The following questions were presented to the audience, both orally and through viewgraphs to encourage their participation in the discussion of applications and requirements.

QUESTION #1: "WHAT ADDITIONAL METHODS CAN BE USED TO DETERMINE PRESENT AND FUTURE PTTI REQUIREMENTS"?

DR. STOVER:

Mr. Bowser has already given us a good start at how this is done, or how he approached it. He has also discussed the difficulties he had in doing it.

Can some of you give us some suggestions as to any other methods that could be used, that might enable us to better determine present and future PTTI requirements?

MR. CLINT FRIEND, Defense Communications Engineering Center

I am in satellite systems engineering requirements. I think that Bob Bowser indicated that there was a lack of organization as far as PTTI and the various components are concerned. If we put out a directive, or pherhaps a revision of the present directive, directing everybody to establish a representative at all levels of command, then we would have an organizational path through the chain of command whereby we could collect the requirements which are now known, as he put it, at a technical level -- you know people in other organizations that are doing the same kind of work that you are doing, and they could all be drawn together through a directed organization for PTTI.

QUESTION #2: "ARE THERE OTHER POTENTIAL APPLICATIONS OF PTTI, IN ADDITION TO NAVIGATION, COMMUNICATION OR RESEARCH?"

DR. STOVER:

Most of the people I talked to felt that most of the various applications would fall under one of these three headings, but if we have missed any, we would like to pick them up.

Are there any suggestions as to other potential applications of PTTI -- other than these three, navigation, communication and research?

MR. MACHERSKI, National Research Council

Geo-physics of timing, for example, if you set off an explosion and you tried to get seismic waves propagating in various spaces, you would like to get the timing fairly accurately. That is another very possible application.

MR. Bill BRIDGE, Mitre Corporation

In the tactical situation you certainly could use time differences of arrival systems for locating emitters.

DR. STOVER:

Well, Mr. Bridge, just mentioned position location. I made a note to myself that another possibility might be system monitoring. For various types of systems, knowing precise time might be useful in system monitoring and control.

Actually, in some cases it might be useful for prediction of events that might occur later, if you know the precise time when each of a sequence of similar or related events that occurred previously. Collision avoidance for aircraft is a possibility. In some cases diagnostics of electronic or mechanical failures in large systems could be aided by PTTI.

QUESTION #3: "WHY DO SOME POEPLE WHO SHOULD BE USING PTTI AVOID ITS USE, SOMETIMES GREATLY REDUCING SYSTEM FUNCTIONAL CAPABILITY, SYSTEM FLEXIBILITY, SYSTEM ENDURANCE, RELIABILITY AND SURVIVABILITY?"

QUESTION FROM UNIDENTIFIED PARTICIPANT:

Do they avoid or do they just neglect to?

DR. STOVER:

Would you like to answer your question?

REPLY:

No, you assume that people are actually avoiding.

DR. STOVER:

You are right, I made that assumption when I asked the question. Now, what is your answer?

REPLY:

I suspect it is just lack of knowledge very often, rather than avoiding such use.

DR. STOVER:

I think that that may be true. Some of my own opinion is that in many cases it is due to their being somewhat afraid of the unfamiliar. Again, that is a lack of knowledge, but it is more than just a lack of knowledge. It is a psychological thing. They are afraid of the unfamiliar.

MR. PETE OULD, Interstate Electronics in Anaheim

I am not a user, I am a builder of equipment, but it would strike me that one of the reasons would be the cost of your clocks or your receiving equipment, whether it be LORAN or Transit, or GPS. The basic cost of the thing -- men might sit out there and say, yes, I could use it, but the budget is limited and we can't afford it.

DR. STOVER:

Don't you think there are some possibilities, some situations, where he actually is picking a more expensive alternative because he has-not looked at all of the things that the PTTI could do for him?

MR. OULD:

That is possible, but not being a user, I don't know.

DR. VICTOR REINHARDT, NASA/Goddard Space Flight Center

In many cases it is a lack of appreciation or understanding of the time dependent nature of errors. Many people outside the frequencies end of business only understand white noise, stationary noise and drifts, and the middle ground is not appreciated. Therefore, the specifications are not realistic, or they don't understand the problem. They avoid its use, again, out of lack of knowledge, not out of willful acts.

For example, in the tracking business, this is one of the problems, in orbit determination all models are based on stationary statistics and there is lack of understanding of the effect of correlated noise on those models.

DR. STOVER:

So far we have lack of knowledge being very important, either knowledge of what it can do for you, or knowledge of the cost.

LT. ROB CONWAY, Space Division

I think that all of these comments are hitting little specific portions of real general problems, that are becoming increasingly widespread, and that is the fact that all of the people that understand PTTI, or specific examples of the frequency standard applications, are engineers and scientists who have spent many years in development of the fringes of scientific progress. Unfortunately, those people who are spending all these years in development are not the people that are making the decisions on its use and its application in space technology, communications, development, navigation and all this kind of thing.

The people who are making the management decisions are just like you have said before, and several other gentlemen have said before. They are afraid of the use, do not know of the use, are ignorant of the capabilities, are using more expensive methods of solving their problems. -- They are not really educated in the possible ramifications of using PTTI to further their own missions.

I think that you have a problem in management because the managers do not know what the engineers and scientists know. And the engineers and scientists are not in the position to apply their knowledge in a managerial sense.

MR. DAVE PHILLIPS, Naval Research Laboratory

Many people who really know about precision time are afraid to use it in their system, as long as they are not really part of the PTTI community. They feel that their system may be somewhat compromised. They want their system to work alone under all circumstances.

If they can be made to be part of the PTTI community, where their timekeeping capability is actually used in maintaining time, then they will be less likely to not use it.

Many times they want just a stand alone system that works under all conditions, and they are afraid that if they have to use PTTI, this will compromise their system at some point.

