# Activities at the Bureau of Standards Jamaica: Developing a Time Monitoring and Synchronization Service

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**BIOGRAPHY**

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Andrew Novick is an electrical engineer in the Time Realization and Distribution Group in the Time and Frequency Division at NIST. He manages and maintains the remote clock and oscillator calibration services and the SIM time laboratory time and frequency comparisons. Novick created and maintains the national web clock, *www.time.gov*, and he is the division's Quality Manager.

**ABSTRACT**

The Bureau of Standards Jamaica (BSJ) has recently achieved direct traceability to Coordinated Universal Time (UTC) with the publication of its official time scale, UTC(BSJ), in the International Bureau of Weights and Measures (BIPM) Circular T. This realization, based on two cesium frequency standards, will be analysed in terms of its performance.

The government of Jamaica intends to introduce regulations requiring the financial industry to adhere to standardized traceability to UTC, ensuring that the time offset does not exceed 50 milliseconds (ms). This paper presents our implementation of the Network Time Protocol (NTP) method to disseminate UTC(BSJ) over the public internet and to monitor each customer's offset in a traceable manner.

**I. INTRODUCTION**

The (BSJ) has made significant strides in the field of timekeeping by achieving direct traceability to Coordinated Universal Time (UTC). This accomplishment was formally recognized through the publication of BSJ's official timescale in the International Bureau of Weights and Measures (BIPM) Circular T report on July 10, 2024.

The BSJ timescale, UTC(BSJ), is created with two cesium atomic clocks, ensuring a robust and stable reference for time synchronization. Data from these cesium clocks are submitted to the BIPM daily for inclusion in the rapid Coordinated Universal Time (UTCr) calculation, as well as monthly for official inclusion in UTC. To achieve this time transfer, BSJ utilizes the Common GNSS Generic Time Transfer Standard (CGGTTS) method and a Precise Time Scale System (PTSS).

In response to this development, the Jamaican government plans to introduce new regulations that will mandate time traceability for key sectors, particularly the financial industry. The regulations will also require organizations to ensure that their systems maintain a time offset no greater than 50 ms from UTC. This paper presents the Network Time Protocol (NTP) based system that BSJ uses to disseminate its official time over the public internet, and its application for traceability to specific customers.

The sections of this paper describe the performance of UTC(BSJ) as measured by the BIPM, followed by a description of the NTP service. That description includes a block diagram showing the hardware, the data flow, data processing, data reporting, and data analysis. A sample report is given in the appendix, and a summary indicates future directions.

**II. UTC(BSJ)**

UTC(BSJ), is generated with a commercial measurement system. As described in (Jones et al., 2024), the BSJ's Precise Time Scale System (PTSS) has many components, including a frequency counter, a dual-frequency GPS receiver, signal generators, and the necessary software to create a timescale using the KAS-2 algorithm, whose details are proprietary but largely based on (Stein, 2003) and references therein. It currently creates UTC(BSJ) by steering an oscillator, stabilised in the short term by observations against two cesium-beam atomic clocks, to the GPS delivered prediction of UTC(USNO) over longer intervals. A third cesium atomic clock is kept as a spare. The timescale is realized via a pulse per second (PPS) output and a Common GNSS Generic Time Transfer Standard (CGGTTS) file summarizing GPS satellite clock observations is generated and uploaded to the BIPM following standard procedures. Figure 1 shows the frequency performance of the two cesium atomic clocks in use, as reported to the BIPM.

