

# 33<sup>RD</sup> ANNUAL PRECISE TIME AND TIME INTERVAL (PTTI) SYSTEMS AND APPLICATIONS MEETING



*Proceedings of a meeting held at  
the Hyatt Regency Hotel  
at Long Beach, California  
27 — 29 November 2001*

---

The U.S. Naval Observatory  
Washington, DC

---



# **33<sup>RD</sup> ANNUAL PRECISE TIME AND TIME INTERVAL (PTTI) SYSTEMS AND APPLICATIONS MEETING**

Editor  
Lee A. Breakiron  
U.S. Naval Observatory

Proceedings of a meeting sponsored by  
the U.S. Naval Observatory  
the U.S. Naval Research Laboratory  
the NASA Jet Propulsion Laboratory  
the U.S. Air Force Office of Scientific Research  
the Defense Information Systems Agency  
and the U.S. Coast Guard Navigation Center

and held at  
the Hyatt Regency Hotel  
at Long Beach, California  
27 — 29 November 2001



**United States Naval Observatory**  
Washington, DC 20392-5420

2002

# ORDER FORM FOR PROCEEDINGS

You can order back issues of the Proceedings from either PTTI or NTIS

Year	PTTI Price	NTIS Number	NTIS Price in U.S.; higher elsewhere
5 - 1973	\$ 25 00	AD-A010786/2	inquire
6 - 1974	\$ 25 00	AD-A018192/5	inquire
7 - 1975	unavailable	AD-A040774/2	inquire
8 - 1976	unavailable	AD-A043856/4	inquire
9 - 1977	unavailable	AD-A123920/1	inquire
10 - 1978	\$ 25 00	N79-24731/8	inquire
11 - 1979	unavailable	N80-29096/8	inquire
12 - 1980	\$ 25 00	N81-27467/2	inquire
13 - 1981	\$ 25 00	N82-20494/2	inquire
14 - 1982	unavailable	N83-35351/6	inquire
15 - 1983	\$ 25 00	AD-A149163/8	inquire
16 - 1984	unavailable	N85-29221/7	inquire
17 - 1985	\$ 25.00	inquire	inquire
18 - 1986	\$ 25 00	inquire	inquire
19 - 1987*	\$ 25 00	inquire	inquire
20 - 1988	\$ 25 00	AD-A217145/2INZ	\$ 77 50
21 - 1989	\$ 25 00	inquire	inquire
22 - 1990	\$ 50 00	N91-25755/0INZ	inquire
23 - 1991	\$ 50 00	AD-A255837/7INZ	\$ 31.50
23 - Tutorial	included	AD-A254745/3INZ	\$ 45 00
24 - 1992	\$ 50 00	AD-A267301/0INZ	\$ 86 50
25 - 1993	\$ 50.00	N94-30639/6INZ	\$ 103 50
26 - 1994	\$ 50.00	N95-32319/2INZ	\$ 86 50
27 - 1995	\$ 50 00	N19960042616INZ	\$ 69.50
28 - 1996	\$ 50.00	inquire	inquire
28 - Tutorial	\$ 15 00	inquire	inquire
29 - 1997	\$ 50 00	inquire	inquire
30 - 1998	\$ 100.00	inquire	inquire
31 - 1999	\$ 100 00	inquire	inquire
32 - 2000**	\$ 135 00	Inquire	inquire
33 - 2001***	\$ 135 00	Inquire	inquire

\*Includes an Errata volume; \*\* Available on CD-ROM only; \*\*\*Available as softback or on CD-ROM (please specify) or both (for \$170.00 if ordered at the same time).

When ordering from PTTI, return order form with payment to:

Treasurer, PTTI  
U.S. Naval Observatory  
3450 Massachusetts Avenue, NW  
Washington, DC 20392-5420  
Tel: 202-762-1414, Fax: 202-762-1511

Do not send cash. We cannot accept credit card orders.  
When you register for the PTTI meeting or order the Proceedings, your name is added to the PTTI mailing list to receive future meeting information.

Proceedings are softback unless otherwise indicated. Papers are indexed on the Internet at: [tycho.usno.navy.mil/ptti/index.html](http://tycho.usno.navy.mil/ptti/index.html) where abstracts are available from 1998 on and texts are available for 1999 on.

