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International Radionavigation Users' Conference

November 15-17, 1995
Westfield's Conference Center
Chantilly, VA

International Loran Association
International Navigation Association
GPS International Association

Proceedings of the 24th Annual Technical Symposium

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INTERNATIONAL RADIONAVIGATION USERS' CONFERENCE

Proceedings of the
Twenty-Fourth Annual Technical Symposium
INTERNATIONAL LORAN ASSOCIATION

Dale E. Johnson, President

November 16-17, 1995

Westfield's Conference Center
Chantilly, Virginia

Published by
The International Loran Association
8 Preston Court
Bedford, Masachusetts 01730

INTERNATIONAL RADIONAVIGATION USERS' CONFERENCE

First Annual Technical Symposium
GPS INTERNATIONAL ASSOCIATION

Francis X. Kane, President

November 16-17, 1995

Westfield's Conference Center
Chantilly, Virginia

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Foreword

This publication contains the full transcript of the presentations made at the November 15-17, 1995 International Radionavigation Users' Conference, held in the Washington, D.C., area. The entire conference was tape-recorded, and these Proceedings are a transcript of the tapes, with the addition of reproductions of view-graphs when these were available. The reader should recognize that many of the sections herein are extemporaneous comments and not prepared speeches. I have tried to retain the meaning in every case, while removing some of the less-pertinent phrases. Even so, the text includes some epithets and some rambling statements where removal might have affected the reader's ability to understand the comments. The intent of editing has been to produce a readable document while retaining the message and the "tone" of each speaker.

Where text or explanation has been added, I have enclosed it in [brackets]. Where phrases have been deleted, were unintelligible or were missed during tape changes I have inserted an ellipsis (...). Graphics or view graphs were not available for all presentations. Generally, the speaker describes the view graphs verbally, and so the text is understandable. In several locations, I have added references to documents either as explanation or because the reference was made by the speaker. To aid in identifying or contacting speakers, a list of meeting attendees and a meeting program are attached to the transcript.

Thanks to the people at Megapulse, Inc., for designing the conference logo, to Paul Burket for managing the audio tape, to NAVTECH's Carolyn and Frank McDonald for audio-visual support, and to Ms. Sharon Conner for preparing the transcript. Any errors are mine.

Robert W. Lilley
Editor

The Host Organizations

The **International Loran Association** (formerly the *Wild Goose Association*) is an organization for individuals with a common interest in loran and who wish to foster and preserve the art of loran, to promote the exchange of ideas and information in the field of loran, to recognize advances and contributions to loran, to document the history of loran and to commemorate fittingly the memory of fellow members.

The **GPS International Association** is a non-profit, professional society dedicated to applying this global utility to the enhancement of its members and the global economy. GIA addresses policy and technology issues of concern to members and others within the GPS user community.

Special emphasis is given to GIA's role to provide the scientific and mathematical bases for multidimensional space-based radionavigation through publications and meetings focusing on the many diverse applications and to educate both members and the GPS community at large.

The **International Navigation Association** is a non-profit association of individuals and organizations having a common interest in applying the art, science and technology of radionavigation systems of long-range coverage and international usage, operation or ownership. The objectives of the Association are to:

a. Advance the worldwide use of the Omega Navigation System as an economical global service to benefit navigation and other applications.

b. Advance the use of other long-range navigation systems, both terrestrial and satellite, to benefit safe, efficient and ecomonical air, land and sea navigation .

c. Advance the synergistic use of these radionavigation systems and self-contained navigation sensors to achieve the aforesaid benefits.

d. Provide an international forum for the exchange of information between the users of these radionavigation systems and scientists, technologists, manufacturers and government authorities.

e. Disseminate information on the status of these radionavigation systems and developments related thereto.

f. Encourage international standardization and the generation of specifications to benefit the users of these radionavigation systems.

g. Work with other organizations to advance these objectives.

Summary Report

International Radionavigation Users' Conference

Westfields, Chantilly, VA November 16-17, 1995

An International Radionavigation Users' Conference was convened by the GPS International Association, the International Loran Association, and the International Navigation Association in the Washington, D.C. area on November 16, 1995 for the purpose of discussing, in open forum, the requirements and concerns of users the world over relating to the future of radionavigation systems.

The conference was well attended by representatives of the international community, U.S. user organizations, and the U.S. government in spite of the government's temporary shut-down caused by on-going negotiations for a balanced budget.

Following the welcoming remarks by the Presidents of the three sponsoring organizations, presentations were made by Mr. Phil Boyer, President of the Aircraft Owners and Pilots Association, and Mr. John Olcott, President of the National Business Aircraft Association. Both speakers strongly supported a transition to satellite navigation but stressed the need to retain current systems while satellite augmentation systems for accuracy and integrity are being implemented. Further, both speakers endorsed the continued provision of Loran-C as a complement and back-up to GPS after full operation of GPS and its augmentations is achieved.

Other presentations on the first day covered timing applications by Dr. William Klepczynski from the U.S. Naval Observatory, and maritime operational requirements by Andrew Bass, Fleet Navigator, U.S. Naval Academy for Sailing. These were followed by a summary reports of the Radionavigation Planning meeting held in Moscow in June given by Mr. Beukers; the Royal Institute of Navigation's GPS Interference Workshop held in London during October provided by Dr. David Last; and the recent Far East RadioNavigation System (FERNS) Council Meeting held in Tokyo and provided by Mr. Peter Kent.

In the afternoon presentations covered intermodal operational requirements by Mr. Ken Kelly of Amtech Systems; railroad applications by Richard Shamberger from the Federal Railroad Administration; and the benefits of precision location in construction and mining by Mr. Adam Gudat from Caterpillar, Inc. The day concluded with a

presentation on Differential Navigation by Andy Bogle of John C. Chance & Associates.

The second day of the Conference was devoted to presentations by officials from the Department of Transportation and other government agencies. This was followed by an open forum for questions and discussion.

The Conference ended with a plenary session, moderated by David Scull, at which conclusions were established and recommendations made. In addition, suggestions for the text of a Conference Resolution were proposed and discussed. The final text of the Resolution with Observations, Concerns and Recommendations is attached to this summary report.

International Radionavigation
Users' Conference
Washington, DC
November 16-17, 1995

Resolution and Conclusions

An International Radionavigation Users' Conference sponsored by the:

GPS International Association
International Loran Association
International Navigation Association

was held in Chantilly, VA, on November 16-17, 1995. Participants in the conference included members of the above organizations and members of aviation, marine, and terrestrial user organizations and interests. In addition, a significant number of non-U.S. positioning, navigation and timing users attended the conference representing the international community's requirements and concerns relating to the continuity and quality of future radionavigation services.

Presentations on a wide range of user requirements were made, followed by a discussion of the Federal Radionavigation Plan in open forum with officials from the U.S. Department of Transportation. The conference concluded with the adoption of the following Resolution:

Resolution

Noting significant technological advances in systems for radio positioning, navigation and timing, and,

Acknowledging the trend towards the use of common systems worldwide endorsed by member States of the primary international organizations,

Calling Attention to the Letter of Promulgation in the foreword to the U.S. Federal Radionavigation Plan (the FRP) signed by the U.S. President's representatives, the Secretary of Defense and the Secretary of Transportation, and,

Noting that the Letter of Promulgation states that the FRP represents the official radionavigation policy of the U.S. government,

Recognizing that governments throughout the world consider the FRP to be a statutory document fully supported by the U.S. administration and depend upon it in developing their own national radionavigation policy,

Further noting the radical policy changes that have appeared in the last two successive biennial issues of the FRP, and,

Recognizingthat such changes are: (a) unresponsive to user-expressed requirements; (b) an indication of the need for better coordination within the Administration and government agencies; (c) disruptive to users and governments worldwide; and (d) responsible for the loss of confidence in the FRP, the process for its development, and those responsible for its adoption,

Calling attention to the United States and international user requirements, concerns, observations, and recommendations as expressed at this International Users' Conference and summarized in the Meeting Conclusions attached to this Resolution,

Resolves:

1. **That a recommendation is made to the Director of the Office of Science and Technology Policy that, in accordance with Title 22 of the U.S. Code of Federal Regulations, Section 2656b, he/she assume responsibility for the oversight and guidance of strategic planning aspects for the Federal Radionavigation Plan including provision of specific services, for the process of coordinating all national and international interests, and for the establishment of the FRP under the Federal Regulatory Process.**

1. **That this Resolution be transmitted to government departments, international organizations, user organizations, and others involved in the evolution of radionavigation systems for national and international use.**

Observations, Concerns and Recommendations follow this page:

Observations, Concerns and Recommendations

At the final session of the Conference, delegates expressed their individual requirements and concerns and made a number of observations and recommendations. These are presented in the paragraphs that follow, in no particular order of importance:

1. Government-Supplied Services

The many benefits that have accrued to a user community of millions over years of government (taxpayer) support of radionavigation services was acknowledged.

It was accepted that governments have a responsibility to provide services in an efficient and cost-effective manner.

2. Satellite Technology

It was recognized that satellite technology as applied to positioning, navigation and precise timing is providing significant worldwide social and economic benefits and that the technology offers capabilities not available from previous systems.

It was also recognized that a global, centralized satellite-provided positioning, navigation, and precise timing service was being planned by the United States to become an alternative to a multitude of currently operating terrestrial services.

3. Worldwide Systems

It was noted that most long-range terrestrial systems and all services based upon satellites are inherently international and have a direct impact on governments and users. It was recommended that international agreements in force must be respected.

4. Transition Plans

Attention was called to the need for the transition from terrestrial systems to a mix of terrestrial and space-based services to be based upon the provision of an assured service and not upon an arbitrary schedule.

It was noted that the transition to a satellite service from nationally owned, decentralized, terrestrial services raises substantial legal, financial, political, and technical issues that require time to resolve.

5. Government Competition

Attention was called to the issue of the Government competing with the private sector in providing differential satellite services.

6. Mix of Systems

It was noted that aviation associations including AOPA, NBAA, NASAO, EAA, HAI, and ALPA; Boat U.S. representing marine users; the European Union and international organizations: ICAO, IALA, IMO, IAIN, and other national organizations have all expressed a requirement for a mix of positioning systems to insure availability for all services and integrity for safety-critical applications. Many European and Far East states have already taken action to meet these requirements.

The provision of more than one independent means for deriving position information to ensure safe navigation was acknowledged as a mandatory requirement. The current activity within IMO to identify the requirement for a second independent navigation input to electronic chart displays (ECDIS) was also noted.

There was support for complementary satellite and terrestrial systems to ensure continuity, availability, and integrity of service.

7. National Plans

The regional and national activity around the world to develop long-term radionavigation plans was noted.

8. U.S. Federal Radionavigation Plan

In considering the 1994 Federal Radionavigation Plan, deep concern was expressed over the decision to transition to satellite technology in the short-term, and the decision to terminate all terrestrial services without input from the Department of Commerce and Department of State.

It was noted that the adverse impact on international trade, the weather services, and other non-navigation users had not been thoroughly assessed.

The lack of involvement and coordination with the Department of State throughout the FRP process was also noted. The announcement in the 1994 FRP of termination of Loran-C by the year 2000 in the United States has resulted in confusion and mistrust within those states (nations) which had, just one year previously, received encouragement from the U.S. government to take possession and financial/operational responsibility of Loran-C assets overseas.

9. Loran-C Service

The strong bipartisan support for continued funding and support for the Loran-C radionavigation system by the Authorizing and Appropriations Committees and by other key policy makers in the U.S. Senate and the U.S. House of Representatives, as reflected in statutory and other provisions advanced in H.R. 1361, H.R. 2002, and S 1004 was noted.

There was a strong recommendation that the Department of Transportation and its agencies, in active consultation with users, fully comply with the statutory provisions and Congressional intent reflected in the above Bills as acted upon by the respective bodies during the first session of the 104th Congress of the United States.

It was also noted that Loran-C for the Coastal Confluence Zone was formally adopted through notice in the Federal Register. It was recommended that termination of the system should follow this same formal procedure.

10. Omega Service

Concern was expressed over the imminent termination of the global Omega radionavigation service. It was noted that some airline operators do not have time to reequip, and weather station operators throughout the world do not have an economic equivalent.

11. User Consultation

Users of current and proposed institutionally-provided services recommended that they be consulted and become intimately involved in matters concerning:

(a) The radionavigation planning process and the development of radionavigation plans.

(b) Establishment of a defined period of concurrent operation for any proposed service transition, based upon assured service.

(c) Development of a transition plan and schedule.

(d) Provision of complementary systems.

(e) Dissemination of technical and non-technical limitations of a centralized positioning, navigation and precise timing system.

(f) Exchange of information within the international community to facilitate international planning and setting of standards.

12. Government Intervention

The recommendation was made that no government departments, whether United States or any other states (nations), should obstruct by political, diplomatic, or commercial means, efforts to enhance peacetime performance of satellite navigation systems. Such enhancements were noted to include GPS augmentations, use of GLONASS, and the provision of an independent satellite constellation.

Conference Transcript
Thursday, November 16, 1995

Introduction

Dr. Francis Kane, President, GPS International Association
(Conference Chairman)

The Institute of Navigation suggested that we three get together and stage a conference, and it took us from April until now to have this room full of people interested in learning more about radionavigation issues, requirements and policy. We planned it very well to give us plenty of heartburn because we picked the dates when we knew the government would be shut down, so half our speakers would be gone. But once again, they fooled us. The DOT budget was signed by the President yesterday so I am assured that representatives from DOT, FAA, Coast Guard and other agencies are free to come to our meeting. If they hadn't come we would have been doing a song and dance up here tomorrow to a different tune.

Then I would like to say, Bonjour Messieurs and Mesdames, welcome to the conference (in French) I regret that I can not say that in Finnish, Swedish, Norwegian, and the other countries represented here, but I trust that you will understand from my English that you are more than welcome. We don't have a view graph of the program because it's printed so you can all see. There are no variations. We are going to go down the list as was printed some months ago. There is one exception though. The luncheon speaker John [Beukers], whom you all know, will speak here after lunch, not over there during lunch so at the end of the morning session we will all repair back to the dining room for lunch and then come here to hear John talk about work going on in Moscow and other international conferences. Then we will resume with the regular technical briefings. We hope to finish by 5:00 pm because Dale wants to have a meeting of the ILA probably here in this room, but other than that the program for today is the way it's printed in the program.

On behalf of the GPS International Association, I personally am very happy to be here. As the three of us talked before maybe this is the start of an annual meeting of our three associations where we can discuss policy and requirement issues. So if there are no questions, I would like turn it over to Ian for a few remarks and then Dale will introduce our keynote speaker.

Mr. Ian Anderson, President
International Navigation Association

Thank you Dr. Kane; good morning everyone. For those of you who don't know me my name is Ian Anderson, and I am the President of the International Navigation Association. This meeting marks a first for all three organizations who are hosting this meeting. In fact, this represents the 25th meeting of the ILA [International Loran Association] and its predecessor, the Wild Goose Association. It's the 20th annual meeting of the INA, and of course its predecessor The International Omega Association. GIA are the new people on the block. I'm not sure if this would be their first annual meeting or not. They are a very new organization, but it is important to recognize that here in this room we do have the three major radionavigation groups represented at one conference. Your luncheon speaker John Beukers is going to be telling you about another international radio navigation conference that was held in Moscow, in June of this year. It's important to recognize that the resolution from that conference needs to be followed up with something similar from this group. As most of you are aware, the 1994 FRP [Federal Radionavigation Plan] issued by the United States government, marked a tremendous change in philosophy in the radio navigation policy. And this meeting will address some of the user requirements. The DOT [U.S. Department of Transportation] has meetings for people to input to the FRP process. In fact, next Spring I believe they will be starting, I am not sure that will be the '96 because obviously they are way behind times and the '94 plan was just issued. But whatever we resolve from this conference will have a great bearing on the next FRP to be issued and it will probably be '98 the way things are going right now, but we have to consider what we as the user community require in the way of service. You will have an opportunity to hear speakers today, and of course tomorrow is mainly forums where you will have the opportunity to talk and discuss the policies that affect all of us in the radionavigation business.

Dr. Kane:
Well those remarks are very pertinent to what I am going to discuss next. When we were putting together this program, I went to DOT and talked to George Wiggers, Paul Larson, Heywood Shirer about what they want from this meeting in return for their appearance here. Heywood made the point that this is what they can now consider a mini-users conference. That is compared to the one that Ian talked about. It is the first time people who are actually using the stuff on a day-to-day basis that can and talk to them. So it is a unique forum, but they wanted something in return and that is what he mentioned. We have to give him some sort of findings or recommendations. So let me show a few view graphs.

First, we are going to have a technical discussion of user requirements; that is today's main topic. And tomorrow when Col. Hunter talks we will talk about the space operations squadron report of the users. Then we are going to have a discussion of the user requirements in an open forum after the people from the government make individual presentations tomorrow morning. So at the end of the open forum discussion we are supposed to prepare some sort of findings for them in return for their helping us understand policy. As you have seen from the program we plan to [have] four or five people from the government discuss policy and see who can come tomorrow. The policy discussions are in this light.

When I mentioned some of the speakers who will be here both George and Heywood said, "They are going to beat us over the head and ears again. We know what they are going to say." Well I hope that's not true. We have some new ideas which can come from studying the FRP. Now Heywood Shirer sent me view graphs that he prepared for George Wiggers which are really excerpts from Federal Radionavigation Plan '94. They would like us to make some concrete suggestions as how to improve it in the present version and the coming version and that's our action item at the end of the day so we're allowed about two hours to prepare such a paper. There are several drafts floating around, I believe, of things we could suggest to them and if you have some thoughts be sure to air them tomorrow because there will be an open forum right after lunch. So I am hoping to cite this conference with a definite purpose as an action step at the end and maybe a prelude to continuing discussions of this kind for people who are the real users of the system. Now I would like to turn things over to Dale who has a few remarks and he will introduce the keynote speaker.

Dale Johnson, President
International Loran Association

Thank you Dr. Kane, and Ian Anderson, a long time friend and thank you all for being here. I know these kinds of things are a challenge and we certainly have our share of challenges today. I am the other third of the triad, representing the International Loran Association as the President of that association, and I would like to give a brief report following my remarks on a meeting held in Capetown, South Africa that I just returned from. Today we're witnessing an unprecedented technology expansion that sometimes is really hard to get our arms around entirely, and that is the good news. Technology is offering us more opportunity, more capability, more of everything at hopefully reduced costs, but the bad news is we are faced with limited resources, tight budgets, to accomplish some very important tasks. We here in the U.S. are not alone in that. The entire world is addressing and dealing with in the best way that they can the issue of how we get the total job done within the budget constraints that we have, recognizing that there are certain minimum performance criteria that we must meet in order to produce the level of service required and the safety required.

We recently had a good example of what can happen when we don't all of our homework quite right in an incident where a cruise ship ran aground off the coast of Boston, and in this case a single receiver was driving the ship's autopilot and there were not good proper procedures or equipment in place being used, I stress being used, to prevent this incident from happening. And what happened is a simple little thing like, a broken wire off an antenna gave the GPS unit no way of getting further information, so the ship's computer went into DR mode, to ded reckoning mode, and this situation went undetected for a significant period of time allowing the ship to drift off course and eventually run aground. This incident highlights the fact that we really do need a partnership of technologies in order to assure that any single failure will not create this kind of an incident, will not result in the loss of navigation capability. The FAA and the Coast Guard have always done a very responsible job, accepted that responsibility for offering the aviation and the marine community safety. They have done a very very good job and my hat is off to them because it is a difficult task. I am confident that commitment will not change as the world transitions into a mix of satellite and terrestrial systems. The ILA is working toward a goal of assuring that the international harmonization of radio navigation services in navigation procedures eliminate the hazards of depending on any single radio navigation service. There are many arguments in favor of a mix of satellite and terrestrial navigation systems in partnership to assure adequate navigation performance for all users. We all know that any system has some limitations but there

should be no common limitations of the mix of systems, whatever that mix is, and for whatever level of services required.

Last year I was involved in a project sponsored by a major air-carrier to evaluate a GPS and Loran receiver or navigation receiver using GPS and Loran in a partnership role. This operation encompassed about a 5 week period on their normal route structure and on a number of occasions we disabled one receiver or the other and were able to demonstrate no loss of integrity in the system [and] that we could continue in a fail-safe mode. That was part of the evaluation. Now I just returned, as I mentioned, from a meeting of the International Association of Lighthouse Authorities, in Capetown, South Africa.

There were about 150 people representing more than 30 countries at that meeting and they were participating to discuss radionavigation issues. It's clear that all of the nations are going to use GPS. It is there, it is free, it produces a high quality signal and it offers world-wide coverage. Almost all of the delegates indicated that they were working on some form of differential GPS: This to assure the adequate level of integrity and safety for their own operations.

And a new word was introduced here; I shouldn't say a new word, but a new term that we have not used in this way before and that is service. The point is that we should be talking, the way we are planning to mix our systems to use earth reference or position reference navigation now we need to be talking about a level of service and then whatever system is required to be put into action to deliver that level of service would be the issue. So we're not talking about just a technology to do a single job, but how we deliver a level of service. It was very clear also that almost all of the nations plan to maintain a mix of terrestrial and space-based positioning systems. Those systems operating in partnership to provide an acceptable level of performance and an acceptable level of safety.

Professor David Last from the University of Wales was the keynote speaker. He talked about all the systems that we have been using in the past and are using today and very nicely put it into perspective and it was clear from the body; most of you have heard David Last speak so everybody is really in tuned with David when he does speak. It is hard not to be. The audience was very clearly in agreement with his remarks, and you will find in your package a copy of that talk [Ref 1]. It is rather lengthy, but it is worth your time going through it. I think you'll agree with what he has to say.

The purpose of this conference here today is to take a close look at the requirements of all users of positioning, navigation and precise timing services. The intent here is to

perform some of the same tasks as the DOT has in holding their user conferences, but we really wanted to try to get all user groups and user representatives together to lay the user requirements on the table so that nothing sort of drops through the cracks or gets ignored by one agency thinking another agency is covering that area. So our goal is to assure efficiency and safety in the development of a well balanced positioning system, and that's what we are here about today. We have a worthy task and goal in front of us and I trust that you will all participate in this thing in a very active way.

Introduction of Keynote Speaker

Dale Johnson:
At this point I would like to introduce the President of the Aircraft Owners and Pilots Association which is the largest in terms of numbers of members in an aviation group. Mr Phil Boyer has been at the head of this organization since 1991. The organization has been rapidly and steadily growing over a large number of years and there is good reason for that. This organization has done a very very good job of representing the general aviation pilot that does not have a large corporate foundation that he can work from, and this organization has done a very good job of taking the users' needs, concerns, requirements to our folks in Washington, and Phil we want to thank you very much for all of your hard work. We know that it is hard work and I personally know that Phil travels long hours to hold town meetings around the country to get that input.

He takes the questions to the user personally and so here's the person who really can speak for the general aviation community which is a large segment of the users. So Phil if you would come forward and address us I would appreciate it. Thank you. Let's welcome Phil Boyer.

Mr. Phil Boyer, President
Aircraft Owners and Pilots Association (AOPA)

Thank you very much Dale, and good morning to you. As a matter of fact, just to put into perspective the group that I represent, think if you would for a moment of little airplanes, and when I'm talking about little airplanes I'm not talking about Gulfstream 4s. I'm talking about Cessna 172s, J3-Cubs, and let's stay with those little airplanes for just a moment. As a matter of fact, the little airplane community is some 190,000 units, and think of us as a typical general aviation plane. That would be the 172; That's right, the typical 172 that a member is flying probably less than 50 hours a year. It's an airplane with a single engine and does about 105 knots true air speed, and has four seats.

As a matter of fact, I am quite pleased to see the very fact that a lot of people are in the room today. I was worried about the shutdown of the government and frankly had the President and the Speaker of the House and the Senate Majority Leader taken one of the planes that I represent over to the funeral, you probably wouldn't have the condition we're in right now because there's no way you can't talk to each other in a typical 4 place airplane. [Mr. Boyer refers to a trip taken on Air Force One where the republicans from

Congress were ushered unceremoniously out the rear door, and on which the President did not converse with them].

Basically what I want to talk about today [to] some degree is the very fact that we have come a long way in the area of GPS. So those of you who are Loran aficionados, and Dale and I have had many a conversation, sometimes late at night about this, don't think that I am going to ignore you because AOPA has been very active in the promotion of GPS, sometimes as Bob Lilley and Dale and I have discussed to a fault they believe, but I've got to tell you that we believe that the only way to really get attention in Washington, is to truly be in a black and white mode. You can't get anything on a fast-track if you are sort of in the middle and say this is good but we're not quite sure of that: One thing AOPA has very successfully done is never take the middle of the road position. We're always usually over here and go for it in a big way and we try to get attention. In a particular case of the navigation systems of our future and really even some of the communications and the surveillance systems of our future GPS is truly, we believe, a step in the direction that we want to go to untangle ourselves from very expensive land-based navigation systems, and I would not cite Loran certainly as an expensive system. So the second part of some of the remarks I want to make is that Loran is truly, as Dale said just a little bit earlier, a way to make things fail-safe. A way to give us a backup, but at the same time provide us a navigation system that would be used in the world.

Dale talked about being in South Africa, and I was there about three years ago and here is a country when you want to add up land-based nav aids they are very very scarce. As a matter of fact, I had one day off and I was able to rent an airplane and at that time I had one of these hand-held GPS receivers and I wanted to go to one of the closest game parks; there was no way I could use a VOR to get there. Very soon out of Johannesburg, I was away from the Johannesburg VOR and therefore used the little hand-held, [it] was the Sony where you put in the Lat, Lon, no database, etc. It is amazing how many planes in this environment had GPS. So please understand from our users perspective, I was just back from Europe two weeks ago, we don't have quite the political concerns that you are going to be hearing from Dale and others through the users that affect the politics, the government, the financing, etc. Two weeks ago in Europe, the general aviation pilots [were] there. They embrace this technology. They don't have the fail-safe concerns and I'll show you why. Because in many respects they just need to get to an airport or get down below the clouds.

Now, as I say, the future is now, and we said this in 1990, when we published a book for the Congress and all interested parties in industry. It hasn't changed much. It is full of very very good information. And basically it centers around those three letters, GPS, the

Global Positioning System, or if we were talking internationally, GNSS. Basically, what we said is we have gotten to [the] point where we have go to take ourselves out of a ground-based system for communications, navigation, and for surveillance, and look at satellites as the way of the future. Well you know when this book came out it was fairly unpopular. As a matter of fact, one our leading technical magazines, the industry magazines, I don't want to cite the specific name of the magazine, but it is published weekly, and it does cover the air and space area, they came through and they said that AOPA is all wrong. GPS for heavens sakes, the typical cost of a GPS receiver, this is in print in 1990 after this report was reviewed, typical cost of a GPS receiver will be something like $12,500 for a typical GA plane. And once again, I represent a constituency where cost is a very critical element.

Well, as you know since that report has been written, and I'll use the work "fast-track" here, because that's what we've been on, sometimes to a fault. We've been on a fast-track for GPS, but it has gotten the attention of Congress. It has gotten the funding levels that we need. For as you well know, on June 10, the FAA, and I was there, and Joe DelBalzo held the meeting recommended the establishment of overlay non-precision approaches. Very very essential to general aviation. In 1992 they authorized GPS to use in conjunction with RNAV to conduct IFR operations in all phases of flight, and as we well know it has been approved as a supplemental means of enroute and terminal navigation across our country.

As Dale knows, for about the five years I have been on this job, four and one-half of those years I have been flying an airplane about 450 hours a year to get to these town meetings and other business appointments that's equipped with GPS and you will be happy to know, GPS coupled with Loran in the same receiver, and it's been very very accurate as far as position information is concerned and it has never as a matter of fact, let me down. In December of '92 through the first half of '93, the FAA authorized GPS as a supplemental means for oceanic and on route, domestic and terminal operations, and recently approved GPS as a primary means, about a week ago, as a matter of fact, less than a week ago, last Friday I visited Oakland Center. I happened to be out attending some meetings in San Jose, and I wanted to take the time in the afternoon and look at the new means for controlling airplanes. The tests that are going on right now with ADS [Automatic Dependent Surveillance], GPS positioning reporting and sitting in the center and being able to look at a display of an aircraft in position in real time as if it was being tracked by radar. Obviously it is a tremendous step forward for both communication and surveillance of the aircraft.

In the first of '93, the FAA began to look at GPS as a stand alone means for oceanic areas. In August, '93 as you know, Dale and I had a lot of conversations about this when

we ran some differential tests with GPS at Frederick, MD. They [RTCA Inc.] began to publish minimum performance standards for GPS CAT I approaches using differential. And very important, and probably overlooked by many was that fateful day in December when we finally passed IOC or the US Air Force declared GPS operational in the system for us to use as civilians. And just this year earlier in the year, Pres. Clinton remained committed to the international community to use this system in the U.S. And I think internationally, as I said a couple of weeks ago, this is of great concern to air carriers, to governments, to CAAs and other governing agencies for aviation in foreign countries. Some of it [is] mixed with politics [but represents] a real concern of [their] own government controlling a system and once again proving a need for a backup.

To the general aviation community, because you wanted to hear from users, this truly is not a concern. They just want the positioning information and they are using it big time. I would say that probably in that South Africa trip three years ago before IOC probably half of the airplanes at Lanceria Airport in Johannesburg, which is the key general aviation facility, were already equipped with some of the early rudimentary GPS receivers. Obviously, our goal is GPS as a sole means of navigation in all phases of flight. But I will tell you just from the three bags of equipment that I brought in here today, there is not a pilot that is prudent that cares about safety who would put general aviation among those that doesn't want a Plan B. Whether you are giving a speech and have it on computer and projector you're giving overheads or you are flying an airplane there's got to be a secondary system. But to have the ability to fly sole means as we do now with VORs or have done in the past with VORs but still able to take that NDB and tune in the local radio station if there is no NDB station provides us an alternative in this environment sometimes hostile of aviation.

In August of '94 the FAA published their implementation plan, and I put up these quotes because I feel they are very important. Most essential: Heavy reliance, heavy reliance on a satellite navigation system and they also indicated by the end of '97 users will [have] more GPS sole means services available than now provided by the conventional VOR, DME, and ILS systems and this to those of us in general aviation is a really important quote. Now, as far as civil aviation and general aviation is concerned their expanded service, the FAA announced, would include 5,000 non-precision approaches. This is extremely important to general aviation just as it was when we were at the forefront of lobbying for Loran approaches and had all kinds of pledges from our then administrator that these would be forthcoming, promises that were never kept. But we have to do the same thing now with GPS approaches.

If you take the typical plane and owner that I described to you, the 172, your real care is getting below the clouds. We're not running an air carrier service. Many aren't flying

in any really inclement weather. Fifty percent of the general aviation population has instrument ratings, but we're not trying to shoot that 200 and one-quarter of a mile forward visibility approach. We're really just trying to get below that cloud deck that may hover at 800 feet, 750 feet, and prevent us from legally using an airport in a VFR condition. So minimums of 500 feet and a forward visibility of 1 mile is sufficient for general aviation. And the thought of having 5,000 non-precision approaches to areas like Alaska for instance where there aren't any land-based navaids close to many of these village strips, to be able to use these stand alone is really important to the general aviation community. The FAA also pledged 2,900 CAT I approaches and oceanic sole means enroute and domestic sole means enroute.

Interesting story here. I was flying one of the international trips on one of the God-awful times I have to get on an airliner, about a year and a half ago and the United captain came back and saw me with the little GPS receiver in the window and I had it hooked to my laptop, and I was looking at a map, it was more of a display than he had in his aging 747 up front, and he was looking over my shoulder and thought, well, this is terrific. You know we start talking about GPS. And he says United just issued a NOTAM, a system internally the FAA use they for pilots, their hot tips things that they are not supposed to do and to do. They just issued a NOTAM that no United captain is supposed file /R that they are RNAV equipped and use a hand-held up on the glare shield because apparently many of them were doing that to be able to get direct routings from ATC.

Well what's really important once again, are stand alone GPS approaches. And in 1994, on July 23, the FAA published three of these approaches, very important we thought for general aviation. They promised us 5,000. I'll talk about that in a second.

So I guess the best way to illustrate the kind of activity that our users are really interested in would be to transport you back to Frederick, MD, about a year ago in July of '94, and take a look at the FAA Administrator and me stoking up the plane in the front of our headquarters building in Frederick, and flying an actual GPS approach, and there has been a lot of conversation about these approaches. Basically we have David Hinson, (for those of you who are not furloughed and here from the FAA), sitting in the left seat. A little unfamiliar flying a 172 as you' ll hear very shortly, but still getting a real kick out of it. He's a real general aviation pilot at heart and we are using the only box approved at the time, which was the Garmin GPS, approved for GPS non-precision approaches.

(Radio transmission in Frederick, MD)

Boyer normal type, Hinson italicized

And I'd say we're ready to go.

OK.

So go out here to the yellow line.

OK is there a parking brake per say?

Right here, but it's off.

Ok, it's off.

We are departing down RW5.

Boy it feels good too, I mean its really solid.

Beautifully made, it really is.

I don't know if you have flown with one of these yet or not, but this is a moving map.

I have not.

And basically what this does is shows us, see our location on the runway environment? There's RW5? This is going to show us these runway intersections as we come in.

I'll be darned.

All right. I'll handle radios if you don't mind.

I'm ready. Just give me a couple air speeds here.

65 for liftoff. Climb out at 75 or 80 whatever is comfortable. And that's it basically.

[On the video tape, Mr. Boyer and the FAA Administrator, Mr. Kinson, spend some time pre-flight checking the aircraft and discussing the approach. The aircraft is a Cessna 172 which AOPA is offering as a contest prize. Rather than an identifying number, the aircraft is referrrred to as "better than new" for this flight. Mr. boyer in person addresses the Conference audience:]

Basically the approach at Frederick is defined by 4 different fixes. We're not really using the Martinsburg Land-based VOR here we're just using it's latitude/longitude as far as position is concerned. SUSII Intersection was designed as the point that you join the inbound approach course and then BAKEE. Each of these boxes, and this needs a lot of standardization, each of these GPS boxes like the Garmon here, needs a little separate annunciator panel or switching box. And the industry has a lot to do for pilots who are single pilots flying IFR. But the display is much like a typical Loran. As you can see this auxiliary box at the upper left corner. The waypoint light is flashing and that means that we're very close; [within] one minute of the fix. And notice from the left here, we're going to Martinsburg, and by software alone it switches to the next waypoint automatically. There's a lot of workload reduced here for the single pilot. All the pilot, actually the Administrator, [has] to [do is] turn the HSI and it even tells you to do that if you have an HSI. Normally on a VOR approach we'd be tuning a different frequency to make that change. We'd be twirling the OBS knob, etc.)

[Back to the tape, now. The Administrator is flying the Frederick GPS non-precision instrument approach procedure. From the tape, Mr. Boyer's comments are in normal type and Mr. Hinson's are in italics:]

If you look quick, everything's in the middle.

Yeah, everything's great.

Bye the way, while I'm up here let me lobby on the GPS thing.

OK.

You know how we have, we know if the VORs have NOTAMS. The GPS NOTAMS system is screwed up.

OK.

It is not good. We're going to use these boxes. Stand alone. We need to know if satellite 13 is going to be available at a certain time. That ought to be flight service.

Have you written to us on that?

No.

OK. Write.

We just found it out.

[Mr. Boyer speaking in person to audience] I find that the best time to lobby to Administrator is when he is flying an unfamiliar airplane flying an unfamiliar approach. Basically as you can see we are going from Martinsburg, to SUSII. Once again, at SUSII we join the inbound leg to the RW5 environment. And like a Loran we're getting a countdown from GPS in hundredth of a mile, we're getting timing information. And I did put this up to show it to you because it is part of the approach procedure in GPS and we'll see that a couple of times later. Here we come to the way point, the SUSII way point where we join the inbound leg. As you can see we are 0.2 of a mile away. The Administrator's now going to turn to the runway heading of 050. Remember this is a non-precision approach so the decent, information the vertical guidance, is provided by the approach plate. Now we're going from SUSII to BAKEE, and BAKEE is the final approach fix where we let down to the MDA. Now once again, I am going to put up the CDI display. That is the course deviation indicator display. This is not normally something you'll look at during the approach. But basically we're at 1 mile full scale deflection of the needle. We're going to ramp down to .3 of a mile, but it is doing it very very slowly. And when it gets down to that point and it has all the correct satellite geometry, in other words RAIM, then the arm light there switches over to active and that means that the box is now able to fly the approach legally. Notice we're coming on to the final approach fix the waypoint light flashes again and we'll in just a second switch over from BAKEE to RW5 touchdown zone. This is really important because you have the ability to locate the touchdown zone.

[Back to the tape again:]

Now your [CDI] sensitivity, you may have noticed has changed to 0.3 of a mile.

Yes I noticed that. It showed me that I can't fly downwind. I've got a little wind.

All our lights are on. Pre-landing. Check gear.

We've got gas, mixture is full rich.

You're going here to 760. Frederick traffic, 172, "Better than new" is now three miles for straight in RW5. We're over the shopping center now.

OK. I'm coming up on minimums. Here is my minimum.

Just level off now

I'm going to bleed off to about 100 knots.

Now we're going to follow that needle until the box, until the thing flips and tells you that you should go missed. "Better than new" is two miles out straight in, just coming up on the gravel pit
for RW5.

Frederick traffic has "Better than New" in sight. We'll be turning base for RW5. You're doing fine.

Here we go.

Remember you've got 1.3.

Right.

Like I tell you, I think these minimums are too high.

OK. Well we'll sneak up on those. We think we can get this to 300 and 3/4.

Well, I mean here's your deal. And look how easy it was to follow. It's not squirrelly with GPS.

OK. I've got .7 of a mile. I'm staying on the needle, I'm staying on the gauges Phil...

That's good. I've got you. We're good on traffic.

OK. There's half a mile. I'd be look'in. Now we can make it. Ah, there we are perfect. I can land it with thin flaps, so we'll go around.

Now let's watch this. You stay at this altitude until you're on instruments.

Right.

"Better than New" will be making a missed approach at Frederick, reentering right downwind.

There it is now, there's your prompt.

I've got it.

OK we go direct to the missed [approach procedure] and here's what it tells you to do. Go to 055 the same heading; the missed approach [altitude], is 3,000 feet so let's just go to pattern altitude. All the way in. 80 knots and this is now taking you without [requiring you to do] anything.

That's the best part, I love it.

[End of tape]

You've seen it there, the satellites alone providing guidance for a non-precision GPS approach. And I can't tell you how important this is to general aviation in this country. I showed this tape in Alaska, and the operators who work with a lot of the medical flights or the people to these small Alaskan villages who have to operate now under special VFR conditions, and their VFR operations are conducted down to 1 mile forward visibility and 500 feet cloud height, and they have to do that because there's no other way to get sometimes 20 miles away to a village strip. If they could go into the clouds and make an approach like you just saw here they'd be able to do it legally and obviously without scud-running below canyons and down ferry routes over rivers, etc., much, much more efficiently.

Now I said there was work to do. The FAA pledged that we'd get those (remember those Loran approaches that each state had recommended, 10 per state?) They said we'd have 500 of those all done by the end of 1995. Well there are 12 non-precision approaches, and if my watch tells me right it's the 16th of November so I don't think they're going to get that much work done in the next 45 days particularly with most of the people not working. So we've got work ahead of us to hold their feet to the fire just as we did in the Loran environment, [when] they let us down on getting these approaches done.

One thing I want to do is just to step back a hair and bring you a message from general aviation loud and clear if you already don't know it. Cost is extremely important to those of us who fly small airplanes. In many cases, remember that $12,500 that magazine said that GPS would cost? In many cases that's as much as the cost of a used general aviation airplane. So we have a very huge sensitivity to cost. And the wonderful thing that GPS is bringing us is this kind of fact right here that the system will be used by far more than just aviation. Because those of us in aviation know that every time they put [on] a "made for general aviation" tag or "commercial" tag, well general aviation is about four times more than the cost of product and in commercial aviation it probably is 10-12 times more. Same product. So we are very sensitive to the fact that the aviation's share of the navigation market is going to drop and that means there are going to be a lot of other users out there. So let's go to another foreign environment. Right now in Japan, there are more than 350,000 cars equipped with a GPS sensor, moving map displays in the car and they're navigating around the streets, a very complex street structure in Tokyo using GPS. I was over there earlier this year and went to their equivalent of our Circuit City, our Best Buys. You know, the big department stores of stereo and TV sets. And go over to one corner of Circuit City and see this rack of car radios and car radio speakers for sale; after market products that you can install in your car so that you can get a better radio than it came equipped with. They have the same sized displays over there selling

after market for your car these moving maps. These sensors they run about $2,000. Installation runs about $250-300, and then there is a market in even the CD-ROM disks for the maps for the various areas of Japan. They are selling like hot cakes. But it's not just Japan. It's also here in the United States, where this year Oldsmobile announced a version of the Oldsmobile 88, that has the ability of putting a moving map display in it in Southern California. And those of you who might have participated sometime ago in Orlando, in the Trav-Tech experiment with Avis, the DOT, etc., now in Orlando there are 73 cars equipped with a state-of-the-art systems that you can buy and install in your car just as soon as the mapping is available.

[Playing a taped commercial for a system in a car]

Now the beauty of this thing is that you do not need to be a geographical surveyor to use it. All you have to do is punch in where you want to go and it will literally tell you the fastest route there. {the box is talking: Destination ahead} Now this device looks like a mouse, but it isn't. It is a satellite antenna and it picks up signals from space, a thing called the GPS, the Global Positioning System. It picks up these signals and it brings the signals to this box right down here and that's all there is to it. Now the guidance knows exactly where you are, but the question is where do you want to go? All you have to do is tell it. I say we are in San Francisco, let's go to Chinatown. The box tells you to go to the highlighted route. The cool thing is it's going to tell you where to go. I don't even need to look at this map. The tape shows how the box tells you there is a right turn ahead. The other person in the commercial is talking to people on the street trying to get directions. His chances of winning this little test are in doubt. The Guide-Star System is the perfect tool for the serious traveler. Immediately at hand are the quickest way possible routes to restaurants, airports, banks, emergency services and dozens more. You need an ATM? Punch in the bank name and scroll along until you find the closest one. You can follow a map or use the instruction [mode] which gives you turn by turn directions. He finds his destination of the shop with his test partner no where in sight. Guide-Star maps are constantly updated and contain the latest road information including routing for freeway and non-freeway travelers. It even knows one-way streets.

(Back to Mr. Boyer)

Now, for the first time I think a navigation system that will be used in aviation will be known to the general public. You won't be seen as a oddity [as] when you are walking down the neighborhood or the city streets saying ILS, NDB, VOR. Nobody knows what you are talking about. If you are a camper, a hiker, a boater, or whatever, GPS is definitely going to be a system that will be known to the community at large and not just general aviation and that has a cost impact.

I'll just briefly cover the interest we have in seeing how LAAS [FAA's Local Area Augmentation System] and WAAS develops. And really for general aviation the most important thing is how WAAS develops (the Wide Area Augmentation System). Will we be able to really make CAT I approaches with a differential correction from 29 stations covering the United States rather than having to have an individual box at an airport location? And once again, what will be the cost of entry for general aviation of this particular system? But just looking at the airline environment, and these are tests that were recently held [at] Atlantic City. And as you can see airliners that have to have zero capability, etc., definitely have been proving their point as far as using a local correction signal to come within very very close tolerances. FAA tolerances as a matter of fact, in landing an airplane. And we were pleased because if there was one thing we were sure of there was no way we would equip our airplanes, our general aviation airplanes, with an inexpensive MLS receiver. The two just weren't synonymous, and therefore we were quite [pleased] to see that the basic MLS orders totalling $1.4 Billion were canceled by the FAA last year. All in the hopes of course of the satellite navigation system. And AOPA by the way, since the middle 70's was a vocal opponent of what was really this outmoded technology.

Now, let's talk a little bit about the backup position. Let's talk a little bit [about] all this enthusiasm, all this fast track for GPS. Believe me, I truly believe in it. I think it is right for our members. I think it's right for aviation. But what do we use in general aviation to back ourselves up? First of all as you know the '94 FRP [Federal Radionavigation Plan] proposal to phase out the Loran system was [to] begin in 2005, and would be completed in 2010. Well we petitioned our DOT to make sure that Loran was available through 2010. Now why? Well, I show these two tapes at a lot of pilot town meetings. And afterwards pilots come up to me and say, "You know, I paid pretty good money for that Loran receiver in my plane." About 125,000 of my members put those in their airplanes. Now do I have to replace with GPS? Should I have to replace? And you know when we are talking about the environment they fly in, generally I use something facetious, like well if you're not going across the North Atlantic, if you're not flying in really heavy heavy IFR weather, and once again I am portraying a typical owner of a 172, is not somebody who flies in heavy weather, the Loran receiver is going to give you the same display that I just showed here from a GPS. Actually, GPS was built on all that micro-processor technology and there is no reason for you to have to upgrade at this time.

Well I don't mention to him what is going on in the user community as far as Loran is concerned. The members that do realize that as we publish these things in our magazine do come up and say, "Be sure you save the Loran system for me 'cause I really have no need at this time to upgrade to GPS." And that is one of the reasons we put in that petition. The same FRP said, NDB phase-out, now get these dates, NDB phase-out will

start in the year 2000 and be completed in 2005. VOR's will begin in 2005 and be completed in 2010. ILS would be into phase out in 2005, and completed in 2010. But then Loran would be terminated in the year 2000. So now you're taking away our primary backup for general aviation, something that users have put a big investment in, before you're taking away things away that are outmoded technology like NDB's, and VOR's.

There's a tremendous cost savings obviously. Seventeen million dollars a year to service the Loran. Hundreds of millions of dollars a year to keep all these things that they want to keep even longer. I am going to get to the cost thing in just a second. So let me give you a few quotes from memordanums that we have gone through and surveyed as far as various agencies and AOPA are concerned.

[Recording]

Every reasonable effort will be taken to ensure that Federal Radio Navigation services will continue to meet the diverse needs of the navigating public in accuracy, reliability, availability, integrity, coverage, operational, utility and cost. The FAA does indeed support the continued operation of the Loran-C system over the next 10-15 years as we transition to satellite technology. Some segments of the user community may use GPS with Loran-C. Others may use GPS plus geo-stationary satellites and still others may prefer GPS plus inertial systems. Each user segment should have the opportunity to evolve into a cost effective end-state system.
[Mr. Boyer resumes]

Basically there is a lot of support for the Loran systems as our primary backup to what we see on the fast track and that's GPS. So in review we called for a space-earth system in our "Future is now" document in 1990. We called for heavy reliance, or the FAA did, on a satellite-based navigation system and said that by '97 users will begin their traditional avionics package with GPS receivers. And I think our members are no less in that group. As a matter of fact, we just got through with a very successful AOPA exposition, in the worst place you can hold one, in Atlantic City, and you know the booths where the avionics manufacturers of GPS were just crowded with people and sales were very very brisk. And this year we told the Coast Guard and Maritime Transportation Sub-committee that Loran should continue, and the important word here is augment, the GPS system until it can be satisfactorily be established [that] GPS is reliable as a sole means system and we should maintain redundant systems to enhance aviation safety.

Well I put up these next steps and they seem to echo what Dale and others said this morning here at the podium. Critical will be the industry voices at the '96 FRP to carry this same message forward. And believe me AOPA will be there with this message on behalf of our members. (...)

To talk just a moment on a little different level because it does affect where we are going with all kinds of radionavigation products. And that's the subject of reform at the FAA. As you well know, several industry groups including AOPA have been against the administration idea of corporatizing or privitizing our air traffic system. The system that uses the systems you talk about for navigation. The good news is that the two year old ill-fated administration proposal is now dead. It's officially dead as a matter of fact. And we just surveyed our members on one of the most critical things about that legislation that was proposed. User fees. Nine out of ten of our members do not believe the user fees needed to enacted by Congress on general aviation to adequately fund the aviation system of the future. And this is one of the things we had a problem with in the corporatization model.

Second, the general public that never flies, that never flies an airplane themselves or never gets on an airliner to pay a passenger ticket tax, should a small portion 10-20 percent of their general fund pay for the operation of a national air transportation system.

Nine out of ten of our members believe that should happen. The person that never gets on an airline, whose life is enhanced by air-mail delivery, by getting packages by aircraft, or by having just some relative come visit by airplane and makes their life a little happier, to have an efficient national air-transportation system. But user fees concern us mostly because all of us, (we're talking about GPS backed up by Loran or INS or Omega or whatever) talking about safety. And under a system funded with user fees will it be safe? Now right now in Congress there are two sets of fees being talked about. Direct user fees to cover safety, certification, security. Well those of you will say, as many of my members did say, "Well we don't have security issues to pay for, we really don't have safety issues like the airlines to pay for big time, and certification: What does it mean?" Well let me tell you. I turned to my members and I turn to you. Those of you who depend heavily on the products in the avionics field and say the certification of products will now have a surcharge from the FAA in terms of the inspectors, in terms of the certifications process. If I go to install one of these new GPS boxes in my airplane and I have it signed off by the FSDO, I as an owner would have to pay to have the inspector sign off. Avionics shops, the manufacturers certifying new equipment, and here we are just beginning to build general aviation planes again. Cessna about ready to open a factory next year in Independence, Kansas. All the inspectors from the FAA that will be looking over all their shoulders during this new production time because of the product

liability reform, all those people will be charged back to Cessna. Who in the end will have to pay these costs? The user once again. It will be passed on by the manufacturer. So there is a big thing as far as certification costs are concerned.

But an important element and probably the most important to us are the direct user fees for using the air-traffic system. And I have just listed a few of the items that might be covered if we were have to pay. You know the joke is you call the tower and you might have to give your Master Card number before they would allow you to land. Just imagine the mechanism for collecting these fees and what infrastructure will have to be set up to collect these fees from people, and the Master Card analogy is probably not a too dumb. In Europe, Euro-Control has some 2,000 people in a Taj Mahal headquarters. It's been set up just for the collection of fees under the system that exists there. And I guess the best way to illustrate it is to take you back to a 172 again and show you how this would affect the users are in part of my community.

[Recording excerpt]

Good morning for Cessna 99441. Cessna 172 I would like VFR weather briefing Teterboro to Poughkeepsie, departing Teterboro in about 30 minutes.

[Ring of a cash register]

Teterboro ground Cessna 99441 with Yankee will be VFR.

The cost one-way is $71.15.

(Mr. Boyer)
And our FAA Administrator says that this won't affect aviation safety! And that's the one thing in general aviation that we can be quite proud of. Last year we closed with the lowest number of total accidents and the lowest number of fatal accidents that have ever occurred since WWII in general aviation's history. And by the way, all you have to do is look at the safety records in the countries that do have user charges for the ATC system and you find pilots who don't get the weather because there's a charge, who decide, "Well I'll take a chance; I'll scud-run because I don't want to have to pay to get into the IFR system." Now, what's going on? Well there's some positive and there's some negative. And once again this all affects the funding, the R&D requirements and the other things. First of all some good news. We have the appropriations process and the authorization process. If you don't understand any of this just remember in this scenario that I am going to present for the rest of the speech, the Senate are the bad guys and gals

and the House are the good people. So we want you to support the House not the Senate.

All right. Let's talk about what happened just a couple of weeks back. The Senate in this case, had $10 million worth of user fees, a very minuscule amount; probably would have cost them $30 million to collect it, but they had $10 million of user fees in the appropriations budget to sign off on FAAs budget for 1996. Who would have to agree to these fees? Well the House had no fees. They got the Conference to finally pass the appropriations bill without the fee structure in it. So a win. But very very important, "win" probably goes beyond no fees in the appropriations process and that is the language that was used when they reported out why they did not put the fees in.

[Recording]

The conferees have not yet seen adequate details from the administration demonstrating the unequivocal need for new fees, an explanation and justification of the specific fees to be imposed or a convincing argument that the FAA's cost structure is in such exigency that new fees or taxes are necessary. There will be substantial savings achieved through the FAA reform provisions enacted in this Bill and the broader revisions currently under consideration in the authorization process. Such cost savings combined with further review of the agencies cost structure could obviate or minimize the need for additional fees.

(Mr. Boyer)
I think for all of us in this room that's very, very important language to have written into a Bill that [is] now awaiting the signature of the President as soon as they get through the little hassles they're in now about airline seating and doors that are used getting out of airplanes. The '96 Appropriations Bill that is sitting there waiting for signature basically funds the FAA at about the same level as last year. [This is] of critical importance because we can talk about navigation, but we've got to have a place to put these airplanes down, airport funding which could have been cut to as low as $1.2 billion remains at $1.45 billion. So that's very, very encouraging. I must tell you though that $1.8 billion was the number we were using in years past. A dramatic decrease in research dollars. A dramatic decrease as you can see is probably the line item of the year that probably has some of the biggest as far as percentages got cut. And that is critical as far as the FAA is concerned. But this budget is just waiting signature right now.

Now let me turn to the authorizing side. The people who are both in the House and the Senate once again I want you to remember Senate bad, House good, as far as our position is concerned at least. Let me put up here a couple names that I think are important. The sponsors of a new Senate Commerce Committee bill are McCain from Arizona, and Ford

from Kentucky. What's critical here is not their names or where they are from but the fact that there is an R and a D that means that all of a sudden these people who haven't been talking to each other at all are now co-sponsoring a Bi-partisan Bill. And of course for any of us who work inside the beltway that is something we don't like to see because that means they have gotten together and we can't pit them against each other. And this has caused us a lot of trouble. Then on top of the whole thing, when I told you the Administration proposal was dead was because the White House has now endorsed this Bill. So not only do we have the Republicans and the Democrats together we have President Clinton and Al Gore saying we're for this Bill; we'll rid ourselves of the Quasi government corporation. And of course there is a companion Bill to this in the House of Representatives. So this causes a great deal of angst at the moment. Now what is even worse is last Thursday, this piece of legislation passed the full Senate Commerce Committee. And this Bill would impose user fees. It passed by a vote of 12 to 7, despite a valiant effort by Senator Ted Stevens from Alaska, who certainly understands the kind of safety impacts and aviation impacts that a Bill with user fees would have on the system.

Now one of the things I think you should understand. Our members truly believe we should have a balanced budget and I think that this is what this aimed at, one of things we're not really in the fray of the fee structure here whether it be general aviation or military, etc., what we are into is a battle between the big airlines and the small airlines. And when I say small, I am still talking about some very profitable airlines like, Southwest for example. As a matter of fact so you best understand this issue if we go back to how our system is funded. It is funded by fuel taxes for general aviation and passenger ticket taxes by those of you who ride the airlines and by a small contribution from the general fund. What they're saying is let's eliminate that very effective and efficient system and let's put in these user fees and set up an infrastructure to collect them. And the people supporting this seem to be the large airlines, why? Because American and United and others are seeing the upstart airlines Southwest, AmericaWest and Reno Air, coming in a taking away passengers.