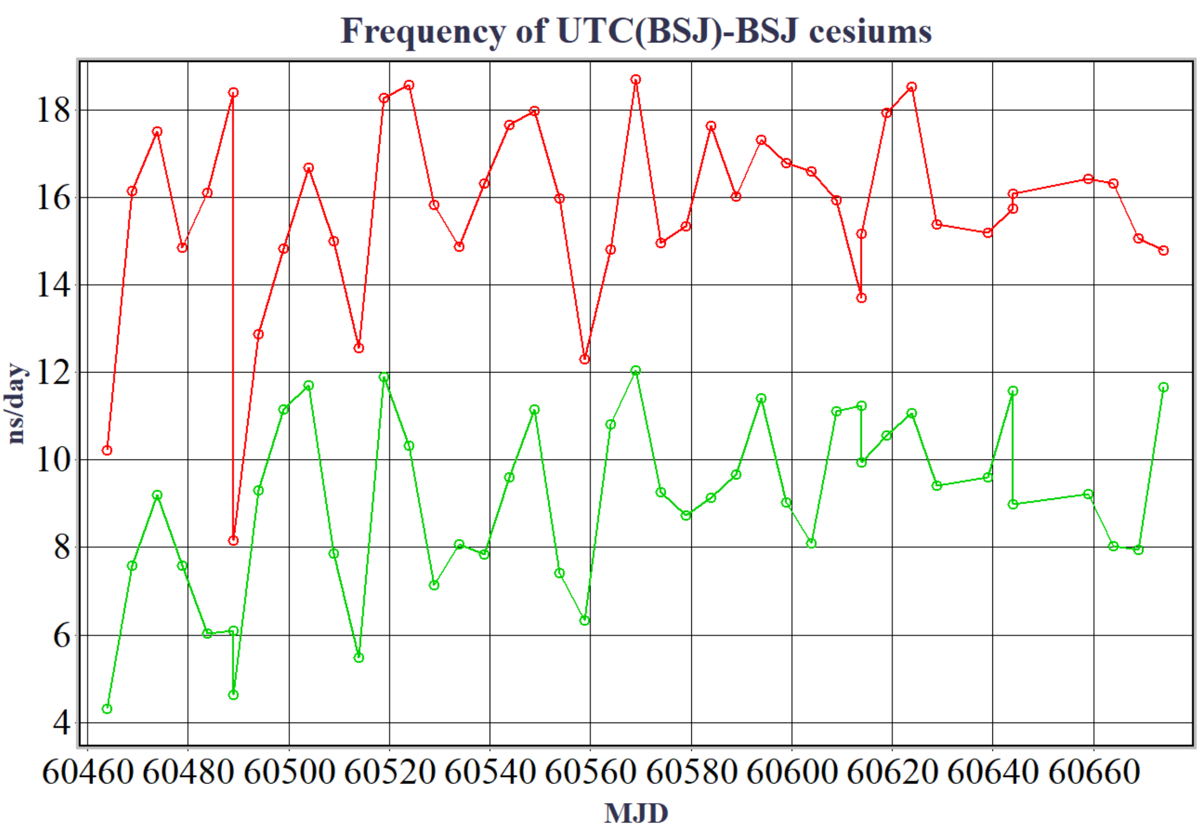

**FIGURE 1.** The frequency offset of the two active cesiums referenced to UTC(BSJ).

Figure 2 shows the performance of UTC(BSJ) relative to UTC and rapid UTC (UTCr). While the standard deviation of recent Circular T data for UTC-BSJ is about 5 ns, and the assigned uncertainties in December 2024 were 7 ns (statistical) and 7 ns (systematic), a bias of approximately 10 ns exists and requires reduction. This bias, which became smaller around MJD 60600 (mid-October), is too large to be explained by the difference between UTC and broadcast GPS prediction of UTC(USNO) to which UTC(BSJ) is steered. Although the cause is still under investigation, with the manufacturer notified, we suspect it stems from shifts in the PTSS system's internal delay offsets.