DR. STOVER:

Do you also think that in some cases it may just be that they don't want to take the time to put it into their system? They think it will take too long? Or other cases that they may think that their application would be very special, rather than something off the shelf and they may even be mistaken -- are those possibilities, also?

DR. ART MCCOUBREY, National Brueau of Standards

I think Mr. Bowser put his finger on much of the problem in his talk, when he pointed out that there is a lack of really effective advanced planning for the use of PTTI. As a result, I think you find many times that the problems of incorporating PTTI into systems come up late in the development cycle for those systems. Therefore they tend to influence completion dates and things of that sort.

As a consequence, I think people may believe that there are more problems in incorporating PTTI into systems than there actually are, simply because there is not sufficient advanced planning to get the ground established for putting the systems in.

QUESTION #4: "HOW SHOULD PEOPLE WHO SHOULD BE USING PTTI, BUT DON'T KNOW IT, BE PROVIDED WITH INFORMATION NEEDED TO COMPARE ITS ADVANTAGES AND DISADVANTAGES FOR THEIR APPLICATIONS?"

DR. STOVER:

How are these people going to find out that they should be using it? The people who have this ignorance of PTTI capabilities that several of you have mentioned.

Do meetings like this help?

DR. VICTOR REINHARDT, NASA/GSFC

Unfortunately, not that much --

One of the problems is that there is very little communication between the precise time and time interval community and the others -- the users. We should be going out and giving papers at the navigation meetings and the tracking meetings and the other meetings, if we are interested in spreading the use of PTTI, not only in this meeting.

DR. STOVER:

How are we going to promote that?

DR. REINHARDT:

It is up to individuals or groups encouraging that sort of thing, from the individual PTTI laboratories.

MR. DAVID ALLAN, National Bureau of Standards

Periodically, the Bureau of Standards holds seminars, training sessions and so forth which we find are very well attended and very productive in terms of helping people appreciate the advantages, disadvantages of clocks and PTTI matters.

Last year, for example, there was a special session, an evening session at the Frequency Control Synposium, and there will be one again this year. I think the attendance at that and, hopefully, again, this year will help communicate and educate people in this field.

DR. STEVE CRESWELL, FEC, Vandenburg

Twice a year there is a meeting called JRIAIG, which is Joint Range Instrumentation Accuracy Improvement Group, and the inter-range

elements get together and discuss trajectory, reconstruction and timing is a very important part of that. So PTTI just evolves and gets into these types of meetings and it gets discussed rather extensively.

DR. STOVER:

If you will recall from Mr. Bowser's paper, one of the items he mentioned was a lack of PTTI standards. If we had such standards would that help this problem? Help to remove the ignorance?

DR. FRED WALLS, NBS, Boulder

We have a number of reprints describing general characteristics of clocks, their uses, size, weight and volume, projections on these. So, if some of you would like those reprints, maybe we can put up a sign-up list and if you are not on our mailing list, we will send you some of these copies.

We also have some reprints describing the short session that was put on at the last Symposium on Frequency Control (SFC) and that will help, at least for people who are represented here.

DR. STOVER:

Going back, just briefly to Dr. Reinhardt's statements, he mentioned giving papers at other meetings and conferences. How about getting some publications in some of the other journals that aren't specifically related to timing? Is there some way that we can promote that?

MR. ANDY CHI, NASA/GSFC

It sounds to me that we need a clearinghouse, perhaps the U.S. Naval Observatory could act as such a center, through which we could identify not only the reprints of past publications, but also, perhaps, organizing groups of speakers from among this group, so that they can be suggested at different meetings, to present the up-to-date information regarding the PTTI.

MR. BILL BRIDGE, Mitre Corporation

I think there are a great many untapped users of PTTI in the tactical weapons community and I think one of the things that we could do to improve their knowledge of it is to really work on the aspects of tactical environmental problems with PTTI instrumentation.

In other words, show them that they can get the kind of precision time that they need, in a tactical environment, not a laboratory curiosity.

DR. STOVER:

How do we get this information to them?

MR. BRIDGE:

If you just tell them that they have it, in a tactical environment, I think they will come to you.

MR. H. STROCKER, Navy Metrology Engineering Center, Pomona, California

I think the problem of design engineers who are people who conceptualize systems, not using PTTI, is very similar to the same situation that happens in the automated test equipment world, ATE world, as far as the use of built-in test standards, BITE and BIT, built-in test circuits and also built-in test equipment.

One of the things that this community is doing to encourage and promote the use of built-in tests, is to develop testability guides, guides for testability, where a design engineer, or a systems engineer could see what is available in the way of the technology in order to implement this, and what he would have to do to accomplish it.

I think what is needed, in the PTTI area of course, is more dissemination of knowledge, information. But how do you do that? Through meetings and conferences, that is fine.

I think there could also be some DoD documents with NAV Air, Army or Air Force numbers, TO numbers on it, whatever, which could be disseminated to the systems contractors to make them aware of what is available and how you can get traceability for your systems, and what you have to use.

DR. TOM ENGLISH, Efratom

There is an abundance of literature on the subject of time and frequency, but unfortunately it is scattered over a very large area. Anybody going into that field has to put in a great deal of leg work in order to sift through it, even to decide what he needs.

I would like to suggest that if there were a book available giving the fundamentals and still comprehensive and also, bibliography, that that might be a help to potential users.

Let me give an example, in the field of vacuum technique, Dushman's book would probably be one of the first that you would go to a very comprehensive book and very helpful to the user. It is all in one place. Maybe something like that would be helpful for time and frequency. Of course, you need somebody to write it though.

PROFESSOR C. ALLEY, University of Maryland

There is a very nice book by Kartaschoff, published several years ago, a bit outdated, but it has all the fundamentals in it. I don't remember who published it or what the exact title is.

