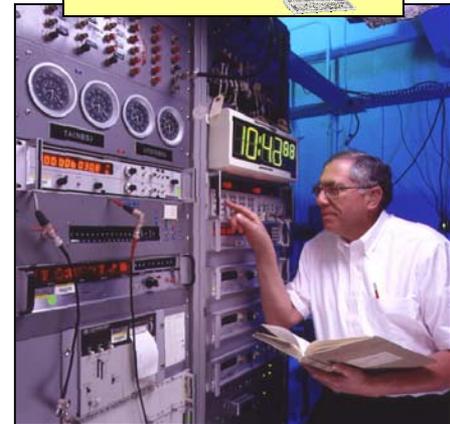
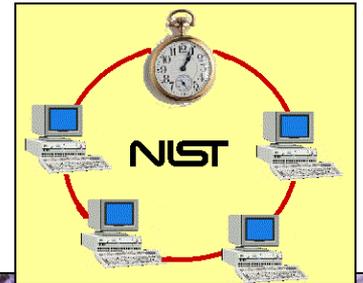
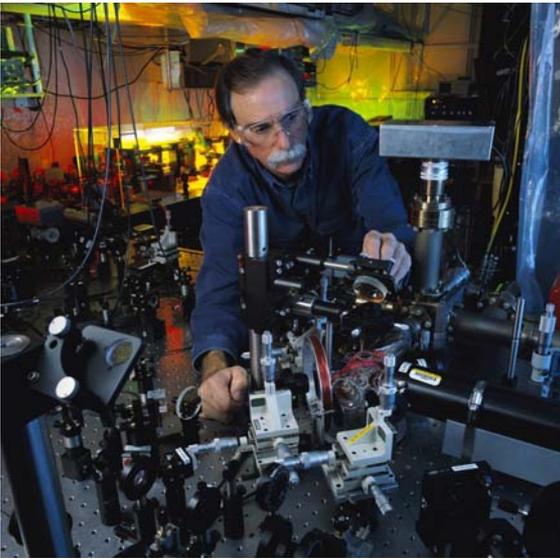


# Implementation of Strategic Planning in the Time and Frequency Division



[tf.nist.gov](http://tf.nist.gov)

# Implementation of Strategic Planning in the Time and Frequency Division

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## Outline:

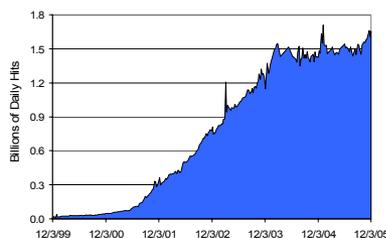
- Brief review of Time and Frequency Division mission and activities.
- Division strategic planning processes.
- Examples of strategic outcomes.

# NIST Time and Frequency Division

Time and Frequency Distribution Services



*Radio broadcasts*



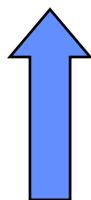
*Networks*



*Satellites*



*Noise metrology*



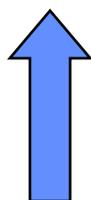
Primary Frequency Standard and NIST Time Scale



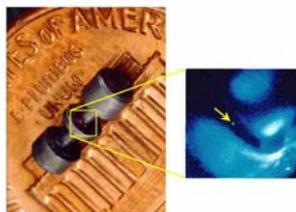
*NIST-F1*



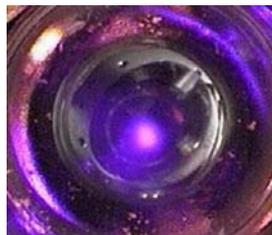
*Hydrogen Maser & Measurement system*



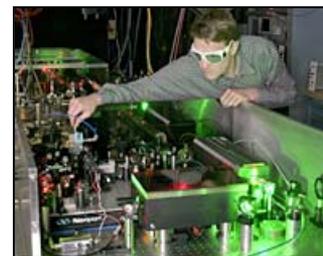
Research on Future Standards



*Mercury ion clock*



*Neutral calcium clock*



*Optical frequency synthesis*



*Quantum computing*

# NIST Time and Frequency Division Strategy

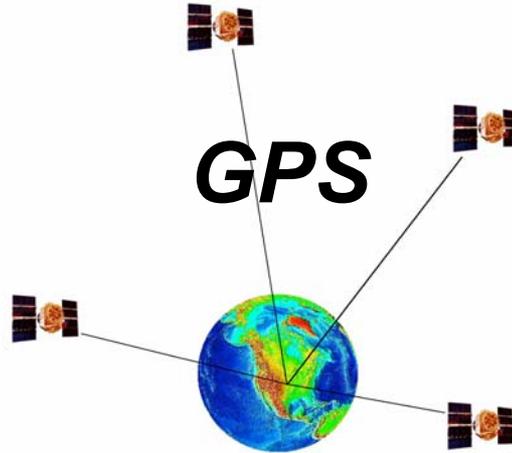
---

- Realize the SI second and Coordinated Universal Time (UTC) with the greatest possible accuracy.
- Efficiently disseminate time and frequency and directly related quantities to a broad range of customers.
- Develop new methods to realize and disseminate the SI second, UTC, and related quantities to meet future needs.

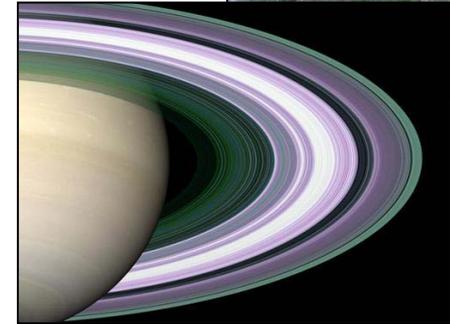
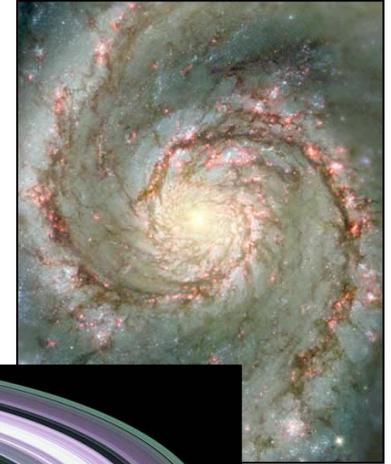
# Time and Frequency Standards Customers



**Telecommunications**



**Navigation,  
Geodesy**



**Astronomy, Space  
Exploration,  
Fundamental  
Research...**



**Electrical Power**

# Key Features of Division Mission and Strategy

---

- Tightly focused on a single SI unit (second) and its immediately related quantities.
- Broad range of customers.
  - Highest level industry customers.
  - Highest level Federal agency customers.
  - International time and frequency coordination.
  - Moderate/lower-end customers in industry and government.
  - General public
- Unique Division research and measurement infrastructure.
  - SI unit and UTC realization, measurement services, research all directly linked and inter-dependent.
- Highly specialized knowledge.
  - Long period of on-the-job training.

# General Division Strategic Planning

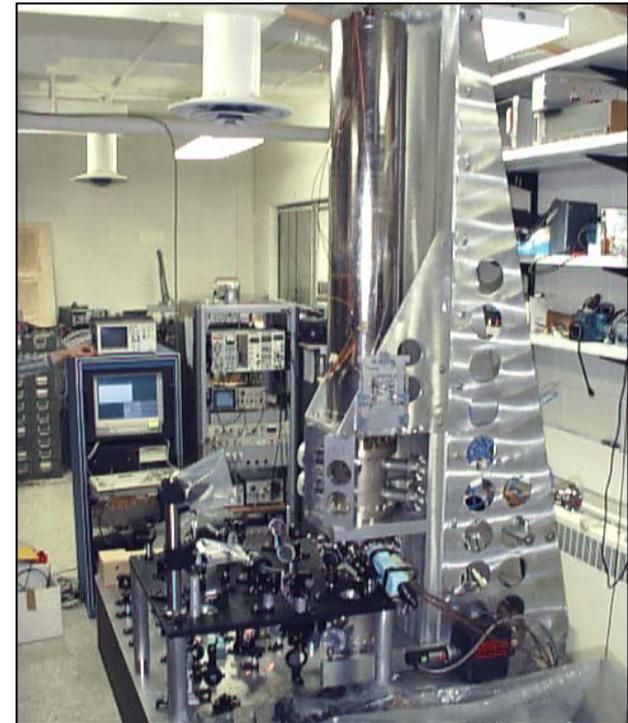
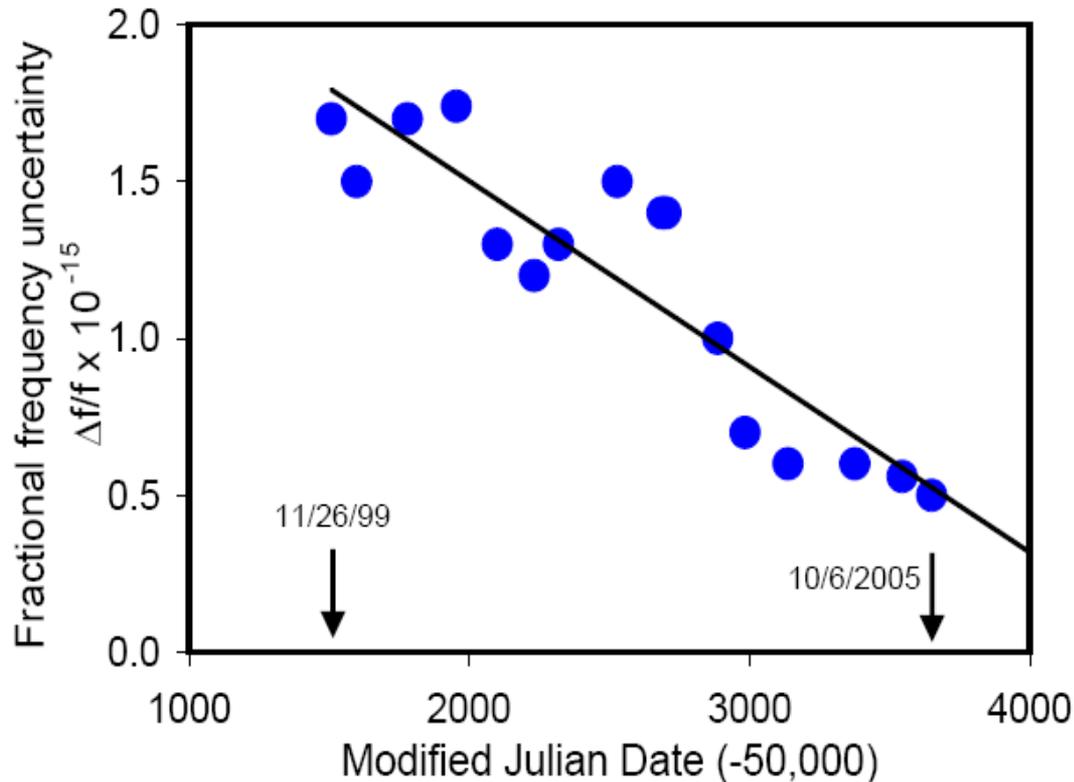
---

Close consultation with key stakeholders in industry, Federal government, international community, NIST/Administration to determine current and future needs for precision timing and frequency.

- Current and potential future customers.
- Division-hosted seminars and workshops for industry, government, academia, international metrology labs.
- Division co-sponsored needs workshops at major international time and frequency conferences.
- Division staff participate on planning committees for GPS, DoD projects, NASA projects, etc.
- Division staff serve as consults for government agency planning.
- Participation in international planning of future time and frequency coordination.
- Administration science and technology priorities.
- Physics Laboratory and NIST Strategic Planning.
- External advisory groups: NRC, VCAT, etc.

# SI Second Realization

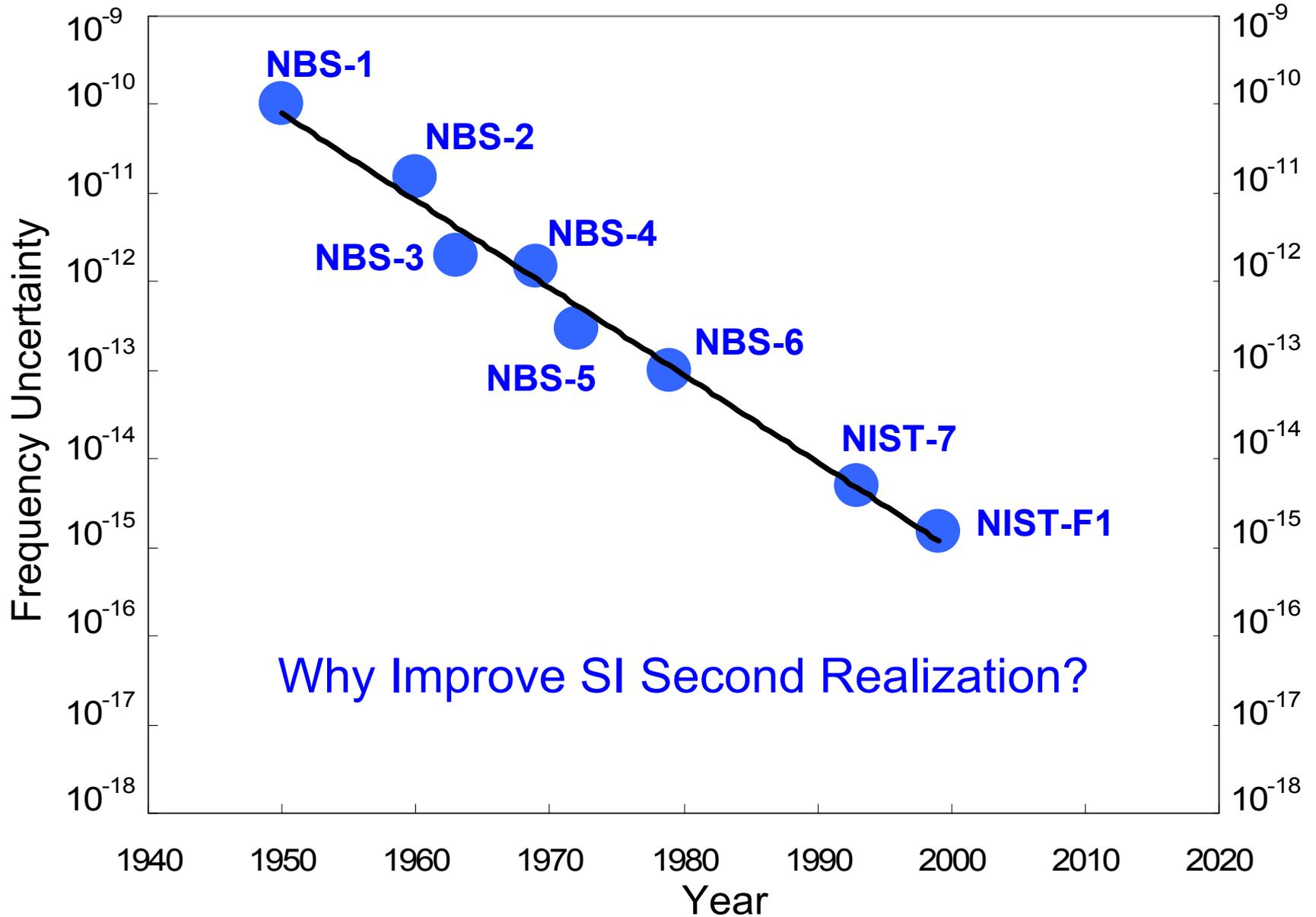
## NIST-F1 Frequency Uncertainty (In-House)



## NIST-F1 Cesium Fountain Standard

- SI second = 9,192,631,770 periods of  $^{133}\text{Cs}$  hyperfine transition.
- $0.5 \times 10^{-15}$  in-house frequency uncertainty for NIST-F1.
- $<0.9 \times 10^{-15}$  frequency uncertainty reported to BIPM.
- Best in the world.

# SI Second Realization



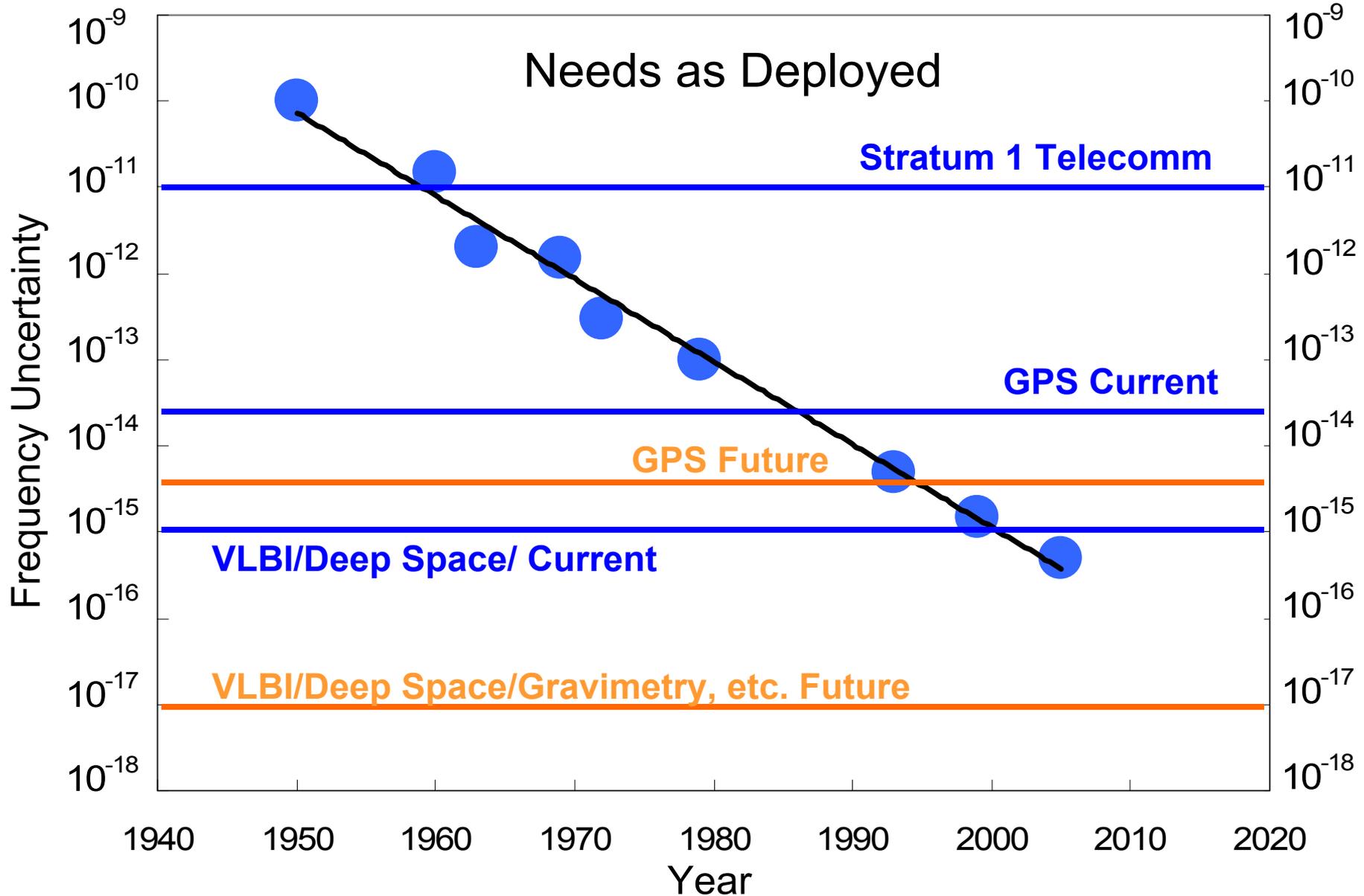
# General Division Strategic Planning

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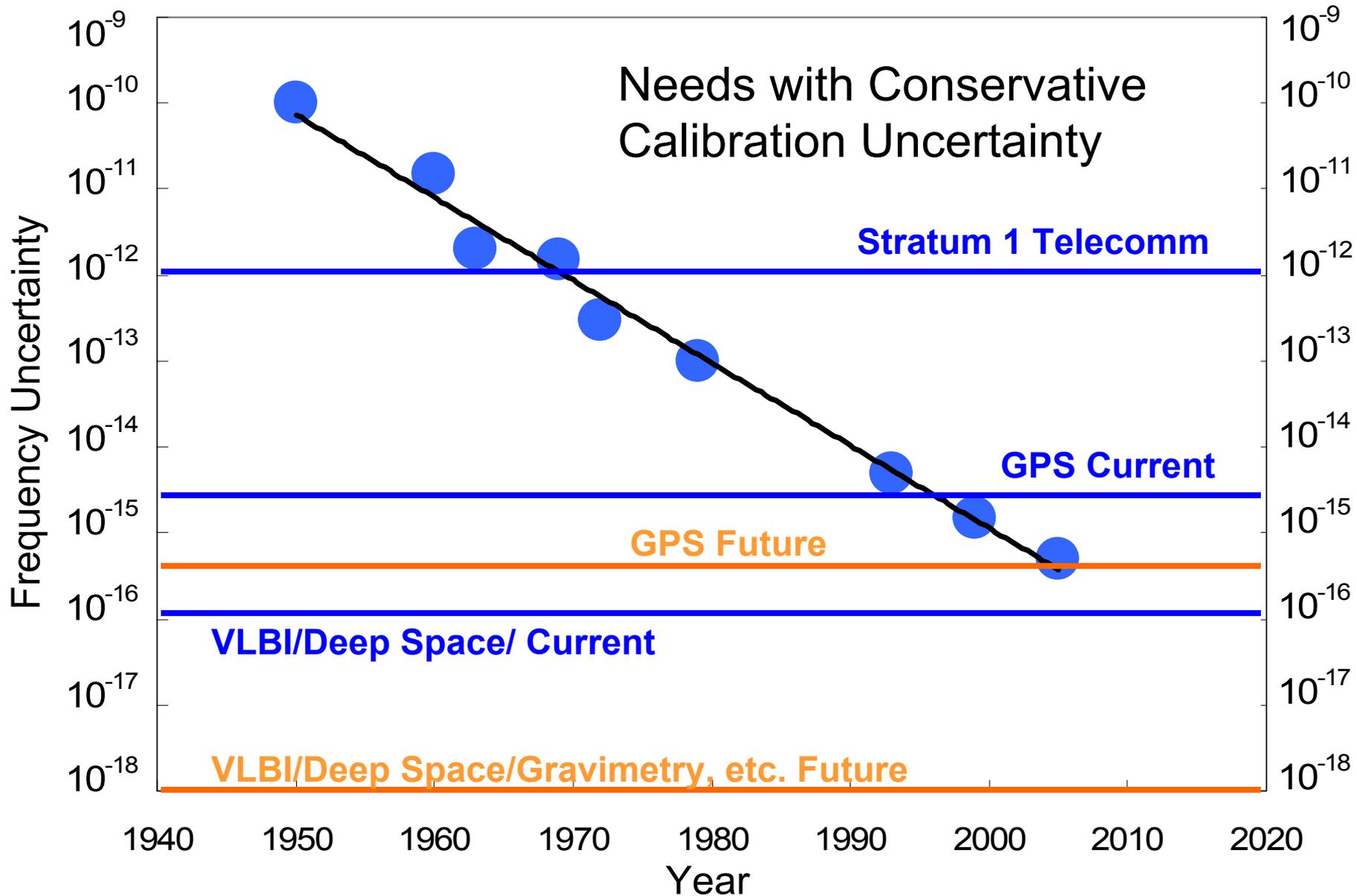
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# SI Second Realization