When ordering from NTIS, contact:

U.S. Department of Commerce  
Technology Administration  
National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161  
Tel: 800.553.6847, Fax: 703.605.6900

E-mail: [orders@ntis.fedworld.gov](mailto:orders@ntis.fedworld.gov)  
WWW: [www.ntis.gov](http://www.ntis.gov)

NTIS prices are subject to change without notice. There is also a handling fee. Microfiche is available.

## **EXECUTIVE COMMITTEE**

**DR. JOSEPH D. WHITE, CHAIRMAN**  
U.S. NAVAL RESEARCH LABORATORY

**MR. RONALD L. BEARD**  
U.S. Naval Research Laboratory

**DR. LEE A. BREAKIRON**  
U.S. Naval Observatory

**LIEUTENANT DAVID FOWLER**  
U.S. Coast Guard Navigation Center

**DR. DENNIS D. MCCARTHY**  
U.S. Naval Observatory

**CAPTAIN THOMAS R. RICE**  
U.S. Coast Guard

**MR. RICHARD C. CAMP**  
Defense Information Systems Agency

**DR. HOWARD SCHLOSSBERG**  
Deputy Assistant Secretary  
U.S. Air Force/AQR

**MR. GEORGE SHATON**  
Department of Defense

**DR. ROBERT L. TJOELKER**  
NASA Jet Propulsion Laboratory

**MS. FRANCINE M. VANNICOLA**  
U.S. Naval Observatory

### *ADMINISTRATIVE ASSISTANCE*

**MS. NICOLETTE M. JARDINE**  
U.S. Naval Observatory

## OFFICERS

*GENERAL CHAIRMAN*

**DR. PAUL KOPPANG**

U.S. Naval Observatory

*TECHNICAL PROGRAM COMMITTEE*

**DR. ANDY WU**

The Aerospace Corporation

**MR. O. JAY OAKS, CO-CHAIRMAN**

U.S. Naval Research Laboratory

**DR. LEONARD S. CUTLER**

Agilent Laboratories

**MR. PAUL F. KUHNLE**

NASA Jet Propulsion Laboratory

**DR. RICHARD L. SYDNOR**

NASA Jet Propulsion Laboratory

**MS. FRANCINE M. VANNICOLA**

U.S. Naval Observatory

**MR. S. CLARK WARDRIP**

SFA, Inc.

*EDITORIAL COMMITTEE CHAIRMAN*

**DR. LEE A. BREAKIRON**

U.S. Naval Observatory

*TREASURER*

**DR. LEE A. BREAKIRON**

U.S. Naval Observatory

*EXHIBITS AND PUBLICITY COMMITTEE CHAIRMAN*

**MR. DONALD H. MITCHELL**

TrueTime, Inc.

*AUDIO-VISUAL CHAIRMAN*

**DR. HAROLD A. CHADSEY**

U.S. Naval Observatory

*TECHNICAL ASSISTANCE*

**MR. PAUL F. KUHNLE**

NASA Jet Propulsion Laboratory

*MEETING ARRANGEMENTS*

**MRS. SHEILA FAULKNER**

SFA, Inc.

*ADMINISTRATIVE ASSISTANCE*

**MS. NICOLETTE JARDINE**

U.S. Naval Observatory

**MRS. CARMEN DOMINGUEZ**

U.S. Naval Research Laboratory

## **DISTINGUISHED PTTI SERVICE AWARD COMMITTEE**

**DR. JOSEPH D. WHITE, CHAIRMAN**  
U.S. Naval Research Laboratory

**DR. LEONARD S. CUTLER**  
Agilent Laboratories

**DR. DENNIS D. MCCARTHY**  
U.S. Naval Observatory

**MR. DONALD H. MITCHELL**  
TrueTime, Inc.

**DR. RICHARD L. SYDNOR**  
NASA Jet Propulsion Laboratory

## **PAST RECIPIENTS OF THE DISTINGUISHED PTTI SERVICE AWARD**

**1994**

**DR. GERNOT M. R. WINKLER**  
U.S. Naval Observatory (Ret.)

**1995**

**DR. JAMES A. BARNES**  
National Institute of  
Standards and Technology (Ret.)

**1996**

**PROFESSOR SIGFRIDO M. LESCHIUTTA**  
Politenico di Torino and  
Istituto Elettrotecnico  
Nazionale G. Ferraris

**1997**

**PROFESSOR BERNARD R. GUINOT**  
Bureau International des  
Poids et Mesures (Ret.)  
Honorary Astronomer, Paris Observatory