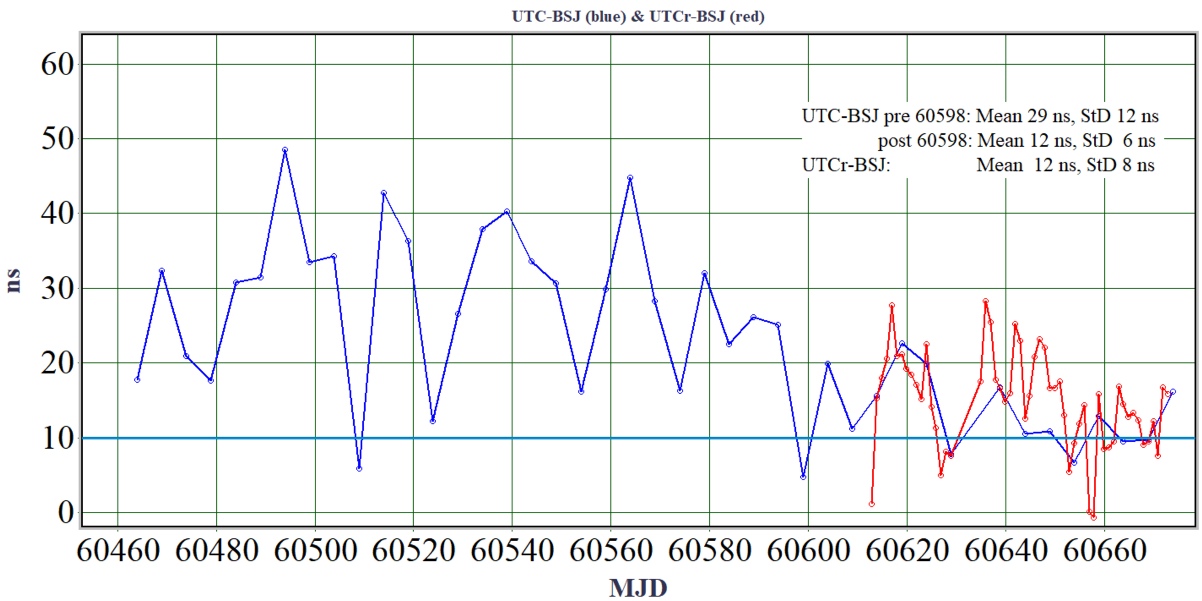


**FIGURE 2.** UTC(BSJ) compared to UTC and UTCr.

In addition, BSJ participates in the Sistema Interamericano de Metrologia (SIM) network (López-Romero et al., 2018), providing almost real-time time differences between cooperating labs. It is possible to evaluate UTC(BSJ) by using SIM-generated time transfer between BSJ and any SIM- and UTC-contributing laboratory *k* using UTC-UTC(*k*) data from Circular T. The two results are not expected to be the same because different GPS receivers are used (and for NIST in particular, Two Way Satellite Time Transfer (TWSTT) is used to transmit UTC(NIST) to the BIPM, which is different from the SIM receiver). Differences would also arise because SIM relies on GPS's broadcast-modelled ionosphere and orbits; instead, BIPM link data are derived from a different BSJ receiver and are computed with the IGS-measured ionosphere and orbits. Figure 3a compares the two methods via double differencing with NIST and NRC UTC data, while Figure 3b shows those with other labs, which happened to exhibit larger variations. The last SIM calibration of BSJ was in 2008; its aging may contribute to the bias. A new, dual-frequency SIM system will be delivered in 2025, which will help determine the bias of the existing SIM system and will produce lower-noise results. Also, the time-transfer receiver used to submit data to BIPM for Circular T is a different type of receiver from the SIM measurement systems.

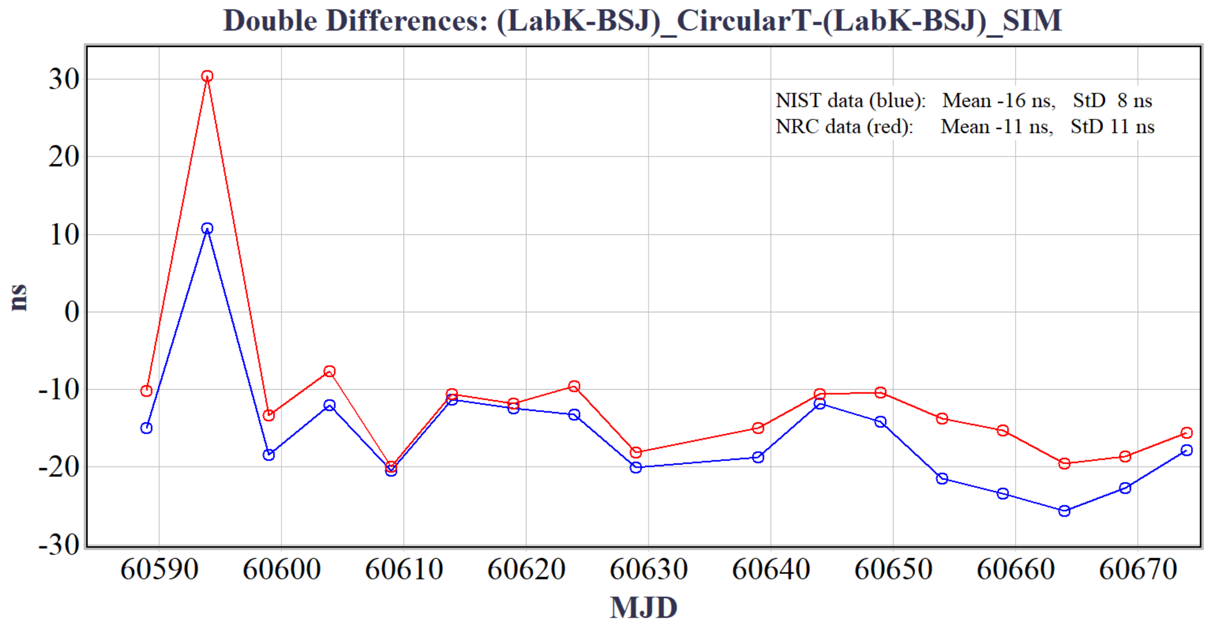


**FIGURE 3a.** Comparison of UTC(BSJ)-UTC(*k*) via SIM and via Circular T for NIST and NRC. The mean and standard deviation of each curve are given on the top right of the figure.

