

TABLE OF CONTENTS

| | |
|---|----------|
| PTTI OPENING ADDRESS | 1 |
| Captain Dennis G. Larsen, Superintendent, U.S. Naval Observatory | |
| PTTI DISTINGUISHED SERVICE AWARD | 3 |
| Presented by Dr. Richard L. Sydnor NASA Jet Propulsion Laboratory (Ret.) to Dr. Leonard S. Cutler Agilent Technologies | |
| THE PERVERSIVE SOCIETAL IMPACT OF TIME AND FREQUENCY | 7 |
| Dr. Helmut Hellwig, Deputy Assistant Secretary of the U.S. Air Force (Ret.) | |

SESSION I

PTTI VENDOR PRESENTATIONS

**Donald H. Mitchell, Chairman
TrueTime, Inc.**

Presentations were made by representatives of Agilent Technologies; Allen Osborne Associates, Inc.; Arbiter Systems; Brandywine Communications; Datum, Inc.; Magellan/Ashtech Precision Products; Odetics Telecom (now Zyfer); Quartzlock UK Ltd.; Stanford Research Systems; Syntomics LLC; Temex Electronics, Inc.; TimeTech, GmbH; Timing Solutions Corporation; TRAK Systems; and TrueTime, Inc.

SESSION II

SATELLITE AND BROADCAST TIME AND TIME TRANSFER - GPS SYSTEM PERFORMANCE

**Thomas E. Parker, Chairman
National Institute of Standards and Technology**

| | |
|--|----|
| 1999 GPS Time Transfer Performance | |
| Capt. M. Rivers and 1Lt. S. Osborne, USAF, 2d Space Operations Squadron . . . | 17 |
| Feedback From GPS Timing Users: Relayed Observations From 2 SOPS | |
| Capt. T. Occhi, USAF, 2d Space Operations Squadron; and S. Hutsell, U.S. Naval Observatory Alternate Master Clock | 29 |
| Multiple-Path Linked Common-View Time Transfer (LCVTT) | |
| W. Reid, SFA Inc. | 43 |

SESSION III

SATELLITE CLOCK PERFORMANCE UPDATE

**O. Jay Oaks, Chairman
U.S. Naval Research Laboratory**

| | |
|--|-----|
| Investigation of the GPS Block IIR Time Keeping System (TKS) Anomalies Caused by the Voltage-Controlled Crystal Oscillator (VCXO) | |
| A. Wu, The Aerospace Corporation | 55 |
| Long-Term Stability of a Rubidium Atomic Clock in Geosynchronous Orbit | |
| J. Coffer and J. Camparo, The Aerospace Corporation | 65 |
| Performance of Global Positioning System Block II/IIA/IIR On-Orbit NAVSTAR Clocks | |
| T. McCaskill, O. Oaks, and M. Largay, U.S. Naval Research Laboratory; W. Reid, H. Warren, SFA, Inc.; and J. Buisson, AEI | 75 |
| Considerations for the Concept of Galileo's Timekeeping System | |
| J. Hahn, Institut für Hochfrequenztechnik, Germany | 91 |
| Redundant Atomic Frequency Standard Timekeeping System with Seamless AFS Switchover | |
| V. Reinhardt and C. Sheckells, Hughes Space and Communications Company | 101 |

| | | |
|--|---|-----|
| The Autonomous Detection of Clock Problems in Satellite Timekeeping Systems | Y. Chan, J. Camparo, and R. Frueholz, The Aerospace Corporation | 111 |
| Space-Segment Timekeeping for Next Generation MILSATCOM | Y. Chan, J. Camparo, and R. Frueholz, The Aerospace Corporation | 121 |

PANEL DISCUSSION POST-GPS END-OF-WEEK ROLLOVER AND UPCOMING Y2K

| | | |
|-------------------------------------|-------|-----|
| Donald H. Mitchell, Chairman | | 133 |
| TrueTime, Inc. | | |

Panel Members: Dennis D. McCarthy, U.S. Naval Observatory, and Steven T. Hutsell, U.S. Naval Observatory Alternate Master Clock

SESSION IV

WAAS, EGNOS, AND MSAS - GPS AUGMENTATION SYSTEMS UPDATE

| | |
|------------------------------------|--|
| Patrick C. Fenton, Chairman | |
| NovAtel, Inc. | |