INFORMATION FROM UNIDENTIFIED PARTICIPANT:

Academic Press, Frequency and Time, 1978, New York and San Francisco.

MR. FRANK KOIDE, Rockwell International

I am both a user and a developer of frequency standards. I find that we have many programs within Rockwell -- we have Navy contracts, Air Force contracts and things like that. The requirements are there, but nobody really knows the requirements of the PTTI until they get to the right type of source, and it takes an abundance of effort to get to the right people.

I think some of the literature is available -- there is one that I know of that is very useful, the one that NBS put out, the Monograph 140. And I think that is very helpful in the PTTI world.

DR. FRED WALLS, National Bureau of Standards

It seems to me one of the greatest inhibitors is lead time, by the time the system has decided exactly what their needs are, they are so close to the delivery time, they are unable to backtrack and develop a specific frequency standard or PTTI hardware in order to accomplish what they need.

One of the things we need to do in planning is to develop building blocks, so that they are well characterized. Rather than systems insisting on odd frequency, 4, 3, 9 and 10, 23 and such, you develop very stable frequency sources and then put some effort in low noise synthesis, so that you can go from a standard frequency with known characteristics, that are well characterized and the reliability is well taken care of; then you put in a synthesizer to produce that odd frequency that you need to make your system run.

In that way you can have these building blocks on the shelf and when you finally decide you really need 10^{-11}, you know where to go; if you need 10^{-13}, that is another set of building blocks.

But, basically, most of the effort when using the building block is already done -- you just need that interface to your specific requirement. I think that will greatly speed up the utilization of PTTI in new systems. And that is what we need to concentrate on in the planning.

MR. KELLOG, Lockheed

The Bureau of Standards Monograph 140 was mentioned. I don't know whether it is apparent, or not, to the Bureau of Standards, but the Government Printing Office thinks that that is unavailable under any circumstances and it is regarded more or less as a classic document. Why don't you contact the Bureau of Standards?

If there is a document of use and it is not readily available, this could account for some of the lack of appreciation of what it could do for you.

QUESTION #5: "WHAT ITEMS SHOULD BE ON A CHECKLIST TO HELP A SYSTEM DESIGNER DETERMINE WHETHER HE SHOULD BE USING PTTI?"

MR. AL BARTHOLOMEW, NRL

I shudder to make this observation, but it seems like when you get ready to do some systems, at least in the NAVY and in DoD, you have to file certain documents for frequency usage, whether you buy a receiver, build one or develop it. Maybe that is the kind of thing that has to be introduced to people that start out in a system that requires PTTI.

DR. STOVER:

File a document? Is that what you are saying?

MR. BARTHOLOMEW:

Right.

MR. ANDY CHI, Goddard Space Flight Center

When you specify, I think one should be very careful to distinguish the need, whether it is precise time, or it is time interval. Although they are combined in this meeting, they don't always mean the same thing.

DR. STOVER:

In other words, is it frequency, or is it phase or time?

How about knowing what the stability requirements are for phase or frequency, is that important?

DR. JOHN VIG, Frequency Control Branch at Fort Monmouth, U.S. Army

Yes, I think knowing it is certainly important.

I think it is also important to have a standard way of specifying frequency stability and some of the other parameters of frequency standards.

If you look at manufacturers' literature today, unfortunately, it is very difficult to determine how two frequency standards compare because different manufacturers use different numbers to specify frequency stability. And I think it would be helpful to have a standard way of specifying the performance of a frequency standard.

DR. STOVER:

Are you saying there should be a DoD standard, or an NBS standard?

DR. VIG:

I think that would be very helpful, yes.

DR. FRED WALLS, NBS, Boulder

To build on what John Vig has said, you should also specify the environment in which you are going to use it, because many systems which work by specs on the lab bench don't work in the field because you haven't specified or even thought about the vibration sensitivity, the temperature transients, or that you are in the humidity, and other kinds of things.

Part of the checklist should definitely be the environment in which this system is going to work.

The particular device that you use for PTTI depends on the environment. Some systems are much less susceptible to a particular environmental situation than others. And so that is one of the things you must consider.

MR. BOB BOWSER, VITRO Laboratories

When you talk about specifications for a system, I was thinking about that very question before I came down. I was looking through last year's symposium notes and I found one on the systems specifications for a communications system -- it was SEEKTALK, I believe. And there are seven sheets of specifications. So, that when we are talking about specifications, it is not just a frequency stability, or a time plus or minus two microseconds to time of day. But there are seven full sheets of performance characteristics to which this engineer is trying to design a system.

The output, input power, transient protection, warmup characteristics, long-term drift, short-term stability, trim, voltage variation, magnetic field, signal-to-noise, temperature, and you go on and on. And there are seven sheets of those.

So, the design engineer needs a lot of information, as Dr. Vig pointed out, when he is talking about an operational system, where it is going to be subjected to a wide variety of conditions. Specifications in seven sheets for one system, are pretty detailed for some of them. There are Mil standards for a lot of those, temperature characteristics, and operating range, susceptibility to magnetic fields and all of that, but I think that a design engineer

has to have a start point and get the framework within which he has to design his system.

Then he has got to make all the trade-offs, he may not be able to have a system that will give him the duration or the long-term stability for his mission duration and he may even have to shorten the scenario of how the mission is going to be accomplished, or he may have to make a trade-off in power requirements, versus weight. You know, redundancy in the system, whether he is going to have two batteries, or three.

He has got to take into account all of the specifications in an operational environment.

DR. JOHN VIG, U. S. Army

To amplify a little bit on the point Fred Walls made about the environment, I would like to give a couple of examples, horror stories.