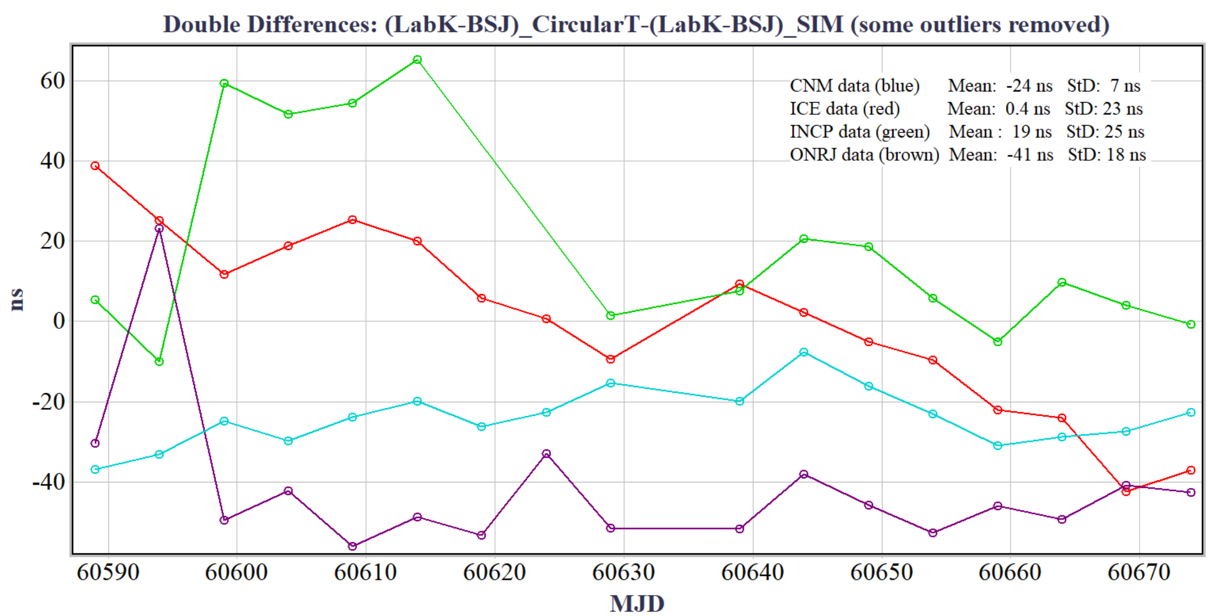


**FIGURE 3b.** Comparison of UTC(BSJ)-UTC(*k*) via SIM and via Circular T for four labs. The mean and standard deviation of each curve are given on the top right of the figure.

The double differences show that there are biases between the Circular T and SIM link computations. Biases may arise from internal delays within PTSS mentioned above as well as the above-mentioned differences. This is a matter under study.

**III. The BSJ TIME MONITORING AND SYNCHRONIZATION SERVICE (TMSS)**

The TMSS hardware interfaces with the PTSS timescale generator via an ethernet switch and an Inter-range instrumentation group timecodes (IRIG) connection for the Pulse Per Second (PPS), as shown in Figure 4. Two NTP time servers are shown with Local Area Network (LAN) IP addresses ending in '.70' and '.71'. These servers feature dual network interfaces. One is linked to the internal network of the PTSS (192.168.x.x) and the other to separate subnetworks for external and internal services. The primary NTP dissemination originates from the '.70' NTP Server 1, which provides a time reference point for synchronization facing the public as well as for the SIM network at address 66.249.155.4. NTP Server 2 (.71) provides a reference for time synchronization only to devices on the internal BSJ network. The GPS receiver used for our SIM collaboration receives its reference PPS within the PTSS.