An Overview of GPS Augmentation Systems

| | |
|--|-----|
| M. Petovello and G. Lachapelle, University of Calgary, Canada; and P. Fenton, NovAtel, Inc. | 141 |
|--|-----|

Wide Area Augmentation System (WAAS)

| | |
|---|-----|
| D. Ormand, Raytheon Systems Company | 155 |
|---|-----|

WAAS Network Time Performance Using WRS Data

| | |
|--|-----|
| C. Griffith, S. Peck, and P. Diamond, Raytheon Systems Company | 161 |
|--|-----|

Geo Uplink Subsystem (GUS) Clock Steering Algorithms Performance, Validation, and Test Results

| | |
|---|-----|
| M. Grewal, California State University; and W. Brown, R. Lucy, and P. Hsu, Raytheon Systems Company | 173 |
|---|-----|

Enhancing GPS Timing Engines Using WAAS Signals

| | |
|--|-----|
| M. Gonthier and E. Masella, Marconi Canada | 181 |
|--|-----|

Time Transfer Using WAAS: An Initial Attempt

| | |
|--|-----|
| P. Fenton, NovAtel, Inc.; W. Klepczynski, Innovative Solutions International, Inc.; E. Powers, U.S. Naval Observatory; and R. Douglas, National Research Council, Canada | 191 |
|--|-----|

POSTER SESSION

**Paul A. Koppang, Chairman
Datum, Inc.**

**(Papers have been reassigned in these Proceedings to
Sessions III, VI, IX, X, and XII)**

SESSIONS V AND VI

NATIONAL AND INTERNATIONAL STANDARDS LABORATORIES ACTIVITIES UPDATE

**John A. Davis, Chairman
National Physical Laboratory, UK**

Time and Frequency Activities at ROA

J. Palacio, F. Galindo, and R. Boloix, Real Instituto y Observatorio de la Armada, Spain 203

Time and Frequency Activities at the CSIRO National Measurement Laboratory, Sydney, Australia

P. Fisk, R. Warrington, M. Lawn, and M. Wouters, CSIRO National Measurement Laboratory, Australia 211

Time and Frequency Activities at IEN

F. Cordara, G. Brida, A. Godone, F. Levi, L. Lorini, M. Mascarello, S. Micalizio, V. Pettiti, P. Tavella, and G. Vizio, Istituto Elettrotecnico Nazionale "Galileo Ferraris," Italy 219

Update on Time and Frequency Activities at NIST

T. Parker and D. Sullivan, National Institute of Standards and Technology 231

Overview of Research Activities on Time and Frequency at the Communications Research Laboratory

M. Hosokawa, M. Imae, T. Morikawa, N. Kurihara, and K. Okamoto, Communications Research Laboratory, Japan 241

Time and Frequency Activities at the National Physical Laboratory

J. Davis, National Physical Laboratory, UK 247

Recent and Pending Improvements at the U.S. Naval Observatory

D. Matsakis, U.S. Naval Observatory 257

Generalization of the Total Variance Approach to the Modified Allan Variance

D. Howe, National Institute of Standards and Technology; and F. Vernotte, Observatoire de Besançon, France 267

| | |
|---|-----|
| New Steering Strategies for the USNO Master Clock P. Koppang, Datum, Inc.; and D. Matsakis, U.S. Naval Observatory | 277 |
| Estimating the Instabilities of N Correlated Clocks F. Galindo and J. Palacio, Real Instituto y Observatorio de la Armada, Spain | 285 |
| Use of Primary Frequency Standards for Estimating the Duration of the Scale Unit of TAI G. Petit, Bureau International des Poids et Mesures, France | 297 |
| Estimation of Uncertainties in Time Error Estimation F. Vernotte, Observatoire de Besançon, France; and J. Delporte, M. Brunet, and T. Tournier, Centre National d'Études Spatiales, France | 305 |
| Development of a Multiple Time Source Comparison System for Disseminative Services in Taiwan C. Lin, S. Lin, and C. Liao, National Standard Time and Frequency Laboratory, Republic of China | 317 |
| Analysis of Delays in Transmitting Time Code Using an Automated Computer Time Distribution System Y. Shan H. Chua, and A. Kyaw, National Measurement Center, Singapore; and J. Levine, National Institute of Standards and Technology | 323 |
| The Design and Implementation of the Integrated Timing System To Be Used in the National Ignition Facility G. Coutts, J. Wiedwald, N. Sewall, and L. Lagin, Lawrence Livermore National Laboratory | 329 |