**1998**

**DR. JACQUES VANIER**  
National Research Council, Canada (Ret.)

**1999**

**DR. LEONARD S. CUTLER**  
Agilent Laboratories

**2000**

**MR. ROGER L. EASTON**  
U.S. Naval Research Laboratory (Ret.)  
and ROBARCO

## ADVISORY BOARD MEMBERS

**MR. S. CLARK WARDRIP, CHAIRMAN**  
SFA, Inc.

Professor Carroll O. Alley  
University of Maryland

Mr. Martin B. Bloch  
Frequency Electronics, Inc.

Mrs. Mary Chiu  
The Johns Hopkins University  
Applied Physics Laboratory

Dr. Leonard S. Cutler  
Agilent Laboratories

Mrs. Sheila C. Faulkner  
SFA, Inc.

Mr. Hugo Fruehauf  
Zyfer, Inc.

Mr. Robert H. Kern  
Kernco, Inc.

Dr. William J. Klepczynski  
Innovative Solutions International

Mr. Paul F. Kuhnle  
NASA Jet Propulsion Laboratory

Mr. Donald H. Mitchell  
TrueTime, Inc.

Mr. Jerry R. Norton  
The Johns Hopkins University  
Applied Physics Laboratory

Dr. Bradford W. Parkinson  
Stanford University

Dr. Victor S. Reinhardt  
Boeing Space Systems

Mr. William J. Riley  
Datum, Inc.

Dr. Henry Robinson  
Duke University

Mr. Ronald C. Roloff  
Geil Marketing Associates

Dr. Samuel R. Stein  
Timing Solutions Corporation

Dr. Richard L. Sydnor  
NASA Jet Propulsion Laboratory

Dr. Andy Wu  
The Aerospace Corporation

## SESSION CHAIRMEN

### *SESSION I*

**MR. PETE LOPEZ**  
TrueTime, Inc.

### *SESSION II*

**DR. BERNARDO JADUSZLIWER**  
The Aerospace Corporation

### *SESSION III*

**MS. LISA NELSON**  
National Institute of Standards  
and Technology

### *SESSION IV*

**DR. EDWARD POWERS**  
U.S. Naval Observatory

### *SESSION V*

**DR. THOMAS PARKER**  
National Institute of Standards  
and Technology

### *SESSION VI*

**MR. DONALD H. MITCHELL**  
TrueTime, Inc.

### *SESSION VII*

**MR. MIHRAN MIRANIAN**  
U.S. Naval Observatory

### *SESSION VIII*

**MR. O. JAY OAKS**  
U.S. Naval Research Laboratory

### *SESSION IX*

**DR. VICTOR S. REINHARDT**  
Boeing Space Systems

### *SESSION X*

**DR. LEONARD S. CUTLER**  
Agilent Laboratories

### *SESSION XI*

**DR. RICHARD L. SYDNOR**  
NASA Jet Propulsion Laboratory

### *SESSION XII*

**DR. DEMETRIOS N. MATSAKIS**  
U.S. Naval Observatory



## **ARRANGEMENTS**

**MRS. SHEILA FAULKNER**  
SFA, Inc.

**MR. PAUL F. KUHNLE**  
NASA Jet Propulsion Laboratory

## **FINANCE COMMITTEE**

**MR. RONALD L. BEARD**  
U.S. Naval Research Laboratory

**DR. LEE A. BREAKIRON**  
U.S. Naval Observatory

**DR. JOSEPH D. WHITE**  
U.S. Naval Research Laboratory

## **THE RECEPTIONISTS AT THE 33<sup>RD</sup> ANNUAL PTTI MEETING WERE:**

**Ms. Nicolette Jardine**  
**Mrs. Aline Kuhnle**  
**Mrs. Betty Wardrip**