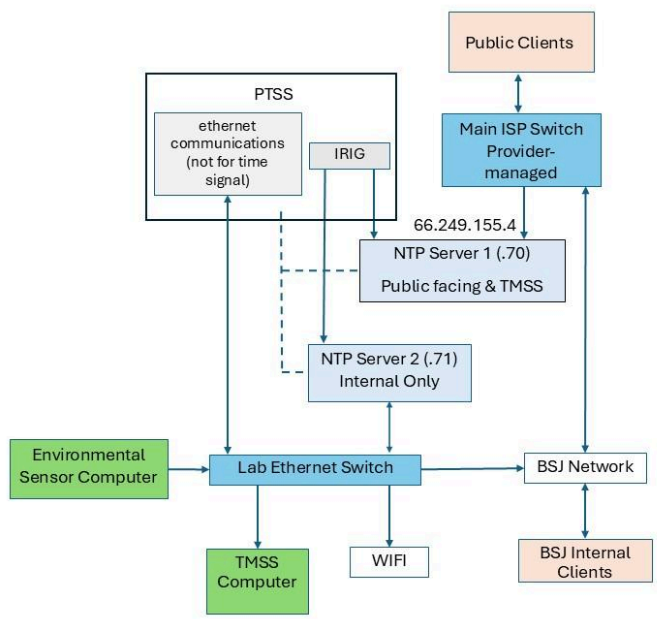


**FIGURE 4.** Block diagram of the TMSS service hardware. Dashes indicate the path of hardware control.

The TMSS service to specific customers will not be available until adequately tested, but it is now running in test mode using several publicly available NTP servers as pseudo-clients. While this system can only verify traceability to the client's system at the point of NTP interface, we also envision assisting customers in establishing traceability to the key points in their internal networks as well. The TMSS works by continuously monitoring the time offsets between the BSJ reference time and each connected customer's clock as seen through its NTP server. Reports are generated regularly to help customers assess the performance of their systems and ensure compliance with time accuracy standards. This section details the set of Python programs that provide the TMSS service, outlining the process of data acquisition, processing, analysis, and reporting.

At this point no automated procedure has been established for handling positive or negative leap seconds. However, it is our intention to notify customers well in advance of any leap second. We note that NTP does provide a means to notify clients of leap seconds, and it will be important to let customers be aware of this.

**III.1 Software System Overview**

The TMSS service relies on a package of programs to collect, process, analyze, and report time synchronization data. The main components of the system include:

1. **Data Collection**: Collect time synchronization data from each customer's server (device under test or DUT) and the public-facing BSJ server (NTP server 1) via the NTP protocol.
2. **Outlier Removal**: Identifying and removing outliers in the data to ensure only valid measurements are retained for analysis.
3. **Statistical Analysis**: Performing statistical calculations on the cleaned data to evaluate the accuracy and stability of the synchronization.
4. **Report Generation**: Compiling the results into comprehensive reports for the client, summarizing the synchronization performance.

These components are executed in sequence, each step feeding into the next to ensure accurate and timely reporting. Although currently not implemented, an email warning to BSJ staff is envisioned should a customer's time deviate from or threaten to deviate from the 50 ms limit. However, the data can also be visually inspected at any time.

**III.2 Data Collection and Client Information Setup**

The first step in providing the TMSS service is collecting data from customer servers. The data are gathered from CSV files that are generated from real-time measurements taken by the BSJ reference server. These files typically contain time offsets, network round-trip times to the BSJ and client servers (RT1, RT2), and related statistics for each client system.

The program begins by reading a configuration file (*clientinfo*) that contains vital information about each client system. This includes:

- Lab Name
- Report Date
- Location
- Device Under Test (DUT)
- Contact Information
- Calibration Period
- IP Address

The *clientinfo* file helps map each lab or customer to the correct report and synchronize the data accordingly.

In this arrangement, the BSJ's outward-facing server is also accessed by the TMSS computer, and its difference with the TMSS computer is subtracted from the differences between the TMSS computer and the other servers being queried. The operating system of TMSS's computer time itself is referenced to UTC(BSJ) with NTP several times a day, a sampling rate that results in noticeable drift between resets but has a negligible effect due to the small elapsed time between NTP queries.

**III.3 Pruning Outliers**

Once the data are collected and referenced to the BSJ public-facing server, they are passed through a pruning process that filters out unreliable data points. The pruning algorithm first removes gross outliers and then identifies other outliers by comparing each data point to the dataset's median. Data points that fall outside a threshold defined by a set number of standard deviations (currently 5) from the median are discarded. We do not currently discard points with large round-trip times, however use of the median strongly reduces the sensitivity to them. The possibility of removing all but "lucky packets" (small round trip times) is being studied. We note that a route from BSJ to NIST that goes back and forth via Haiti would be preferable to a route that has a shorter round-trip time because it travels outbound to Colorado via Haiti but returns over a shorter path through Mexico.

The outlier removal process process involves the following steps:

1. **Initial Data Read**: The program reads the raw CSV data, which for each client gives the MJD (Modified Julian Date) and associated time offsets in sequential order.
2. **Filtering Based on MJD**: The data are filtered by a range of MJD values (if specified). Only data points within this range are considered valid. Currently, filtering is done one day at a time.
3. **Outlier Detection**: Gross outliers, defined as ±200 ms, are initially excluded. For each remaining data point, the program retains only those within the acceptable range defined by median ±5 standard deviations which is typically a few ms, as shown in the Appendix. So far, only once has more than 1% of the points been discarded..
4. **Iterative Refinement**: The process of recalculating the mean, standard deviation, and median is repeated iteratively until no further significant changes are detected.