SESSION VII

THE FUTURE OF MILITARY GPS RECEIVERS

| | |
|---|-----|
| Joseph D. White, Chairman U.S. Naval Research Laboratory | 339 |
| Panel Discussion — Chairman: Mihran Miranian, U.S. Naval Observatory; Members: Steven T. Hutsell, U.S. Naval Observatory Alternate Master Clock, and Donald H. Mitchell, TrueTime, Inc. | |
| A Better Way of Life for PPS Users...GPS SAASM and P(Y)-Direct, the New Wave of Military Receiver Technology for the PPS Navigation and Time and Frequency User H. Fruehauf, Zyfer, Inc. | 347 |

| | |
|---|-----|
| Initial Test Results for a New PPS GPS Timing Receiver M. Miranian and E. Powers, U.S. Naval Observatory; and J. Brad and J. White, U.S. Naval Research Laboratory | 357 |
| Testing the Effects of M-Code on GPS Timing Receivers J. Brad, I. Galysh, D. Koch, and J. White, U.S. Naval Research Laboratory; and G. Landis, SFA, Inc. | 365 |

SESSION VIII

SATELLITE AND BROADCAST TIME AND TIME TRANSFER — GPS AND GLONASS TIME TRANSFER

**Thomas E. Parker, Chairman
National Institute of Standards and Technology**

**Francine M. Vannicola, Co-Chairman
U.S. Naval Observatory**

| | |
|--|-----|
| Time Transfer Using P-Code Measurements from GPS/GLONASS Receivers F. Roosbeck, P. Defraigne, and C. Bruyninx, Royal Observatory of Belgium .. | 373 |
| SATMIX Time-Scale Comparisons Using a Single-Channel Fast-Sequencing GPS Receiver With Carrier-Phase Smoothing P. Hetzel, Physikalisch-Technische Bundesanstalt, Germany; D. Kirchner, Technical University Graz, Austria; T. Polewka, Physikalisch-Technische Bundesanstalt, Germany; and H. Ressler, Space Research Institute, Austria . | 383 |
| Comparison of Common-View and One-Way GPS Time Transfer Over a 4000-km East-West Baseline R. Giffard, Agilent Laboratories; and R. Pitcock, Agilent Technologies | 393 |
| Estimation of GPS Ionospheric Delay Using L1 Code and Carrier Phase Observables R. Giffard, Agilent Laboratories | 405 |
| Use of IGS Ionosphere Products in TAI P. Wolf and G. Petit, Bureau International des Poids et Mesures, France .. | 419 |
| GPS-Based Optimal Kalman Estimation of Time Error, Frequency Offset, and Aging Y. Schmaliiy, Guanajuato University, Mexico; A. Marienko, IRVA, Ukraine; and A. Savchuk, Ukrainian Scientific Research Institute for Communication .. | 431 |

SESSION IX

SATELLITE AND BROADCAST TIME AND TIME TRANSFER — GPS CARRIER PHASE

**Thomas E. Parker, Chairman
National Institute of Standards and Technology**

**Francine M. Vannicola, Co-Chairman
U.S. Naval Observatory**

| | |
|--|-----|
| Calibration of GPS Carrier-Phase Time-Transfer Equipment E. Powers, U.S. Naval Observatory | 441 |
| Comparison of Atomic Frequency Standards at NIST and PTB Using Carrier-Phase GPS L. Nelson, J. Levine, and T. Parker, National Institute of Standards and Technology; K. Larson, University of Colorado; and P. Hetzel, and J. Becker, Physikalisch-Technische Bundesanstalt, Germany; | 449 |
| Recent Results With Transatlantic GeTT Campaign R. Dach, T. Schildknecht, and T. Springer, University of Berne, Switzerland; and G. Dudle and L. Prost, Swiss Federal Office of Metrology, Switzerland .. | 461 |
| Frequency Transfer Using GPS Codes and Phases: Short- and Long-Term Stability C. Bruyninx and P. Defraigne, Royal Observatory of Belgium | 471 |
| Attenuating Day-Boundary Discontinuities in GPS Carrier-Phase Time Transfer K. Senior, E. Powers, and D. Matsakis, U.S. Naval Observatory | 481 |
| Analysis Noise, Short-Baseline Time Transfer, and a Long-Baseline GPS Carrier-Phase Frequency Scale D. Matsakis, K. Senior, and L. Breakiron, U.S. Naval Observatory | 491 |