For example, one manufacturer specifies the acceleration sensitivity of a standard as parts of 10^{12} per G and you could take that standard and turn it upside down and sure enough, it might change parts in 10^{12} per G, but if you put it in a helicopter, or tank and it is vibrating, you will find that instead of parts in 10^{12} per G, it is more like parts in 10^{9} per G.

Similarly for phase noise, the specs on phase noise might read 130 dB down at X number of hertz from the carrier. That is nice. If you put it on a vibration-free environment, you probably will see that it meets the specs. If you put that same oscillator into a helicopter, you will find that you have degradations in a phase noise of up to 60 dB or even more sometimes.

So, it is extremely important to specify the environment, and I couldn't agree more with what Fred Walls just stated before.

DR. STOVER:

You know this, but how do you tell that design engineer?

DR. VIG:

That is why I said before that it is very important to specify, because we have had some people for example, who were designing a Doppler radar system that was intended to work in a helicopter.

When they went out initially, they looked at the manufacturers' specs, and they found that they could meet the phase noise requirement with off the shelf oscillators. They bought some oscillators, they mounted them on the bench, and lo and behold, it met the phase noise requirements.

They went ahead with the system and eventually they put it together and put it in the helicopter and the system would not work, because that low-noise oscillator when in a helicopter became an oscillator such that you couldn't see anything on the battlefield, because of the vibration and noise.

Therefore, it is extremely important to have the manufacturers specify the stability in some standard way, both at rest and under various environmental conditions, so that when a system designer is looking for a standard of a certain characteristic, he can look at that spec sheet and tell right away whether or not that device will meet his needs, rather than having to wait until much later and find out the hard way that some of the specs were omitted, unfortunately, from the spec sheet.

MR. BALTER, TRACOR, Incorporated

In addition, to the clock or the oscillator, there is also the problem of how the clock is set, or how the oscillator is synchronized or calibrated. This should also be part of the specifications. It does no good to specify an extremely accurate oscillator, or a clock, unless there is also a means of specifying how it will be periodically calibrated and/or synchronized.

DR. STOVER:

Most of the discussion has been on the basis that the fellow knows that he will have a precise time requirement with a known specification; But what about some of the things he looks at to determine whether he needs that, whether he really should be using precise time, or whether it is important to him, or not?

How does he look at the question of whether or not precise time or frequency will add some potential for future improvements in his system, or how does he look at the advantages versus disadvantages of even getting into a precise time requirement, versus other options that are available to him?

In many cases there are other ways of accomplishing what he wants to do, without getting into a precise time situation.

How does he approach that?

DR. VICTOR REINHARDT, NASA/GSFC

At NASA, what I have found is that the only system that really works is for the users inter-act actively with the builders and the experts of PTTI, because nobody wants to design a system that goes beyond the state-of-the-art in anything. Everybody develops their requirements for practical systems, based on what is available.

Then the people like us go around and try to look for requirements, and we contact them.

Unless there is an informal channel back and forth, you get into all kinds of crazy things because, in fact, what is going on is a loop and we can't say that they are going to give us requirements, because the requirements are going to be based, at anytime, on what they think we can do.

Again, the problem is communication. If they don't know what we can do, they will never give us the proper requirements. I think what should be on a checklist for the designer is to contact the people in the field and find out what is available.

I think that when there are problems, they are contacting the wrong people.

QUESTION FROM AN UNIDENTIFIED PARTICIPANT:

We just wonder in the precise time theory if a lot of the requirements are for long-term stability. We make things that transfer information from WWV and have millisecond accuracy that you can start up cold, such as in an airplane sitting out on a runway, and have it work and you are still within a millisecond or two of the actual time. And these are relatively cheap systems and not, you might say in the so-called precise time community, but we wonder if there are not a lot of requirements in the military of this nature, so that you know that you are actually on time, within a few milliseconds, as opposed to buying very expensive oscillators for long-term stability?

QUESTION #6: "IS THERE A NEED FOR MORE EXTENSIVE COORDINATION OF PTTI APPLICATIONS AND IS THE NAVAL OBSERVATORY THE BEST CHOICE FOR SUCH COORDINATION?"

DR. STOVER:

I think that certainly Mr. Bowser's paper made it clear that there is a need for more coordination. Don't we have some comments on this question?

The previous question we had a great deal of discussion about standards and the need for having some standards and for our specifications.

Should the Observatory be providing guidance on how the specifications should be written for military applications?

No comments?

(No response.)

QUESTION #7: "WHAT CRITERIA SHOULD THE DESIGNER OF A DoD SYSTEM USE TO DETERMINE WHETHER HIS SYSTEM REQUIRES NOTIFICATION AND CONSULTATION WITH THE NAVAL OBSERVATORY RELATIVE TO PTTI REQUIREMENTS, UNDER DoD DIRECTIVE 5160.51?"

DR. STOVER:

Now, this is the question that prompted the committee to have the DoD directive handed to you as you registered. So, all of you should have some idea of what is in the DoD directive. It does say that DoD users should consult with the Naval Observatory relative to PTTI requirements. It also defines what it means by PTTI. Is that adequate criteria, the definition of precise time and the definition of precise frequency?

QUESTION FROM AN UNIDENTIFIED PARTICIPANT:

It is not a very long directive, could you read it, because not all of us got a copy?

DR. STOVER:

I can read a couple of points here, like the definition of precise time and precise frequency. If I can find them.

It defines precise time as a time requirement within 10 milliseconds; it defines precise frequency as a frequency requirement within one part in 10^9 of an established time scale. Over under section c, as to what different people do, it says, "All DoD components which require, utilize or distribute time and time interval information -- note those words "utilize" and "distribute" -- "or have a need for a specific time scale, shall: (1) refer time and time interval to the standards established by the Observatory; (2) maintain specific time scales such that the relationship to the standard established by the Observatory is known; (3) prescribe technical requirements for the coordination of techniques, procedures and periodic calibrations of systems, (4) promote economy by prescribing requirements for precise time that are consistent with operational and research needs for accuracy".

