GNSS disciplined Frequency Standard Internal Calibration Report

Report date : 2026-10-29 21:54:45 GMT+00:00

Instrument description : GNSS disciplined Rubidium Frequency Standard

Instrument ID : Pendulum FTR-210R

Product code : 9446 102 10171

Serial number : 709277

Period of calibration

From : 2026-06-24 (UTC)

To : 2026-10-29 (UTC)

Description of calibration procedure

The local Rubidium oscillator output of the Frequency Standard is continuous and gap-free phase-compared with the 1 PPS signal derived from the timing GNSS receiver, in the built-in independent measurement system.

Samples of the Time difference between the corresponding 1 PPS pulses from the GNSS receiver and the 1 PPS output from the Rubidium oscillator, are taken every 30 s. A single measurement data record based on it is stored in a database located in the non-volatile memory inside the instrument.

A single measurement data record includes:
• UTC time reported by the GNSS receiver
• UTC time uncertainty
• various flags (e. g. GNSS receiver fix state, Rubidium oscillator state)
• an internal timestamp
• 1 PPS phase offset value and uncertainty

After the number of records stored in the database reaches the equivalent of roughly 4 years and 1 day of continuous operation, a clean-up is triggered, and a set of oldest records, roughly equivalent to 1 day of continuous operation, is deleted from the database. In other words, after this limit is reached, the instrument will contain raw data for traceability measurement for the last 4 years, given that it was operating continuously all this time, or even more if it had gaps in the dataset due to being offline.

10 MHz Reference Frequency offset calculation method

From the phase deviation data (TIE - Time Interval Error) over the last 24h and 1h, a linear least square fitting line is computed. The 24h mean frequency offset of the local oscillator, relative GNSS, is calculated as the slope of this line (TIE-vs-time).

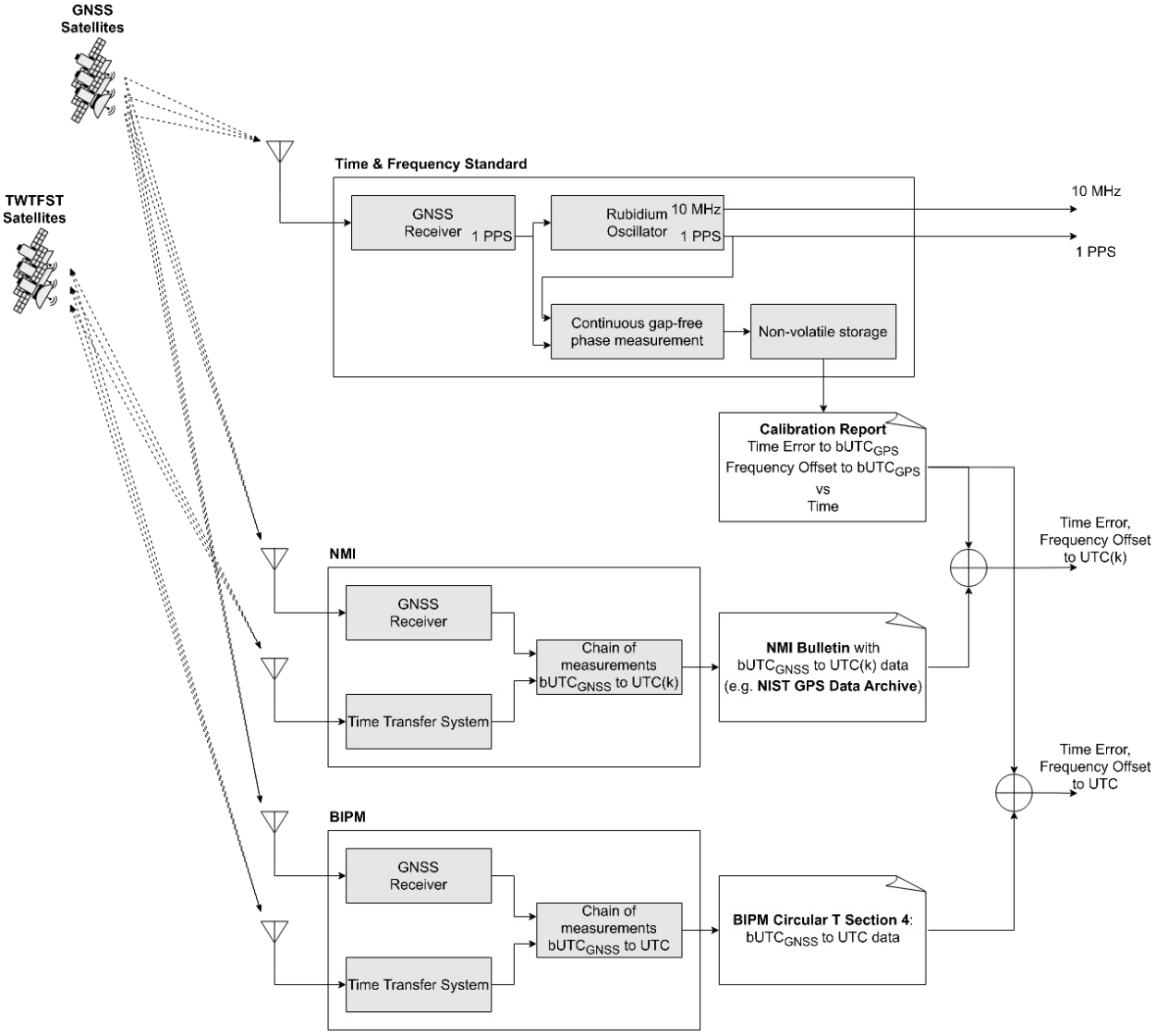
1 PPS Reference Time (phase) offset calibration and 10 MHz Reference Frequency offset calibration