# SI Second Realization



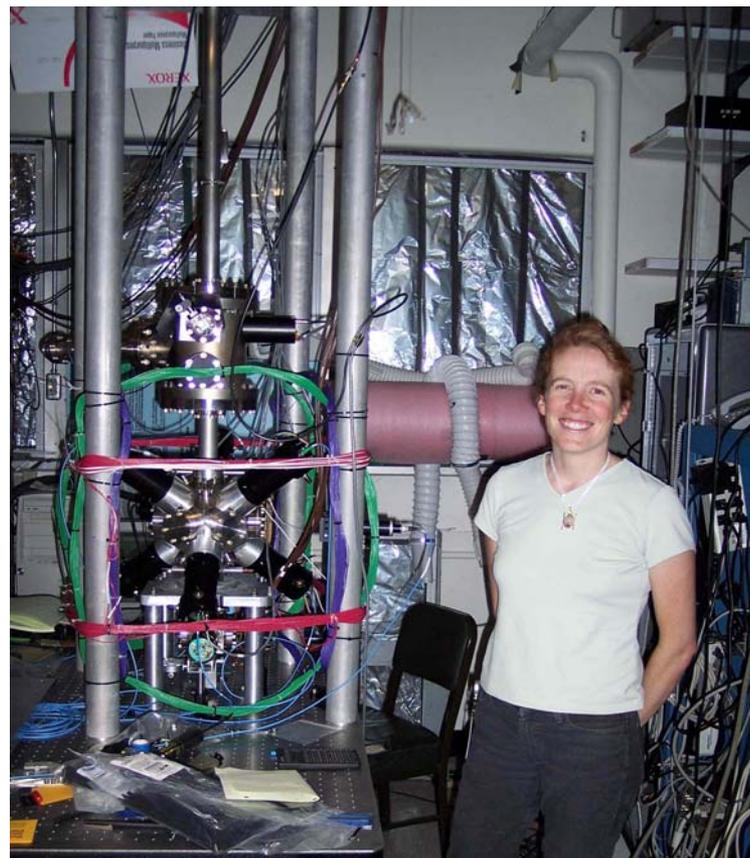
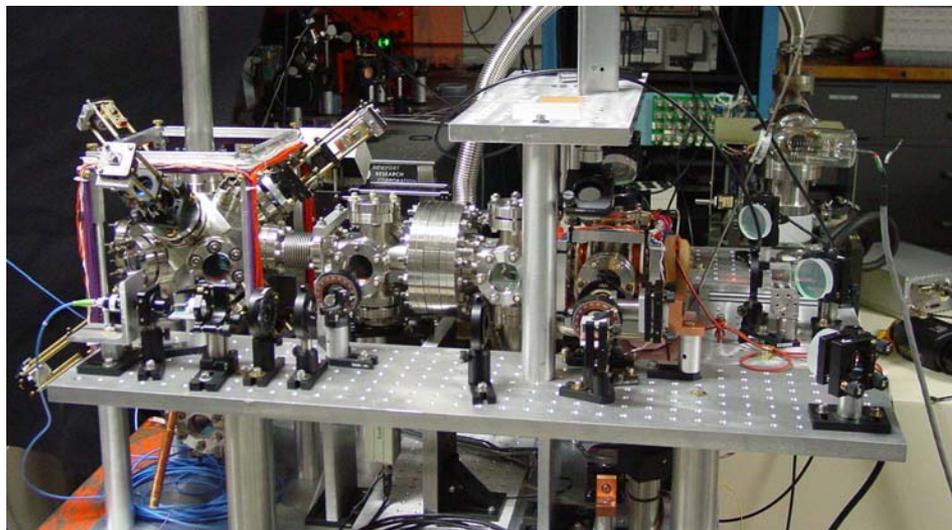
# SI Second Realization

---

To meet current and future needs:

- Short-term strategy
  - Second generation cesium fountain primary frequency standard to  $\sim 1 \times 10^{-16}$  uncertainty.
  - Initial deployment  $\sim$  June 2006.
  - Ultimate uncertainty  $\sim$  2008.
- Longer-term strategy.
  - Optical frequency standards to  $\sim 10^{-17}$  uncertainty by  $\sim$  2012.
  - Optical frequency standards to  $\sim 10^{-18}$  uncertainty by  $\sim$  2018
  - Research on multiple candidates.
    - Cold neutral atoms in lattices.
    - Single trapped ion.
    - “Logic clock” – principles of quantum computing applied to frequency standards.
    - Develop final candidate(s) into primary standards  $\sim$  2010.

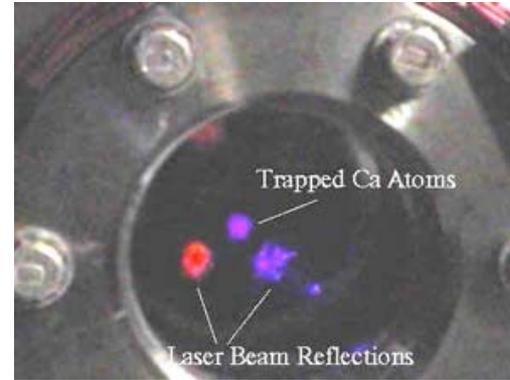
# NIST-F2 Primary Frequency Standard – Development



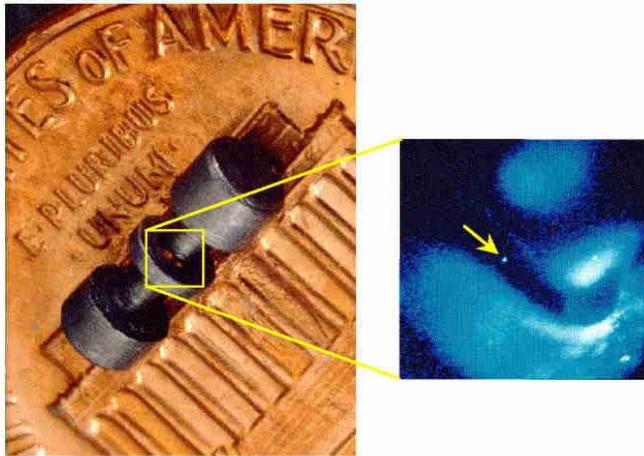
*NIST-F2 prototype components*

# Optical Primary Frequency Standards – Development

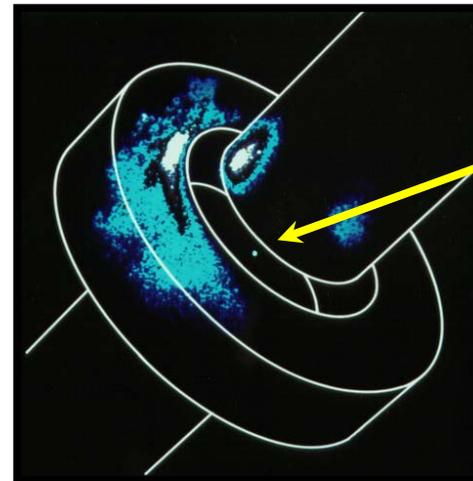
- Optical clocks have the potential for accuracy at the  $10^{-18}$  level, more than 100 times better than NIST-F1.



**Laser-cooled calcium atoms.**

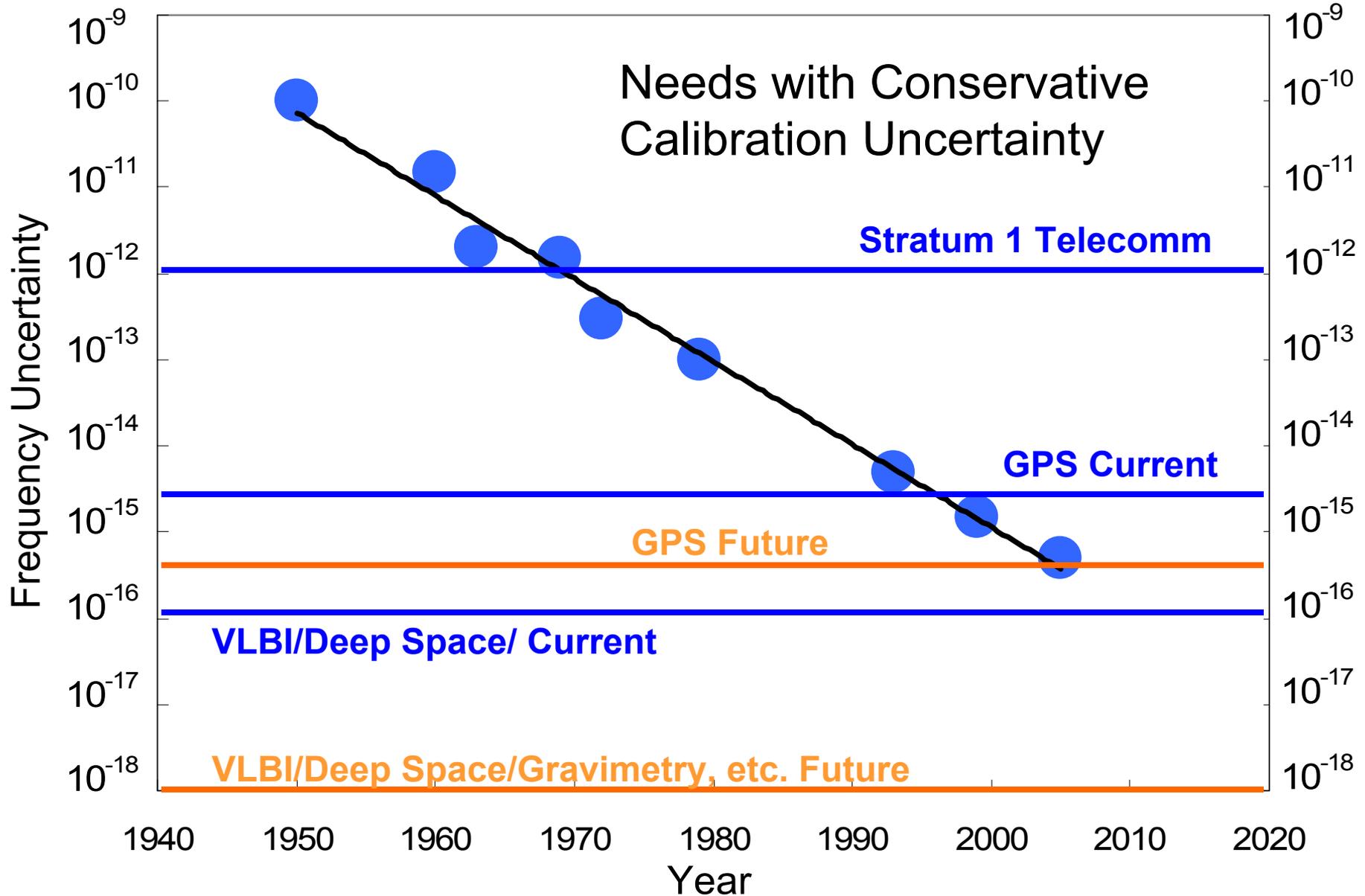


**Single mercury ion trap.**

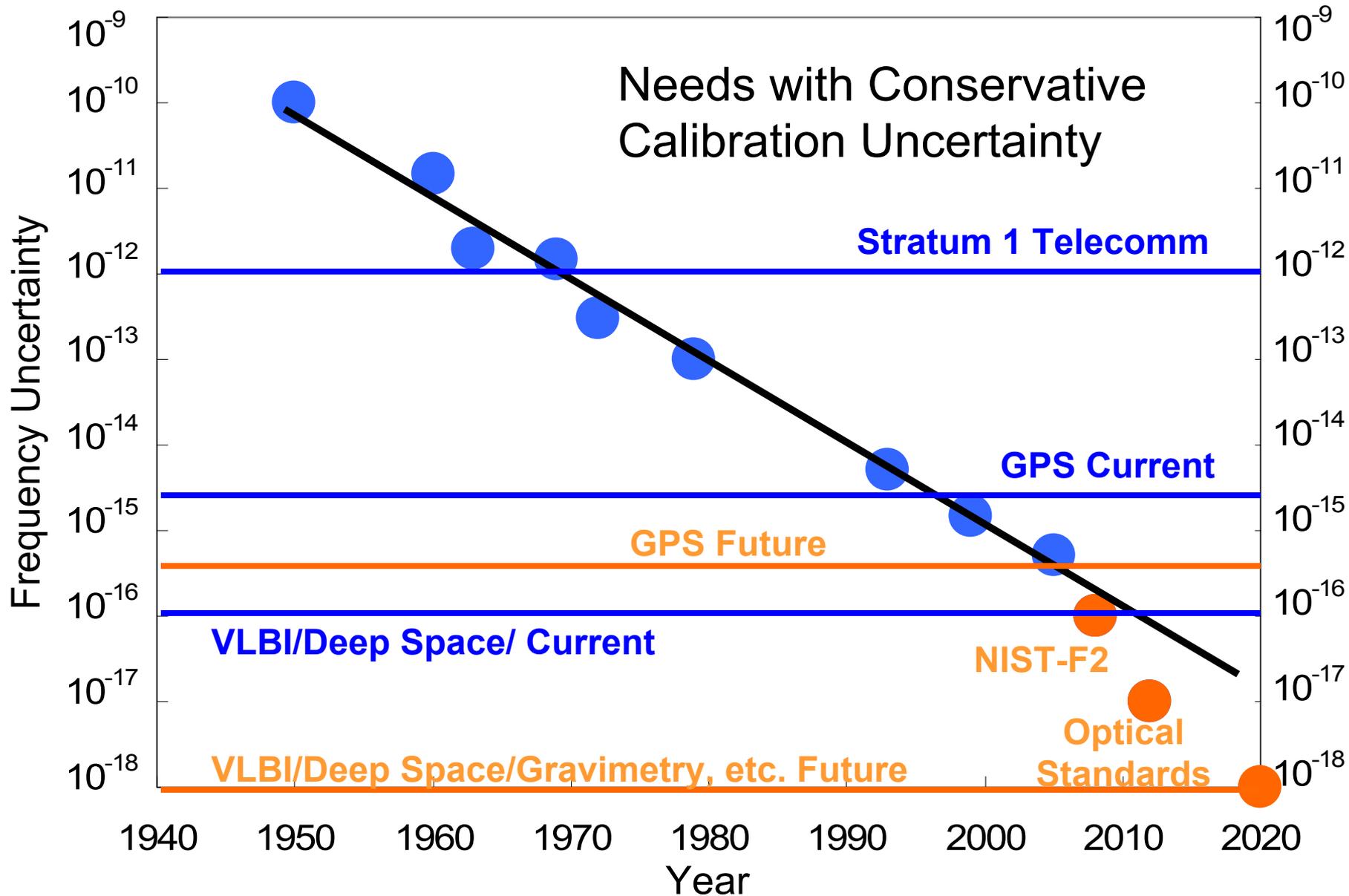


**Single mercury ion.**

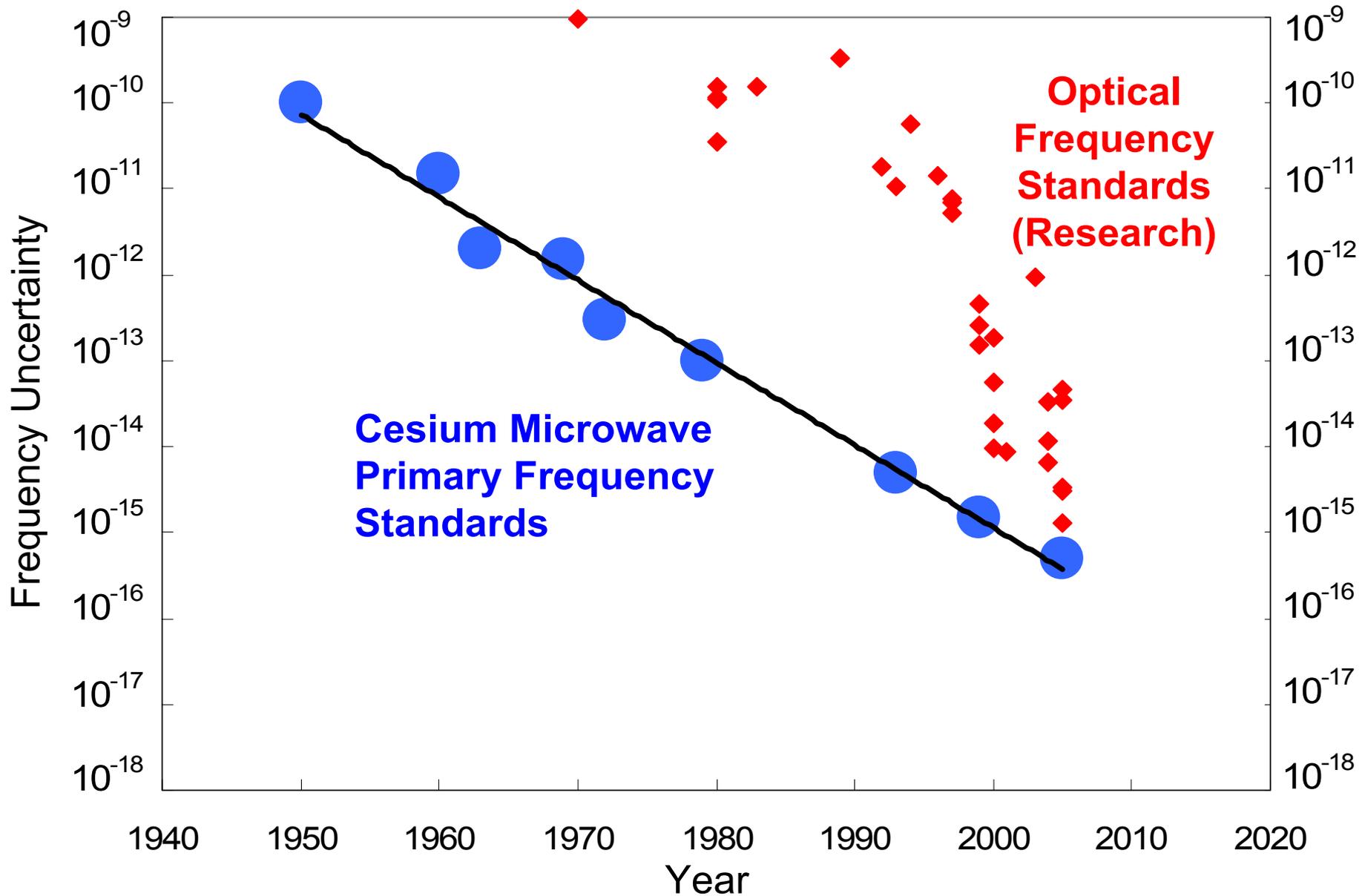
# SI Second Realization



# SI Second Realization



# SI Second Realization



# NIST Time Scale

## 4 Cesium Beam standards



## 5 Hydrogen Masers



UTC(NIST)

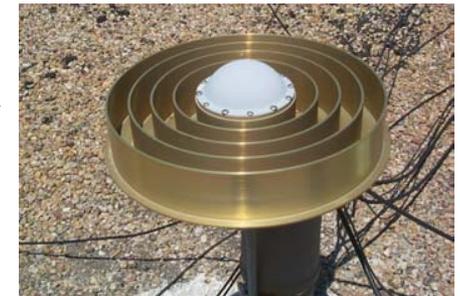


Measurement System

## Two-way satellite time & frequency transfer



GPS

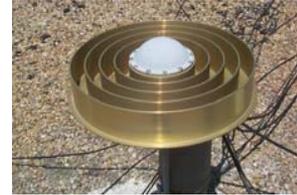


# NIST Time and Frequency Measurement Services

Serve the most demanding needs of timing laboratories, research laboratories, telecomm industry, etc.