Think about it for a second. I can go to Chicago, to the Washington area for about $550 on United. I can go round trip on Southwest, Baltimore to Midway, same city structure almost for $99. Now think about how this system is funded; a 10 percent ticket tax. So the American passenger American Airlines is saying is paying $55 into the system. And yet, we are only getting less than $10 from the Southwest passenger and we are flying to the same place using the same routes, using the same structure. So the large airlines say the way to kill off these upstart airlines, hurt the general public who benefits from lower prices on tickets, is to make the small airlines pay a user fee the same the big ones do for using the system rather than the ticket tax which adversely affects them. And this is

really the crux of the matter, not general aviation or business aviation or anything else.

The Commerce Committee said to some of the members who were in dissent, why don't you come with your own way to do things. And by golly, when I say valiant effort by Ted Stevens, he carried [in] a formula that AOPA worked very closely on that we called Linked Financing. And basically it was is a different look at how to continue to use the ticket tax and the fuel tax, but allow it to fluctuate as the proven need of the FAA to use the money was there and the problem is that if you raise more money for the FAA that way by increasing the tax or decreasing it as the case may be, the problem is you sit with spending caps on the aviation trust fund. So what we were asking [was] to make a discretionary change in the cap every time you change the tax. As a matter of fact, it was embraced by a lot of people but a little too late and by 12 to 7 the committee voted for the McCain Bill.

Now what is very important before I have you go out of here slitting your wrists like I did last Thursday almost, is to get the details. First of all on this Bill, there were six Republicans voting against it. Now any time you can get the party that's in control of the Congress to have this much support against a Bill makes it that much harder to get to the Senate floor for a full vote. Now look at some of the people. Stevens should be no surprise to you. Senator Larry Pressler, is the head of the entire Commerce Committee. McCain works for him. So it's very good to see that the head of the Committee voted against this Bill. We have some other surprises in fact. As a matter of fact, the Democrats voted as a bloc. But Inouye was a sole Democrat who voted on our side of the Bill, and very important, Southwest Airlines, and American Airlines, are housed in Texas. It is obvious that the Senator Kay Bailey Hutchinson, from Texas, doesn't believe the lobbying activities; perhaps she heard from American. Or does it signify that maybe the large airlines now are no longer considering this as the way to go?

Now there are a few good things in the Bill. Five year appointment for the Administrator. I've been in this job 5 years, I have known five Administrators or acting Administrators. It that any way to run a $9 billion dollar company? A 50,000 employee base at least when they are all working and not on furlough. There's a 15 member advisory council that can be made up of general aviation, the airlines, airports, etc. There are a number of Federal procurement and personnel rules that would be changed, and these are the things that really need to be addressed. And it would give funds out for a three year period, rather than this year-to-year appropriations process where the FAA can't plan for instance on future radionavigation systems because they only have funding for one year out. But the erroneous part of this would be that effective after 45 days of the Bill there would be these certifications. Remember safety certification, and security

fees unless Congress disapproves of them. Now disapproves of them, it's a negative option almost.

My wife's a member of a book of the month club, and she always says, "OK I can always cancel the book. They will send me a little thing, and I send it in, it's OK." I keep seeing books arriving in the mail. And this is the crux of the negative option. Do you think Congress is going to have the FAA go to them and say that we need these fees for the safety of the system and then have Congress disapprove them? Absolutely, not. What's even more erroneous to use however, are air-traffic control fees. Within one year they have to develop these. They once again are effective unless Congress disapproves them, and they are affective for three years and then they can be renewed. Now we polled our members in the 19 states, I think it was, that are represented on the Commerce Committee. We sent a two-page Western Union letter to them, and we basically said, "Don't allow them to raise these user taxes." As a matter of fact, here is one of the letters that went to Hutchinson that speaks about the fees in Europe, how hard it is to administer these fees in Europe, and how counter-productive they are to safety. Maybe that's one of the letters that did some good. Or here's a physician that travels to small communities and is saying to his Senator, that if this happens probably I would not be able to provide service to many of the out-lying areas. Or to Senator Ford, who really was one of the co-sponsors and somewhat of a turncoat on general aviation in this case, and this is telling it right. "We don't need back door means, and that's what this is, back door taxes. Don't call it a user fee, call it a user tax put upon us."

Well finally the Department of Defense, and I see some of you are here, weighed in on this issue also. Remember that the DOD would be asked to pay user fees also, and they're a pretty big user of the system. They're pointing out that military controllers provide about 6 million ATC services a year to non-military aviation. The crux of this whole thing is that the FAA says that in the seven years to balance the budget we're going to have to spend $59 billion dollars, and Congress has outlined for them to only have $47 billion or a $12 billion short-fall. Well the big thing I ask you to ask and continue to ask is there really going to be a $12 billion dollar short-fall? They're even talking now about amending that. In a recent meeting, as a matter of fact, the Administrator was talking to all of us in the aviation community about the woes of this $12 billion dollars, and he says now here's how we expect this to work. Through user fees we'd raise $5 billion dollars. Through the personnel and procurement reform we'd raise $2.5 billion dollars. And from the DOD if this isn't the biggest joke I've heard, we would $2.5 billion dollars.

Now you know our Administrator's name as you can see from the tape is David Hinson. I said this is going to be the David and Goliath negotiation. Can you imagine a little

FAA going into the big DOD which provides these 6 million services a year already and start negotiating for $2.5 billion dollars of the Defense budget to pay user fees and for the use of the air-space, etc.? Well we add that up, and you don't need a calculator; it comes to $10 billion. That's still a little short. So our Senior Vice President, many of you know Steve Brown, said to the Administrator, "That's short of the $12 billion dollars." "Oh that's all right" he said. "It's close enough for Government work."

Now the good news on the other side, remember I said House good news is that they have been working on a Bill called the Federal Aviation Revitalization Act of 1995. It was introduced on September 7, and it passed the full committee. This is the new Public Works Committee just a few weeks ago. And it was a unanimous vote, there was not split like I showed you between Republicans and Democrats, and this particular Bill creates a fully independent FAA, it takes the trust fund, our user fees, off budget so that instead of reducing the Federal deficit with the money we've paid in the aviation trust fund it can be used for purposes that we're all about in this particular session in these couple days here, personnel and procurement reform, and it's sets up a three member board, five members actually, two are non-voting members that would run the FAA very much like running a business. Appointing a CEO, who would be the Administrator validating some of the decisions, etc. Well, of course, this was immediately opposed by our Secretary of Transportation, who knows as we know a great deal about aviation particularly about building airports that can run $3 billion dollars over budget. And here's his quote, "I would recommend the President veto any Bill to establish an independent FAA."

At any rate, Dale I'm sorry to take time away from radionavigation but I think this issue should at least be on the table as far as funding is concerned because it's one we're going to be with for quite some time, and when you ask what is on the users minds this is probably primary on the users minds. And then how to use the system that is designed in the future. AOPA membership is at 341,604 at the end of last month. That's 52% of all certificated pilots, and up some 40,000 while the market place is been down 50,000. I say this because I hope to leave you with a comfort factor that these members are also voters. We are not a trade association. We are an individual membership organization. There is no business or associate membership to AOPA. It's just one membership individual. And these people are very active voters. For instance in the '92 election nine out of ten AOPA members voted in that Presidential election. The average for the general public 55%. [In the election on] November 8, last year, just about the same number nine out of ten AOPA members voted in that election, 38% of general public voted. And you what, our Congress knows this. The people we call on do know that we have an active group. We rally them into letter writing campaigns. We're using more sophisticated telephone campaigns, etc., through our Washington lobby group AOPA

Legislative Action. So therefore, to put a spin on this to where we're going with [this] particular issue rather than me telling you, let me give you a quote from the Speaker of the House:

[Recording]
Mr. Boyer: The proposal to corporatize or privatize ATC so far in the early hearings have gotten anemic support.

The Speaker, Mr. Gingrich:
One of the keys clearly is how do you get the airline, the aircraft owners and operators to decide that they have a vested interested in it. What you get of course, is that the private aviation folks don't want to see an air-traffic control system dominated by the scheduled carriers. And so we have not found a way to resolve this. I have asked some of the carriers to go back and sit down and talk to the AOPA and really look at, is there really a way to structure control so that everybody has a fair sense of involvement because you probably can't pass the Bill against AOPA's determined opposition.

[Mr. Boyer resumes]

At any rate, that allows me to sleep at night with all that goes on in Washington, thank goodness. Maybe [I] shouldn't. I'm not sure, with what I see. Dale said we have just a few minutes for any questions. I'll try to provide answers.

Question:
A couple of comments that are relevant to [what you're] saying to the Conference. You referred to the vehicle location systems by Japan. I just want people to know that my knowledge of every vehicle location system that's out [in] the public now contains either a dead-reckoning backup compass system or map, and show they are very redundant systems so basically I think the point is that as history already recognizes GPS is not infallible and they are developing some support systems. (...)

Answer:
Just for the tape, I guess the comment here being that the vehicle moving map displays do use ancillary systems for position accuracy in many cases dead-reckoning. And you are absolutely right. The vehicle, the situation I say in Japan uses the wheel speed and actually the installation cost is basically in that equipment, and if you try to take as I have done, take a GPS receiver, a moving map of streets, you'll find yourself over in the ditch driving or one street away so the accuracy and the positioning is probably less for redundancy but just to provide extreme accuracy in terms of putting you on the road that

you're on, and then there are some very complex algorithms to place you on the proper highway.

Question:
Phil, I was wondering what your feelings are on legislation that just came out directing the FAA to commence the installation of the Loran automatic blink system that people know sort of removes any main questions on the reliability of Loran blink. I do think the FAA will do it. They can't get around this and people will question.

Answer:
It's hard for me to prognosticate because you know I'm working on issues like this. We are totally in support of that aviation blink. It was supposed to have been done before. I think it is integrally tied into the tables I put up there. [We have the] ability to tell them how very very important this is. In terms of trying to predict what is happening now, I thought everybody would be back to work today [referring to the Government shutdown]. So I'd better not go out on a limb here.

Question:
I was very interested in your cost [sensitivity] in general aviation and also the dates you gave from the Federal Radionavigation Plan. It talks about phasing out equipment between the year 2000 and the year 2010. As I understand at the moment that GPS will be free to the civil community for 7 years from 1994. What do you think is going to happen after that period? Who's going to fund the GPS project?

Answer:
Well, if we have anything to say [about] it our Government will continue to fund it. It's going to be once again one of these difficult mechanisms to collect. I note from your accent that you may be a part of communities in which they face some of these issues like broadcast licenses of state broadcasters, and so a license fee is attached to the receiver purchase. That is one of the things that has been talked about in terms of the funding of the system down the line in the future. But once again, it's going to be very difficult because of its free availability. Probably the things I would sense on the horizon [are] that we might first pay for might be the correction signals to [serve] certain users that need greater accuracy. There would be charges that [are] there now from private companies for that kind of service.

Question:
Dave Scull, Secretary General for the IAIN. First Lieutenant in the Virginia Wing of the Civil Air Patrol. My question deals with the aviation trust fund. One nice thing about it was it was you felt like your aviation fuel taxes were going into that fund, and even

though Congress maybe wouldn't let the FAA spend money to improve airports from that fund at least it was identified. Now with this Senate Bill, if that is passed, will we no longer have an aviation trust fund?

Answer:
The Bill is actually complex in terms of if the trust fund; there are limitations on the user fees they can propose. But basically it's a myth that the trust fund is there for aviation purposes at this point. And what's very interesting is the Senate language goes into, and we guarantee these user fees will be placed for aviation purposes, and we go back and look at when the trust fund was established that's exactly the same language that was there. Now if we believed them then and it didn't happen why should we believe them now?

The key thing is that if the passenger growth (it's all airline oriented here) occurs that the FAA is projecting, the trust fund could grow to as much as $17 billion dollars if you just leave the system the way it is. And the key is we've got to be able to get at that money. The key is we must be able to do something like that. But you're right. This user fee system is, rather than addressing the problem, the Senate is saying, "Well we've got to have more money, we can't get it here, let's go around and create a new piece of legislation, we'll call it a fee then we control it." If it's a tax we don't control it. And what we're trying to do is maybe we ought to look at how trust funds operate.

The House Bill's going to have the trust fund off budget. That's going to be a tough row to hoe even with the Speaker of the House who gave us some support there. That's going to be tough. There are a lot of powerful people behind it. We're all for it. So if we say, well, Plan B if the trust fund doesn't go off budget, [there had] better be a way to get some more money out of the trust fund, and maybe it's as these enplanements go up as they're predicting that general aviation's going to increase by 7% over the next 7 years. There is nothing, and I work in this industry 80 [hours] a week, that says that general aviation is going up. It's been dropping dramatically. So we're got to figure a way to get at that money in the future.

Question:
John Beukers: Just as a comment Phil. It is my understanding that in fact the aviation trust fund cash does not exist. That money is used to decrease the deficit. In fact [if] it goes back into the trust fund to be used, we increase the deficit.

Answer:
That's correct. And this is a problem and one of the reasons we want to take some of the caps off. There's anywhere between $4-6 billion dollars that's just used for that purpose

at the present time. And this is one of the reasons that on a scale of 1 to 10 I'm not going to give a 10 that the trust fund ever [goes] off budget, because it would then affect what both Republicans and Democrats want to do and that is balance the budget.

I thank you very much for your attentiveness. Pardon me for a little bit of the political talk. Nobody believes in the future of both the GPS system, or the backup that all of us pilots have to have, the Loran-C system, more than we do. We know it's a wave of the future. Our members encourage us along these lines, and I think as an organization we're very compatible with the aims of this particular industry group. Thank you very much.

Dr. Kane:
I've been very fortunate to have the help from Ian and Dale in having individuals come and talk about their individual user requirements. So the next speakers will deal with segments of the systems that use GPS and other radio navigation aids. Those of you who saw the newsletter we put this time last year, saw on the back of the GIA newsletter that the number of users are in about 123 different categories in 10 major types of users. So I was very happy to see Phil emphasize what is going on in a piece of that population which we now believe numbers in the millions. The number of applications keeps growing every day as you will hear in these technical discussions. So my thanks to the individuals who have come and I would like to turn it back to Dale to introduce our first speaker on user requirements.

Radionavigation Users Conference

AOPA President Phil Boyer
November 16, 1995

The future is now

The future is now

AOPA white paper, 1990 — *Aviation: The Future is Now*

- "Technology has advanced to the point where implementation of a hybrid air traffic system linking satellites with a ground-based system for communications, navigation, and surveillance is feasible..."

GPS "fast track"

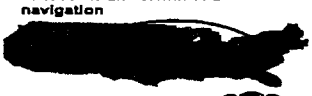
- June 10, 1992: FAA recommends establishment of "overlay" non-precision approaches

GPS "fast track"

- July 20, 1992: FAA authorizes GPS for aircraft with multi-sensor RNAV to conduct IFR operations in oceanic, domestic enroute, terminal area, and nonprecision approach operations

Global Positioning System

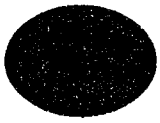
- Approved as <u>supplemental means</u> of enroute and terminal area navigation



GPS "fast track"

- December 1992 - July 1993: FAA authorizes GPS as <u>supplemental</u> system for oceanic, enroute domestic, and terminal operations

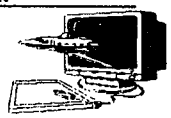
Global Positioning System



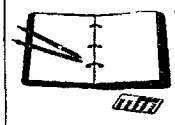
- Approved as <u>primary means</u> of oceanic/ remote airspace navigation

GPS "fast track"

- January 1993: FAA begins to examine possibility of GPS approval as <u>stand-alone</u> means in oceanic areas



GPS "fast track"



- August 1993: FAA publishes minimum performance standards for GPS Category I precision approaches

GPS "fast track"

- December 1993: U.S. Air Force declares GPS operational (24 satellites)

Global Positioning System

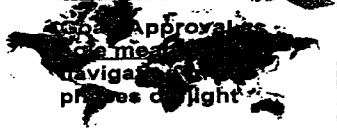
- Constellation of 24 satellites
- System designed by DoD
- Accuracy for civil use: 100 meters
- Made available to entire world

President Clinton says,

- "The United States remains committed to provide GPS signals to the international civil aviation community and to other peaceful users of radio navigation and positioning systems."

March 16, 1995

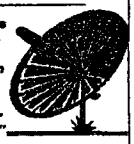
Global Positioning System



GPS "fast track"

- August 1994: FAA publishes GPS implementation plan —

"The FAA is embarked on an ambitious modernization program.... most essential, heavy reliance on a satellite-based navigation system...."



GPS Impact on Civil Aviation

- "By the end of 1997, users will have more GPS aois means services available than are now provided by the conventional VOR/DME/ILS system."

FAA, April 1994

GPS Impact on Civil Aviation

"This expanded GPS service will include:

- 5,000 nonprecision approaches
- 2,900 Cat I precision approaches
- oceanic aois means enroute
- domestic aois means enroute"

FAA, April 1994

Global Positioning System

- First stand-alone approach flown in July 1994 (FDK)
- FAA to add 5,000 over 10 years

Global Positioning System

- Worldwide market will quadruple by 2000, but aviation share will drop from current 7.3% to 4.4%

Global Positioning System

- In Japan, 350,000 cars are already equipped with GPS

Global Positioning System

- Microwave Landing System

Global Positioning System

- ~~Microwave Landing System~~
- MLS orders canceled June 9, 1994

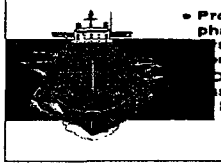
New terms

- **WAAS: Wide Area Augmentation System**
- **LAAS: Local Area Augmentation System**

LAAS

- 100 "hands-off" Cat 3 approaches (ACY)
- Within 6.4m horiz, 3.7m vert at threshold
- All autolands within zone set by FAA

1993: Hearings on 1994 Federal Radionavigation Plan



- Proposal to begin phase-out of loran
- stem in 2008, to be mpleted in 2010
- OPA petitions DoT to sure the availability loran through 2010

1994 Federal Radionavigation Plan

- NBD phase-out to begin 2000, completed 2008
- VOR/DME phase-out to begin 2006, completed 2010
- ILS phase-out to begin 2006, completed 2010
- Loran terminated in 2000

Internal Coast Guard memorandum

- "I am very concerned that our multiyear budget strategy...may be driving the USCG position on Loran-C termination towards a precipitous year 2000 or earlier date rather than allowing the deliberative process we've used in the past to establish a credible and defensible agency position."

Oct. 26, 1994

Internal Coast Guard memorandum

- "This talk of an early shutdown date, contrary to Federal policy, and being driven solely by our budgetary considerations, is generating a growing ground swell of concern domestically and internationally. Quite frankly, our customers are starting to question our integrity and motives."

Oct. 26, 1994

Internal Coast Guard memorandum

- "This 'year 2000 shutdown' is contrary to my understanding of what our policy and strategy regarding the Loran-C termination to be."

Oct. 26, 1994

Letter to Wild Goose Assn. from USCG Commandant

- "Every reasonable effort will be taken to ensure that federal radionavigation services will continue to meet the diverse needs of the navigating public in accuracy, reliability, availability, integrity, coverage, operational utility, and cost."

May 4, 1994

Letter to Wild Goose Assn. from FAA assoc admin

- "The FAA does indeed support the continued operation of the Loran-C system over the next 10-15 years as we transition to satellite technology."

May 10, 1994

Letter to Wild Goose Assn. from FAA assoc admin

- "Some segments of the user community may use GPS with Loran-C; others may use GPS plus geostationary satellites (the WAAS); and still others may prefer GPS plus inertial systems."
- ***"Each user segment should have the opportunity to evolve into a cost-effective end-state system."***

May 10, 1994

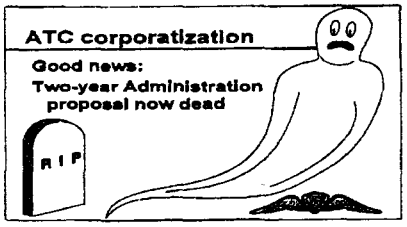
A review

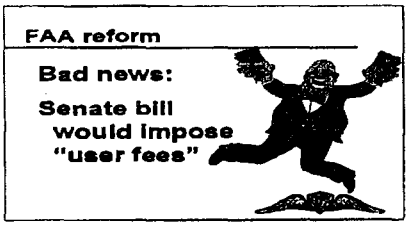
- 1990: AOPA calls for a "space-earth system"
- 1994: FAA calls for "heavy reliance on a satellite-based navigation system," and says that
- By 1997, users will "begin to replace their traditional avionic equipage with GPS receivers."

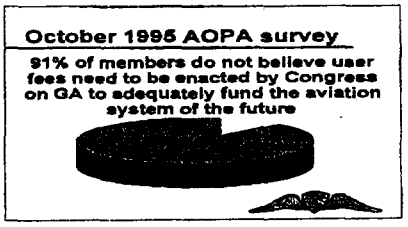
In 1995

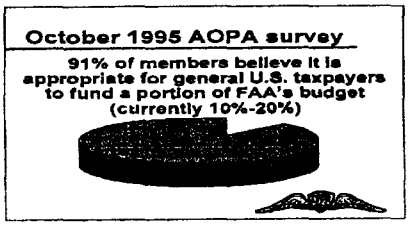
- AOPA tells Coast Guard and Maritime Transportation subcmte that loran should continue to "augment the GPS system until it can be satisfactorily established that GPS is reliable as a 'sole means' of navigation" and "maintain redundant systems to enhance aviation safety."

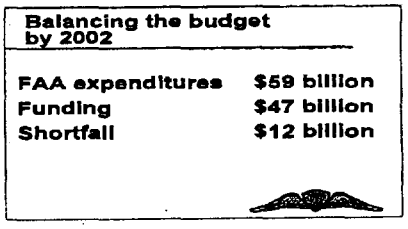

CORPORATIZATION
ATC
PRIVATIZATION

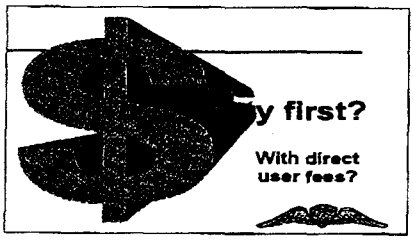

ATC corporatization
Good news:
Two-year Administration proposal now dead
R I P

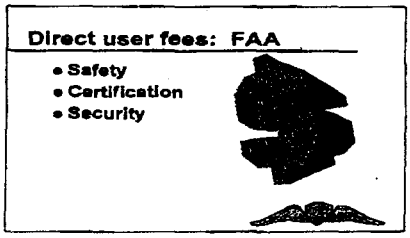

FAA reform
Bad news:
Senate bill would impose "user fees"

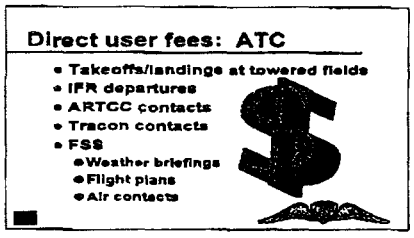

October 1995 AOPA survey
91% of members do not believe user fees need to be enacted by Congress on GA to adequately fund the aviation system of the future

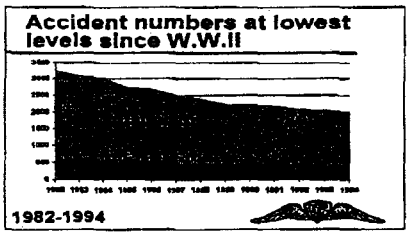

October 1995 AOPA survey
91% of members believe it is appropriate for general U.S. taxpayers to fund a portion of FAA's budget (currently 10%-20%)

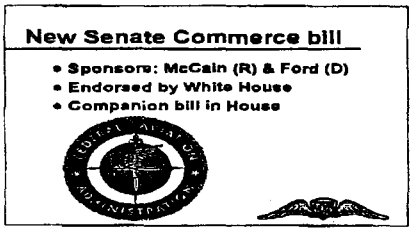

Balancing the budget by 2002
FAA expenditures $59 billion
Funding $47 billion
Shortfall $12 billion

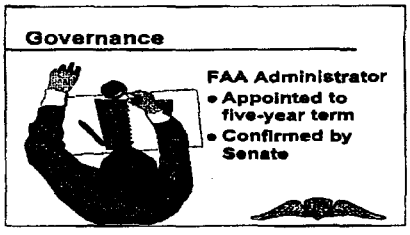

y first?
With direct user fees?


Direct user fees: FAA
• Safety
• Certification
• Security

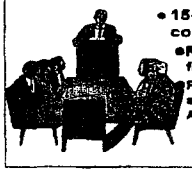

Direct user fees: ATC
• Takeoffs/landings at towered fields
• IFR departures
• ARTCC contacts
• Tracon contacts
• FSS
• Weather briefings
• Flight plans
• Air contacts


Accident numbers at lowest levels since W.W.II
1982-1994


New Senate Commerce bill
• Sponsors: McCain (R) & Ford (D)
• Endorsed by White House
• Companion bill in House


Governance
FAA Administrator
• Appointed to five-year term
• Confirmed by Senate

Governance: Mgmt Advisory Council



- 15-member advisory council would:
  - Review budgets and fee policies
  - Provide management advice to FAA Administrator

Personnel & Procurement

- A number of existing requirements under federal Procurement & Personnel laws may be waived

Certification/licensing fees

- Effective 45 days after submitted, *unless Congress disapproves*

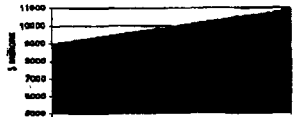
Air traffic control fees

- FAA must develop fees within 1 year
- Fees effective unless Congress disapproves
- Effective for 3 years, then can be renewed

Multi-year appropriation

- Bill requires that FAA funds be appropriated for 3-year periods

FAA outlays



FY1995-FY2002

Balancing the budget by 2002

FAA expenditures	$59 billion
Funding	$47 billion
Shortfall	$12 billion

Balancing the budget by 2002

User fees	$5 billion
P&P reform	$2.5 billion
DoD	$2.5 billion
Total	$10 billion

The $2 billion difference?

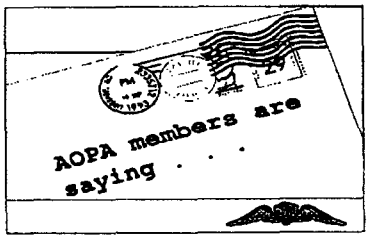
"Close enough for government work."
FAA Administrator, September 13, 1995

DoD weighs in at last on Senate bill

- Pentagon ATC chief: It's a "myth that DoD imposes a large cost on the FAA...In fact, we off-load [FAA] costs."
- Military controllers provide 6 million ATC services a year to non-military aviation

AOPA member support

- 2,000+ letters
- Western Union letter campaign
  - Commerce Cmte states
  - "Do not allow these added taxes!"



Duncan-Lightfoot bill

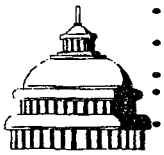
- Immediately opposed by Secretary of Transportation Pena

Duncan-Lightfoot bill

- Immediately opposed by Secretary of Transportation Pena

"I would recommend the President veto any bill to establish an independent FAA."

FAA reform within government



- Companion bill in Senate
- Inhofe-Burns-Kassebaum bill (S.928)
- Introduced June 15
- Similar reform initiatives
- No five-member board

FY1996 appropriations

- House/Senate Appropriations Conference Committee action:
- Senate provision for $10 million in user fees deleted
- New Personnel & Procurement language included

FY1996 appropriations

	FY95 (millions)	FY96 (millions)
Airway modernization (F&E)	$2,087	$1,935
FAA operations (O&M)	$4,595	$4,646

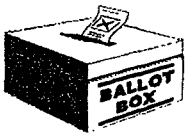
ATC corporatization

Good news:

House aviation subcmte passes Duncan-Lightfoot bill for independent FAA

AOPA Legislative Action

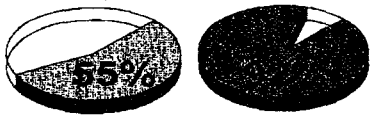
AOPA membership



341,604 members = voters

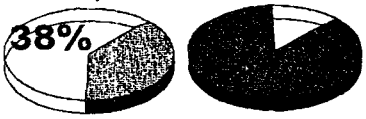
Voted in 1992 Presidential election?

General public | AOPA members

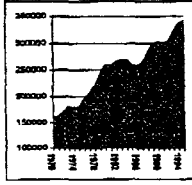


Voted in 1994 mid-term election?

General public | AOPA members



AOPA membership: 341,604



- More than half of all certificated pilots
- Up 40,000 since 1990, while pilot population dropped by almost 50,000

Questions and answers ....

Introduction

Dale Johnson:
Thank you Dr. Kane. I do want to say that this is not an aviation conference. We will move on to other things too. But, the next gentleman that is going to be speaking Mr. John Olcott, known to all of his close friends as Jack, is the National Business Aircraft Association President, and has been for most [of] the '90's. He was previously the Vice President of McGraw-Hill, and those of us in the aviation community who read Business and Commercial Aviation for years, Jack was the publisher of that magazine for about 15 years, I believe, '78 - '92. He's been a part of the aviation industry for over 30 years. Jack is highly respected by everybody that knows him as being one who tells it very accurately and the way it is and I am very happy to have Jack able to be here to address us today. Jack is an airline transport pilot rated in many of the corporate jet aircraft, he is also a commercial helicopter pilot, he has a lot of hours in the air and he holds a Masters Degree in Aeronautical Engineering. So please welcome Mr. Jack Olcott.

[Mr. Olcott excerpted materials from "National Business Aircraft Association Survery, 1995," National Business Aircraft Association, Inc., 1200 18th St. NW, Washington, DC, 20036, September 1995. For Further information call NBAA at 202-783-9000.]

Mr. John Olcott, President, National Business Aircraft Association

Thank you very much Dale, it is really a pleasure to see such an informed group of people. You certainly represent the community that has the most knowledge on GPS and long-range navigation systems. The objective that I have this morning is to describe the state of business aviation and give you an indication of the needs of the business aviation community in particular for GPS, but in a more general sense a fully capable world-wide navigation system.

Let me start by saying what is Business Aviation? We heard an excellent presentation by Phil Boyer. Phil represents individuals who use general aviation for a variety of purposes. Pleasure, personal business, other aspects of business transportation. Our association, the National Business Aircraft Association, represents companies, not individuals but companies. Companies that use general aviation aircraft for business

transportation. Not only domestically but internationally. I'll try to describe the trends that we see within the business aviation community. In those trends I will emphasize there has been steady growth in this community since about January of 1992. To give you an idea of the size of this community, and I'm going to concentrate now on turbine powered business aircraft. Turbine powered means either a jet engine or a turbo-prop power plant. You can see from this particular view graph that there are approximately 10,000 turbine-powered business aircraft operating in the United States. That number has been growing since about January of 1992. Those 10,000 aircraft are operated by approximately 7,000 companies. The low point in the number of companies operating business aircraft as the economy turned down [occurred] in the early '90's, and as some of the changes occurred within American industry as a result of the flamboyant period in the '80's, the number of flight departments reduced to about 6,700 but it has been growing since the beginning of 1992. And now numbers a little over 7,000 U.S. companies operating turbo-powered [aircraft] for business transportation. If we look at the world-wide size of this community we find that world-wide there are about 16,500 turbine-powered aircraft operating. This does not include any airliners or commuter aircraft; these are aircraft operated by companies for business transportation, and those 16,500 aircraft are operated by approximately 10,000 companies world-wide. I think it is significant to note that about 2/3 of all the turbine-powered aircraft used for business transportation and 2/3 of all companies world-wide that are using business aircraft are in the United States. So the United States is a key player in the international community for GPS long-range navigation systems.

The overall trends that you will see within this community are increasing needs for travel. As the economy has been expanding since the early 1990's, and as international market opportunities are burgeoning, there has been an increasing need for travel internationally. And I will point out in just a minute the type of international activity our member companies have. But I want to also emphasize that there is an expanding need for travel domestically. If we look at the domestic needs for transportation we need to examine what is available today. The airlines provide excellent service. Airlines service approximately 550 locations in the United States. About 330 locations are served by your major air-carriers, and approximately 220 additional locations are served by commuter or regional air-carriers. In the United States domestically, there are about 550 locations served by scheduled airlines. However, 75% of all airline passenger enplanements occurred at only 55 locations. Turbine-powered business aircraft ranging let's say from a King-Air on up to business jets, can serve approximately 5,500 locations. So what I want to emphasize is that business aircraft can serve 10 times the number of locations with any scheduled service and 100 times the number of locations with convenient service. This is an extremely [important] element in understanding business aviation. Business aviation brings the flow of commerce [even] to locations that

otherwise would not have access to air transportation. Business aviation is an integral part of the nation's air transportation system. And as such, it is important to the growth of the economy of our country.

Throughout history travel capabilities, transportation resources and transportation capabilities have always driven the economy. Go back to the time [of] Solomon, 3,000 plus years ago. The wealth of his kingdom was to a large extent was dependent upon being able to trade over a large region, and he had the transportation system of the time to allow him to do that. If we look at the early beginnings of our country, Washington said, "Build roads and canals and it will pay you great dividends." Lincoln had as one of the planks of his Republican platform in 1860, completion of the inter-continental railroad because it would bind the nation together, and it would expand the economy. When President Eisenhower developed the interstate highway network in the 1950's, which incidently was developed for military reasons, moving ICBMs around the country, the real beneficiary of that transportation system was the American public. It completely changed the face of our country. We went to shopping centers. We went to remote residential areas because the transportation capability available through the interstate highway system was a tremendous benefit to the nation and the national economy. Transportation drives the economy. As a result, the work you are doing to provide a navigation system for transportation is good for the nation as a whole, for people who will never use GPS they will see a benefit from the work you are doing.

I want to emphasize the aspect of travel that our member companies participate in. Here is an operator's survey that we just did. We did a survey of our members. If I can walk you through this a little bit. These are NBAA member companies that use their aircraft to reach international markets. On average nearly 82% of all our member companies are flying internationally at one time or another during the course of a year; even smaller companies with gross sales under $100 million dollars, to companies that have gross sales of over $10 billion dollars. There is a high correlation; a lot of international operations. Of the total hours flown, about 10 to 11 % of the total hours flown by member companies are flown internationally. Obviously part of that international travel is to Canada or Mexico, but I think you will be interested to note that the countries reached by business aviation include all the continents in the world. Particularly, Asian market destinations are very popular. Very important for business aviation, as business reaches out to capitalize on new markets.

I want to emphasize something. It relates to the importance of transportation. Our member companies are the largest users of business aircraft in the world. But they are also heavy users of the airlines. Last year our member companies purchased about $11 billion dollars worth of airline tickets. What does this say? American industry needs

transportation. They turn to business aviation when it's appropriate. They turn to the airlines when it's appropriate. Transportation drives the economy; companies need transportation. I pointed out that we can anticipate expenditures in the area of business aviation. This is the total spending per flight department. We find that anything prior to 1994 is past history, anything obviously in '95 and '96 is projected. But it looks like our member companies' flight departments are going to be spending in the neighborhood of $2.5 to $3 million dollars per year in their operation of their flight department. So we are talking about resources that are significant, and companies that are willing to make investments in transportation.

We asked our member companies where they were going to spend some of those resources, and I think you will find it interesting that they talk about new aircraft acquisitions. About a quarter of them say that they will anticipate acquiring a new aircraft. I think you will find that those new aircraft will be highly sophisticated with respect to navigational equipment. We asked about avionics specifically. This would be avionics add-ons to their particular aircraft and we find that nearly a third said that they would be adding avionics equipment. As a result, I think you will find that a lot of those purchases are in the area of long-range navigation equipment.

What are the anticipated requirements of this community? Basically, we say there is general agreement with the Federal Radionavigation Plan. We see Omega phaseout. Our member companies were large users of Omega. That use has been replaced by GPS [and] inertial systems. Loran-C phase out by 2000 with pressures to balance the budget. Obviously, there will be a tremendous effort to reduce the cost of Loran-C, but we must note that about 34 countries throughout the world are presently using Loran-C systems. So I do not anticipate that there will be wide-scale abandonment of Loran-C. In fact, I think that probably that phase out of 2000 may be 2005-2010; may be a little too optimistic. And perhaps there should be a new look at a phase out of Loran-C because as I will point out later our community wants to see a viable back up to GPS. Little interest on the part of our community in TACAN.

Basically, what we are telling our members is, "budget for GPS." But we really don't have to shout that very loud because basically our user companies are already using GPS. We are very strong in our recommendation that there be a back up for GPS. I say here it is wise. It is mandatory that there be some back up. But, what are the back ups? Loran-C obviously is an option. However, as you know from using Loran-C in an aviation environment it's dependent upon certain P-static constraints and we have all flown with Loran-C in heavy rain and lost our signal. We have to go back to DR or something like that. The VOR/DME option. There will still be a lot of VOR/DME stations, but the emphasis on a balanced budget, the emphasis on FAA reform, says let's

move away from these discrete land-based systems. So I don't believe that the VOR/DME option is going to be a strong one. But how about redundant GPS options? What about the GNSS concept? There are strong arguments that there should be the GPS system and the GLONASS system, and that they should be essentially encouraged so that there are two totally independent GPS systems. The likelihood of a systematic error occurring in both systems would be low and there you have a high degree of redundancy and accuracy. It's an issue I suspect that you people will address, and address with a great deal of interest.

I want to point out a little more about the current characteristics of this community because I believe you'll find that the business aviation community will pace the use of GPS. Let's point out for a minute the hours flown within this community. If we take a look at the hours flown by MBAA member companies as a function of size, you will find that these business aircraft are being flown at about 10 times the hourly rate that Phil talked about, as the hourly rate for his members. The average of our member companies is about 430 hours per year, and the larger companies are flying upwards to the neighborhood of 600 or more hours per year. So this an active form of transportation. It is something that is extremely important in today's era of right-sizing. Companies are trying to do more with fewer people. They're trying to reach out to customers and markets quicker. As a result, for a company to get maximum use of people and time they have to be extremely efficient. That's why we see the use of business aircraft increasing as fewer people need to cover more markets. I could go on to the characteristics of turbo-props and pistons and such, but basically it's the same story. The activity levels are high.

What I do want to point out is that there has been growth in the flight hours that the tendency is for the operations to increase as a function of time. (...) But I want to emphasize something that is quite important. Flight hours are highly dependent on the cost of those operations. We queried our members and [asked], what would be the impact on your flight hours, which we know now are about 430 hours per year average, what would be the impact on your flight hours if you were hit with significant fees, the type of fees that are proposed by the Reason Foundation, and the type of fees that the McCain Bill might use as an ATC charge? We found that the price sensitivity of our community it high. There is a high degree of elasticity if the Reason Foundation numbers were applied to the McCain Bill so that there would be a charge per ATC flight plan.

Allied-Signal's study and our study coincided. These were independent studies. And basically I'll use the Allied-Signal figures. Twelve percent of the business aircraft operators would probably not cut back their operations at all if there were ATC charges of the magnitude that the Reason Foundation has suggested which is $188.00 per flight

plan. However, 28% of those companies said that they would sell all or part of their fleet, and 55% of the companies queried would cut back their flight operations by about 35%. So when you look your considerations for GPS and you look at what the cost of future GPS systems will be, remember that within the business aviation community, a heavy user of GPS at the present time, there is cost sensitivity. So the elasticity of our community suggests that it is highly dependent upon the efficient use of dollars. Anything that increases the cost of flying will have an effect on it in one form or another. Even within the major users of major aviation. I want to point out the degree of penetration for GPS at the present time. We asked our members, what pieces of avionics equipment are you using today? Presently over half of our member companies are using GPS. Now these are not hand-held devices that are pasted up on the windscreen. These are typically cards within flight management systems. I also want to point out that part and parcel of the future need will be communications to any aircraft any place in the world. And therefore, the satellite system will be used not only for navigation but will be used for communications. One of our member companies has operations all over the world, and they have the ability to communicate with about 40 aircraft any place in the world, [and] they can send fax messages to 40 aircraft any place in the world. So when you look at the satellite requirements of the future please consider not only navigation but voice and data communications.

The other point I would like to make is that it's far easier for the business aviation community to transition to new technology than it is for the airlines. When we talk about transitioning to a new form of navigation or communications we're talking about an installation in only a few aircraft. We are not concerned or are we constrained by the requirement to equip a whole fleet of let's say 100 or 200 aircraft, or training a whole community of 1000 pilots. As a result, you will find new technology moving into business aircraft ahead of where you see [it] moving into the airlines.

Our community showed a relatively low interest in CAT II and CAT III approaches. We would be very comfortable with a CAT I capability with GPS. But perhaps this represents the heavy use of domestic airspace where the number of times we require a CAT II or CAT III capability are much lower than, let's say, in Europe. And also you'll find that CAT III requirements tend to be highly localized. Business aviation has the ability to go into a variety of airports. If Newark is down, you can go into White Plains, or if White Plains is down you can go into Morristown, or if Dulles is down you can go into National, or other locations. The flexibility of business aviation means that we are not as dependent upon meeting a schedule and getting into that one airport where you have 50 airline passengers you must pick up. There's a high interest in our community in the technology that is inherent within GPS systems, and you'll find that high interest

in other areas. Great use of flight management systems within our community. A lot of computer systems involved with maintenance management and trend monitoring.

So I would like to conclude by saying that business aviation has a pressing need for GPS. It's expressing that need faster than the government is implementing GPS systems. We're not waiting for other people to say, "This is what you should do." We're moving ahead aggressively. Why? Because we have a pressing need for transportation capabilities. We have a pressing need to be able to reach destinations throughout the United States and throughout the World. We also are committed to greater efficiency in the use of business aircraft. There is a high degree of price sensitivity. If you can decrease the time of flight, it's a benefit. If you can increase the number of airports and locations you can go into, that's a benefit.

I would like to mention one little vignette that relates to the important economic aspects of GPS and acceptance of GPS. A GPS approach was put into a hospital in Tennessee. The hospital is located in a valley. And the valley would frequently be fogged over. Consequently, the med-evac helicopters that operated from he surrounding area to this high trauma center hospital needed the GPS approaches. When there was no GPS approach to the top of the hospital, the med-evac helicopters had to go to a local airport where there was an approach facility, and the accident victim was transported via ambulance to the trauma center. The hospital loves the GPS approach. Why? Because the hospital administrator's figured out that if they were not able to get accident victims within that golden hour, if they had to land the helicopter at the fixed-wing airport, and then transport the victim to the hospital via ambulance, frequently it took too long. The victim didn't survive. The hospital figured that if they got a victim that was unsavable and the victim died the only revenues that the hospital could collect were for an autopsy and some processing fees. But if the victim arrived within the golden hour and was saved the typical hospital bill was about $30,000. So the hospital totally endorsed the GPS approach.

So the bottom line, business aviation will move aggressively into GPS. We're moving into GPS at a high rate of speed. We welcome this opportunity to endorse the work that you are doing here and we encourage you to move ahead swiftly. This is a great form of technology. It will benefit both the user and the non-user. Navigation is fundamental to the transportation problem, and the more you can increase navigational capabilities the more lifestyle and economic way of life will be improved. Thank you very much. I appreciate it. I will answer any questions you might have.

Question:
Dale Johnson. Thinking [about] aviation particularly and maybe somewhat the marine community, how do you see human factors; what role do you see that taking now that we see ourselves transitioning from the old VOR/NDB way we used to business, (tune in a frequency and fly to and from a beacon), but now we see a lot of things. Software is playing a big role and we see lots of different types of equipment. How important is human factors going to be as a way of continuing to use all of this equipment?

Answer:
Human factors could potentially be a show stopper in the early and easy implementation of GPS at least for approaches. We know of companies that are leading firms in the general aviation avionics field that have backed away to a certain extent from GPS approaches, because they are not comfortable with the human factors aspects of making that approach easy and you might say, litigation proof. So Dale, human factors are extremely important. The things we used to accept 30-40 years ago in terms of pilot workload just aren't acceptable today. The ability to predict what type of pilot problems will occur is greater today than it was in the past. As a result people are much more concerned about factoring into their procedures low-workload systems. So there will be a strong emphasis, there should be a strong emphasis on how you make this technology user friendly? No only user friendly for the weekend pilot, but user friendly for the professional pilot whether he or she flies in the airlines or business aviation.

Dr. Kane: I would like to reinforce what Jack said. As we observe history's introduction of GPS into the civil community we see the following trend, and I would point to the surveyors first, because they were the ones who lead the way into using it, and that was the big promise up front. A lot of money was spent. Then people got disenchanted and the number of surveyors using GPS dropped out. But then when the cost came down, and the surveyors found they could do a lot more with GPS they went back and learned how to use it properly. So what's happening in the industry, not just for surveyors, but as Jack said everywhere, training of the individuals has become a very important factor in using GPS. So we are going to see more training, I believe, in helping introduction particularly (...)

Question:
48.8% of your aircraft used Omega, and bearing in mind that Omega is going to be phased out by the 30th of September, 1997, and that GPS is still not certified as a stand alone system, what is going to be the policy about replacing the Omega?

Answer:
We feel that the phase-out date probably will slip a little bit. But I think you will find that a lot of the systems that are presently in place are there in association with an FMS flight management system box, and as a result you will find companies upgrading to the type of navigational capabilities that is necessary to replace the Omega capability. So we are not overly concerned about the phase out of Omega; we think it will go a little slower than that particular federal requirement states.

Question:
Peter Morris, TASC: Phil Boyer brought up the point that the user fees may impact safety. Did you find that among your users in NBAA?

Answer:
There is no question, if the nation imposes user fees for air-traffic control, for IFR flight plans, there will be an impact on safety. Give you a vignette, and then an opinion. I was flying a Seneca III over in England about 10 years ago, I was in the publishing business at that time, and I had dinner with one of my British counterparts. A man who was recognized leader in the field of the general aviation community within England. I was located at the time at Gatwick, and I was flying down to Yeovil the next day, and he said, "You are not going to file IFR are you?" And I said, "Certainly I am going to file IFR." He said that we don't do that around here. He said that the costs are so high that the general aviation community universally gets outside the airport area, goes into the clouds off airways, flies at the altitudes associated with the cardinal rule for heading and altitude, "We tune into the nearest military radar and ask for some assistance." He said it's the normal way we do it, we don't want to handle the fees.

Well, I was appalled, I mean this would be one thing if this individual who just happened to be a 172 pilot was talking about a cocktail conversation, but here is a leader of general aviation, the owner of the leading general aviation publication in England advocating to me who is also in the communications business, do not file in order to cut down on fees. If we had even 5% of the turbine community in this country looking for way to avoid fees, we would have as many as 500 aircraft short-cutting the system. We you say, well the turbine powered aircraft isn't going to short-cut the system. They have to fly above 18,000 feet, everything is positive control. I question that. A turbine powered aircraft can fly at 17,500 feet VFR. The average flight of a turbine aircraft is about 1 hour and 30 minutes. If there were high ATC fees, you would find a certain percentage going up to [the] bottom of the positive control airspace and dashing VFR. It doesn't have to be a very large percentage to be a difficult situation from a safety perspective. Now, would it ever happen? I am afraid [it] would happen. It certainly happened back in 1981 when we had the general aviation reservation system. If you remember back in [the]

controllers strike you had to file a request for an IFR flight plan in the general aviation system. There were a number of operators who needed to go and were going VFR just below the positive airspace altitude of below 18,000 feet. So do not assume that turbine aircraft will always absorb whatever ATC costs are imposed upon us. One, it's a price sensitive industry, and two, past history suggests that general aviation will look for ways of getting around those fees. Getting around those fees is not in the best interest of safety.

Question:
Bill Brogdon: Why do you think the Omega turnoff date might slip?

Answer:
Well I don't have a very good hard reason for saying it will slip. I am just going to use the same answer that Newt Gingrich gave this morning when somebody said why is seven years better for balancing the budget than ten years? He said, "The only reason I think seven years works better than ten years is intuition." I am just going to give you my personal feeling. Things have always slipped in our community. There is an element of the aviation community that wants Omega, there are elements if the other user community that wants Omega, and as a result I think there will be pressure to probably keep it a little longer. But whether it will I have nothing to offer other than as Newt Gingrich said, intuition.

Question:
Ed McGann: One of the themes of [this] conference is over-reliance or over-dependence on a particular system. We have had a report from France of a aircraft pilot being told by air-traffic control that he is flying too low. He told them, "No I am not. My GPS says I am at the right altitude," and he flew into [a] mountain. We've the Royal Majesty incident of over-reliance on a particular system, whatever it is, off the coast of Massachusetts. And last month we had a very experienced mariner off the coast of Maine run aground because he was solely dependent on a particular system. Is there any effort in your organization toward the education of people not be become dependent on one particular system, but in the words of one Coast Guard Captain who said, "For God's sake, once and a while look out the window."

Answer:
There is most certainly an element an effort on our part to increase what we call positional awareness. Where is the aircraft with respect to the airspace, with respect to the ground. We have a strong effort, an educational effort to expand pilot sensitivity to these problems and to increase positional awareness. I am reminded of an adage that was in a book on radio-navigation that I read 40 years ago, and that adage was, although there

are great systems now available, and this book was talking about Adcock ranges and ADF and VOR, they said although there are all of these wonderful radio-navigation facilities never give up on dead reckoning. Always know that in the final analysis, all those systems can fail, and you've got to back in essence to earth, fire, and water. I think we have to keep that in mind. That regardless of how magnificent these GPS are or how great all these systems are, in the final analysis, the pilot is responsible for getting that airplane safely from point A to point B.

The pilot should never abdicate that responsibility to a box. I urge all of you in considering the long term importance of what you are doing to emphasize that a box in itself should never be the sole means to safety. The pilot should always look for some sort of redundancy even if that redundancy is, as you say, looking out the window.

Question:
Ed McGann: Can I just add one more question to that? That is one of the alternatives you mentioned is the addition of GLONASS in the GNSS system. We in the United States are pressing the rest of the world to adopt and assimilate into their airspace and into their navigation systems the GPS. Are you aware of any effort in the United States, any formal effort of any way to introduce GLONASS into the national airspace or into the navigation systems in the United States?

Answer:
I am aware of no efforts, I do not profess to be an expert in this area but I am not aware of any efforts. I do feel that it is probably unrealistic to expect the Russians have the resources to make a major effort on their own at this time. I do think that perhaps that the concept of a dual GPS system totally independent on the other is idealistic than realistic.

Question:
Peter Moore, British Airways: It might interest you to that I flew on an aircraft in June of this year, which had a combined GLONASS GPS receiver, at that time it received 19 of the GLONASS satellites. It was extremely accurate. It was interesting to note too, that in the final analysis the accuracy of the GLONASS fixes was 35 meters.

Answer:
That's excellent. I don't want to discount GLONASS. RTCA is an organization that is worthy of all the respect that our community shows to RTCA. They had an extremely important study about two years ago, they emphasized that GLONASS was a viable system and a system that should be used. I believe that we should try to factor in that capability to the maximum extent possible. I am not aware of any specific efforts in this

country to move forward with those plans that were ably recommended by RTCA. Thank you very much.

Introduction

Dr. Kane: [I would like to introduce] Dr. Bill Klepczynski, who is the department chief of the Time Service Department of the U.S. Naval Observatory. Bill was originally educated at the University of Pennsylvania. He received [the] B.A. in 1961. He received [the] M.A. in Georgetown, in 1964, and his doctorate from Yale University in 1969. Bill's interests, of course, are always to do with time and is also involved with astronomical time and rotation of the earth. Some of Bill's achievements are, he was the editor of Navigation, from 1971-1978. He was the President of the ION here from 1987-88. He was the general chairman of the annual precise timing conference 1973 and 1984, he is the co-editor of Asteroids, Comets and Meteoric Material, he is the President of Commission 19 which has to do with rotation of the earth and of the international reunion 1985-1988. Won't you please welcome Dr. Bill Klepczynski.

Dr. William Klepczynski, U.S. Naval Observatory

I have here in my hand one of the most accurate clocks in the world. For about $200 now you can get a clock that is a lot more accurate than a Rolex but a lot more reasonable in price. If you don't realize it now, the time is based on about 29 cesium beam frequency standards or atomic clocks flying around the world or on the ground and also on one of the most accurate and stable time scales in the world. You can't go wrong with that as a clock, I'll tell you that. There are many uses for GPS other than navigation. What I want to try and to today is talk to a little bit about the observatory and its master clock and its U.T.C. because it is the basis for GPS time. I talk about time and GPS and how we get time from GPS and then talk a little bit about timing requirements and then if you have time, how you can get it out to meet these requirements.

GPS is obviously one of the most economical and global ways we can distribute time at this point in time. The master clock at the observatory is a complex system. Not very simple. We have about 50 cesium beam frequency standards, and about 10 hydrogen maser clocks. We sort of average these things together in a way in that we come out with a master clock which then is the physical realization of our mathematical time scale. And we make all our measurements against this master clock which is a representation of our time scale because a lot of institutions make measurements and then you have to wait two weeks to find out how they are against a time scale. We try them out [on] our time scale in real time so that when an admiral calls or a general calls and says what time

is it, we have to tell them right then, we can't wait two weeks to tell them, "Well let me think about this a little bit."

Once we have a good time we have to have an alternate or backup. A lot of people here have been talking about backups, we just recently moved our backup master clock or alternate master clock from Florida to Colorado Springs, Colorado at Falcon AFB. So it will now be in the same physical building that GPS is located, because that is where the Air Force controls a lot of the space systems which require time, and we thought it was easier for us to move our system there than it is to develop their own out there. Maybe we will talk a little about that as time goes on. The reason I am going to spend a little time about this because that people talk about GPS and traceability and where we are with regard to UTC., "the time scale for the World". And this is why I want to get to this point because I want to show you just how important GPS is to the world.

You have a number of clocks, cesium frequency standards or hydrogen majors, they all go into a measurement system. The data from that measurement system is passed through another computer which then forms your average time scale. Once we know how the different clocks differ with regard to the average time scale we then have a control computer which takes our best clock, which steers it and tries to run it after the average time scale or mathematical time scale. That we tap off of and that is what we make all our measurements against, and we then feed it back into the system to see and make our measurements against this to later compare to all the clocks. We do have some external input into the computing of the time scale, because that is how we actually get traceability to the UTC as determined by the International Bureau of Weights and Measures outside of Paris, France, in a little town called Syve. And to show you how some of the importance of this, (...) there are 80 contributors to international atomic time. Of those 80, I list here the largest ones, and the observatory itself absorbs about 40% of the weight. The next group that comes in to that is the French, and they get about 7-8% of the weight. Our time scale is the basis of GPS so our time scale so GPS is pretty much reflecting international time.

