

Proceedings of the Nineteenth Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting

**A meeting held at the
Sheraton Hotel
Redondo Beach, California
December 1-3, 1987**

Sponsored by

**U.S. Naval Observatory
NASA Goddard Space Flight Center
Space and Naval Warfare Systems Command
Naval Research Laboratory
National Bureau of Standards
Army Electronics Technology
and Devices Laboratory
Rome Air Development Center
USAF Space Command**

EXECUTIVE COMMITTEE

Sheila C. Faulkner, Chairman
U.S. Naval Observatory

David W. Allan
National Bureau of Standards

James A. Buisson
U.S. Naval Research Laboratory

Jimmie B. Collie
Space and Naval Warfare Systems Command

Hugh S. Fosque
NASA Headquarters

Raymond Granata
NASA Goddard Space Flight Center

Denise A. Kaya
USAF Space Command

Dr. William J. Klepczynski
U.S. Naval Observatory

Dr. Arthur O. McCoubrey
National Bureau of Standards

Dr. John R. Vig
Army Electronics Technology and Devices Laboratory

Dr. H. Beat Wackernagel
USAF Space Command

Dr. Joseph D. White
U.S. Naval Research Laboratory

Dr. Gernot M.R. Winkler
U.S. Naval Observatory

Dr. Nicholas F. Yannoni
Rome Air Development Center

SESSION CHAIRMEN

SESSION I

Col. Gaylord Green
U.S. Air Force Space Division/YE

SESSION II

Dr. Nicholas F. Yannoni
Rome Air Development Center

Dr. Ed Jones
Naval Research Laboratory

SESSION III

Dr. John R. Vig
Army Electronics Technology
and Devices Laboratory

SESSION IV

Dr. Len Cutler
Hewlett Packard

SESSION V

Dr. Gernot M.R. Winkler
U.S. Naval Observatory

PTTI ADVISORY BOARD COMMITTEES

FEBRUARY 1988

<u>OFFICE</u>	<u>NAME</u>	<u>ORGANIZATION</u>
Chairman	Mr. S. Clark Wardrip	BFEC
Vice Chairman	Mr. Martin B. Bloch	FEI
Finance Committee	Mr. Martin B. Bloch, Chairman Mr. Frank Matthews Mr. S. Clark Wardrip Mr. James L. Wright	FEI FEC/WTR BFEC PanAm/ETR
Exhibits Committee	Dr. Martin Levine, Chairman Dr. James A. Barnes Mr. Jeffrey W. McDonald Mr. Jack McNabb Mr. William J. Riley Mr. Don Mitchell Dr. Robert F. C. Vessot	FTS Austron Truetime TRAK EG&G DATUM SAO
Guest Speaker Committee	Mr. Robert H. Kern, Chairman Professor Carroll O. Alley Dr. Leonard S. Cutler Dr. Bradford Parkinson Dr. Victor S. Reinhardt Dr. Samuel R. Stein Dr. Richard L. Sydnor	KERNCO University of Maryland HP Stanford University Hughes Ball/Efratom JPL
Reports Committee	Mr. Lauren J. Rueger, Chairman Mr. Terry N. Osterdock Dr. Harry Robinson Mr. Philip E. Talley	APL STI Duke University Aerospace
1988 PTTI Officers	Dr. Bradford W. Parkinson PTTI General Chairman Dr. Henry F. Fliegel Program Chairman Dr. Richard L. Sydnor PTTI Editorial Chairman	Stanford University Aerospace JPL

NOTE: NON-GOVERNMENT OFFICERS OF THE PTTI ARE AUTOMATICALLY MEMBERS OF THE PTTI ADVISORY BOARD FOR THE YEAR(S) THAT THEY ARE IN OFFICE.

1988 PTTI ADVISORY BOARD MEMBERSHIP ADDRESS/TELEPHONE LIST

Professor Carroll O. Alley
University of Maryland
Department of Physics and Astronomy
College Park, Maryland 20742
301/454-3405

Dr. James A. Barnes
Astron, Inc.
3300 Mitchel Lane
Boulder, Colorado 80301
303/440-7282

Mr. Martin B. Bloch
Frequency Electronics, Inc.
55 Charles Lindbergh Boulevard
Uniondale, New York 11553
516/794-4500

Dr. Leonard S. Cutler
Hewlett-Packard Company
1651 Page Mill Road
Palo Alto, California 94304
415/857-5259

Dr Martin Levine
Frequency and Time Systems, Inc.
34 Tozer Road
Beverly, Massachusetts 01915
617/927-8220