The discarded data are not lost. They are retained for possible future study.

### III.4 Statistical Analysis

After pruning the data, the next step is to calculate the statistical properties of the cleaned dataset. These metrics are essential for evaluating the timing performance of the client's system. Key statistical measures include:

- **Average (Mean)**: The arithmetic average of all data points, representing the typical time offset.
- **Root Mean Square (RMS)**: This measures the magnitude of time time accuracy of each unaveraged observation. It is the Root Sum of Squares (RSS) of the mean and the StD. s.
- **Standard Deviation**: This indicates the spread or consistency of the time offsets, with a lower standard deviation signifying better syntonization.
- **Median**: The middle value when the data is sorted in order, which is less sensitive to extreme values (outliers).
- **Minimum and Maximum**: These values indicate the range of time offsets in the dataset, helping to understand the worst-case scenario for time deviation.

In addition to these metrics, the program calculates averages for other parameters, such as round-trip times (RT1 and RT2), which help assess network stability and synchronization accuracy.

### III.5 Report Generation

The final step of the TMSS process is to generate a report that summarizes the synchronization performance for each customer’s server. The report contains:

- **Customer Information**: A header section that includes basic details about the customers, such as lab name, device under test, contact information, and the calibration period.
- **Calibration Procedure Description**: A brief explanation of the calibration method used, outlining the NTP synchronization process and how the accuracy is assessed.
- **Time Difference Statistics**: A table displaying the calculated statistics (e.g., median, RMS, standard deviation, etc.) for each day or reporting period.
- **Summary of Time Measurement**: An analysis of the time accuracy, summarizing the results of the time offset measurements and network round-trip times.

The report is formatted into a PDF using the Free PDF (FPDF**)** Python library. The final report is saved to the designated output directory, where it can be reviewed by the client. For each MJD-day, the accuracy can be conservatively estimated as the RSS of the RMS and half the average round-trip time. While the process is automated, we envision that human inspection will be an essential last step before sending monthly reports to our customers. Emergency alerts will be sent to our staff as soon as a problem is detected so that appropriate action can be taken.

### III.6 Discussion of NTP Data

Figure 5 shows some sample one-day averages in which the TMSS computer acted as a client against several servers. While the subdaily jitter in those data (not shown) is normal for NTP, it is also evident that the outward-facing BSJ NTP Server is apparently biased negatively with respect to most of the external labs. The same order of magnitude bias is seen from observations of BSJ by the SIM network, by Masterclock's facility in St. Charles, MO, and at a residence in Washington, DC. The reasons for it are under investigation, but its magnitude is much less than the traceability limit in any case. If the bias is due to asymmetry in the long and undersea connections between Jamaica and the other countries on this graph, it would have no impact on the accuracy of the service as seen by the Jamaican financial industry.