Now, that can be interpreted, and I do interpret it to say that anything that falls within a requirement for -- a timing requirement of 10 milliseconds, or a frequency requirement of one part in 10^9 should be referred to the Naval Observatory. But if for every 10^9 oscillator you put into any radio or piece of equipment

which you build, you go to the Naval Observatory and ask them if it is all right to use it, they are going to be overwhelmed, isn't that right?

Can you handle that, Dr. Winkler?

DR. WINKLER, Naval Observatory

If it goes along like it has for the last 20 years, yes.

I don't think the intent of DoD instruction is to do what you just said. The idea is to bring out, as early as possible, requirements for the provision of standards.

A new system, for instance, which plans to use precise time in a remote corner, which will need the precision of one microsecond, we should know about that, as early as possible. Because it will influence project decisions and it will influence strategic decisions between systems for timing and so on.

It may also, if brought to the attention of similar systems, in other services, establish a cooperation to the extent that they can both supplement each other.

So, the essence of the DoD instruction, in my view, is that timing is a two-way affair, when each user enters that so-called timing community or PTTI community, he can benefit and he can also provide benefits to others from being in a coordinated system.

Now, how does he accomplish that? To what degree should management exercise control? That is what we have, in one way or another, been talking about all morning. To what degree is it necessary to plan such a huge thing as the use of precise time and time intervals for DoD?

That is the big question. You can understand the possible range if you go from one extreme to the other. One extreme is complete chaos, where everybody does what he pleases and we don't have that.

The other extreme would be strict funding authority and line item funding from DoD through the services. It requires a huge management effort. And I think the size of the PTTI effort simply would not support such an approach.

Let's not forget about it, but the use of clocks and frequency standards is a very small item -- it is important, but it is a small item when it comes to the size of modern systems.

Today it is so small that, in fact, its smallness may be the major problem which we have; it is too small to catch the attention of high enough management levels to do something about certain things which have to be done.

As I mentioned before, there is a joke which goes around which says "if you want to have the attention of any real high management official, the cost must be at least $50 million".

Well, we just don't reach that threshold. And the question is what should we do? To which of these two extremes should an improved management tilt, to a very strict one, or to a complete chaos?

And it appears to me that one has to sort out two things, and keep them as separate as possible in our minds. Number one, the technical details, coordination at the technical level where there is no help unless we have educated engineers and managers. And as we provide better information, we provide handbooks and possibly standards, this will be helpful.

But, make no mistake, the main reason why people do not get information, is not that it is not available, but in fact there is too much paper. In fact, Dr. English, before when he said such a book would be needed, did not know of the existence of quite a number of these books. And I don't blame him, because today every system designer who talks about a system concept has to absorb an absolutely incredible amount of information, of technical details.

And, again, the question of oscillators, timing and so on, is a small item. Unfortunately, however, as small as it is, it requires coordination because otherwise we would have chaos if everybody provides for his own timing, globally with systems of his own making, it would be increasingly expensive.

So, what I think we have to do, and have to accomplish, is to prevent unnecessary duplication. And, again, the best way to do that is to keep our lines of communications free, refrain from unnecessary things which also means unnecessary paperwork. Every sheet of paper today that you cause to be printed is a load, an increasing burden on everybody who is in the system.

I do not think that, therefore, in view of the size of the overall PTTI effort, which is very small and in view of the necessity to provide technical information communication, that we should further load down the system with paper requirements.

But what is necessary, however, and has come out very clearly in Mr. Bowser's talk, and that is that we provide for shorter lines of communication by strong suggestion in the form of regulation, that each service, each agency, which uses precise time and time interval must establish their own internal communication and coordination by appointing clearly visible PTTI manager.

That, in many cases, could be a part-time proposition for somebody. And in agencies, such as DCA, for instance, I think such an appointment is very, very necessary.

The same situation exists for the military services. The only service which today has such a PTTI manager is the Navy, and I think we have benefited very greatly from that. The fact that such an office exists, that things can be referred to that office, that office has the information about similar systems, what they do, that they can plan for certain equipment development which is common to everybody, such as the platform distribution system, for instance, which is an important item -- maybe the most important item in the Navy PTTI.

That is what I think we can and must accomplish in the next phase of management improvements.

Much beyond, that, I don't know. I don't think the Observatory has to know about every crystal -- to come back to your question. That is the function of the service PTTI manager which has to be established.

DR. STOVER:

Let me try a summary on you now. If it is within 10^9 in frequency, or 10 milliseconds, and it is also a new type of system or it is a system that interfaces with other systems, or may in the future interface with other systems, then they should come and consult with you, is that your answer?

DR. WINKLER:

Yes.

DR. STOVER:

Thank you.

MR. SAMUEL WARD, Jet Propulsion Laboratory, California

I think that this document could be improved tremendously and serve the purpose of educating the user that doesn't know he needs this by spelling out in terms of location, or velocity acceleration parameters how these translate to those things.

The man who is designing a collision avoidance system may not know that he needs precision time or very accurate frequency in order to do that. And so in navigation we spell it out in terms of how many kilometers at such a distance and translate these frequency and time parameters into others and make them a part of such a document.

If you have a system that must measure location, to whatever level you spell out, then you also have a timing problem, a need for precision time.

DR. STOVER:

Thank you.

Perhaps those people who are working on a revision of this directive will take your remarks into consideration.

DR. VICTOR REINHARDT, NASA/GSFC

I don't think this problem will ever be solved at the management-administrative level. It is a technical problem and unless technical people go out and educate other technical people as to what the problems are, things will not be solved.