## Global Time Service

- Calibrate remote clock with respect to UTC(NIST) via Common-View GPS.
- 10 ns uncertainty.
- Daily preliminary analysis and monthly report.



## Frequency Measurement and Analysis Service

- Full measurement system (“black box”) with continuous remote monitoring by NIST.
- “In-house”  $\Delta f/f \sim 2 \times 10^{-15}$ .
- GPS transfer  $\Delta f/f \sim 2 \times 10^{-13}$ .

# General Division Strategic Planning

---

Close consultation with key stakeholders in industry, Federal government, international community, NIST/Administration to determine current and future needs for precision timing and frequency.

- Current and potential future customers. [Customer surveys – current satisfaction and future needs..](#)
- Division-hosted seminars and workshops for industry, government, academia, international metrology labs.
- Division co-sponsored needs workshops at major international time and frequency conferences.
- Division staff participate on planning committees for GPS, DoD projects, NASA projects, etc.
- Division staff serve as consults for government agency planning.
- Participation in international planning of future time and frequency coordination.
- Administration science and technology priorities.
- Physics Laboratory and NIST Strategic Planning.
- External advisory groups: NRC, VCAT, etc.

# Time and Frequency Division Customer Survey (2001)

The screenshot shows a web browser window with the URL <http://tf.nist.gov/timfreq/survey/survey.htm>. The page header includes the NIST logo and the text "Physics Laboratory Time & Frequency Division". The main content area is titled "Results of 2001 Customer Satisfaction Survey".

The page contains several sections:

- Home**: Links to Welcome, Current Time, Exhibits, FAQ, Glossary, Links, Publications, Staff, Postdoctoral Opportunities.
- Radio Stations**: Links to WWV, WWVH, WWVB.
- Services**: Links to Computer Time, Telephone Time, Calibrations, Seminars, Survey Results.
- Standards**: Links to NIST-F1, Space Clock, History.
- Time Transfer**: Links to GPS, Digital Time, Two Way.
- Metrology**: Links to Phase Noise, Tutorial.

The main text of the survey results includes:

**Results of 2001 Customer Satisfaction Survey**

The Time and Frequency Division of the National Institute of Standards and Technology conducted a customer use survey from April through September, 2001. The bar graphs on the following pages illustrate the results of the survey.

Three methods were used to advertise the availability of the survey. A voice announcement was placed on the [WWW / WWVH](#) high frequency broadcast, advertisements were placed in several trade magazines dealing with time-and-frequency technology, and a link was established from this web site. Nearly 15,000 people responded to this survey with the vast majority of submissions arriving via the internet. This more than doubles the responses received in the last customer satisfaction survey conducted by the Time and Frequency Division in 1987.

Please keep in mind that a large segment of our customers were difficult to alert to the availability of the survey. These include users of the [WWVB](#) low frequency broadcast, the [Internet Time Service](#) and the [Automated Computer Time Service](#). We have direct evidence of the popularity of these services and yet the survey does not directly reflect this due to the low participation rate of these customers.

**Survey Results**

- [WWV and WWVH](#)
- [WWVB](#)
- [Overview of Other Services](#)
  - [ACTS](#)
  - [Internet Time Service](#)

**Survey Results**

- [WWV and WWVH](#)
- [WWVB](#)
- [Overview of Other Services](#)
  - [ACTS](#)
  - [Internet Time Service](#)
  - [Web Page](#)
  - [Telephone Time-of-Day Service](#)
- [Miscellaneous Questions](#)
- [Customer Data](#)

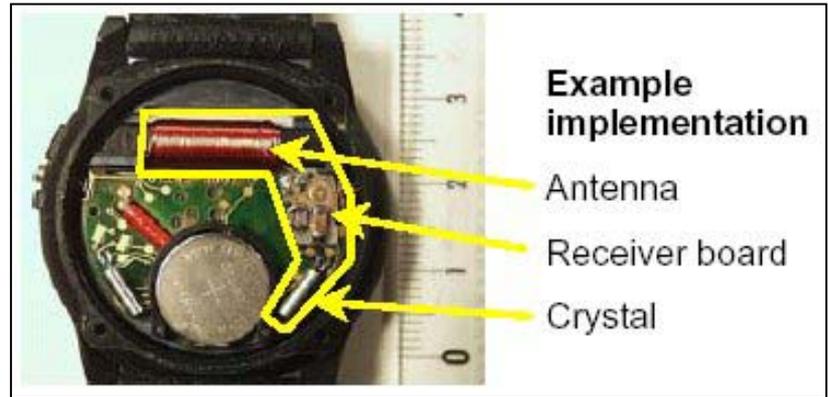
**User Comments**

- [Would the value of this service be decreased if only a high quality voice announcement were available without the weather, geoalert or GPS status information?](#)
- [What present service do you feel needs improvement and what type of improvement \(i.e. stability, coverage, added features...\)?](#)
- [What new time and frequency service would you find useful? \(Please explain briefly\)](#)
- [Additional Comments Submitted by Respondents](#)

[Return to home page](#)

- Survey on radio broadcasts, ACTS, Internet Time Service use and customer satisfaction.
- Nearly 15,000 responses.
  - About 2/3 “consumer” applications.
  - About 1/3 “technical” applications.
- All results posted on public Time and Frequency Division web site.
- Specific questions about NIST time and frequency services.
- Four open-ended questions.
  - About 8,000 written responses, nearly all highly complimentary.
- *“You're doing a great job. Wish my income taxes were spent as wisely elsewhere in the government!”*
- *“Wonderful service. Have used it for years. One of the best functions the US Gov't furnishes.”*
- *“Great service - if more people knew about it, it would be used more.”*

# WWVB Use – Radio-Controlled Timepieces



Example implementation

Antenna

Receiver board

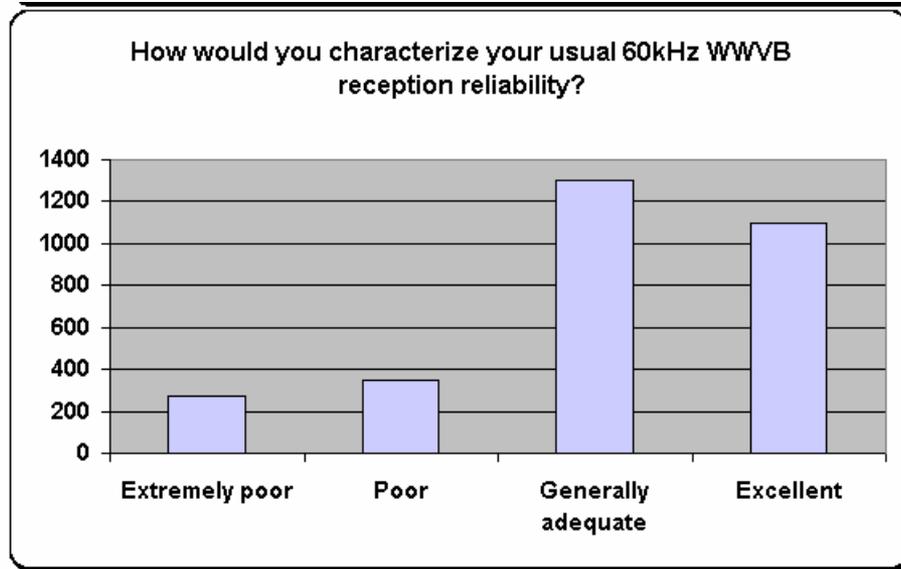
Crystal

WWVB-controlled wristwatch

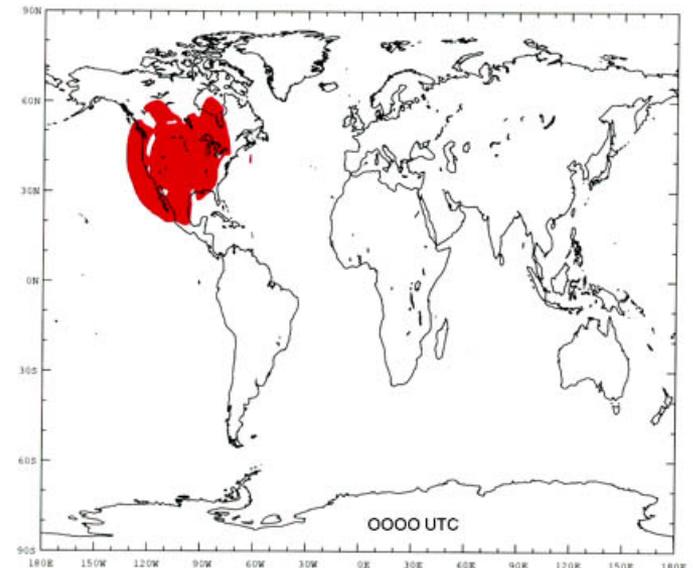
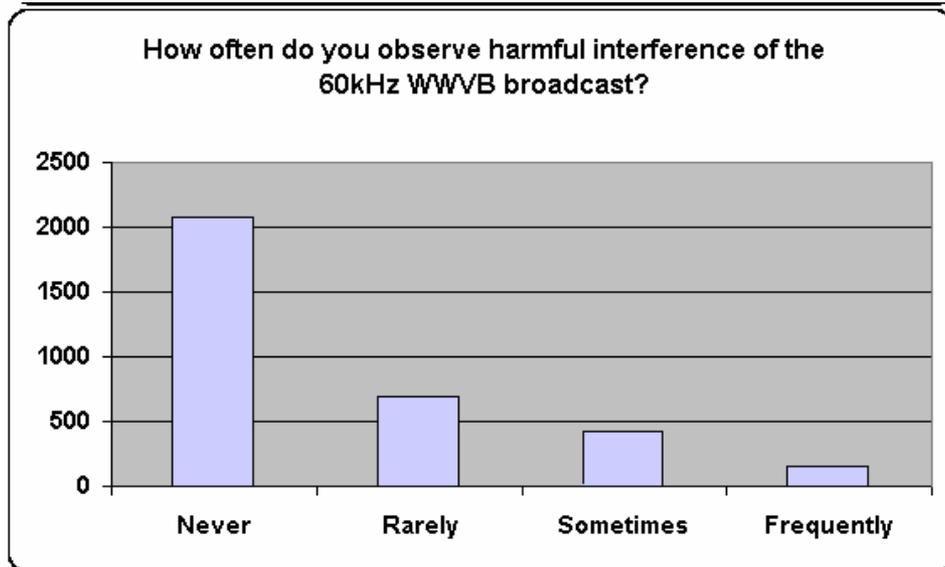


NIST 60 kHz Radio Station WWVB  
Colorado

# WWVB Use – Radio-Controlled Timepieces



Too many respondents indicate poor WWVB reception and/or presence of interference (which often indicates marginal WWVB broadcast power at receiver).



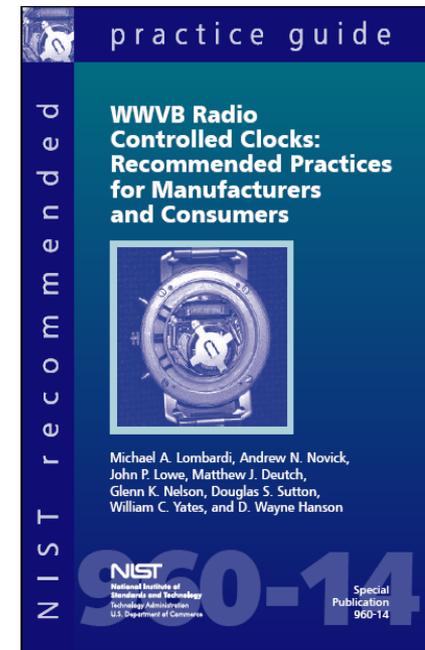
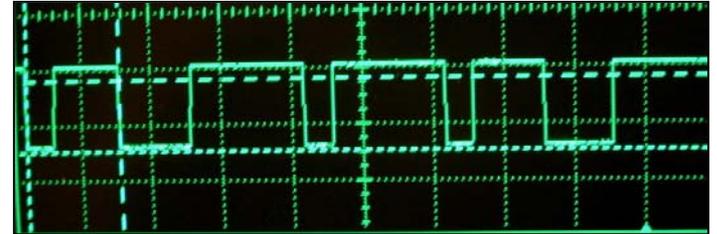
# WWVB Use – Radio-Controlled Timepieces

## Challenge:

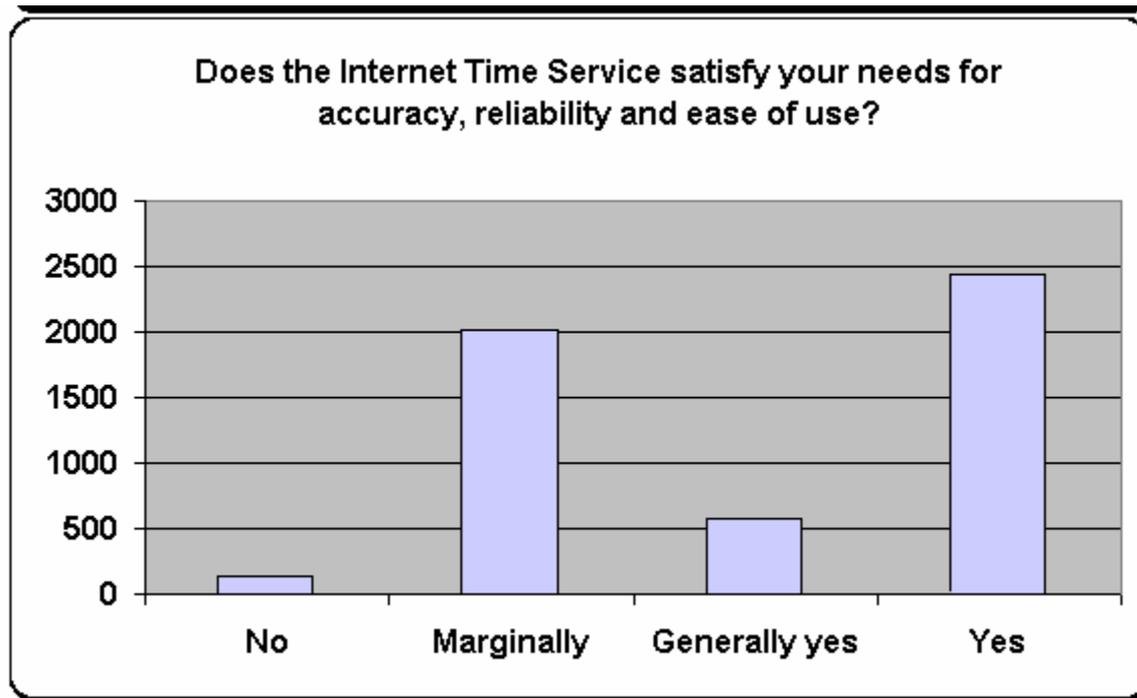
Too many respondents indicate poor WWVB reception and/or presence of interference (which often indicates marginal WWVB broadcast power at receiver).

## Responses:

- Increase digital signal modulation depth.
  - Experiments with major receiver and timepiece manufacturers.
- Publish recommended practices for radio-controlled timepiece manufactures and users.
  - Winner of 2005 Condon Award for best NIST publication.
  - Sales of radio-controlled timepieces have increased by about a factor of 10 since 2001.



# Internet Time Service Use



Too many respondents indicate challenges with reliability and ease of use of service.

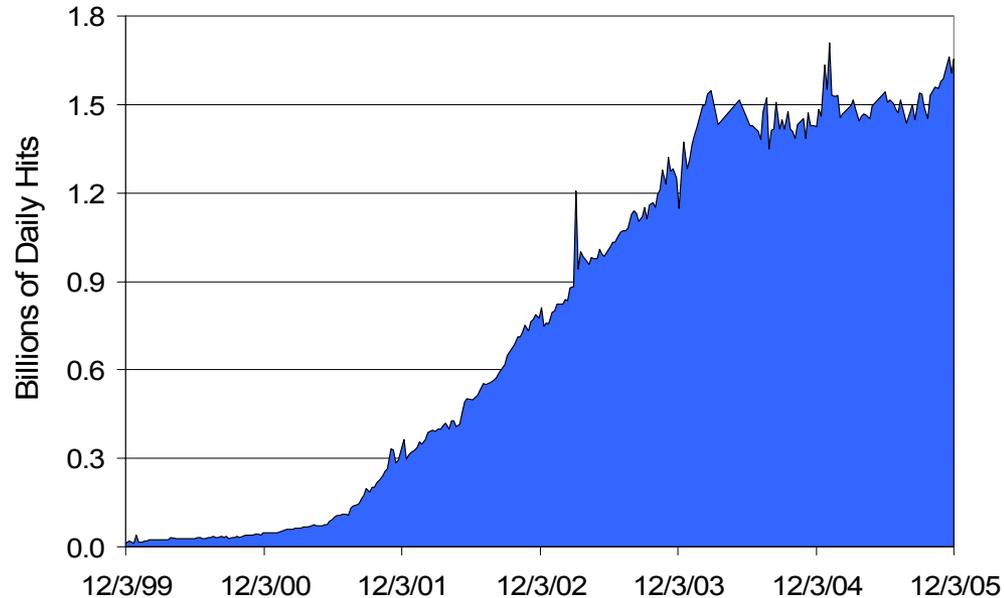
# Internet Time Service Use

## Challenge:

Too many respondents indicate poor reliability or difficulty in ease of use.

## Responses:

- Increase number and geographic distribution of servers.
  - 15 servers.
  - 12 locations across U.S.
- Improvements to service.
  - Automated load balancers.
- Improved documentation of software use readily available on the NIST web site.



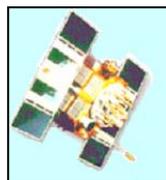
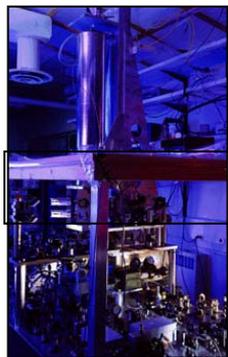
Survey period  
~50 million/day



Today  
~1.6 billion/day

# Applications of Time and Frequency Standards

## NIST-F1



## Very Rough Estimates

$10^{-15}$  clocks  
(0.1/month)

$10^{-13}$  clocks  
(10/month)

$10^{-11}$  clocks  
(1,000/month)

$10^{-9}$  clocks  
(100,000/month)

- Master clocks (long term synchronization)
- Secure communications
- Deep space navigation
- GPS Master clock (ground)

- Large scale communications systems
- Power grids
- GPS Space Clocks
- Local synchronization

- Local communications hubs
- Instrumentation level flywheels

- Short haul navigation
- Local communications

**Opportunities for Improvement?**

# General Division Strategic Planning

---

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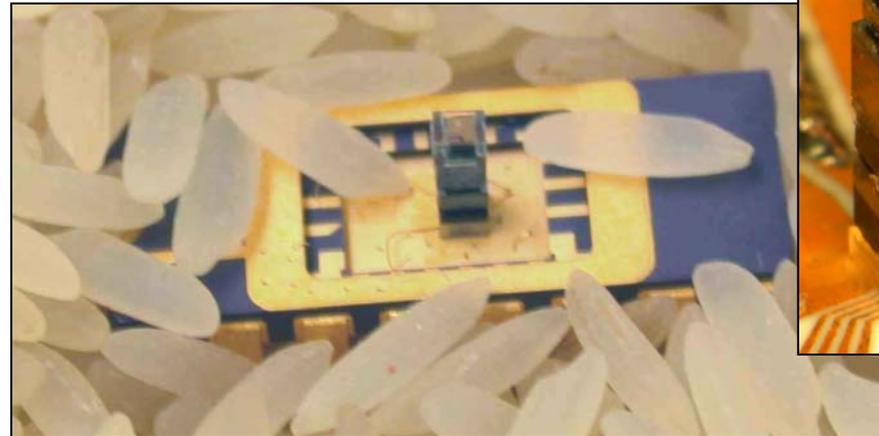
# Strategic Planning Example: Miniature Atomic Clocks

Consultation with industry, government:

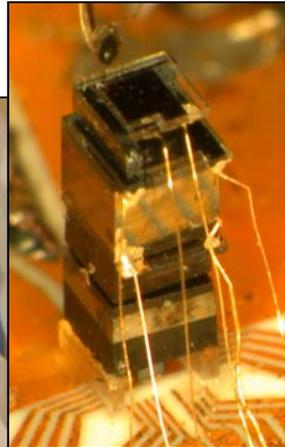
- Ultra-miniature atomic clocks.
- Atomically-precise timekeeping for portable applications.
- Small size, low power, high performance, low cost.