Over the last few years, to see how well our time scale or master clock does against UTC, I have here a little plot. One major division on the X axis is 100 days. So from here to here is about a year. And one major division here is about 10 nano-seconds. Now I guess you are all navigators and you realize that 1 nano-second is the length of time it takes light waves or radio waves to travel a foot. So really a nano-second is a foot. Three nano-seconds is about a meter. An over the last more than a year and a half or so the observatory has been within + or - 30 nano-seconds of the BIPM, and in the last year or 6 months or so we fell within 10 nano-seconds. Now this is an interesting thing, and to me it's a little bit more impressive than you people realize because the BIPM doesn't

tell us till 2 months after the fact where we were. So we learn today where we were two months ago, and then we try to steer based on that to be today as close as we can to the BIPM. And within 10 nano-seconds.

Clocks now-a-days, the newest cesium clocks, for your information, probably are going at about 2-5-10 nano-seconds a day, so they drift and change some of these things. So just to give you a little bit of flavor of how time really affects navigation a little bit. And then if you want to look at not only the absolute sense but in the relative sense, stability. We have plotted here the stability of say our time scale versus the international time and its down here at about 2 ½ parts in 10^{15}. We're about the next contributor, then the next contributor in this instance for stability is the Soviet Union, after that.

That was interesting you talking about GLONASS and the possibilities of that. We have been investigating and looking into how that GLONASS is from the time distribution point of view. Even though the Soviets have a very stable time system, they are about 17 micro-seconds off UTC. There are some reasons for that. I won't go into them, but I'll bring that fact up again as we go later on into the talk.

You're obviously all aware of some of the characteristics of GPS, and how we get into time. I won't enumerate them. I did have some copy of the handout or view graphs that are available, I brought about 10 copies with me, and we'll see what happens. But now when we talk about GPS and time, there are about three different areas you've got to really consider and think about. First of all, there are the clocks on the spacecraft themselves. Each of the space craft have either rubidium clocks or cesium clocks on board. They're running. The next thing is system time, the GPS system time. That is the one that you really navigate by. And the reference time which we are, UTC/USNO. So there are three different areas that you have to be concerned with in GPS time. But keep these things in your mind that there are three different areas that we work with, with regards to time. Now the satellite clocks are all free-running, and the monitor stations when they are tracking them to get orbits for the satellites are effectively just determining the offset of each of the satellite clocks from GPS system time. Now the GPS system time is a composite clock. It's also a mathematical time scale. That's what we do at the observatory. They do a similar type thing with GPS. They look at all the satellite clocks and all the monitor ground station clocks. So there are about 29 clocks that go into the formation of the GPS composite clock. This composite clock is independently synchronized to UTC/USNO. And I'll talk about that as we go along about the procedures and process by which we do this.

A little bit more to elaborate on the GPS composite clock. This is GPS system time. Again, it is based on all the satellite clocks and the ground station monitor station clocks.

In practice, the cesium clocks are the only contributor right now to the composite clocks the rubidium clocks do not contribute. The algorithm used to compute composite for GPS does not take into account the drift of the rubidiums. That will be changed, and in future versions the operational release software will be changed. We can either automatically or manually steer the composite clocks to UTC/USNO.

I mentioned now in addition a few years ago, the Navy and the Naval Research Laboratory, and the Naval Observatory, put in an ensemble of six cesium and one hydrogen maser clock at the GPS Master Control Station in Falcon. That ensemble of clocks was the basis for the monitor station clock at Falcon. And that still is. And I also mentioned we're moving the alternate master clock to Falcon, we've moved it and that is going to be a separate clock in a separate room by itself, which will be linked indirectly to the Navy clock ensemble that is there. GPS is the only system that will require time. There are a lot of other systems controlled from Falcon that use time, and we will be working with them also, MilStar and a few other ones. With regard to USNO and GPS time. GPS time is physically kept within 1 micro-second of UTC/USNO, regardless of leap seconds.

GPS time is not UTC, and that is a very important factor to remember. There is about 10 seconds difference now between GPS time and UTC; come this December, there will be 11 seconds difference between GPS time and UTC. We monitor GPS time at the Observatory. We then transmit corrections back to Falcon every day, and then Falcon uses these corrections to upload the steering of GPS time. Now again, since I mentioned that UTC/USNO was the only real-time extrapolation of true UTC, and GPS time is true to that, you can see that GPS time is then really very close to be being a means of distributing in real time UTC/BIPM. How well do we do with regard to that? Let me show you a plot here and let me talk about it a little bit. From here to here five major divisions again is about 100 days, now full scale is ± 1 micro-second. One little division along here is 100 nano-seconds. And you can see that this is data taken with a keyed receiver, and you can see the red line, the red positions are all the points we take and the black line is the daily average through those points. What we are sort of looking at if you can imagine this, and I'll go through this one more time, is that if you were able to start a clock going with GPS received signals, and generate one pulse per second. If you then took the one pulse per second from the master clock and you started an integral counter going with one a stopped it with the other, that interval would be in the order of the nano-seconds you see here. So that is how we are comparing the clocks and that is what that difference is showing here. You see this little glitch around December of this past year, this is actually September of '95, so it is reasonably a little bit out of date, two months out of date but around December there was a little glitch and that was due to a switch of clocks at Falcon, and some procedures weren't followed properly, but if you will still

notice the specification calls for it to be within ± 1 micro-second and this little glitch was about 200/300 nano-seconds. So the system performs really well. That's the difference between GPS time and UTC/USNO. If you then try and derive UTC from GPS and compare with the Master Clock, this is what you get today. Now full scale is ± 100 nano-seconds. All the points here are lie about ± 30 nano-seconds. The blue line is the daily average of all that, and you can see the black line is the sigma of that line, the sigma of those values. So you can see that well within about 10 nano-seconds if you want time you can easily get it from GPS if you are careful and do a good job.

Now GPS can be used in a lot of different ways to distribute time. I'll talk about two different modes of using GPS for time. One I like to call the distribution of time, is the clock on the wall type. You have a GPS receiver like you have here. You turn it on and you are getting time out of it. That's one way to do it. So you have this clock in time while you are walking around. The other way is the two-way mode where you need two people and you have to exchange information. That becomes a little bit of an active way. The military likes the passive way, the first way. You just get time from a system, and you don't have to radiate or give out any information about where you are located. The other way if you really want care and you want to get down to nano-second levels then you have to do the two-way methods where you exchange data or radiate in some form or another.

Again, how do we get time from GPS? I'll go through this little diagram here. Here is your local clock in your laboratory or your platform or whatever it might be. Usually you have some form of atomic frequency standards, say it's a cesium beam frequency standard, or rubidium clock even. We go through a device called a phase micro-stepper which is a sort of a phase shifter, so that we offset the frequency coming out from the clock itself. Then the offset frequency, or the controllable frequency, which we can change, goes into a clock. This is how we set the face of our clock with hours, minutes, and seconds and things like that. Here we have our GPS/GTU with time transfer unit. It has receiving signals from GPS satellites. We have input from the local clock. We compare the received signals from GPS with this local clock and then we put out into a computer these numbers. The computer then can figure out the difference between your local clock and GPS time. They can then go through a feedback loop here and change the phase micro-step or the phase shifter a little bit to put your local clock back on time with GPS. So you have a big servo-loop going through here, and this is how you can control your clock. And then you run all your measurements off this clock at some point in time, or some place wherever you want.

I have been trying to emphasize that time and navigation are very closely related. It is obviously to people, many of you here who may not [be] high-tech types, but a long time

ago, I guess in the mid 1700's was a guy named Harrison who developed a clock which the British Navy took out to sea with them so they could compare their locally determined time with the time of the reference point which was Greenwich England, at that time, and this was the way they solved the longitude problem. So time and navigation have been associated over a long, long history here. Conversely, if are using a time system to navigate by, if you know your position you get time from that system very easily. It drops out right away. Because of that, if you have a GPS receiver such as this and you know your position, you get time out of it. And [there are] really some benefits from getting time from GPS. When you look at time from GPS you only need [one] satellite. You don't have to have four, five or six. You might need four, five, or six to get your position, but once you have your position determined then all you need to do is track one satellite to get time. For positioning you need four satellites. Your coordinates, if you want to look at it, X, Y, Z, and T time, longitude, latitude, height, and time you have to get. You need time to compare against the time being generated in your local receiver here by the local crystal that is in there. Some of the benefits though of that are interesting, or setbacks, if you want to look at it that way. With regard to timing, right away you know if a satellite goes bad. You know your position and right away if the clock goes bad you will know that. In positioning if a satellite goes bad, it's diluted right away by the other three satellites, so it's going to take a longer time for that error in the GPS to progress through the system, because it's being diluted by 3 other satellites, cause you're tracking 4 satellites to get your position so you don't see it that well. But right away if you want to check for integrity or anything else like that with GPS time becomes a very important way to do it. A very quick way to do it, an efficient way, because you can see with keeping time with 10 nano-seconds and that's 10 feet, and you clock jumps to 50 nano-seconds or 50 feet you see it right away. You know you're not moving, so it's got to be the clock, something's gone wrong with the system. So you can tell very quickly whether something goes wrong.

Requirements for time. This is sort of a difficult thing to do. The clock on the wall, you walk into an office building or somewhere like that you have time on the wall and everybody just accepts it. Because nobody ever checks to see if it is right. I way going to ask everybody to set their little digital to beep on the hour, but I hopefully will end before then so nobody will see the spread. Who's right? I was going to say that I will talk until the last beep goes or something like that, but who knows when the last one is going to ever occur? I could stop with the first one, I could be done right now if I do it that way. That's is where these times come from. This is an interesting thing; we talked about it earlier in GPS World they were talking about I guess it's Motorola or somebody was going to come out with a new chip for about $50 in a large quantities for GPS track 12 satellites. Can you imagine now, if you only get time out of that to a mili-second for $50 what you are getting? You could put one of these things in almost every traffic light

in the city and synchronize the whole bloomin' network and move traffic freely, and just imagine how much it would save in gasoline and stuff like that. Some of things that can come about are really mind boggling what happens here. We've got telephone time voice announcers, you can call in and get that. That's good to about a mili-second. Navigation and position, we've talked about that, that's down to the nano-second region right away.

Synchronization of communication networks and power grid, that's a new area developing. And this becomes a very important thing with the last line on their uniformity of reference. AT&T uses GPS to synchronize their whole network. Suppose now MCI or Sprint uses GLONASS as another satellite system. I mentioned that there was about a 17 micro-second difference between GLONAS and GPS time or UTC. Stratum-1 in the communication field, they talk about something called Stratum-1 levels of synchronization. That's at the micro-second level of per day, which just a minor thing of probably 10"/11th. Here with these numbers we are talking probably 10"/14th a day. For communication purposes you only need synchronization part 10"/11th. Now with the digital data and stuff like that coming on, it's trivial to use GPS to synchronize and AT&E does it. But if you don't have the same time reference, somebody is using GPS time, not UTC, [and] you're 10 seconds off. When you go to send data packets in digital form through a lot of these networks now you can have a real big problem somewhere, somebody is going to lose some data a page here or there or something like that at some point in time. So synchronization is especially in communication networks is becoming more and more important. And in fact, I know with the military right now you are talking about redundant systems, right now the military is using GPS for time. And they love it. They're getting great time for great quote GPS. But what is happening though they say I am using nano-second time now; what happens if GPS goes away. Where am I going to get the time to the same level from another system? They just don't exist right now. Well GLONASS does. We're looking into other things, and I spend a lot of my time trying to think of how to utilize a MILSTAR or some of the new direct-broadcast satellite systems to get time as a backup to GPS, something along those lines.

Power grids, that's an interesting thing, they use it from two points of view. One is if they are monitoring their power and one of these big grids go down, towers go down, if you have time to a micro-second that's about the spacing of these towers. So if they can isolate when a time the tower goes down at three different stations they can almost pinpoint to which one of those towers goes down or where the problem or fault lies. The next biggest area or where the power grid synchronization area is in when they transfer power from one grid to another. There's an intricate system of power grids within the United States, and when they pass power from one system to another it has to come in phase, if it doesn't in phase it really bogs the whole system down. So if you can synchronize your networks so that all of your electricity is in phase when it passes from

one grid to another, it literally saves millions and millions of dollars when that happens, because they don't slow down the other systems as the other systems pick it up.

Time. How do you get time? A little commercial here. A little handout I put out on a desk out there, if you want telephone time voice announce you can call it in. If you want it for your computer, we get about 7,000 calls a day for time on the computer. About a month ago, on the Internet, would believe that we had about 300,000 inquires per day for time over the Internet. Today it is up to about 500,000. So can imagine what is happening. We actually call our two servers on the Internet tick and tock. (...) And voice again is good to about good to a 10th of a second. The computer times [are] good to about a mili-second, and Internet time is good to about 10th of a mili-second time about the time that we can get requirements for that.

The military has a fantastic use for time. I'll talk about time systems. Battle group management is a big area. You have these big things flying around and they are all getting fixes and radar things. How do you know if you have two or three of these things? How do you know whether three of these stations are all looking at the same target? Are there more than 1 target? Is somebody moving in? Time tagging information now with these more sophisticated systems really becomes a high priority thing. We don't really need time for radar to better than a 10th of a second, I think, or a milli-second when you are trying to identify whether you are looking at the same aircraft coming in against you, or something like that where there is more than one. Navigation; you all are aware of the importance now of time to satellite navigation. I mentioned some of the things, the communication frequency hopping. A lot of the military tactical communications systems or frequency hop. So you've all got to change frequencies at the same instant of time, and I was gonna do this thing with all the digital watches beeping at different times just for you to see in this room what the spread of time is with people on the hour, so that you can just imagine or get a feel for how bad or how well time has to be synchronized for a lot of these systems to work.

We talk about these systems, there are different levels of accuracy and precision, that is sort of what I'm listing here. Here are these groups here that up to about a milli-second, here we go down to about 10 micro-seconds, here go down to around 50 nano-seconds, here about the nano-second region, and here below the nano-second region over here. You can see that most of the users really require time only to modest levels, a milli-second, and there is where your greatest number of users are. As you get down to the very high levels of accuracy, obviously the costs go up and the number of users go down, but these are the most stringent requirements and needs, and I don't even know there are requirements for them out there I don't know what they are used for. I don't have the

clearances high enough to get through to that level, so I don't get too involved in that, but we provide the time for them.

We talked about time distribution. Obviously, we try and do it by monitoring the various time systems. Obviously, GPS, Loran, and we do synchronize time. Satellite communication stations we try [to] synchronize. We use these as a means to distribute time or set up what we call precise time reference stations, so that these stations we know their difference with regard to the master clock and therefore people can go to these areas to get time on a local level sort of the hierarchial of way time is distributed. Time transfer right now, I started to talk about the levels we can do this at. This view graph is a little bit better when it comes to how to give you a little bit of comparison. Loran-C can give you time somewhere between 50 and 200 nano-seconds. It depends upon your experience, your history, how well your system is that you're using, things like that. It is a reasonably good system and satisfies a lot of needs, but it is not totally global. We go to GPS, and GPS is a global system, no question about that. We talk about time from anywhere from let's say the clock on the wall type thing, about 10 to 50 nano-seconds. Then if you take care and you do common view or melting pot methods you're down to about five nano-seconds or so, something like that. If you need time better than that, you have to use two-way satellite time transfer. We actually exchange signals through a satellite and there the precisions are on the order of about 250 pico-seconds, which is the next level, and then a whole new world of physics is opening up there, cause then you've got to worry about temperature changes, everything, all sorts of things.

So in summary here a little bit about how we get time around the world to a lot of people. We start out the observatory with a set of atomic clocks. We use two-way satellite time transfer to Falcon, through the Defense Satellite Communication Station. Falcon in turn, takes that information, uploads it to the GPS satellites and GPS distributes it around the world for us. And again, the levels at which we can do that range from anywhere about 5 nano-seconds is a conservative estimate. We can say about one or two, but I don't know if there's that much difference between one and two. That's like knowing the distance of whether that book or piece of equipment over there or over here in the room or something like that. Not significant I don't think for most purposes. And I guess with that I will entertain questions, if there are any.

Question:
The name is Rolf Johannessen, from Lambourne Navigation in the U.K. Your last slide showing GPS as the means for getting time brings out the problem which may arise if the world community relies more and more on GPS to get time and something goes wrong with GPS as happened with [satellites]12 some months ago. Could [you] please

comment on how we should protect ourselves against the impact of such failures on the world's communications systems.

Answer:
Right now the only viable alternative to GPS is GLONASS in a world-wide basis. However, and unfortunately, there are not too many commercially available GLONASS timing receivers or receivers which can easily get time from GLONASS. There is one manufacturer in the U.S., 3-S, that makes those. We've been doing some experiments and a report will be out in a couple of weeks about how to do it. So as a backup to GPS for time distribution right now today, you would ask me what to use you would have to use GLONASS, but then you have to be a little bit careful because when you look at the timing aspects of GLONASS there are some problems there. Right now what effectively is happening as far as we can see from the data, there is a group of guys running GLONASS, somewhere outside Moscow or somewhere like that. A few doors down the road is the GOSTAT, the Soviet equalivient of the observatory or something like that. It seems that when you look at the data there is not too [much] communication between the guys running GLONASS and the timing people in the Soviet Union. And that is why you see large shifts and swings getting UTC from the GLONASS system itself. So right now, yes, the only alternative is GLONASS, but you have really use extreme judgement when you use it. You have to have some experience. I don't know if I have answered the question adequately for you or not.

Question:
Same person. What I wanted to say is that one of our purposes these two days is to put forward some views as to requirements, and if we are going to be relying on GPS for time then there has to be a clear message in terms of requirements that there some certainly must be no fiddling about with time in GPS. That must be part of our requirements and I have not seen [user] community expressed that as a requirement.

Answer:
Oh, well I guess the only requirement for time from GPS that maybe comes close to what you are talking about is from the NATO community. That's why we are so careful to make sure that we steer UTC/USNO to UTC/BIPM because the only way the NATO community would accept GPS time is if we could guarantee to them that we would keep UTC, and there's a commitment to do that. That's the only sort of formal one I know, and there is a document which I don't think is written yet, but should be coming out shortly from NATO with the timing requirements for NATO in it which express this.

Question:
John Beukers: Bill, a question regarding Loran-C master synchronization. As we know that if we can synchronize the master stations we can use Loran in cross-chain work which greatly extends the coverage. It is my understanding that DOD were reluctant to let the Loran community do this. Has this changed, and what is happening with the synchronization of the funds and the Northwest Europe chains?

Answer:
OK. That's a very interesting question, because I was just at a meeting about a month ago, and talking with some representatives from the French Navy, and they were talking about that they may not have their Loran on the air for about another year or so. I've heard that, so the European Loran -- I don't know what is going to happen there. They want to do external synchronization of the Loran chain, and it looks like they are proceeding that way, but their plans have been delayed and things are being set back. In the U.S., I don't know of any plans to non-synchronize the chains. We still track and monitor and publish the data which allows the users to synchronize the data to be able to do this, to use cross-chain work. I don't know of any formal plan to stop that within the United States right now. We're doing the best we can, but some of the problems are with the propagation. That's some of the error that's inherent in it. And that is why I say we need some time and good judgement, and when you try and get time from Loran it's a difficult process because wherever you set up a monitor site, whether you're going to have this problem because you're sort of in a catch-22 situation. You can synchronize the Loran chains at the antenna, but you don't know adequately the propagation path the user is going to receive in the field. Consequently, if you put monitor sites out in the field, the time you'll receive with these monitor stations that you're looking at, there going to be affected by the propagation path relay, and how do you relate that back to the master station? There is always a little bit of error involved in there because of snow on the ground and things like that which affect these problems. So the 500 nano-seconds is a reasonable guess. We should be better, but that is sort of like a conservative CYA type of number that some people want to put out to make sure that there are some things that affect the system, but we just have no control over for that purpose. I don't know if that is answering your question or not.

Question:
Bill Brogdon: A question of GPS time, having absolutely nothing to do with accuracies you're talking about. Do you realize that the average navigator that is using celestial as a fallback has no idea that his GPS receiver may be indicating time 2 or 3 or 4 or 6 seconds off from UTC?

Answer:
I know. That's my job, I'm trying to get that word out.

Question:
Brogdon again. And when you finally get through the advertisers to the engineers, they say that is not a time transfer device. But the guys got a 6 or 7 or 10 second error because they don't extract that information in these little low cost receivers, and that's a considerable distance even for celestial navigation up to a couple of miles.

Answer:
Correct. That's why I guess you have to be careful what you buy. I know even the one I have here, because of the processor involved, this little hand-held thing you can see that all of sudden because its doing something the display sort of freezes and about four seconds later you see the time jump by about three or four seconds. And that is mainly because of the way the processor works inside of these things. But once you see it moving and ticking along, you really have good time at that point.

Question:
Brogdon again. The navigator really believes that is just as good as your wrong guess time.
Answer: Oh well, I hopefully am trying to dispel that myth.

Question:
Dick Rich: In about the next five or six years you are going to see the first peak in the solar cycles since GPS now has been fully commissioned, and I am wondering what particular problems you might see in time transfer when the ionospheric activity gets pierced.

Answer:
You should see them in navigation also. What will happen is, there is a model for the civilian community. The CA code transmits a model that is used to correct the received GPS signals for ionospheric refraction. When you go into a high solar cycle year which you will in about five years, the model can break down a little bit. In the past, I know in the last time we went through a peak in the solar cycle, there were some times when you have to update the coefficients or the numbers which go into this model to make sure that they are reasonably good. But for timing, we have seen errors the last high solar cycle of about 30 to 40 nano-seconds because the model was wrong. We just couldn't predict what was going to happen. And that was about the level that we saw there.

Dr Kane:
Thank you Dr. Klepczynski. A very interesting discussion.

Time & GPS

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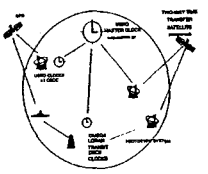
PRECISE TIME AND TIME INTERVAL



Provision of Standards for PTTI
Dissemination of these Standards worldwide
Coordination of PTTI use and R&D in DoD
Coordination of the Standards with others

Outline

USNO

Master Clock & UTC(USNO)

Time & GPS

Timing Requirements

Time Distribution

Master Clock = UTC(USNO)

USNO

Clocks & Hardware

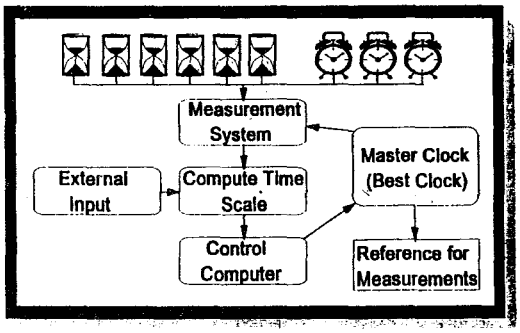
Data Collection

Data Analysis & Algorithms

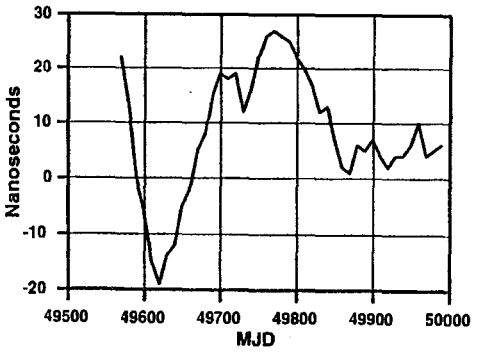
Control & Steering Systems

Alternate Master Clock

Advanced Clock System



UTC(BIPM) - UTC(USNO)



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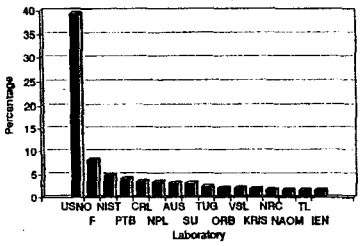
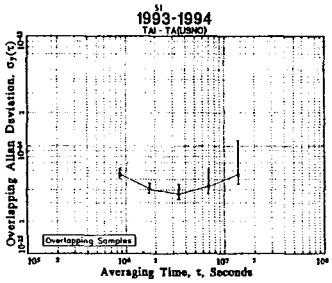




GPS System Characteristics

USNO

24 Satellites = 21 + 3 spares

6 planes / 4 satellites each

Inclination = 55

Period = 11 hr 58 mn

2 Cs & 2 Rb Clocks

Frequencies
L1 = 1575.42 MHz
L2 = 1227.60 MHz

Each satellite has unique PRN code

GPS for Time Distribution

USNO

Satellite Clocks are free-running

Determine offset of each satellite clock from GPS MC

GPS MC is a Composite Clock

GPS MC is synchronized to UTC(USNO)

GPS Time

USNO

Satellite Clocks
Rb or Cs

System Time
GPS

Reference Time
UTC(USNO)

GPS COMPOSITE CLOCK

SOFTWARE CLOCK (OR 5.22)

All satellite & ground station clocks contribute to Composite Clock

In practice, only cesium clocks contribute to Composite Clock

Composite Clock can be steered to UTC(USNO) either manually or automatically

NAVY CLOCK ENSEMBLE

HARDWARE ENSEMBLE

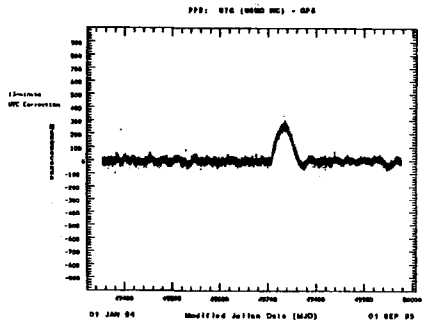
6 CESIUMS and 1 HYDROGEN MASER

Steered to UTC(USNO)

Monitor Station Clock at CSOC

Reference for other timed systems at CSOC

As Monitor Station Clock it is part of COMPOSITE CLOCK



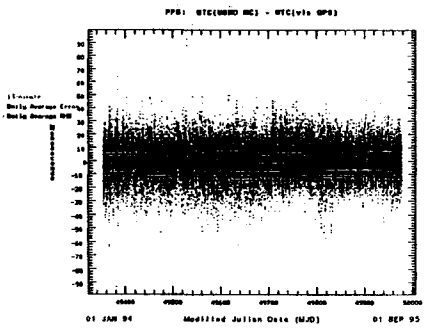
USNO and GPS

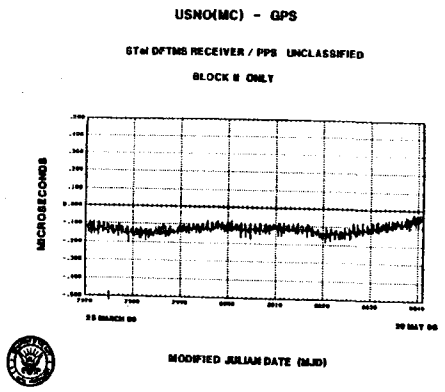
★ UTC(USNO) is reference time for GPS
UTC(USNO)-GPS < 1 usec.
UTC(USNO)-UTC(USNO)' < 100 ns.

★ USNO monitors GPS with keyed and unkeyed receivers

★ USNO transmits corrections to GPS MCS

★ UTC(USNO) is the only real-time extrapolation of UTC(BIPM)





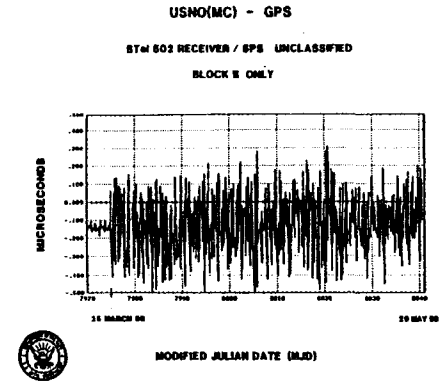
USNO

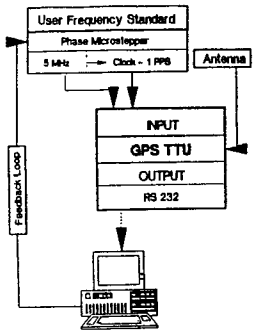
Modes of GPS for Time

One Way Mode — Distribution of Time

Two Way Mode — Synchronization

Melting Pot
Common View





USNO

Time & Navigation

User needs time to determine position

If user knows position, can determine time

Therefore, GPS can be used as
a Time Distribution System

Timing vs Positioning

- **Timing - Full effect of errors enters directly into timing data**
- **Positioning - errors from 1 satellite diluted by combination from 3 others**

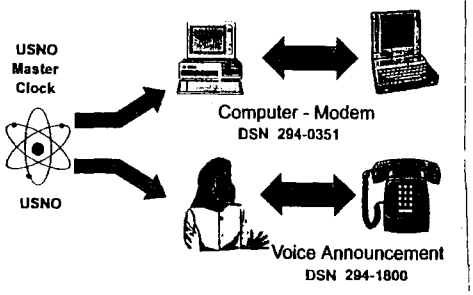
Timing vs Positioning

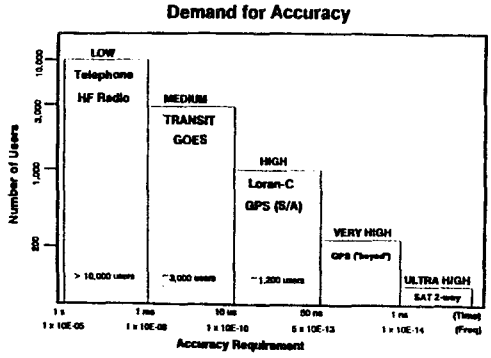
- **Timing - look at 1 satellite**
- **Positioning - need 4 satellites**

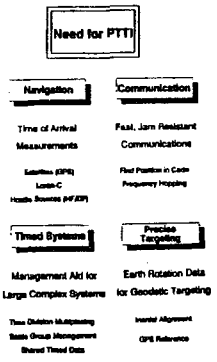
USNO

Time Requirements

Clock on the Wall
Telephone Voice Time Announcer
Navigation & Position Location
Synchronization of Comm. Networks
Power Grid Synchronization
Uniformity of Reference







TYPICAL PTTI SYSTEM REQUIREMENTS

LOW	MEDIUM	HIGH	VERY HIGH
SINCGARS	HAVE QUICK JTIDS MARK XV, IFF SEECM ELF MILSTAR PLRS SCOTT	DMA/GPS NETWORK DSCS/DCS DAVID TAYLOR JTC-C LAMEOS/SPACETIME OMEGA PMEL PTRS SATCOM/MM TDRSS TOPEX TRANET VERDIN MARK XV, IFF	DSN/GPS EOS ERS-1 GEODETIC POS LORAN-C PWS VLBI INTELLIGENCE

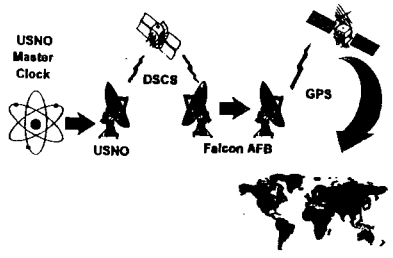
TIME DISTRIBUTION

Monitor Timed Systems
GPS, Loran-C, DSCS, etc.

Control Time distributed via these systems

Time Transfer
Passive - GPS (5-20 ns.)
Active - TESTT (<1 ns.)

Precise Time Reference Stations (PTRS's)



Systems Distributing USNO Time

System	Mode	Accuracy Normal	Accuracy Best
Loran-C	Passive	200 ns.	50 ns.
GPS (Keyed Rx or no S/A)	Passive	50 ns.	10 ns.
GPS Common View (Keyed Rx or no S/A)	Active	15 ns.	5 ns.
Two-Way Satellite	Active	< 1 ns.	

Introduction

Dr. Kane:
Now for another change of pace, our next speaker is Dr. Andrew Bass from the U.S. Naval Academy. Dr. Bass holds a Ph.D., in meteorology. For the past 13 years he has been responsible for the navigational readiness of the training vessels at the academy, that range from a 40 foot sailboat to 108 foot patrol vessels. This fleet covers quite a range of operations, from the Great Lakes to Europe, and all the way from Halifax, to the Gulf of Mexico. During the training exercises they use a lot of NOAA charts, and about 10 years ago, Dr. Bass created or developed an automated system for applying chart corrections to these charts. Over the years he has utilized many navigation systems during the training. Manual sextants, automated sextants, Loran, Omega, Transit and of course, GPS. Dr. Bass teaches at the George Washington University here. He belongs to the following professional organizations, the Naval Institute, the ION, the IEEE, AFCEA. Dr. Bass has stated that the views he is about to express are strictly his own and do not necessarily reflect the position of either the U.S. Naval Academy or the Naval Academy Sailing Squadron. Dr. Bass please.

Dr. Andrew F. Bass, Fleet Navigator
U.S. Naval Academy, Sailing Offshore Navigation Training.

They asked me this fall or summer, I don't really remember when, to discuss Marine user requirements for GPS. You have to understand that during the summer is my busy period. I often agree to things or forget things so at the end of the summer I don't quite remember what I agreed to, but this one I remembered. Marine users; unfortunately I do not have surveys of the size of vessels that use GPS, the number of users by category, etc., some previous speakers have had. My presentation this morning is more of a technical one toward user requirements, what types of things need to be done for marine users. They are the same concerns for many of the areas for other users as to a knowledge of what is correct, what is not correct, and I hope to address those things in more depth.

The marine user expectations for GPS systems are really very simple. They want to put in a destination with the ability to put in intermediate waypoints of interest to them for one reason or another, and have the system provide navigational output data in terms of steerage, etc., which takes into account all the hydrographic information for depth, buoys, fairways, etc., between points A and Z with intermediate points, and have the system drive them to their destination safely. Unfortunately, this is not a realistic expectation

from a user standpoint, but that is what the users are looking for. The current expectations of this group have been raised to a level that is not realistic. For those of us who understand GPS, part of it is advertising [on] the part of the manufacturers. The other part is caused by discussions of accuracy that do not [take] into account the two types of user communities out there.

Unfortunately, for many years the users were told that GPS was accurate to 10 meters or so, discussions of P-code accuracy. The community, however is broken in two groups, [users of] C/A and P-Code. The C/A users are given accuracy to about 100 meters 95% of the time. The problem is that they understand that 100 meters is 300 feet, but the other part of the problem that they do not fully comprehend or understand is 95% of the time. What happens the other 5%? We've run studies where we've tied receivers to logging devices and we have seen excursions of accuracy on non-differential type devices, of up to three to five miles on occasion for various reasons. Multipath atmospherics, internal, we're not sure what they are, but periodically we can see large excursions.

I think some of the examples of the mythical expectations versus reality can be seen as measured recently in the Royal Majesty grounding off of Nantucket. Here's the vessel [going] from Bermuda to Boston. Outside of Bermuda it lost its antenna system. It was disconnected, unplugged however it lost it, it lost its ability to receive information. Nothing in its integrated bridge system or in [the] user interface loudly told the user that they were getting bad information, and it sailed merrily on for several days until it ran aground. Because the numbers looked realistic, OK, there was no wide excursion. It didn't put them in a different part of the world or anything else. The data [did not] look like anything was wrong; it looked realistic, they were heading in the right direction, they never bothered to look outside until it stopped going forward. What I am trying to say is, that GPS systems in of themselves and by themselves, particularly C/A versions, have no way of determining when they are not functioning properly as a stand alone entity whether it be on the ground or in the air.

As Loran proponents, a large number of you have been in the business far longer than I have. GPS was originally developed and then deployed as a simple navigation solution for the rest [of the] world not covered by Loran. Loran has one major shortcoming. It tends to be in a localized area along the coast where there is land. We don't find too many Loran chains plugged out into the middle of the ocean whether it be Atlantic or Pacific. GPS is a perfect navigation system even at the C/A level out in the wide ocean. In ocean navigation it meets all the requirements. Who cares if you are 300 feet off, who cares if periodically for extremely short durations it takes wide excursions? You're sailing along, it tells where you are. The problem that we are going to see with the user community comes about when you transition from ocean navigation to coastal navigation

to harbor navigation. As the requirements decrease, I find it very interesting that the general range of thought is that the most precise requirements are for harbor navigation and yet if you look at tolerance levels for navigation coastal navigation in fairway channels, traffic separation schemes, etc., often require greater precision of navigation than do harbor navigation scenarios unless you are trying to dock the vessel automatically [or] to determine how you are going to land. Unfortunately, the preponderance of users are relegated to the less accurate method of navigation. Are there any expectations, should we have expectations that it will change in a stand alone environment? I would have to say probably not in the foreseeable future.

There [are] methods being deployed to increase the accuracy of GPS. Differential GPS is the [one] being deployed in this country. The Department of Transportation is undertaking an extremely large expenditure of money, both in the Coast Guard and the FAA to overcome DODs dithering of GPS signals. The DOT owns both entities that are trying to undo the Department of Defense. DOD puts the money in to make sure you can't get good accuracy. The DOT is spending large sums to try and determine how you can do it in spite of DOD. The problem is that differential GPS again leads to an expectation level or will lead to an expectation level that is not technically correct or proper for all its users all the time.

I would like to make very clear that my discussion is going to center on a very small percentage of the time of usage of GPS. Not the large majority of it. I am going to talk about and hopefully start the discussion here as to what happens during the percentage of time when it is not accurate. We must understand that this is a small amount of time.

Differential systems are accurate only for small geographical locations. The receiving unit [for] the differential system must be using the same constellation that the differential station is using. In marine units, particularly the inexpensive marine units, the algorithms in reality bear no resemblance to the algorithms used for satellite acquisition by the differential stations. Additionally, antenna placement, heights tend to be very low in marine applications, and if you [are] several hundred miles away, 100 miles away or 200 miles away from the differential station, it [is] not uncommon for the unit to acquire a different satellite constellation that the differential signal is being derived from which can put extremely large errors into the solution.

The other problem is that the atmospherics at 1.5 Ghz are not uniform over large areas. The atmospherics of ducting, multipath E-level problems vary greatly over even small geographical areas. The 2 GHz systems were deployed about 40 years ago by the telephone company for microwave systems. They developed a methodology called space diversity where they put two antennas on the same tower. Same frequency, and they built

the system where they picked the one with the best signal. They found that at 2 GHz they only had to separate these antennas by 40 feet in order to assure that at least one path would be running at all times. One path [goes out]; 40 feet away the path would still be good. This indicates that the atmospherics are not monolithic as the model assumes for differential GPS. It also means actually, that further research is necessary in order to determine how large of a geographical separation you can have before you lose accuracy. The empirical data indicates that it might be an extremely small space. How do you overcome this problem? One solution, and the only solution that really works, is to actually have two frequencies originating from about the same point. Have receivers and processors receiving the data and determining the atmospheric co-efficients from the two frequencies. We have that in GPS, we know that as L-1 and L-2.

Unfortunately, in order to [use] the second frequency, you must have P-code permission and the passwords to basically mathematically remove the pseudo-random noise superimposed on the second carrier. What I am saying is, that the civilian community is not likely to ever to get the second frequency. They need to derive the proper atmospheric coefficient. Is all lost? The answer is no. All is not lost. We have Loran. We have other methodologies, Omega, inertial navigation etc., to compare positions to. When it basically says if you are going to rely on a navigation system in close proximity to anything hard whether it be a dock, coastline, rocks, etc., you have to derive multiple positions from multiple sources and determine whether or not the data is in sync. If the data is not in sync and errors exist, someone has to or the system has to start looking at what is the most probable data and start displaying it to the user in a fashion that they understand that it is degraded data.

Is differential GPS as being deployed by the Coast Guard a waste of time and money? The answer is no. The problems which I am discussing will probably occur in one percent or less of time. Though no one knows, because as previously mentioned under the time presentation, we have yet to experience this system in the high solar activity periods of time. We do not know really what's going to happen years hence with this system. What period of time do we have years hence, it turns out to be the year 2000. As you have seen from some of the other presentations this morning, we are talking about in the year 2000 unplugging Loran, VORs, ILS's, Omega. How then are we going to be able to determine whether or not GPS systems are running accurately over a period of time in a marine environment. A marine environment at sea leads to atmospheric anomalies that are completely different than land-based systems. You have temperature inversions. You have ducting. You have a whole series of other problems that you don't tend to experience on land, that are sea-borne phenomena. And yet, we may be relying totally on a system where we do not have any ability to cross-check.

The other problems that the marine user has is how he develops his data on positioning. Marine navigators rely on charts to determine latitude and longitude of the location which they are trying to navigate to. In my experience as the fleet navigator for the Naval Academy Sailing Squadron, it has become abundantly obvious over a period of time that our current method of dissemination of positional information leaves something to be desired on occasion. The marine user takes a chart, determines features latitude and longitude from the grids of latitude and longitude on the side of the charts. Charts were developed and drawn cartographically based on range and bearings, not on latitude and longitude. Latitudes and longitudes were added to charts solely for the purpose of reference. It meant that everyone sailing on the same chart could basically arrive at the same point. For those of you who are Loran users you will remember being told that the problem has always been your Loran, not the chart. The reason the system doesn't work is the Loran systems are all messed up. Don't take your Loran numbers and apply them to the charts. With the use of satellites we are starting to realize that the problem really wasn't the navigation system all along; it might have something to do with the charts.

The other part of the problem is the fact that most charts were surveyed using NAD-27 as the datum. Satellites have a bad habit they don't go around in perfect circles. I wish someone here would fix the physics of that so we could go back to NAD-27. We have shifted to NAD-83 which is based on the true magnetism and true orbital mechanics of how something goes around the earth based on density at various points and changing densities. NAD-83 was applied to the charts by simply taking the grid of the chart and moving on average to a new position for the center of the chart or to what the average of the chart was, not on specifics. In reality, that doesn't work and it leaves the positional errors. The end result is, that if we are going to have extreme accuracy for coastal navigation in fairways, harbor navigation, etc., we are going to have to resurvey the charts based on a satellite-based latitude and longitudinal surveying system rather than a earth-based baseline type surveying methodology. As a matter of fact, when they were developing the datum for NAD-83, they found out that they couldn't derive any empirical mathematical formulas for general shifts in the country and they went out and surveyed approximately 2.75 million points in the country in order to derive true values. And yet we are moving the grids on the charts based on averages. It's fine if you happen to be in the right place at the right time, but if you are working on the edges of the chart, it tends to get off.

Let me give you an example of that. The entrance to the C&D Canal at the north end of the Chesapeake Bay is a major waterway transition between the Chesapeake Bay and the Delaware River. It appears on five charts. If you take the latitude at the largest scale for the chart that shows you the best area of it, and then to the smallest scale chart which I have to admit is not meant to be used for navigating into the C&D Canal. But if you just

take that position to see how the charts line up the difference is about 5.2 miles. And yet the waterway hasn't moved, OK? It has to do with the relationship on the charts. We need to change our charting methodology. Unfortunately, as it has been alluded to this morning we have great budgetary problems, and I for one, do not foresee any solution to this problem. We can't undertake the resurveying of our waterways to change them into GPS. I'm not quite sure how this problem is going to be resolved or what's going to happen. All I can say is that it's an error or area of error that has to be calculated and applied to the navigational solution.

How the information should be disseminated to the user remains to be seen. Are we going to start to say to harbor X,Y, Z, is not really where it is showing on your charts in published little notices for that type of thing? I don't know. I see some glimmer of hope. The Coast Guard three weeks ago, published a notice for Narrangansett Bay that stated that the longitudinal axis of the chart is incorrect and shouldn't be used. They said use the one at the top; that was better than the one at the bottom. I am not sure, I haven't really been able to look at it well enough to determine what the true answers are. Again, I would like to stress that it important to understand that these navigation errors aren't significant most of the time. They only become a problem if electronic navigation is attempted in confined waters with the electronic solution as the sole solution.

GPS currently has severe limitations when viewed as a navigation system with all of its inputs, etc., when applied to harbor navigation. The solution would be to turn off SA, which only solves a fraction of the problem would be to turn off P-code [encryption] and give everyone access to L2 to derive the correct solution, which I don't think we are going to see, and I am not representing this as any hope that it can happen. NOS resurveys all of its charts, and I can only talk for the U.S. chart, I assume the problem applies world-wide because I have not seen in the literature nor have my discussions with other people in my field lead me to understand that a current resurveying of the entire world is underway for electronic navigation. And for the federal budget process [would have to be] to be turned upside down by Congress and the President to put major resources into this resurvey process.

But you have to understand one thing. I want to close on a positive note. GPS with its accuracy is 95% of the time within 100 meters is better than any celestial navigator has been able to produce 95% of the time day or night in any weather condition. You can't do a manual sight to that resolution no matter how you go. Well, I came [here] with an understanding that the purpose of this meeting was to discuss user requirements, how we impact user requirements, how we talk about things that ought to be done for the community. One is something must be done to get the user community to understand the true limitations of the systems that we are talking about. They are not perfect. We have

come a long way. We have taken a magnitudinal step toward improving toward the perfect system, but we are not quite there yet. The other thing that really should be done, standards by the organizations need to be set so that the user is made aware, and you can decide how they are made aware, turn the display off, blink it, do whatever you want to do when the solution is not within a predefined range, when the excursion takes place out of some value. Now if you are trying to use GPS for sliding the vessel directly up to the dock, that has to be a lot lower tolerance than if you are willing to [use] a 300 foot wide channel and get you down on one side of it or get you down in the center. If you want to go down the center, that means 150 feet. It keeps you in the channel. Those standards need to be set. We also need to look at the methodology and propose the methodologies that needs to be done so that we can determine when the excursions take place. GPS as currently used by the majority of the user community can not determine when the excursions take place. We have to develop the methodologies whether it's within that system or a combination of systems to determine when the excursions take place.

The Royal Majesty found out brilliant blinking numbers to large decimal points are very seductive whether they are correct or not. You are seduced into believing they are accurate. Because if you went out and you stood on the bridge and you took a sun sight while the GPS was off and the DR was taking place and the numbers were being displayed you probably wouldn't get an answer too much different than the numbers coming out of the machine. And what would you believe? You were at fault. Because you did it manually. At least when you took the sights manually you had a feel for the accuracy of the data. When you went out and it was glass clear and you were standing at 108 feet above the sea on a nice aircraft carrier you could rest pretty well assure that you got a reasonable sight. When you are around pitching on a 44 foot sail training vessel on a 20 foot sea and you take a sight and you know darn well that you are lucky to get it within 10 miles or 20 miles. You have a feel that data isn't too accurate no matter how much double precision you get out of those tables. It doesn't really mean anything. Those basically are my comments.

I hope I can help participate in trying to get the discussion going in coming up with some ideas as to how we make these determinations. They are not easy answers. And unfortunately, we have a budgetary process that may close out some of our options, if we don't start working rapidly toward them. Any questions?

Dr. Kane:
I would like to make a few comments as the Chairman's prerogative. First of all, before there was GPS there was all the activity I had as the Air Force base planner. I was a fighter pilot. I didn't like Loran-C. I wanted some way to drop bombs accurately, or do other things militarily accurately. I wasn't worrying about navigation. Weapons on

targets, marines on the beach. We did 70 analyses of how GPS accuracy would improve military effectiveness. I was once asked by [a] university professor [at] Rice whether we built GPS in order to do some scientific experiments of the transmission of signals from the satellite to earth. I had to write back to him and say, all I wanted to do was drop bombs. And the prime example during the Vietnam War when we started GPS, then called 621-B, was to bomb the bridge over the river. They dropped hundreds and hundreds of bombs and never hit. We showed with GPS accuracy you could take out a single pier anytime you wanted to.

So the origin of the use by the Air Force as we pushed it through the system in the 60's, was military effectiveness, and that was the main purpose of it. Now we realized at that time that many of the people in tanks, trucks and so on didn't need fighter pilot accuracy, so that's why we have 2 codes. P-code for weapon delivery. The other code for normal military operations. That's the origin of the system today. Now things have happened a lot differently Andy, and your point about charting. The whole country is going to GIS. The trade association in the Dept. Of Commerce has fostering GIS all over eastern Europe. Business people have reasons for precise location, objects on the train. In fact, San Antonio, where I live, the city council passed an ordinance that all future developments will locate the property to GPS accuracy. The same thing can be done for harbors. If there is an economic reason people will develop those charts. They don't have to depend on the U.S. government. GIS with its interface, GPS makes charting landmass very popular. So there's hope if people find out ways to make money from charting the marine areas.

[Question: not recorded]

Answer:
The odds of running into [atmospheric] anomalies from a temperature standpoint, are lower at elevation, but as you approach the ground you start running into them. The problem of ducting, scintillation, there is a whole series of atmospheric type anomalies or propagational type anomalies [that] exist at elevation. Again, they become more pronounced as you reach toward the surface particularly if you have a landing type environment and if you are talking about aircraft and you are interested [in] landing, basically at sea level. Where you run into the same type of atmospheric meteorological type conditions they will exist.

[The] question then is are relating to the other types of errors that are related to the process from a systems standpoint of charting. I deal in charts. The people who like to get muddy and dirty deal in maps. We get out in the water and deal in charts. We draw

this very distinct line. Do these problems exist with maps? Can it be carried over to other systems? The answer is yes.

As a matter of fact, the aviation community in its beginning kind of discovered from an electronic standpoint that they had these problems. They came up with a series of low enroute and high enroute charts that really removed the geographical features over large areas except for some general references, but they don't try to represent the thing to scale because they found out lo and behold that electronic navigation worked a little differently than mapping or charting of land features. The point that was brought up leads to the solution. If you are going to use electronic navigation in a maritime environment you almost have to change the methodology you use for presenting that data or showing or plotting it. As I alluded to with the resurveying process. The fact that you had to go out and resurvey everything. The question is if you go through and you change the survey process is it time to rethink the charting process from a hydrographic standpoint.

We're using chart technology or terminology that was developed 150-200 years ago. Yes we've made improvements on it, but it's the same basic presentation methodology. Maybe it's time to change our presentation methodology so that it is steered to electronic navigation. Can you take the current presentation methodology and change it to represent accurately and correctly electronic navigation without distorting it for the range and bearing type of navigation, i.e., looking out, sighting this lighthouse here, sighting that point of land over there, drawing two lines and coming up with the correct [point] where you are. Or taking radar off of something and determining its range and bearing and plotting those positions. We've looked at some of that and there are enough anomalies in GPS navigation from a multipath standpoint within harbor navigation to cause one to seriously doubt if range and bearing type charts can be corrected without severe distortion for electronic navigation in GPS frequencies.

We ran some surveys with the Coast Guard, a group out of Baltimore, up in Baltimore Harbor. It was caused by the fact that we took, we have an oceanographic [vessel] out at the Naval Academy that's geared to research on the Chesapeake Bay, and does research outside the Chesapeake Bay. We took it up into Baltimore Harbor, and one day when I was sitting there I mentioned we had excursions, it was 1.7 miles into the city of Baltimore, making two knots, while tied up to the aquarium. The aquarium did not appear to be going uptown. And it did [this] for an extended period of time. It did this for a couple of hours before it came back to where it was, and we had three different manufacturers worth of GPS equipment onboard and they were all moving through town. All at different locations and different velocities. The problem, we sat down and we started looking at and we did some things with the antennas. [It] turned out to be multipath reflections off of buildings, because those buildings at 1.5GHz are basically

reflectors; the signal does not penetrate them. The signal reflects off them. In a high wind, temperature inversion type situation, and that's [what] we saw. We feel pretty sure we understand what was going on. We don't think it was GPS signals. We had no other base receivers anywhere else recording anything to see if GPS was doing anything to us. Being in the Navy we wanted to blame the Air Force, but couldn't prove it. Joint program and we're not sure what happened.

We then went out and put some commercial receivers onboard a Coast Guard 40 foot cutter out of Baltimore, and ran them around Baltimore Harbor, and found the same results. Related to both multipath and to interference type problems of radio signals, RF type interference. We are fairly sure we understand what was causing it and we found that inductive heating [equipment] at Spiro's Point Steel Plant and shipyard could cause variations of up to 3.2 miles on a GPS, and could get consistent results if the ovens were running. So that would lead us to believe [that for] the other surveys we did out where we didn't have multipath, we started to see that if we applied the data to the charts that we had, things were going to get skewed and distorted. I really don't have any answers as to how you resolve it. I think people need to look at it. All I have is some data that says, yes, its got to be looked at and I really don't know what the solutions are. I know that in the aviation community they've looked at it and they've applied a solution where they took the mapping detail off the electronic charts. That is why when they talk about approach plates and certifying approaches into an airport they actually go out and measure and survey that data for that approach plate in a very localized area. You are now looking at very large geographic areas and tying them all together. That's why they only produce so many plates a year. (...)

One of the things I meant to say; I am not sure whether or not I said it. I truly believe from a harbor standpoint DGPS for harbor works only if the DGPS transmitting an error deriving location is in that harbor. And you would literally put one in every place you want to do that type of thing. The geographical area I think that it works is well under 50 kilometers accurately or you have any hope for. We don't know what's going to happen to a lot of these atmospheric anomalies at the high end of the sun spot cycle. Sometime around [the year] 2000 we're going to find out.

Question:
Have you run any of the Coast Guard R&D Center studies, the extensive data collected during the last cycle of sun spots?

Answer:
Yes.

Question:
It did not show any problems. It showed reference stations in Groton, Connecticut, corrections derived there being applied in West Florida, and the area never got worse than 10 meters. So that the spatial de-correlation [was minimal] (...)

Answer:
Late to mid 80's from Groton to Key West in a temperate latitude is not half as bad as the errors you tend to see in tropical latitudes related to these things.

Question:
Baltimore?

Answer:
Baltimore, is related to multipath due to the structures around it. And when you get into a harbor environment with structures around it, reflective paths around it, reflecting the signal you have entirely different factor.

Question:
Let's stick to propagation anomalies please. What are you basing that on?

Answer:
Basing that on studies that have been done by AT&T, by the Navy and various other people related to radar in these frequencies.

Question:
Have they published these reports?

Answer:
Yes they have.

Question:
What part of the Navy?

Answer:
I think you will find that they have been published by the radio branch and avionics etc., related to a number of things that they have found in these areas. I know that shipboard radars, shipboard fire control, suffer from these types of problems from a multipath standpoint. Again, we're talking about a small percentage of the time.

Question:
Just one percent?