The average values for the phase offset (GNSS vs. Rubidium) and reference frequency offset over the last 24h (2880 values) and 1h (120 values) is computed. There could be a gap in the data, e.g. temporary loss of GNSS lock.

Once every 30 s, when new measurement sample arrives, average values for last 1h and 24h, along with uncertainty are immediately re-calculated and displayed on the main screen. Individual 30 s interval measurements are saved into the internal database.

1h and 24h average data is not stored in persistent storage and is re-calculated at the time of report generation, based on a range of 30 s interval measurement records.

Traceability chain diagram



Uncertainty of 24h mean 1 PPS offset

The contributing uncertainty factors are:

Rubidium output to GNSS receiver output:
• Uncertainty of Time Interval measurement process itself, including a.o. resolution, systematic errors and noise factors, which is < 0.5 ns rms.
• Variations of the local Rubidium oscillator timing output due to temperature variations and the disciplining algorithm, which is < 0.5 ns rms.
• Systematic delay from Rubidium 1 PPS input to 1 PPS output, which is < ±4ns, after compensation using 1ns stepper.
• The 1 PPS output jitter of the GNSS receiver, which is < ±4 ns.
• The overall random uncertainty value is based on the actual distribution of Time Interval values for each 24h period.

GNSS receiver output to $bUTC_{GPS}$:
• Uncertainty to $bUTC_{GPS}$ is provided by the GNSS receiver module. This uncertainty depends on GNSS signal quality and geometry, fix mode and environment conditions. Can be down to < 10 ns rms best case.

The minimum of this uncertainty is achieved when:
• High quality antenna and cable are used.
• Antenna location ensures an unobstructed sky view to avoid uncertainty due to phase fluctuations of the received GNSS-signal, due to e.g. bad antenna reception, and multi-path interference.
• Antenna cable delay is properly compensated in the user interface of the Frequency Standard.
• Frequency Standard is configured to use multiple GNSS constellations and multiple GNSS bands.
• Self-survey is completed and fix mode is TIME.

$bUTC_{GPS}$ to UTC(NIST)
• Uncertainty with respect to NIST. For exact figures, see NIST GPS Data Archive: https://www.nist.gov/pml/time-and-frequency-division/services/gps-data-archive.

$bUTC_{GPS}$ to UTC
• $bUTC_{GPS}$ to UTC is estimated to be in the range ±5 ns with typical uncertainty of 5 ns (1-sigma), based on published information from BIPM (Circular T).

For exact figures, see BIPM Circular T, section 4: https://www.bipm.org/en/time-ftp/circular-t.

