that we need for P(Y)-code.

As Hugo says, we've had a lot of reluctance with JPO to share information with us. When I make changes to my Mark V P(Y)-code receiver, I have to go back to JPO and get approval to make any changes with that. Fortunately, I had enough sense to recognize this in the first place, so I did it so that I had plug-in modules on the back that do not interfere with the JPO-approved portion. So we can add things and take things away from the box without having to go get JPO approval. And I assume that Hugo built his back on the same premise that he could add and delete modules without having to go back for JPO approval. What I think the community really needs is some solid, good information from the Joint Program Office that tells us what the direction is that we need to go.

As a manufacturer, I went out strictly on my own to build the Mark V, and we put a lot of money into that. And we did that with the anticipation of being able to have a large volume of receivers available and sold. And that hasn't occurred. When we're talking volume, to get on the manufacturer's side, you're talking into the hundreds rather than in tens. Because if you want to get the cost down to anything, you have to get into the hundreds of receivers rather than into the tens of receivers.

There again, if you go out with an open procurement, we haven't seen anything toward the timing side that's been even anticipated. Joe, do you know of anything?

JOE WHITE (NRL): I see bits and pieces, Don. But, no, I think you're right, there's nothing really organized. Eddie and I have been involved with some of the user equipment folks talking about new timing receivers. But it's been more oriented towards the high precision users like the Naval Observatory.

It's disconcerting because if you talk to the JPO, they will tell you that timing is one of the bigger and more important features of GPS. In fact, some will even say that it's more important than the navigation feature. And yet, the emphasis on timing and the building of the new receivers doesn't seem to be there strongly yet. It would be nice to see that solved.

MARC WEISS (NIST): Just to make the GPS system work, the monitor stations need timing receivers. There have to be some there or the system isn't working. What's the status of upgrading those? What are they using now and what are they heading toward? Does anybody know that?

STEVEN HUTSELL (USNO AMC): Only if Steve doesn't mind my picking on him, I definitely feel Lt. Steve Osborne of 2SOPS might be in a better position to give an update on that. I

mean, we can talk about sort of the derivative of that receiver, but I'm not as current as Steve is on how it's being used for MSRE. Do you want to volunteer, Steve?

LT. STEVEN OSBORNE (USAF 2SOPS): You're talking about the MSRE receivers?

HUTSELL: Yes.

OSBORNE: Well, right now we're undergoing operational assessment and evaluation of the Cape monitor station. We have five operational monitor stations right now. We're thinking about including a sixth into the network. So right now we're just kind of testing out the MSRE and seeing how it works, if it's going to work at all for us. That's currently underway right now.

HUTSELL: Thanks, Steve. And also – I'm sure you would agree, Mihran – we're kind of waiting for the progress of that to sort of see how that pans out before we really become totally consumed with the model that we want to be testing and so forth. Because we want the lessons learned of that development. We would prefer to wait for that to go into the development of the new receiver for our application. But, like you said, Marc – I mean, you're exactly correct. That does definitely help. It's one effort that will contribute to another effort.

Of course, we're still talking still in the tens of receivers. As Steve mentioned, five or six monitor stations with redundancy at each site and the number of receivers we have – we're still talking in the tens.

MIRANIAN: Is Ed Powers here? Ed, do you want to comment about the new specifications for receivers? The meeting you went to? Or can you comment?

ED POWERS (USNO): For the 2-F program? Or the straight MSRE?

MIRANIAN: Yes.

POWERS: Yes, there's a third-generation monitor station receiver undergoing development spec. They're just trying to get their initial requirements put together on that. And that will come around probably in the next 4 or 5 years.

MIRANIAN: But isn't that going to be timing also?

POWERS: That is one of the key performance items that they're going to try to put into specifications that it be time-synchronizable as well as just a regular monitor station receiver. So it will cover several of the high-end users, like NIMA, the Control Segment, and USNO.

HENRY FLIEGEL (Aerospace): To add to what Ed just said, the Boeing Corporation is leading a working group to specify the new MSRE for M-code, and they do have an aggressive schedule. My understanding is that they want to put out the RFP for the system by April. And to do that, they want to put out a request for information, an RFI, to the manufacturing community generally. And I believe they're trying to hold to a schedule of delivery in January.

Ed, I, Mike Full from NIMA, a bunch of others are working over the RFI. It's not looking quite as sick as it was when we did our first draft, but it will go out to manufacturers. And then we are pushing for a manufacturer's conference, a bidder's conference, to raise questions, define issues, so we don't run into some of the problems that Steve and others have identified in the past.

WHITE: This is quite a frustrating process for the user community and for the developers. In part, I think it's because of the complexity of the whole GPS modernization program. It's a very ambitious undertaking; there are a lot of things that don't work easily. And it's just

moving slower, I think, than most people expected.

Again, thank you to the panel.