NIST, 2001



NIST, 2004



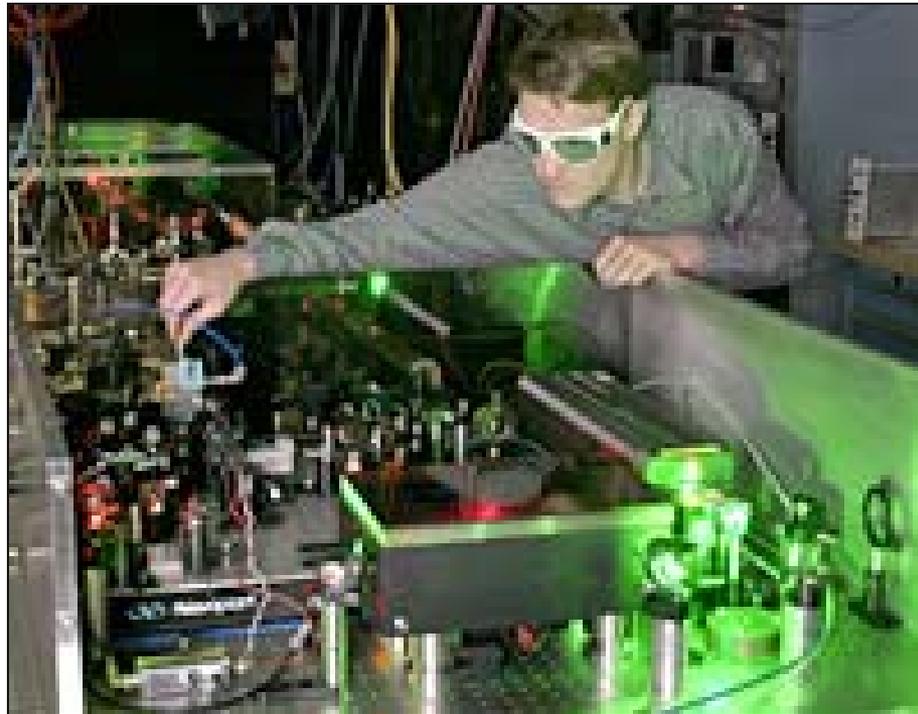
Chip-scale atomic clock  
Chip-scale atomic magnetometer  
Chip-scale precision gyroscope

# Strategic Planning Example: Optical Frequency Standards

Future of primary frequency standards requires evolution from cesium microwave standards to optical frequency standards.

1999: No method to directly “count” optical frequency.

NIST Competence program on optical frequency combs.



# Strategic Planning Example: Optical Frequency Standards

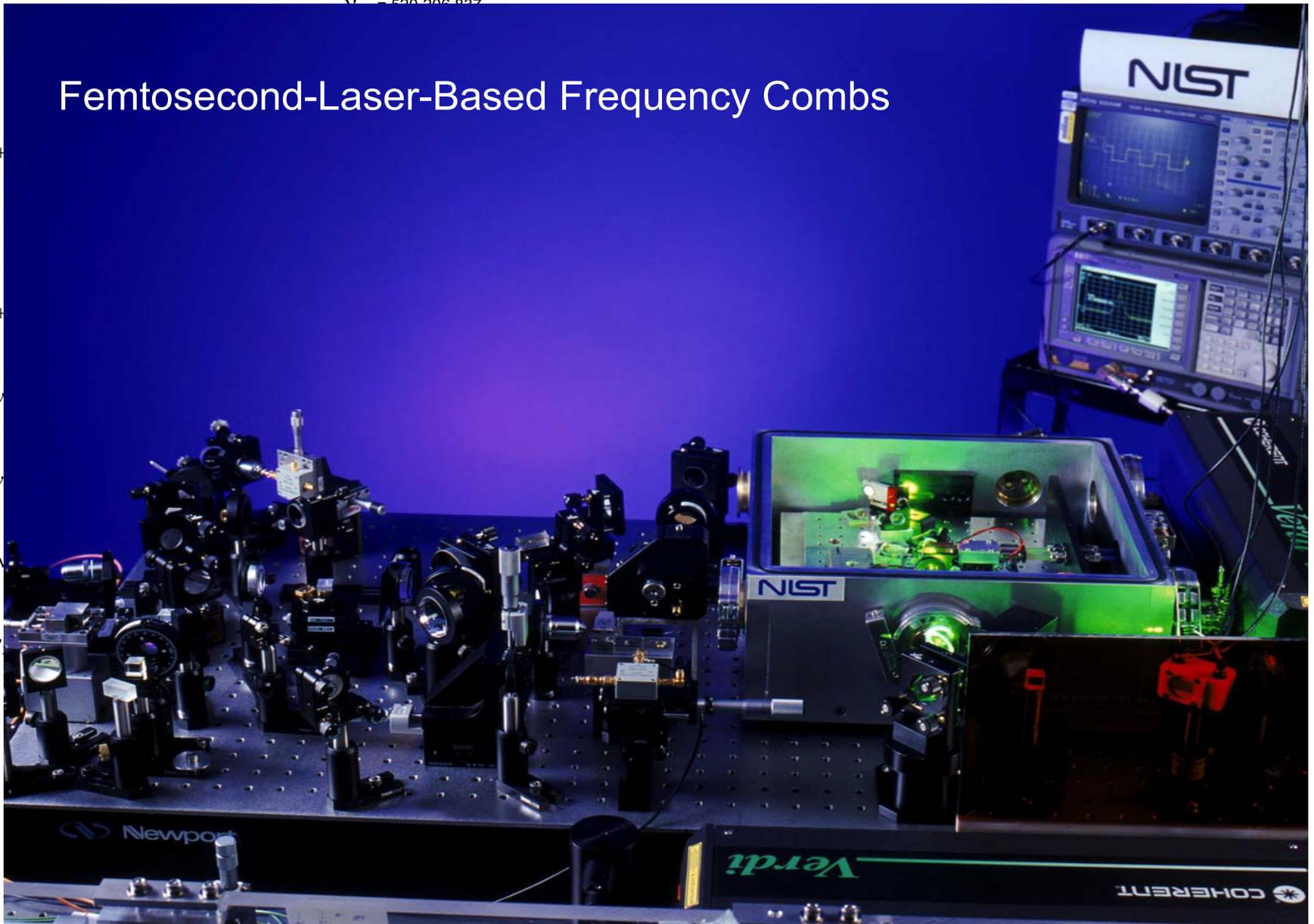
V<sub>9</sub> = 590.206.827

## Femtosecond-Laser-Based Frequency Combs

V<sub>9</sub> = V<sub>8</sub> +

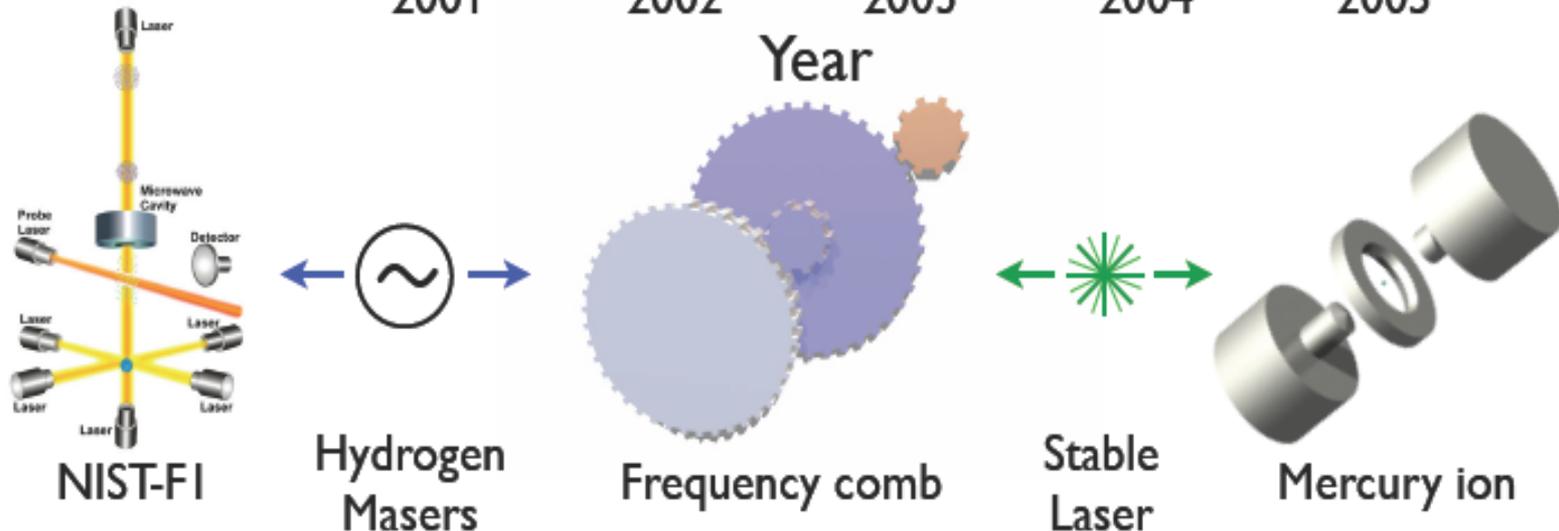
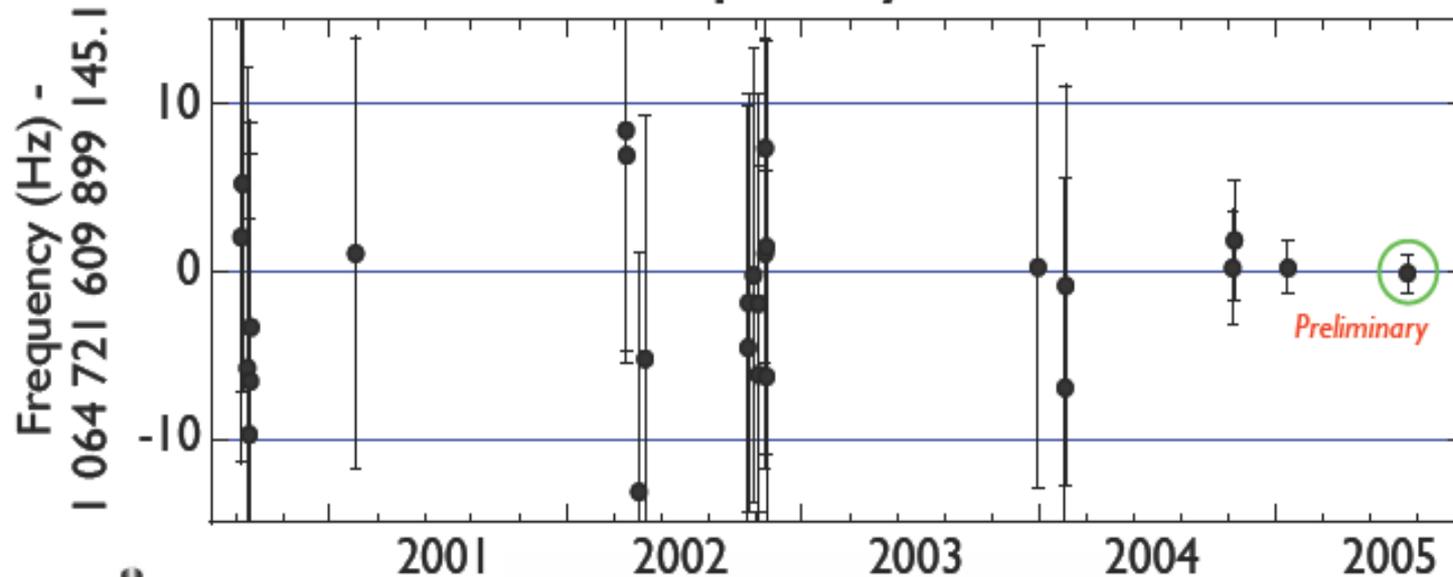
V<sub>7</sub> = V<sub>6</sub> +

V<sub>5</sub> = V



# Strategic Planning Example: Optical Frequency Standards

## Absolute frequency measurements





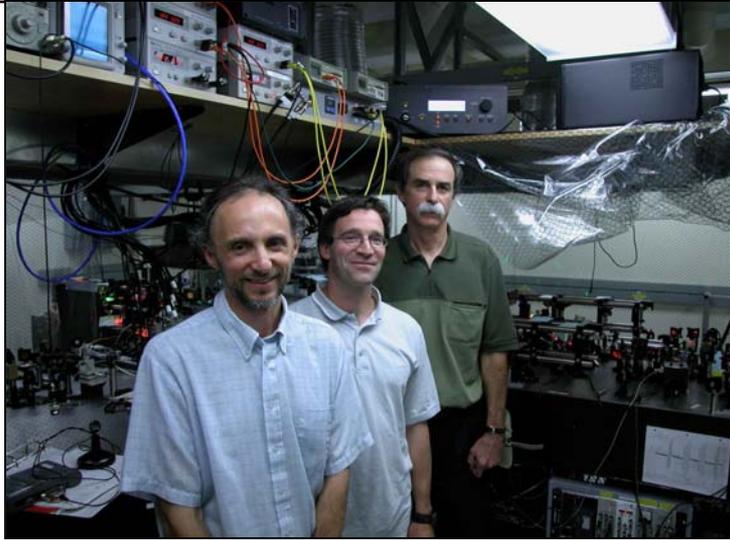
## Lab Tour on Optical Clocks and Frequency Combs This Afternoon



Jan Hall, 2005 Nobel Prize in Physics



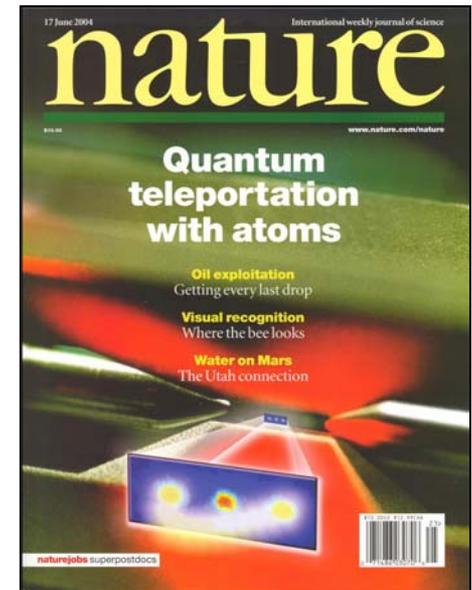
# Strategic Planning Example: Quantum Control



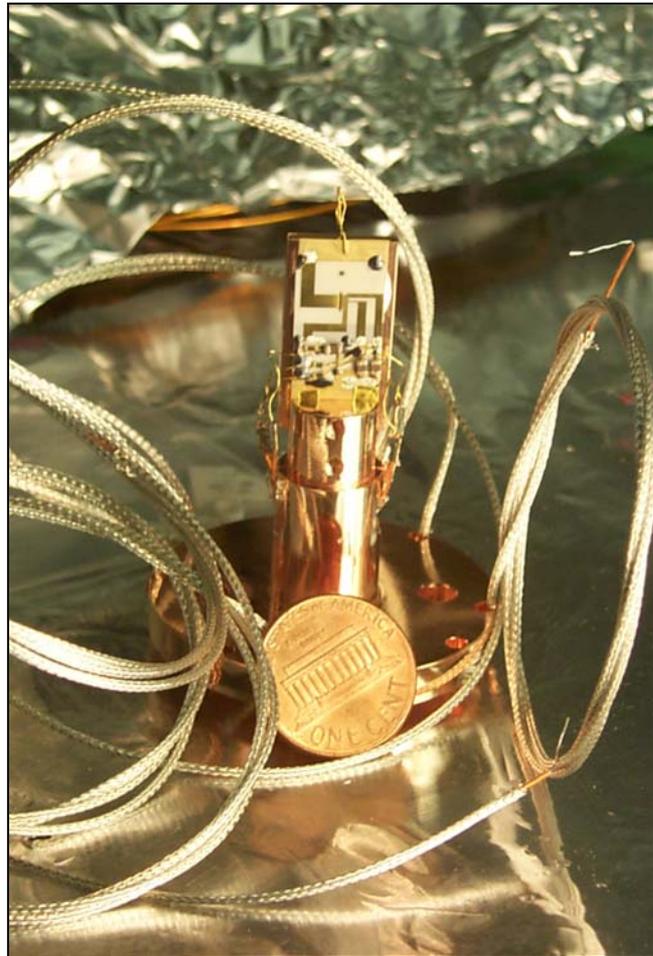
*Manny Knill (ITL), Didi Leibfried,  
Dave Wineland*

- World-class trapped ion quantum computing project as part of NIST-wide Quantum Information Program coordinated by PL's Carl Williams.
- Strong collaboration with Information Technology Laboratory (theory) and Electronics and Electrical Engineering Laboratory (microtrap fabrication).

- Only demonstration of all the components of a scalable quantum computer (DiVincenzo criteria).
- Multiple world's firsts and world's bests in quantum computing.

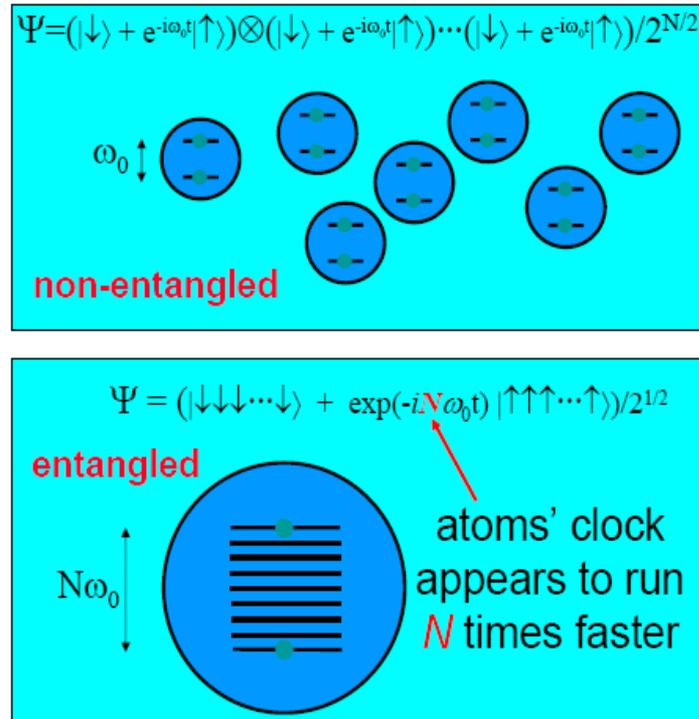


# Strategic Planning Example: Quantum Control



“Logic Clock”

Principles of quantum computing applied to frequency standards.