Answer:
I think one percent [or] less. My question and as I said in my talk, can we compete with GPS in any other methodology of navigation that we have had [as] a long range basis for accuracy? The answer is no. We're here basically to talk about what happens in that five percent or under that five percent period of time, and how to inform the user when the system exceeds some specification of accuracy. And I think that is what people need to be brought up to understand. They need to understand that what happened when the integrity of the system exceeds some value. We have to: (1) I think, part of our definition should be a way to determine what that integrity level ought to be and which point the user ought to be notified that he has a problem, whether it's on a system basis or an individual basis. I think it's got to be brought back to an individual station, user station basis so that he knows he's in an anomaly. (2) What methodology from a standards standpoint ought to be applied to tell that user so the user is aware of it, rather than some subtle type thing where a comma appears or something else and you have to be looking at it; how is that announcement given to the user? How is display done in a fashion that he realizes that it is not functioning properly? And what types of systems ought to be applied from an integrity standpoint so that we can determine these things?

My discussion has been based on, "How does a single GPS user, using a single GPS receiver determine whether or not his system is operating properly?" And I don't think in today's environment you can make that determination. The user keeps getting information that indicates that it probably ought to be working correctly, and he has no way of knowing whether or not he has exceeded that integrity. Now, if you are going to use it only for coastal navigation, or open water navigation, it's not material. If you're going to change the utilization of the system to a series of areas that truly were not envisioned by the creators of the system for the civilian community to use it in a precise methodology in a different way then they had in mind, how are you going to evolve that system, and how is it going to evolve?

Question:
Dick (...) Air Force navigator. When you were using your commercial units did you see any indication [as] to a solution of the precision, estimated positional errors, did you have that kind of a read out on those?

Answer:
The question was when we were using the civilian units did we see any indication on the unit that the solution had been reduced in accuracy or was there anything within the unit

that gave us any reason to believe that we were not getting an accurate solution? The answer was no. I am familiar with the read outs. Unfortunately, the problem was that when you are looking at the civilian units as currently constructed for position and velocity, you don't necessarily get those accuracy type read outs within the unit. When we [logged] the information and looked at the information from [the] multipath standpoint one of them gave us an indication that it was unhappy with its solutions, but still displayed information and nothing on the display told us. When you do the logout, you get a whole series of things you don't get on the display. The other two gave us no indication.

Question:
In other situations where you have had excursions other than multipath were you in bad geometric alignments?

Answer:
The question was related to the other excursions; were we in bad geometric alignment. The answer is no. Because we could repeat them time and time again. The moment you drove up to Spiro's Point, you drifted off out to somewhere else latitude and longitudinally versus what's on the charts. It was consistent.

Introduction

Ian Anderson:
Our next speaker is Mr. John Beukers. John's probably well known to everybody here. In fact, I think he one of the few people I know who belongs to all three organizations represented here, ILA, GIA and INA. John was born in England, and he graduated from London University in 1954. In 1957 he left the U.K. and emigrated to the United States to continue his career in radio-navigation where he continued to work on Doppler radio direction finders and Doppler VOR. In 1963, he formed Beukers Laboratories specializing in the implementation and the use of Loran-C, Omega, and VLF communications. In was in this field where he pioneered navaid retransmission technology that is now used world-wide to track balloon-borne meteorological weather probes. John is twice the winner of the ION's Burka Award for the best paper of the year; he's authored many papers covering the radio navigation discipline. He is a fellow of the Royal Institute of Navigation, a senior member of the IEEE, a member of ION, a director of the INA, and a director of the ILA, he's also an ex-president of the Wild Goose Association [now ILA]. John is currently a consultant and a riter on radionavigation matters devoting much of his time to finding an acceptable approach to realizing the potential of global satellite navigation technology. Won't you please welcome John Beukers.

John M. Beukers
Beukers Technologies, Inc.

Thank you Ian. My presentation today is called Moscow Conference, but in actual fact it goes a little further than that in that it is a potpourri of international reports, so if you will bear with me. More than two years of preparation and many uncertainties, the International Conference on Global Radio Navigation Planning was held in Moscow, Russia, during June of this year. It was heralded as an unqualified success by the organizers and participants. So much so, that planning of a second conference, in June of 1997, is well underway and there are brochures about this at the registration desk. A simple report confined to the program itself without embellishment would be brief and somewhat dull. The conference resolutions and conclusions have been published and circulated and speak for themselves. Therefore, if you will bear with me, I would like to digress for a moment and give you some background on how the conference came into being, and its organization and the people behind it.

Great credit must be given to the chairman of the conference who originally conceived of the idea more than three years ago. It [was] Mr. Denisov's vision to hold a radio navigation conference in Moscow and it was his determination to overcome major difficulties along the way that enabled it to take place in accordance with the original plan and at the appointed time. Originally, the Wild Goose Association, now the International Loran Association, and the International Omega Association, now the International Navigation Association, were the

driving force behind the conference having agreed to hold a combined annual technical symposium in Moscow during 1995. But during the formal planning phase, the widespread press reports [of] social unrest, criminal activity and economic disruptions in Moscow gave cause for great concern for personal safety for visiting Moscow. Adding to these concerns was the State Department's cautionary advisory to those contemplating visiting Russia. Since much of the financial support of the conference was budgeted to come from the West, and in particular the United States, a poll was taken of a sample of those who would normally attend these meetings and the organizations. Of those polled it was determined that few were prepared to be subjected to the reported environment and those that indicated they might attend were not prepared to expose their spouses to the perceived threat to their safety. Anticipating financial loss, that neither the INA nor the ILA could withstand, the board of directors of both organizations found it necessary to withdraw from the organizing body.

Fortunately, the European Commission and the International Association of Lighthouse Authorities, stepped forward to provide Mr. Denisov and his team with the necessary support and encouragement to continue with the preparations. In addition, a few of us continued to assist on a personal basis.

In retrospect, what transpired might have achieved the best of both worlds. The ILA and the INA did an effective up-front job of planning and promoting the conference. And the International Navigation Committee under Mr. Denisov's leadership demonstrated that it could successfully hold a complex international conference on its own which has certainly raised the stature of this organization in the eyes of the international community. My personal opinion is that the losers are those of the United States who decided not to attend. There were only 14 U.S. participants of which 11 represented manufacturers. There were a total of 250 plus attendees, 67 coming from outside the CIS. Much of the credit for the success of the conference goes to the Inter-Navigation Committee staff. They worked many long hours preparing for the event and worked tirelessly at the administration and the written and verbal translations during the conference. Their cooperation and the pleasant disposition of the individuals making up this team made working with them a delight. Perhaps the biggest accolade should go to Norm Mathews and Peter Kent, both of whom provided a guiding light to those in Russia, who found themselves in the unfamiliar territory of running an international conference.

Now some good news and some bad news. The good news is that with Norm Mathews and Peter Kent are on the 1997 steering committee for the 1997 conference. The bad news is that I am on the steering committee as well and will be twisting a few arms to be sure that the United States is better represented in 1997. So please put June of 1997 on your calendar. A draft of the advance notice is available at the registration desk.

Now as to the conference itself. Following the formal opening of the proceedings by the chairman, Mr. Denisov, the participants were welcomed with addresses from the Deputy Chairman for the Russian Federation, the Deputy Chief of the Department of Defense

Industries of the Government of the Russian Federation, and the Deputy Commander of the Space Forces from the Ministry of Defense of the Russian Federation. Fifty-seven papers were presented on a wide variety of subjects, in Russian and in English. Simultaneous translation was provided throughout the conference, which was a monumental task for the inter-navigation committee staff and helpers. The proceedings will be published in both English and Russian and IALA has undertaken to publish the English version. The final plenary session of the conference addressed the resolution and served to confirm the conferences' conclusion. Both these documents are available and can be picked up at the registration desk.

In summary, the conference called for international cooperation in the development of a world-wide radio navigation plan and for the continued diversity of terrestrial and satellite radionavigation systems. This would appear to be a timely message in view of the current development of the European radionavigation plan, [and] preparation for the 1996 Federal Radionavigation Plan in the U.S. The existence of the CIS plan and the meeting being held this week in Capetown, (actually it was last week, though) the radionavigation committee met last week and there is a meeting this week in Capetown, South Africa, to discuss radio navigation for the African continent, and similar activities of other countries around the world. As is usual at this type of conference there were many informal meetings and discussions. Contacts and friendships were made which will serve to further international exchanges and cooperation. [Of] particular note are the informal meetings relating to the GLONASS program resulting in a commitment by the Russians to provide regular information bulletins on the status and plans of the GLONASS space segment. The reports that I have been distributing on the Internet are evidence of the willingness to share this information. And as many of you know GLONASS has a home page and there is also an HTTP site in Canada.

I would like to comment on the GLONASS program in general. It is quite evident that the Russians treat the program seriously, and have given the space segment a high priority regardless of the severe budget constraints imposed upon by the military. The same can not be said for the receiver industry, which [has] little to show in the way of equipment and technology at this time. However, a representative of one of the U.S. manufacturers expressed optimism from the podium that with joint ventures [and] licensing arrangements this situation could be quickly remedied. The products of another manufacturer [are] noted to have available receivers capable of combined GLONASS and GPS reception.

As far as the social events, the cultural program was appreciated by those who participated, and the dinner trip up the river was a memorable event. But perhaps the highlight of extra-curricular activities was the banquet given by the Inter-Navigation Committee. The meal was excellent, the music was good and so was the dancing. It was an evening to be remembered. And if I may be permitted to end this report with a personal observation, visiting Russia for the first time for some is a difficult experience. Seventy years of authoritarian rule have taken their toll both on the country's infrastructure and the minds of

the populace. Evidence of the decay abounds, making one want to pick up a screwdriver and a paint brush and do something about it. The sad part is that the initiative to do this has been flushed out of much of Russian society. Many wait to be told what to do and are reluctant to make decisions, perhaps for fear of reprimand. This conference showed that given the leadership and a little guidance a phenomenal response is achievable which should give encouragement to those in Russia who are striving to improve the lot of the Russian citizens. I showed this report to Mr. Denisov with a little fear that he might be resentful of what I had said. In actual fact, he came back and congratulated me on an accurate and a true report of what he felt the situation was in Russia. I was happy to hear that.

One comment I would like to make about navigation systems in general. ILS has been around since the 1940s. With the ICAO meeting that took place some months ago, ILS was given a reprieve for another 20 years or so. In all probability by the time ILS does give over to something it will be 100 years [old]. Loran-C is an evolution of Loran-A an evolution Dectra-G and so on. Hyperbolic navigation has been around for that same amount of time, and again that is probably 100 years. The time frame of these systems exceeds our own lives, [and] certainly exceeds politicians' stay in office. And I think that perhaps what we should bear that in mind when we are considering what we do, and we are really talking about long term use of these systems. And now what I would like to do is to turn to a brief report, a summary report, on the Royal Institute of Navigation workshop on GPS interference. David Last, who many of you have heard [give] presentations did a wonderful summary and unfortunately, I certainly don't have his style and I will try my best with his permission to read his summary that he gave at the end of the workshop. I think it is important for this meeting.

[Reading from David Last's report on the RIN Conference on GPS Interference]

Ladies and Gentlemen, the time has come to conclude our discussion, and indeed our workshop and to review briefly what we have learned. When the RIN proposed the meeting on GPS interference no one knew what would happen. It was a first. The question is was there a problem? It was January. Was it sufficient to engage us for a day and a half meeting, or was GPS interference nonexistent or negligible as one has been told and continues to be told by some of the most distinguished bodies and individuals. The fact that some 100 delegates registered, and promptly, for the first meeting of the topic gave clear proof of the level of interest in GPS interference. Either there is a problem here or there is a substantial proportion of the key people in the radio navigation business this side of the Atlantic [who] have too much time to spare on their hands!

We've heard evidence of interference to GPS from microwave [links]; broadcast transmitters, especially UHF television. Video telemetry, faulty EPIRBs, surveillance radar, VHF and UHF transceivers including cell phones; amateur radio HF transmitters; Digi-pieces and fixed installation, airborne DME, VHF comms, VOR oscillators, satellite

communications, marine VHF communications, cranes and winches and many so far unidentified sources. That being [the] experience throughout the U.K., in Holland, including Rotterdam Harbor, the busiest in Europe, in Stavenger Norway, in Switzerland, Boston, Hawaii, France, and most notably in and around Italy where it may be the first evidence of God's revenge for all the wicked things they show on UHF television there. Stripping housewives and I don't know what!

Ladies and Gentlemen, let me be bold and tell you, interference to GPS does exist and it is a problem. Sometimes it's just a short-lived transient phenomenon. Sometimes it only affects a tiny geographical area or an individual ship or aircraft. Sometimes it's trivial, other times it is not. But then steps are being taken to resolve the problem. We've heard from Dutchmen, and the Swiss and the Norwegians and the Englishman undertaking heroic investigations to track down the culprits. Maybe they will also be able to suppress the interference. And maybe not.

We have heard that receiver manufacturers are employing filters extending their linear ranges and advancing [their] processing to make their products more robust. Undoubtedly, that will help. But as one said yesterday, there is only so much you can do. The regulatory authorities are in on the act creating ties to receiver specifications protecting the frequency band, identifying problems where they have the resources. But many interferers are operating perfectly legally within the terms of their licenses. But as John Owens showed us, are still capable of causing severe interference [by] GPS. Can we suppress them? I suggest that if we make the effort to remove the interference to broadcasters to aircraft instrument landing systems (for safety for life services if there ever was one), and we are unsuccessful, the prospect of protecting GPS which will be principally used for non-safety of life services on navigation and so on is slim. Dr. van Willigen has pointed out that there is a substantial gap between the protection GPS requires and that imposed on other services such as UHF TV. They're legal, they're decent, they're honest, yet they still interfere.

And what of the unidentified sources of interference? What of the interference that pops up for a short time and then disappears? We've heard plenty of evidence of how it can render receivers useless. Because this is the nature of GPS interference isn't it? Of the time, in most places there is none. We sail or we fly like Mr. Richardson's helicopters in clear skies with excellent GPS performance, and then it appears, and then it disappears. GPS is like the little girl with the curl. When it is good, and that is almost all the time, it's very very good. But when it's bad, it's horrid. And if you are depending on it on GPS alone, if you are landing an aircraft under high category instrument conditions for example, when it's horrid it can kill you.

So that is the challenge we are left with at the end of the intriguing workshop: On the one hand satellite navigation is here to stay. The future now is overwhelmingly GPS. There are strong [forces] in favor of making it the sole means system in safety critical applications. One the other hand, we have transient, sometimes short-lived interference, often of unknown

origin [and] usually unintentional, but possibly malicious and occasionally, as we have learned today, officially sponsored. And I would like to just inject here this morning there was a news announcement of the BBC and the announcement was to this effect: The RAF is to begin jamming GPS in the Irish Sea. The Royal Institute of Navigation has expressed concerns over military interference in what is increasingly seen as a civilian utility. These tests are being performed because there [are] more and more people thinking of using GPS in weapons delivery systems. It is necessary for countries to start developing counter-measures so these jamming tests now are being put forward to look into the situation which brings the whole subject of civil and military operation in GPS. And the last sentence he had was an injection. "To deal with it if we can be dealt with will require the efforts of the receiver manufacturers, regulatory authorities, the research community, navigators and surveyors, all of us who have attended this fascinating meeting."

John Beukers:
That is what David Last [said in] his summary. There is a report of mine which is sort of a rather dry one more specific on the details of what happened at the meeting. I think that is on the registration desk too. And finally, if you can bear with me there is a navigation system out in the Far East, it's called FERNS, which is the Far East Radio Navigation System. This is a consortium of countries Japan, China, Russia and Korea. After the U.S. Government decided to transfer the [overseas], Loran-C when the DOD expressed no more interest, these countries picked up the stations and they have not only picked them up have put in additional stations. This is the report of the FERNS council that took place last week. It is the fourth session of the council of the FERNS. The fourth session of the FERNS council was held in Tokyo, during the period of 23-27 of October, 1995, under the chairmanship of the Director General of the Aids [to] Navigation, the Japan Maritime Safety Agency, Mr. Yuko Esaka. The session was attended by representatives by the People Republic of China, Republic of Korea, Russian Federation and Japan, with observers from the U.S. Coast Guard, NELS, that is the Northwest Europe Loran System, [and] IALA. The representative of the association IALA was Mr. P.L. Kent, and this was his report.

[Reading from Peter Kent's Report]

As the FERN's joint Loran-C service is due to become fully operational on the 1st of January, 1996, the session addressed mainly matters relating to the operating and coordinating arrangements for the operating chains. In particular, the configuration of the FERNS chains and the administrative and communication arrangements for those chains for the transmitting stations in more than one country were finalized. The council adopted operating guidelines for the radio navigation service. The guidelines which have been discussed briefly, at the [third FERNS] council session and has subsequently been redrafted and edited substantially by IALA sets out the operating procedures and organization structure of the service. The council noted that IALA was preparing an information booklet on DGNSS (stations in operational plan) and agreed to work in close cooperation with the association to produce a similar document on the Loran-C and Chayka systems in operation

throughout the world. The council (this is also important) also agreed to use the FERNS forum to discuss and coordinate other radio navigation services in their geographic regions.

Question:
Peter Moore, British Airways: Some of the aspects of your Moscow meeting. That you will recall of course, that we had a number of planning meetings about this. The last one I can remember at Gatwick, and everything seemed to be going well ahead. Then we had statement where you were principal arbitrator, that INA was not to participate in this, and yet I was quite astounded to find out at the end of it, of course, to find that yourself and the President were then going ahead and then also, of course, that it was such a success. And then you turn around and said well I've only got 14 Americans attended, and yet that you were probably the reason for that. I know a number of Americans who were planning to and certainly a vast number of Europeans were planning to go.

Answer:
I think we have a chicken and egg situation. The decision was not made by me. It was made by the two boards of directors of the two organizations. What I did was to prepare a report for them indicating the financial liability if things went wrong. And that was based upon the number of people that we had polled that said that they were going to attend, which was very minimal. So my report was a financial one and this was purely a financial decision as far as I am concerned.

Question:
Peter Moore: Sorry to say that John. But as a board member of INA, I was not polled, and hence of course it couldn't have been a board decision 'cause I was not actually asked. It must have been a decision of the officers.

Answer:
Well, as member of the board of the INA, I would have to refer you to the President because that report was sent to both the INA and the ILA boards. We'll talk about it after.

Question:
Dave Scull: John, I just want to make a comment, and I certainly don't want to appear critical. But one of our problems, and I think the problem facing us with the meeting in Russia, is the fact that we have so many meetings. So many navigation meetings, so many international meetings. In fact, in 1997, in about that same time frame the International Associations will be having its conference in Amsterdam, you know. So a lot of us will have to make a choice, maybe, of attending meetings. I don't know how we get around that. But it is a problem. Hopefully, we can work towards cutting down the number of international meetings.

Answer:
You are absolutely right Dave. The biggest problem is trying to find a clear space. And June, well I know the ION has their meeting, [and] when you get into the Fall it's hopeless.

Introduction

Dr. Kane:
Our next speaker is Mr. Ken Kelley from AmTech Systems. Mr. Kelley has worked in the electronic industry since 1968. His career includes experience in maintenance, manufacturing and the service markets. He has held positions as an engineering technician, an associate engineer and a project engineer. Since joining AmTech in May, 1988, Mr. Kelley has been responsible in numerous successful [projects] both nationally and internationally. These projects include [the] "Toll Road" [concepts], which are marketed domestically and overseas, fuel depot systems, marine terminal inter-modal systems. His direct experience with marine terminals include AEI systems designs, and installation for APL, maps and navigation and AmTech APLALC pilot project. Mr. Kelley now provides sales and technical support for AmTech's intermodal market. This includes systems integration efforts for applications, and development in the marine terminal access and yard management fields. Won't you please welcome Mr. Ken Kelley.

Mr. Ken Kelley
AMTECH Systems
Intermodal Operations Requirements

My name is Ken Kelley and I have worked with AmTech Systems Corporation since 1988. Our claim to fame in the technology industry is making field disturbance devices that record identification. We're in the toll road markets, we're into rail markets; every rail car in America has two of our tags on it, using radio frequency identification. The market that we are proposing to use now, and we have been working for four or five years to kick it off and are having a hard time kicking it off, is the maritime intermodal container tracking. We can identify the containers but our customers kept asking us, "Well now that I know what it is, can you tell me where it is?" So that's how we got tied up working in integrating systems with GPS. So today, I would like to review what I have found out talking to our customers that have used our systems. We have done some testing with GPS, and will review those results with you.

The intermodal covers a lot of area. It's a pretty generic term, but basically it's tracking containers that can go on ships, rail, or trucking. These containers are multi-modal devices. In the tracking of them basically the containers are big tin cans, they have no intelligence, no power supplies, no computers on them so they would be hard to retrofit with any kind of technology to track them individually. Across the country, across an ocean, through the air. You can track the device that is carrying it, (a ship, a rail car) easier. All you have to do is associate that container is on it. But within the terminal area itself is where they need help in their inventory systems, and this applies to the marine environments as well as the rail terminal environments. I will introduce some new acronyms, (everybody loves acronyms)

in a minute. But basically it is helping the terminal operators manage their inventory to remember where they put things.

In a one-page synopsis of a terminal operation we have gate systems for trucks to check in and check out and identify all of the equipment. We have gate systems for ships to be loaded and unloaded, and the same thing with rail cars. Some terminals have one, two or all of the above devices to bring all of the equipment in and out. They have different modes of storing these devices, and we will talk about it briefly, and different types of container handling equipment. Which just leads to a more complicated solution, but what basically happens is the terminal operator is responsible for everything in that terminal, and like me as I get a little bit older every day, I can't remember where I put things. GPS at our AEI [Automatic Equipment Identification] solutions will enable a software yard management system to do the proper memory checks on it. The computers they've got, the yard management systems have to improve the information that they put into the computers. It's true today as it was in the 50s and 60s; [put] garbage into a computer you get garbage out. In the terminal environment container equipment, some of them are top picks and some are side picks, some are yard cranes that move the equipment around the yard. Straddle carriers are another different type of yard crane. Ships cranes to load and unload the ships, yard hostlers to move the containers on wheels on chassis from one point to another. Inventory vehicles to drive clerks around to check to see where they'll find things that they have lost.

What you are seeing here is a yard crane that stacks these containers three high and eight wide. It can unload containers from a truck or with the side and stack them in a stack or feed a ship. Typically in this massive of an operation the outside trucker brings it right up to the crane, they unload it into a stack and when the ship gets ready they unload it out of the stack onto the ship's crane which loads it onto the ship. Reverse that process for unloading. A little closer view of it shows actually picking up the container. The device the spreader that attaches to the container on the cables, the operator sits above it and controls the movements of it. The operator gets paid to drive that crane. It's a very special talent and they are very good at it. The thing they're not good at is writing down identification numbers or where they put something or where they picked it up from. They have to automate this process to get better. I'll show you an RLI figure to show you about this in a minute. They get paid to do the job. They don't get paid to record it. So generally they have someone else down on the ground recording it. There is a lot of improvement and the shipping industry is looking to improve these processes in an effort to save money.

This type device is a top pick or a side pick. It's on a forklift type chassis. It can stack them three to five high. The trouble with this one and where GPS really comes in the crane I showed you before is with NASA and it's got a sensor-type location system and it works very well because it's on a steel rail. They can calculate and control the sensors. Sensors don't work well on rubber wheel devices like these top picks. They can move all around the area and store them anywhere. The depiction is what we call an MIV, a Mobile Inventory Vehicle equipped with an identification and a GPS system to report location and identification of

containers and the chassis, the rubber wheeled frames that they are sitting on within the yard. Typically the MIV would run down the row at about 5 MPH, collecting data. Location data, position data and if there is something there. It might be an empty slot. They want to report an empty slot to use in their information, their yard management systems.

Some of the acronyms that may be new to you are AEI (Automatic Equipment Identification), ELS (Equipment Location Systems), yard management systems and radio frequency data communications. To get an effective [system], we had to use a little bit of all these technologies integrated together to provide automated data to the terminal operator. We have been looking that these problems in this industry since 1989, and GPS came to our attention about four years ago. We knew of it. We knew it was accurate within 100 feet, and that's not good enough in the terminal environment. That's fine crossing Utah and some parts of Arizona and New Mexico, if you are tracking a truck or a rail car. It's not if you are tracking an eight foot wide container in a stack eight deep. That's when Trimble Navigation and some other people started talking about differential GPS.
The Cargo Handling Cooperative asked two years ago to look at seeing if we could put together a proof of concept that would prove that this technology integration is doable. And the Cargo Handling Cooperative in this case is the joint venture between [the] Maritime Administration, and some civilian operators, Crowley Marine, American Prism Lights, and Matson, and they sponsored to develop and integrate this system.

I would like to talk about what we call an Equipment Location System just for generic terms. The project manager of AmTech served as project manager on it. Now Solutions, out of Santa Clara, CA, was the integrator of choice. The first thing we had to do was make sure [of] GPS. We had played with the AEI, our part of it, a long time. We knew that some of the sins involved there, but we didn't know anything about GPS so we started playing around with it.

What you're looking at is an outline of the Matson Terminal in Oakland, CA, through a vehicle equipped with a GPS system. We played for about two days before we were convinced that the Differential GPS would work in the environment. And we used a differential GPS in this case with the differential coming from Trimble Navigation across the Bay; we were in Oakland. There was about a mile [distance] and we calculated about a meter error, but it was consistent. As we played during the day we started making circles around a stack of containers that were three high. We picked one stack or one row that was by itself. We found that when [we] got into the valleys of containers it was separated by 10 to 12 feet. The GPS would lose lock. We were doing a proof of concept here; we weren't trying to debug the system. So we picked an isolated case just to give us a reference point. So we made four or five circles around it, blew up the information we had and found one meter accuracy. This gave us the confidence that it could be done if we could control the multipath because we found cases in the valleys where we were still receiving. (...)

In integrating our systems we had to look at the customer, what the operator would want and identifying the customer as the terminal operator, not the shipping company or carrier, but the people operating the terminal. The people that load and unload the equipment. We had to look at the differential systems as the location, AEI as the identification system. We had to have an operator display to communicate with the operator and we had to have a radio device to communicate and handle the traffic. We chose a radio system that emulated a local area or wide area land system. This one shows a repeater. We didn't need a repeater for our testing but it could be, and the different stages of equipment. We built the system modularly so that the same system would fit in any type of equipment and the only thing that would change would be the software and the communication controller to handle the difference in problems we saw in the different kinds of equipment. And that would be basically elevation. The GPS wasn't accurate enough in elevation. We had to use a sonar device that I will explain in a minute.

A little primer on our AEI system. It's a field disturbance device. We put out a constant carrier wave in the 915 [MHz] band, or 2450 in Europe and Asia. As a tag passes through it, it receives that carrier, modifies it according to the program and reflects it back. The tags are programmable with 20 user characters, and the identification is decoded from that information and sent back to the host computer for usage. We had to have a measurement device to tell how far we were in the case of elevation, how far off the ground, in the case of the MIV, how far away or if there was an actual vehicle there. Presence detector. Now Solutions makes a sonar device, and this a sample of the output. These are actual 40 foot containers that were parked along the row. It's just a sonar presence detector. Sort of like your construction people use to measure the studs in your wall in your house now. Same concept, accurate to within inches up to about 40 to 50 feet.

We had to identify the type of operation that each piece of equipment would have to use. We decided on two types of terms. Static and dynamic. Static would be where the vehicle [was] at the point of transaction for a few seconds to a minute. Dynamic describes the vehicle correlating the information on the fly as it is traveling down the road, in this case the mobile vehicle at 5 MPH. The other container handlers generally are stopped for anywhere from 20 seconds to a minute to pick up the container and put it down. That was our point, not to track it all the time during the process in the terminal. Only when you pick it up and put it down. Report what you do with it. Don't report where it is between those points.

Our testing goals. With the efficiency of the ELS, (this includes the AEI as well as the GPS), the efficiency of the unit anytime during the day, the satellite constellations, all kinds of weather, operate with existing containers, and this is towards the AEI, tells us that something is there. If it's not tagged and they can't identify it, they still want to know something's there, it is not an empty space they can use. Accurate to within one slot. The slots are about 12 feet wide. We gave ourselves one slot, and nobody's gotten it this accurate before. We improved on that as the testing will prove here in a minute.

We equipped a little 4-Runner with AEI, GPS, and a computer radio system. We used a spread spectrum radio set to two Megabits throughput. The [system] used a little laptop for a processor on the vehicle. We have an antenna array on a pole. The very top antenna is the GPS antenna, getting out of the way of the metal. Getting it above the multipath. So we get accurate readings about where the vehicle is. There's a couple of antennas below that read the tags on the containers and the tag on the chassis. Also on the pole is a sonar device to tell that there is something physically there. This vehicle would go down the row, calculate where it is; it had to use the dead reckoning as well because if it did get an error it would use the dead reckoning to say OK I really haven't changed course, I'm still on it. Wait for the next repeat before you make a decision that you have changed course. The engineers at Now Solutions did a wonderful job.

This is all handled in the software on the vehicle itself. We used a start and stop for our inventory collection of the data that would be handled by the operator for this proof of concept. It was the easiest. In real life, you may want to tie that in with a GPS solution. Tell your operator to go to inventory row G-3, and when he got the appropriate position, turn it on automatically. But this is in a production model, not proof [of] concept.

[In] the workstation, the differential unit is between the two computer screens. The computer screen on the right is the one handling the DGPS information and the radio communication with the vehicle. The one on the left is the user's interface computer. It converts all that [position] information to user slot information; from latitude and longitude to slot 101-102. We went out and mapped the yard where we did the testing, converted that into user-defined information. When the information was sent from the mobile vehicle to the workstation it would convert it to information that the operator can use.

Some of the test conditions that we put on the parameters: A vehicle speed of at least 5 MPH; we were successful between 5-10 MPH. A minimum of six inches separation between containers. Our identification system needs this. It can't read a tag in a can. It's a radio system. So we had to have separation between the containers. Some of the drivers can really park those things closer than six inches together. The test was mapped with GPS, as I mentioned, and manually prior to the testing to determine the slot positions and determine accuracy. An observer watched all the tests. We were in a live yard. This was a live test at the APL Yard in Oakland. We tagged and untagged containers. We tagged and untagged chassis, and with vehicles moving all this stuff around at the same time so as we gathered the information and went back to check it we had to have someone out there to make sure that nothing moved in between.

Most of the test results, and I just have a synopsis of it here, most of the test results showed that we were 98% accurate within one slot. That doesn't mean GPS accuracy, that means identification and location accuracy. Most of it was due to manual error in our checkers that we had to swallow in the testing, or AEI error. AEI on our system, multipath is a good term for what we seek as well. We point an antenna at a container, if the power level's not just

right, it will read four or five containers off [due to] multipath. So most of the errors you see here are associated with identifying the container to the slot. The container mapping location to specific slot was 92%. Now the containers, what contributes to the container accuracy is the fact that these containers are not identified on the front. The tag is on the side so as we drive along on the front we have to aim either forward or rear to get the identification. So that makes the identification a little harder as well as locating an offset or identifying an offset when you read it. That's where the accuracy comes in, not the accuracy of the ELS. The ELS proved consistently, the GPS proved consistently in operation to identify locations in this environment up to one foot accuracy.

The tags on the containers were on the side. On the devices where the chassis were underneath then, they were facing forward, so that your antenna addressing those chassis had a better relationship to identify it to the slot. That's why you see the next information we can identify chassis to 100% accurate to within one slot, 97% within the identified slot it was in. This also includes empty spaces in there. So there's a lot of particulars in this environment that we had to take into account.

There's no mandatory standard. There's no association of terminal operators that's going to tell everybody that it's a requirement to use. So how are we going to sell this to the terminal operator? They have to make money. It has to reduce costs. There [are] two ways to reduce costs. Reduce labor or reduce equipment. You have to identify both of them in this case. The terminal operator makes his money by loading and unloading that ship, or train, or truck. You have to improve his processes and you have to do it in a cost effective manner so that he's putting more money in his pocket as well as putting money in your pocket. Sea Land published a report that said if you increase the average load or transaction on a ship by one container an hour in a small facility, you will realize a quarter of a million dollars savings a year. A medium facility is a little over $500,000 and it's well over a million in a large facility. The average ships crane loads and unloads about 25 containers an hour. The crane can operate faster than that. The crane operators can operate faster than that, but if you are moving an army don't get the gunners in front of the ammunition supply. Supplying that crane is the key. I have seen cranes in the four or five years I have been working on it, stopped for 10 or 15 minutes waiting for the correct container to be loaded into the correct spot on that ship. Identification in the terminal and feeding that crane is how the system will pay for itself.

Getting less expensive. This is a very expensive GPS system, [and] it's a very expensive AEI system. In the future we have to address the costs of the integrated technologies to improve these systems. We're doing it with AEI. We need GPS to do the same thing to get that accuracy down so that we can distribute the cost of business over a mass [market] instead of concentrating on one industry. When we do that it does everybody a lot of good in this GPS environment.

This test was done in cooperation with CHCP; they funded about half of it, AmTech funded about half of it. It was done about a year ago, and Now Solutions is marketing this system. They are designing it in a modular systems so that it can operate with a radio system and GPS or AEI, plug in what you need in the rail and maritime industry in North America. There is also a company in Europe, Rhode and Schwartz, that has a GPS system installed in Hamburg, that they are marketing. It is only telling them where the operators are. They're putting it on the container handling equipment and there's no tie in with AEI, and there is no tie in with the operators radio console, so it's getting into this industry. It's in its infancy. To spread it out we need to reduce the cost and the operational [cost] of it. We need the consumer educating the industry about GPS. A lot of these people have hand-held GPS systems on their boats, and they wake up in the morning and move 50 feet. And then they see the $14,000 high end of the units that we introduce, they need a general public education. I think that is where these industry groups can help us to educate and advertise the GPS and how it works and what it's doing. We talk about user fees. They've asked us about user fees. Well what is this GPS? How much do they charge us to use it?

We used a differential on one located at the terminal. We put that differential unit at the terminal. Our engineering agreed with some of the earlier speakers that using a unit a mile away would probably be OK, but for our testing for this proof of concept we wanted it within an accuracy that was controllable. That meant that the differential unit had to go on the terminal. But these terminals are located pretty close together. Los Angeles, San Francisco, Seattle, New York, Charleston, Miami, we believe that these Coast Guard systems are a viable alternative to the expense if the differential signal can be calculated and be reliable. This isn't a safety factor, this is just doing business. [Somebody] might miss a shipment of tennis shoes, but I don't think its a life and death issue. It's just a company reducing costs, making money. So a commercial differential correction signal is a good idea. Again, the user fee, we keep saying, there is not user fee. I mean it's free. It's a satellite. The government does it for you. If there's a user fee associated with it, then you are going to start seeing the same thing, the controversies you see in the other pilots associations now. Users fee will be an issue when this kicks off in this field. Some of these issues could be addressed in the advertising. Right now these terminal operators are paid to operate the terminal and they are very good at it. There's a lot of black magic with GPS and AEI, and so anytime we can get media information disseminated in the industry papers and magazines it will help everybody. Can I answer any questions?

Question:
When you stack containers three high does it hide the GPS constellation?

Answer:
It does. We looked at it and we surveyed the equipment and what we found was in most cases that we've been associated with, on the container handling equipment, that you're taking the GPS reading at the time of transaction. Some device has to be above the container so that is, you want to locate the antenna in the highest point. In the case of the yard crane

it would be near the operator that's above, in the case of the top pick it would be on the boom, in the case of the MIV we had to put it on a pole about 14 feet above the ground, because that's where the top of the containers are. Multipath is the sin that you fight and it will confuse things.

Question:
Have you thought since your engine isn't moving around very much or your unit isn't moving around very much have you thought of using a small inertial set? Just a couple of gyroscopes up that you could check every 10 minutes or so to augment the GPS readings?

Answer:
Yes. That's one of the considerations and basically that is what our engineering people at Now Solutions did. They used it through the odometer interface and they had some sort of sensor, inertial sensor there to tell them when the GPS said well you jumped three feet, everything else had to correlate with that jump. But it was a prototype proof of concept system. As you see in the cities as you go through and [with] the multipath to confuse you, you need a dead reckoning system to augment the information.

Question:
This application is very similar to that being used extensively now in the utility industry usually by the guy on the street; link up a transponder that's hooked up to gas, water and electric heater and a unique ID output, and sends back the reading on the meter to a vehicle driving around the city. [The vehicle] will have a GPS receiver on it and they'll go back to the utility office and download it into the GIS system. Is this real time differential? And if so, the way it's set up it is my understanding that we have a reference station now with the terminal itself. How are you communicating with differential corrections if you are using real time?

Answer:
It was a semi-real time. Every second we would broadcast the corrections into the terminal area from the terminal DGPS. Once a second the entire broadcast over a spread spectrum data radio, and the receiving unit would pick that up and use it. And in the meantime we used that same radio to transmit information back to the host computer. So we were using the radio as a communication device both for intelligent information coming back and for the correction information going to the vehicles. This would be set up in a broadcast mode. The radios were capable of understanding. You didn't have to address the radios one at a time. To send a correction they understand a broadcast command and then they would identify themselves as they send the information back. Does that answer your question? The concept that we've talked about is using some of maybe the Coast Guard facilities on their DGPS's in their harbor areas in that terminal environment. Some of these things have to be investigated to see if they are an accurate alternative to each terminal having its own DGPS on site. But we're not there yet. That's just a cost solution alternative that's been brought up.

A gentleman asked me if we used bar codes anymore. And basically our system is an electronic version of a bar code. Our AEI system is a niche. It's a high speed, high range field disturbance device on a radio frequency band. Bar codes are optical. You can make a bar code label for 10 cents that will read in an inside environment such as we have here. These [tagging] devices work in all kinds of weather, all kinds of mud, and work very well outside where the bar codes don't. So we have a niche product, if you will, that fills the market. It's the same concept.

The railroad in the '60's spent a billion dollars on a color coding bar coding system that's still optical, it still gets dirty, it still fails. Radio frequency doesn't. It all the same law of physics when you are talking about radio frequency. We have the same multipath. We have the same attenuation as anybody else in the radio business or in the GPS business and we understand these terms and how they affect us. But mud, dirt, and water don't bother us.

We have two models. This AEI is battery powered. We have a beam powered one that will use the power that is transmitted to it to activate the chip inside here. This one is a international tag that works at 2450 and 915 MHz. At 2450 world-wide the power settings that are allowed are so low, 30 Milliwatts to 300 Milliwatts, that the beam power won't operate that low so we had to put a battery in these versions to power up [the] 2450 operation to get us a little more power. We have both.

Question:
Why can't you tag the slots in the row?

Answer:
We did. The slots in the row are about $50 a piece. So if you get $50 bill every 12 feet, and then the terminal operator wants to restripe or change things it gets expensive, [but] we tried it. And that's why we are at GPS. GPS so far, we looked at triangulation, we look at tagging, GPS is the cost-effective method for locating.

We invited our people out to demonstrate this. Several presidents of Matson APL, and lo and behold it didn't work. We had a bad coax at the antenna on top of the terminal. We're very embarrassed by coaxes and connectors and you have to have a good installation. Thank you.

Introduction

Dr. Kane:
Our next speaker is going to talk about the railroad system. He is Mr. Richard Shamberger. Richard graduated from the Johns Hopkins University with a BA in Industrial Management. He's had 12 years experience in Class I [railroads], and 21 years with the Federal Railroad Administration, which is a division of DOT. He is primarily engaged in policy and program development with special emphasis on next generation information/operations/control systems. His current assignment is with the research & development team within the Federal Railroad Administration for positive train control and high-speed passenger train operation. Won't you please welcome Mr. Richard Shamberger.

Mr. Richard Shamberger
Federal Railroad Administration
Positive Train Control

Good afternoon. From what I have heard so far today I am in the company of the men and women who are part of the solution, not part of the problem. You always have a choice. You are part of the problem or part of the solution. I also believe there are no victims, there are only volunteers. I heard some remarks this morning, and this is not a derogatory statement at all, about the Administration, about the Congress, even about the Department of Transportation, and when I get to thinking along those lines I usually reach into my wallet and pull out a dollar bill and I study it and it doesn't say in technology we trust, in the Administration we trust, or in the Congress we trust. It says in God we trust. Whatever you conceive that to be, that's it. Well I trusted in God. The Department of Transportation, is one of the two that went back to work [after the shutdown].

We heard some remarks about transportation and the economy. Transportation and Agriculture are back to work. Some of the rest of it is still balancing the I forgot the word, what was it? The Department of Transportation does have its strategic plan that it put out in 1994. I would just invite you to open your minds a bit and listen to some of the words about what these goals are, and think about GPS and DGPS and the kinds of automation we've been talking about today within this context. The writers of this plan define the Department of Transportation as the federal steward of the transportation system; all modes. Here's the mission. We're going to tie America together with a safe, technologically advanced, efficient transportation system that promotes economic growth and international competitiveness now and in the future [and] contributes to a healthy and secure environment for us and our children. Now I can applaud that.

What we are doing in the rail industry fits within that mission. Our Administrator, Jolene Molitoris knows full well that FRA stands for Federal Railroad Administration. But we all

got some coffee cups. You can't give away coffee cups so they became pencil holders. FRA also stands for friendly, reliable Americans.

Now here's some of DOTs goals. Remember the context is GPS. (1) Tie America together with an effective intermodal transportation system. (2) Invest strategically in transportation infrastructure which will increase productivity. (3) Stimulate the economy and create jobs. (4) Create a new alliance between the nation's transportation and technology industries to make them both efficient and internationally competitive. (5) Promote safe and secure transportation. (6) Actively enhance our environment through wise transportation decisions. (7) Put people first in their transportation system by making it relevant and accessible to users. (8) Transform DOT by empowering employees in a new team effort to achieve our goals. Now the fact that they let an optimist like me out of DOT into a gathering like this with no guard dogs is a sign perhaps that they have empowered some of us.

The product I'm going to talk about this afternoon, positive train control, is a GPS-based specifically differential GPS-based, train control system. And I would submit to you, and watch carefully and to see if I am in error that the system I'm about to describe fits into this general mission both nationally and internationally and fits into these specific goals. One of the gentlemen made comment that it was President Lincoln in the early 1860's, understood that transportation would connect this country and [that] transportation also drove the economy. The railroads connected the two oceans in the 1860's. Watch the newspapers carefully over the next year because this is a deep down drive within the railroad community. Somebody is going to merge to get to the Atlantic come hell or high water. Whether it makes sense or not they will join the oceans. One of the things President Lincoln did was to ensure that there was a standard gauge railroad in the United States of America, and incidentally in Canada and Mexico. Here's a number you don't have to remember. Four feet eight and one-half inches standard gauge. Railroads are unique. They are autonomous. They're all different and they made one decision unanimously in the 1870's and that decision was never to agree on anything unanimously again. So standard gauge railroad is a standard.

Now we're faced with standard gauge electronics. Trains run on tracks. Railroads run on information. This is really a family of technologies that I'm going to talk about, but DGPS is at the heart of it. Let me give you a definition of what a railroad is and what kind of vehicles we're pulling and what the railroad infrastructure looks like. A train is a very big thing. It's three [thousand] horsepower per unit. The locomotive unit is $2 million at the curbside. Usually two of them on a train. Trains may be a mile long. Nine thousand plus tons. You just don't slam on the brakes and stop it. It is big. It goes up hills and down hills, and left and right at the same time. An engineer puts an instruction into the throttle system or the braking system and in his gut intuition, he/she knows it going to [be three] maybe four minutes for all of this to take place. We're dealing with some old technology.

Now the problem arose in the railroad industry when somebody decided to run more than one train a day, that started it. You have a following train or you have an opposing train. Many places in the country years and years ago there were main line track situations three, four or five tracks wide. Now here's a number I want you to remember. From track center to track center for adjacent parallel tracks is 11½ feet. So when the rail industry first heard about GPS they said, "it won't work." And it was tried and there was a lot of money spent in the iron range of Minnesota, by Rockwell International. The Burlington Northern Railroad won't even tell us how big those numbers were.

There weren't that many satellites up at that time, and the board of directors didn't want to believe that it was going to work. They didn't want to put all the money into it and the implication was that if one railroad does it all railroads are going to have to do it.

I didn't read this morning's paper; maybe another [railroad] merged with another one, there [are] nine big railroads in the United States, and they make a lot of their decisions and some things along with the two big railroads, Canadian National and Canadian Pacific north of us. These are corporate entities. Their own stock holders, their own locomotives. There used to be 115 Class I railroads in the nation and I just told you that there are nine. Do you see what is going on? Merger. Back when I started railroading there were 2½ million people in employment in white collar and blue collar on the large railroads and today there's less than 192,000. This is just doing more with less. There's 160,000 miles of main line railroad out there.

Radionavigation conference. We're going to build this platform on an RF communication foundation. Navigation. Trains navigate the rail, right? It's a limited guideway. It's a fixed infrastructure. Some of the railroads liked VHF down in the '60s and that's the stuff that's real popular with the folks that want to auction things and I'll come back to that. And the FCC out of the goodness of their hearts gave us six dual channels up in 900 MHz for a new train control system with no thought as to whether that would be enough or not. We also have some down around 450 MHz for some of the end-of-train devices, head-end devices and that kind of thing. Less than 2 MHz of frequency. Most of this is up for grabs in the new "let's auction it off and make some bucks". But remember, it's in God we trust, not the FCC. This has been going on for 100 years. How does the railroad segment its physical plant and keep trains apart? (...)

The interesting thing about a switch, there's only two things you can do with it. You proceed thought it normally or you go reverse, you change direction. Fixed blocks. Wayside signals. Now how is the block length determined? It might have been determined years and years ago by signal engineers and it's based on the maximum stopping distance of the longest, heaviest, high speed train that goes through there, which might be every third Sunday. You see what has defined the block? The operation is therefore restricted in a particular block occupied by a train and at least one adjacent block. Now this consumes a lot of geography. Do you follow what I'm saying? There's a train in a block out there. There's a vacant block behind

him. Here's 30 miles of railroad, one train. There's an empty block ahead of him. There's 45 miles of railroad. The dispatcher sitting in some headquarters 2,000 miles away is in radio communication with the train, analog talk-talk. We call it mis-speak. I spoke it wrong, you heard it wrong, you repeat it back wrong, human factor.

Railroad signal systems. Red. Absolute stop. Do not pass go do not collect $200, go through it and you're fired for this and the next life time. It enforces nothing. The railroad is an old industry. The hours of service laws that control the rail industry were written in September 1909. If you work more than 12 hours they've got to give you 10 hours off then you can go work for 12 hours and they give you 10 hours off and you're not sleeping at home. You're sleeping at some place up on the other end of the railroad. The work force has been cut back and back, and back. So they are running engineers as fast as they can. You people in the aircraft industry understand what the problem is. You have hours of service and fatigue problems. Every truck driver, for instance, has two sets of logs. One he turns into the cops and the federal highway people, and [the other is] what he actually does. A locomotive engineer in a period of 30 to 45 days, goes to work, gets to other end of the railroad and tries to go to sleep. The phone wakes him up two hours before he goes back to work, and by the time he's worked for a month and a half, his body has been in 16 different time zones. Around the world flyers go through this. They are not sure who they are, where they are, and what the destination is. Human factor. Mini-sleeps that doze off. We've all done it coming back from a long vacation. They run the signal. They sail right through the signal. It's kind of a problem with the systems, the laws and the regulation, they run the signal.

The system which I am going to describe is electronically based, radio frequency communication based foundation. Digital, not analog information. With displays that the engineers themselves had been in on; this is what they want to see. The dispatcher has a board, they build dispatching centers, (centralization is intriguing to mankind, let's centralize everything). So now we've got two railroads out there that are 30,000 miles big, with the dispatch center as big as a football stadium, with the railroad on the wall. A video camera from behind. Every piece of track of track laid out, 360 degrees worth of it. Three tiers of people. The dispatcher, the supervisor of several dispatchers, the grand supervisor locomotive authority, safety officer, big operation. Just like NASA for instance.

You've got a red light in the middle of the block. The block is 15 miles long. You know there's a train in there. You remember talking to him, but you don't know where he is in the block. You don't know whether he is moving and you really don't know whether he stopped for a moment and decided to back up. Therefore, his position is not known. Nobody can calculate ETAs. You don't know whether the tail end of him is sitting right here on this switch or whether he's 12 miles that way. Pretty sloppy. They've been doing it this way for 100 years. One half of the railway system out there is signaled in this fashion and it chews up a lot of plant capacity. Very few trains can eat up a lot of railroad. Half of the nation doesn't quite have enough trains on a periodic basis so it's called dark territory. There are

not signals. Railroads have had mile posts for years; 193.6. Kind of next to that big white rock sort of around that turn past Aunt Minnie's barn. The engineers know where there's dark territory. The dispatcher doesn't know where he is. Interesting kind of a problem.

You all are radio navigation experts. The railroad industry has had some rear-end collisions or head-end collisions that are very notable. For instance, that Chase, Maryland, thing with the locomotives ran through a switch ran though a light, got on a main line, thank goodness they were 200 yards short of the Bush River or that whole train would have sunk and drowned, and the guys said to themselves, "Oops! Shouldn't be out here". They had Amtrak coming up behind them at 110. Shouldn't be out here. Big accidents. The news media likes train wrecks, cause you can get a little flimsy helicopter and get just high enough to take a fantastic picture, and everybody goes, "Oh my God look how bad that is!" National Transportation Safety Board just licks their chops. There are parts of Congress, Science and Technology and Commerce, and we have our advocates in there too. Something's got to be done about this awful railroad problem. Federal Railroad Administration is a regulatory agency, safety regulations, that kind of thing. Inspections, user fees, that's stung them. You know, you inspect us and fine us and we're paying for it.

The US rail industry is not subsidized by anybody. Not the Congress, not the Federal Highway, not nothing. They're victims. And they're afraid of my agency because we're going to regulate them to do something. Well opportunity and economic need and safety and technology coincided at the same point in time. And some guys started thinking, this differential GPS will get us close to the position of where we are on the track. And since a couple of railroads had also gotten into some private GPS-based site survey type people, they were inventorying their property and come to find out that they're getting the track, the switch, and the signal location and so forth down to 3 centimeters. You know how the survey industry does that. And they put that into a database. You put the whole bloody railroad on one CD-Rom, the entire United States. I just described 160,000 miles. All the side track, all the industry tracks, all the passing sidings, all the double tracks, you put the whole nation on 1 CD-Rom. Well, [you could] probably put that in on an onboard computer, couldn't you? The railroad doesn't move around unless a barge hits a bridge, (we have our little things too). You've got to look out the window but when there's a lot of fog it doesn't help. Systems fail. Not all that often, but they do fail. The railroad is surveyed, latitude and longitude and also elevation. I learned that from the survey people. They know the elevation of it. So now we have the same CD-Rom that describes the railroad piece by piece by piece as you traverse from A to Z. The elevation and the grade and the turns, and the switch locations, on the locomotive.

You can also put on the locomotive the operating rules. There are several speed restrictions. In highway driving there are some of these ramps you don't want to come off of it at 55 MPH. It says 25 because it means 25. That's a civil speed restriction. What's to keep a man from going through it too swiftly, particularly if the general manager has just screamed at him, "I'm going to threaten you, your wife, your kids, the dog, and burn [your] house down

if you don't get there by... He's going to advance the schedule. That's a civil speed restriction. The system I am going to describe will enforce that he does not do that. He's authorized to move to the end of a certain block and then stop, as in absolute, complete stop. He can't get past it, and here's why. The location determination system is going to give us the speed, the location, because a part of that onboard computer every four seconds is calculating and recalculating a braking algorithm. Remember I said the fixed blocks were determined by the maximum train length, weight and speed through a block. What's it going to take you to get stopped. But suppose you had an onboard computer that had available to it, train length, horsepower, train weight, aerodynamics of the cars (there is a difference in how empty cars stop and loaded cars stop) and it knows the terrain.

And here's where the DGPS comes in. The locomotive sensor suite, position, location and speed, is kind of driven by the DGPS. It is supplemented by the track database down to three cm. It is further augmented by a fiber optics gyroscope. Remember you can go through a switch two ways, you go straight through it or you reverse. What does a fiber gyro do? It leaves an electronic signature so every switch, every crossover has an electronic signature. This becomes known over time. So DGPS in conjunction with the fiber optic gyro, in conjunction with whatever you prefer, tachometer/odometer situation, in conjunction with an onboard database that knows the entire rail plant, with some software and a Kalman Filter is calculating, recalculating and re-registering the exact location. As a matter of fact, [with] the specifications we have along the line of track we could be any place within 20 feet because on main line railroad switches can not possibly be closer than 60 feet apart. They just don't put them on main lines. You put that in the yard where you are moving along at 3 MPH. On main line railroad the switches are a good deal farther apart. The primary purpose of this, it's calculating a braking algorithm out in front of him. It's sort of like an FAA system where an aircraft is in an envelope and the rule that you write is that the envelope does not touch something else. It's just calculating and recalculating. What we have is positive train separation, and I would go so far as to say positive train control. We're going to run it at first in phantom on top of the signal system. The signal system, the lights, the radio instructions will be given the orders and set in the authority. What we are after first is proof of concept. We'll have that by the fall of 1996. By the 4th of December, 1997, we're going to have a production system totally checked out. There's a test bed of 863 miles of railroad up in the states of Washington and Oregon, that goes from Vancouver, British Columbia, and [when you] hit the border there's a place called Blaine, Washington. So Blaine, Washington, down through Seattle, Tacoma, and Portland, and then you turn east along the Columbia River Gorge, which ought to be a really nifty test of DGPS.

Now this location problem is different from other modes of transportation because we have a fixed guideway. I know what track I'm on which means I have a one-dimensional problem. Not a three. I have a one dimensional problem. I know what track I'm on with 99.999, five nines, certainty. I know what track I'm on. I only need to see two satellites and the second one for time. I only need to see two, and if DGPS drops out I've got the track database, the switch locations, the fiber optic gyro and the odometers counting. Yeah, you're right they're

kind of accumulating error as it goes along but one of these situations is going to pop up that I either go through a switch and match its signature and know exactly where I am and get a re-registration of exact location. Or I've got full DGPS coverage. Everybody's happy. The odometer/tachometer system is amassing what it's doing.

This kind of makes me smile. The places where DGPS is likely to fall out would be urban canyons or terrain masking. One of my railroad friends said, "Dick, you know it's not going to work cause we've run through West Virginia and there's all these big, tall trees". Wish I'd thought of that; it's terrible. But think about this for a second. The place where you've got big tall trees and terrain masking or you are in a river gorge or you are in a urban canyon, what is the likelihood of having absolute straight tangent track? Zero. You're going to be making turns and curves. You don't have to go through a switch. All you have to do is move the gyro a little bit and it will find itself on the map.

