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24th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting

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Jet Propulsion Laboratory
Pasadena, California

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CONTENTS

OPENING ADDRESS

Captain Winfield Donat, III, USN
Supertendent, U.S. Naval Observatory

SESSION I

GPS Program Update

Chairman: Keith McDonald
SAT Tech Systems

SESSION IIA

Workshop on PTTI Applications

Moderator: Gernot M. R. Winkler
U.S. Naval Observatory

WORKSHOP A

Clock Performance and Its Measures: Stability and Accuracy

Moderator: Leonard Cutler
Hewlett-Packard Laboratories

WORKSHOP B

Clock User Interfaces

Moderator: Joseph D. White
U.S. Naval Research Laboratory

WORKSHOP C

Present and Future Needs: Is GPS the Only PTTI Source

Moderator: Raymond L. Filler
U.S. Army Research Laboratory

SESSION IIB

Pulsars and Relativity

Chairman: Henry F. Fliegel
The Aerospace Corporation

SESSION III

Program PTTI Requirements

Chairman: Philip E. Talley, Jr.
The Aerospace Corporation

SESSION IVA

Clock Devices

Chairman: Leonard S. Cutler
Hewlett-Packard

SESSION IVB

Time Transfer Modems

Chairman: Marc A. Weiss
National Institute of Standards and Technology

SESSION V

Evening Workshop
Measurement Techniques and Algorithms for Time Generation and Synchronization with High Reliability

Moderator: Samuel R. Stein
Timing Solutions Corporation

SESSION VIA

Telecommunications Synchronization

Chairman: R. Brown
Bellcore

SESSION VIB

Fiber Optic Frequency Distribution

Chairman: George F. Lutes
California Institute of Technology
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SESSION VII

Clock Modeling

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CORRECTIONS AND ADDENDA

IN MEMORIAM—CECIL C. COSTAIN

Robert J. Douglas and Derek Morris
Institute of National Measurement Standards
National Research Council
Ottawa, Ontario, Canada KIA OR6

It is with sadness that we record the untimely passing of Dr. Cecil C. Costain on Decmber 18, 1991 in Ottawa, Canada. Cec was well known to many people in the field of time and frequency and he often attended the PTTI meetings. For many years he was the official Canadian delegate to the Consultative Committee for the Definition of the Second (CCDS) and took an active part in the committee work. He served on the CCDS Steering Committee for TAI. He was also an active participant in the work of Study Group 7 of the Consultative Committee on International Radio (CCIR). This Study Group deals with time and frequency services, and related topics. He also served as a member of Commission 31 of the International Astronomy Union (IAU). In addition to his work in the field of time and frequency, Cec played an important role in the development of science in Canada. His stature, his keen intellect and sense of humour, his cheerful optimism, and his forthright opinions will be sorely missed.

Cec grew up in farming country in Saskatchewan, and attended the University of Saskatchewan as an undergraduate, receiving his B.Sc. in 1941. During the Second World War, he was commissioned in the Royal Canadian Navy, then served with distinction on secondment to the Royal Navy as an officer handling the newly developed radar systems on board ship in the Pacific. At the age of 21, Cec was on top of the aircraft carrier HMS Victorious in full charge of radar with 40 men under him! With his skillful experimental touch, his radar had greater range than anyone else's, and he received a commendation from the Admiral for having the best record in the fleet. He was awarded the Distinguished Service Cross in 1944, and retired with the rank of Lieutenant-Commander in 1945. After the war, Cec returned to the University of Saskatchewan for M.Sc. work, then traveled to Britain on a scholarship to study for his Ph.D. at Cambridge with Sir George Sutherland. After returning back across the Atlantic with Prof. Sutherland to finish his Ph.D. at the University of Michigan, he was recruited in 1951 into the new Spectroscopy Section in the Division of Physics at the National Research Council in Ottawa, where he put his wartime radar experience to good use in setting up an important laboratory in microwave spectroscopy. This rapidly became one of the major world centers for microwave spectroscopy, and many of the notable international figures in the field worked with him as postdoctoral or visiting workers.