required averaging time reduced by  $N$

$N = 3$  demonstration  
NIST  
*Science*, June 2004

Entangled State Measurements

# Strategic Planning Challenges

---

Facilities

Budget

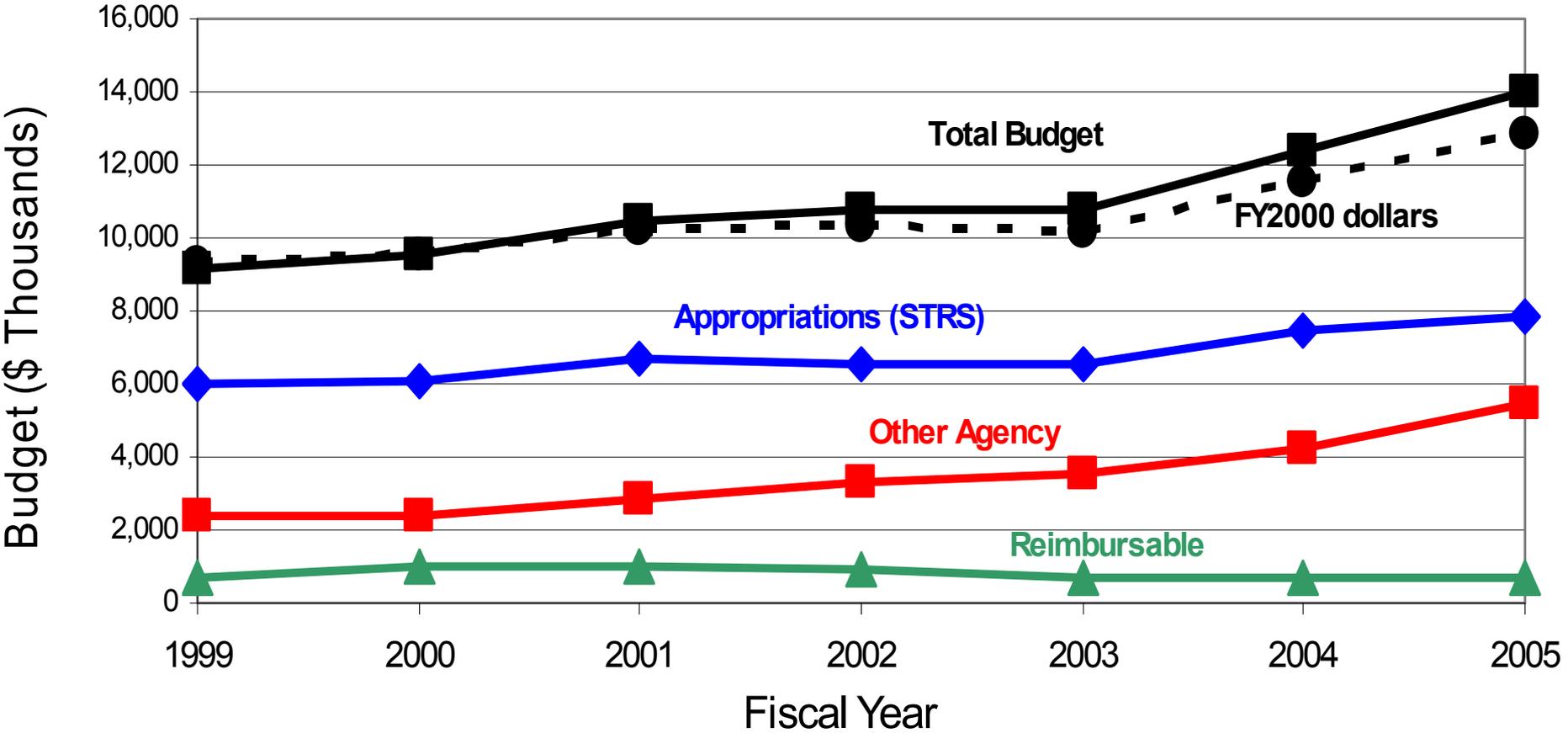
People

# NIST-Boulder Laboratories Facilities

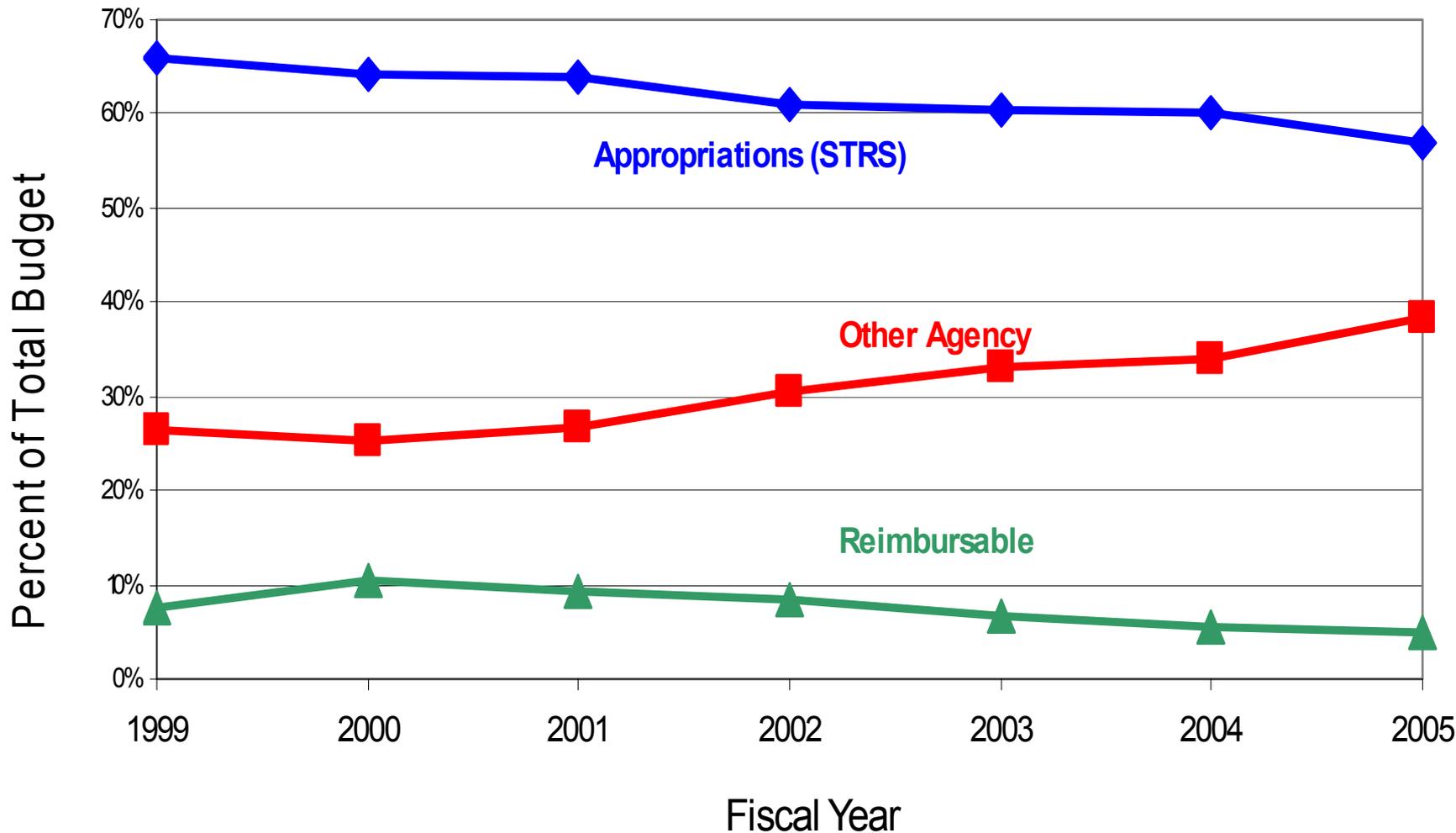
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- Facilities built in 1952 inadequate for 21<sup>st</sup> century metrology and research.
- Lost productivity for existing measurements and research.
- Lost opportunities for more demanding measurements and research.
- Long-delayed renovations urgently needed.

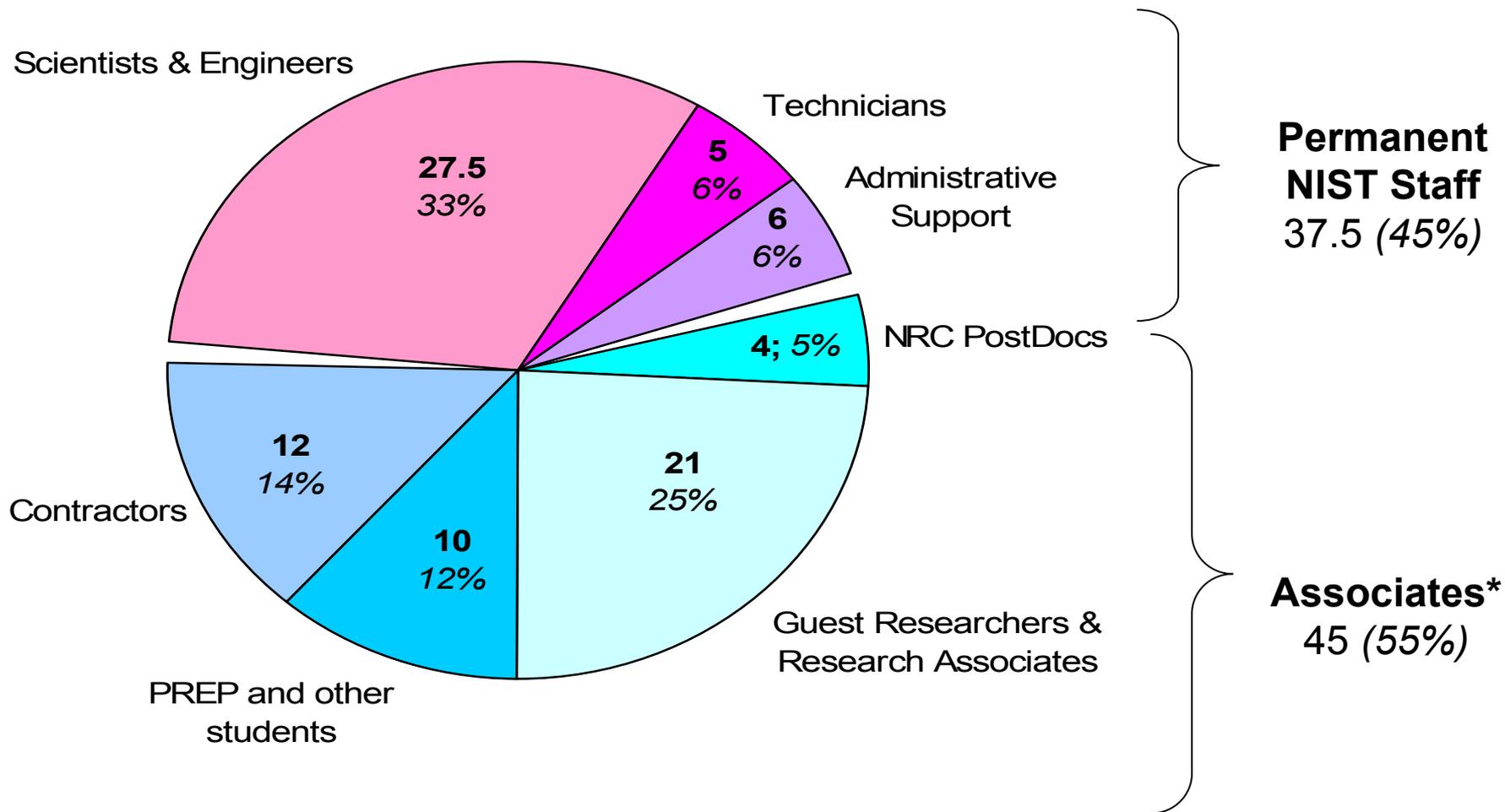
# NIST Time and Frequency Division – Budget Trends



# NIST Time and Frequency Division – Budget Trends



# NIST Time and Frequency Division Staff



*\*Numbers vary throughout the year*

# Training in Time and Frequency Research & Metrology

## Formal training provided by Division experts:

- Annual Time and Frequency Metrology Seminar (30<sup>th</sup> annual seminar in 2005).
  - ~60 participants from industry, academia, federal labs.
- New NCSLI Time and Frequency Measurements and Applications Seminar.
- ATIS-T1X1 Synchronization Workshop.
  - ~200 participants from telecomm industry and related organizations.
- Tutorials and Short Courses at several conferences.

## “On-the-job” training provided by Division:

<b>NIST Associates working in Time and Frequency Division</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>
Postdoctoral fellows	7	7	8
Graduate students	5	4	8
Undergraduate students	3	8	6
Summer Undergraduate Research Fellows	N/A	2	3
Guest Researchers and Research Associates	25	27	28

# Training in Time and Frequency Research & Metrology



NIST-Boulder SURF Program

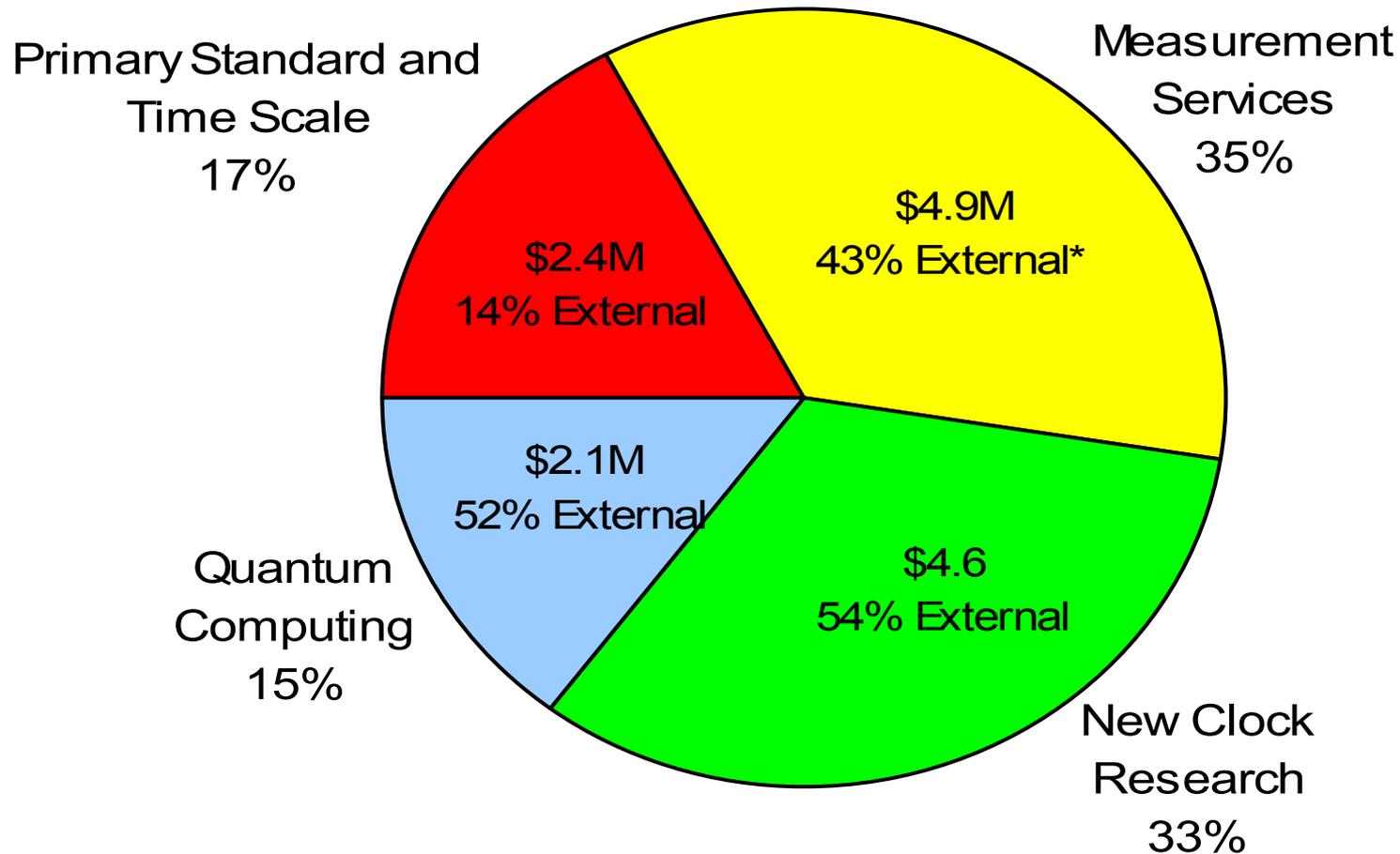
# Key Features of Division Mission and Strategy

---

- Tightly focused on a single SI unit (second) and its immediately related quantities.
- Broad range of customers.
  - Highest level industry customers.
  - Highest level Federal agency customers.
  - International time and frequency coordination.
  - Moderate/lower-end customers in industry and government.
  - General public
- Unique Division research and measurement infrastructure.
  - SI unit and UTC realization, measurement services, research all directly linked and inter-dependent.
- Highly specialized knowledge.
  - Long period of on-the-job training.



# NIST Time and Frequency Division Budget – FY2005



\$14.0M total program budget (FY2005)

56% appropriation, 38% other agency, 6% reimbursable services

*\*Include reimbursable measurement services.*

# NIST/USNO Cooperation and Assignment of Responsibilities

## EQUIVALENCE OF TIME AND FREQUENCY BETWEEN UTC(USNO) AND UTC(NIST)

The Time Service Department of the U. S. Naval Observatory (USNO) and the Time and Frequency Division of the National Institute of Standards and Technology (NIST) agree to the following Equivalence Statement:

### Equivalence Statement

**Time** UTC(USNO) and UTC(NIST) are equivalent to  $\pm 100$  nanoseconds at all measurement intervals longer than 1 second.

**Frequency** Fractional frequencies of UTC(USNO) and UTC(NIST) are equivalent at  $\pm 3 \times 10^{-14}$  for averaging times greater than 1 day.

Fractional frequencies of UTC(USNO) and UTC(NIST) for a two hour averaging time.

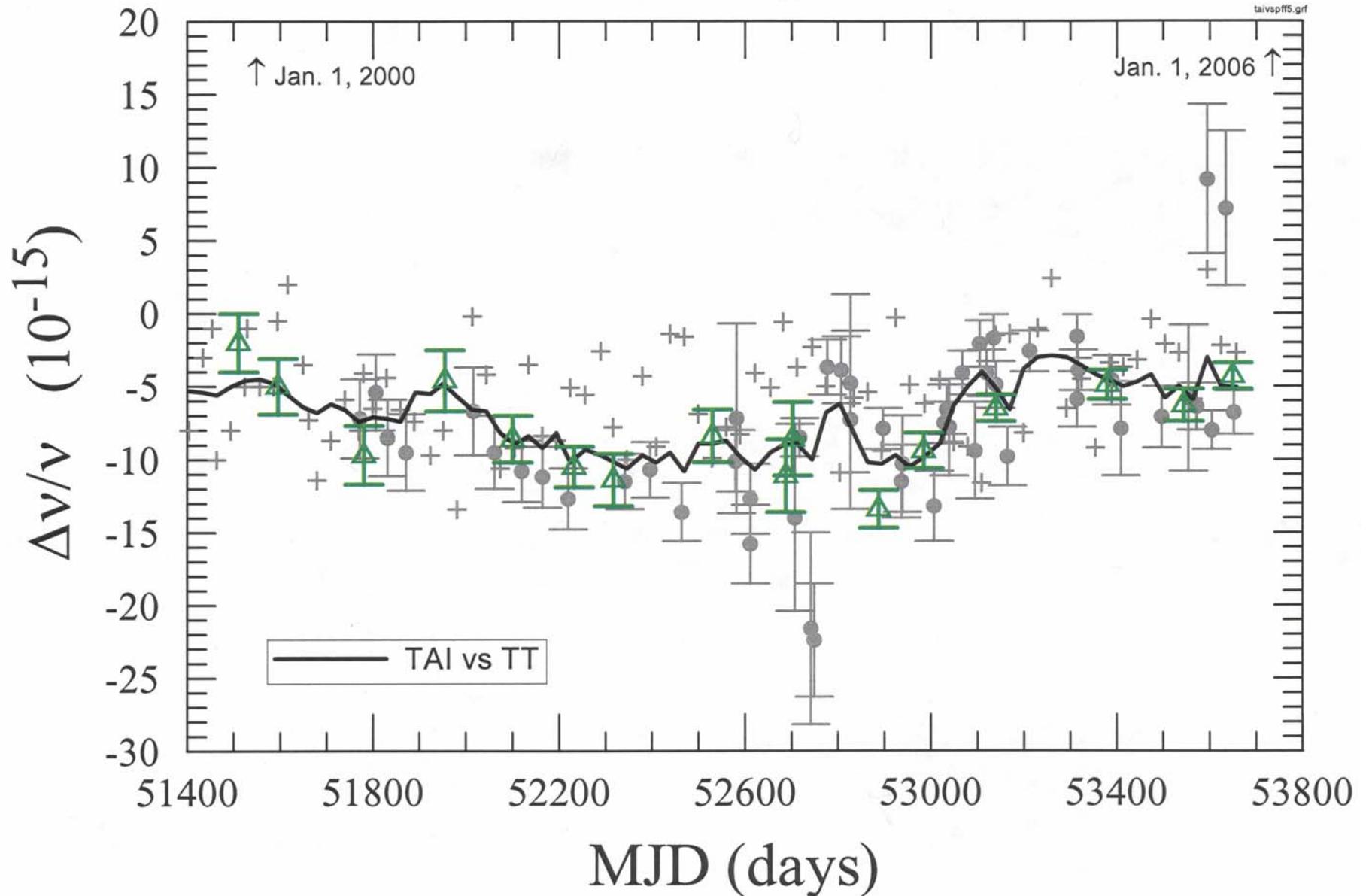
Fractional frequencies of UTC(USNO) and UTC(NIST) for a 100 second averaging time.

## MEMORANDUM OF AGREEMENT BETWEEN NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) and U.S. NAVAL OBSERVATORY (USNO)

1. GENERAL PRINCIPLES
  - 1.1. USNO and NIST will coordinate their programs so that there is no unnecessary overlap (and associated waste) in the content of the two programs.
  - 1.2. Collaborative efforts will be established in areas of mutual interest to assure optimum use of resources of both institutions.
  - 1.3. Areas of mutual interest will be identified, and appropriate staff exchanges will be encouraged to achieve mutual objectives and develop a better mutual understanding of the scope and directions of the two programs.
  - 1.4. USNO and NIST will establish a framework for representing the two programs to the public in a manner that makes it clear that the two programs are well coordinated. A key element of this will be a clear expression of both joint and individual responsibilities for maintaining standards and disseminating time and frequency signals.