So here's a system [that] is redundant in that it's getting its sensory information input from several different sources. Half of the rail industry likes VHF, the other half of the industry likes UHF, so we are going to put a joint system radio, UHF and VHF where the server can handle either. The rail industry has one of the largest, if not the largest privately owned telecommunications systems in the nation, 16,600 base stations. The FCC is trying to say that the railroad radio service is not something that should be kept together. Why not enter with cabs and the donut company and you the guy that delivers pizza. They don't understand yet. We're talking about a nationwide interoperable radio frequency communication-based, state of the art, location determination system [calculating] braking algorithms. We call them moving blocks. As the train goes the block moves ahead of it. What's the first implication? The whole fixed wayside infrastructure comes out. Quite possible, quite possible. The one half of the nation that is now dark with no signals is lit up. The engineer knows where he is. The dispatcher knows where he is. Other trains know where he is. They are running off of one base station.

What can you do when you do this? You can meet and pass trains. You're not stuck with these long blocks anymore. You can put them close together. How many of you have ridden the Metro systems like this Washington system downtown? Alright, it's closed like a bowling alley. It's under cover. They've got controllers and fixed blocks. And how long do you wait when you miss? Thirty-five seconds? How many times do they stop, you in the tunnel when the computer stops the train, and you say, "Oh beans", and you hear the man's voice come on. The man talks on the radio; that's why he's there. "There's a train on the platform ahead of us, we will be moving momentarily, be sure and take your newspapers and belongings with you". And just about the time you get finished saying, "Oh beans", it starts off again. We're going to do this out-of-doors with nothing much in the track, wayside interface units that control points to look at the health of them.

The biggest problem that we are going to have is the fact that with this 160,000 miles of main line railroad in America, there are 280,000 at-grade crossings for rubber-tired vehicles.

Some of them with just cross bucks. Some of them with lights. Some of them with gates and a public that's forgotten the size, the weight and the devastation that goes along with a train. People drive through these things and splinter up the cross arm. Half of the collisions are folks that drive into the 5th car. The locomotive doesn't hit them. They drive into the 5th car, (a train's pretty big). You weren't drinking 7-Up. Something's going on here. People don't believe the blinking lights. They look at an approaching headlight; you know that Doppler effect. You don't know whether it's two miles down there or 50 yards and you don't know how fast it's going and they try it.

So Administrator Molitoris would have me leave you with this thought. Always expect a train. Stop, look, and listen means actually that. We're going to try and hook this positive train control system into what the intelligent transportation system people come up with and make some more robust and vital grade crossing situations. One of my ideas quite frankly, and this is no [stuff], is a readout that would go 7,6,5,4,3,2,1 dead! And a couple of guys said to me, " ya know psychologically you're wrong because there's the driver that's going to sit there and say that doesn't mean me, watch this." And he'll try it. I don't know what we're going to do about that.

But at any rate, the Federal Railroad Administration told the United States Congress that unequivically the Coast Guard differential system would really cut the mustard and support positive train control in the United States of America, and in the parts of Canada where it comes up. Mexico is about to move that route. It would give a standard-gauge electronic foundation. And you all know in your hearts as well as I do that it's going to work; it's here. We're not doing it just because we can do it. It coincides with economic need. It coincides with all these wonderful things in the strategic plan and it fits right in with what you all are doing, and it's something to watch. It will show up in GPS World. It will show up in Traffic World. It will show up in the railroad magazines here and there and one of these days it's going to be real.

The ROI [return on investment] on this: Suppose I said that if you took out the fixed block system, that the rail plant capacity, the infrastructure that sits out there now, the track, could support 30% more trains safely. You could run 30% more trains. This is done in partnership. [The] U.S. Government with the states of Washington, [and] Oregon. Two of America's larger railroads, Union Pacific and Burlington Northern, have an awful lot of their own money into this. We're entertaining the notion of moving up to Vancouver, and adding British Columbia, or Canada, if you will, into that partnership. We're going to run some high speed trains up there. And when I say high speed I mean 110-125 MPH, and we're going to prove that you can co-exist.

Freight trains. After all, the freight railroads own the railroad. Amtrak runs trackage rights. Those two trains, passenger and freight, can co-exist safely, not to the detriment of [either] one, and this [is] a brand new paradigm for railroading.

If there's any questions I'll be hanging around here and I'll be here all day tomorrow. If there are any ideas, my ideas are not cast in stone. I mean about how to inform people, how to sell the notion like the gentleman from AmTech said, "to get the users and the public to understand what we are faced with here". We are all interested in this as consumers. Railroads move one hell of a lot of goods. They're environmentally friendly. Everybody knows about congestion around big cities. Balancing a national transportation system. This problem exists all over the world. So here we have economic need, economic opportunity, a political whatever, and technology that coincided at one particular point. Jolene Molitoris' favorite word is, "I'm excited". Well you all don't look too excited but maybe you'll be better when you get some coffee and Coke. I thank you for your time, your indulgence, and if you have anything to share with me, please do so. Thanks for your attention.

[Mr. Gudat submitted the following materials for use in the Proceedings.]

Introduction:

Adam J. Gudat graduated with an electrical Engineering degree from the University of Illinois in 1965. He attended UCLA and USC for graduate work and spent 13 years with Hughes Aircraft Co. In Los Angeles, California, designing and developing communication and spy satellites, radar system, and ECM equipment. He joined Caterpillar research Department in 1978 where he has been the lead engineer in the design and development of automatic and autonomous machines.

His current responsibilities include, searching out new technologies and combining these with GPS and automation leading to autonomous machines.

He is a registered professional engineer in California and Illinois. He has 15 patents issued and numerous applied for in the area of sensing and machine control.

Mr. Adam Gudat
Caterpillar, Incorporated

PRECISE LOCATION AND COMMUNICATION

IN

CONSTRUCTION AND MINING

Adam J. Gudat
Staff Engineer
Caterpillar Inc.
Peoria, Illinois

GPS International Association
Radionavigation Users Conference
November 16-17, 1995

Biography:

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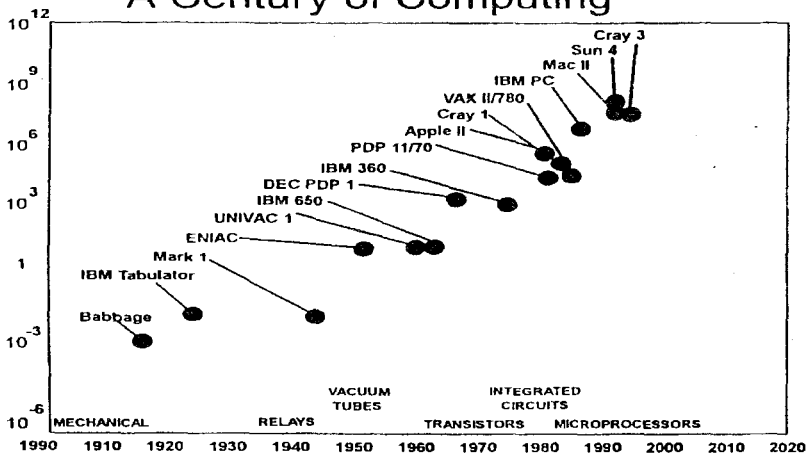
ABSTRACT

The Global Positioning System (GPS) satellite constellation opens up new vistas in tracking machines in construction and mining. Position determination down to the inch allows new technologies to be developed that will revolutionize the way we control machines. Automation and autonomy will combine with GPS to reduce both the cost of production, and labor in the future.

Several developments in positioning, navigation and machine control will be discussed that forge the basis for future concepts in construction and mining.

OUTLINE

A Century of Computing



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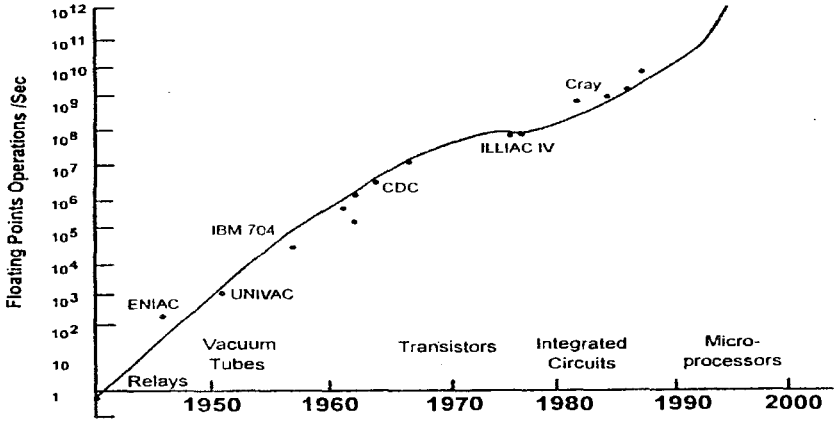

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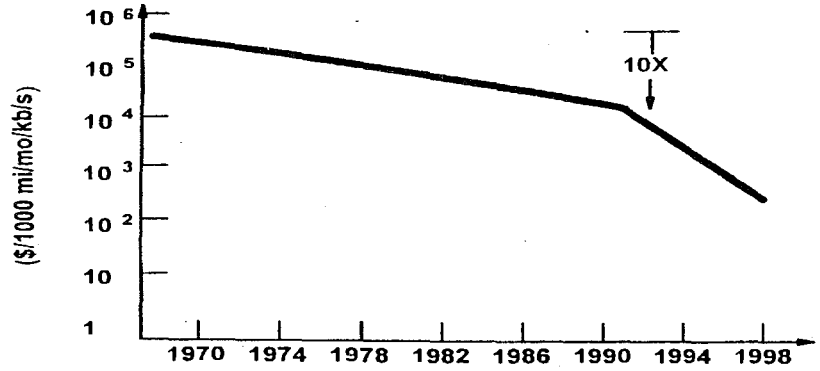

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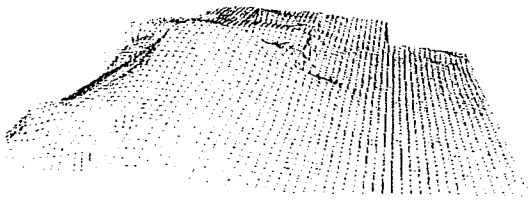
Digitized Site Plan



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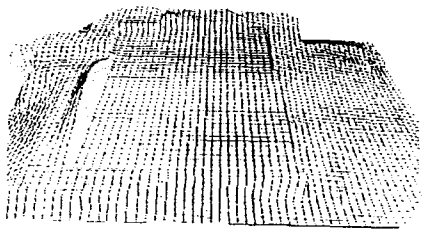

Site Plan

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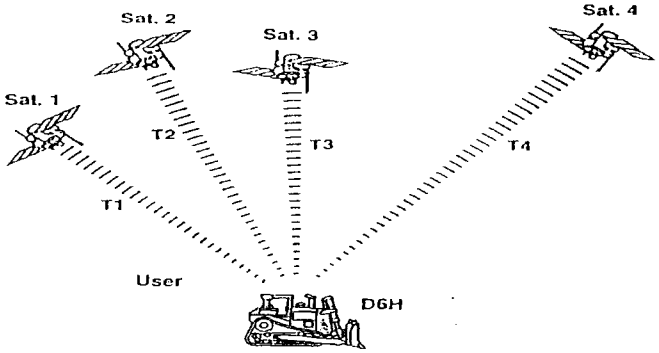
Precise Location



GPS Positioning

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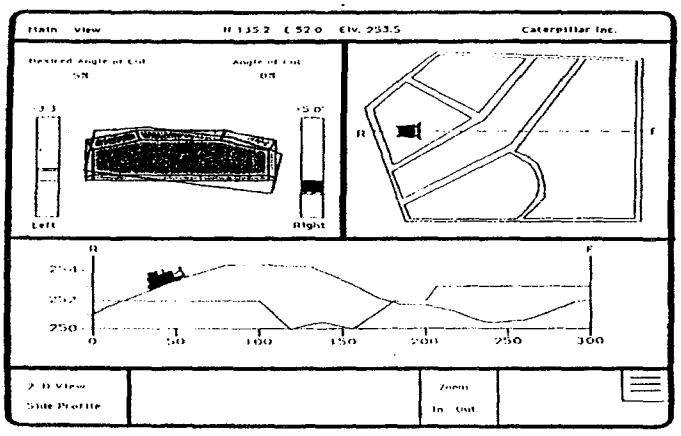
Navigation & Operation



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SITE INFORMATION MANAGEMENT

Machine Utilization
Performance Documentation
Progress Reports
Reduced Human Effort
Improved Job Quality

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PROBLEM AREAS

Technical:

The technical goals are achievable with today's technology

Policy:

Uncertainties in the long range management of Radionavigation Systems becomes more of a problem

Availability
Reliability
Integrity
Cost

SUMMARY AND CONCLUSIONS

* Computers, Precise Location and Timing, and Automation will greatly effect the future of earthmoving in Construction and Mining.
* Precise Radionavigation Technology will become a utility, giving rise to increased industrial efficiency.
* Construction and Mining will become a Controlled Process similar to today's factories and assembly lines.

Introduction

Dr. Kane:
Andy Bogle has worked in navigation and positioning for more than 25 years. During this time he has been involved in the radical evolution of the radionavigation industry -- from the early hyperbolic systems such as Hi-Fix and DECCA Navigation, to the revolutionary Starfix system from John E. Chance & Associates (JECA), and today's true Global Positioning System (GPS).

Andy began his career in 1968 with the DECCA Company and that company now of course called Racal Survey. He was employed by them as a hydrographic surveyor where he worked on a variety of surveying and positioning projects on the North Sea, the Mediterranean, West Africa and the Middle East. In 1974 Andy formed his own company, [offering] surveying services off-shore and subsequently developed one of the leading surveying consultancy companies in the off-shore industry. Andy moved to the United States in the early 80's. Andy joined John Chance & Associates in 1986, to develop markets for the company's new star-fix satellite positioning system. As the business development manager for John Chance & Associates, he is instrumental in the development of new business markets including the introduction of the Omni-Star Differential GPS service. Andy was born in the United Kingdom, and you'll denote a little bit of a brogue in his accent as I did. He earned his original diploma in navigation from South Shields Marine College in 1967, and he later studied surveying at the Worcester Polytechnic [Institute]. Won't you please welcome Mr. Andy Bogle.

Mr. Andy Bogle
John C. Chance & Associates

I am going to change my text here. I was hoping that most of you would have left by now or fallen asleep because the worst thing I can ever get is technical questions. Looking at this august body in front of me reminds a little bit of when you go to Paris, and everybody says, "don't be frightened to use your French. Just get out there and talk to those guys in French and they'll love you". What they don't tell you, is that you talk to them in your school-boy French and they've got this awful habit of replying to you in French, and you still end up going, "I'm sorry, I don't understand what you say. Could speak English?" So go a little easy on me here on my little change of text.

In talking about differential GPS, one of things that's really come through to me in listening to everybody today is that the number of new applications that have been developed and are really moving very very quickly, GPS right now is moving as fast as the computer hardware industry was moving 10 years ago. Extremely fast. But I do want to put this into perspective that DGPS has been around since 1984. In fact the Coast Guard was one of the innovators in DGPS. Real time DGPS, I think probably [there was] a Coast Guard system in 1985. The

first satellite-broadcast DGPS from single satellite was here in the U.S. in 1985. The first commercial DGPS, primarily for the off-shore business, was in 1987. So the technology is getting to be 10 years old now. I included kinematic in here. Kinematic goes all the way back to 1988. It's is just now as the equipment is getting lower [in] costs and the applications are beginning to develop as the [system] becomes more pervasive.

The off-shore business has some very unique requirements with perhaps the first real market for DGPS. The reason is that it's a very very high risk environment. Anything from I guess $2,000 an hour in operating costs to several hundreds of millions of dollars in capital equipment. It is not unknown in this world to put in my drilling rig off-location. When I talk about off-location I'm not talking about yards off-location, I'm talking about miles off-location. It's happened. So it's a very very high risk environment, and of course in today's world with the environmental risks it's even greater.

Very remote areas. I've spent my life in the off-shore business and I've never yet been anywhere nice other than Houston, TX, of course. I'm a Texas boy. In places like West Africa, off-shore Indonesia, Alaska, all of those remote areas, civilization is hard to come by and putting radionavigation systems up is even harder. GPS and DGPS have been a great boon to this industry.

And of course [you get] the immediate high accuracy. They are too high in accuracy sometimes. Remember the guys in the seismic business [were] saying what we really need to do is to position the seismic boat, the 300 foot long seismic boat to a meter. Two hundreds miles off the mouth of the Mississippi River. And you're out there, you've got 15 foot waves, the antenna's going backward and forward like this and everybody is [sick] and you want a meter accuracy and it's like the guys can't steer this boat to within a meter, you know? But high accuracy is very very important. Because of the risk in the off-shore business there has been a set of operating standards adopted over the years as far as errors and accuracy. And this is really what I am going to change [in] my presentation, to and just talk about errors and accuracy because everybody's talking about this.

GPS: How accurate is it? I'll bet nobody here would bet their next month's wages on an answer to that question. DGPS in particular; there's a lot of mis-education. I was looking at a GPS manufacturer's box, the box the GPS receiver came in, the GPS receiver was less than $1,000 and yet on the side of the box it said, "Differential, 1 meter". And everybody says it, differential equals 1 meter. I'm going to show you some data that will hopefully clarify this. (...)

We measure differential GPS over some very very long baselines. This is a satellite broadcast, it's a DGPS service. It's a wide-area network. These are our reference stations. We bring everything back to Houston. So you can see that some of our baselines, we measure them in thousands of kilometers. We've been doing this since 1986, and have got a tremendous amount of information and knowledge about what happens with differential

over these long baselines.

I'll show you some data. The top left panel is raw differential. This is with SA on. The panels are measured from 24 hours of data, [and] it's all the same data set by the way. This is the difference easting from a known point, and this is the difference northing, and we are measuring on two axes. It's a relative measurement. We're merely tracking here the noise with GPS. As you can see from the top panel raw GPS, if you are willing to sit on a point for 24 hours, you know the mean is zero. You're going to get a pretty good position. However, if we measure the sigma value, this is a one sigma horizontal, 1 sigma I guess is 67% probability, you can see we are about 14 meters in eastings and about 17 meters in northings over the period. We take that same data and we now correct it differentially using one site on a 1,500 kilometer baseline, if we are measuring this at Houston, our measuring site is in Cocoa Beach in Florida. It's a nice place to be, by the way. The guy who sets this system up has a holiday house in Cocoa Beach, and this is why our reference site is there. It's 1,500 kilometer baseline, and as you see we have improve the standard deviation by a factor of 10. We're now at 1.4 and 1.5 [meters].

But on mean the eastings has gone to 5 meters. And a long time ago we asked ourselves a question. Why have we suddenly now got this offset, this bias? The answer is, and I think it illustrates it quite clearly, is it's atmosphere. It's the atmospheric errors, and it all translates into the eastings because Cocoa Beach, is about due east of Houston. We're not seeing any offset in the northings. If we'd measured a north/south baseline we would have probably seen nothing in the eastings and maybe a little bit in the northings, I don't know. So this is was differential does for you. We then on this bottom panel here, we then correct for the ionospheric and a little bit for the tropospheric delays, and as you see we've now again doubled the accuracy or halved the error whichever way you want to look at it. It's now about a half meter. This is one differential site. We've now introduced on this last panel, another two sites into a wide area multi-site solution, and we've now again improved those results by 20 cm. What we are taking out here in this last panel is multipath errors from each individual reference site, and the last of the tropospheric errors. We believe that's probably as good as you're going to get with DGPS. We believe we've taken out the majority of the errors, DGPS errors, and that the only thing we have left now are the receiver noise. This by the way, I have to tell you, is a Trimble 4000-SE. It's a very expensive receiver but it's also a very good receiver, and its a $15,000 receiver, I think as somebody pointed out a little bit earlier. So this is what you can expect from a multi-station or a network solution. It's not bad.

What I want to show you now is the difference in some receivers and why you can't necessarily say that [if] I've got a differential solution I'm going to get a 30 cm position. That is in the individual receivers. We title these $3,000 GPS receivers because we don't want to upset any particular GPS manufacturer, because we're nice people down there in Houston. This is a 3-D plot in fact; this is height in the middle. This is a $3,000 GPS receiver and as you can see it's OK. People will call up though and say, "How long have I

got to stand at a static point in order to get 1 meter accuracy?" And my answer is, forever. And that kind of illustrates why. The scale here by the way is 0 - 10, plus or minus 0 to 10 to the top. You can clearly see from this though that if you went to any one point you can be as much as 15 meters off in eastings. Fifteen meters in northings and you know when you take the factor between those and you've probably got up to 18 meters if you took one point. You may [get really] lucky and go in here at 3:00 in the afternoon and get 0. But at the end of the day, we are talking about statistics here. And to get close to 100% probability, we have to multiply these signals here by three, if there are any statisticians here that hopefully will agree with me here, so you can see that to get 100% probability we're probably going to be saying this is a six meter system. This is a six meter GPS receiver. And please ask questions if anybodys got any comments while I've got these slides up here.

We can go to a little better receiver. A $4,500 receiver. It's a little quieter. You can see that the short-term noise is a lot less. But we are still saying that if we want to know what the accuracy of this receiver is 100% of the time we're still about at five meters. These sigmas that are one second we logged more than [a] 24 hour segment. The sigmas are based on 24 hours of data that are based on [the] entire data set. Zero to 24 hours. It never changes. I'll come to this in a minute, actually. Because this is receiver noise, it will always be inherent in the receiver.

This is about a $12,000 receiver. And now you are beginning to see the sigmas again. These sigmas are not 24 hours [because] I had a data collector and this is all we could store, but it's based on 1 second samples over that period of time. And the 1 sigma horizontal, we're into sub-meter now you can seen this is about 66% of the time. The question is if you are on a survey mode what 66% are you going to choose. And of course that's really an impossible question to answer.

I'll go back again to the $15,000, this is the Trimble 4000 which again on a 3 sigma level is truly a sub-meter receiver a sub-meter DGPS receiver. I'm not selling Trimble by the way, please don't get me wrong. There are other receivers that will do this. (...)

Question:
What's the top panel?

Answer:
The top panel is HDOP. We plot that to see if there are any anomalies in the data [so] we can refer back to the horizontal dilution of position.

But someone said earlier on that a lot of education needs to be done in GPS. I think as I go on and talk to people, people are asking a lot less questions about GPS. Three, four, five years ago they wanted all the details about it. Now they buy a GPS receiver and they're happy with it. A little bit of same is now happening with DGPS. They used to ask a lot of questions about it and now some are beginning to accept it.

One particular area, what are the differential applications? Well you know we started with off-shore exploration, and we at John Chance are up to positioning farming right now in agriculture. Agriculture is estimated to be the largest market for DGPS applications by the year 2000, and it came from absolutely nowhere. Two years ago, all the studies all the marketing studies, all the gurus out there, did not even see the agricultural market, and I suspect that a lot of markets are going to come up and be very very similar. Transportation is one of them. Not for navigation. I don't think commercial companies like ourselves should get involved with the federal radionavigation mandate as far as safety of life on sea and air is concerned. But let's call it not navigation, but position processing because that's what we are doing. We're processing a position to provide information. That's what position farming is all about.

Just to finish, I'll go on to some future looking. The position farming market is potentially huge and it's like on a daily basis people keep coming up with new applications. I think as this GPS, DGPS becomes more accessible, either it be private commercial services such as ours, or through the Coast Guard, it's going to become more adopted into different applications. And as I said, in transportation, actual processing of positioning is probably going to be the next largest market. Does anybody have any more questions?

Comment by Dr. Kane:
In [the] 1960 period we were already exploring the concept of differential for fighter pilot scramble when the INS was not stable. We could climb up to within 10 feet of accuracy to get to the rendezvous point.

Answer:
Yes. We actually used differential Loran-C for route positioning up in Alaska. I think we also used in the Gulf of Mexico. A great system.

Question:
You are comparing 3 GPS receivers which you called $3,000, $15,000 and something else thousand. I presume in each case the differential corrections which were being applied are transmitted at the same rate so that the update rate is the same. In that case, to what do you attribute the difference in quality of the residual errors?

Answer:
We believe we have taken out [most or] all of the errors, and we kind of prove that by that 30-cm plot. The only thing that we can conclude is that what is left is receiver noise. We do these tests, we have 11 reference sites throughout the U.S., and we measure or monitor each one 24 hours a day, 365 days a year, so we know when there's any aberrations with our network. The data you saw was not actually measured on the same day necessarily, but I think all the parameters are the same. And again, getting a little bit out of my area of knowledge here, but we say that what you have left after we have taken all those errors out is receiver noise.

Comment:
Receiver noise is a function of receiver bandwidth.

Question:
What do you mean by repeatable.

Answer:
We see the same standard deviations, the same means on a day in and a day out basis. Not the same excursions. That varies you know with the HDOP.

Question:
I am curious from a marketing perspective. How do you market your services versus some of the other commercial differential services in terms of how you distribute the differential corrections and so forth. And I am also curious about your company's positions or actions in terms of SA and the marine radiobeacon and so forth.

Answer:
OK. I'll answer the easiest question first. As far as SA is concerned, we believe that it should be turned off. I think there is a lot of money being spent trying to defeat SA. As you've seen we have kind of been through this. For us we are free of a lot of bandwidth in our [system] because we do not have to do the range corrections so quickly. So there is some cost advantages to us having SA turned off and I think from a marketing standpoint we're still going to have the niche there in the sub-meter type applications. So the SA thing that's my response to that one.

On the marketing side. We've had to go through a number of learning curves, because you know there really is no precedent for providing positioning on a fee basis. A lot of people are talking about user fees. A very straight answer to that and a way to do user fees is to leave precise positioning in the hands of commercial entities and let them collect the fees from those who use it. This is the United States of America, and hopefully we'll maintain our capitalistic base and I think commercial companies can go do that. We're doing that with John Deere. We've got to a price that John Deere's happy with and probably more importantly what John Deere customers are happy with. And John Deere's going to know that we are going to provide our service day in and day out. Our livelihood depends on it.

The Coast Guard beacon system, just to go on from that. Probably my biggest fear is that the U.S. Coast Guard are going to have a 1-800 U.S. Coast Guard service number. You know somebody could call 1-800 and get immediate service when there is a beacon down. That competes with me. I think as long as the Coast Guard is in the business of providing DGPS and radio navigation for the safety life at sea, that's fine. When the Coast Guard starts going and touting their system for agriculture use, I'm going to get a little upset by it. I'm a tax payer too.

Question:
Do you have an on the fly kinematics system?

Answer:
Yes we do have an on the fly kinematic system which we developed in conjunction with U.S. Army Corps of Engineers. It's not part of Omni-Star. The problem with kinematic is that we have not yet found a way to deal with the spatial correlation that you get as you move away from the base station. I think like the gentleman earlier said [you limit it to 20 miles]. And currently to get on to that centimeter Z component you need dual frequency, and dual frequency receivers are quite expensive too, so we're not quite there yet.

Comment:
Good evening gentlemen. I am sorry to intrude at the last moment. You've heard a lot of words from British people and I'm an official Brit. I'm the Civil Air Attache for the British Embassy, and I represent the UKCA. Questions [were] asked this morning about the relationship between user charges and the safety of operations. I think that it is important that I stand up and say that from the U.K. point of view, and I think from the European point of view, there is no correlation between the use of user charges and safety of systems. The operation in the U.K. is managed by the National Air Traffic Services. It's a joint military and civil operation and the service provided outside controlled air space by military radar controllers uses the same equipment and the same integrity of systems as the civil operations. And I think it would be wrong to talk [about] anything between user charges and safety of systems.

What I think is important, and I can say this from a personal point of view, is that there is a relationship between user charges and the way that an organization spends money. And I'm the manager of the New Scottish Center which is the second air traffic control center for the U.K. airspace. An important aspect of the way we did our investment analysis is the way we charge airlines for the use of the services, and the way the user charges change as a result of our investments. I think that is the important aspect that should be connected. You already have a type of user charge in the United States. It's the ticket tax, it's the waybill fees, it's the av gas tax as well. And that's the important aspect you need to keep. It is wrong to conclude that there is a relationship between safety and the user charges.

Dr. Kane:
Well, I guess we all agree we've had nothing but outstanding presentations today. I'm really gratified that everybody volunteered readily to give us so much information on what we're working on. It's the future of GPS. So tomorrow we'll have a very dull day because we will have policy discussions and no ones allowed to ask any questions you know (!) And [the government representatives are] anticipating being beaten over the head and ears by the usual madness in the room, so it ought to be even more lively tomorrow. Once again thank you for coming and participation. And we are now going to adjourn. (...) Thanks again for a wonderful day.

Conference Transcript
Friday, November 17, 1995

GOVERNMENT POLICY DISCUSSION

Introduction

Dr. Kane:
George Wiggers is here to lead a panel including Paul Drouilhet and Dick Shamberger, and I believe there are two others in the room. We will be talking later. I just want to make one point at the beginning. You recall that yesterday at the opening session I made the point that in order to have the policy panel I had to deal with George Wiggers and his negotiations, and he convinced me that he would come and have the panel talk if we gave him in return some constructive ideas on improving the Federal Radionavigation Plan '94 and inputs to '96. Also as I pointed out, Heywood said this is sort of unique in that we are a "mini-users conference". It's one of the few times when the individuals actually operating with GPS and other radio navaids have a chance to talk to the people who set policy and explain it. So it's a unique event in that regard. And if we're successful in helping George and company today maybe we can [have] future user conferences like this for individual users and make their needs and requirements felt.

The format this morning, to get to our action: I'll turn the podium over to George and he will introduce the subject and the panel members who are present, I believe Jules McNeff is not going to make it. I believe the others are all speaking for the respective agencies. George asked that the questions be held until this afternoon. So the speakers will go through their presentations and we'll get through early for lunch.

After lunch we'll come back here and have a session of discussion. Now you all know Dave Scull, and in a moment of madness he agreed to be the moderator [for the workshop this afternoon]. And I pass on to you Dave the charge that George gave me months ago, "I'm used to being beaten over the head and ears let's not have more of that today." So by way of introduction, I would like to turn it over to George from his position as Director of POS/NAV, DOT. Thanks again for coming.

Mr. George Wiggers
Chief, POS/NAV, Dept of Transportation

Panel Chair

Thank you very much Duke for that very kind introduction. It's a pleasure to be here today. I see a lot of smiling faces out there. That's good. My face is smiling cause I'm being paid today, which is somewhat unusual for this week [referring to the temporary government shutdown earlier in the week]. What I'm going to do is go through some slides which just provide an overview of what the Government policies are on radio navigation. Then I will turn it over to each of the panel members who will give a brief presentation on what their agencies are doing. Again, I think it's very unfortunate given the turn of events this week that not everyone could be here. I believe that Lou LaPine from the surveying community was scheduled to be here as well as Jules McNeff from the Defense Department. Of course [they are] the co-managers of this system with the Department of Transportation.

Not all of us could be here today because of the events in the Federal Government, but those who are here we will try our best to let you know what's happening. I do hope that since we do have a smaller panel than anticipated, that we can perhaps get through our presentations a little earlier this morning and have the questions and answers immediately after the presentations. Again, time permitting, I believe there is other business that has to be done. But if we can do that we can keep the program on track and get you an immediate response to your questions.

Again, just going through a quick overview of what the federal policies are and how it works. We have the Federal Radionavigation Plan which is the official source of radio navigation policy and planning for the U.S. Government. It's strongly developed by the Dept. Of Transportation and Defense. The first FRP was released way back in 1980 as a report to Congress responding the INMARSAT Act, and ever since then it has been updated on a biennial basis.

The systems policy for GPS, is in the FRP. Anyone who does not have one, we can make sure that you get a copy of this report. There's two levels of service for the GPS. The SPS which is available world wide, free of direct charge, and then the PPS which is available only to authorized users, and that's because it has encrypted codes in it. The signal specifications are published in a separate document called the Signal Specification Document, and there's been a recent revision to that several months back if you haven't got the latest release of that.

Continuing with the systems policy. For augmented GPS the Coast Guard differential system will be [in] operation in 1996 and will provide better than a 10 meter accuracy for harbor or harbor approach. The FAA is planning the Wide Area Augmentation System for CAT I and

the Local Area Augmentation Systems for CAT II and III precision approaches, and there will be a special CAT I service for private users.

The Loran-C in the current edition of the FRP the plan is to phase out in the year 2000. Any continuation beyond that date will be dependent upon requirements for the system that will need to be identified. Omega will be phased out September 30, 1997. And again continuation will depend on requirements identified to continue it past that date. The VOR/DMEs, GPS WAAS will replace those systems. Target date for transition to GPS is the year 2010. Radio beacons, the non-DGPS marine radio beacons will be phased out by the year 2000 and most of the aeronautical beacons will be phased out by the year 2005.

For precision landing systems, the MLS development program has been terminated. The ILS for CAT I will be phased out by the year 2010, and ILS for CAT II and III also phased out by 2010. TACAN is the military counterpart of the VOR/ DMEs, and the land based TACAN phase-out will begin in the year 2000. Transit, the system will be terminated by December 31, 1996. That concludes the overview of the federal policies on radionavigation systems. And what I would like to do at this time is introduce each of the other members of the panel that could come today, and they will explore a little bit more detail what some of the policies are and how their programs are working. Paul Drouilhet, who is with the Federal Aviation Administration, will now give a brief presentation of the FAAs programs.

FEDERAL RADIONAVIGATION PLAN

- ***Official source of radionavigation policy and planning for the U.S. Government***
- ***Jointly developed by the U.S. Departments of Transportation and Defense***
- ***First FRP released in 1980 to Congress in response to the INMARSAT Act of 1978***
- ***Updated biennially***

SYSTEMS POLICY - 1994 FRP

AUGMENTED GPS:

- Coast Guard DGPS operational January, 1996 with better than 10 meter accuracy for Harbor/Harbor Approach.
- FAA planning WAAS for CAT I and LAAS for CAT II/III precision approaches.
- Special Category I (SCAT-I) provides service for private users.

SYSTEMS POLICY - 1994 FRP

GPS:

- Two levels of service :
  - SPS - available worldwide free of direct charge,
  - PPS - available only to authorized users.
- Signal specifications published in Signal Specification Document.

SYSTEMS POLICY - 1994 FRP

LORAN-C:

- Phase-out in the year 2000.
- Continuation will depend on a requirement(s) for the system.

OMEGA:

- Phase-out date Sep. 30, 1997.
- Continuation will depend on a requirement(s) for the system.

SYSTEMS POLICY - 1994 FRP

VOR/DME:

- GPS WAAS will replace VOR/DME.
- Target date for transition to GPS is 2010.

RADIOBEACONS:

- Non DGPS marine radiobeacons will be phased out by year 2000.
- Most aeronautical NDBs phased out by 2005.

SYSTEMS POLICY - 1994 FRP

TACAN:

- Military counterpart of VOR/DME.
- Begin Land-based TACAN phaseout in year 2000.

TRANSIT:

- System will terminate by Dec. 31, 1996.

SYSTEMS POLICY - 1994 FRP

PRECISION LANDING SYSTEMS:

- MLS Development program terminated.
- ILS for CAT I phaseout by 2010.
- ILS for CAT II and III phaseout by 2010.

Paul Drouilhet, AND-500
Integration Product Team for GPS Navigation
Federal Aviation Administration
Washington, DC

Good morning. I'll expand a bit on what George has said regarding the FAA-specific programs. We'll probably still leave much still unsaid and we'll be glad to discuss that as the morning goes on. What I want to talk about is how the FAA plans to use GPS to move into a GPS-based system for air traffic control and navigation and landing guidance. I probably hardly need to remind this audience of what the basic GPS system is. The system that we have in place today is the 24 satellite constellation provided by the Department of Defense. It reached its official IOC (Initial Operating Capability) towards the end of 1993. It was made a formal part of the National Airspace System by the FAA Administrator in 1994, and it's getting increasing use throughout the system as a supplemental navigation system. The basic system, the system that we have now falls short in a number of respects in meeting the requirements to serve as a principal, primary sole means. Each word has its own specific connotation, but [GPS is viewed] as the basic navigation system for aviation. The main characteristics that are requirements for navigation [and] landing guidance are integrity, availability and accuracy. In each one of these parameters the system we have today falls short, and the major thrust of the FAAs program is to provide the augmentations to GPS which will let the GPS as augmented serve as the sole means navigation and landing guidance system for aviation.

There are two main thrusts which I will talk to. I'm sure you're familiar with these terms, the WAAS (Wide Area Augmentation System), and LAAS (Local Area Augmentation System). Two separate activities so that GPS as augmented with these capabilities will be able to serve as a sole means system for aviation. The WAAS is a network of ground reference stations, monitoring stations on the ground. The present plan is to have one station at each of the air route traffic control centers in the U.S., bringing the data from each of this network of stations together at two master stations, where the corrections will be computed for each of the GPS satellites in view. The integrity information will be generated and [the system will be] essentially continuously monitored for any anomalous output, and the results of these computations will be broadcast via synchronous communications satellites to aircraft in the coverage area. These signals radiated by the communications satellites will be GPS-like signals themselves so they will provide additional ranging sources for operators as well as providing the data link that provides to the users of the system the integrity information saying on a very rapid update that each GPS satellite is providing valid information. And it will be providing both the clock corrections, ephemeris corrections and data on the ionospheric delay which will allow the users to precisely determine their positions.

The WAAS is currently on contract. The contract for the system was signed earlier this year in August. It was originally intended to be in May, but it was in August of this year and we are currently on a schedule that the initial WAAS operating capability, one that involves the reference station network that I described transmitting the signals, the WAAS signals through three INMARSAT communication satellites, will be operating in early 1998. That is what is called initial WAAS or IWAAS. That will be augmented by options on the contract over the following few years to reach EWAAS standing for (end-state WAAS), around 2001 which will provide additional reference stations and additional satellites to provide a sufficiently robust system to meet all of the requirements to serve as a sole means system for navigation and landing guidance. The coverages of IWAAS is illustrated here. This is the coverage provided by the three INMARSAT satellites which will be used as the initial source of the WAAS signals. It provides double coverage on eastern and western parts of the U.S. and single coverage in the center of the U.S. WAAS will provide sufficient accuracy to provide navigation and landing guidance down to CAT I minimums. CAT I minimums are a landing criteria that is a 200 foot decision height and down to a half mile of visibility. Those are the limits to which the aircraft can descend on a precision approach before it has to be able to take over visually to see the runway or the runway lighting and land from that point visually.

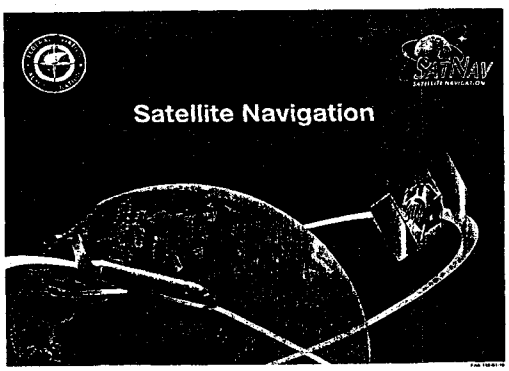
The accuracy of WAAS is not sufficient to support the higher categories CAT II and III precision approaches. CAT IIIb full autoland [is] where the aircraft flies to touchdown based just on the electronic guidance signals. To provide those additional precision landings the FFA is pursuing a LAAS program which would have a reference station at each airport for which we are providing CAT II or III service and then a local broadcast of corrections by a line-of-sight data link from the reference station directly to the aircraft. A number of different techniques have been tested. I'm sure you have read about these tests in the press. There have been extensive tests like 100 or so autoland operations with each of about half a dozen of techniques which differ in detail but are all of the same general architecture. The status [of] that program now is that the technical feasibility of providing autoland guidance through CAT III capability has been established and the issue now is to narrow down to a single technique and to then go into development and production of certifiable equipment. The rather ambitious schedule that we have laid out is to accomplish this and to have an initial operating capability first operational systems installed around 2001 and by 2005 to have LAAS capability at all airports where we are providing CAT II or III approach guidance. The other use of WAAS is to provide even CAT I guidance at airports where for one reason or another WAAS doesn't provide adequate coverage. Particularly far northern airports or airports where terrain shadowing may preclude adequate WAAS coverage.

Taking then the basic GPS as augmented with WAAS and LAAS we fill in all the squares on this matrix of the various phases of flight and landing and the criteria which I introduced earlier of integrity, availability and accuracy. The basic GPS alone is adequate to meet the requirements in oceanic operations, but it must be augmented with WAAS and/or LAAS as shown here to provide a sole means for these other parts of the matrix. These systems will

come and in their very early phases just as GPS is today, it's an augmentation, an addition to what we already have. But the systems in place are expensive to maintain both through the FAA and the aircraft operator, and our goal with GPS as augmented is that it will eventually replace, not just augment, the ground-based systems that in use for air navigation today. And this is a primarily a dollar driven issue. We're spending today just to operate and maintain the existing ground based navigation and landing guidance infrastructure around $200 million a year. And that doesn't include the cost of replacing it as would need to be if a new generation of ground based equipment were required.

The transition strategy is to bring the new systems on line and start getting operational benefits from them as we are doing today, but with the systems in a supplemental basis we're using it but the new system is not sufficiently robust yet, to operate without keeping the current ground based systems in place. The next step is to bring the new system, the augmented GPS to a sufficient level of robustness with internal redundancy that we can begin to operate GPS as a sole means system. We can begin to have aircraft flying with just GPS onboard. And then to give the aircraft operators from the time GPS is augmented (provides an equivalent capability to the existing ground based system) around 10 years before we're removing the ground based system. About five years of full capability and then a gradual phasing out of the ground based system.

Given that philosophy, and George gave you most of these numbers in his introductory discussion of the Federal Radionavigation Plan, it talks to a phase-out of the various existing navigation systems. [For] all of the ones which are primary systems within the NAS, the phase out begins around 2005. The exception to that is the present plan on Loran. It has never been a primary system. It's a supplemental system in the NAS. GPS has provided equivalent capability to Loran starting in [the] '94 time frame, and at this time the Coast Guard ceases to support Loran in the year 2000. There is no plan at least at this point for the FAA to pick up support for that. So let me close at that point and we'll be glad to later answer any questions.



Basic GPS System Limitations

Does Not Satisfy Civil Aviation Requirements for:
Primary Means Navigation

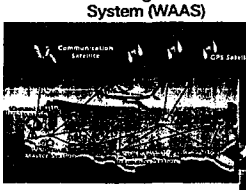
- **Integrity**
  - Notification Time: 15 Minutes or Greater
  - Not Sufficient for Civil Aviation
- **Availability**
  - Position Determination (90-95%)
    - 24 Satellites - 70%/21 Satellites - 98%
  - Not Sufficient for Primary Means Navigation
- **Accuracy**
  - En Route Through Non-Precision - OK (100m)
  - Not Sufficient for Precision Approach

Basic GPS System

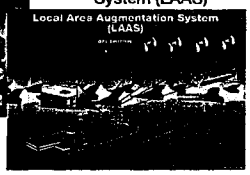
- 24 Satellite Constellation
- DOD Developed and Operated
- Cost: $10.5B
- Initial Operating Capability - Dec 1993
- Civil Aviation Approval Feb 1994

Augmentation Systems

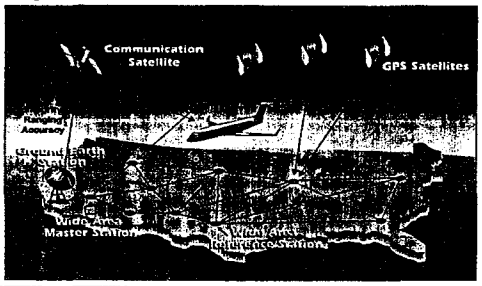
Wide Area Augmentation System (WAAS)



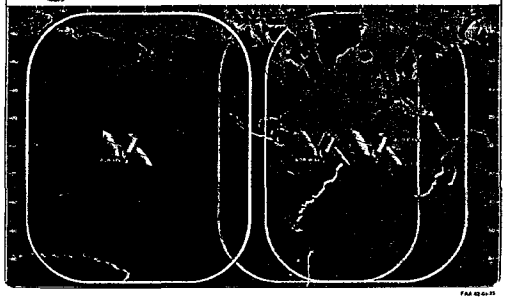
Local Area Augmentation System (LAAS)



Wide Area Augmentation System (WAAS)



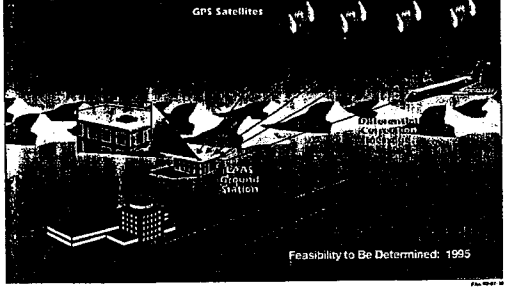
Initial WAAS Coverage Using Imarsat III Satellites



WAAS Current Status

- Acquisition Approved - 10 Feb 94
- Request for Proposal (RFP) Released - 8 Jun 94
- Proposals Received - 22 Sept 94
- Contract Award - 3 Aug 95
- Initial WAAS - Early 1998
- End State WAAS - 2001

Local Area Augmentation System (LAAS)



Local Area Augmentation System (LAAS)

Objective: Produce LAAS for Use in the NAS to do Terminal Area Nav, Precision Approach (All Categories), and Surface Navigation

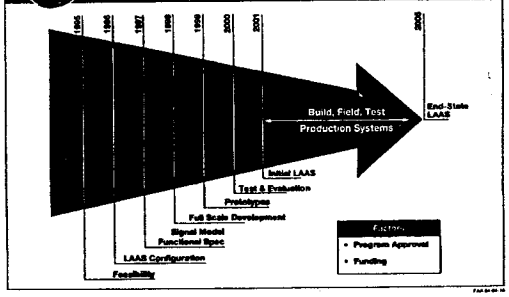
- Primary Means System
- Complement WAAS
- Expandable
- Common Architecture for All Locations

Augmented GPS Service for Civilian Aviation Use

Phases of Flight		Primary Means of Navigation		
		Integrity	Availability	Accuracy
En Route	Oceanic			
	Domestic			
Approach & Landing	Non-Precision Approach			
	CAT I Precision Approach			
	CAT II & III Precision Approach			
Surface	Ground Movement			

GPS & RAIM | WAAS | WAAS and/or LAAS | LAAS

LAAS Forecast



GPS Transition Plan

Goal:

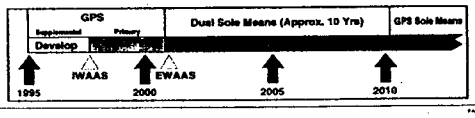
GPS Replaces (Not Supplements) All Ground-Based Navigation and Landing Guidance Systems

Why:

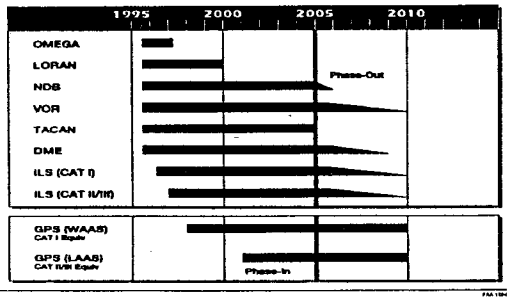
- Lower Cost to FAA
  - Acquisition, O&M, Sustainment
- Lower Cost to Aircraft Operator
  - Acquisition, O&M, and Training

Transition Strategy

1. System is Available on Supplemental Basis
   - Users Get Operational Benefits
   - Induces Equipage
2. System is Certified as "Sole Means"
   - Functional Equivalence to Existing System
   - User no Longer Needs to Equip With Conventional Avionics
3. Conventional System is Removed
   - User Must Equip With GPS



Navigation Transition



Introduction

George Wiggers:
Thank you very much Paul. At this time I would like Dick Shamberger to come up and just give a couple of brief highlights of his excellent presentation that he gave yesterday for the purpose of setting [the] tone for the question and answer period. For those that don't know, Dick is going to talk about railroads not about airplanes.

Mr. Richard Shamberger
Federal Railroad Administration

Good morning and happy Friday to all of us. I'm going to reiterate a little bit of what the Federal Railroad Administration policy has been as that policy relates to the railroad industry in the U.S. and also as that policy relates to this relatively new thrust in government of divesting the central federal government of power and influence, if you will, and putting that out [to] the local state level on the theory those that live in the area are more familiar with the problems and certainly are more familiar [with] potential solutions. So we have a concept going on up here which is an effort to partnership transportation problems and challenges and opportunities. And that's part of what I was talking about yesterday with the states of Washington and Oregon. There always has been a [partnership] with the Federal Railroad Administration as the primary regulator of the rail industry dealing with safety, life, hazardous material, derailments, [and] collisions between trains. As I said yesterday, there's about 160,000 miles of main line railroad which is relatively heavily used in the U.S., and there's also simultaneously about 280,000 at grade crossings where railroads intersect public highway, and in some cases this might be a dirt road that a farmer uses to get his tractor from one field to another. But there are 280,000 opportunities to have conflict between a rubber-tired vehicle and a train. There not only is the safety impetus that the National Transportation Safety Board and the Congress pay a lot of attention to. Even though relative to highway accidents and so forth it's really minuscule. But there's a lot of attention paid to rail accidents and the potential of hazardous material spills or evacuations of population and such like.

Also, simultaneously after spending quite a few years in committee an effort has been mounted in late 1994, to bring high speed passenger service back into the U.S. This is not the magnetic levitation isolated guideway kind of a thing as we see in Japan, France or Germany or Italy. It is simple Amtrak intercity service that would be elevated. They are now limited to speeds of 79 MPH unless you have absolute, positive train control so they don't run faster than 79 MPH. Back in the old days of steam engines, back in the 40s and 50s, where there was a lot of signal system out there and its very very expensive, they were running some of that stuff at 100 or 110. Well we're going to move back to the 110 and the

125 MPH kind of an Amtrak operation. We're going to use the positive train control and positive train separation that we're investigating in the Northwest in Washington and Oregon. We're going to use that in similar fashion on Amtrak trains.

Lest you think this is sort of railroad hobby approach, "gee whiz we can control things let's do that", "gee whiz we can run trains faster so why don't we", let me give you a couple of numbers from the state of Washington where they talk about what is going on in their part of the world. The Intermodal Surface Transportation Efficiency Act a couple of years ago identified five major [corridors] in the U.S., that were highly populated and terribly congested, rather high ridership of people moving between cities, and Amtrak which is a quasi-government subsidized rail passenger corporation runs over and has trackage rights over freight railroads. They don't own the railroad, they are users of it. Now there is a perception in the freight railroad industry that this is bad news. I don't want passenger trains on my freight railroad, why? High liability. Chevy Chase, Maryland, where two ConRail engines ran out ahead of an 100 MPH passenger train. It was a human factor mistake and 16 people died. A lot of wreckage. High liability; I don't want to incur that. The second perception of the freight railroads.

Everybody wants to give the passenger train priority because people and passengers and travelers are very very important. They have an estimated time of arrival on their mind, they have a schedule in their pocket and they want to get there. Well as the passenger moves through the freight trains that are out on the railroad there's a little bit of confusion (and some of this is simply perceptions not factual). You're ruining the movement of my freight trains. You are impinging on my ability to provide service and service reliability to my customers. I don't want the passenger trains there. Now for passenger trains, particularly high speed passenger trains, to co-exist on a freight railroad, we are going to come up with a proof of concept of positive train control and dynamic simulation of positive train control and the co-existence of Amtrak high speed service in and amongst sets of freight trains to the satisfaction of both parties. And this is the beauty of this. We're not building a pilot demonstration, we're building a production model up there. This is the exercise up in the Pacific Northwest, Washington, and Oregon, soon to include some activity in British Columbia, from Vancouver.

The state of Washington has every reason to believe that population in that area, Seattle, Tacoma, Portland, is going to increase by 40% in the next 20 years, and we all know what's going on in this nation. Population explosion. They also predict that intercity travel is going to increase 75%. The queuing up at airports of both airplanes and automobiles bringing people to the airports is congestion, and it's also not environmentally sound if you would believe what EPA says. This particular 863 miles of railroad is jointly owned in some cases and there [are] trackage rights where one railroad runs over another, by the Union Pacific Railroad, based in Omaha, and what is now Burlington Northern Santa Fe, (recent merger), that is based in Fort Worth. Some [of] it's going to be in Topeka and some of it is in St. Paul, they're not really having a happy time with their merger.

The reason that this area was picked and these two railroads decided to go together was simple. All of America's railroads and the two Canadian railroads had spent 13 years in committees with ARINC, out of Annapolis, which is a big system design firm, and in some cases an implementation firm, trying to build something they called automatic train control. Thirteen years. Earlier this week, I was at the 14th Annual Positive Train Control meeting up in Baltimore, at the Inner Harbor. We're written books, books and books, and specifications and specifications on and on and on. There are three test beds, two of which were in Canada. Lord I love those people. They make a decision spend money and do something. Meanwhile we're still in committee. Two railroads, Union Pacific and Burlington Northern, simply decided, "I'm tired of doing this". "I can't make any progress."

The rail industry has kind of fallen apart. It's not getting its return on capital. The Interstate Commerce Commission for instance makes calculations year by year on recovery of cost of capital. One railroad in the nation made it last year and that's the little old Illinois Central that runs up and down the Mississippi. Recover costs of capital, that means they're spending more than they're bringing in. Can you imagine that? Drug dealer going home and telling his girlfriend, gee whiz honey I've had a great day, I've recovered my costs of capital. What a heck of a way to run a business. Particularly when it is a backbone of Americas transportation system.

Railroads handle 40-50-60 and 70% of the goods we all consume. Seventy-two percent of all the auto parts and all the assembled automobiles in the nation that are either built and consumed here or exported or imported, run on the railroads. Heavy appliances, coal, steel, you know the big stuff. The high-priced business merchandise runs in trucks. So the freight [trains] are carrying the ton miles and the intercity freight dollars are going to the trucking community. They're out on the crumbling highways and so forth. We've all read all kinds of stuff about that. What we're trying to do in the Federal Railroad Administration is somewhat balance the National Transportation System. This is the area that is picked.

For 13 years there was confusion and consternation over what RF frequency we would use, and would we use GPS, would we use that network? Or would we use tags and transponders in the track? This argument went on and on and on. It's as simple as I like chocolate ice cream and he likes vanilla. We're going to write a report one of these days and come to the conclusion which one of those two flavors is best. So we took UP (Union Pacific) that liked UHF and BN (Burlington Northern) that liked VHF and the BN liked satellites and the UP had liked transponders and they said, "we're going to take the best of everything we've learned and take all the mistakes and all the foot dragging and put this stuff together up in this territory and see if we can make it work".