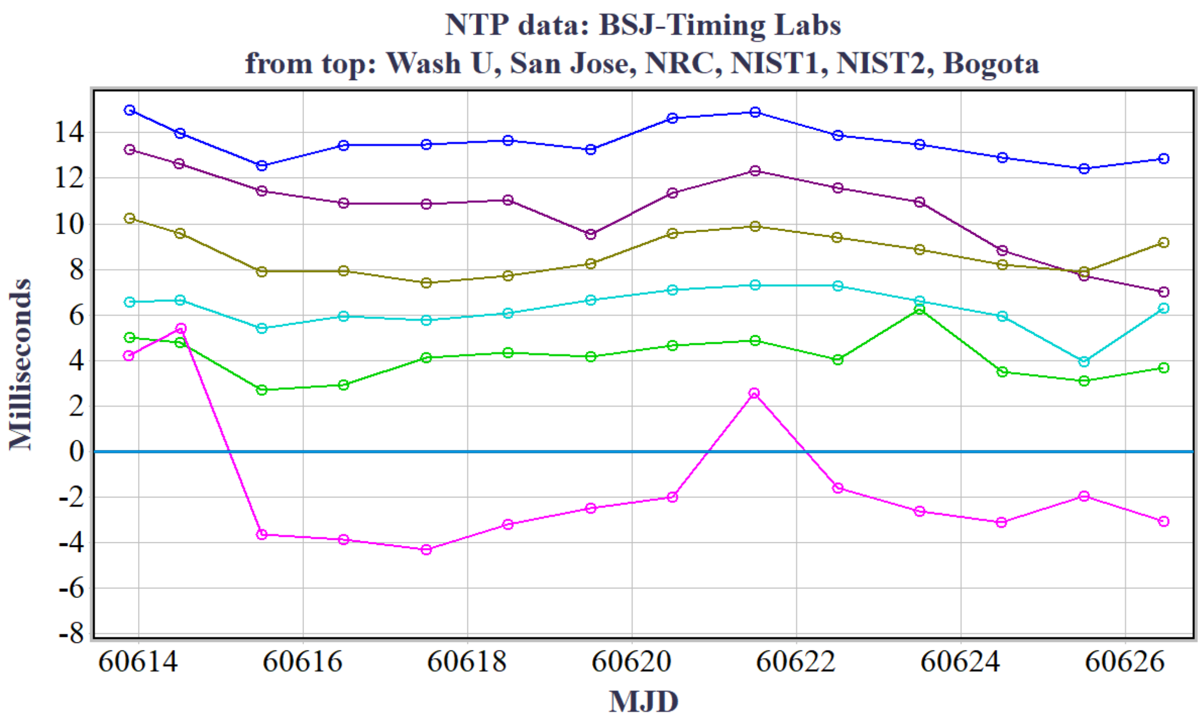


**FIGURE 5.** NTP-measured values for UTC(BSJ)-UTC(k) for several timing labs.

**IV. Summary, Conclusion and Future Work**

In 2024, the BSJ began regular reporting of clock data and UTC(BSJ) to the BIPM. Recent Circular T data for UTC-UTC(BSJ) have a standard deviation of about 5 ns. In December 2024 the Circular T evaluations of UTC-UTS(BSJ) were assigned a statistical uncertainty of 7 ns and a systematic uncertainty of 7 ns (with a combined uncertainty of 9.9 ns). A bias of approximately 10 ns bias needs to be reduced and may be due to internal delays in the time scale generation equipment.

An NTP-based service for providing and verifying traceable time to BSJ customers is in the process of development, and an apparent 10 ms offset is also under investigation but may be due to the asymmetries in the undersea connections. However, neither this bias nor the ns-level one in the Circular T is large enough to be of concern for the NTP service.

**V. Disclaimer**

Certain equipment, products, or proprietary methods are identified in this paper in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement of any product or service by Masterclock, the BSJ or NIST, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

**VI. Acknowledgement**

We extend our gratitude to Dr. Judah Levine of NIST for his invaluable assistance with the software used in this work and to the BSJ Time and Frequency team for their dedication and support, which made this paper and the lab's progress possible.

**VI. References**

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**APPENDIX. Draft Calibration Report**

# Report of Calibration

| | |
|---|---|
| Customer: | Date of Report: |
| Location: | Device Under Test: |
| Contact: | Period of Calibration: |
| Server IP Address: | |

## I. Description of Calibration Procedure

The BSJ's Time Monitoring and Synchronization Service (TMSS) offers clients a secure source of time synchronization, utilizing the Network Time Protocol (NTP) for precise clock synchronization over the public internet. Each Device Under Test (DUT) connects to the BSJ's reference Dynamic Host Name (DNS) or IP address to synchronize its time. The BSJ continuously monitors the difference between its reference time and the DUT's server time through NTP, ensuring accurate synchronization. TMSS clients receive reports on their server's time accuracy, with monitoring results such as time offset and network round trip delay helping to ensure compliance with quality standards and regulatory requirements.

## II. Table of Daily Time Differences between the Device Under Test and UTC(BSJ)

Daily measurements of the time differences between DUT and UTC(BSJ) are provided in table 1 below. The daily measurements are average data taken my making measurements every minute over a 24-hour period.