Mr. Robert H. Kern
Kernco, Inc.
28 Harbor Street
Danvers, Massachusetts 01923-0678
617/777-1956

Mr. Frank Matthews
ITT Federal Electric Corp.
P.O. Box 5728
Code OE600
Vandenberg Air Force Base,
California, 93437
805/866-7590

Mr. Jeffrey W. McDonald
Kinometrics/Truetime
3243 Santa Rosa Avenue
Santa Rosa, California 95407
707/528-1230

Mr. Jack McNabb
TRAK Microwave Corporation
4726 Eisenhower Boulevard
Tampa, FL 33614-6391
813/884-1411

Mr. Donald Mitchell
DATUM
1363 S. State College Boulevard
Anaheim, CA 92806
714/533-6333

Mr. Terry N. Osterdock
Stanford Telecommunications, Inc.
2421 Mission College Boulevard
Santa Clara, California 95054
408/982-5903

Dr. Bradford W. Parkinson
Stanford University
Hansen Labs, Via Palou
Stanford, California 94305-4085
415/725-4107

Dr. Victor S. Reinhardt
Hughes Aircraft
Space and Communications
S12/W322, P.O. Box 92919
Los Angeles, California 90009
213/416-0160

Mr. William J. Riley
EG&G, Inc.
35 Congress Street
Salem, Massachusetts 01775
617/745-3200

Dr. Harry Robinson
Duke University
Department of Physics
Durham, North Carolina 27706
919/684-8226

Mr. Lauren J. Rueger
Johns Hopkins University
Applied Physics Laboratory
Johns Hopkins Road
Laurel, Maryland 20707
301/953-5288

FOREWORD

These Proceedings contain the papers presented at the Nineteenth Annual Precision Time and Time Interval Applications and Planning Meeting. The meeting was held for the first time on the West Coast, at the Redondo Beach Sheraton Hotel. An excellent attendance at the meetings and the banquet was an indication of the interest in this field in the Southern California area. A number of invited speakers presented talks which are not given here. The discussion following each talk are printed following the individual paper.

There were 221 registered attendees and eight paid non-attendees. Of the attendees, 137 were from West of the Mississippi (98 from the L.A. area), 67 were from East of the Mississippi (32 from the Washington D.C. area) as well as 17 from 9 foreign countries (13 from 6 European countries, one from Japan two from Canada and 1 from Africa).

The objective of these meetings is to provide an opportunity for program planners to meet those who are engaged in research and development and to keep abreast of the state-of-the-art and latest technological developments. At the same time, they provide an opportunity for engineers to meet program planners.

This year the program emphasized GPS technology and applications as well as developments in the fields of time keeping, frequency standards and time synchronization.

The Program Chairman and the Session Chairmen are responsible for the excellent technical content of the meeting. This year was a particularly difficult one for the organizers because of the new location and the distance between Washington and Redondo Beach. Their unstinting efforts achieved an outstanding success which we hope will be soon repeated.

CONTENTS

SESSION I

GPS Time and Frequency Aspects

Chairman: Col. Gaylord Green
U.S. Airforce

Update On GPS System Status	1
Col. G. Green, U.S.Airforce Space Division/YE	
Use of GPS Time Transfer at BIH/BIPM	3
B. Guinot and W. Lewndowski Bureau International de l'Heure	
Comparison of Time Scales Generated with the NBS Ensembling Algorithm	13
F. Varnum, D.R. Brown, D.W. Allan, and T.K. Peppler National Bureau of Standards	
Dual Frequency P-Code Time Transfer Experiment	25
J.R. Clynch and B. Tolman, Applied Research Laboratories and M.A. Weiss, D.W.Allan, and D. Davis, National Bureau of Standards	
Apparent Diurnal Effects in the Global Positioning System	33
M.A. Weiss, National Bureau of Standards	
An Off-Air Observatory Time Service	49
A.R. Seabrook, Royal Greenwich Observatory, England	
Global Positioning System for Time and Frequency Measurements	58
G.F. Knoernschild, Rockwell International	

SESSION II

Current Applications

Chairman: Dr. Nicholas Yannoni
Rome Air Development Center and
Dr. Ed Jones
Naval Research Laboratory

A Reappraisal of Frequency Domain Techniques for	69
Assessing Frequency Stability Measurements D.B. Percival, Applied Physics Laboratory, University of Washington	
Timing Operations and Data Processing in the	81
Goddard Laser Tracking Network A. Clinton, E. Detoma, W. Hanrahan, and P. Kushmeider Bendix Field Engineering Corporation	
Measurement of Delay Variation in Digital Communications Networks	96
K. Hilty and J.D. Mellana, Swiss Post Office Technical Center	