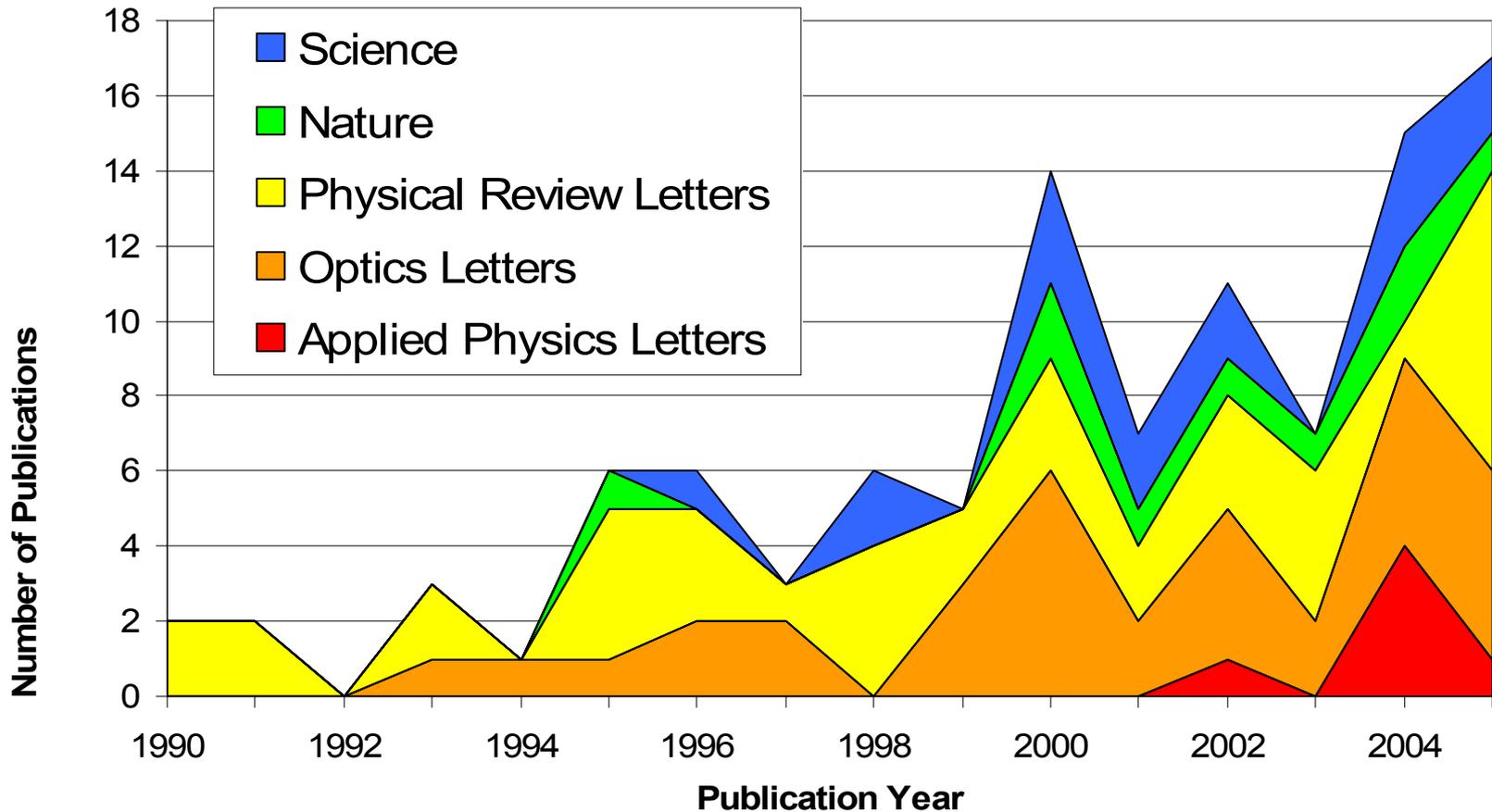
# NIST-F1 International Comparisons

## TAI vs Primary Standards



# Time and Frequency Division Publications

Increases in “high impact” publications.



Calendar year of publication. Partial data for 2005.

# Time and Frequency Division – Examples of Collaborations with Other NIST Programs

---

- **Quantum Information.**
  - Extensive program involving Information Technology Lab, Electronics & Electrical Engineering Lab, and several Physics Lab Divisions.
- **Chip-Scale Atomic Devices.**
  - Chip-scale atomic clocks, magnetometers, gyros, etc.
  - Possibility of low-cost mass production using standard MEMS techniques.
  - Electronics & Electrical Engineering Lab.
- **Optical Frequency Standards and Dissemination.**
  - FY2005 Competence project led by Time & Frequency Division.
  - Time & Frequency Division (PL), Quantum Physics Division (PL), Atomic Physics Division (PL), Optoelectronics Division (Electronics & Electrical Engineering Lab), Precision Engineering Division (Manufacturing Engineering Lab).
- **Wavelength metrology for fiber optic telecommunications.**
  - Electronics & Electrical Engineering Lab's Optoelectronics Division and Time and Frequency Division.
  - Precise frequency/wavelength metrology for 1300 to 1600 nm range using optical frequency comb.

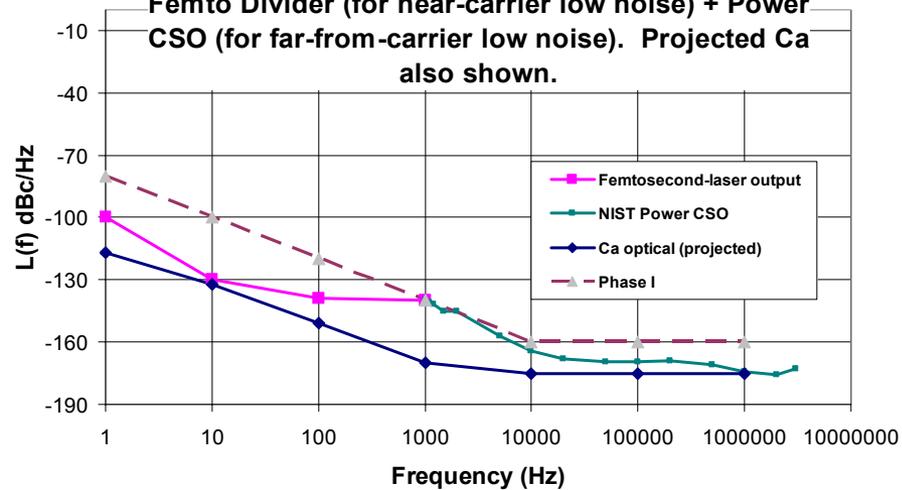
# Time and Frequency Division – Examples of Collaborations with Other NIST Programs

---

- **Research on length metrology.**
  - Manufacturing Engineering Lab's Precision Engineering Division and Time and Frequency Division.
  - Explore use of “factory floor” optical frequency comb calibrated against GPS frequency standards.
- **Statistics of clocks and oscillators.**
  - Information Technology Lab's Statistical Engineering Division and Time & Frequency.
  - Develop formalism for commonly-used time and frequency statistics.
  - Statistics of “dead-time” in measurement and dissemination.
- **Broad areas of frequency metrology and research.**
  - JILA's Quantum Physics Division and Time and Frequency Division.
  - Optical frequency standards, precision frequency metrology, optical frequency synthesis (frequency combs), other areas.
  - Highly productive exchange of students, postdocs, staff, ideas.

# NIST 2010 SFA: Public Safety & Security – Phase Noise

aPROPOS Performance Goal at 10 GHz vs. NIST Femto Divider (for near-carrier low noise) + Power CSO (for far-from-carrier low noise). Projected Ca also shown.

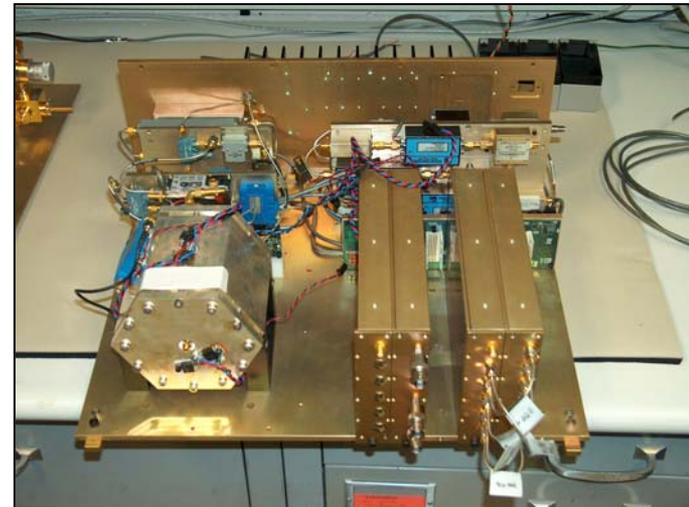


Applications in:

- Surveillance.
- Threat detection.
- Communications.

## Optical oscillator metrology:

- Extremely low noise.
- Vibration/acceleration testing.



- DARPA program with close connections to industry and research organizations.
- NIST providing core metrology support.

# Time and Frequency Division – Examples of Collaborations with Other NIST Programs

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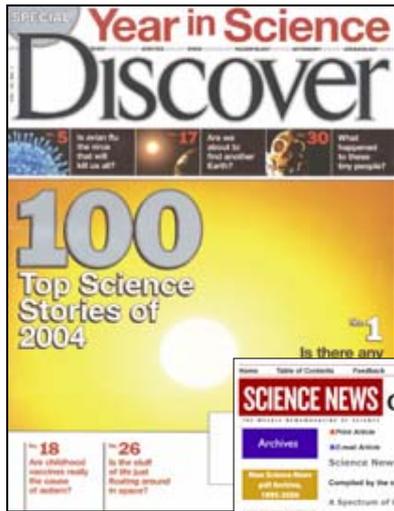
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  - Chip-scale atomic clocks, magnetometers, gyros, etc.
  - Possibility of low-cost mass production using standard MEMS techniques.
  - Electronics & Electrical Engineering Lab.
- **Optical Frequency Standards and Dissemination.**
  - FY2005 Competence project led by Time & Frequency Division.
  - \$800k/year.
  - Time & Frequency Division (PL), Quantum Physics Division (PL), Atomic Physics Division (PL), Optoelectronics Division (Electronics & Electrical Engineering Lab), Precision Engineering Division (Manufacturing Engineering Lab).
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# Recognition of Physics Laboratory Accomplishments



## “Top Stories of 2004”

- Fermi condensate (Quantum Physics)
- Chip-scale atomic clock (Time & Frequency & EEEL)
- Quantum teleportation (Time & Frequency & ITL)



- Discover Magazine “100 Top Science Stories of 2004”
- Science News "News of the Year 2004"
- American Institute of Physics "Physics News Update top stories of 2004"
- Popular Science "Year in Science 2004"
- PhysicsWeb (Institute of Physics, Great Britain) "Highlights of the Year“
- Others...

# Recognition of Physics Laboratory Programs



*Nov. 19, 2004*

# Time and Frequency Division Publications

<http://tf.nist.gov>

**Physics Laboratory**  
**Time & Frequency Division**

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Standards and Technology

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The division broadcasts standard time and frequency signals using radio, Internet, and telephone links. These signals synchronize millions of clocks every day.

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- [Radio Station WWVH](#)
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- [Frequency Measurement Service](#)
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# Time and Frequency Division Publications

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[Tutorial](#)

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[Chip Scale](#)

## NIST Time and Frequency Publication Database

The NIST Time and Frequency publication database allows you to freely access a total of 1987 time and frequency related publications authored by NIST personnel. The publication list includes conference papers, journal and magazine articles, government publications, books, and book chapters covering every facet of the subjects of time and frequency.

Our goal when creating this database was to make all time and frequency related publications authored by NIST personnel (or by the personnel of its predecessor, NBS, the National Bureau of Standards) available to the public as an educational and research tool, as well as a comprehensive historical reference. As a result, we've included publications dating back to 1914. To the best of our knowledge this database is now complete, but at least a few publications are probably missing. **If you know of any NIST/NBS time and frequency related publications that aren't found in this database, please [send us email](#) and we'll add them to the database as quickly as possible.**

The publications are made available as PDF files that can be viewed using the [Adobe Acrobat Reader](#). All time and frequency documents released for publication by NIST are listed in this database, but PDF files are usually not made available until after the actual date of publication.

You can search for publications by entering at least one search term in the submission form below, and clicking the submit button. You only need to enter partial terms, such as the author's last name. Words can be entered as either upper or lower case. Multiple words entered on the same line are treated as if "AND" were between them, which narrows your search.

After you click the submit button, a list of publications will be displayed. If a publication is available as a PDF file, the title will be underlined. Simply click on the title to access the publication.

If you are interested in time and frequency but are not sure what to search for, visit our [list of selected general interest publications from the time and frequency database](#). Please [send us email](#) if you have questions or comments about the time and frequency publication database.

Author(s)

Title

Place of Publication   
[List of Conference and Journal Abbreviations](#)

Year Published (last 2 digits)

Keywords   
[List of Available Keywords](#)

Bin Number (4 digits maximum)

# Time and Frequency Division Publications

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## NIST Time and Frequency Publication Search Results

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**>2,000 publications (pdf format)**

Authors	Title	Journal	Vol No.	Page Nos.	Pub. Date	Bin No.
T. Hasegawa, M.J. Jensen, and J.J. Bollinger	<a href="#">Stability of a Penning trap with a quadrupole rotating electric field</a>	Phys. Rev. A.	71	023406 (6)	11-FEB-05	2016
C.W. Oates, G. Wilpers, and L. Hollberg	<a href="#">Observations of large atomic-recoil-induced asymmetries in cold atom spectroscopy</a>	Phys. Rev. Lett.	71	023404 (6)	10-FEB-05	1913
M.A. Lombardi	<a href="#">Calibrations and Standards in Time Measurement</a>	Handbook of Measuring Systems Design	Ch. 200	1346-1350	01-FEB-05	1844
M.A. Lombardi	<a href="#">Characteristics of Time and Frequency Measurement</a>	Handbook of Measuring Systems Design	Ch. 199	1341-1345	01-FEB-05	1845
D. Budker, L. Hollberg, D.F. Kimball, J. Kitching, S. Pustelny, and V.V. Yashchuk	<a href="#">Microwave transitions and nonlinear magneto-optical rotation in anti-relaxation-coated cells</a>	Phys. Rev. A.	71	012903 (9)	27-JAN-05	2031
M.J. Jensen, T. Hasegawa, J. J. Bollinger, and D.H. Dubin	<a href="#">Rapid Heating of a Strongly Coupled Plasma near the Solid-Liquid Phase Transition</a>	Phys. Rev. Lett.	94	025001 (4)	21-JAN-05	2028
T. Schaetz, M.D. Barrett, D. Leibfried, J. Britton, J. Chiaverini, W.M. Itano, J.D. Jost, E. Knill, C. Langer, and D.J. Wineland	<a href="#">Enhanced Quantum State Detection Efficiency Through Quantum Information Processing</a>	Phys. Rev. Lett.	94	010501 (4)	07-JAN-05	1836
R.W. Fox, S.A. Diddams, A. Bartels, and L. Hollberg	<a href="#">Iodine-stabilized HeNe-laser frequency measurements referenced to the GPS system</a>	Appl. Opt.	44	113-120	01-JAN-05	1951
A. Bartels	<a href="#">Gigahertz Femtosecond Lasers</a>	Femtosecond optical frequency comb: Operation and Applications	Ch. 3	78-96	01-JAN-05	1912
M.A. Lombardi, A.N. Novick, J.P. Lowe, M. Deutch, G.K. Nelson, D. Sutton, W. Yates, and D.W. Hanson	<a href="#">WWVB Radio Controlled Clocks: Recommended Practices for Manufacturers and Consumers</a>	NIST Spec. Publ. 960-14		64 p.	01-JAN-05	1976
P. Schwindt, S. Knappe, V. Shah, L. Hollberg, J. Kitching, L. Liew and J. Moreland	<a href="#">Chip-scale atomic magnetometers</a>	Appl. Phys. Lett.	85	6409-6411	27-DEC-04	2001
	<a href="#">What is the fastest event (shortest time duration) that</a>				27-	

# NIST Time and Frequency Division – Technical Challenges

- **Continued improvement of primary standards.**
  - NIST-F2 expected to reach  $\sim 10^{-16}$  uncertainty.
  - Optical clocks expected to eventually reach  $10^{-17}$  to  $10^{-18}$  uncertainty.
  - FY2005 Competence funding.
  
- **Dissemination of future highly accurate standards.**
  - Current  $10^{-15}$  uncertainty at limit of existing satellite time transfer technology.
  - Research to improve systems planned. Finalist FY2004 Competence proposal to improve satellite time and frequency transfer – not funded.
  - Explore optical fiber transmission using frequency combs.
  
- **Responsiveness to new applications of time and frequency standards.**
  - Chip-scale atomic devices for portable electronic applications (defense, research, consumer...)
  - Certification/authentication challenges in time distribution.
  - Flexibility to respond to unforeseen applications.

# NIST Time and Frequency Division – Program Challenges

---

- **People.**
  - Increasing reliance on Associates rather than permanent staff is a challenge and an opportunity.
  - Retention of top early career scientists and engineers.
- **Resources.**
  - ~5% unfunded/under-funded mandatory increases in labor expenses annually.
  - Increasing reliance on other agency funding vs. NIST internal funds (appropriations).
- **Facilities.**
  - 50-year-old Boulder facilities inadequate to support cutting edge Division research.
  - Module-by-module renovations too costly, too time-consuming, too ineffective.
- **Customer focus.**
  - Developing productive relationships with new potential customers to better understand and respond to their technical needs.
  - Capitalizing on the NIST “brand” for accurate time.
- **Planning.**
  - Continue and strengthen successful short-term and long-term planning to meet technical goals and customer needs.
  - New financial system, CAMS, severely impairs short and long-term budget planning.

# For More Information...

<http://tf.nist.gov>

**Physics Laboratory**  
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---

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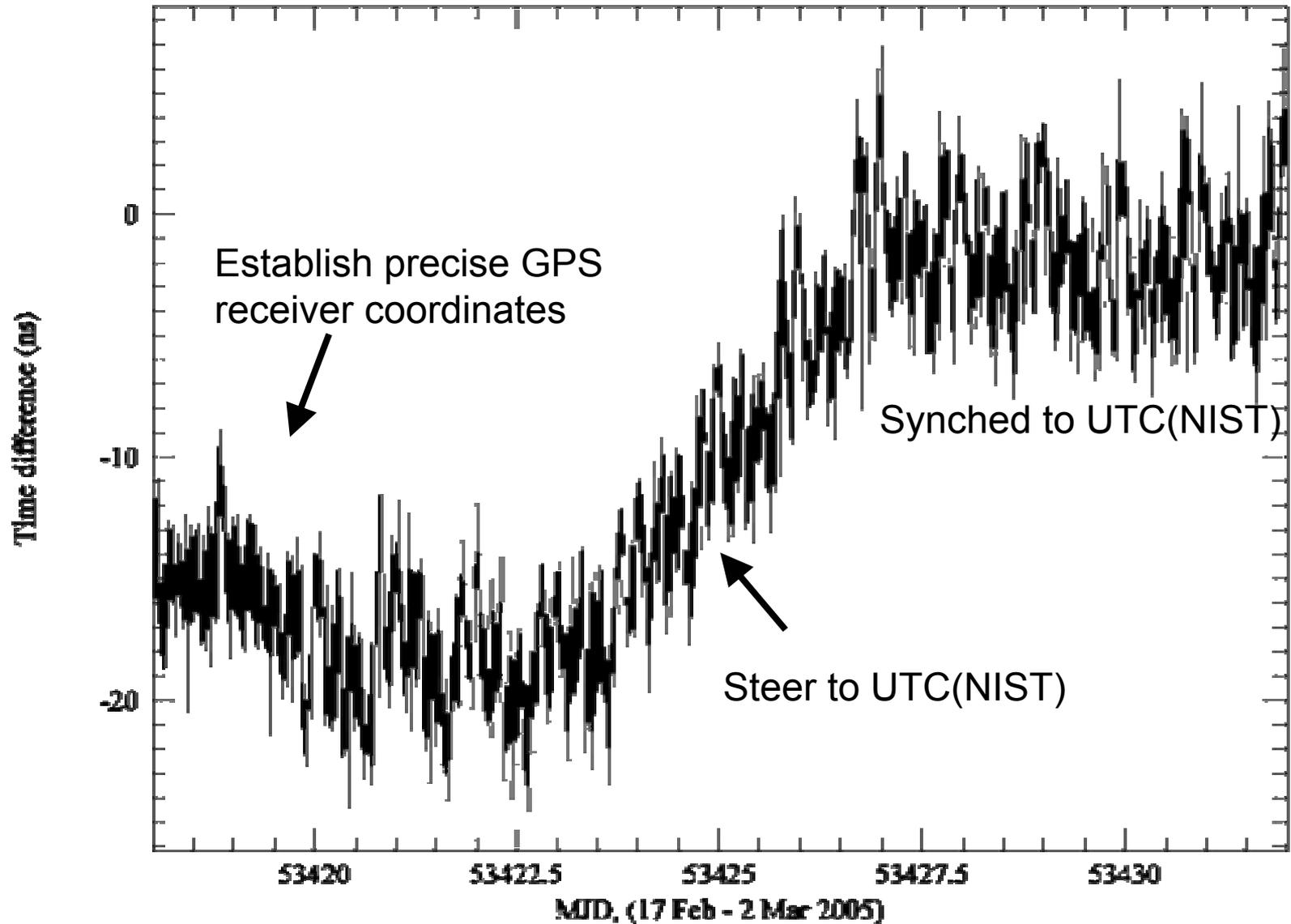
# NIST Time Scale Backup

---

- Remote ensemble of atomic clocks and redundant measurement system.
- Synchronized to UTC(NIST) by GPS common-view.
- Work remaining:
  - Backup for Automated Computer Time Service (ACTS).
  - Backup for Internet Time Service (ITS).
  - Additional redundancies and infrastructure.