You have to get in at the early design phase, at the early idea phase. You have to go out and show people what range rate tracking errors are, as a function of precise time, so that whatever the other people are use to using in terms of requirements are known in terms of precise time, before you get anywhere.

I don't think putting books or directives together will mean anything, unless they are educational on a technical level.

And I just want to reiterate what Sam Ward is saying, that these documents should be highly educational and try to translate as best as possible from the precise time domain into the radar domain, or whatever domain people use in the field.

DR. STOVER:

So, you are saying that standards or any directives should be made educational tools?

DR. REINHARDT:

Yes.

DR. STOVER:

Thank you.

MR. KELLOGG, Lockheed

I don't understand why the burden of the responsibility gets down on the technical people, when one can review in the immediate past a rather large system which at present nobody would argue depends basically on the precise time and time interval accuracy. That is the GPS satellite system.

Before DoD started out to make equipment and test it, it would seem the responsibility should at least be considered as whether or not there should be some kind of conference with the Naval Observatory as to whether, (a) this was a reasonable system to try to inaugurate; (b) whether the equipment could do what it was intended -- that it was suppose to provide; and (c) whether or not it could be tested; and (d) whether the Navy Observatory was in a position to be able to assist in the testing.

At the present moment one could at least entertain the proposition that great effort has been made to exclude the greatest source of help for something which is the greatest advantage to quite a few people who use time and time interval.

DR. STOVER:

Thank you.

QUESTION #8: "WHAT ADVANTAGES OF COORDINATING WITH NATIONAL AND INTERNATIONAL STANDARDS ARE MISSED BY THE SYSTEM DESIGNER THAT SAYS, 'I AM ONLY INTERESTED IN MAINTAINING A CONSISTENT PHASE OR FREQUENCY WITHIN MY SYSTEM; I DON'T CARE ABOUT OTHER SYSTEMS'?"

DR. STOVER:

This was a point that was brought out by Mr. Bowser in his talk. Let me suggest a couple to get thing started since no one offered a response.

It can provide an external reference for monitoring purposes for one thing, so the system can use the timing in a different system for monitoring what is going on in his own system.

It can accommodate future operations requiring the cooperation among different systems.

It can provide an alternate or fallback timing capability.

It also can provide for a possible improvement in performance or reduction in cost by using cooperation among different systems.

These are all points that Dr. Winkler mentioned in his answer to the previous question. Apparently these are points that are frequently overlooked by the person who goes off on his own. Mr. Bowser pointed out in his talk that this is an important thing, but it seems to be the standard procedure for each project, to just go off on its own.

I felt that it was an important question to get in here.

MR. LAUREN RUEGER, JHU/APL

One of the major advantages of tying into the national and international standards is to get rid of some false sense of security. You can run your time instruments, you think everything is working beautifully, you have tested the instrument in your laboratory, side-by-side; and you come to find out that the instrument is pressure sensitive, or sensitive to some kind of environmental factor that you never see because your measurements were not made relative to the more anchored national standards.

DR. STOVER:

Thank you.

DR. SAM STEIN, National Bureau of Standards

I think the principal advantage in coordination between systems comes from an ability to evaluate systems, but we shouldn't overlook the fact that most of the time people who are taking maximum advantage of precise time and time interval technology are doing so in order to guarantee system independence and in order to be able to deny the use of the system to other people.

There is, therefore, a conflicting approach between, say, providing frequency syntonization and timing synchronization between nodes of a system the way the telephone company would do through coordination, and providing the same functions the way the military would do, by having independent high quality standards.

DR. STOVER:

Dr. Stein, don't you believe that he can have that independence and still have it coordinated with the standard? Can't he have both, can't he have the best of both worlds?

DR. STEIN:

The answer is a partial yes, but the two approaches provide totally different aspects and totally different qualities to the system, and they can't be combined to provide a single aspect to the system.

DR. STOVER:

Thank you.

QUESTION #9: "WHEN A SYSTEM DESIGNER RECOGNIZES THAT THERE MIGHT BE ADVANTAGES TO REFERENCING THE PHASE OR FREQUENCY OF HIS SYSTEM TO A NATIONAL AND INTERNATIONAL STANDARD, WHAT METHODS SHOULD HE CONSIDER FOR PROVIDING SUCH A REFERENCE?"

DR. STOVER:

I am going to pass over this question, because I think it will be covered adequately in some of the papers in other sessions.

So, let's go on to the next one.

QUESTION #10: "WITH LIMITED RESOURCES FOR MILITARY TIME REFERENCES, IS IT BEST TO USE THOSE RESOURCES FOR REDUNDANCY IN A SINGLE SYSTEM, OR TO DIVIDE THEM AMONG REDUNDANT SYSTEMS?"

DR. STOVER:

Let me word that question a little bit differently. Is it better to spend all of your money on one very good basket to put your eggs in, or is it better to use that same amount of money on several, perhaps not so good baskets?

DR. WINKLER, Naval Observatory

That is an extremely important basic strategic decision. And in the case of PTTI, fortunately, it is not a very difficult one to make. The reason for that is that with so many time systems in existence today, the additional expense to use one or any one of them to provide time is very, very small. It is merely a management effort. Where costs come in would be the development of the receiving equipment, or of user equipment to interface with these systems.

But, again, most of our users have to do that anyway. Most military users have to interface with some navigation equipment, with some communication equipment and to have several avenues available by which time can be picked up, I think it is an absolutely indispensable principle.

So, again, here I think one can have both advantages without having to pay an inordinate penalty in cost.

DR. STOVER:

Thank you.

QUESTION #11: "WHAT CHARACTERISTICS ARE IMPORTANT FOR A USER TO CONSIDER IN SELECTING A SOURCE OF REFERENCE TO A NATIONAL OR INTERNATIONAL STANDARD, AND WHAT SOURCES BEST PROVIDE THESE CHARACTERISTICS?"