| MJD | Median Offset (ms) | RMS (ms) | StDev (ms) | Ave RT1 (ms) | AveRT2 (ms) | Ave Offset (ms) | pre-edit Npoints | Npoints after editing |
|---|---|---|---|---|---|---|---|---|
| 60571 | 10.27 | 12.04 | 4.44 | 0.05 | 157.78 | 11.20 | 697 | 695 |
| 60571 | 6.54 | 8.50 | 5.12 | 0.57 | 163.21 | 6.78 | 3876 | 3869 |
| 60572 | 8.15 | 10.52 | 6.05 | 0.20 | 170.14 | 8.61 | 2765 | 2748 |
| 60573 | 7.58 | 9.33 | 5.12 | 0.15 | 167.26 | 7.80 | 1353 | 1351 |
| 60577 | 9.08 | 13.72 | 9.02 | 0.05 | 170.22 | 10.34 | 720 | 717 |
| 60577 | 8.08 | 21.41 | 17.70 | 0.19 | 176.42 | 12.05 | 1456 | 1447 |
| 60579 | 7.87 | 9.56 | 5.08 | 0.10 | 166.46 | 8.10 | 1924 | 1921 |
| 60579 | 20.79 | 21.72 | 6.72 | 0.14 | 146.91 | 20.66 | 1270 | 1268 |
| 60581 | 20.34 | 21.48 | 5.22 | 0.00 | 145.42 | 20.84 | 181 | 181 |
| 60581 | 19.95 | 20.81 | 5.59 | 0.07 | 142.76 | 20.04 | 1127 | 1124 |
| 60584 | 22.43 | 24.88 | 8.59 | 0.32 | 146.61 | 23.35 | 849 | 845 |
| 60584 | 23.42 | 25.85 | 9.21 | 0.23 | 151.09 | 24.15 | 3329 | 3315 |
| 60587 | 21.35 | 22.26 | 4.25 | 0.02 | 131.84 | 21.85 | 1202 | 1201 |
| 60587 | 21.24 | 21.70 | 2.79 | 0.02 | 126.25 | 21.52 | 2601 | 2587 |
| 60591 | 23.05 | 22.58 | 2.43 | 0.06 | 130.15 | 22.45 | 1300 | 1296 |
| 60591 | 19.22 | 17.49 | 9.58 | 0.12 | 139.60 | 14.63 | 3428 | 3422 |
| 60592 | 7.18 | 9.61 | 7.13 | 0.06 | 164.23 | 6.45 | 563 | 558 |
| 60614 | 3.07 | 8.43 | 7.33 | 1.55 | 161.84 | 4.18 | 419 | 415 |
| 60614 | 3.15 | 14.93 | 13.91 | 1.30 | 161.92 | 5.41 | 3271 | 3256 |
| 60615 | -3.68 | 5.44 | 4.00 | 0.10 | 149.26 | -3.69 | 3443 | 3434 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 60616 | -3.79 | 5.61 | 4.03 | 0.11 | 150.31 | -3.91 | 3454 | 3450 |
| 60618 | -4.36 | 5.96 | 4.10 | 0.09 | 150.52 | -4.32 | 3441 | 3434 |
| 60618 | -3.18 | 5.02 | 3.83 | 0.11 | 149.88 | -3.24 | 3420 | 3416 |
| 60619 | -2.33 | 4.76 | 4.05 | 0.11 | 149.05 | -2.51 | 3426 | 3422 |
| 60621 | -0.74 | 4.27 | 3.76 | 0.13 | 146.01 | -2.04 | 3432 | 3426 |
| 60621 | 0.47 | 11.46 | 11.18 | 0.22 | 152.48 | 2.55 | 3296 | 3293 |
| 60623 | -0.51 | 4.17 | 3.84 | 0.18 | 145.74 | -1.63 | 3441 | 3398 |
| 60623 | -1.49 | 4.71 | 3.90 | 0.14 | 147.20 | -2.64 | 3444 | 3432 |
| 60624 | -2.93 | 5.04 | 3.95 | 0.13 | 149.20 | -3.14 | 3332 | 3328 |
| 60626 | -1.91 | 5.30 | 4.91 | 0.16 | 153.29 | -1.99 | 3430 | 3418 |
| 60626 | -2.89 | 5.23 | 4.20 | 0.11 | 148.53 | -3.11 | 3230 | 3222 |
| 60634 | -2.31 | 3.75 | 2.83 | 1.95 | 149.81 | -2.46 | 894 | 892 |
| 60634 | -2.25 | 3.92 | 3.01 | 2.05 | 150.12 | -2.51 | 3100 | 3093 |

## III. Average Summary of Data

Table 2 provides a summary of data for the period being measured. The average offset is 7.14ms with a minimum round-trip delay of 0.32ms. The root mean square (rms) representing the uncertainty of the measured data is 11.86ms.

| Month | Median Offset (ms) | RMS (ms) | STD (ms) | AVRT1 (ms) | AVRT2 (ms) | AVE OFFSET (ms) |
|---|---|---|---|---|---|---|
| September | 7.00 | 11.86 | 5.96 | 0.32 | 151.86 | 7.14 |

This report allows the customer to show traceability to the SI through the national standard of frequency and time interval maintained at BSJ.

This report shall not be reproduced, except in full, without the written approval of BSJ.

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