# NIST Time Scale Backup

## Fort Collins (b) - UTC(NIST)



# 2004 NIST Survey

---

- Surveys collected November 15 – December 22, 2004.
- NIST employees only. (NIST Associates such as guest researchers and contractors were not surveyed in 2004.)
- 59% participation for NIST overall (66% overall in 2002.)
  - 58% participation for Physics Lab (70% in 2002).
  - 69% of Time and Frequency Division employees participated (74% in 2002).
- Approximately 54% of Gaithersburg employees (63% in 2002) and 62% of Boulder employees (72% in 2002) participated.
- 58 questions, plus demographic information, plus two open-ended questions.
- (2002 survey: 146 questions, plus demographic information, plus three open-ended questions.)

# 2004 NIST Survey

---

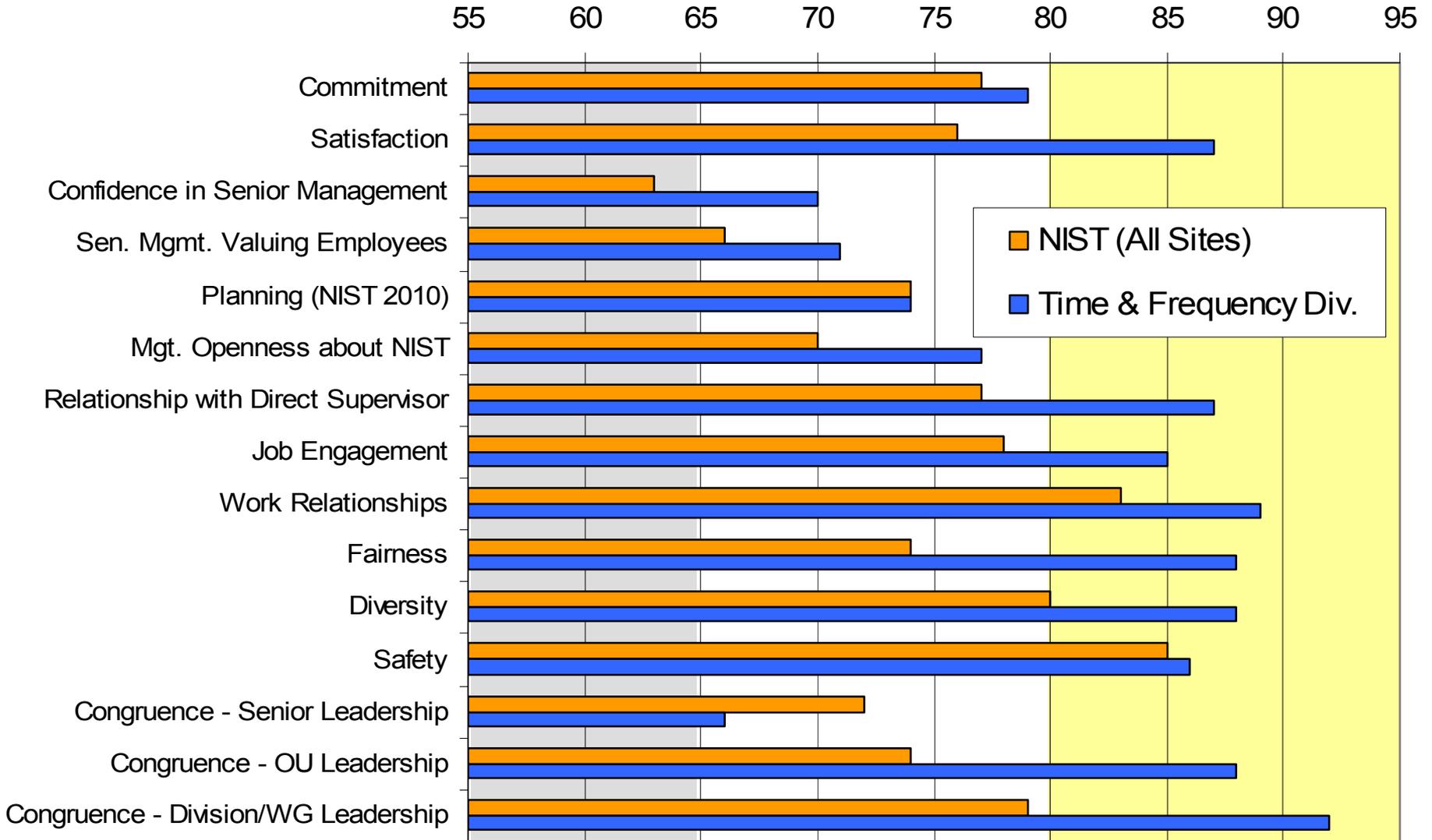
2004: 58 survey questions grouped by contractor into 15 categories:

1. Commitment
2. Satisfaction
3. Confidence in Senior Management
4. Senior Management Valuing Employees
5. Planning (NIST 2010)
6. Management Openness about NIST
7. Relationship with Direct Supervisor
8. Job Engagement
9. Work Relationships
10. Fairness
11. Diversity
12. Safety
13. Congruence - Senior Leadership demonstrates NIST values
14. Congruence - OU Leadership demonstrates NIST values
15. Congruence - Division and Group Leadership demonstrates NIST values

See detailed survey results for the list of questions in each category.

# 2004 NIST Survey

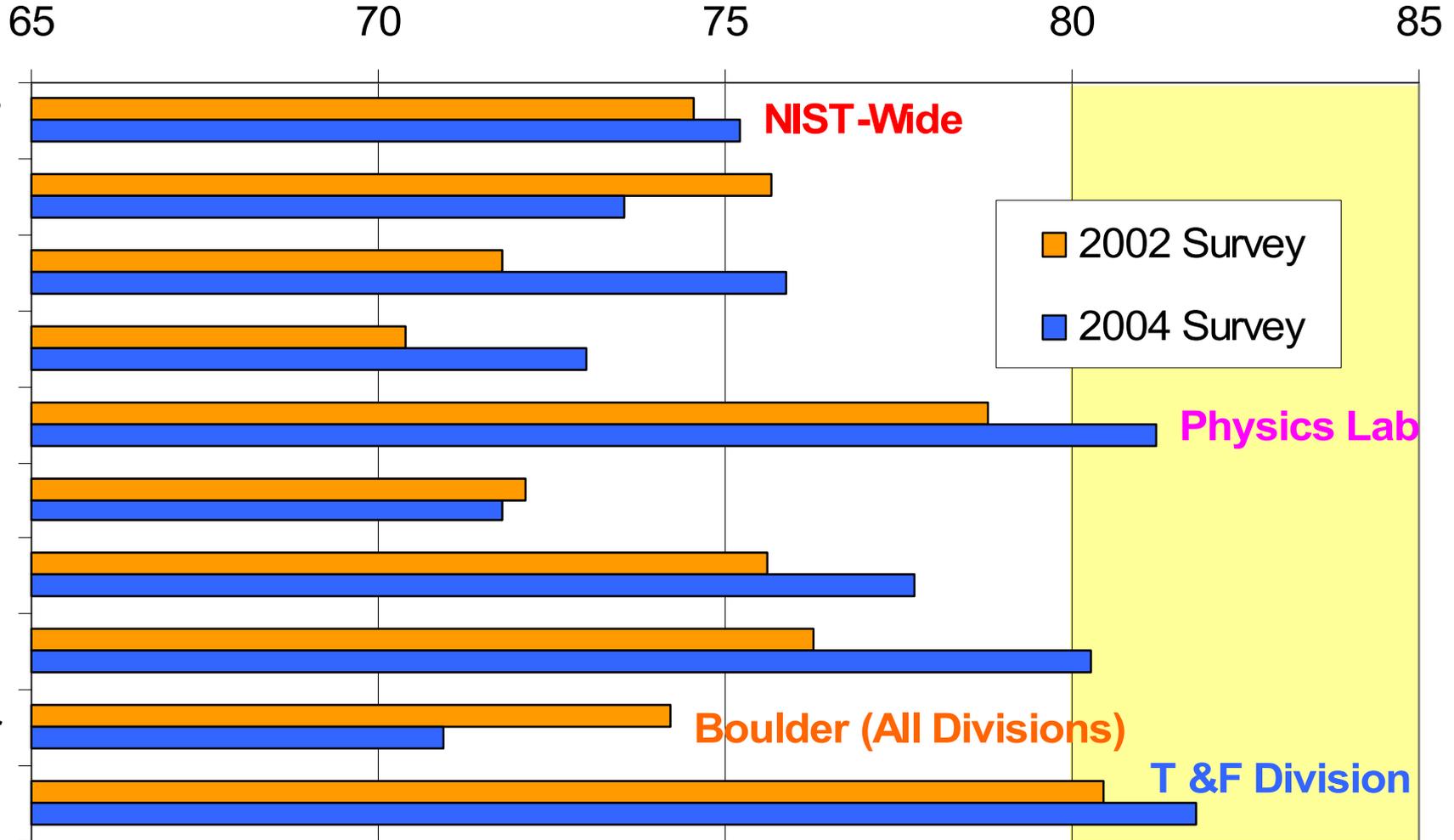
## 2004 Survey: NIST & Time & Frequency Division



Survey contractor characterizes >80 as excellent, 70 as average, <65 as poor

# 2004 NIST Survey – Trends

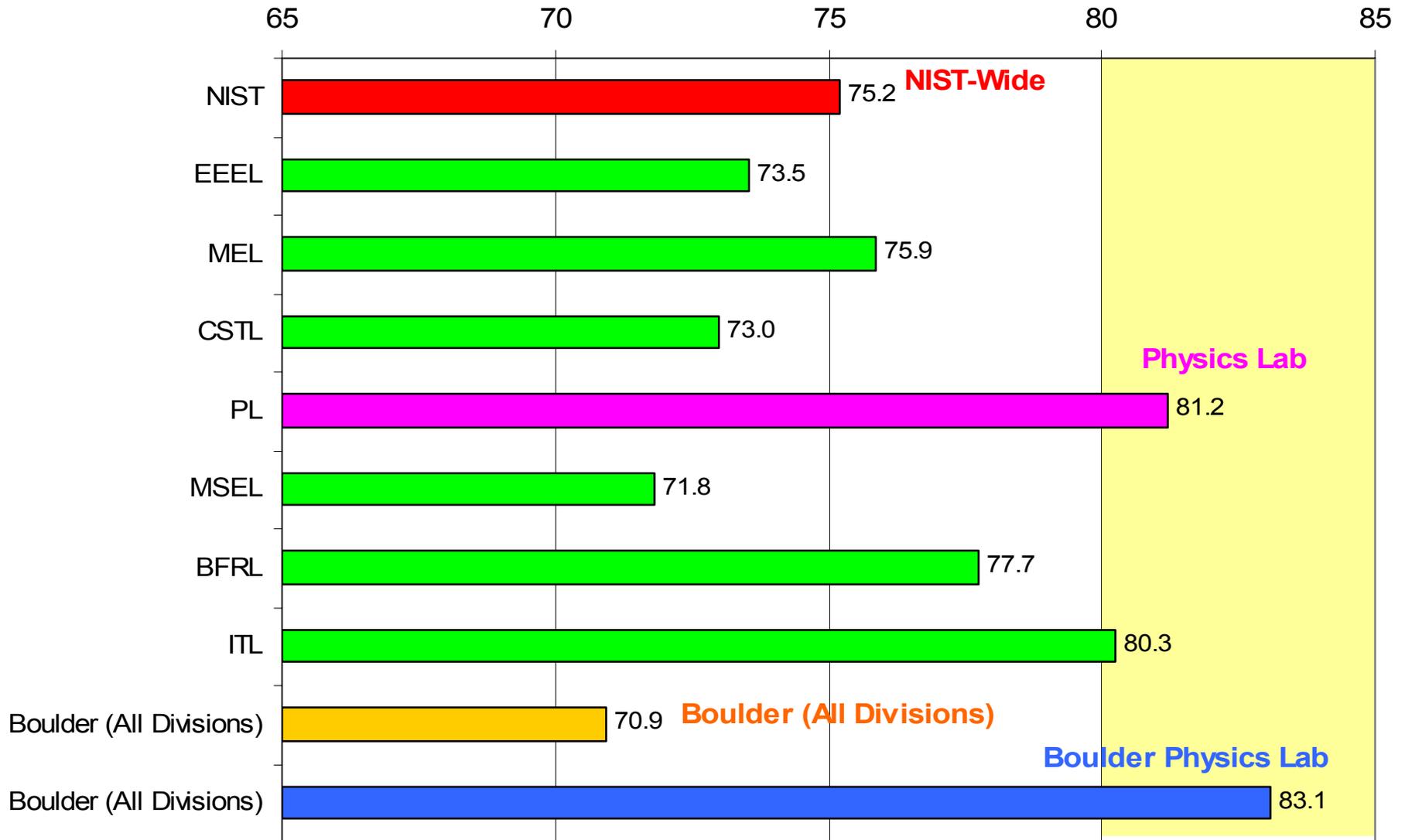
2002 & 2004 Surveys: Average for All Fifteen Indices



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# 2004 NIST Survey

## 2004 Survey: Average Score for All Fifteen Indices



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# Trends on 2002 and 2004 NIST Surveys

---

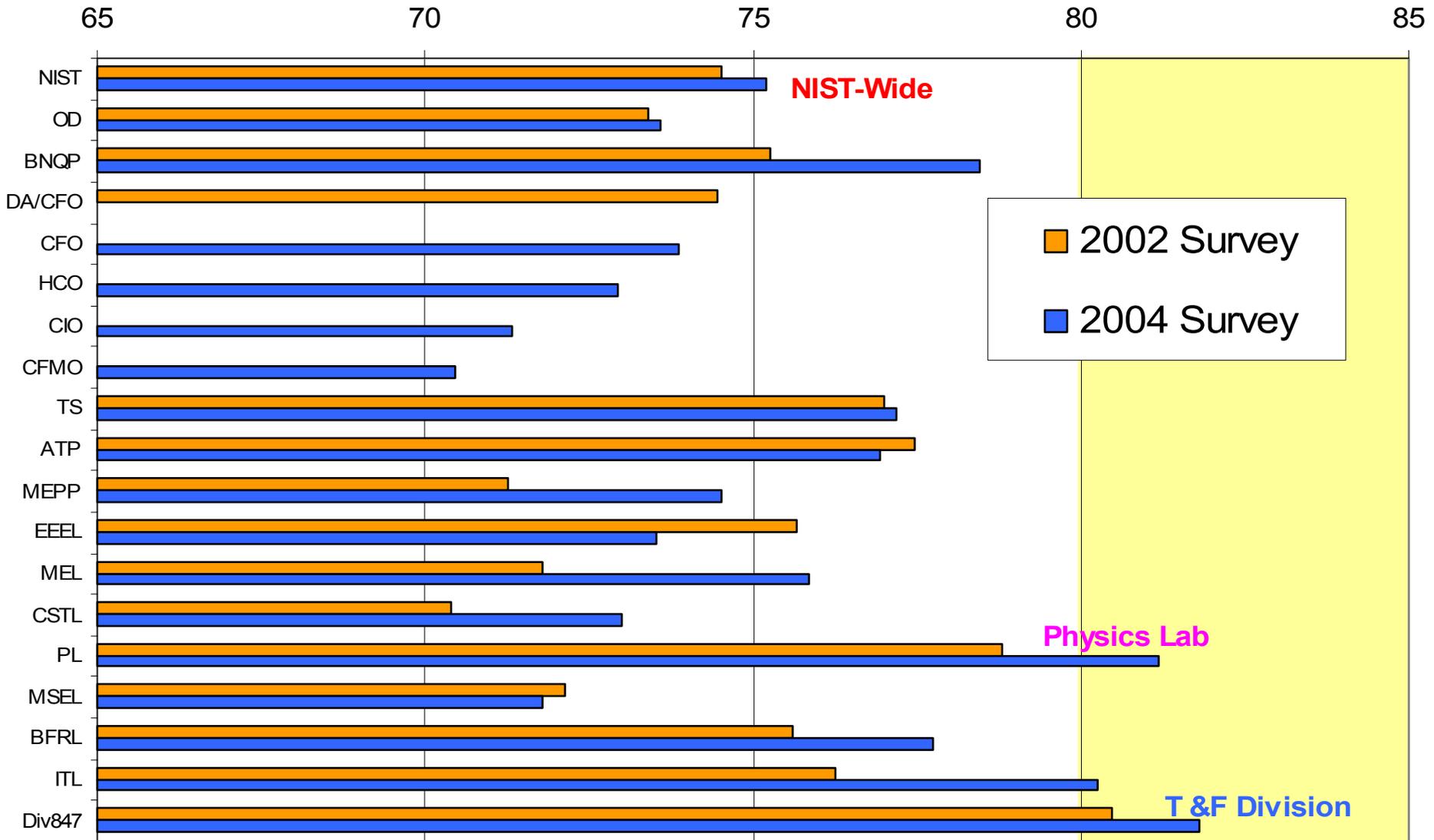
2002: 146 survey questions grouped by contractor into 15 categories:

1. Morale and Commitment
2. Overall Satisfaction
3. Confidence in the Future of NIST
4. Attitudes toward Senior Leadership
5. Attitudes toward Division Leadership
6. Effectiveness of Division Leadership
7. Effectiveness of Immediate Supervisor
8. Attitudes toward Job
9. Performance Providing Resources
10. Fairness and Equity
11. Consequences and Benefits
12. Career Growth and Advancement and
13. Attitudes toward Work Group
14. Operating Unit - Aligning Values and Behaviors
15. Division - Aligning Values and Behaviors

See detailed 2002 survey results for list of questions in each category.

# 2004 NIST Survey

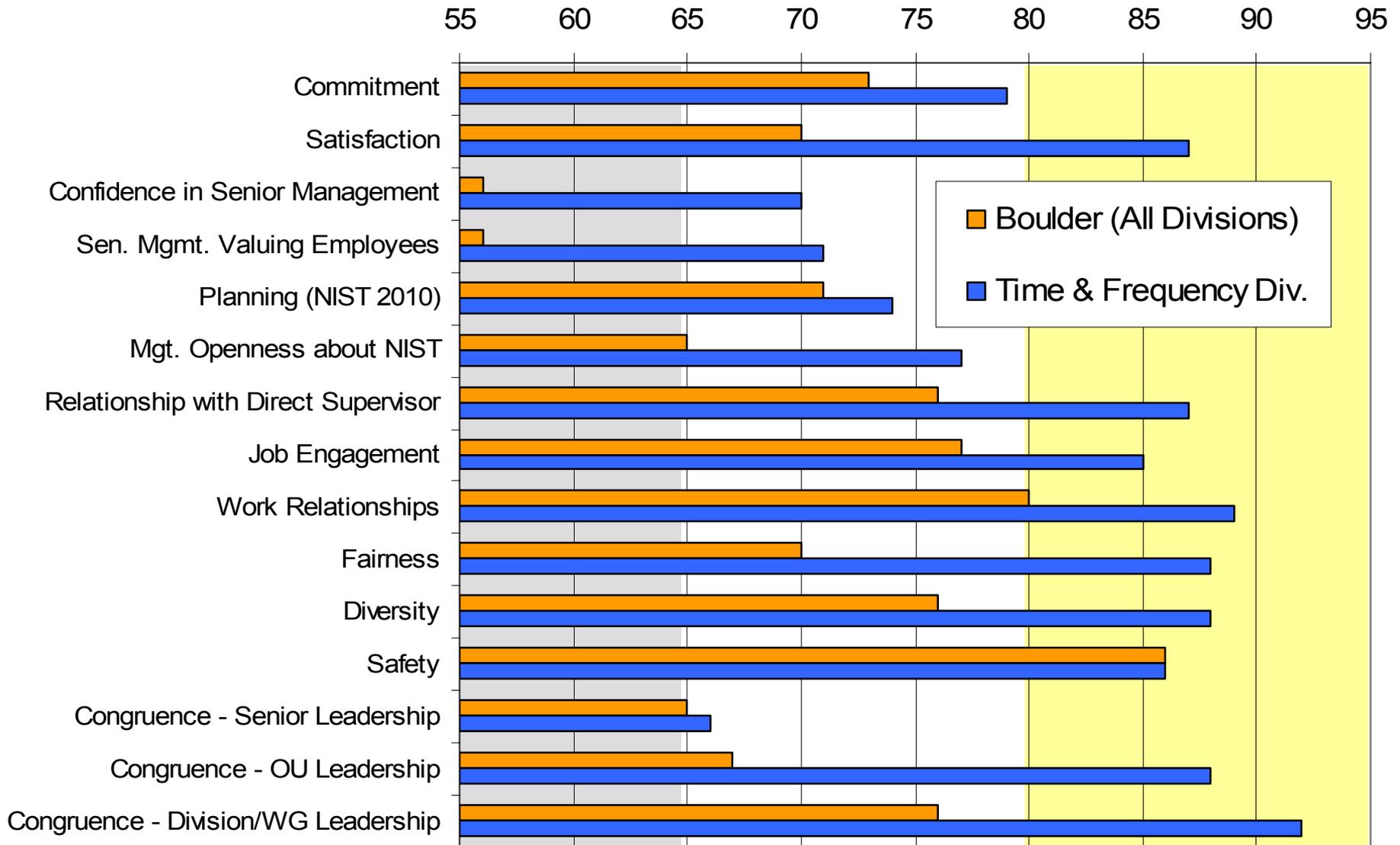
## 2002 & 2004 Surveys: Average for All Fifteen Indices