The government comes out with a notion that all the government agencies that want position, location, and timing, and guidance information that maybe the civilian part of government, that is the DOT [and] Mr. Wiggers here would get some civilian use from a system that was put up for the safety of life in navigation of ships. That being the differential system put up

by the U.S. Coast Guard. You know what government agencies do. Everybody's going to out and contract for their own little system. Why not use a national system for the benefit of all those government agencies. Let's call it the least common denominator, and who are the beneficiaries? Each and everyone of us is a traveler and a consumer, and a tax payer. FCC talks about the government use of frequencies like government does what it wants to do for the sake of government. Who is the beneficiary of the FAA's Air Traffic Control system? You and me as the flying public. I mean the Coast Guard doesn't misuse its frequencies just because it likes uniforms, and boats, and water, and this and that; it's for the benefit of the user, of the consumer, of the taxpayer. So while we were trying to line up how many government agencies would use a Coast Guard common differential system we got the Dept. of Commerce, NTIA, and the Institute of Telecommunications Sciences in Boulder, to write up a big report on this. And right to the surface comes a Coast Guard differential system, and guess what? The Corps of Engineers can use it, the Dept. Of the Interior, the Forest Service, and NOA geodetic survey, we know about all that. So it seemed that coming to the surface is a common service that already got a lot of investment in it and big use, certainly by the boating public, and also some of the crowd in Avis Rent-a-Car and so forth and the mapping and whatever. While Federal Railroad Administration was talking with the Union Pacific and the Burlington Northern it came to note that the Coast Guard had some plans of putting some differential up where we could use it in the Northwest. Now let me point specifically to just this last September, at Fort Stevens Oregon, they put up a differential tower and turned it on. AT&T put the comm into it, and it's going to handle maritime situations. But it also goes up and down that [corridor]. Where we're going to run the high speed trains.

Now we're negotiating and again trying to [form a] partnership with the Corps of Engineers, Federal Railroad Administration, and the U.S. Coast Guard to put another tower someplace out there. Courtesy of my good friend Commander Taggart, this is what the coverage would look like. Well this partnership business, well here's the Federal Railroad Administration going to put some money in Coast Guard, Corps of Engineers, Geodetic Survey and attempting to put up a tower simply so that the railroad can come up with a proof of concept. Now guess what? The Corps of Engineers gets to use it, any of the navigators on the Columbia River; I didn't know there was such enormous amount of hazardous material moving on the Columbia River. [Once] we get proof for concept of the railroad the tower stays there as a monument and the rest of the nation gets to use it and it's hooked into the control centers either in Alexandria, VA, or San Francisco, and it becomes a national thing. I'm going to pay for every bit [through] FRA. The tax payers are going to pay for it.

They tell me that the plane of our GPS satellites is such that as they are going around the world that we have an absolute north/south situation here and we also have an east/west. So the satellite is going to give us this kind of coverage. Kind of elliptical. We wonder if it's going to be more accurate on the north/south piece or on the east/west because the elliptical pattern is going to run that way on the Columbia River gorge. One railroad is on the north end of the gorge the other one's on the south. They've 19 UHF towers up, 14 VHF towers

that they put up. The two railroads are spending $52 million on this. To write specifications that the rail industry and the Association of American Railroads could not write for 13 years. Now we have the state of Washington, the state of Oregon, the Federal Railroad Administration, Amtrak, two private concerns [we] have hired and are paying for a systems integrator.

The whole project has taken a five month slip and let me tell you why. One of the things that's going on in America is [that] bigger is better, merger is wonderful and there is an intrinsic value, so the Union Pacific picked up the Chicago Northwestern. The Burlington Northern picked up the Santa Fe. Santa Fe's management will run the Burlington Northern. And the electronic systems sector of Harris Corporation out of Melbourne, Florida, got into a joint venture with GE Locomotive to come [up] with the most intelligent locomotive anybody has ever seen, so they now have a joint venture. They're a profit center and they have no accounting system. So everybody is merging having a joint venture and we have an organizational free-for-all. And a whole bunch of people were told, don't get sick and don't go on vacation; we have a lot of work to do. And your friendly reliable Americans, FRA, are right in the middle of this with a grant to the states of Washington, and Oregon, of $1.7 million to help them pull some of this off. So here is money and effort coming from several quarters. If this does not go down in history as a partnership I'm going to be vastly surprised. That's what's going on.

What's at stake are two or three things. To prove that the Federal Government can partnership with States, and do some things that have meaning. And acting as an advocate of an industry, help two members of that industry to come with some production standards, operating specifications and that kind of thing, that will suffice and work for the rest of the nation and also incidently Canada. Canada is part of our Association of American Railroads. Canadian National and Canadian Pacific. They're trying to privatize. They're having pains.

In the midst of this we have a potential that somebody possibly might make a policy to put some kind of a standard differential system across the lower 48 states and give us continuous coverage. Somebody just might make that policy. NTIA (National Technical Information Agency) has suggested it; the Federal Railroad Administration has suggested it. In the presentation I gave you yesterday were the highlights from a report that a couple of us wrote. And the report simply was responding to a question. It wasn't asking for money. (Like hell we weren't!) This is the appropriations committees who ask this question in the fiscal '95 appropriations bill. "The committee supports the current activities within the department to utilize differential GPS as a means of promoting surface transportation safety and technology. As part of DOT's examination of the potential uses of this technology the FRA is directed to submit a report to the House and Senate Appropriations Committees by May 1, 1995, on the benefits, costs, desirability, feasibility, and implications of using current and planned DGPS as a means of further promoting the accuracy and utility of positive train control systems". We simply were responding to a question.

Let me tell you something about Government that maybe you don't know. If the question comes from the Office of Management and Budget (OMB) it is a budget problem. I think stands for beans. The bean counters. So it goes through the budget offices within government. Never mind the technical content. Never mind what's going to happen. Never mind what the product is it goes through all the budget people. So I missed the first of May. They put me in charge of moving this through the system. It had to be signed off by people you wouldn't believe. I finally got it out of the building. I had to threaten some people bodily on June 29. I've got 5 or 6 copies of this with me and if you want to leave me with a business card I will mail you one for only this reason. This report in 16 pages encapsulates the concept that I introduced you to yesterday. The concept of what's going [on] here and includes the high speed passengers component where passenger trains are going to co-exist with freight. Now here is the last charge that a couple of us within Federal Railroad Administration had been given. See to it that the positive train control system is nation wide, incidently includes Canada, and is interoperable because these 18,000 locomotives range all over [the] nation, trackage rights, lease arrangements, and run-through trains. This is like getting a bunch of people together and convincing them they all want to be one religion.

I've got four or five years left in government. I hope to live to see this thing in operation. I'm so tired of meetings, conferences and trying to convince people of this or that I can't see straight. Twelve years in the rail industry and 21 in government I joked with some of my close friends, what did I do in the other life to deserve this? Now, God's been good to me. He's introduced me to the GPS community, the differential community, the radio navigation community, the U.S. Coast Guard, the likes of George Wiggers, conferences like this of people that kind of understand radio-based systems, navigation, differential, position, guidance, all this kind of stuff. So I am spending more time with people like you. And it is uplifting. Less time with the railroads.

We run a different kind of railroad down here; there's tall trees in West Virginia, well maybe we'll get DGPS to survey the tall ones that are shadowing the others and we'll selectively cut them out. That remains to be seen. Proof of concept is proof of concept. It's either going to work and it's going to work well or it won't. Positive train control. It will enforce civil speed restrictions. It will enforce authority limits. Period. The human is out of the loop. We're going to have an onboard computer that knows the dynamics of the car behind it. The air drag coefficients. Weight. Headquarters 2,000 miles away can pace trains, can save on fuel, manage power, manage trains, meet and pass them safely. And just suppose just on that piece of network there we could run 30% more trains on the same physical rail plant safely and expeditiously. And in our wildest imaginations run some high speed passenger trains through at 110 and possible 125 on this north/south route. Answers a lot of needs that the government has said it wants, that Congress has said it wants, that the Secretary of Transportation says it wants, that the NTSB says it wants. It kind of baits us to do it.

What's the benefit? To each and everyone of us as consumers and as a potential traveler, the NTSB that's balanced, I hate to use that word this week, a balanced transportation system

as sort of balancing the budget. This is a big task. Nationwide interoperable radio frequency communication based DGPS, an inertial guidance system, supported onboard computers. One last remark. I was given 30 days to get off of one railroad before I went to my second, which was the Chessie, predecessor to CSX. And here was the remark. I made what somebody thought was [a] derogatory remark about computers located in Baltimore, MD, [on the Chessie] Railroad. And the gentleman in the audience asked me what I meant by that remark. And I said, well Chessie's version of computers goes more or less like this. They're are electronic filing cabinets that keep track of freight cars that are thought to be in or near certain cities. A gentleman in the press sent a telegram up to Baltimore, and I had a pink slip on my desk with 30 calendar days, not 30 working days to leave that place. Now I'm still capable of such remarks and you might have heard some of them. This business is exciting and if there's one quality about me that I've not been able to work on too well over the years its patience. I kind of get impatient with what seems to be obvious to me. We're trying to develop a system for 13 years. It was a beautiful ice sculpture and it melted and ran out under the door and now we have all kinds of opportunity. And you men and women are part of this effort from a government situation, from a vendor and supply sector, from other transportation modes to make this stuff work.

Introduction

George Wiggers:
The DOT is indeed intermodal. The report that Dick referred to earlier the report to Congress is available from the Coast Guard. You can get it either from their bulletin board service or their new home page on the Internet. At this time I would like to call upon our anchor person, Cmdr. Doug Taggart to talk about the Coast Guard system.

Cmdr. Douglas Taggart
U.S. Coast Guard

Thanks George. I think it was right before Dick spoke that we had the announcement on the essentially your folks' budget. I guess I thought it was kind of interesting here that we have the government panel siting in front you and then you have an administrative announcement talking about your fees and taxes and what you need to pay. Maybe down the road we'll find ourselves in those same kinds of situations as it relates to the services of radio navigation. We heard yesterday some comments on the issue of user fees and whether or not there was any correlation between public safety and user fees. I guess that's an issue in some of the discussions that will take place hopefully as soon as I finish up here. I would like to see [it] addressed, because I was quite surprised yesterday when that comment was made at the close of business. Maybe everyone was tired. But to simply say that there is no correlation between safety and user fees I thought was quite interesting, and something you can think about as I am making this presentation.

Looking from a Coast Guard point of view, we find ourselves asking the question, "why is the Coast Guard involved in radionavigation"? And it's essentially an hierarchy of reasons. We're bound by this in an international agreement point of view. The safety of life at sea is essentially a reason why a country would be involved in it. Now stepping down into that in trying to point out which organization would be responsible for those from a maritime point of view. We look at 14 U.S. Code 81, which essentially provides the Coast Guard the authority to do this radionavigation service and then we look further down into it from a regulation point of view and we heard some comments yesterday as it relates to the issue of navigation versus positioning service and essentially 33 CFR 66 talks specifically about the use of electronic aids, specifically navigation aids, and who has the ability to provide those services. Recognizing the composition of the groups that's in front of us here I am going to go through each of the systems the Coast Guard is involved with.

The first one I'll talk about here is the Omega system. I think it's obvious to everyone that the makeup of the Omega system is essentially a partnership involving eight stations providing navigation information throughout the world. Recognizing a reason why the Coast

Guard would be involved in providing a radio navigation service for the world from a land based system, essentially we can not find in our way of doing business the reasons why we would do it. We have to look to other government agencies. And if you go back in the language of 14 U.S. Code 81 it provides [for] other agencies to approach the Coast Guard, and in this case specifically up until 31 December, 1994, the authority of the Coast Guard to provide this service was based on the DOD need. Essentially that need terminated on 31 December, 1994, and although I'll not talk specifically about the Loran-C portion of it, in fact that need applied to our Coast Guard involvement overseas on the Loran-C facilities. It was based on a DOD need, not only in the case of Omega, but also in the case of Loran-C. Jumping back to Omega, on 31 December, 1994, when DOD said we no longer have a need for the Omega service the Coast Guard essentially at that point in time, if it was not in a position to find another user or another requirement to provide those services from a U.S. point of view, essentially we would have been put in a position on 1 January, of this year having to turn that system off because we wouldn't have had the authority to do that. However, we did look to the FAA, they stepped forward and said they do have a continuing need for that service for aviation purposes. And in the '96 budget, the one that allows us to be up in front of you here today, we find that the Coast Guard no longer has in its base the funds to provide that system but rather those funds are now in the FAA's base and they will be for what we project to be FY '96 and FY '97 in accordance withv [the] Federal Radionavigation Plan.

As George already pointed out to you and as Paul indicated, the current '94 Plan shows a projected termination date on 30 December, 1997. The Coast Guard, not having those funds within its budget, has recently written a memo, that final bullet there the CG/FAA Memo, to the FAA just confirming that [in] the current plan the '94 Plan is in fact the projected termination, and whether or not the budget for FY'98 will in fact not reflect any funds for the Coast Guard to continue that mission.

I mentioned that there is a partnership on the funding of Omega and essentially this is just a breakdown of those countries [where] the U.S. provides funding versus those countries that provide funding on their own or the sharing. It is important to point out that it is a partnership. It is not the U.S. funding the entire operation of this system, but rather in that international agreements, the bi-lateral agreements that are put forward to put this system in place. The issue of funding is addressed and pointed out as indicated on this slide.

The next system is the Loran system. I indicated that when we terminated the involvement in the overseas Loran, essentially the wind down of that program began in FY '93 when we closed the Central Pacific Chain down. We moved forward in FY '94, turning over the stations in the Far East to the FERNS Group which you heard a little bit about yesterday from Mr. Beukers' presentation. And then we completed that effort on 31 December, 1994, when we turned over the facilities and activities to Europe. Back in the '92 time frame when essentially we had a not a domestic system but also the overseas system, immediately following the development of the Mid-Continent Expansion which in fact was funded by the

FAA for aviation purposes.

Essentially the Coast Guard was operating with 46 Loran-C stations in place throughout much of the Northern Hemisphere in those overseas and domestic chains. The system that we have today involves 29 Loran-C. We are providing service not only for maritime but also the aviation community. The timing community was pointed out yesterday in one of the presentations. The timing community is taking advantage of GPS and they are also a big user of the Loran-C system in the current configurations. [Also] the Weather Service, etc. Of the 29 stations 24 of those are U.S. [and] the other five are Canadian in the breakdown of the chains. We do have the eight domestic Loran chains which includes the two chains for the Mid-Continent Expansion [and] reflecting the chains that operate in Alaska. We also have a connection with the Russians, and that chain is not part of the FERNS Group that was talked about yesterday, but rather it is a joint chain operated between the U.S. and CIS, and we've had that in place essentially in an operational status since the 1st of January of this year. And then we have the three Canadian chains. I would simply point out that the Canadians recognize we are moving out of the overseas in recognizing that the Labrador Sea Chain, which involves a station in Greenland, which was in place for DOD. When we terminated the operations there last winter, the Canadians took it upon themselves to develop a new chain, East Foundland Chain, and that is one of the three Canadian chains that is being operated there. As indicated in the FRP the current projected termination date for the Loran-C system is the year 2000 as reflected in the 1994 FRP.

Moving on to the Radio Beacon System. As indicated on one of George's introductory slides, the Radio Beacon System is slated for phase-out by the year 2000. We've actually seen a significant decrease in the number of radio beacons. The maritime radio beacons traditionally have been in place since about the 1920 time frame. At one time I think this country for its maritime needs had in excess of 200 sites. When I did this briefing for Adm. Peshel, in June, when [he] came in the office of navigation, I prepared a similar slide for him and we had 54 beacons in place at that time. I prepared this slide for a meeting here in Washington, two weeks ago, and doing a summary of the existing beacons, we are down to 21. (...) We [have] 18 traditional radio beacons remaining now. We're moving rapidly toward a phase out of this service. I would simply add too, in our work with international community the radio beacons are reflected in the IMO (International Maritime Organization) as a navigation source that many of the countries of the world are moving away from this technology. In fact, this kind of activity has been reflected in those international organizations that are involved with maritime navigation systems. The International Lighthouse Association, in a meeting last week in Cape Town, this was one of the discussions of a rapid transition to GPS/DGPS services, etc., and away from this traditional beacon-type system.

The Coast Guard's developing DGPS. This is an update on it. We've heard a lot about it in the last few days. As of the 1st of November, we went in to what we're calling a pre-operational phase of doing business within the Coast Guard. This is essentially playing by

the rules as we are putting them forward to ourselves. The navigation center down in Alexandria is the operational commander for these sites now going away from the traditional way that the districts manage these radio beacons. When we go to a differential system we're talking about a national system. We plan on being in this pre-operational phase up until the 1st of January. And as George's slides indicated, at that time we will follow the pattern as when GPS was declared operational and it went through this phase of the initial operational capability, the IOC phase, and we plan on doing this similar kind of activity.

In the FY '96 budget mark-up we do have funds in place to procure new radio beacons for the system. Those of you that may have been very close to this subject there was an initiative put forward by the Coast Guard to expand the current system, expected to be 48 sites, into the 2nd District, essentially the western rivers region of the U.S. That would be the Mississippi basin, Missouri River, etc. We went forward with the '96 budget mark-up having that reflected. That was, in fact, not approved so we do not have funds to move forward from a Coast Guard point of view with those. But we are working with the Army Corps of Engineers and may find some of those sites coming on line as a result of Corps funds and the desire to take advantage of this technology to improve efficiencies within the Corps work, and again, these are on navigable waters of the U.S. That's where the Coast Guard's involvement came. And we did hear enough as it relates to the information from the railroads, as to the Snake River area, and this is essentially the slide that Dick showed you. This slide, if paid strict attention to the numbers counted it says 49 in the top lefthand corner, the last slide said 48, the extra site is the Walla-Walla site up here in the Snake River area, and that with the slash marks under there is potentially a future site, and that is based on the conference language and the budget language we've seen in the railroads appropriation. Essentially, Dick [Shamberger] didn't read the '96 language. But I think if you look at that '95 language that he pointed out they are directed to move out to take steps to prove the positive train control in '96 language in the railroad bill. [This] indicates that they are to move out in cooperation with the Corps of Engineers and the Coast Guard to establish a site in this region. So that's why we reflected it on here.

Currently, although we are in the pre-op status there as of I believe Monday, there are 30 of these sites on-air today being controlled by the navigation center, either at Alexandria, or the Petaluma site. We do have a redundant control site and I'll show you a slide on that in a moment. We expect to have by the 1st of January, when we declare IOC, at least 47 of the sites up and operating. We have a problem down in Key West, from an environmental impact point of view and we may not be able to move forward with that site and actually have it up on air by January of '96, but we expect to be successful in doing that very shortly after the 1st of the year.

This is essentially the antenna pattern at a differential site. The redundancy is a big part of our system with a very high attention to not only the accuracy component of what we are providing to the maritime user, but also we have, based on our involvement on Loran-C, a real desire to have a very robust redundant system, and with very heavy focus to the integrity

of the information that we are putting out to the user. With the exception of the transmitting tower which is the 90 foot tower to the right, the whip antenna that you see is not actually part of this site, but it is actually on the Coat Guard infrastructure. The pair of GPS towers is the integrity and the reference monitor. A foot down on the middle of the tower you can see on the closest one to you it's actually the beacon receiver. It's essentially a near-field receiver tied into the integrity monitor system. It's a redundant type network recognizing the radio beacon procurement that I talked about. We will be going in and replacing some of the older radio beacon systems with a more soft-fail kind of solid state device that provides us with even higher levels of redundancy and improved reliability in the system.

The control facility. This is a picture of the facility that is in place down at the navigation center. A similar configuration [is] in Petaluma. Very strict attention [is paid] as to how this system is being operated and the data that is being logged and monitored. We're building upon the expertise that the Coast Guard has had in operating not only the Omega system but the Loran-C system. We're very concerned about liabilities and the ability to show compliance, with our signal specification as it relates to the accuracy of availability and the integrity figures that we're putting forward. And this is a big part of us reaching IOC capability just to have our control facilities up and operating where we can insure that the data is being logged and made available for future possible cases involving the use of our system and how it may or may not be questioned in providing the service that we're doing. When we are in a position to declare full operational capability. We are currently projecting a 99.7% availability for the harbor/harbor approach environment. That essentially works out to about 26 hours per year [that] a site would not be available for this to strictly meet those availability requirements. In the areas [of] VTS (Vessel Tracking System) activities about 99.9% is our stated availability requirement. We're working to achieve that with overlapping footprints from multiple sites.

We have very great attention put toward providing high integrity in the system,so during the IOC stage we'll be attempting to validate not only the integrity of this system, but also the time to alarm and insuring the coverage we are projecting is in fact the coverage that we are able to achieve. We also have stated liability figures and it's stated as 500 outages per million hours of operation. And this is based on some risk analysis on the use of this system for maritime applications, making some assumptions on the type of channels to be navigated, the dynamics of the vessels and what kind of expectations we have of this system to improve the safety of the maritime environment. As I indicated on this slide, we recognize [that] in Alaska, we may have some additional needs in that area. And although we will be in an FOC kind of environment we may find ourself having to put some additional sites up in Alaska.

The final slide is some of near-term issues that we will be working toward. Obviously, [we're] going [to] IOC in January, '96. I indicated that we've asked the FAA on the use of the Omega beyond the '97 projected date. That is why the question mark is there. Recognizing that many decisions today are being driven by budget considerations, we do have in place a Loran-C consolidated control project. We were able to show that the

investment in some technologies could have a very quick payback in reductions in personnel so we hope to have in place by FY '97 a consolidated control environment essentially taking our control facility in the Loran environment from Seneca, New York, and Malone, Florida, to Alexandria. In making that consolidation here on the East Coast there are billet savings. Billet savings equate to costs. Out on the Petaluma site where we have our West Coast DGPS control facility, we will also consolidate from Middletown, CA, back to that same facility. With similar type equipment we will achieve some savings. We're driving, based on the Coast Guard budget, for reductions of approximately 30 people. Thirty people is approximately $1 million in annual personnel costs so we will achieve some savings in a very short period of time with that project.

Again making the connection to near-term, the Coast Guard will be involved in the development of the '96 Federal Radionavigation Plan. I believe that the public hearings for that plan are going to be occurring in the January, February, March, time frame of next calendar year. And although our Coast Guard R&D budget is not as large we might like it to be, as least from a program point of view, we're trying to take steps in our '98 R&D budget [to] develop a project looking at the future mix of radio navigation aids. And I might indicate there that mix not only implies the type of systems, but it also may involve an analysis of what kind of availability capabilities can be achieved in a mix between government systems and potentially private systems, something from an R&D point of view. Look out and think outside the box. If we indicate that we need to have 99.7% availability for harbor/harbor approach, can we in fact achieve [that] simply with one system such as the Coast Guard differential system, or do we need to maybe bring in a little bit more interroperability from other sources and enhance that capability? It's not yet clear whether or not we'll be able to in fact with a very small budget, a very limited budget be able to compete for that. But that's something that the program has a vision.

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Coast Guard Overview Addressing 1996 Planning

- **DGPS**
- **Radiobeacons**
- **Vessel Traffic Services**
- **Loran-C**
- **Omega**
- **Navigation Information Service (NIS)**

Planning, Policy, Operations, Support & Training

Headquarters - Planning & Policy
G-NRN ---> G-OPN-3 (ooa 1 JUN 96)
Navigation Ctr & Detachment
Operations
Engineering Ctr & Supply Ctr
Support
Petaluma & Yorktown
Training

Radionavigation Program

- **International Agreement**
  - *SOLAS...requires signatory nations to establish, maintain and provide information on aids to navigation....*
- **Authority:**
  - *14 USC 81 ...the Coast Guard may establish, maintain and operate...*
- **Regulation**
  - *33CFR66.01d ...electronic aids to navigation as private aids will not be authorized.*

DGPS Resources/Outlook

- **Harbor and Harbor Approach**
  - *8 to 20 meters navigation accuracy*
- **Initial Operational Capability - 47 Stations - 30 Jan 96**
  - *O/M $4.4M annual (includes cost for 51 personnel)*
- **Full Operational Capability**
  - *Meet availability, integrity and accuracy*
    - *Transmitter replacement $1.7M FY96*
- **Carriage requirements for GPS**
  - *33CFR164.41*

DGPS Resources/Outlook

Future
Alaskan Coverage
other U.S. Navigable Waters
VTS areas
Continue interagency partnerships
Corps of Engineers
NOAA
NGS
Federal Railroads
TVA

Introduction

Dr. Kane:
We wanted more time for uninterrupted questions and answers so we decided to bring on a few speakers who would have been on later. So as soon as they're finished we'll go to lunch. And then we can beat them over the head and ears for the rest of the day. Dale tells me there are two speakers who want five minutes each on two subjects. After these two to give his after-lunch talk as his before-lunch talk. So that will wrap up the morning session.

Mr. Joe Kunches
Space Environment Council

Thank you so much. I'll just take a few minutes of your time. I'm Joe Kunches, from the Space Environment Center, in Boulder. We used to be called the Space Environment Laboratory up until about a month ago and then we were incorporated into the National Weather Service as part of the national centers for environmental predictions. So now we've gone from a space environment laboratory to a space environment center for instance the Hurricane Center in Miami is one of our sister organizations.

What I would like to tell about this morning very quickly, you can see this a brand new service which we began this past Monday, and I hope it had nothing to do with bringing the Federal Government to its knees since then. You heard yesterday some comments from users about how their particular interest is affected by solar activity or geomagnetic activity. So what we've tried to do is put together an Internet page that has real time solar and geomagnetic data available so you can go in there and look and see what space environment is doing. And I don't how visible this is from where you are sitting, but right below the little graphic there you can see there [are] references to GPS, Loran-C, and Omega, and if you were to click on one of those, for instance, if you are interested in GPS, (and I would like to thank the Coast Guard for allowing us to steal their nice graphic here), you'd get a short explanation on what kind of data might affect GPS in the geomagnetic middle latitudes and high latitudes. And if you click on the hyper-text, you can get real- time data and I mean real time up to the current minute upon, for instance, on the behavior of the earth's magnetic field or solar x-rays which are impinging on the earth which cause SIDS, for instance. It's just an effort to allow people to see what's going on right now, and we've done this for GPS.

This is Loran-C. But again a short explanation on what things we think affect Loran-C and have been shown to affect Loran-C. And finally Omega. And what I invite you to do, I'll put the address of this page up here on the board behind me, and if you do have access to the Internet to try it out to see if you find it to be useful to send me some e-mail and comments because this will be hopefully an evolving feature. And our laboratory is in a very nice position. We have lots of real time data that pertains to the space environment, both in the

radiation domain as well as the kinds of things that affect signal propagation and are related to ionospheric scintillation for instance. And you can easily access the data and see for yourself if you find it [to] be useful or not. Now the address of this page, and I'll just write it over here. It's HTTP://WWW.SEL.NOA.GOV/NAV/NAV.HTML, so give it a try and send me an e-mail or your comments as a way to do that via the page. I think this is a unique service and I don't know if anyone else is doing it but if we're lucky you'll find it's something you can use.

Just very quickly, if you were to look today at the page if you click on and the questions come about sun spots cycles and where are we now in the sun spots cycle. On the front page of the navigation systems page you can click and find out what the current data show and what we've got here is these are sun spots in the upper graph and solar radio flux in the lower graph. These are the last 16 or so solar cycles that are normalized. I don't know if you can all see that. The current cycle is in dark and we plotted all of the data up 'til now; it's monthly data, then you can see this sort of M shaped thing is working its way downward. We don't think we are quite to the solar minimum yet. We expect that to be in the next year.

You've heard the date 2000 mentioned a number of times for different plans of different systems. The sun also has its plans for the year 2000. If you look to see the prediction for the next solar maximum it should fall right in that time frame. We don't really know how big it's going to be or how it's going to compare to the last solar cycle. There's many studies and much effort is made by a number of groups, NASA being one of them, to try to predict the magnitude of the solar cycle, and that frankly is beyond our means at this point. This is statistical prediction that you see. But we do feel fairly confident that the timing is going to be right about then. So this is one of the things that will be available on the navigation systems page.

Navigation Systems Page

- GPS
- Loran-C
- Omega

PURPOSE: To provide data on the state of the space environment that may affect the proper operation of navigation systems. Click on the appropriate system for more information on conditions that may impact its' operation.

To assist in better understanding the text descriptions, SEC provides you with a glossary of space environment terms.

Current Space Environment Alerts & Warnings

Longer Term Space Environment Outlooks

Weekly Summary and 27-Day Forecast

27-Day 10.7 cm, Ap, and Max Kp Outlook

Follow the Progress of the Sunspot Cycle

DISCLAIMER: This SEC data base is real-time and is not recommended for research, since the values are preliminary. The National Geophysical Data Center (NGDC) is the national archive of data approved for research.

GPS Page

Continental United States Users (Geomagnetic Middle Latitudes)

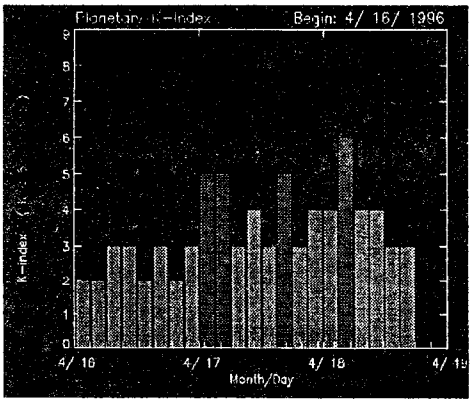
The behavior of the Earth's magnetic field is the most significant factor for GPS operations in this locale. Select the Planetary K-Index Plot to see if the magnetic field has been disturbed, as denoted by red bars, during the past 72 hours.

Canada/Alaska Area Users (Geomagnetic High Latitudes)

Particle precipitation in the auroral zone results in increased scintillation in the ionosphere. The auroral oval is usually near the areas of increased scintillation. GPS operations may be hampered when the signals from the spacecraft to the ground pass through the auroral oval. The NOAA/TIROS Hemispheric Power Input Plot shows the likely location of the auroral oval, using recent data from the past few hours. The auroral oval will move equatorward when geomagnetic activity increases.(NOTE: This feature is still in implementation. A mock-up is used for illustration.)

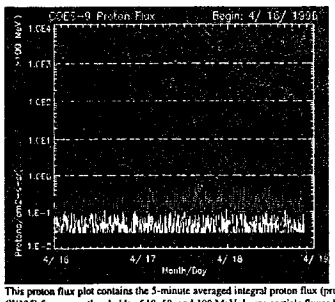
Large quantities of solar energetic particles can also cause scintillation at high latitudes. Check the Proton Flux Plot to determine if the proton environment is enhanced. If the red trace (E >10 MeV) exceeds 1.0E+1, conditions may exist that are adverse for GPS users.

Forecasts of Solar and Geophysical activity for the next few days are sometimes helpful in planning future GPS operations at both middle and high latitudes. The Joint USAF/NOAA Report of Solar and Geophysical Activity contains information on geomagnetic activity (parts II, V, and VI), and solar energetic particles (part II).



GOES-9 Proton Flux

Updated Apr 18, 1996 at 21:22



This proton flux plot contains the 5-minute averaged integral proton flux (protons/cm2-s-sr) as measured by GOES-9 (W135) for energy thresholds of 10, 50, and 100 MeV. Large particle fluxes have been associated with satellite single event upsets (SEUs).

Loran-C Page

Loran-C operations are hampered when the sky wave arrives at a receiver at the same time as the ground wave. This occurs when the reflecting height of the ionosphere drops, as it does during times of increased activity in the space environment.

This activity can be of different types:

- Solar flare x-rays, with the effect most acute on the dayside of the earth;
- Solar energetic particles, impacting Loran-C operations at all local times, but strongest at high latitudes;
- Geomagnetic storm activity, hampering operations at all local times and at all latitudes.

The net effect of each of these three types of geophysical activity is a lowering of the reflection height of the ionosphere.

Check Today's Space Weather to see if any of these three conditions have occurred. If the x-ray flux, as measured by the long wavelength (1.0 - 8.0 A) channel on either of the GOES spacecraft, exceeded "M" level (>1.0E-5 W-sq. m.), dayside Loran-C users may have been affected.

Solar energetic particle fluxes are available on the Proton Flux Plot. If the red trace surpassed a flux of 1.0E+1, enhanced fluxes of protons were observed at geosynchronous orbit and have the potential of impacting Loran-C in the polar regions.

The state of the Earth's magnetic field can be determined from the Planetary K-Index Plot. Red bars denote periods during which the magnetic field was sufficiently disturbed to affect the proper function of the Loran-C system.

Forecasts of Solar and Geophysical activity for the next several days can be helpful in planning future Loran-C operations. The Joint USAF/NOAA Report of Solar and Geophysical Activity contains information on solar x-ray activity (parts I and III), solar energetic particles (part II), and geomagnetic activity (parts II, V, and VI).

Omega Page

Today's Space Weather has information pertinent to Omega operations. Check the *X-Ray Flux Plot* to see if the 1.0 - 8.0 A trace has attained the "M" level (>1.0E-5 W-sq. m.). A large influx of solar x-rays of this magnitude or greater can cause the ionospheric reflection height for the Omega signal to be unstable. Also look at the Proton Flux Plot to see if large abundances of solar energetic protons have impacted the ionosphere. If the red trace has attained the 1.0E+1 level, this condition may have occurred. Larger fluxes will be increasingly more severe for Omega.

The Planetary K-Index Plot shows activity in the Earth's magnetic field. Disturbed periods, shown by red bars, may be problematic times for Omega.

Forecasts of Solar and Geophysical activity for the next few days are useful in planning Omega operations. The Joint USAF/NOAA Report of Solar and Geophysical Activity contains information on solar x-ray activity (parts I and III), solar energetic particles (part II), and geomagnetic activity (parts II, V, and VI).

Prepared jointly by the U.S. Dept. of Commerce, NOAA, Space Environment Center
and the U.S. Air Force.

JOINT USAF/NOAA REPORT OF SOLAR AND GEOPHYSICAL ACTIVITY
SDF NUMBER 108 ISSUED AT 2200Z ON 17 APR 1996
IA. ANALYSIS OF SOLAR ACTIVE REGIONS AND ACTIVITY FROM 16/2100Z
TO 17/2100Z: SOLAR ACTIVITY WAS VERY LOW. REGION 7956 (N05W36)
STABILIZED AS A SMALL BIPOLE, BUT ITS ASSOCIATED PLAGE FIELD
GREW AND BRIGHTENED. IT PRODUCED ONE SMALL X-RAY FLARE DURING
THE INTERVAL. THE REMAINDER OF THE DISK AND LIMBS WERE QUIET.
IB. SOLAR ACTIVITY FORECAST: SOLAR ACTIVITY IS EXPECTED TO BE
VERY LOW.
IIA. GEOPHYSICAL ACTIVITY SUMMARY FROM 16/2100Z TO 17/2100Z:
THE GEOMAGNETIC FIELD HAS BEEN AT UNSETTLED TO MINOR
STORM LEVELS AT ALL LATITUDES THE PAST 24 HOURS. SOLAR
WIND DATA SUGGEST THIS DISTURBANCE IS ASSOCIATED WITH A HIGH
SPEED STREAM FROM A LOBE OF THE SOUTHERN POLAR CROWN CORONAL
HOLE. THE GREATER THAN 2 MEV ELECTRON FLUX VARIED FROM
MODERATE TO HIGH.
IIB. GEOPHYSICAL ACTIVITY FORECAST: THE GEOMAGNETIC FIELD IS
EXPECTED TO BE UNSETTLED THE NEXT THREE DAYS. SHORT EPISODES
OF LOCAL NIGHTTIME SUBSTORMS MAY OCCUR IN THE NEXT 24 HOURS.
III. EVENT PROBABILITIES 18 APR-20 APR
CLASS M 01/01/01
CLASS X 01/01/01
PROTON 01/01/01
PCAF GREEN
IV. PENTICTON 10.7 CM FLUX
OBSERVED 17 APR 069
PREDICTED 18 APR-20 APR 070/070/070
90 DAY MEAN 17 APR 071
V. GEOMAGNETIC A INDICES
OBSERVED AFR/AP 16 APR 011/010
ESTIMATED AFR/AP 17 APR 020/020
PREDICTED AFR/AP 18 APR-20 APR 015/015-010/010-010/010
VI. GEOMAGNETIC ACTIVITY PROBABILITIES 18 APR-20 APR
A. MIDDLE LATITUDES
ACTIVE 35/20/20
MINOR STORM 15/15/15
MAJOR-SEVERE STORM 05/05/05
B. HIGH LATITUDES
ACTIVE 35/25/25
MINOR STORM 15/15/15
MAJOR-SEVERE STORM 05/05/05

Dr. Peter B. Morris
The Analytic Sciences Corporation

Thank you for this opportunity. It occurred to me that there are two reasons for this presentation. The first one is I don't think there has really been a DOD navigation systems presentation, so I guess I'm taking it upon myself to represent DOD. The other reason for the presentation is that it occurred to me early on that one of the rumors for the 1994 FRP delay was TACAN. (...) So it seemed to me we ought to say something about TACAN at a radionavigation users' conference. I don't think I'll make it in five minutes, but I'll try to make it 10. So throw me out if it's inconvenient.

Anyway Dave Olsen and I are presenting this work that we are doing in support of ASD-120; Dave's sitting over here. Just briefly just a couple of words on principles of TACAN in case anybody forgot what it is. It's about a 30 year old system. I didn't know myself what it was until about a year ago, but the more I get into it the more appreciation I have for the system. The range is obtained using DME in the usual way and I have a few more slides. The signals again in the usual DME way are channelized as shown there and [they are] actually broken into two bands, a high band and a low band. There's reply and interrogation frequencies. The airplane transmits a signal. It's replied at a frequency separated by about 63 MHz, and basically you can handle about 100 users.

Now the azimuth information on TACAN comes from a rotating cylinder. It's a plastic cylinder and rotates at about 15Hz. The inner cylinder has one element that gives you coarse north information and also there's an outer cylinder [with] nine parasitic elements, and that gives you finer resolution within the 40° sector as shown here. I'm showing this just to show you what the rotating antenna looks like. You can see the inner cylinder, and the outer cylinder is the nine parasitic elements. The inner central radiator shown there, is really the DME antenna. Now the way it forms in space looks something like this. But basically you can see this the north reference burst is here. That's a code. It comes out of the DME out of the central radiator. And then the envelope of this wave form is what's actually received by your TACAN receiver in the airplane. You can see the peak of it is just a little bit farther. It indicates that you're just east of north if you were an aircraft and this was your received wave form. The higher frequency modulation as shown there is the 135 Hz, 40° resolution within that. So you can find your azimuth as we'll see later to an accuracy to about a tenth of a degree. a little bit better, a little bit worse some times. Most of the TACANs, not all of them but many of them are located with VORs. The result is called a VORTAC and is shown here. As you can see, the DME antenna is in the middle of the DME/VOR, DME giving you the distance, the range; the VOR giving you bearing. The rotating part of the TACAN surrounds the DME antenna in the middle. And this is both for the Doppler VOR as well as the regular VORs.

TACAN coverage, what is it? Well, [it's] protected to about 130 nautical miles. But the signal itself is usable out to about 180 miles. Altitude again, 60,000 feet protected. There's a cone of exclusion because of the beam pattern with roughly about a 50° half angle, and that's really for the low power system. It's not quite as large as for the other systems. We'll talk about that in a minute. The accuracy of TACAN shown here, ranging accuracy, about 80 meters, and it varies for several reasons. The azimuth again [is] about a tenth to two-tenths of a degree. The overall accuracy is about 200 meters. And again, I've seen numbers as low as 120 meters and higher than 200 meters, but that's kind of a rough average. And the principal source of error as you could expect is multi-path. We've seen that before in this meeting.

The current TACAN configuration. The operating agency is shown over here on the left. This means the people that actually operate the sites. The VORTAC is shown in TACAN. Now TACAN is without the VOR. It's just the same thing but it doesn't have the VOR. So a para-military site. The FAA as you can see, operates most of the VORTAC sites, 639. That number fluctuates too. TACAN sites alone about five. DOD operates mostly TACAN sites. And then there's other users. That includes Canadians, other US Government, private outfits, and the totals are given down there. Something over 800. A little bit about the status of TACAN even though as Paul Drouilhet showed, it's shown for phase-out there's actually a program to implement some new systems, believe it or not, just before phase out. But it's a good idea because it's saving money and providing the same coverage. So it's to everybody's benefit. The old ones, the rotating TACAN antenna, RTA-2 which are deployed almost everywhere in TACAN. It's 20 years old and it's kind of a hog on power, 3 kilowatts. Its maintenance and utility costs are high. It requires backup engine generators, which are expensive, and environmentally they are a problem, especially with the new EPA regulations. So a program was put in place to develop a new low power TACAN antenna. Originally, all the TACAN antennas were going to be replaced, but the program was only funded to replace about 195 of the RTA-2s. This new low power TACAN antenna consumes only 400 watts, so it's a lot cheaper to run. We already have about 58 installations so far at least according to the schedule. I haven't checked if they are really out there yet. And the completion of the whole thing is by the end of next year, 31 December of '96. Well that's the new part of the TACAN program. We'll see what the ultimate fate of TACAN is in a minute.

As far as the TACAN usage, this is DOD. The Air Force has the most TACANs. Well I actually shouldn't say that, it doesn't have the most. The Army has the most airplanes, but zero TACANs. I guess the Air Force, of the services that have TACANs, the Air Force has the largest number of aircraft, that's about the only thing you can say about that slide. The reason for the hyphen there in the Air Force is because I had two databases and gave two different numbers. So I'm not sure between those two numbers what it is. The Navy of course, has the shipboard systems in addition to the land based systems. So that's why they have a large number of TACANs as shown here. So TACAN as we saw is going to be phased down or phased out: The reason we say phased down is we still have a sliver of hope that some of it may survive to the indefinite future. Originally, it was phased out, now it's

phased down. Ten to fifteen of these older antenna sites are phased out every year as kind of a result, a natural attrition and kind of an agreement between the local FAA regions and DOD people involved. So there is kind of a gradual phase out happening anyway.

The 1994 FRP as we [have] seen before, says if you read it closely, modification of DOD/GPS user equipment, to meet this required navigation performance criteria, will not be completed before 2005. And that date seems to grow a little bit. So I leave yourselves to conclude what you will. The FRP further states, that in reaching any final agreement it will be a mutual DOD/FAA agreement on the final decommissioning. And the kicker is, that the requirement for shipboard TACAN will remain until a suitable replacement is operational. The Navy is adamant. TACAN for the carriers is going
to stay in place for a while. Its system works and it's very important the training that goes [on] for carrier pilots and so on. TACAN for ships is critical and so they intend to keep that for a long time, and I haven't seen any more definite figures on replacement of shipboard TACAN to date.

I just want to say one more thing. The FAA has sponsored a TACAN phase down study as the slide says, the FAA is comparing resources needed to support TACAN for several phase out scenarios. And we're looking at these scenarios on the basis of cost savings to the FAA, and the need to fully support DOD operations. This is a system which is a cooperative effort between DOD and FAA. Everybody wants to save money and everybody wants to have their missions running and so we are going to try to put together a plan that does that for both.

Dr. Kane:
Thank you very much. I find the usual problem as the chairman that I don't have control of the agenda. Nature does. We're going to take a short break. (...)

Introduction

Dr. Kane:
Lt. Col. Roger Hunter. He's the Commander of the 2nd Space Operations Squadron, in Colorado Springs, and that word space makes all the difference. He's stationed at Falcon AFB. He commands a world-wide organization with over 200 military and civilian personnel to operate the GPS system. And their mission, and that's why I asked him to come, is to provide precise navigation data, precise time data, and nuclear detection to the world-wide users. So they're the people under Col. Hunter's command that keep the satellite system operating and tell the world the health and status of the individual satellites and the operation in general. His installations around the world are valued at $2 billion dollars. An impressive number.

He was commissioned in 1978 after getting a B.S. degree in mathematics from the University of Georgia. After commissioning he became deeply involved from the very beginning in space business serving as a commander and training officer for the defense support program, the Geostationary Satellite Program, which provides warning of missile launches and other functions. He also serves as part of the consolidated space operations program system which oversees the design, development, and acquisition of the mission control element at the Falcon AFB. In the late 1980's he was responsible for development of command and control requirements for the Strategic Defense Initiative, [which] as you know is for ballistic missile defense. He most recently served in the Pentagon where he lead special access programs designed against the problem [of proliferation of] weapons of mass destruction, and he served as staff officer developing roles and missions on DOD future space forces.

In addition to his B.S. and mathematics in '88, he is a M.S., in space operations, from AVTech in Dayton, and an M.S. degree in Air-Power studies from Yale University. So he has gone [from] a crew commander of an operations squadron at Buckley, to the Defense Support Program in Woomera, Australia, back to the Pentagon, and back to Colorado, over the years. He has meritorious service medals with three oakleaf clusters, Air Force Commendation Medal, Combat Readiness Medal, and he's an Outstanding Young Man of America. So please welcome Col. Hunter to talk about his operation.

Lt. Colonel Roger Hunter
USAF Space Command

My mission today is two-fold. First I want to give you an operator's perspective on GPS, and my second mission of course is to model the new U.S. Air Force uniform. Don't get used to it because it's changing. We change uniforms almost as much as we change our Chief of Staff. Frequently, when I walk through an airport, I have old ladies asking me if I'm flying

their plane down to Miami. And of course I tell them that I am and they seem upset, later on when I get on the plane and I'm sitting in the back in coach with them. As Dr. Kane said, I'm Commander of the 2nd Space Operations Squadron; we are at Falcon AFB, Colorado. We run the master control station and a number ground antenna and monitor stations around the world that we use to operate the satellites whose signal you've come to enjoy. On the slide you see up here of course you see the different shields of the Air Corps. There's a Squadron patch, there's a AF Space Command shield, and of course there's a shield up there which is the shield for the 50th Space Wing, which is our parent wing. And some people look at that creature up there that's on that shield and they say it looks like a space goat. It's actually called an opinacus, which is a mythological creature that supposed to [be] kind of nasty, but I guarantee you that the people at the 2nd Space Operations Squadron are not nasty people. We are customer oriented, and we are here to serve our users. Here's what I would like to talk about today.

Dr. Kane has already referred [to] our mission. I want to talk about the constellation description, a little bit about the operation control segment and the user interface, in which many of you more are interested, and finally the future of where we are going with GPS. We have a three-fold mission. Our primary one of course is to provide precise navigation data. The second one is timing transfer data, and we essentially provide the timing data that's provided to us by the US Naval Observatory. And there's a third mission that not too many people are familiar with and that's Nuclear Detonation and Detection data. And we fly a number of sensors onboard a GPS satellites that are used by certain users our there for treaty compliance and treaty monitoring type activities. As you know people have already mentioned earlier in our program here that GPS achieved initial operational capability back in December, of '93. General Ashey, the Commander of US Space Command, declared fully operational capability in April of this year. That essentially means that we have 24 satellites on orbit and the constellation is up to speed and up to its full configuration as required by previous documents that have been established for a number of years. It also means that the ground antennas, monitor stations, and also people who fly GPS are ready to perform a mission.

The satellites, of course, fly at 11,000 nautical miles. They have a 12 hour period, and some of this stuff you are very familiar with. There are some interesting facts about GPS that have always fascinated me. First of all, these are probably some of the most energy efficient satellites that the DOD flies today. Many of you have come to expect the typical appliances used at home like your hair dryers and your toasters and stuff like that, those things consume about 1,500 watts of energy to do their job. The GPS satellite, each one of these little hummers only uses 800 watts of energy to pump out a navigational signal to users at 11,000 miles below them. To me it's [the] kind of system that was designed in the late 1970's and early 1980's. [The satellites] are in six orbital planes; there's four satellites per plane. For a while we actually had 25 satellites on orbit. We had an old block-1 satellite SVN-10 that had been around for 11 years, and it was still pumping out a good navigation signal, but like people they age and eventually they die. And a matter of fact we've begun a disposal plan

for SVN-10 now, and many of you if you are on the access list for the NANUs that we send out, we are about to turn off the navigation package for the SVN-10 because it just won't last through the next eclipse season. We are planning however, another launch of a GPS satellite in March of next year, March 29, and it's going to go into the C Plane. We also have a reservation for a slot at Cape Canaveral for another launch in June, but I don't think we're going to launch then. But I guarantee you we will launch when March comes.

Here is what the operational control segment consists of. The Master Control Station which is located, of course, at Falcon AFB, in Colorado. We have five ground antennas that are scattered around the world. Four of those ground antennas are dedicated to us. We count a 5th antenna which actually is located at Falcon AFB, it's called Pike, but that antenna is part of the Air Force (...) network and we have to schedule that through its operators to use it for contacting the GPS satellites. In addition, we have five monitor stations or five specialized antennas which are scattered around the world which we use to monitor the constellation and verify the accuracy and the integrity of the navigation signal that we are transmitting to all the users out there. That big green square of course, is Colorado. It's one of the only states that we have that's square.

How many of you have been to Falcon AFB? How many of you have taken a tour of the Master Control Station? We sometimes refer to this as Tours"R"Us. And we don't mind that actually because it's a great was for us to interface with a lot of users. We get tours all of the time at Falcon AFB, and I conduct a lot of them. And we get quite a number of luminaries that come through the control station. Colin Powell has been there, Margaret Thatcher has been there, General Shalikashvilli has been there. Earlier this year for the first time we hosted the GLONASS delegation. As a matter of fact, Dr. Salaschev, who's reputed to be the father of GLONASS came through as well as Col. Lebedev, who is my counterpart who flies the GLONASS satellites. Incidentally, they're up to 22 satellites now and they will be up to 24 I think sometime early next year. Their characteristics are very similar to ours but there are also some differences. Instead of operating in six orbital planes, they operate in three planes, and they have eight satellites per plane. If any of you attended the ION Conference earlier this year in Palm Springs, there were a couple of really [good] papers that were presented there on all GLONASS operations, and I commend them to you.

This slide basically talks about our ground antennas. Each one of those antennas are about 30 feet across. They are a bit smaller than the antennas that the Air Force (...) network uses. Their antennas generally are 60 feet to 70 feet across, and the little red stars indicate where those ground antennas are. I just got back from Ascension Island, visiting our site there, and that is a God-forsaken place. There's only 1,200 people on the island, it's about 56 sq. miles and it's volcanic in nature. If you ever do get down there, climb up Green Mountain, 'cause it's an experience you'll never forget. When you start at the bottom it's kind of volcanic and looks like the moon, but when you get to the top there's a bamboo forest on top of the mountain because you get more moisture up there. But nevertheless, we have about six people there on that island who support GPS operations. The total island population is about

1,200 and most of them are Brits, because the British have BBC and also cable and wireless outfits there they have to operate.

These are the monitor stations I talked about. They are generally collocated where our ground antennas are, but there are a few differences. We do have a monitor station in Hawaii, and most of my people tell me they want to go visit, and I tell them no, that's on my reservation list. I'm the one who gets to go to monitor the station in Hawaii. I'll send you to the ones at Diego Garcia and Ascension Island. But they are a bit smaller than the ground antennas. They're only about 4½ feet across. They are essentially a large GPS receiver. They have about 12 channels on them. They do a pretty good job of helping us monitor the health and status of the constellation.

Everybody has a "pat on the back" slide. And this our pat on the back slide. And I want to stop here for a minute and talk about the men and women of 2-SOPs. I'm not yet 40 years old, and I'm the oldest person in the squadron. I have people sitting on consoles who are not even legal drinking age, who are sending commands to satellites that are worth over $ 80 million dollars. Some of these people aren't too far out of high school. Carl Bonet, is one of our satellite systems operators; he's only 20 years old, but he is one of the most intelligent and most enthusiastic and most mission oriented people I have ever met in my life. You're getting a bargain when you have people from the DOD and people from the 2-SOPs operating this constellation for you. This constellation is worth $2 billion dollars on orbit, and we have a ground system that is worth about $300 million dollars, and the average age of the operators sitting out there on the ops floor is only about 23-24 years old. I'd give them a round of applause everyday I walk into the ops floor because they are the most proficient people I have ever met in my life, and I've been in the Air Force for 17 years and getting into the Air Force today is a bit more a challenge than it had been. You read in the newspaper all the time about the youth of America and how it's declining, drugs, crime, gangs, stuff like that. Come to 2-SOPs and walk on the ops floor and I guarantee you your faith in the youth of America will be renewed. Now I'll get off my soap box and get back to reality.

Here's something you want to talk about, or hear more about and that's the purpose of our user interface. a lot of you who are familiar with the NANUs and that's not from the show Mork and Mindy, this is the notice advisory to the NAVSTAR users. We have an electronic bulletin board. We use these interfaces to answer questions and provide you points of contact, and also support different projects that may be going on in support of GPS. (...)

Let's talk about the future a little bit. These are not the issues of policy futures and things like that, this is more along the lines of what we are doing with the constellation and also what we are doing with the operation and control segment. The 24 satellites we have on the orbit right now are all Block-2 and Block-2A variety. As I mentioned earlier we are going to have another Block-2A launch in March of next year. Block-2R satellites are currently going through thermal vac tests with a contractor at their facilities, and the initial launch is August 29, of '96. I can't speak for the JPO. They are the ones who are more familiar with

when the real launch is going to happen. I've heard through the grapevine they're having a few problems with the thermal vac tests for the first Block-2R satellite, and I don't know if that's going to delay the launch or not, but for right now what they are publicizing is an August 29, '96 launch for the first Block-2R satellite. And these things look a lot different than a Block-2A. They cost a lot less too. For example, the current Block-2 and 2A satellites are around $80-85 million dollars a pop, and these are about $40 million. So they are getting cheaper. Their configurations [are] entirely different, so we're going through quite a bit of training in 2-SOPs to allow us to be able to fly these satellites as well as we fly the Block-2 and 2A variety. They do present a new challenge for us because we will be flying Block-2 and 2A and 2R satellites at the same time, and so our people are going to have to get a lot of training for that.