As a microwave spectroscopist, Cec was noted for his careful work, and insight into the problems of accurate molecular structural determination. He largely resolved the ambiguities then encountered among bond lengths and angles determined from different isotopic variants of a molecule in a seminal paper in 1953 which showed that the systematic isotopic substitution of each atom led to a consistent set of structural parameters. The "Costain r_s–structure" quickly became the standard technique in the field.

In 1972, Cec left the Spectroscopy Section and became head of the Time and Frequency Section of the Physics Division of NRC. There he oversaw the development, by Al Mungall, of the NRC cesium clocks used as Canada's primary standards of time and frequency with accuracies of $5x10^{-14}$. He improved the dissemination of accurate time throughout Canada by radio, telephone, and satellite. He put into operation talking clock systems and computer time systems which give accurate time by telephone. He was also pivotal in early international comparisons of time scales using the Hermes, Symphonie, and Anik geostationary satellite for two–way time transfer amongst NRC (Ottawa, Canada), NIST (Boulder, Colorado), USNO (Washington,D.C., USA), LPTF (Paris, France), and PTB (Braunschweig, West Germany), achieving a precision as good as 0.2 nanosecond.

Cec worked for many years trying to persuade governments to extend the period of daylight–saving time. He was pleased when his suggestions wee finally accepted by North America. He was elected as a Fellow of the Institute of Electrical and Electronics Engineers in 1981, "For leadership in the development of primary frequency standards and two–way time transfer techniques via geostationary satellites". He continued in charge of Canada's time standards until his retirement from NRC in 1986.

He served as President of the Canadian Association of Physicists 1980–1981 and in 1985 he was honoured with the presentation of their Medal for Achievement in Physics. He was elected as a Fellow of the Royal Society of Canada in 1974. These honours were richly deserved, and Cec continued to play an active role in support of science until his untimely death.

Cec was loved and respected by all who knew him for his integrity and his contagious enthusiasm. We are proud to have had him as a colleague and as a friend. He will be greatly missed in the years ahead.

IN MEMORIAM—FRANCIS H. MULLEN

Ron C. Roloff
Frequency and Time Systems
34 Tozer Road
Beverly, Massachusetts 01915

It is with deep regret that we announce the death of Francis H. Mullen of Reading, Massachusetts at his home on February 10, 1993. He was 62 years old.

Frank was born in Worcester, Massachusetts and attended St. Peter's High School, Worcester Junior College and the Wentworth Institute. He joined the U.S. Air Force and was a veteran of the Korean Conflict.

Frank is remembered for his extraordinary dedication to Cesium Standards over a period of more than thirty years. He was involved in the engineering, operations, and sales of Cesium Standards. While his main strength was always sales, he also had a world wide reputation for technical knowledge, integrity, and dedication.

It was once said that Frank had a miniature Cesium Standard implanted in his brain because he was always contemplating a better cesium and a better use for Cesium Standards.

Frank started selling Cesium Standards in the early 1960's for the National Company. His first sales were the vacuum tube Cesium Standards of the time. He was Sales Director at National Radio from 1971 through 1980. He started with Frequency and Time Systems, Inc. in January of 1980. During his years at FTS, he was Manager of Government Sales, Product Manager for Cesium Standards, and Sales Manager for Cesium Instruments. He received a merit reward for "Outstanding Salesmanship" in 1982.

Frank was a member of the PTTI for many years. He served in various roles in the organization. His most recent position was that of Exhibit Chairman.

He was also a member of the Old Crows Association.

He is survived by his wife, Jean M. (Butler) Mullen, 2 daughters, his mother, Vera (Hildreth) Mullen, a brother and 3 sisters.

His work for the PTTI and the community will be sorely missed. We have lost a good friend and an active participant in the Frequency and Time field.

Opening Address

Captain Winfield Donat, III, USN
Superintendent, U.S. Naval Observatory

It is, indeed, my pleasure to welcome you to the 24^{th} Annual PTTI Planning and Applications Meeting, and, at the same time have the opportunity to make a few comments at the outset.