DR. LESCHIUTTA, Istituto Elettrotecnico Nationale, Torino, Italy

I just remembered that the main basis for international comparisons is relying on the books of the CCIR, the International Committee for Radio Communication, whose group is dealing with frequency and time topics. Thank you.

DR. STOVER:

Thank you.

Since there doesn't seem to be any more comments, I will make a couple of suggestions of things that you might want to consider: Convenience, continuity of service, accuracy or stability, geographical coverage, time when it is available, cost, reliability, survivability, or any unusual requirement.

Let's go on to the next question.

QUESTION #12: "DOES THE EQUIPMENT PROVIDED BY MANUFACTURERS MAKE IT CONVENIENT TO APPLY PTTI TO NEW SYSTEMS?"

DR. VICTOR REINHARDT, NASA/Goddard

I think it is very convenient, there are lots of sources, lots of different types, but I just want to address something that happened in connection with this.

I think a lot of users think it is not convenient because of the philosophy of designing many systems, especially military systems in which they say, gee, that box is beautiful, but it is four foot by five foot, or four inches by five inches and we would like it five inches by four inches. They don't realize the implications of redesigning a system, and the impacts on reliability or performance of what seems to them slight changes in size, weight, electrical characteristics.

I think there isn't enough use made of off-the-shelf equipment in many of these fields. This also happens in the satellite field. Risks are taken that don't have to be taken because people insist on making changes which are critical to performance.

DR. STOVER:

Do you think a set of standards for PTTI equipment and PTTI applications would help alleviate this problem?

DR. REINHARDT:

Yes. I think especially a set of standard frequency boxes, clock boxes that meet the kind of requirements people need in critical applications, such as satellite work, military applications.

DR. STOVER:

Can you suggest who might be a desirable choice to produce such standards?

DR. REINHARDT:

I think that it has to come from DoD, if DoD is the user. The way to do that is to get some standards groups, get some Mil standards and to encourage manufacturers, which of course, requires money, to produce some sort of standard box.

But I think it is never going to be successful if the users of these devices don't listen to these standards. I think there is going to be a lot of communication required before this kind of thing happens.

NASA has gone towards these standardizations and standard buses for satellites and whatever, they are only beginning now to address the problems of standardized clocks.

For example, right now every satellite builds its own clock from scratch. And I think because of that, especially in the crystal business, the devices that they use are just behind the state-of-the-art, because they don't take advantage of the commercial standards that I think are better performance than some of their satellite standards that they use now.

DR. STOVER:

Thank you.

DR. SAM STEIN, National Bureau of Standards

I think we should try to learn from past experience in other fields where these same types of problems have been addressed. I think the situation that we are looking at here is one which can be characterized in that the government is at least viewed to be the principal user of a certain type of equipment.

That did happen before in the early 1950s in the computer field, where it was decided that the government would develop the technology in the field.

Now, in that case the preception turned out to be incorrect in the long-term.

In order to provide an orderly marketplace and to prevent the government from overly distorting private competition in the computer field, it was decided to develop both government use standards and government procurement standards for computers.

I can only say that -- this is just a purely personal opinion on my part -- the result of an overly rigid process of government regulations, is that the government has an inventory of computers which is more than one generation out of date, on the average. That is the average government computer is more than seven years old at this time.

I don't think we can afford to produce this kind of result in the precise time field. I think, therefore, we need to tend much more in the direction that you mentioned before, of improved education and improved coordination, and communication of information, and less in the direction of developing standards boxes, or standards for the utilization, standard interfaces, or things which tie down the ability of systems to change and react to changing demands.

DR. WINKLER, Naval Observatory

I concur completely with that comment, in fact, there is a basic directive out in the Department of Defense for quite a few years for system designers to design as much as possible their systems around the available equipment, on the shelf items. And to stay away from custom design models.

And there are several reasons for that, in my mind maybe the most important one is that by using modules which are available, which have been designed and tested in the field, you obtain greater reliability and lower costs. There is no question about that.

That directive stands, in fact, it goes back to David Parker's time as Deputy Secretary of Defense. Those instances which we have in mind when we talk about boxes not being three by four, but four by three, and so on, these are simply cases where this basic directive has been almost deliberately disregarded.

I completely agree with Dr. Stein about his comments that if you overly restrict by regulations the use of frequency standards, you will have the same situation as in other areas, that you are 10 years behind the state-of-the-art.

In addition, you apply a management effort to an area which does not really merit it by its small size.

What we have to attempt, however, is, again, let me repeat that, is to cut out the bad instances to achieve some overall improvement of communication. This can be accomplished. And I think the proposals which the Observatory will make very shortly, will go in that direction and I think they will be successful.

DR. STOVER:

Thank you.

QUESTION #13: "ARE THERE A NUMBER OF OSCILLATORS AVAILABLE AT LOW COST FOR A WIDE SELECTION OF FREQUENCIES WHICH CONVENIENTLY PHASE LOCK TO ONE PULSE PER SECOND SIGNALS?"

DR. STOVER:

Now, let me explain why this question is in this list.

Phase lock oscillators are usually locked to references of their own frequency, and if a 5 megahertz reference were unavailable for an extended period of time, then an oscillator locked to that 5 megahertz reference would drift. If it drifts more than 200 nanoseconds, then when the reference becomes available again, the oscillator will lock to the wrong cycle.

If the reference is one pulse per second, there is very little likelihood that it is going to drift a full second in the period of time that the reference is unavailable. So that when it comes back it will lock onto the correct cycle.

That is the reason for this question. I don't know whether such equipment is conveniently available, or not. But I suggest that there are many applications for which this characteristic is very important. And when we need something of a longer period of time, it seems natural that the definition of time, the second, be the best interval to choose.