Uncertainty of 24h mean Frequency offset

The contributing uncertainty factors are:

Rubidium 10 MHz output to GNSS receiver output:
• Uncertainty of measurement process itself, including a.o. resolution, noise factors, and number of samples during the 24h period. For a 100% sample coverage during the day (2880 samples) the random uncertainty is < 1.5E-14 rms.
• Variations of the local oscillator frequency due to intrinsic ageing and temperature drift and the compensation of these factors through the disciplining algorithm.
• The 1 PPS output jitter of the GNSS receiver, which is < ±4 ns, after compensation using 1 ns stepper, corresponding to 4.6E-14 rms over 24h.
• The overall random uncertainty value is based on the actual distribution of TIE-values for each 24h period, taking into account the number of samples and the spread of the samples related to the regression line slope.

GNSS receiver output to bUTC$_{GPS}$:
• Uncertainty to bUTC$_{GPS}$ is provided by the GNSS receiver module. This uncertainty depends on GNSS signal quality and geometry, fix mode and environment conditions. Can be down to < 10 ns rms best case.

The minimum of this uncertainty is achieved when:
• High quality antenna and cable are used.
• Antenna location ensures an unobstructed sky view to avoid uncertainty due to phase fluctuations of the received GNSS-signal, due to e.g. bad antenna reception, and multi-path interference.
• Antenna cable delay is properly compensated in the user interface of the Frequency Standard.
• Frequency Standard is configured to use multiple GNSS constellations and multiple GNSS bands.
• Self-survey is completed and fix mode is TIME.

bUTC$_{GPS}$ to UTC(NIST)
• Uncertainty with respect to NIST. This uncertainty factor is assumed to be < 1E-13 (k=2), based on published information from NIST (GPS Data Archive).

For exact figures, visit NIST GPS Data Archive: https://www.nist.gov/pml/time-and-frequency-division/services/gps-data-archive.

bUTC$_{GPS}$ to UTC
• Uncertainty with respect to BIPM. For exact figures, see BIPM Circular T, section 4: https://www.bipm.org/en/time-ftp/circular-t.

The Calibration Report

The calibration report is created on request by the user, in the User Interface of the Frequency standard, where the date range shall be entered.

The calibration report is based on the contents of the internal database.

Uncertainty in the calibration report is calculated with a coverage factor of 2 (k=2).

The following fields are displayed for each date from the range requested by the user:
• UTC date (in YYYY-MM-DD format)
• MJD date (1 integer value)
• Computed mean 24h 1 PPS offset over each 24h period (1 value/day)
• Computed mean 24h 1 PPS uncertainty over each 24h period (1 value/day)
• Computed peak-peak range of 1 PPS offsets over each 24h period (1 value/day)
• Computed mean frequency offset over each 24h period (1 value/day)
• Computed mean frequency uncertainty over each 24h period (1 value/day)
• Mean oscillator DAC value used to steer its frequency. It is a measure of the intrinsic ageing of the Rubidium oscillator, that is compensated by the disciplining. Typically, there is an approximately linear relationship between change of DAC values between adjacent days and the frequency adjustment during that day.
• Computed DAC value standard deviation. Indicates the statistical variance in the frequency control loop over given time period, quantifying the intensity of steering adjustments caused by oscillator drift or external environmental factors (e.g. GNSS signal instability, temperature variations, etc).
• Comment field

Raw phase offset data for the date range specified by the user is saved along the Calibration Report as CSV file.

UTC Date, YYYY-MM-DD	Date, MJD	Mean phase offset to bUTC_GPS, ns	Mean phase offset uncertainty (2 sigma), ns	Phase range, ns peak-peak	Mean 10 MHz frequency offset relative to bUTC_GPS	Mean 10 MHz frequency offset uncertainty (2 sigma)	Mean DAC value	DAC StdDev	Comment
2026-06-24	61216	-12958.62	1142935.25	25196481.63	1.33e-09	1.54e-09	8417536	4841	Instrument restarted. Hold-Over. No GNSS Fix.
2026-06-25	61217	2.44	46.49	14.99	1.16e-15	1.16e-13	8417943	3545	No GNSS Time Fix.
2026-06-26	61218	2.46	44.52	16.66	1.98e-15	1.16e-13	8418332	3445	
2026-06-27	61219	2.52	44.50	15.88	1.02e-15	1.16e-13	8415662	2667	
2026-06-28	61220	2.47	44.50	18.19	-1.49e-15	1.16e-13	8414222	2677	
2026-06-29	61221	2.54	44.52	21.18	-1.25e-15	1.16e-13	8414770	3182	
2026-06-30	61222	2.46	48.46	18.41	-1.87e-15	1.16e-13	8414675	3322	
2026-07-01	61223	2.50	44.49	11.26	2.98e-16	1.16e-13	8412252	2003	
2026-07-02	61224	2.42	44.48	10.76	-3.68e-15	1.16e-13	8412191	2042	