Today, the field of Precise Time and Time Interval seems to be a real enigma, because it seems to violate one of the fundamental paradigms of good timekeeping. The ideal condition in timekeeping is usually described in terms of a well–defined, repetitive phenomenon, one that never varies, both in the short term and in the long term. Stability is the key! But when one looks at the field of PTTI these days, one sees change, innovation, and exciting technological advances. Because we did things a certain way yesterday in no way means that we will be doing it the same way tomorrow.

The fundamentals of PTTI change as new technological advances are incorporated into systems; and, now, change is truly commonplace in our field. With the new technology, current and potential users are closely reviewing the possible applications to do their jobs more accurately, more securely, faster, and more cheaply. Yes, the "C–word"... change... extends these days far beyond the political arena, and our historically quiet and constant area of interest is anything but quiet and constant today.

In one area, near and dear to my heart, we can see this most clearly. The nation's Master Clock at the USNO is a dynamic, evolving entity. If anyone here visited the USNO a year or more ago, then please visit again because you will see change. As you know, the USNO Master Clock is a very unique timing system. It is the heart of all DoD timed systems and is the national time reference. It is the real–time, physical realization of a mathematical time scale based on a large number of diverse clocks. Currently, all of these clocks are located on the grounds of the USNO. But that will not be the case in the near future.

Historically, the USNO has used a network of Precise Time Reference Stations (PTRSs) to distribute and monitor time in different geographical areas, but they have not served in the Master Clock system *per se*. As we reported in our Annual Summary of PTTI Requirements and Operations this year, the establishment of our Ultra–High Precision Time Reference Stations (UHPTRSs), to serve as a part of the Master Clock, will change the single–site Master Clock concept. We expect that this new type of timing facility will include some of the latest developments in clock systems technology and environmental stability currently achievable. It is an exciting, new concept in the way time will be kept, computed, and distributed in the future. It is the first step toward a distributed timekeeping infrastructure, a node with significant timing capability, in support of what is anticipated to be increasing requirements of PTTI systems in the DoD and throughout our nation.

Over the past year, I have become more and more concerned over the need to increase the precision and interoperability of timed DoD systems. In order to derive the full measure and benefit of military systems within constrained resources, the need for standardization and automation is essential. While it may not be obvious to all end-system users, there are many systems in which timing is imbedded, even hidden, in the overall specifications, but is vital to the system achieving its specified performance.

In order for these systems to reach specifications, timing requirements must be addressed and clearly articulated in development. Such systems will—no doubt—take advantage of the rapid improvements being made. For example, through sophisticated mathematical techniques, a local timekeeping system in very remote areas can be maintained with impressive stability. Systems engineers are and will continue to incorporate into their projects other such advances in order to reduce and remove the traditional human interface with timed systems.

Historically, the fields of navigation and timing have been strongly linked. From the times when the Englishman John Harrison made his seagoing chronometer, to our modern satellite navigation systems, clocks have played a major role in navigation systems. In order to get a mile accuracy in his position, Harrison's clock only had to keep time to within 4 seconds. Today, our modern navigation systems—TRANSIT, LORAN, OMEGA, Global Positioning System—with their clocks can determine position very much better, GPS in fact to within meters, the latter corresponding to several tens of nanoseconds accuracy.

While time has played such an important role in navigation, it is appropriate to note that navigation systems have played an important role in PTTI, as well. Having knowledge of one's position by some means allows the PTTI user to derive time from all modern navigation systems with greater simplicity than actually deriving position. In the early sixties, the PTTI community was getting time from the Navy Navigational Satellite System (TRANSIT) to about 35 microseconds on a routine basis. LORAN-C allowed the timing community to get time to about 200 nanoseconds on a regular basis. Even Omega was used for a while for timing.