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# 2004 NIST / Time and Frequency Division Survey

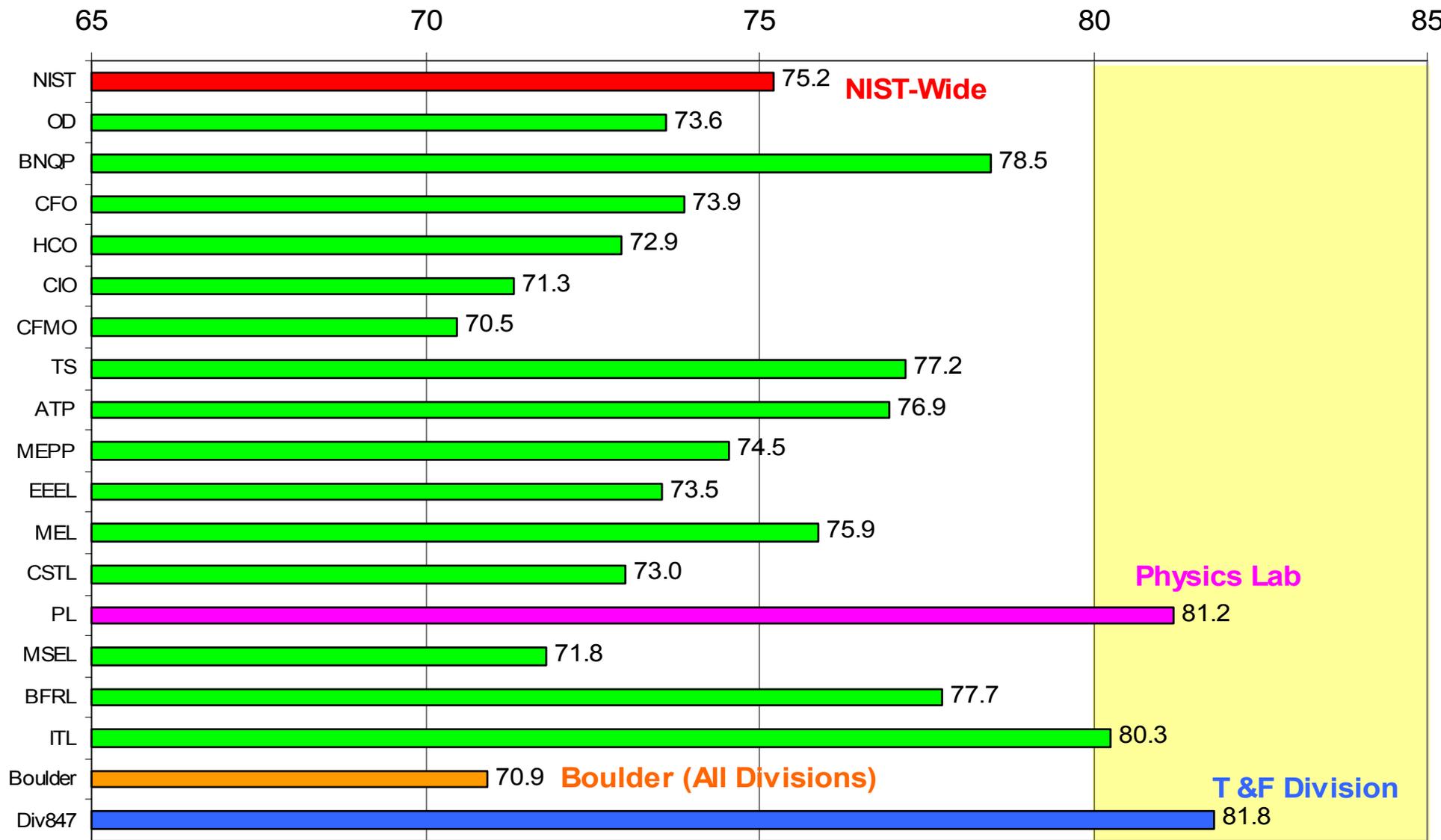
## 2004 Survey: All Boulder Divisions and Time & Frequency Division



Survey contractor characterizes >80 as excellent, 70 as average, <65 as poor

# 2004 NIST / Time and Frequency Division Survey

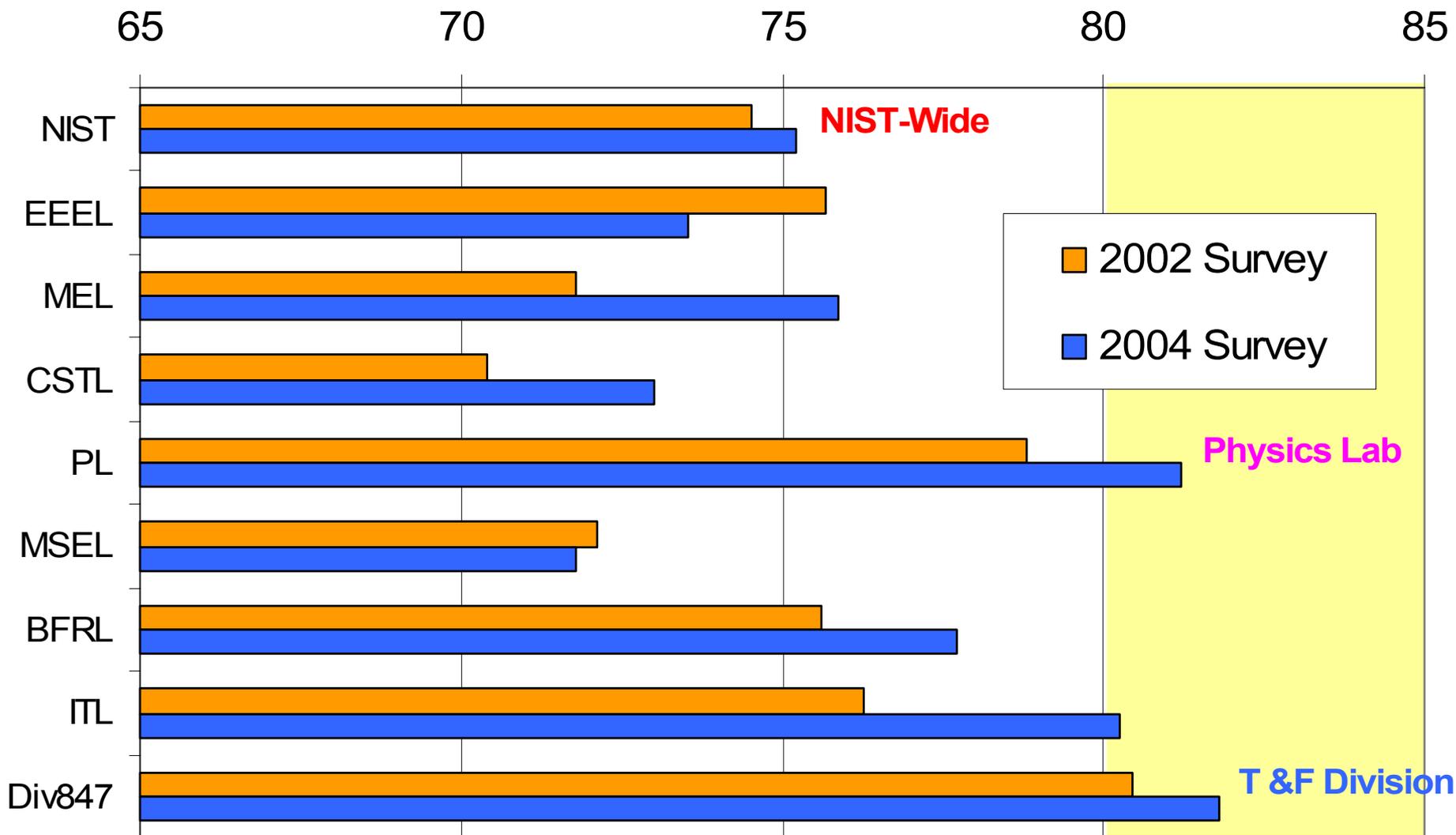
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# 2004 NIST / Time and Frequency Division Survey

2002 & 2004 Surveys: Average for All Fifteen Indices



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# 2004 NIST / Time and Frequency Division Survey

## Ten Most Favorably Rated Items

Time and Frequency Division 10 Most Favorable Items	Div % Fav.	NIST % Fav.
1. I understand how my job contributes to the success of my Operating Unit.	100	90
10. I know the results expected of me on my job.	97	85
22. I have been adequately trained in relevant safety practices in my work place.	97	86
26. I understand the standards by which my performance is evaluated.	97	75
49. To what extent does the leadership of your Division (Group Leaders and Division Chief) exhibit the behaviors associated with the people value?	93	65
2. I am aware of the NIST safety policies and procedures.	93	94
21. I recognize and report safety issues.	93	88
25. Differences among individuals where I work are respected and appreciated.	93	72
29. I feel proud to work for NIST.	93	82
52. To what extent does the leadership of your Division (Group Leaders and Division Chief) exhibit the behaviors associated with the integrity value?	93	67

Data ID = 847

## Ten Least Favorably Rated Items

Time and Frequency Division 10 Least Favorable Items	Div % Fav.	NIST % Fav.
31. I believe implementing the NIST 2010 Strategic Plan will benefit NIST.	10	23
12. I am familiar with the NIST 2010 Strategic Plan.	24	43
47. To what extent does leadership (NIST Director and Deputy Director) exhibit the behaviors associated with the people value?	28	32
56. To what extent does leadership (NIST Director and Deputy Director) exhibit the behaviors associated with the excellence value?	31	41
50. To what extent does leadership (NIST Director and Deputy Director) exhibit the behaviors associated with the integrity value?	38	38
53. To what extent does leadership (NIST Director and Deputy Director) exhibit the behaviors associated with the customer focus value?	38	44
18. Senior management can be trusted to do what it says it is going to do.	45	38
17. Senior management works well together in providing direction to NIST.	48	34
19. Senior management truly cares for and considers employee welfare in decision making.	48	37
16. The actions of senior management demonstrate that employees are genuinely trusted.	55	41

Data ID = 847

# NIST Time and Frequency Standards

## Unique aspects of NIST time and frequency:

- **Time is one of the seven fundamental SI units.**
  - Basis for other units and measurements, including length, electrical properties, power, etc.
- **Division's program is fully integrated and focused.**
  - From delivery of services to general public to operation of world's best primary standards to world-leading research on future standards.
- **Time is by far the most accurately known fundamental SI unit.**
  - Better than  $10^{-15}$  accuracy with continuing improvements of a factor of ten per decade expected.
- **Time is by far the most heavily used NIST measurement service.**
  - 1.5 billion requests per day for NIST Internet Time Service to automatically set computer clocks.
  - Projected annual sales of 2 million commercial timekeeping devices automatically synchronized to NIST radio broadcasts.
  - About 3 million users per month for NIST/USNO web clock ([www.time.gov](http://www.time.gov)).
- **Time is arguably the NIST function best understood and most widely recognized by the general public.**
  - Many members of the public equate NIST/NBS with the "atomic clock."
  - Everyone intuitively understands time and the importance of accurately measuring time.

# NIST Time and Frequency Division – Customer Focus

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- **Broad base of customers.**
  - Daily, extensive use of Division services by general public. Highest volume, lower accuracy.
  - Broad use for industry and military applications. High volume, moderate to high accuracy.
  - Crucial use in scientific applications. Lower volume, highest accuracy.
- **Customer surveys.**
  - Response data posted on Division website: [tf.nist.gov](http://tf.nist.gov)
- **Seminars, short courses, tutorials.**
  - Industry, military, national labs, researchers.
  - Feedback on surveys and direct interactions.
- **National and international standards-developing organizations.**
  - Time and frequency.
  - Telecommunications.
  - GPS.
  - IT.
  - Potential opportunities for broader productive participation.
- **Vigorous scientific publication, conference, and seminar programs.**

# NIST Time and Frequency Measurement Services

Oct. 1, 2003 - May 25, 2004

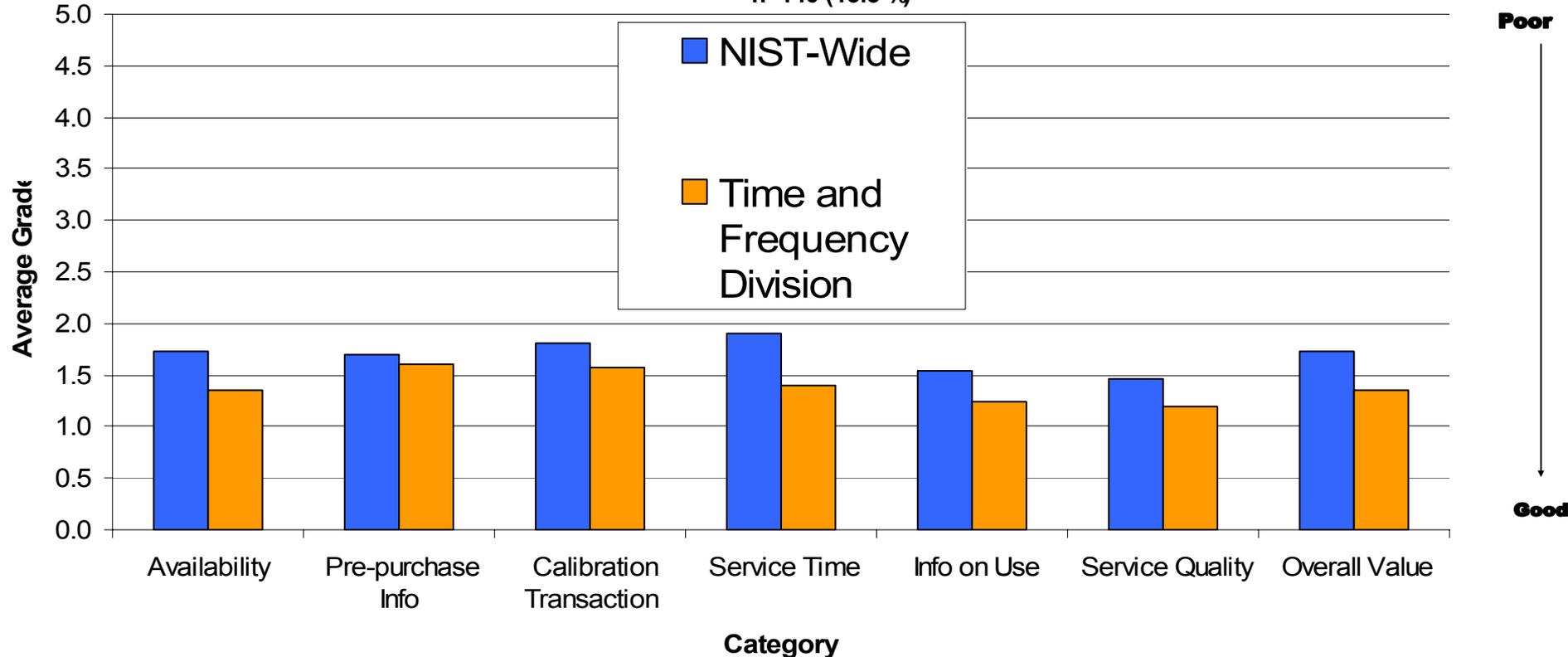
Calibrations Report

All Divisions

Average Grades

(1=Excellent, 2=Very Good, 3=Good, 4=Fair, 5=Poor)

n=140 (13.5%)



20 responses from NIST remote calibration service customers, representing about 1/3 of those total customers.

# Time and Frequency Division Customer Survey

The screenshot shows a web browser window with the address <http://tf.nist.gov/timefreq/survey/survey.htm>. The page header features the NIST logo and the text "National Institute of Standards and Technology". The main content area is titled "Results of 2001 Customer Satisfaction Survey".

The page includes a left-hand navigation menu with links for Home, Welcome, Current Time, Exhibits, FAQ, Glossary, Links, Publications, Staff, Radio Stations (WWW, WWVH, WWVB), Services (Computer Time, Telephone Time, Calibrations, Seminars, Survey Results), and Standards (NIST-F1, Space Clock, History).

The main text describes the survey conducted from April through September 2001, noting that nearly 15,000 people responded. It lists three methods used to advertise the survey: a voice announcement on the WWW / WWVH high frequency broadcast, advertisements in trade magazines, and a link from the website. It also mentions that a large segment of customers were difficult to alert to the survey, including users of the WWVB low frequency broadcast, the Internet Time Service, and the Automated Computer Time Service.

The "Survey Results" section contains a list of links:

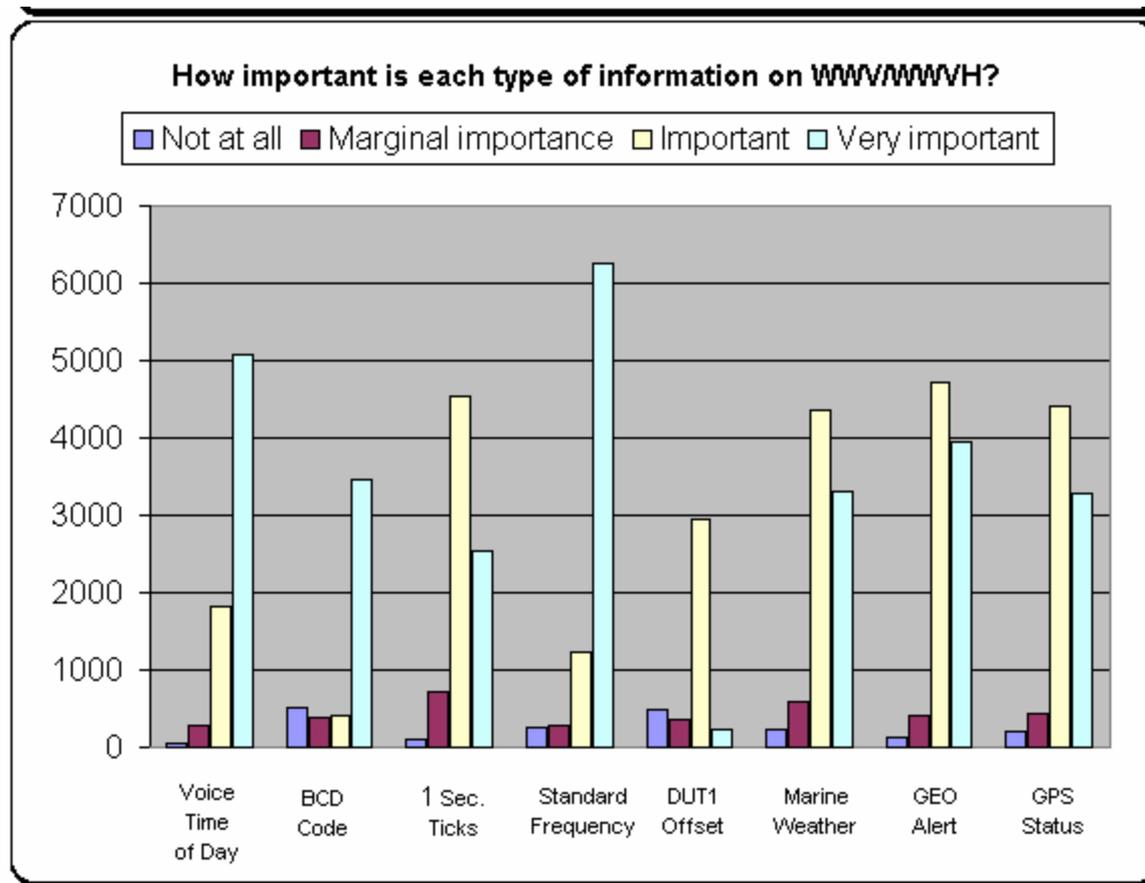
- [WWW and WWVH](#)
- [WWVB](#)
- [Overview of Other Services](#)
  - [ACTS](#)
  - [Internet Time Service](#)
  - [Web Page](#)
  - [Telephone Time-of-Day Service](#)
- [Miscellaneous Questions](#)
- [Customer Data](#)

Nearly 15,000 responses.

About 2/3 “consumer” applications, about 1/3 “technical” applications.

- *“You’re doing a great job. Wish my income taxes were spent as wisely elsewhere in the government!”*
- *“Wonderful service. Have used it for years. One of the best functions the US Gov’t furnishes.”*
- *“Great service - if more people knew about it, it would be used more.”*

# WWV and WWVH Shortwave Broadcast Use



Large number of respondents indicate all WWV/WWVH broadcast services are “very important.”

# WWV and WWVH Shortwave Broadcast Use

## Challenge:

Maintain WWV/WWVH services with limited resources.

## Responses:

- Replace steel WWVH towers with fiberglass towers.
  - Reduces need for continual, expensive maintenance due to sea air corrosion.
  - Fiberglass towers hinged for lowering to ground, eliminating need to climb towers for maintenance.
- Obtain surplus Navy transmitters at almost no cost.
  - Substantial savings over purchase of new transmitters.
- Improved efficiency of coupling transmitters to antennas.
  - Reduced electric power usage.
  - Reduced wear on transmitters.



Old WWVH steel tower, with climber conducting maintenance.



New WWVH fiberglass tower – dramatically reduced and simpler maintenance.