Loral Corporation was recently awarded a hefty contract to do an OCS re-architecture for us. OCS is of course is once again, the Operational Control Segment, that's the master control station, ground antennas, the monitor stations that we use to fly the satellites. We're if you will, I want to use an analogy, we're flying satellites right now with a DOS system. And we want to go to Windows. It makes it a lot easier for our operators on the floor to point and click and send commands to a satellite as opposed to continually typing all the time. It makes it a lot easier. It cuts into personnel errors and things like that, and that is one of the objectives of this OCS re-architecture, and we're going to be doing that for the next five years. It'll be transparent to you the users of the data. It's more applicable to us as the operators as opposed to you. (...) I want to talk about selective availability. Everybody knows about C/A, and P code and things like that. But what I want to say [about] selective availability is the decision to implement it. To turn it on turn if off, change its level, it doesn't happen at my level. It happens at levels much higher than me. Matter of fact, the National Command Authorities are the ones who have the ultimate responsibility of whether SA is turned on or off and what level it's set at. Now it does happen on our operations floor within the MCS, that's where ultimately the rubber meets the road as far as the SAs being changed. I can't however, even as a commander of a Squadron, walk out there on the operations floor and tell the operators change SA to this level. I don't have that authority. If you want to get SA turned off, I suggest a writing campaign or whatever to Congressman, Senators, the Secretary of Defense, and the President. They're the ones who ultimately will have the decision as to whether it stays on or off or what level it's set at if it stays on. And basically that is the intent of this chart here to talk about who has the authority for setting SA.

This is sort of my get off the stage chart. If there's anything I want you take away from today's presentation, other than that 2-SOPS is here to listen to you, we won't ignore you. We are here to satisfy the users. That's why I have a job. I don't fly satellites for satellites sake. We fly it because we have millions of users around the world who use navigation data. But I like also to end up on also a semi-funny note and that is, don't forget the motto of 2-SOPS, and it has a GPS and navigation theme. It goes something like this, "We won't tell you to get lost, but we will tell you where to go, and we'll put you in your place". Now with that I'm ready for any questions you might have.

Dr. Kane:
Thank you very much for giving us a rundown on what you're doing.

Question:
It's been said that the Block-2R satellites [are] built to spec and when they fly they may emit a signal 5-6 dB less than we're experiencing today. Do you have any comment on what we should expect from the Block-2Rs?

Answer:
I have to say that I am not qualified to answer that question. I was hoping that somebody from the JPO would be here. I don't know if there is or isn't. Because typically they are the ones who are more familiar with the specifications and the operational requirements for the Block-2R satellite. If I knew the answer I would tell you.

Introduction

Dr. Kane:
George Wiggers, we have changed the schedule all around the room. Since you want to leave in 45 minutes, we'll give everybody a chance to throw darts at you for that period of time.

Mr. George Wiggers
Chief, POS/NAV, Dept of Transportation

Questions and Answers

Thank you very much Duke. I'm sorry but I'm being recalled back to the office. So I won't be able to stay this afternoon, but I do want to give [you] the opportunity to ask myself or any of the other members of the panel from the Government any questions that we might respond as best we can.

Question:
Marty Shuey
I wonder if you would put up that slide of the transition schedule from the FRP showing the stuff that's being shut down because I would like to discuss that. I would like to talk about the '94 FRP and I guess the first part of this is for Mr. Wiggers. You know we had the meetings and user input was in fact requested. In fact, when the draft FRP was put out Loran was shown I believe as 2000-2005. This created a minor furor, you might say, within not just the aviation industry and a lot of people wrote letters back and said, "By God we would like it longer than that", and, I thought, gave some eloquent reasons. The final report came out,

dropped it five more years down to 2000 and I guess my basic question is did anybody read the users' input, and if they did, what did they do with it? That's question number 1. And that's for DOT.

Answer:
G. Wiggers.
Yes indeed. We certainly have read the input and I guess even subsequent to the FRP going out we have continued to get input. I have a box this high next to my desk of letters that have come in on the subject specifically on Loran-C and I am sure that the Coast Guard, Doug you probably have your box of letters as well. We have certainly heard from the user community the desire to keep Loran-C going further into the future. The difficulty of course that we're in, part of the reason that we almost didn't make it here today and that is the budget crisis. If you look at the struggle going on between the executive and congressional branch over when they're going to balance the budget, you know that just about every penny we spent on systems is being watched very closely and any reason for saving some dollars by turning off systems early we are being requested to do that. For the Coast Guard on Loran-C basically the dilemma for them again given the budget constraints that is if that they do run Loran-C further into the future, there [are] going to be some other programs that they will need to retrench and cut back further because there is only so many dollars being made available. I think the we did leave it open in the '94 FRP that if there are requirements that are identified that can justify keeping it going past the year 2000 they would be considered. But they will of course have to be very closely scrutinized internally within the government. We would have to make the case to justify why those systems need to be continued and in effect compete for very scarce dollars with other systems. That's why we're here today letting you know about that and we would very much like to hear from you to give us the information we would need to make a case for continuing those systems.

Question:
Marty Shuey
I'm glad you brought up the budget. And just for the train guy over here, I just happen to be one those guys from W. Virginia, by the way, and some things I've just got to question about. You know I see you talking about the budget now I can't talk for any other organizations, other than about the largest aircraft user in the country and the pilots to go with it. But I look at the time line and I say Loran, I say NDB, VOR, TACAN, DME, Hmmm. You know what my Loran set does for me? Well, even though it's non-precision I find a runway directly out of the windshield and if you'd been here yesterday, you'd have seen Mr. Hinson doing that with a GPS. [referring to the video shown by Mr. Boyer] Loran and GPS are transparent because they meet the same requirements.

Let's go to that budget. I heard earlier $200 million dollars to operate everything except GPS. Loran only costs $20 million a year to operate. With Loran I get additional safety benefits just like the database on the GPS 'cause it's transparent. I get frequencies, I get where the airspace is [class] B&C, special use airspace if I'm approaching that. I get DME,

I get fuel, I get winds, you know I get all that stuff and it doesn't get less accurate the further I get away from the station such as the NDB or the VOR. You know I'm looking at the numbers here and maybe I don't understand something and I'd appreciate it if someone would tell me. $180 million bucks to operate everything on that chart up there and $20 million for Loran, yet that's the first thing going out. You know my pea brain up here says maybe we ought to keep that and close some of those other ones down earlier, which is what I thought the input was that went to the FRP.

So let's get to the bottom line. Now the '96 FRP is coming up. Well you're hearing form one user right here, we want to keep it and continue it. And more than that I would suspect that "not invented here" syndrome within the FAA and I'm not going to name any names, but I think there is a real movement afoot within the FAA not to do it. I'll like to drop back to the 1990 document that Phil Boyer talked about yesterday. We love GPS, we think it is great. However, sole means for the FAA means one thing: GPS only? I find that difficult to believe because the requirement has always been for two navigation modes for IFR flight.

Now does this mean that the FAA is changing that so it will just be space-based only? Because If I drop back and quote original documents sent to Congress that started the GPS train before the airlines ever did, we said a space-based/terrestrial. Seems like that got lost in the process. I don't know but that freight train's going 200 miles down a track and for my constituency I'm worried about it. Now the airlines aren't. Why? Whenever they say GPS or GNSS, what you hear or don't hear is FMS, IRS, INS. Well number one we can't afford that. $25,000 for a INS set is more than what the aircraft is worth. Yet, we have 175,000 aircraft in the U.S. alone that are not going to be able to have that set. If the FAA's job is safety, I think it would be nice to have a backup until GPS is proven to be a stand-alone sole means of navigation, for which I would like a definition forthcoming from either DOT or FAA. Other than that I have no strong feelings on the subject.

Answer:
G. Wiggers:
Very good. Perhaps P. Drouilhet would like to respond; you're getting into some aeronautical areas which he is much better able to do.

P. Drouilhet:
Let me comment on a couple of things, Marty. The airlines are not all FMS, IRS equipped. In fact, many of the airlines are looking to GPS as their means of not having to equip with the very expensive FMS, and IRS. Loran, I like Loran. I fly with Loran all the time. Almost all of the Loran equipment out there, 80 plus percent of it, is not certified for IFR flight. All of the VOR equipment out there is certified for IFR flight. Loran does not have the proven capability to operate as a independent IFR system. It's has never been certified. You can't fly, you can't operate with just Loran in your aircraft. You say that the IFR requirements are for two means of navigation, I'm not sure what you are referring to, because, NDB is not required for IFR flight. NDB is only required if you're going to shoot an NDB approach.

There are a lot of NDBs out there but the basic IFR system is built around VOR. Many aircraft have DME also which augments used for approaches. We don't use NDB for en route navigation except in Alaska.

I think there are two issues on Loran that we need to look at and keep separate. There's a large equipage of Loran that exists right now in aviation and a much larger equipage that exists in the boat fleet. The system should be operated long enough that users get fair economic value from the equipment they've already bought. Men of good faith can argue about when that is. The equipment's wearing out. It's not being replaced and at some point it will get down to the point where it is not longer economic for the tax payer to support the continued use of Loran. [The year] 2000 has been picked as a date for that to happen. One can argue about that.

I am sure there will continue to be arguments about that. The other side of the coin. Should Loran be enhanced? Is Loran part of the future? And we think not. We think that the direction we're headed is a direction in which GPS with its augmentations will provide the ICAO definition or the aviation definition of a sole means of navigation. It will [be] sufficiently robust that it's the only thing you need to operate. I couldn't agree more that that's yet to be proven. And I think in the transitions schedules we show there's plenty of time to prove it before things are turned off.

G. Wiggers:
I think Doug Taggart would also like to respond on that.

D. Taggart:
Thanks. Recognizing that on this chart there's a lot of stuff showing here. I just wanted to say from a Coast Guard point of view recognizing that the Coast Guard is a user of operation of one of those systems, and that is the Loran system, and as I indicated the Omega system for '96 and '97 is in the FAA's budget. I think the issue on Loran-C right now is in fact driven entirely by budget. The Coast Guard has a strong awareness of the cost of the operation of the Loran-C system simply because of the transition away from providing that overseas [service]. As I indicated, in FY '93,'94,'95 we have taken significant cuts in our operating budget from the radionavigation program because of the chipping away of that DOD [requirement] not only from a personnel point of view but also on an annual operating budget. As I indicated we had at one time 46 Loran-C sites. Manning those facilities were approximately [470] Coast Guard men and women. As I indicated, if you look at the Loran system today, we're down to 230 so, and as I indicated for the '97 consolidated control project we will eliminate another 30 so approximately we'll have gone from 470 or so people down to 200. That represents a significant cost reduction for the Coast Guard.

My point in bringing this up is that for us the U.S. to make a transition to a single system such as GPS and the awareness of the folks that are driving the Coast Guard budget, we as a nation can rely on GPS because it is being provided for our purposes. I look at the overseas

work that I was involved in and transferring the overseas mission to the other countries, and I see a move on their part to not only look at GPS as an asset that they can take advantage of, but also I see an awareness on their part for the future that they need to have an ability to meet their own requirements under the SOLAS (Safety of Life at Sea) agreements, etc., and with GPS being a U.S.-provided system, such as Loran-C for our own purposes, they don't have as much confidence in making that transition to a GPS as a stand-alone for meeting their needs. And therefore, in an international place you do see a continuation of terrestrial-based systems, Loran of which is one, VOR, MLS, ILS, etc. From an aviation point of view in the non-U.S. sense [this] is also something that they're concerned with. Recognizing that we in the United States can transition to a single U.S.-provided system and they have confidence in that, and recognizing the very difficult budget environment at we're all in, I think these are some of the issues that are driving the transitions as indicated on this chart.

G. Wiggers:
Thank you very much Doug.

Question:
Marty Shuey:
The last thing is a 2 part question of which part of it goes to George, the first question, and that is, I understand that the FY '97 FAA budget that went up to DOT had zero money when it was returned back for the Local Area Augmentation System to the FAA, and they're probably going to have to take it out of their hide; and that ties into the second question which is on the GPS and the [TSOC-] C-129 boxes with the recent Transport Canada Advisory Circular that's been issued, and I believe something coming out of the FAA on the possibility of maybe eliminating the 129 boxes for the problems. Will this delay the implementation of GPS?

Answer:
G. Wiggers:
With regard to the FAA budget, I don't have a knowledge of the details of that but I think you may have answered it yourself when you said they'll take it out of their hide. I think the priorities are very high and they will be likely moving ahead with it. Paul did you want to respond?

P. Drouilhet.
I'm not sure what you're referring to in the Transport Canada Circular. The status of the when Marty refers to the C-129 boxes, let me just explain what that is. All equipment that is to be used for aircraft navigation under IFR has to be certified or built to conform to an FAA Technical Standard Order. The current GPS equipment which is being used is being built to TSO Order 129 which defines a series of several classes of equipment which can be used for different functions. And all of these are restricted to use as a supplemental navigation system. They're to use the current GPS, the 24 satellite constellation. They do not operate with WAAS. They're restricted except for certain oceanic applications. They're

restricted to use as what is referred to as a supplemental system. You can't just equip your aircraft with that box and fly IFR. You still have to be equipped with the primary systems of VOR and ILS as your navigation and landing guidance systems. However, you can use GPS to give you an area navigation capability point to point capability.

What's the future? The MOPS (Minimum Operational Performance Standards) for the GPS WAAS boxes has been completed, it has not yet been published. It's been completed for the box through non-precision approach capability. The precision approach capability is yet to be added to it and it will probably be fully complete in another year. That will define the characteristics of the GPS/WAAS equipment which will then be qualified as a primary means of navigation, a stand-alone means for aircraft operations. The equipment built to the current TSO-129 will continue to be usable but as a supplemental system. Unless it is upgraded by the manufacturer to whatever TSO number becomes the TSO for the GPS/WAAS equipment, it will never be able to be used as a primary navigation system. So there are a large number of instrument approaches that are being written around the TSO-129 boxes. Essentially all of the non-precision approaches which exist now can be flown with this box as part of the so-called overlay program. In addition, the FAA plans to publish approximately 1,000 GPS only instrument approaches based on TSO C-129 equipment. Those will be supported for a period which is at least to 2005 and perhaps beyond that. But eventually the TSO C-129 equipment will be phased out as the GPS/WAAS equipment becomes the standard. That answer your question Marty?

Question:
J. Beukers:
I look at the cover of the program here and I count eight times "international" is mentioned. In addition, we have here a number of people who have come from overseas so I think this legitimizes my question. Recently, within the last couple of years, the U.S. has written letters to IMO and ICAO. These letters offered GPS to the world, but also they directed the international community to decide how to implement an internationally-provided system. In response, the international community has started to spend money and the examples of such are INMARSAT, we have the GLONASS system. The last launch of the GLONASS system is scheduled for December, and we will have an operational GLONAS system. This is going to be basis for the international system. The perceived attitude in the United States, is that we only require one system, the GPS. And the FAA is not addressing anything but GPS. The NAPA/NRC report recommends that we certainly not only [do not] need additional systems but these are contrary to the security of the country. Now we understand that there is a move towards classifying the navigation payloads as significant military equipment on the INMARSAT P and also on the new corporation, the ICO Services Limited, private corporation. We believe that the navigation payloads on these satellites are going to be classified as I said military equipment. My question is what is the U.S. policy? And who is setting this policy towards a civil GNSS? And also, what export classification of space satellite hardware is going to be put onto the supplemental orbiting satellites? And I think it's a pity that Jules McNeff is not here to answer some of these questions, but I would like

to pose them to the panel anyway.

Answer:
G. Wiggers:
The U.S. position on the GNSS is that the GPS will be a component of that and I guess our request to the international community is that however that system evolves that it should at least be backwards compatible with the GPS system. I think clearly that is in the interest of all the users out there that their equipment would not be obsoleted by new developments in that area, and that has been the position of the U.S. and the FAA at the ICAO, and I believe with IMO where we have offered the use of GPS as part of the GNSS. With respect to the question on munitions, indeed we don't have someone from the Defense Dept. here to talk about that. As you indicated you identified that as a move within the government, but the government has not made a decision on that yet. So there is at this point no policy established by the government. Did that respond to the questions?

J. Beukers:
It sort of answered the question, but the real question is, what is the U.S. policy? Is it GPS only or is it encouragement for the international community to come up with a system which is internationally funded and internationally controlled? There is confusion in the international community and we need, I am speaking as a U.S. citizen actually, but we need clarification of what the U.S. position is. It is confusing.

G. Wiggers:
I think the U.S. position is quite clear that we do support an internationally sponsored or controlled or whatever GNSS. The NAPA report as I hope you all understand, is not U.S. policy, that was simply a report by an independent group to the Congress which Congress requested it. And that does not establish policy. But our stated policy is that we support GNSS and again we have offered that the GPS be a component of that and [that] it be backwards compatible with GPS.

Question:
Linn Roth:
I just have a comment because there has been so much emphasis here on the economics of this situation and so forth. And I'm very concerned about it, particularly in regard to the current and future evaluation of the economics of the Loran vis a vis the technology that is available. When the DOT was making their recommendations regarding the Loran system: I'm curious as to whether this was based on evaluation of contemporary technology as applied to Loran. (...)

I'm from Madison, WI, near Chicago, and we typically monitor virtually all the Loran transmitters in North America. And in fact, we're just beginning to pick up European transmitters. Just before I left we were actually picking up four stations inside the building under very noisy conditions. So this sort of shows the value that's available now. Basically

what we can say is that availability and integrity will go up phenomenally well beyond what is currently listed in the FRP and other government documents. Probably a couple of nines more. The coverage will probably be transoceanic in the northern hemisphere. In addition, the application of Loran could be inversely everything from [vehicle location] to telecommunications. For example, recent studies have demonstrated that could drive down the street in Manhattan, and get contiguous Loran coverage whereas you could not pick up a single GPS satellite. (...) In terms of the timing performance, it can virtually give you a cesium clock at the receiver and you can also get UTC out of Loran.

In summary, application of contemporary technology to Loran gives [a] system that is virtually bullet proof in combination with GPS; it's an ideal complement to GPS. It's a low frequency versus a high frequency system. It has a high signal level versus a low signal level. It's ground based versus satellite based and on a relative scale it is incredibly inexpensive to operate versus the level of expenditures we see for GPS. So my comment is that if you apply contemporary technology to Loran couple it with GPS you end up with virtually a bullet-proof system. And by that I mean you would probably have to shoot the receiver to have it lose the ability to navigate or provide precise timing information. If we were to turn off any one of these other ground based systems for a single year and save that $180 million dollars that Marty refers to, you could probably run the Loran system for 10 or 15 years, and provide an incredibly robust system. Did the DOT and the DOD take contemporary technology into account when making these economic evaluations for the future of Loran and all of radio navigation? And by that I mean not just navigation but also the applications within the telecommunications community?

Answer:
G. Wiggers:
Doug, would care to comment?

D. Taggart:
I have to watch myself in answering this here. As a member of the Wild Goose Association for the last 15 or so years, I think we can all recall a gentleman by the name of Jim McCullough. I haven't seen Jim in a while, but I think he did a paper back in 1983 time frame, and the title of it was based on, "Why don't we use GPS to calibrate Loran"? I think that's pretty much the title of that paper. Jim was one of the first that I recognized coming up through my involvement in the Coast Guard's R&D program. It was taking the stand back then that we need to move ahead and show the compatibility between Loran and GPS. And he spent a lot of time in his work at the Woods Hole Oceanographic Institute, taking that message forward. Unfortunately, though, I think we went through another period of time where we lost that partnership or that desire to move ahead in a partnership with GPS and Loran. Playing Monday morning quarterback and looking back on the events that took place, we got into an involvement of a head butting kind of situation, an us versus them, or them versus us situation. Now that led into a lack of confidence, I guess I might use that phrase, in the receiver development community and we lost an opportunity at a very critical point in

time I think in the late 80's, early 90's when we saw the FAA moving out with Loran-C, specifically the Mid-Continent expansion. That was a project that had been kicked around since the early 80's if not even before that time frame. In trying to come to a conclusion as to why today is the U.S. focusing in on one system, GPS [alone] versus a more robust [system], taking advantage of technology Linn as you suggest, really focusing in on how many systems can work together and provide a more robust higher availability kind of signal, it comes down to a matter of what was the government providing for a message and what was the commercial receiver community willing to invest in R&D to take those two forward. Now you have to figure out in your own mind where did the breakdown in communications occur? But I do think it takes root in that funny period of time in the 80's when it was an us versus them kind of environment, and I think that's kind of the downfall of why we're right now recognizing what is driving this issue is the budget, rather than stepping back and looking at the capabilities from a technology point of view. I don't know if I really answered your question, but rather just tried to provide a rationale that how we got to the point we're at right now. And it really is driven from a Coast Guard point of view. And the Coast Guard is the only one up there that is funding Loran. The other systems are FAA based, and it is an issue of budget.

P. Drouilhet:
It goes back to the discussion I had with Marty Shuey about the two ways which we are looking at Loran as a continuing support for what's out there or doing something new with it. And with one exception, which I would be interested in your basis for, I don't think it's broadly accepted that the P-static problem has become a non-problem for aircraft. But with that exception, I agree. Loran could operate with modern technology, both at the transmitter sites and in the aircraft in receiving sites far better than it does today, far better than the current generation of equipment what we're living with now. The question we have to ask is do we re-invent Loran? Given GPS in coming along as a fact of life do we re-invent Loran? Do we go out and deploy a new generation of transmitting sites and will the users equip with Loran as well as GPS, or will GPS do the job? Because everything we're talking about here is you're talking about with Loran is not using either what's on the ground now or what's in the vehicles now. It's basically starting from scratch. Certainly none of the airborne equipment would be usable. I hear Ed saying not true it may not be totally true for the transmitters, although you're talking about what you can do with a new generation of transmitters. So I think that is the question you have to ask. There are two different questions. How long do we support the current generation of equipment so that the users can get their value out of what they've spent? And secondly, do we re-invent the system for a totally new generation of user equipment and provider equipment?

G. Wiggers:
Thank you Paul. I guess one additional thought I would add to that myself about the ability to receive Loran-C in the Manhattan area, within the urban canyons, and that was a question I had myself and I asked our intelligent transportation systems people, have you really looked at Loran-C? They sheepishly said, well probably not really. But when I pressed them on it

they said well in terms of the developments in that area of technology in intelligent transportation systems that they had what they felt comfortable with a number of fixes for GPS based usage where they would have map matching, they would use the electronics that are being built into vehicles for automated braking systems and other developments, to account for the minimal reception to GPS in those systems, so it perhaps there could have been some more work in that area but there is the whole technology which is moving. It has many partners from both the private sector and state and local governments, the federal government, that it's very difficult at this point to turn back the clock on that and get that whole thing moving in a different direction. (...)

Question:
First of all I have to say for G. Wiggers, I sympathize with George I know he's getting attacked from all sides. There's a lot of difficult issues here to come to grips with. My question is really very simple. As a number of you have mentioned George, we have my favorite, the ITS report. We've had the NRC, the NAPA reports. We've had of course the FRP and more recently OSTP report which I understand is still in debate. Could you give a little overview of where the recommendations from these reports are going? How are they fitting into the DOT's own strategic plans, and perhaps give us an update on where the OSTP recommendations are? And I'm being very nice to you today Mr. Wiggers (...)

Answer:
G. Wiggers:
I think this year has been a very exciting year in the whole area with the different reports coming out. I guess maybe going back a little bit earlier to the joint task force report between the DOT and DOD, which is basically setting the stage for a whole new set of developments and for the introduction of technologies which indeed may be changing what we do in this country and around the world. These navigation systems have been around for a very long time, but the applications of them are just mushrooming and really penetrating just about everything that we do. With the communications companies using them for timing, whenever you make a telephone call you're also using the radio navigation systems. It's really staggering. I think we've been making a lot of progress, but clearly the necessary government involvement in these systems requires a tremendous amount of internal debate within the government as what really should we do to provide not only for the national security uses of these systems which is why some of them were developed, but also to make sure that the civil users get the most benefits from them. I see that we are converging on decisions that will indeed meet both those requirements, both the systems that will support the national defense, the national security requirements of the country, as well as provide benefits for the users, maximize opportunities for industries to grow and develop and make use of the systems, provide services with the systems, generating employment the economic activities which is part of what it is all about. Unfortunately, I can't tell you how all of this is going to come out, because I don't have that crystal ball that gives me the answers that everyone else might be looking for, but I feel in terms of my involvement in the process that we are making a tremendous amount of progress. I guess I could not even say when the dust

settles because I don't see it ever really settling, because we are in a very dynamic era where the technology keeps changing. So it will never in that sense settle. But I think in terms of the user needs, the people involved, the industries involved in this will all come out very much ahead as the government does its part in providing the systems in the basic infrastructure to support the systems.

Question:
D. Johnson:
George, representing the [International] Loran Assoc. I want to first of all say that I am not here to do an us and them thing; I agree with Doug. We need to be working together as a team rather than throwing darts at one another. I'd just like to lay some things out for discussion and I'm responding to my pile of communications brought to me by Loran users and aviation users. We're an international association so part of that pile is international. I don't hear anybody saying that we should re-invent the Loran system from the transmitters. The NELS folks are doing it a little bit differently. I would say that from the receivers side it is not a matter of re-inventing, it's just a matter of application because most of that has been done by at least one manufacturer, and he's talked a little bit about it. I have been briefed on the system, and I find it very very interesting, and I think we do need to apply today's best knowledge on any of these systems as a mix. I don't know of any Loran receiver manufacturer out there that's even thinking about doing IFR work that wasn't multi-chain master independent, and that's not a part of this equation as I understand it.

If we're going to look at a mix of systems the international community as well as the local community are concerned about efficiency and cost of operation. We see the term multi-modal a lot, in other words marine, aviation, everybody's using this one system as well as land users. All of the international community I have talked to has said, we should seriously be looking at a mix of terrestrial and space based systems however you want to define space based: GNSS, GPS, GLONASS, they are all parts of that. But if we are looking at a what I am going to call a well- balanced system, a mix of technologies, then I look what can play well together and on that list probably the thing that stands out more than any other or to play as a partner of satellite technologies is Loran. It is available not everywhere in the world like GPS is. The people that are flying in the open oceanic areas normally have inertial systems anyway, so if we're talking about having some kind of a mix of systems, inertial and satellite systems would provide that function, that coverage. If we're talking about a mix of systems for domestic use in the northern hemisphere certainly I think that some satellite system, whether you want to call it GPS or something else plus some terrestrial system will support it, and I think Loran is as good as any, then I think we're talking about real efficiencies here. I am sure you're up on the operating and maintenance costs. (...) The NDB is strictly an aviation piece. The VOR is strictly aviation. It looks to me like we could move back the NDB at least, and possibly the VOR phase-out numbers and fund the Loran for a longer bridge of time and talk about phasing that out because in fact the people on the Pacific Rim, the FERNS folks, the people on the Mediterranean and [the] Europeans, are embracing Loran and I get asked questions from the International community quite a little bit. Wouldn't an

approach like this make more sense? So my question after having said all that is, is there any possibility of making that adjustment and giving us a little bit more phase-out time or more time to evaluate a proper balance for Loran technology and space-based technology as working partners? We have seen every system that's ever come on line, including Loran-C, has not been as good as it ought to be when it first came out of the box and it has taken some years to work with it, and a lot of effort has been pushed in that direction. I think we have really gone a long way. But to kind of sum up a whole lot of statements that come to me, and I'd feel remiss not to bring them to this forum, isn't that a possibility?

Answer:
G. Wiggers:
If I understand, I guess the gist of that question is, whether it would be possible to do some economic tradeoffs within these systems. Some of the ones that would be phased out later might be phased out yet earlier in order to keep Loran-C going a little bit longer or extend that a bit. It seems to have some logic to me. Paul would you like to talk about that?

P. Drouilhet:
There's a problem with that approach at least from the aviation standpoint. And that is that you mentioned phasing out NDBs. NDBs today are the only means of non-precision approach at a large number of airports. I say only means, GPS can also be used for those approaches. Loran can not. No equipment that is out there today is certified for approach use for Loran. If you were to in fact, at least if you go up to one of states, Alaska, you'll find a lot of continuing of NDB both for en route navigation as well as for approach. Aside from the issue if it's technically possible and I think we have heard statements today that I certainly wouldn't argue with, it would be technically possible to use Loran as a replacement for early phase out of NDB or VOR would require a whole new generation of user equipment. The current equipment cannot do it, the current equipment in aircraft. So from the operator's standpoint, that would appear to be an unattractive alternative. They would have to go out and there would have to be developed, and certified and then I would have to buy new Loran avionics in order to be able to use it as an alternative to the NDB or VOR that you are proposing to phase out sooner. I think that's the central issue.

G. Wiggers:
Thank you Paul.

Question:
I'm Larry Barnett. I don't know very much about any of this stuff. But one thing I do know is that Doug Taggart is the most honest guy in the room. We can stand here and debate a lot of things and a lot of issues, but we're asking the wrong questions. It's not a question of reinventing Loran. The key question: Is the International community wrong about Loran? Is the user community wrong about Loran? We have a strong bi-partisan consensus in the authorizing and appropriations committees in Congress that Loran ought to supported and funded. Are they wrong too? Who's paying for the system is the question that ought to be

asked. It's the users. The user community. Virtually everybody is saying that you ought to continue to support and fund Loran. A key question is, do we make decisions based on budget? As Doug has pointed out. And they're [the Coast Guard] carrying the water.

They've been asked to carry all the water and they can't carry all the water. Or is the right question to ask, should we be doing what the operators, the users say they want and what they are paying for? And I think that's the right question. It's a matter of safety and efficiency. It's not a matter of competition. It's been a long standing policy in this country to have redundancy built into our system, backup, system mix. That's the issue. Again, not an issue of reinventing Loran. It shouldn't be an issue of budget, it is an issue of budget and that's wrong. We need to continue to make our case maybe for all these systems. I mean it is, Marty Shuey's members, over a million users of Loran out there saying that it ought to be continued. Everybody is saying that it ought to be continued, supported and funded except the FAA generally, and DOT.

Simple question. Tell us who made the decision in FAA and DOT and we'll go talk to them. We think there is a cadre of people in FAA, in Coast Guard, and in other agencies, Surface, Marine, all saying the same thing. Let's continue to fund it. Let's continue to support it. Let's upgrade it. And it's baffling that we can't do that. So I guess the question is in my mind. Which decision maker do we need to get to, George, to at least get the department to respond favorably or in a reasonable way to all the issues that have been raised in this debate about Loran? I sat in a user conference something like this a couple of years ago. Heard many of the same statements made and same comments made, the presentations were very similar. Since that time, I've heard an awful lot from the user community on one issue: Loran. I've been involved in a lot of issues over the years, political issues, that had not substance no merit to them. Both the substance and the politics are right on this issue. And it just baffles me that we can't find a way to continue to support Loran the way every FRP has said we should do up until 1994. Also baffles me to understand what changed so dramatically between 1992 and 1994 in terms of the FRP, and I fully recognize all the benefits of GPS. It's not a question of GPS or Loran it's a question of when on Loran. And when is a long time beyond the year 2000.

Answer:
G. Wiggers:
Thank you Larry. I guess I don't know who else I can refer you to other than myself. I'm supposed to be taking all this information in. I guess the decision making within the government it does involve the budget offices and the program offices and so on. And indeed there are tough choices that have to be made [and] they don't always come out the right way. That does happen. But I think it is very important that you know we do continue to hear this information, because if we don't hear from you then it's definitely a done deal that it's not going to happen. And again, we need to have substantive support as to why it should continued.

Question:
This is just a basic question on the FRP. In the preamble or the early parts of the FRP it talks about arriving at a proper system mix. System mix. If you look at this picture here after 2021 there is no system mix, there is only one system. I would like you to explain that.

Answer:
G. Wiggers:
You I think have a very good point. Maybe I could dodge that one very quickly. Heywood is saying no don't ask me. But as our expert on the FRP verbiage, Heywood, would you like to say anything about what system mix means?

H. Shirer:
It is true that the FRP has said all along that one of our primary goals is to find the optimum system mix that could satisfy both military and civil requirements. Through the years we have been looking at GPS technology advancing the way it is, it has been determined that GPS properly augmented, and they stated in the 1994 FRP properly augmented, will be to satisfy civil requirements for accuracy, integrity, and availability will be the primary navigation system for the foreseeable future. Of this again, does this qualify as a determination of the system mix? We are looking for a system mix, whatever it was going to contain. We looked at Loran-C, Omega, everything else to satisfy civil requirements and I think one of the original premises of the FRP as mandated by the INMARSAT Act was the envision of looking at how GPS as expensive as it was could meet the requirements of civil, military uses that these other land-based systems were currently meeting.

I don't think that the premise from that original statement was to look at qualifications that GPS and other systems could meet, and therefore since they all could meet those requirements continue those systems just because they could meet the requirements. The intent of the government was to look at scaling down and arriving at a system or mix of systems that could satisfy virtually all military and civil requirements without having to have unnecessary redundancy. And the FRP, whether you consider it a wise document at this time, it is still up for debate and whether the policy decisions were wise or not, that's still up for debate. The FRP has arrived at the determination that GPS properly augmented will be the primary navigation system for the future. And based on that, a phase-out plan was developed. Looking at when GPS as you see up there would be certified as sole means navigation, therefore after the year 2010. The current plan is to operate these systems in concurrence with GPS along with GPS until GPS has been proved to be able to be sole means of navigation. Is this set in concrete? I don't [think] anything is set in concrete. That's is why we update the FRP Plan every two years and, I don't have a crystal ball to tell you what is going to be in the 1996 FRP. We haven't really begun serious work on it. We're meeting at the first of December, to start talking about the user conferences that we are planning in February. And I think that we're going to have to see what comes out over the next year and a half. With current legislation that's come out of Congress, we're going to be taking a look at Loran-C. We're going to be doing a study on Loran-C. Probably

coordinated out of our office with George Wiggers, so it still remains to be seen what the 1996 FRP is going to hold as to the requirements of these systems.

Comment:
There was just one phrase in there that caught my attention, and that was unnecessary redundancy. And it seems to me that what you have to think about is necessary redundancy in order to navigate properly.

Question:
Peter Moore, British Airways.
I think those of us of the international community have been well aware of the budget problems that you are presently enduring. One of the anxieties that we have first of all is that Heywood's statement last year that this was going to be free to the civil community for seven years, and I think in the 1996 FRP perhaps you'll probably redefine that again so that we're not at some stage in the future faced with a large use charge on that.

The second question I have really concerns Omega. In the FRP the door is still left open. Those of us who use Omega do need a firm statement as to when the thing is likely to be turned off because basically we have aircraft still flying with Omega and I think there has to be a decision day once they say, "Right we're going to turn it off," so there's going to be nothing else after that because we have to reequip those aircraft.

The last question I have really concerns the turning off of VORs and DMEs, and really as to how the general aviation aircraft are then going to find their way around, or right with GPS they find out where they are, but how are they going to find out where they're going to go. Are they just going to be able to fly direct from air field to air field? Are they going to have a large database which they can have all the reporting points in, or are they actually going to put in Lats and Longs and have all the problems we've had, shall we say in the international community with air associated with Lats and Longs? So three questions in all.

Answer:
G. Wiggers:
I will do my best to provide some answer then turn it over to our modal experts for the others. One the GPS I guess we have spent a bit of time within the government trying to figure out how we can say that we're going to keep it on for a long time. We I guess there have been various formulations of that I believe it originally started out for the next 10 years, and then for the foreseeable future. It seems however we try and formulate that it is an interpretation; well it's not good enough. I don't think we can say forever because we're taking on something that is above any government in the world to say forever. I think it is clear on GPS that the U.S. is in it for the long term. We have just announced the request for proposals on the Block-2Fs. I believe that will take the system out to the year 2015-2020 when that award is made. So even though it's difficult to come with that right formulation that gives everyone the comfort level that they want, if you look at what we're doing it's

clear that we're in it for the long term. We have made a commitment as long as it's up there the signals will be available. We don't see even if we wanted to charge for it how we could possibly do that in terms of direct charges. If there's suggestions that you can give us as to how we can better explain that we're very much open to inputs on that.

Let's see the next part on the Omega System the decision right now is to turn off at the end of FY '97, and that is basically an international decision which will be made by the partners who are providing that system. I'm not sure; I guess we're hearing from the community they want it on longer. I guess I haven't, I guess I do have this box of letters coming in on Loran-C saying please don't turn it off. But I haven't got a box next to it from Omega users saying please don't turn it off. It's a small box. I'm not quite sure what can be done with that. We're certainly open to views that it ought to be kept going longer. That there is a hardship on the community, etc. But so far we haven't heard that. I see there was one last part to the question. Paul would you respond to that.

P. Drouilhet:
I think the last question is fairly easy to answer. There will be a big database just as there is today in Loran equipment and the GPS equipment which is in civil aviation. I bought a hand held GPS a couple of weeks ago, that has I don't how many thousand waypoints and tells me everything except the name of the attendant at the FBO that I'm flying to. Right now those way points that are in the systems are primarily the locations of the existing navaids; the NDBs, the VORs. But what they'll be in the future when and if the VORs and NDBs no longer exist is to be determined. But there still will be certainly an array of navigation way points which are the basis for aircraft navigation.

And just to comment on Omega. Indeed the user community needs a final answer on that. The FAA is being petitioned by various users to extend the date. That is an inconvenience and added expense to the users to re-equip with GPS to meet the end of '97 date. It's a fiscal inconvenience to the FAA and the government to keep it going beyond that and that balance is being worked. But as of right now the official cut off date is end of September, 1997.

Question:
D. Johnson again. I would like to pick up on Heywood's comment, [on] a properly augmented GPS. I think that means that no single failure or some words like that would bring the system down, or some definition of failure that would not bring the system down. How do we define properly augmented GPS or satellite. Now I've flown all over the country, and one flight I spent three weeks flying 12,500 miles evaluating a GPS/Loran receiver at different altitudes. I looked for every tough place for Loran I could find in the country. Without fail, the Loran/GPS agreed within 0.2 of a mile everywhere and within 0.1 of a mile almost everywhere. Now that was with a multi-sensor master- independent, later-technology receiver, but what happens if somebody jams L-1, and WAAS is also on L-1 and you take the whole thing down for an area of I don't know, pick a number for whatever period of time. Have we really figured that out? Loran [is] being a low frequency system,

very difficult to jam. High power low frequency as opposed to the high frequency low power satellite- based system. It looks to me like there is a good partnership relationship there that no single failure could take that partnership of systems down. And as I look at the list up there those two can be used by anybody and meet anybody's criteria within limits. Now I understand Loran is not as accurate as GPS, no argument there. But for the aviation community and the marine community it is quite adequate for [non]-precision approaches, and that's a different issue. I'm not really trying to talk about precision approaches. I guess that is my question. What is the definition [of] properly augmented?

Answer:
H. Shirer:
Thank you Dale. I don't have a technical definition for you at this point. I think the issues that you raised in terms of the integrity and reliability of the system are really important. Both the FAA and Coast Guard are looking very closely at those requirements to assure the adequate redundancy and so on of the systems to make sure that they will provide the "five nines" I guess is the phrase for aviation, whatever the equivalent is in maritime side. But there are also other developments that are ongoing that you all need to be included in. We have agreement with the Air Force right now, for example, to put the second civil frequency on the Block-2F. Depending on how that develops if there were interference on L-1 then I believe the latest number is L-5, but if they keep telling us a different L number as to which one it's going to be. But the way the technology is evolving I don't think we can say that it's you know we're not going to have the adequate redundancies, the reliability, the integrity of the systems. I believe what the charge to the system providers both FAA and the Coast Guard is to assure that whatever they provide is robust enough to do the job. Is that an adequate answer, or would you like to add more to that?

D. Taggart:
In terms of I think the way adequate redundancy or the appropriate mix can be defined is really doing a risk analysis and looking at the availability requirements versus the issue of integrity, and associated with those risk analyses, what is the impact if that system is not available? That's really where the answer lies. I'm not going to sit and say that any of these systems here provide that mix or any of the systems that we haven't even talked about on this slide particularly. You know the potential of looking at the seamlessness, I guess, of navigation being a little bit more under the GNSS kind of environment, the satellite systems associated with the EGNOS system and the WAAS system and how that whole configuration as it's being fielded from an aviation point of view may play into the final requirements for terrestrial navigation systems as well as maritime applications and other surveying and that other whole segment that's not even represented on this panel here today, the highway industries, etc. There's a whole group of navigation users out there. This slide would simply say is an aviation type slide. Looking to the question that was put to Heywood, you know we don't see a mix at the end of this slide. Well you know this is the aviation approach and Paul indicated in one of his bullet slides that the aviation community is driving toward a navigation system with GPS as the final answer on space based systems. So that's how he

looked at that. What we need to have to do is bring in those other navigation modes; that maritime, etc., I understand that.

If you look at the Block-2F operations requirement document that's being put out for the civil community to comment on, it's being entirely driven by the aviation community right now. There's not to a great extent we're trying to get maritime requirements put into that. You're not seeing the requirements being brought forth from the railroad industry for example, from the terrestrial based nav systems for the surveying community, etc. The aviation community has a very important role on where radio navigation is going today, but does that meet the needs of the entire user base? That's an issue that needs to be brought into the final mix equation. It can't be looked at from a single mode point of view. It's got to be a conglomerate of all those modes brought together. That's what I would offer. It's not an answer, it's just a statement.

Question:
The capital investment has already been made, as I understand, for implementing for the ABS (Automatic Blink System). Can you give us any idea as to when that system is going to be implemented?

Answer:
D. Taggart:
OK. A little bit on ABS. We did hear yesterday in Mr. Boyer's presentation a comment on the language as it exists in the FAA's appropriation for the ABS. The automatic blink system was conceived back in the 1989-90 time frame. In fact I was involved in some of the development of that system from an engineering point of view. The FAA was the primary driver behind it, and they were the driver behind it because of the expansion to the Mid-Continent region, etc. Looking back really at what the system is intended to do is just to provide that added degree of integrity necessary for Loran-C to be used for aviation purposes. It's taking that manual blink capability which the Coast Guard provides from the maritime point of view at the 60 second threshold and bring it down to a less than 10 second requirement; with the performance of that ABS equipment showing around a two second capability.

We went through the development of that and the FAA was the primary driver for that from a budgeting point of view. The equipment does exist. It has not yet been installed. The reasons for that not happening I think fall into that funny period of time that I was talking about where GPS was coming on line, we reached IOC, we saw a lot of initiative on the part of the FAA to embrace a satellite based system. We lost some of that drive to focus in on a terrestrial mix. We got into the battle between Loran and GPS and head butting, etc., and we lost that opportunity two or three years ago to really move out and get ABS into the field. Again, recognizing the Automatic Blink System is one component of finally certifying Loran-C for that sole means phase of flight. We also needed to get receivers out there, etc. But to answer your question directly on ABS, has the capital investment been made on the

equipment, the answer to that is, yes. Where will the FAA move out as to the language that was reflected in their [congressional] Bill? It won't be the Coast Guard taking the brunt of that on from a budgeting point of view. We don't have the capital behind us to do that. I will admit we have been approached by the FAA recognizing that that language is in there. I don't have the answer as to where that will lead. But the Congressional language does drive the government organizations.

Question:
Ian Anderson:
George made a statement about Omega and about users. For the 1994 FRP we submitted a twenty-six page brief [Ref. 2] to the DOT, to the U.S. Coast Guard, and to the VNTSC [Volpe National Ttransportation Systems Center]. In that twenty-six pages, two surveys that were done by the late Dr. Andrew Stratton and Mr. John Beukers. Dr. Andrew Stratton updated the '89 civil aviation users report on Omega. In the '93 version of that report, I forget what percentage increase, but the [number of] users of Omega in the civil aviation world was increasing. The other report that we gave you was the use of Omega in the meteorological world [Ref.3]. And Mr. John Beukers, who is an expert in this area, helped in producing that paper. So you have the data in your office. Whether somebody read it appears as questionable at this point in time.

OK, we're talking about here a system that becomes, all these systems become one [GPS, according to the 1994 FRP] [Ref. 4] in the year 2010. A single system. I'm an international airline operator, and we spend a great deal of our time and money on safety related items. Our aircraft in areas that we define as critical to flight safety have at least triple redundancy built into them. And in fact, in some sub-systems there is more than that built in. So we have a backup. Now I believe that navigation has a safety element involved. And for us to go from all of these systems back to one doesn't give us any backup. And I really question that GPS can do everything for all the users throughout whether it be the U.S. or the rest of the world.

Now I'll give you one instance where GPS will not work, and that's your underwater fleet. Your nuclear submarines cannot pick up GPS signals underneath water or the ice caps. You do pick up Omega signals. Now if you look at the amount of money that you are spending on GPS, it's an horrendous amount compared to most of these other systems. We're talking, I understand, $200 million dollars for all of these things [present-day navaids] up in front of me and I'm not sure what GPS is but it's probably in several hundreds of millions of dollars. Now Omega by itself is about 5%, I understand, of the GPS budget. And Omega is a certified world-wide system. Now what the user community and especially the international one is probably hinting at is that why are you going to a single system in the year 2010? Because it just doesn't make sense to anybody that you would go to a single system. There is no backup. And safety in itself requires that you should have redundancy built in, and really we don't see that redundancy at all. Thank you very much.

Comment:
J. Beukers:
I'd like to comment on this question of Omega. Last night we had a very interesting talk from a Vice President of Boeing, and during that talk he mentioned how important it was to get wind information, and I think that his figures for cost saving ran into millions. I don't remember the exact figures. Now I don't know whether the DOT read my statement, but [there are] 1,000 upper air stations around the world and 25% of these use Omega for obtaining winds. If we turn off Omega we're going to lose 25% of the upper wind network. Doesn't this make somebody sit up? This is aviation winds. I don't understand.

Answer:
H. Shirer:
Thank you very much. The question of use of Omega for weather is one that I have been particularly concerned about myself, and I have been asking to make sure that we have the all the input that we need from the weather services. I'm not satisfied that we do. I believe that there is an international system. There is the world meteorological organization, our National Oceanographic and Atmospheric Administration provides the representatives to that, and we have about a year ago informed them of what the status will be with Omega, and as far I know we have not yet heard back from them, but we are certainly in the listening mode if and when we do hear from them.

J. Beukers:
The reason you don't hear back from them is because if they stand up they're going to have to sponsor . But that doesn't mean to say that the system is not important to aviation interests.

Heywood:
Doug [Taggart] or Paul [Drouilhet] did you want to add anything to the response?

Paul:
We're aware that there are GPS based substitutes being developed for that application, but I'm not up on the details.

Heywood:
Yes. That's my understanding that they are working on that. I guess the concern that I have is that assuming that there will be substitutes, whether they would come on line in the appropriate time. I understand there is that cost [concern]. The analysis that we've done in the case of the cross-over point, in other words where it pays to stop working Omega, is that when you get a price differential of around $50, and I understand that will be happening. And again, I would be very concerned that if there will be substitutes coming on line that they will be on line in time to provide kind of a seamless transition to GPS. With respect to the submarine use, I think that was mentioned. That's something that's always been curious to me, but our defense people who are in charge of the U.S. submarines anyway, (I don't think that we have any civil submarines out there) have said that they're not really interested

in the continuation of Omega for that service.

Comment:
Jeff Girsch, Johns Hopkins Cryo-Physics Lab:
We talked to the Navy. The Navy is now scrambling looking for alternatives because they see that the Omega system is going to be shut down so they are trying to figure out what they can use as a replacement. For example, VLF transmitter stations. [They] are looking at reinventing Omega using Navy VLF transmitting stations.

Heywood:
Yes. And again, I can not speak for the Defense Department. They are part of the sign off on the FRP and if they do want Omega, then the Defense Dept. has adequate opportunity to speak up and have it in there.

At this I would like to turn it back over to Duke [Kane], and really appreciate the opportunity to be here and talk to you about our systems.

Dr. Kane:
We kept George one hour longer than we had planned, but I would like to remind everybody that while you have voiced all the objections you have to the current plan, George has also given us the option of making our case again. So if you're not happy, be talking to George and others in a written form in a report from this committee from this conference, and such a paper is being drafted, and will be circulated after lunch.

As [a] pioneer in GPS I watch you struggle with what's called according to the cynic, brother can you spare a paradigm? We're in a paradigm shift, and the struggle is fierce. The case has to be made on an individual basis, as you have seen here, and on a mixed basis. GPS can't do everything. Truck drivers going through mountains and tunnels know they're going to lose signal, but there are many millions of other people who use GPS on a constant daily basis that don't require all the add-ons that are necessary for anomalous situations. So, I'm happy you all think GPS is great, but at the same time if you want to make the case to George and others there's an opportunity to do it, in the meeting after lunch, and I would hope that at least you three [government] gentlemen can stay in case there are additional questions people want to ask. Thank you.

Introduction

Dale Johnson:
What we want to do now is to continue with the questions and the discussion. Some of the DOT folks are going to remain with us for about another hour and we will have Mr. Dave Scull moderating this session to keep us on track. For those of you who have been around the navigation business for a while I'm sure the name Dave Scull is not a foreign name to you. He is the current Secretary General of the International Association of the Institutes of Navigation, and he's served as President of that association from 1985-88. He's the past president of the U.S. ION and a fellow of the Royal Institute of Navigation and an honorary member of the French Institute of Navigation. Since 1985 Dave has been involved in just about every kind of navigation system and business that there is, and so he is well informed and certainly the proper person to moderate this forum because we are talking about a wide range of issues and a wide range of systems. So with that I think I'll ask Dave to come up and keep us in line.

OPEN FORUM
DISCUSSION OF USER REQUIREMENTS AND POLICY ISSUES

David Scull:
International Associations of Institutes of Navigation

Thank you Dale. I think what he didn't mention that I retired from the DOT in 1989, after having spent about seven years working on the FRP. I worked on the first issue, and I don't know if you people realize what generated the FRP but it was a report by the Office of Telecommunication Policy. The White House got the idea that they could save millions of dollars replacing current navigation systems with GPS. For seven years I sort of fought that issue personally but [I was] helped by many others in trying to get what we often talked about as the optimum mix of radio navigation systems. I'm a little discouraged here to find that the last two years we have moved back to the single system type mentality, but hopefully with the results of the conference today maybe we can get things back to thinking about an effective mix of navigation systems. Another thing that J. Beukers brought up, and I want to emphasize is that this is an international meeting. How many people in here, just out of interest, would you please raise your hand if you are from overseas. So at this stage now we haven't --- like Andy Bass pointed out, he was the only one that drove any discussion on user requirements yesterday. We have a little bit of that but I think we've really got to get in there, and this is your chance. Now you know we're had FRP conferences before, but never one like this where we've had the chance to record everything. When I was at the DOT we recorded everything, but I kept it and threw it...but we're in charge here. After we have gone

over user requirements, make recommendations and so we really have some control here so let's really make the best of it.

Question:
My name is Fred Koorey, and I'm with Science Applications Int'l and I support the Joint Program Office, and I've been involved with the DOD side of this GPS business for over 10 years. Over lunch, sitting down with the Coast Guard and the DOT rep, we're talking about the issues that we're all concerned with just before lunch and it occurred to me, I have to make an admission. I didn't come here with a pre-conceived agenda or notion on whether or not I supported Loran's future or not. I admitted this at the beginning of lunch that I wasn't I'm still not convinced. I'm still on the fence. Through the course of the conversation at lunch I'm starting now to become an advocate of the continued use of Loran. And may I propose then that...let me back up a second.

DOD just got a bunch of money out of nowhere in the last couple of months to address vulnerabilities. And the vulnerabilities had been identified and catagorized in classified sessions for the DOD. And what it is driving is a fast response to correct the problem using direct Y as a solution, and there is a number of technical approaches to do direct Y. Direct Y could [enhance] acquisition for DOD receivers. It means that you don't have to go through the L-1 to get to your L-2 solution. That is a shortcoming of the DOD receivers. The P-Code receivers. They recognize their vulnerabilities and they figured out they have to do direct Y. And the vulnerabilities have to do with the potential for jamming and denial and things like that.

What I picked up yesterday, for the first time, [is that] integrity of the timing signal seems to be important. Particularly to the communications world. That's a concept that I hadn't heard in my 10 years. We've always considered integrity as applied to position and velocity. So based on the fact that DOD came up with money very quickly under Secretary Perry's Advanced Concept Development Program for Navigation Warfare, it's a program in the DOD, and they have bucks to spend on it. And it got prioritized way up at the top. It might be a good approach for the civil community in its attempt to build a case for the perpetuation of Loran, to address the vulnerabillities issue. I heard some vulnerabilities discussed vis a vis, Loran and GPS earlier today, I don't have to review them again. Maybe if they have been documented or if they haven't been documented maybe they should be documented. But we've been talking about risk assessment addressing integrity. We've been talking a risk assessment cost and schedule. Maybe we should address a risk assessment based on the vulnerabilities to the civil user. And that may be the lever that you might want to consider using to get Loran perpetuated. That's all I had to offer.

Dave Scull:
That's one testimonial for Loran-C. Who would like to be next? Another SAIC man:

Question:
I'm Chip Dorman, also and SAICer like Mitch and I'm supporting [FAA Systems Integration] ASD-120 on the Systems Engineering and Technical Assistance contract. The main question I had was a two-part mainly directed to Doug [Taggart, USCG] and then the second part Paul [Drouilhet, FAA] may want to chime in on.

There were a bunch of comments made yesterday by Andy Bass, and Andy Bogle and others pointed towards the [concept that] DGPS integrity is functionally related to the range to the transmitter; I think I boiled it down to that. I think it interplays there. Your integrity, the further you get away from it, the lower your integrity is is what we're getting at there. (...) What is the critical distance that we're talking about? The second part is (Paul to chime in on too), is there some possibility or technical capability to integrate those 48 or 49 Coast Guard sites in conjunction with the FAA's vision of the WAAS [GPS Wide-Area Augmentation System]? It seems to me that if there was a possibility technically to integrate those things they would just increase differential augmented GPS or the robustness considerably.

D. Taggart:
Let me address the first part. Then what I would like to do is make the transition from the panel discussion into the user requirements, and therefore I feel like I'm not standing up here as part of this morning's panel discussion on where DOT government policy is going, but rather to contributing to this group from a technical approach to what the user requirements may reflect. That will come out hopefully as I go through this here.

Addressing your question as you pointed out making reference to the comments yesterday on the issue as you put it forward, integrity of the DGPS [U.S. Coast Guard's Differential GPS] beacon-based system as you move further and further from the signal, there may be a question of integrity. It comes down to an issue as I like to view it from a semantics point of view. I guess if you back off and look at a service as it is being provided, leaving the stick, leaving the source of the signal the issue of integrity is being defined pretty much in the FRP etc., is putting in the form of its ability to react to an abnormality [and] inform the user that there is an error in the system and therefore it shouldn't be used. I'm going to try to answer your question but I wouldn't want to phrase it in the form of integrity. I think the integrity feature is independent of the distance you are away from the site. The Coast Guard integrity as a service provider is maintained independent of the distance.