Of course, along came GPS. GPS now has 19 satellites in orbit providing not only the best navigational data available to DoD components, but also the best timing data that have ever been made available to the vast majority of PTTI users in the field. GPS PTTI performance over the last year, as in previous years, has improved. While the GPS system time is kept to within one microsecond of UTC(USNO), as a time transfer mechanism it provides precise time to users at an accuracy to within plus/minus one hundred nanoseconds of UTC(USNO).

Similar to the field of navigation, the atomic clocks used in our laboratories have seen significant progress over the last few decades. The workhorse of the industry, the cesium-beam clock, was introduced in the early sixties. It kept time to within several hundred nanoseconds from day to day. By the early seventies, the high performance cesium-beam tube was introduced. These clocks kept time to about 20-40 nanoseconds per day. Today, we have on the market an improved version that promises to minimize the effect of environmental conditions on clock performance. Preliminary data indicate that these new clocks are performing remarkably well in a variety of conditions. Another great stride forward.

New timing procedures are showing up everywhere. The evolution and transformation of one of our national communications systems into a state-of-the-art digital network using GPS as the precise time source, rather than an independently maintained clock system, shows the capabilities that are being integrated into many timed systems. Obviously, both efficiency and effectiveness were served in this upgrade. Other national communications networks rely on precise time from LORAN.

During the year, several other areas have made some new strides forward. Regularly scheduled two-way communications satellite time transfers between North America (USNO) and Europe (Technical University of Graz [TUG] & Observatoire de la Côte d'Azur [OCA]-were inaugurated utilizing an INTELSAT satellite. Envisioned international networks, such as this, will soon become a force in the improved development of the international time scale. I consider these to be important events for several reasons, including the Observatory's need to coordinate the DoD time reference standard with other international standards to ensure continuity of precision, and the strengthening of time coordination that supports our European allies.

In addition, the use of laser pulses to synchronize clocks between North America (McDonald Observatory) and Europe (OCA) was accomplished for the first time. This technique still holds the promise of being the most accurate time transfer method currently possible. Time transfer accuracy around 300 picoseconds was realized in this exercise.

Yes, everywhere we look today in the timing business, change is at hand. The magnificent work of so many has delivered to us great technological capabilities. Our challenge is to be smart in their use. PTTI is becoming such a important part of our everyday life that we cannot afford to ignore the necessary considerations regarding infrastructure support and compatibility.

Certainly in the DoD, precise time plays an ever-increasing role in effective employment of our assets, and in this age of sophisticated weaponry and very complex battle-group management and tactics, split second timing is far more than just a catch phrase. We must be always conscious of the need to address issues of precise time calibration and verification; interoperability of multiple systems; precise coordination of sensors and fire control systems, communications links and navigation systems; internal precise time distribution and local control; physical vulnerability and risks to critical timing sources; and overall data fusion.

Even the PTTI Meeting has innovation this year. Over the years, the PTTI meeting has attempted to bring together the users and the developers of PTTI. Sometimes there have been panels which discussed a topic relevant at the time. This year we are hoping to make you – the attendees – the panel. It is very important that we get you to share your experiences and learn about operating systems and those nearing operational status in regard to their timing capabilities. We also need to know what the future needs are for timing support. Clearly, realizing the extent of change today forces us to become very aggressive in planning for the timing support for tomorrow's systems.

This afternoon, we will have a set of three workshops. All attendees are strongly encouraged to voice their opinions, concerns, and requirements. Speakers are encouraged to join in, too. In order that the thoughts brought out during the workshop become more focused and more useful as background for the numerous discussions which take place during the meeting, Dr. Winkler will summarize the results of the workshop. His comments will surely be a catalyst in fostering the exchange and sharing of ideas.

It is the purpose of this conference to stress the important role of PTTI to everybody concerned with timed systems, e.g., engineers, managers, planners, users, designers, etc. The role of this meeting cannot be underestimated. It is the ONE conference not edicated solely to the "technologists" of the industry. Its audience is broadband, and we have attempted to bring in people whose interests in the subject range across the constantly expanding PTTI field of today.

So, I wish you every success in this conference and am excited to join with you as we benchmark and assess the ever–changing world of precise time and time interval.