SESSION X

SATELLITE AND BROADCAST TIME AND TIME TRANSFER — OTHER TIME TRANSFER TECHNIQUES

Thomas E. Parker, Chairman
National Institute of Standards and Technology

Francine M. Vannicola, Co-Chairman
U.S. Naval Observatory

New Trends in Two-Way Time and Frequency Transfer via Satellite

W. Schäfer, A. Pawlitzki, and T. Kuhn, TimeTech GmbH, Germany 505

Precise Time-Transfer Experiment Using Two-Way Carrier-Phase Method Planned for ETS-VIII Satellite

M. Hosokawa, M. Imae, H. Kiuchi, Yu. Takahashi, Ya. Takahashi,
Communications Research Laboratory, Japan; and H. Noda and
N. Hamamoto, Tsukuba Space Center, Japan 515

WWVB Improvements: New Power From an Old Timer

M. Deutch, W. Hanson, G. Nelson, C. Snider, D. Sutton, and W. Yates,
National Institute of Standards and Technology; P. Hansen, Space and
Naval Warfare Systems Center; and W. Hopkins, Pacific Sierra Research
Corporation 523

Design of a Satellite Data Manipulation Tool in a Time and Frequency Transfer System Using Satellites

S. Yoon, J. Lee, M. Lee, and J. Kim, Korea Telecom 537

How To Distribute GPS-Time Over COTS-Based LANs

U. Schmid, M. Horquer, and N. Kerö, Technische Universität, Austria 545

A High Performance Multi-Channel Time-Interval Counter With an Integrated GPS Receiver

A. Novick, M. Lombardi, and V. Zhang, National Institute of Standards and
Technology; and A. Carpentier, Bellaire Design 561

Evaluation of Mitrex Modem Transmit and Receive Delay Instability

M. Mascarello, P. Tavella, V. Pettiti, and F. Cordara, Istituto Elettrotecnico
Nazionale "Galileo Ferraris," Italy 569

SESSIONS XI AND XII
ATOMIC FREQUENCY STANDARDS RESEARCH UPDATE

**Pascal Rochat, Chairman
Temex Neuchâtel Time, Switzerland**

| | |
|---|-----|
| Progress in the Development of IEM KVARZ Passive Hydrogen Masers N. Demidov, A. Pastukhov, and A. Uljanov, Institute of Electronic Measurements KVARZ, Russia | 579 |
| Vertical Cavity Lasers for Atomic Time Standards H. Zappe, Centre Suisse d'Electronique et de Microtechnique, Switzerland | 591 |
| Improved Timekeeping Using Advanced Trapped-Ion Clocks R. Tjoelker, J. Prestage, and L. Maleki, NASA Jet Propulsion Laboratory | 597 |
| On the Use of Lambda Transitions in Atomic Frequency Standards F. Levi, A. Godone, Istituto Elettrotecnico Nazionale "G. Ferraris," Italy; S. Micalizio, Politecnico di Torino, Italy; and J. Vanier, Université de Montréal, Canada | 605 |
| A Cost-Effective Time and Frequency Reference V. Candelier, G. Marotel, D. Thorax, and C. Trialoup, C-MAC Frequency Products, France | 615 |
| Rubidium Atomic Clock for Galileo A. Jeanmaire and P. Rochat, Temex Neuchâtel Time, Switzerland; and F. Emma, European Space Technology Centre, the Netherlands | 627 |
| On an Improved Method of Resolving the Frequency Difference Between Two Very Accurate and Stable Frequency Signals R. Percival and C. Green, Quartzlock, Ltd., UK | 637 |
| An Automated Alarm Program for HP5071A Frequency Standards H. Chadsey, U.S. Naval Observatory | 649 |
| Airborne Comparison of an Ultra-Stable Quartz Oscillator With a H-Maser as Another Possible Validation of General Relativity A. Grishaev, Institute of Metrology for Time and Space, Russia | 657 |
| List of Attendees | 661 |