Now dropping back and trying to address your question from the accuracy component, which is a piece of the overall development of that service, and I would try to characterize it in the following way and essentially putting it out on the table. The Coast Guard system as it is being fielded today has a basis for actually taking shape as indicated on the presentation yesterday back from some R&D work that was done in the early 80's, and the representative from John Chance, I don't see him in the audience right now, but he did indicate that the concept of the DGPS beacon based system essentially took place in the Coast Guard. That

was well before any of the private providers had come on to the scene and that grew out of some work that we were doing on differential Loran-C, etc., etc., so we do have a long history of being involved in developing this service. And it was primarily the technology was investigated from an R&D program primarily to meet Coast Guard mission areas, in the area of buoy positioning, VTS services, etc. At the same time we recognize in the harbor/harbor approach requirement a form of navigation that had never been met through any government provided service existed out there. It took place back in the early 70's, essentially the 8 to 20 meter figure that we're seeing reflected in the FRP, and at one time we were looking very closely trying to have those requirements met through Loran and differential Loran, etc. There were a number of reports done in the early 80's which tried to quantify the ability in all areas and 21 some critical ports were defined.

(...)

The Coast Guard is in the process of buying a new buoy tender. Because of DGPS technology we're able to outfit those with less people, more efficient operation, etc., etc. So there is much efficiency within our own operating program to move forward with DGPS. But those efficiencies are being gained through accuracy being provided by our system. And the accuracy that we are working, some have stated from the private provider point of view, why are you, the Coast Guard providing accuracy components which exceed essentially your mandate of 8 to 20 meters from your differential system. The point to be made here is if you back off now and look at the system requirements at the user end you don't have any control as a service provider of all of the error budget that you have to deal with at the end user point of view. The slides that were presented by John Chance yesterday indicated that of the various classifications based on the cost of the receiver, you have different performance reflected in those. That is one of the potential unknown error contributions that the system has to deal with. The accuracy component, as you have spatial decorrelation, is another unknown. How far away are you going to be taking advantage of this radio beacon signal which is essentially just the communications of that information? There's also the probability of missed detection. You have to deal with the issue of noise bursts, etc.

So the point to be made as you have asked the question, as you get further from the source of the signal what is the accuracy of your system and how does that play in to the entire use of that system this service at the system level, how does that play into the ability to meet the 8 to 20 meter requirement for the harbor/harbor approach? That becomes the basis for providing a much higher degree of accuracy at the source of the signal and as you work through the entire error budget you have to deal with, you can have some degree of confidence, and now that word confidence is as it applies to the system, could be interpreted to mean integrity and that's something I think we need to deal with as integrity at the system level versus the integrity as it's being defined at the source of the signal. The overall point to be made here during the validation period we talked about this morning during the Coast Guard going from the pre-op condition that we're in right now in DGPS into the IOC [Initial Operational Capability] way of doing business on the Coast Guard DGPS system. We're

going to be looking at the ability of our system to meet the 8 to 20 meter requirement with a high focus on the issue of integrity from a system point of view and also our ability to meet the accuracy components for navigation in an 8 to 20 meter environment.

I don't think anybody in this room would at all disagree that a positioning user has a much different requirement as it relates to confidence or integrity in his position than a navigation user. The positioning user can sit there for a long period of time and thereby gain confidence and integrity in that solution. A navigation user who has velocity and is trying to navigate on the fly has a different requirement as it relates to integrity. I've gone into a number of areas but I think it was important to point out as we transition away from the panel discussion into the user requirements.

Chip Dorman:
Would you follow up on the second part of the question? I guess to finish up on that one, the only question is did you in your analysis to find or come with a critical range you came up with 48 or 49 sites and I assume you did that with forethought in mind and positioned them appropriately; there had to be a range identified. (...) Andy Bass and Andy Bogle talked about a ball park range they had discovered.

D. Taggart:
(...) Recognizing that the Coast Guard came up [with] the footprint of coverage that is trying to move forward and have in place by the first of January is based on a radio beacon transmission, essentially in an internationally protected maritime band. That is why it became attractive [as] a means of communicating that information. And now looking again at the spectrum as we manage it, we the Coast Guard have the frequency management for that particular band, the maritime band. And the way that those transmitter frequencies are assigned is based on so many micro-volts per meter in accordance with FCC requirements and the spectrum requirements for using that. So that in itself begins to define the footprint for each of those beacons. The issue of where the spatial decorrelation of the individual reference stations: each one of those 48 sites tends to decorrelate to the point where it does not any longer provide the necessary accuracy to meet the 8 to 20 meter end of the footprint. Radio communication is a different question. And I think that (...) pointed out back in the mid 80's and the point that he brought forward when he pointed this out was it was during the peak of the solar activity. The work that was taking place on evaluation of the DGPS radio beacon system was that data done at Groton, CT, applied to a solution in Miami, essentially showed that you still could meet the 8 to 20 meter requirement from an accuracy component. That's evidence of trying to show the issue of accuracy as it would tend to degrade from a point. Now that's an example that you know some could dispute. Well what were the results they were using? Was it a sub-meter system, etc. But the point to be made is that the footprint for each one of those sites does not become the limiting factor in its ability, but rather the communication link is what limits the size of those footprints. The other question you had is could the Coast Guard system contribute from a ground-based system to the reference stations, etc., merge into the FAA's system? From a technical point

of view I would be a fool to say that it couldn't. Now how that would integrate into what the plans for the FAA system that's another issue and I pass that on to Paul.

P. Drouilhet:
That issue of using the Coast Guard broadcasting differential corrections for aviation was looked at as part of the ITS [Institute of Telecommunications Sciences, Boulder, CO] study. And the conclusion was that it would be a fairly limited range service and not a high availability unless you went into an extremely dense network. Low frequencies are not a good band for communicating to an aircraft, especially over land. The range of the stations are less over land than over water and aircraft have a P-static environment [due to] electrical static. Low frequencies are a difficult part of the spectrum to be receiving. We've moved everything. Communications used to be in that band for aircraft. We've moved out of that to VHF. So it would be a service that would have some availability but to make it a high availability service would require an extremely dense network of transmitting sites and it's a question of whether it would be worth while to equip an aircraft to certify the aircraft's ability to use these corrections for the relatively limited increment of performance you would get for the proposed network.

Andy Bogle:
I've been fairly quiet of these last two days much to the surprise of many of my colleagues regarding the government interference with DGPS services and what has been a very strong private sector business for the last 8-9 years. I'd like to remind those representatives from the Coast Guard and the DOT, I think they have already left unfortunately, we don't have anybody here from the U.S. Corps of Engineers, that as long as they continue to challenge a private sector they're going to have continued difficulty in doing what they need to do for this nation's safety of marine and aviation. The reason is there is a conflict. There is an encroachment by the government.

There is spending by the government which in our mind is unnecessary. This is not a time of federal spending, this is a time of federal constraint. We're turning off systems like Loran-C which in my mind is very unnecessary and spending money in other areas. Well let's take some of that money and go spend it on Loran-C and you've probably got what you want at the end of the day. Let's stop being so enamored by the sexy GPS systems and go over there and look at a few practicalities. And one of the practicalities that we have to look at is that we don't have an unlimited budget to go out and do what we want to do. It's very nice to put it down on paper but we just don't have that budget. The guys at the U.S. Coast Guard are being pushed by some other agencies, the Army Corps of Engineers being one of them, to replicate what the private sector has already done. And they may not be listening right now but we're going to go to the Hill and we're going to pass this message on to the Coast Guard, that's there no point coming up with a federal "not invented here" syndrome that "Hey guys, we don't need to listen to this".

There is a private sector out there which is not going to shut up until there is some compromise reached. In answer to your question about spatial decorrelation and the accuracy as you move away from the baselines from the reference stations, I again want to remind the Coast Guard that we have been doing this since 1986. We've been working on baselines that have measured thousands of kilometers, and if you want any data we would be quite happy to give it to you free of charge. Thank you.

Dave Scull:
Before you go Andy, I just want to clear up maybe a misconception on my point. I thought yesterday in the statement you made that you were perfectly happy with the Coast Guard differential system, in the fact that it wasn't competitive with your services. Then today I sort of got the opinion that you feel the Army Engineers proposed system, I don't know if there is one or not, but I think you alluded to one, would be something that you felt would be unfair competition. Would you just clear that up what you feel about the Coast Guard?

Andy Bogle:
First off let me say that we believe that the federal government has the responsibility to provide radio navigation services for the safety of life and property. We don't argue with the fact that the Coast Guard needs to put up or should put up a beacon network whatever the rights and wrongs of that may be. That is one instance and one situation I think which in our point of view is really unarguable. What we object to is the expansion. We get people like the federal railroads coming on saying boys if you spend another several millions of dollars and put this system here, here, and here, we can get this out of it. You know my answer would be, go look at two things right now. Go look at Loran-C which will more than meet your requirements in the area that you are talking about. Differential Loran-C will probably more than meet your requirements without any additional expenditures. Why go put another Coast Guard beacon in Walla-Walla, when you've got everything you need right now. Go look at what's out there both commercially and there's not just ourselves. There's Omni-Star, there's FM stations, there's Loran out there. You know. Go do it. Why should the taxpayers of this country go out and subsidize an industry which by your own admission you know is falling apart. Let's go and see what we've already got before we start going and spending additional dollars and additional taxpayers funds on reinventing the wheel. This is an American business here you know. Does that answer your question.

Dave Scull:
That was very good. That was well done. Yes. Dr. Johannessen.

Question:
My name is Rolf Johannessen, my company is Lambourne Navigation Limited, and I speak to you only on my own behalf. I want first to say that when it comes to vulnerability there are two technical vulnerabilities in GPS you need to remember. The first is for vulnerability to RF interference, and that vulnerability is very great. At the GPS conference in Salt Lake City, we reported on some tests we had done on board a Trinity House vessel some years ago

when we had a 1 watt transmitter at L-Band located at the lighthouse and we steered a vessel towards that emitter and found that three different GPS receivers failed at the range of about 30 nm. So you can imagine what that might do to GPS reception in any of your harbor approaches. The second kind [of] vulnerability has to do with software vulnerability that has problems in the GPS receiver itself which comes about because its complicated software is inadequately debugged. We have some tests going on with the Civil Aviation Authority in London, where we are exploring the probability of software in TSO-approved receivers failing simultaneously, and the results coming out of that are not very attractive. So I would say to have some system other than GPS is very valuable whether you fly or you sail.

Anyhow, the point I wanted to make was really to respond to this opportunity to make some suggestions for the next radionavigation plan, and I would like to make four distinct proposals. They all have the value but they do not cost very much. And if one your problems is budget constraints then I hope you will consider seriously my four suggestions.

The first has to do with velocity errors in GPS. It's my understanding at the moment the spec for GPS SPS does not have any constraints on velocity errors. And as we heard it yesterday, the ship is tied up on the dock side and the GPS shows that you are moving at three knots. That's not very good for your confidence. If you are sitting in an airplane and you are holding for clearance to take off; brakes are on, and the readout says that you are moving at three knots. That's not very good for confidence. And I do not know how far that velocity error can go before the control segment will say that's too much because I don't think there is a spec on the SPS GPS. And I would suggest that in the next radionavigation plan we ought to say there is a user requirement which poses a limitation on what we are happy with. And I would suggest a wording like this, and I have given the words to David: "The proposal is, that the velocity error in GPS SPS should be limited to one knot in every 3-D direction for 95% of random combinations of world-wide locations in time in any 24 hour period." That this, velocity should be derived in a code-based non-differential receiver with each velocity sample being the result of a one second averaging. The purpose of those words is just to be specific in terms of what the number means, and you may want to have a debate on whether the maximum should be one knot or three knots. The point is I think we need to know what the spec is.

My second suggestion is that I think we are getting a bit wooly in the SPS specification in terms of this 100 meter 2-D 95%. Now the reason for my concern is that when the 100 meters was first postulated it was fairly clear that a GPS receiver would be using four satellites and would select those four that had the best VDOP. And now of course, most GPS receivers are all in view, or if they're not all in view then there certainly is more than four satellites. We have several TSO-approved receivers installed back in England and we're logging them every 15 seconds to see what their output provides. There are two different designs. We have two Garmin receivers and two Trimble receivers, all TSO-approved and are looking at the statistics of the 2-D position. They are clearly very different. So what do you mean when the SPS specification says 100 meters? What kind of receiver? I don't think

it matters particularly what we mean as long as we know what we mean. Because the user who has the choice as to whether to buy a low cost receiver or a more expensive receiver if he gets more performance with a more expensive receiver he needs to know what the tradeoff is. Therefore, my second suggestion is that there would be no need to say in the radionavigation plan what I think we tried to say some years, and the proposal is: "That this velocity error along with the 100 meter 95% position error be based on a algorithm which uses only those four satellites which forms the lowest VDOP." So it's a question of knowing what we mean by the 100 meters.

My third proposal concerns a development which I was first made aware of in Palm Springs. I think it was Rick Kuhn who made the suggestion. May I ask is he here now? I don't see any hands so I presume not. I think the time when he made his presentation in Palm Springs, was in the Civil GPS Service Interface committee. And the message which I got from him was that there was a move now to move away from defining performance against a particular constellation. You remember that Gaylord Green many years ago defined the primary and the optimum constellations and the almanacs were published. And so we understood what we were talking about when performance was discussed. Well the point that was being made in Palm Springs, was that one wanted to move away from talking about 24 or 21 satellites and instead only talk about performance. This particular person, as far as I could hear him, said that his requirement was now turning towards providing X meters of error, 95% of time, 90 something else percent of space. And I quote, " If I can achieve that with a single satellite than I will achieve it with a single satellite", he said. Of course we all know that you can't achieve it with a single satellite, but the point was that he seemed to be driven towards a statistical average without any boundaries on the exception for that. Now suppose I operate survey operations in the North Sea. I don't, but suppose I did. It would not be much comfort to me if Brazil and the U.S. and China for all the time have very good performance, if I rarely have. If I operate a helicopter flying to a hospital in Alaska, I likewise don't care what the performance is anywhere else. I do need to know what is the performance going to be where I am operating. And so it seems to me there has to be some bounds on this averaging. And to move into a situation where we say the aim is only to provide a statistical value, never mind how I do it, becomes dangerous because I can not as an operator translate this average thing into what it means to my locality. And therefore my third suggestion is, "that in the next radionavigation plan a nominal GPS constellation almanac should be published defining the constellation for which the operators aim in providing the position and velocity performance." If that is there you can see that we can then take the percentages which they are trying to achieve and we can translate that into what I can expect in my area without having to rely on what it will be anywhere else. And again, I submit that it doesn't cost anything to provide that sort of data.

My final suggestion has to do with NANUs. And I had a very helpful discussion at breakfast time with Roger Hunter about this and I would like you to know about it. Now I study the NANUs very carefully because one of my challenges is to try to think through what do we do when a satellite fails, what do we do in terms of advising the air traffic controller? There

is a requirement in the ICAO's annex something or other, that we advise the air traffic controllers about the state of navaids within his flight information region. Those of you who are not in aviation may like to know that as you make an approach to an airport it is frequently defined relative to a particular navaid. There is a procedure for how you make a standard arrival route using a DME or a VOR. And if the light comes on in front of the air traffic controller that says that this VOR or DME is not longer working then he simply switches to an alternative procedure. He knows what to do about it. Some of the air traffic controllers now say, "when something goes wrong with GPS, what do I do about it?" And in thinking through that kind of question (...) quite helpful because there is factual sources of information about what's going on in GPS. The trouble is, that the NANUs as they stand at the moment have very limited information. I say for instance, PRN-26 was unusable from the 1st of July 12:00 to the 1st of July at 1:00. It doesn't tell me why. Now the problem is that you can be unusable in a number of ways. If the satellite switches to a non-standard code than probably my receiver will simply lose lock just as it will if I bank an aircraft or just as will happen if the satellite sets below the horizon. It's an operation which happens to the receiver all the time. So it's quite safe. But if unusable means that the health bit warns that this satellite is dicey, then there are various options for how the receiver will deal with this. And when we see GPS receivers misbehave, as they frequently do, we need to try to understand why they misbehave and what is the consequence of this kind of misbehavior. So my request is that we should extend the NANUs system to provide a bit more information. Proposal number four therefore is, "For the next radionavigation plan that NANUs be extended to include information about how and why a satellite was unusable so as to assist users in explaining malfunctions in their receivers." Let me give you some examples of the malfunctions we've seen. British Airways have a 747 with a GPS receiver on board. It is linked to a satellite communications link so we can see how this GPS receiver operates in flight. Quite often it tells us that the aircraft is flying at 180° south latitude. Now if any of you have been there please raise your hand. Quite often it tells us that that receiver is flying 132,000 feet below sea level. I haven't been there either, and we are trying to understand why this happens to the receiver. TSO receivers which we have installed (...) frequently put up a message which says power down and reinitialize. Why does this happen? Well the first thing we do is turn to the NANUs to see what happened to the space segment when this happened and NANUs can be a very valuable source of information. Thanks David.

Dr. Kane:
Well those are all very good suggestions and I would like to have a copy of them. I will give them to the Joint Program Office and to Col. Hunter, because some of the things you suggested are in their purview to correct. But I would like to make a comment on the speed at which the receiver technology is progressing. This month or maybe next month Rockwell will start manufacturing the key chip at $20 per chip set, and they'll produce them in millions, and that's a 12 channel receiver. You can always see four or six satellites. So you are concerned about dealing with four satellites; I think the current generation receivers is going to be outmoded when this very cheap, readily-

available receiver is on the market for everyone to use. So I think some of your concerns will be overcome by the rapid change in the receiver technology and the greatly reduced cost. I think it might give you some comfort.

Dr. Johannessen:
I suppose you're referring to the way we might define the position with reference to the particular receiver architecture. I'm not really clear as to whether we say it relates to a four satellite setup or a normal view setup as long as we know what the performance means. The benefit of relating it to the best VDOP, that is well defined. There is only one set of satellites which represent the best VDOP [whereas should] you have a 12 channel receivers there is a large number of ways in which you can use all the satellites in view. It will give you a different performance.

Dr. Kane:
The point we are trying to make along the line we're talking about is the Joint Program Office is very concerned about this question of the reliability of the receivers. So they have a task force and some people from industry are on it which is trying to establish standards like the Universal Laboratories have for electronic equipment. So you don't have to go there to have your receiver qualified, but if you want to be on the market with a qualified receiver that avoids some of these problems you're talking about you put it through the test program which they will probably run at Hollman AFB. So some of the concerns that you have about receiver performance would be certified in a laboratory in advance of being marketed. That may overcome some of your concerns. And the others I'll leave to the experts.

Dave Scull:
Just one comment. Rolf, have you gotten a copy of the GPS signal spec that was issued? OK. It probably won't have your velocity information in there I'm sure.

Doug you said he wanted to make a short comment on going to go back to Andy Bogle's statement.

D. Taggart:
My comment is more aimed toward the user requirement, (...) the open forum aspect. But just to address Andy's point there in trying to create a flavor of where we may want to go with this user requirement discussion here. I would simply say that from the Coast Guard trying to encroach into those areas that may be met by the private provider that's not in any fashion our intent on the radio beacon system. And I recognize that in your comments yesterday you said that the use of the beacon system in the maritime application, you agreed with, as Dave pointed out.

No one foresaw in that a market analysis 2 years ago that the agricultural community was by anyway a potential user of GPS technologies, and just to show that by no means did the Coast Guard in expanding the DGPS system. I think most of the people in this room

recognize that it takes three years essentially to build a budget request. So right now we're working on the '98 request and here it is '95. We had budgeted for '96, meaning that we built that budget in '93 so you can see that there was no intent to go into an area where we saw an agricultural market developing. I guess if we had that vision I might have a different line of work, but the point is that we were pursuing that for maritime applications and navigation environment.

The cooperations that were being expressed between various facets of government recognizing that the General Accounting Office has seen much activity or did see much activity a couple of years ago on the expansion of DGPS technologies recognizing that the Coast Guard was a government provider, was on the forefront and directed the railroads and essentially directed the Army Corps of Engineers, etc. [to use the system]. So that's kind of the history on that.

But just for purposes of discussion from a user requirement I made a point earlier today that at the close of business yesterday I was kind of surprised that we didn't have any discussion of the correlation between user fees and any issue of safety. (...) That was the comment that was made yesterday. I will have to say I did talk to the gentleman that made that statement and he made it for different reasons than I am turning this into a discussion point of view. We didn't get any response from the audience. And the way it was put forward and the way I understood it, there was no correlation between safety and user fees. I find that interesting.

Dave Scull:
Maybe there would be somebody that would like to address that issue. Nobody? OK Larry. Do you want to come up and (...)

Larry Barnett on behalf of Aviation Management:
I feel most qualified to speak on this issue on behalf of aviation rather than other segments of the user community. I think Phil Boyer made the point very well yesterday in terms of the general aviation community that there is a direct, an absolutely direct correlation between user fees and safety, and the imposition of user fees will lead to a possible derogation of safety because pilots who don't want to pay for the services will find ways to avoid paying for the services or just are not asking for the services. So there's a direct correlation. That's for the general aviation community. The business aviation community feels exactly the same way and there's a large segment of the air carrier industry, primarily the -- I shouldn't say the smaller carrier, -- primarily carriers such as Southwest Airlines, Value Jet, America West. Alaska Airways to give you an idea of some of the air carriers interested in this issue who also are adamantly opposed to Senate legislation that was approved last week that would impose new fees on aviation users. So Doug, I hope that for one segment of the community at least addresses the issue from your point of view.

Dave Scull:
Thank you Larry. Another requirement. Capt. Brogdon would you like to come up and address us please.

Capt. William Brodgon, Jr.:
I have a couple of things to say on requirements, but let me say one quick thing on user fees. In the marine world we've had several examples in recent years, VHF FM radio licenses probably being the primary one, with user fees of $115. This is the way the people call the Coast Guard. A very large number of people are not only aware of the fact that the user fee costs as much as the radio, but the fact that there's an $8,000 fine for transmitting with an expired radio license or no radio license (and these have been imposed), have just said the Hell with it. We'll leave the radio at home and hope for the best. The licensing fees have gone up; it costs me a couple of hundred bucks to renew my license. I suppose it's no big deal. But you know it's a few dinners. And a relatively large number of people are simply not renewing their licenses. Are we missing this group of people? Relatively experienced people. The whole burden of the licensing cost was placed on the licensees. It seems that the public derive some benefits from these licenses, and should bear some of the costs. If not, let's just cancel them and let anybody that wants to sail any kind of a boat he wants to if the benefit is only to the licensee. And these are what we've seen in the marine field. Every time we put on a licensing fee of some type, people avoid it, people quit carrying their equipment, people reduce their safety rather than paying these fees.

Dave Scull:
Thank you Bill. More requirements please? Anybody?

Anthony Vandrey:
The Civil Air Attache at the British Embassy
The main reason that I made that comment yesterday was a specific reference to U.K. airspace, and as the representative in the U.S. for the United Kingdom Civil Aviation Authority, although I am appointed through the diplomatic service; it is incumbent on me to respond to criticism. What I will say is that in the U.K. we have a single organization, the National Air Traffic Services who provide air traffic management over the U.K. airspace, and also part of the North Atlantic. It is divided into regulated air space and unregulated air space. The regulated air space is manned by civilian controllers, and the unregulated air space is manned by military controllers. It's a joint operation. They work from the same air traffic control center. They use the same facilities, the same multi-radar coverage, the same radio sets. They use identical -- or the equipment is certified in exactly the same way. My point yesterday was that it is incorrect to assume that if you do not pay your user fees in the U.K. and you go VFR that you are operating in an unsafe environment. That is not the truth. That's a specific reference.

I would like to make a general point. I think it's important. You can have an unsafe system with no user fees. You can have safe system with user fees. The combination is right. You

can either [have] user fees or not user fees. You can have a safe system or you can have an unsafe system in both of those. Safety is about how technology and people operate together. It's about procedures and human man-to-machine interfaces and the technology that supports it. What happens is that you've got to fund it. You either fund it through taxes, and therefore the general taxpayer carries the burden for it, or it's funded through direct user charge. I do not believe there is a correlation between the two. I think that it's common sense that there isn't. What you have to do is make sure that the system is designed correctly from the top down and demonstrated to be safe. You can operate safe in a user charge system and you can operate safely in a non-user charge system. There is no correlation between the two. Thank you.

Dave Scull:
Thank you. How are we doing? Are we sort of done with the requirements at this point? We have another part this afternoon, and that's putting together our recommendations.

Capt. Brodgon:
Let me just talk for a moment on user requirements. I stay in pretty close contact with the marine community of whom there are at least a better part of a million Loran receiver users owning and having invested in equipment that is worth several times the Coast Guard's investment in equipment partly on the basis of the promise that this was going to be a 10 to 15 year overlap. The requirement for marine navigation, contrary to popular belief, is much more detailed than for air navigation. Airplanes go to 5,000 locations. They go to several thousand in-between locations. Boats and ships go to an infinite variety of locations with tight requirements along the way. They don't have separation. Don't have altitude. We've got lousy charts. It is impossible to fish today or to dive on sites off shore without electronic navigation. The marine users have shown themselves quite willing to double their costs, which in on the order of a half a billion dollars in user equipment to get greater safety, greater continuity of service, because they experience breaks in continuity with every radio navigation system yet devised, and they lose the day's charter, they lose the day's fishing, they get into an unsafe situation. They themselves are quite willing to double their costs to improve their safety. That is a measure of what their requirements are.

For untold generations maritime navigators have required multiple inputs, multiple cross checks. Those that haven't, have made the headlines. Many of those recently have done so by sole reliance on a single system. And [based on] the charts that we've looked at [here], the air people have some time, but [for] the maritime people everything stops at the year 2000. Five years from now. One more thing. They require some time with receivers for the new system like DGPS which are not out there yet. There is not a single maritime receiver available in this country that meets the requirements of the signal specs with respect to acceleration and antenna leveling on a boat. Not one. And the maritime community is a bit unhappy at being pushed into a system that is unproven, they have had no overlaps, and there will be no backup for, and they are pretty vocal about it. So this is how they are expressing their requirements.

Dave Scull:
Thank you very much. Ed McGann [has a requirement;] would you come forward please.

Ed McGann:
I'm not really sure about the order of this and I'm not exactly sure if I put this in placement for user requirement, but if I can follow up on what Bill just said, and what was said a little bit earlier in the day by Doug that a lot of the requirements are driven maybe by budget, but a lot of it is driven by aviation. There's a lot of things that we haven't mentioned today. Things like liability. The biggest factor that we have. And then there's costs.

Do you know that it costs more money to clean up after the single incident of the Exxon Valdez than it would cost to clean up every aviation accident since Wilbur Wright crossed his legs? Do you know that if we actually had an accident of a Royal Majesty, 1,500 people on board, and if the fact that they were at 26 knots and they hit rock, you would have lost more lives and had more ecological damage from that incident alone than all of the aviation accidents in the last ten years? So frankly, I basically say to the Coast Guard you have my sympathy. You have cut your costs. You have done all the things that your supposed to do and Congress came back and took $60 million out of your funds, or at least took the authority to take $60 million out of your funds. I don't think aviation ought to be driving these requirements. I think there is a hell of a lot more requirements out there that are far safer including the railroad. And that's why we are so critical, and I am critical, I don't believe your system can work. So I'll go back on to the next one after I jump over liability.

There is some criticism on the evaluation of Loran and how it came. I think there was enough talk about it. We know how to handle the technology. Can we hand handle the P-static rejection? Of course we can. I think Bob Lilley has been flying for 20 years, he's never had a P-static incident because his aircraft [is properly] equipped. He's not properly equipped [just] to fly with Loran. He's properly equipped for all if the electronics on his aircraft. What can Loran do? Loran can navigate, it can position. It can be modulated. We can put out integrity today for nothing, GPS integrity signals. In a half a second. We can collocate all the GPS monitors at the [Loran] sites. We can provide incremental corrections. Down to a meter? Hell no, who wants to conflict with Andy? It's like getting a tiger by the tail. How about if I get you down to 20 meters. Nobody know where the 8 to 20 meters in the Coast Guards harbor/harbor entrance came from anyway. There's no backup data on that. There's no analysis. It came out of somebody's head. I'm sure we can get you down to 25 meters very easily.

What kind of redundancy do we have? If you can pick up 20 stations across the U.S. and have integrity messages on it for GPS you've got a back up nav system, you've got a back up positioning system, and you've got integrity on 20 messages.

Now let's look at costs. Let's look at the year 2020. How much is it going to cost us to bring GPS with its augmentations, and with its limitations, because no matter how many

augmentations you put on it you are never going to get beyond the primary consideration which is, if you're lucky, you get 21 satellites 98% of the time. The Captain says, well that ain't right. Well that's the way the JPO thinks of it. Now we are happy. We've got 24 satellites; everything looks wonderful. Are we always going to have it? Probably not. What we need a completely compatible comparable soft fail capability to back up and to augment and whatever.

(...) Do you know that every analysis that we have ever seen shows that if you use Loran and GPS together adequately, it increases the availability by a factor of 1,000 for whatever your application is?

Money. I'm a peddler. Right? [If you gave] me the job of upgrading Loran in the U.S., and you gave me a blank check, I couldn't spend more than a $100 million dollars and that's hand rubbing some of the antennas. I could get you to a status that by the time you got [to] $100 million dollars, this system would work to 2050. I mean the Canadians are telling me for God's sake that they don't think it will ever die; they're out kicking it. "Stop will you?" We got a total budget of repair parts from Canada last year [for] $15,000, I think they estimated.

So we can build for $100 million dollars we can do everything, and I'm not talking about really improving the Loran situation I'm talking about putting in backup power supplies. I'm talking about painting the antennas or maybe taking down some of the four towers and putting up one. New timers, I'm putting in aviation blink. I'm going to put self-monitoring in there. I'm going to take all the people off the stations and run it the way the French did, the way the Canadians do.

I'll run the damn stations for $5 million, all of them. That's another $5 million for Alaska. Now how much is that going to cost me? $10 million a year. $10 million a year for 25 years is $250 million plus $100 million to upgrade. $350 million dollars. How much is it going to cost us to operate GPS and its augmentations? A billion dollars a year? Yeah. Everybody will tell you $500 million. That's a joke. If they could launch a satellite for $150 million like they tell you, that'd be the cheapest launch vehicle in the world. They would drive Ariane right out of business. But let's give them that. $500 million to operate it. All the augmentations. (...) So if we go another 25 years on a half a billion, that's twelve and half billion dollars on top of the $10 billion dollars it is said that we've spent to date. Of course that $10 billion dollars was on that same view graph in 1992, so I presume we have not spent anything from 1992 to 1995. But you are going to spend $12-13 billion to get to 2020. If you're going to spend $13 billion why don't you spend $350 million and then keep Omega going and [cost] another $50-60 million?

And we are now looking at these from a policy point of view. Go back again and look at the what the availability of GPS is. I don't care how many times you augment the system, if the basic system fails or is unavailable, or has less than availability criteria, and it is, at 20 and

21 satellites no matter what your requirement is, that's like building a house with one brick. Pull a brick out and out you go. I don't care how many things you've got on top of it. So my suggestion is we look at going back to this mix of systems, and try to figure it out.

I'm amazed. Aviation interests get up and say in front we're willing to give up some navaids. And for some reason or other some people say, no we don't want you to give them up. The aviation interests are the only ones who benefit from VOR, or DME, or ILS. I'm not trying to sell them out. We're just saying, you show us how we can do this. We're willing to have some of the money taken out of this and put over there but we don't seem to be listening do we? We tell the people from the railroads, "Hey we can do that." Well hell, that's a simple thing for Loran to do. I mean to get a fixed track grid. That's easy. That's the simplest problem we've ever had, and your velocity is going to be a lot simpler.

While I listen to DGPS stuff, no matter how you use it, we operate in Bedford, MA, 40 mi. away from the Portsmouth, beacon, over land using whatever we can find of todays equipment including the DGPS receiver we developed with the Coast Guard R&D Center which is within 1% of the what would be the optimum. We can not receive Portsmouth, all the time. Now and then it does disappear. Twenty-six percent of the time? No. Only half an hour a day, whatever. But if you come into one of the harbors we're looking for 99.999 of whatever. I'm not just selling Loran, I [am] saying what are you doing? Where are the policy issues? I say let's take a look at it. Let's take a look at the money. Remember what I told you. Thirteen billion minimum to keep GPS to 2020. Three hundred and fifty million to keep Loran for the same period of time. Not a bad insurance policy. If I could get that insurance on my life, especially at my age, I'd be happy to do that kind of stuff.

If George were still here, I would say to George, what do you want us to tell you? He keeps saying give me inputs. Well he got a hell of a lot of inputs today. And he's had inputs in the past. What does 30,000 signatures, and 3,000 letters, and 15 organizations all up saying let's keep Loran, and I'm using Loran, but we could probably use Omega too. If we drop 30,000 signatures on a Congressman's desk, we would motivate him, and we never did. The Loran community didn't do that. It responded to the requests of the DOT to tell us what's your feelings and got ignored, obviously. How did 30,000 come about? Did we rap on the door of everything across the country? We went to three trade shows in '84, three maritime and one aviation, Bill do you know any better, or Linn? I can't remember. Three or four trade shows with amateurs standing at a booth saying here want to sign this, and people took the time to write 3,000 letters. Three thousand letters to a Congressman is an avalanche. It's just incredible.

So when George says tell us about it, what are we going to tell him? That there are a million users that were very comfortable with what they're doing? Do I have to tell you that the marine maritime patrol boat went up on a rock in October? He'd gone for 15 years using Loran. He went out and was [told] that Loran was crap. He was given a new GPS set. (...) I don't know how he made a mistake, but he became overdependent on it. First time he used

it. Emergency going on what ever the heck that island [that] is out there; somebody was shooting up the island, and they had to get a law enforcement guy out, and they went out on a bad storm, and went, right on the rock, sank the boat. The most confident maritime person in Maine. He became over-reliant on the single system. How do you get the wrong waypoint? I don't know. When the people talked to him, he was amazed, absolutely went white, with the fact that GPS did not give him 15 meters accuracy, because that's what it said in his spec, and he wrote every single word of that document. He didn't know that he could have been off 300 meters this way, and 300 meters that way. Not that he was going to be, but could be. And he might have been. He ended up 900 meters off course for some reason or other. We need an education. We need some realism. We need to get back with this.

Another reason for using Loran, and I'm not pumping Loran in this place. I'm even talking for myself right now. Why did you do it? Because somebody talked about jobs up here. I agree, a billion dollars worth of GPS industry is 30,000 jobs. Let's keep it. Let's build it to 20 million. I'm for that. But for God's sake let's why can't we build it to 21 million and include some Omega or Loran jobs or whatever if they complement the system, and I think they do. Because I think the easiest way to get GPS accepted abroad, is for us to accept Loran and promote the both of them abroad. Say hey, we'll give you GPS you put up Loran. Now if we take away GPS you've got something to fall back on.

What about interference? If an organization carries both Loran and GPS what motivation is it, I'm talking motivation not capability, what motivation is it to jam Loran? Or jam GPS? Because you have the other system to go on. And don't think you're going to get around it with this L5. What is L5 going to do to me if I want to destroy L1? It cost me $100 to destroy L1, and it cost me another $100 to destroy L5. Come on now. That's Dulles, Manassas, and everybody, National, and whatever. Get real in here. Let's just think about what would happen. What are the advantages of melding systems? What are the advantages of redundancy?

What are the advantages of cost benefit studies? What are the advantages of having a regulatory procedure we go through? What do we do about liability? We haven't talked about liability. What's this Government's policy? By the way, we're talking about GPS as existing, is it going to exist? You know it doesn't work militarily. Now that's a very controversial statement. But it doesn't. There's no way in a hostile environment GPS will ever, ever, ever work. They'll be 50 jammers out there. Sixty-four different things, all for a couple of bucks, spoofers. Desert Storm was the last laboratory experiment for GPS. And there were 50% more Loran receivers working in there than there were GPS receivers. I'm not against GPS. I want to see we get it out there, but we have to get there in an acceptable way. How do we do it?

We're being told by our Government now that COMSAT is prohibited from participating in the newest (...) thing that comes out of INMARSAT. Why? Because then they have an unlevel playing field for our (...) people. Oh really? Now gee. That's another navigation

capability. That's what they were planning to do, comm and nav. Really called GNSS-2, and the policy in Europe, and the policy in the Far East, is to retain their basic terrestrial aids, and I know, Duke, you're going to refute me, that's OK. The policy in the Mid East and the Far East, and in Europe will be to retain terrestrial aids until GNSS-2 is finished. So the appeal I make to you people, remember by the way, when I said we can distribute integrity on Loran we can distribute integrity world-wide on Omega. No trouble at all. No trouble. We only have to see one Omega station, or one VLF station, and we can distribute integrity, and we can distribute messages. (...) There's enough message capability in either one of them.

We're going to build WAAS, I know. We like to spend a billion-seven. It's a big company involvement. But let's get down to it. Now when we come to these discussions meaning to do something, and one of the things is to revise the FRP, and I've got to start right up front, and I think somebody mentioned it. Us guys in business can't invest money based on statements, like "reasonable transition times". What am I going to do, go to my accountants and say, give me cash flow for a "reasonable transition time". Finished. So I ask you again. Consider these facts. The user requirements are all tied up with what we provide to the users. If we tell the users that Loran is gone, of course there will be no investment. If we tell them Omega is gone, we take away all the possibility, take away all the drive, take away all the investment. There were comments that we would have to rework all the Loran receivers if we go to this, this, and this. Don't you think we're going to have to rework all the GPS receivers when we go to WAAS? And when we go to LAAS? And you need to buy another one or need to modify it if you want to go to a Coast Guard receiver?
(...)

Dr. Kane:

[Discussing new multiple-satellite systems coming soon...]

The one program has a construction manufacturer of satellites 2,000 items long; it goes out for 10 years. With them you can communicate from any place on earth to any other place on earth. In fact, when Iridium starts working you will have a wrist watch which has communications capability and a GPS read out. So the technology which exists is being completely outmoded. In fact, if you're a long range planner you ask yourself, what comes after GPS? Because there are going to be data relay satellites up there which give good position at very low costs. So if you constrain this analysis as to what we have and don't look out to what's almost in hand you'll get the wrong answer. There are ways to solve all these problems from new technology which is about to appear on the scene. And we don't have to shoot down GPS in order to make that happen.

Bill Roland:

Megapulse, Inc.

Good afternoon I'm Bill Roland with Megapulse. I think I should apologize to the body assembled here. I haven't been here for the last couple of days, I was in South Africa, at

another radionavigation users conference, and it's amazing how the concerns and the behavior is very much the same. There's not a lot of difference. But what I would like to do right now is first of all bring us back to the question of user requirements. Quite frankly, I think that we should open the question of whether or not we have formulated user requirements in an adequate way. The formulation of our requirements to date has been in terms [of] radionavigation service, accuracy, availability, integrity, and coverage, and all of the other parameters. And I never met a user who had any interest in what's the coverage. Who even knew what integrity was, and who put his feelings in those terms. What we've done is we've turned a discussion of user requirements into a discussion of what can we provide with various radionavigation services. And what I would like to do is try to challenge you to think about the user requirements in terms of the way the user has requirements and the way he actually navigates.

Now I'm not arguing that he doesn't need position information, he certainly does. But go back to the beginning of what does a pilot do, or what does a ship's navigator do when he's going to make a voyage. What's the first thing he does? Well he breaks out the charts and he plans his trip. The aviator files a flight plan. The navigator does a route plan. Breaks out the right chart and draws lines on it, and looks at what are the safety hazards. The question has to come up, "What's the integrity of that?" How good a job did he do with route planning? How good was the data he used as a basis for route planning? And that's just as important as how accurate is his navigation. And we haven't even addressed it. We haven't even thought about it.

And then the next step in this thing is what about his route monitoring? One of the elements of his route monitoring is perhaps the use of radio navigation services. But he uses a compass, he uses a speed log or a (...) tube. He uses observations of, not many who do it now, use actual astronomical observations. Seems to me that the Coast Guard Academy doesn't teach those any more, do they? "They go Huh?" (...). They don't; I checked. They taught me, too. Those are all inputs to the route monitoring. We've taken all those things away and said, he's going to use radionavigation and what do we have to provide for services, and the requirements for that service are everything that he's going to need. And that's wrong.

I tried to invent a term. The term was navigation integrity. And that navigation integrity includes the integrity of the charting, the integrity of the route planning, and the integrity of the route monitoring, what he does along the way. Let's talk about The Royal Majesty because it's kind of an interesting one. You know obviously it's of direct interest to anyone who wants to see that GPS doesn't get a black eye, because GPS was the thing that failed. But it wasn't the service that failed. During the entire voyage the integrity of the use of GPS, the service, was 100%. There was never anything wrong with GPS. But include that receiver, which isn't even mentioned in our radionavigation plan, and the integrity was 0. The antenna wasn't connected. OK. There are a lot of reasons for that. But he, the navigator, sure in hell has a need for the integrity of the whole system. Not the service, the

system.

Now as far as route monitoring is concerned he needs integrity of route monitoring. That's really what he needs. And that means he should be doing more than just looking at a radio navigation service. He should have looking at radar. He should have looking at his fathometer. He should have been looking at his Loran. There's lots of things he should have been looking at. If he'd looked at any of them, his route monitoring would have been sufficient to tell him hey, something is wrong. It may not have solved his problem for him, because you've still got find out what's wrong. But he suddenly finds out he's only got 5 feet of water under keel because he looked at the fathometer finally, and he didn't look at it until after he was aground, so he didn't even have that.

The idea of navigation integrity is what we should be looking at and using [to] define user requirements rather than beginning with the service performance and saying GPS can do this, Loran can do this, Omega can do that. Start from the beginning on the user requirements and then we can get to what do we need for radio navigation service. What is the DOT going to supply? It's not just the performance of the individual systems. And that's my point. Thank you.

[David Scull also moderated the final session of the conference, a workshop, which provided the raw material from which the conference resolution was prepared. See the Resolution, presented earlier in this document.]

References

1) Professor David Last, University of Wales, Bangor, United Kingdom, Presented at the Annual Meeting of the International Association of Lighthouse Authorities, Cape Town, South Africa, November, 1995.

2) 104th Congress, 1st. Session, House of Representatives, Department of Transportation & Related Agencies Appropriations Bill 1996, Report 104-177, Revision A960229, for fiscal year ending September 30, 1996

3) Comments Submitted by the International Navigation Association, Inc. In Support of the 1994 United States Federal Radionavigation Plan, Ian S. Anderson, President, International Navigation Association, February 11, 1995.

4) 1994 Federal Radionavigation Plan, DOT-VNTSC-RSPA-95-1/DOD-46505, Department of Defense & Department of Transportation, May, 1995.

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Aircraft Owners and Pilots Association

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Conference Banquet
November 16, 1995

INTERNATIONAL LORAN ASSOCIATION
INTERNATIONAL NAVIGATION ASSOCIATION
GPS INTERNATIONAL ASSOCIATION

Menu

WONTON SOUP
a Chinese classic

FRESH GARDEN SALAD
with Westfield's own house dressing

BROILED FILET WITH ORIENTAL SHRIMP

seasonal and appropriate accompaniments

CHOCOLATE MIDNIGHT TORTE
with vanilla sauce

Program

WELCOME

INVOCATION

DINNER

INTERNATIONAL LORAN ASSOCIATION:
AWARDS

PRESIDENT'S AWARD

MEDAL OF MERIT

BANQUET ADDRESS, BY

RICHARD W. TAYLOR
CONSULTANT
THE BOEING COMPANY

RICHARD W. TAYLOR

RICHARD W. TAYLOR, AIRPLANE DESIGNER, TEST PILOT, AEROSPACE EXECUTIVE AND ACTIVE PILOT, RETIRED FROM THE BOEING COMPANY IN 1991 AFTER 45 YEARS OF SERVICE.

TAYLOR HOLDS A COMMERCIAL AIRPLANE PILOT LICENSE AND HAS FLOWN SUCH AIRCRAFT AS THE B47, KC-135 AND ALL OF THE BOEING "7-7" AIRPLANES. HE HOLDS NINE WORLD SPEED RECORDS IN HIS PIPER AEROSTAR, AND ALSO OWNS AND FLIES A PIPER CUB.

A NATIVE OF INDIANA, MR. TAYLOR WAS GRADUATED FROM PURDUE UNIVERSITY. HE IS A FELLOW OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, A DIRECTOR IN THE EXPERIMENTAL AIRCRAFT ASSOCIATION AND A FELLOW OF THE SOCIETY OF EXPERIMENTAL TEST PILOTS.

AMONG MANY OTHER HONORS, IN 1991 HE RECEIVED THE FAA'S DISTINGUISHED SERVICE AWARD FOR HIS CONTRIBUTIONS TO AVIATION SAFETY AND INTERNATIONAL AVIATION.

HE WAS THE GUIDING HAND IN ACHIEVING THE TWO-PERSON CREW FOR THE 737 AIRPLANE, LEADING TO APPROVAL OF TWO-PERSON CREWS IN 757, 767 AND 747-400 AIRPLANES. HE LED THE CERTIFICATION EFFORT FOR TWIN-ENGINE LONG-RANGE OPERATIONS (ETOPS). HIS 1986 RTCA PAPER PROVIDED THE POLICY FRAMEWORK FOR THE CURRENT FREE FLIGHT EFFORT.

HE WAS DIRECTOR OF ENGINEERING FOR THE 737 PROGRAM AND SERVED AS VICE-PRESIDENT OF THE BOEING MILITARY AIRPLANE SYSTEMS DIVISION, VICE-PRESIDENT IN CHARGE OF THE WASHINGTON, DC OFFICE; SPECIAL ASSISTANT TO BOEING'S PRESIDENT, VP OF PRODUCT DEVELOPMENT AND VP OF GOVERNMENT TECHNICAL LIAISON.

Awards

At its annual conference and Technical Symposium, the International Loran Association presents awards to members and others who contribute to the art and science of radionavigation, with emphasis on Loran-C and its partnership with other radionavigation aids.

At this multiple-sponsored conference, the Association presented only its Medal of Merit and President's Awards, with the remaining customary service awards to be given at the next Annual Conference and Technical Symposium.

On the following page are the citations for the
Medal of Merit and the President's Awards for 1995.

The International Loran Association

Presidents Award

Presented to

Larry P. Barnett

For his distinguished commitment and successful activities on behalf of the Loran-C user community toward the establishment of safe and effective U.S. radionavigation policies. In this time of radionavigation policy change Larry has used his many years of experience in governmental activities to:

- ***Identify the Congressional and departmental points of responsibility for radionavigation activities;***
- ***Organize and participate in presentations to identified people by navigation community representatives urging the application of a mix of Loran and GPS technologies to meet all user requirements;***
- ***Coordinate Congressional support activities of aviation and marine user groups;***
- ***Focus the specific wording of legislation to meet the needs of the Loran user community and then guide legislation through the political process.***

Larry represents the epitome of professionalism, giving strength, humor, and spirited support to associates in his work.

The members of ILA extend our grateful appreciation and best personal regards,

The International Loran Association

Medal of Merit

Robert W. Lilley, PhD

For his dedication and contributions to the technical development and diversified global applications of Loran-C technology as a premier radionavigation system

Robert W. Lilley has been a staunch supporter of Loran-C technology for more than twenty years. His visionary insight and technical prowess have been major factors in the expansion of Loran-C from its early maritime beginnings to broad usage in the terrestrial and aviation fields. Through painstaking research and detailed experimentation, he established basic techniques that paved the way for adoption of Loran-C as the general aviation radionavigation system of choice.

With Ohio University since 1974, and Director of the Avionics Engineering Center since 1990, Dr. Lilley was the personal advisor to numerous graduate students who went on to do pioneering work in Loran-C. He participated in every phase of the Loran-C program conducted by the Federal Aviation Administration and provided valuable support to working groups and forums striving for the acceptance of Loran-C in the National Airspace System. In recent years he has been a leader in developing strategies for the interoperable use of GPS and Loran-C.

Dr. Lilley has served the ILA faithfully as President, Director, Newsletter Editor and Convention Chairman. Today, the International Loran Association gratefully acknowledges his long service and many contributions.

Presented this 16th day of November, 1995

Dale Johnson, President

AVIATION DAILY

November 17, 1995
Page 272.

U.S. Should Keep Loran-C, AOPA Tells Radionavigation Conference

DOT's Federal Radionavigation Plan, which calls for Loran-C to be turned off in four years, is wrong and should be revised, Phil Boyer, president of the Aircraft Owners and Pilots Association, said yesterday. Boyer, speaking to the International Radionavigation Users Conference in Washington, D.C., said FAA and DOT "just are not listening"--users "clearly want multiple-system navigation with Loran-C ignoring both safety and the desires of the general aviation community."

AOPA wants the FAA and the U.S. Coast Guard to maintain Loran-C funding through the year 2010 as planned before GPS became available. Loran-C, a marine system under Coast Guard control, has been adapted for aviation, and some 130,000 Loran receivers are in aviation use. "We need Loran-C to augment satellite-based navigation," Boyer said. "GPS is the system of the future, but until GPS is established as a reliable, sole means of navigation, FAA must maintain redundant systems to ensure aviation safety."

The 1994 Federal Radio Navigation Plan now calls for the phaseout of all non-directional beacons (NDBs) by 2005 and the elimination of all instrument landing systems and VOR/VORTAC stations by 2010. It terminates Loran-C in 2000. "That just does not make fiscal sense," Boyer said. "We can maintain the Loran-C system for about $17 million a year. In contrast, the nation's 1,039 VOR/VORTACs and 1,335 NDBs cost hundreds of millions of dollars annually. Loran-C is clearly the most cost-effective national navigation signal available." He said FAA and DOT "must revise the Federal Radionavigation Plan and keep Loran operating through the year 2010."

Boyer noted that Loran-C is used widely outside aviation in industries ranging from electrical power generation to broadcasting. "In fact, aviation Loran units represent just 12% of the 1.3 million Loran receivers in use in the U.S. alone." Boyer said European and Asian governments are expanding Loran-C coverage. The Radionavigation Users Conference was jointly sponsored by the GPS International Association, International Loran Association and the International Navigation Association.

OHIO AVIATION NEWS

Newsletter of The Ohio DOT Office of Aviation

Promoting Aviation in Ohio *Winter 1996 Vol.8, No. 1*

International Radionavigation Users Convene

This year's International Radionavigation User's Conference was held on November 15-17 at the Westfield's Conference Center in Chantilly, Virginia. The conference was hosted by three organizations - the International Loran Association, the GPS International Association and the International Navigation Association. Conference attendees numbered about 80, including Tom Thomas who represented both the Wisconsin Bureau of Aeronautics and NASAO at the meeting. The overall program consisted of two major discussion topics: user applications and government policy.

Introductions for the conference were provided by Dr. Francis Kane, GPS International Association President, Ian Anderson, International Navigation Association President and Dale Johnson, International Loran Association President.

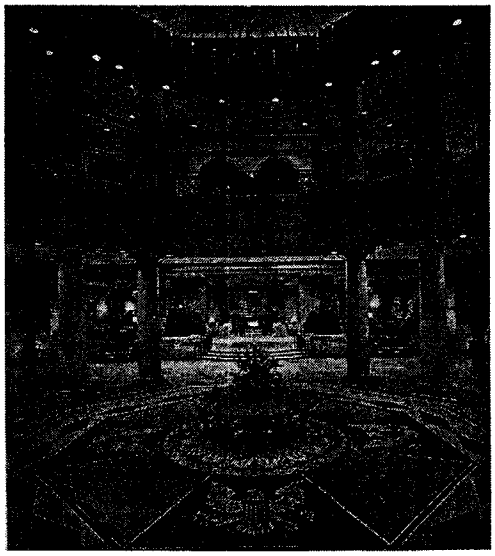
Phil Boyer, President of the Aircraft Owners and Pilots Association, provided the meeting's Keynote Address for general aviation. Boyer stated that some 125,000 AOPA members are still using LORAN. The association is excited about the expansion of GPS into the general aviation community, while at the same time is apprehensive that only seven years remain on the military's ten-year free use of the system. National Business Aircraft Association President John Olcott followed Boyer and gave some additional statistics -- about 52 percent of business/corporate aircraft have GPS, while 35 percent have Loran. Olcott stated that NBAA members strongly support a backup navigation system to go along with GPS.

Paul Drouilhet, from the Federal Aviation Administration's Product Team for GPS/Navigation, and George Wiggers, from the U.S. Department of Transportation, discussed the aviation industry's radionavigation issues from a federal perspective. Drouilhet stated that the initial Wide Area Augmentation System (WAAS) is expected to be available in 1998, it will be totally in place by 2001 and it "will meet all of the requirements for sole-source system." Where adequate signals are not available, Local Area Augmentation System (LAAS) will be used. LAAS will be installed to provide all CAT II and CAT III operations.

Other issues discussed during the conference included: precise timing requirements by Dr. William Klepczynski of the U.S. Naval Observatory; operation of the current GPS satellite system by the Commander of the 2nd Space Operations Squadron; and plans for discontinuing LORAN in the Year 2000 by the Coast Guard representative. There are DGPS units at 49 Coast Guard Radio Beacon sites across the country (coast lines). Thirty of these sites are on line today and 47 are expected to be operational by January 1996.

Radionavigation Users' Conference

WESTFIELDS
INTERNATIONAL CONFERENCE CENTER
Marriott



Photograph Album

Good hallway talk...

Good food...

And more food...

And even more!

Conference Chairman Duke Kane with Dale and Jean Johnson, ILA President.

The food's gone, but the talk goes on!

Mike Moroney and Paul Burket take a break...

As Linn Roth and Damon Gura discuss fine points...

And Joe Kunches is a good listener!

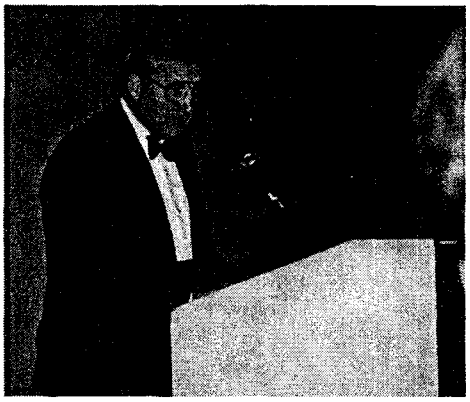
What evil?

Four Medal of Merit recipients were on hand; Bob Lilley, John Beukers, Mike Moroney and Ed McGann.

Bob Lilley receives the ILA Medal of Merit from President Dale Johnson. Got a good grip on it, too!

What are you hiding there Dale?

Ruth Scull is nearly caught in the cross-fire as Boston's Ed McGann talks with Canada's David Waters.



Banquet speaker Dick Taylor at work.

The hospitality suite in action.

INTERNATIONAL RADIONAVIGATION USERS' CONFERENCE
November 16-17, 1995
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