Those are my opinions. Now, I would like to hear some of yours.

FROM AN UNIDENTIFIED PARTICIPANT:

There is a technical invitation to this, if you try to use 1 PPS as the standard lock frequency, many crystals would not be capable of keeping this without introducing glitches into the system. That is you have to pick locked time constants on the order of 10 to 100 seconds if you want to avoid the granularity of hitting a crystal with 1 PPS. Many crystals are not capable of doing that, due to vibration and other factors.

You really need an intermediate frequency, 5 megahertz or 1 megahertz, as well as 1 PPS to do the job.

DR. STOVER:

I guess maybe I didn't give my proposition quite correctly. I am assuming that the 1 pulse per second would be used to select the right cycle of some other frequency that might be used. And I think that is what you are saying, is that you need that other frequency.

FROM AN UNIDENTIFIED PARTICIPANT:

You need a reference at 5 megahertz or 1 megahertz, or something, as well as the 1 PPS to do the job, technically, with crystals.

QUESTION #14: "ARE THERE A NUMBER OF EQUIPMENTS AVAILABLE AT LOW COST WHICH PROVIDE PRECISE PHASE ADJUSTMENT OF THEIR OUTPUT, RELATIVE TO THEIR INPUT AND THEREBY PERMIT PHASE LOCKING THE OUTPUT OF AN OSCILLATOR WITHOUT DISTURBING OSCILLATOR PARAMETERS?"

DR. STOVER:

I think the answer to that question is, yes, they are available, so let's move on to the next question.

QUESTION #15: "IS THERE GUIDANCE AVAILABLE TO SHOW POTENTIAL USERS HOW PRECISION CLOCKS, SOURCES OF UTC PHASE REFERENCE, FREQUENCY DIVIDERS, FREQUENCY MULTIPLIERS, MIXERS, PHASE SHIFTERS, ET CETERA, CAN BE CONVENIENTLY CONNECTED INTO SYSTEMS AND THAT THESE DIFFERENT DEVICES HAVE COMPATIBLE INTERFACES FOR BEING CONNECTED INTO THE SYSTEMS?"

DR. STOVER:

Are there any comments on that question?

(No response.)

DR. STOVER:

I can't stimulate a comment, I guess.

Let's go on to the next question.

QUESTION #16: "ARE THERE PTTI DEVICES AVAILABLE WHICH ARE DESIGNED TO PERMIT CONVENIENT INTERFACES WITH MICROPROCESSORS?"

LT. KARL KOVACK, GPS Program Office

The answer is yes, and it is called GPS.

DR. STOVER:

That sounds like a commercial. Maybe somebody would like to comment on what it takes to make a PTTI device convenient to interface with a microprocessor? What characteristics are required in a PTTI device to make it convenient to interface with a microprocessor?

Surely we must visualize that there are going to be some situations in the future where we are going to want to interface PTTI devices with systems that are employing microprocessors for a wide variety of purposes.

DR. EDMUND CHRISTY, Offshore Navigation

Just to name a few devices that are available without being exhaustive about it, there are, in fact, precision phase shifting devices that are available with RS232 and HPIB type interfaces, and there are microprocessors available which also support RS232 and HPIB interfaces.

Likewise, you can now buy direct digital synthesizers which can be phase locked to a cesium standard or some other standard. These are available with microprocessor S100 bus.

So, that is three items right there that I know of, which are easy to connect to microprocessor systems.

I can give someone details on specific part numbers or things like that, if they are interested, later.

DR. STOVER:

I think you answered the question, yes, there are devices available and you also named some of the factors that should be considered, those things that would make them compatible.

With that, let's go on to the last question.

QUESTION #17: "WHAT IS THE MOST PRESSING NEED IN THE FIELD OF PTTI APPLICATIONS?"

DR. WINKLER:

I should say money. Curiously, I think the most pressing need is not the development of small demanding specifications, but greater reliability. Timekeeping stands and falls with reliability and, in fact, when we discussed before what are the difficulties, why don't more people use precise time and time interval, I think many of them are simply afraid that more complexity, more equipment will bring an impairment in the reliability of time systems.

So, clocks and connected equipment, such as distribution amplifiers, what have you, must have extreme reliability in order to be useful as clocks.

And I would suggest that this is the most important answer, and not greater performance. Thank you.

MR. BILL BRIDGE, MITRE Corporation

I would agree with the need for the reliability, but I would like to see that reliability in a tactical environment which includes all the Gs that are involved in aircraft and all the temperature and vibration problems involved with tank-type environment.

DR. SAM WARD, JPL

I think one word says it "education".

DR. STOVER:

I think that has come out throughout the whole session, everybody has discussed the lack of PTTI knowledge that many people have.

DR. FRED WALLS, NBS

The greatest inhibitor to reliability is lack of number and the insistence on specialized packages for new systems and the insistence on odd-ball frequencies. Those things drive a company to put their best engineers, their best people on producting custom changes, rather than working on reliability and improved performance and other things.

If you want reliability, you have got to get the numbers up, there is no way to make two or three, or even 10 of a device and have enough money and time to test it, and to get the data to

prove that it is reliable. If you want reliability, you need to standardize some frequencies, you need to get configuration that you are willing to accept on a number of systems, so you can go to multiple units. I believe that is the only way.

MR. FRANK KOIDE, Rockwell International

I think system reliability comes from system maturity, maturity of the system. If you would look in a spacecraft type world, you take the cesiums or the rubidiums, they have very little system maturity in respect to transmitters, multiplex systems, and things like that, that are on other types of space vehicles.

We have to get maturity into the system, before we get the reliability.

DR. STOVER:

Thank you very much.

I want to thank all of you for your comments and discussion, and I think that this turned out very well. I was very nervous when we started, for fear that we wouldn't get this kind of response. Thank you very much.