Single State Selection System for Hydrogen Masers	107
E.M. Mattison and R.F.C. Vessot, Smithsonian Astrophysical Observatory	
Triply-Redundant Precision Time and Frequency Standard	113
D. Silvermetz, M. Bloch, M. Meirs, Frequency Electronics, Inc	
Local Oscillator Induces Instabilities in Trapped Ion Frequency Standards	133
G.J. Dick, Jet Propulsion Laboratory	
Influence of Acoustic-Gravity Waves on Propagation of Loran-C	149
Y. Zheng, Purple Mountain Observatory, China	
Linking Saudi Arabia Loran-C Chain to Mediterranean Chain	155
S. Samuel, National Institute for Standards, Egypt	

SESSION III

Specifications and Environmental Effects on Oscillator Stability

Chairman: Dr. John Vig

Army Electronics Technology and Devices Laboratory

Specification of Precision Oscillators	163
S.S. Schodowski and J.R. Vig, U.S. Army Electronics and Technology Laboratory	
The Effects of Ambient Conditions on Cesium Clock Rates	175
L.A. Breakiron, U.S. Naval Observatory	
Analysis of the Seasonal Effects on a Cesium Clock to Improve the Long-Term Stability of a Times Scale	185
E. Bava, F. Cordara, V. Pettiti and P. Tavella, Istituto Elettrotecnico Nazionale "Galileo Ferraris", Corso, Italy	
Large Sample Simulation of Flicker Noise	203
J.A. Barnes, Austron, Inc. and C.A. Greenhall, Jet Propulsion Laboratory	
Likelihood and Least Squares Approach to the M-cornered Hat	219
C.A. Greenhall, Jet Propulsion Laboratory	
Variances Based on Data with Dead Time	227
Between the measurements J.A. Barnes, Austron, Inc. and D.W. Allan, National Bureau of Standards	

SESSION IV

Chairman: Dr. Len Cutler

Hewlett-Packard Company

Atomic Transit Time and Delayed Ionization Effects on Cesium	235
Beam Frequency Standards B. Jaduszliwer, The Aerospace Corporation	

The Optically Pumped Cs Frequency Standard at NRLM	245
Y. Nakadan and Y. Koga, National Research Laboratory of Metrology, Japan	
Alkali Reactions with Wall Coating Materials	255
Used in Atomic Resonance Cells J.C. Camparo, R. Frueholz and B. Jaduszliwer, The Aerospace Corporation	
Stability Test Results for GPS Rubidium Clocks	267
F. Danzy, U.S. Naval Research Laboratory and W.J. Riley, EG&G Frequency Products, Inc.	
Design and Performance of a Compact Passive Maser	275
L.L. Lewis, T.E. Smith and S.R. Stein, Ball Aerospace Systems Division	
Trapped Ion Frequency Standard	285
J.D. Prestage, G.L. Dick and L. Maleki, Jet Propulsion Laboratory	
Application of High Temperature Superconductivity	299
to Ultrastable Frequency Sources G.J. Dick, D.M. Strayer and L. Maleki, Jet Propulsion Laboratory	
Application of Kalman Filters and ARIMA Models	311
to the Design of Digital Frequency and Phase Lock Loops J.A. Barnes, Austron Corporation and S.R. Stein, Ball Aerospace Systems Division	

SESSION V

Advance Applications

Chairman: Dr. Gernot Winkler
U.S. Naval Observatory

Performance Of Atomic Clocks Flown on the Space	325
Shuttle Experiment NAVEX J. Hammesfahr, H. Nau and S. Starker, Institute for Radio Frequency Technology, FRG	
Redundant Time and Frequency Reference Unit	337
for Satellite Applications Satellite Program A. Vulcan, C. Gloeckl, M. Meirs and T. McClelland, Frequency Electronics, Inc.	
Portable Hydrogen Maser Clock Time Transfer	345
at the Sub-Nanosecond Level L. Rueger, M.C. Chiu and S.D. Deines, Johns Hopkins University and R.A. Nelson, J.T. Broomfield and C.D. Alley, University of Maryland	

A New Test of Relativity	367
T.P. Krisher, L. Makeki, Jet Propulsion Laboratory and C.M. Will, Washington University	
A Study in Long-Term Stability of Atomic Clocks	375
D.W. Allan, National Bureau of Standards	
Standard Time and Frequency Signal Dissemination	381
Service via Indian Domestic Satellite INSAT-1B	
A. Sen Gupta, A.K. Hanjura, P. Banerjee, and B.S. Mathur, National Physical Laboratory	