2026-07-03	61225	2.55	44.49	10.48	-3.19e-15	1.16e-13	8411607	1825	
2026-07-04	61226	2.48	44.50	13.82	5.95e-16	1.16e-13	8409581	2554	
2026-07-05	61227	2.49	44.48	13.64	-2.58e-15	1.16e-13	8407911	2221	
2026-07-06	61228	2.45	44.49	11.42	2.03e-15	1.16e-13	8406546	1983	
2026-07-07	61229	2.59	44.50	17.06	-4.24e-15	1.16e-13	8407913	2870	
2026-07-08	61230	2.51	44.49	12.44	-2.72e-15	1.16e-13	8407523	2866	
2026-07-09	61231	2.59	44.49	12.42	-8.32e-16	1.16e-13	8408194	2309	
2026-07-10	61232	2.57	44.50	12.02	-2.77e-15	1.16e-13	8407512	2670	
2026-07-11	61233	2.46	44.49	11.51	1.16e-15	1.16e-13	8405777	2072	
2026-07-12	61234	2.56	44.49	12.35	1.45e-15	1.16e-13	8404360	2214	
2026-07-13	61235	2.52	44.49	12.64	-1.33e-15	1.16e-13	8404524	2171	
2026-07-14	61236	2.51	44.49	11.20	1.39e-15	1.16e-13	8403165	1990	
2026-07-15	61237	2.52	44.51	24.04	-2.33e-15	1.16e-13	8404783	3327	
2026-07-16	61238	2.51	44.51	28.82	-1.8e-16	1.16e-13	8402240	3063	
2026-07-17	61239	2.49	44.50	10.63	2.29e-15	1.16e-13	8400714	1577	
2026-07-18	61240	2.53	44.49	11.00	3.4e-16	1.16e-13	8401664	1605	
2026-07-19	61241	2.53	44.49	11.13	-3.06e-15	1.16e-13	8400094	1856	
2026-07-20	61242	2.50	44.50	17.30	4.25e-17	1.16e-13	8398600	2727	
2026-07-21	61243	2.56	44.49	11.86	1.87e-15	1.16e-13	8397913	2162	
2026-07-22	61244	2.49	44.50	13.13	1.79e-15	1.16e-13	8397904	2633	
2026-07-23	61245	2.53	44.49	10.81	-1.4e-15	1.16e-13	8398390	2262	
2026-07-24	61246	2.47	44.50	11.42	1.45e-15	1.16e-13	8395939	1854	
2026-07-25	61247	2.50	44.48	10.58	-1.6e-15	1.16e-13	8396802	1898	
2026-07-26	61248	2.52	44.50	13.22	-1.58e-15	1.16e-13	8394424	2166	
2026-07-27	61249	2.51	44.49	13.36	3e-16	1.16e-13	8394989	2058	

2026-07-28	61250	2.45	44.49	11.62	-2.22e-15	1.16e-13	8393460	2606	
2026-07-29	61251	2.46	44.49	10.98	2.01e-15	1.16e-13	8392797	2791	
2026-07-30	61252	2.55	44.49	12.62	-1.95e-15	1.16e-13	8395538	2108	
2026-07-31	61253	2.49	44.49	13.84	9.49e-16	1.16e-13	8394613	2306	
2026-08-01	61254	2.46	44.51	18.64	6.51e-16	1.16e-13	8395408	2422	
2026-08-02	61255	2.53	44.50	11.26	2.06e-15	1.16e-13	8392768	2438	
2026-08-03	61256	2.60	44.50	12.16	-1.61e-16	1.16e-13	8390867	2290	
2026-08-04	61257	2.55	44.48	10.43	2.61e-16	1.16e-13	8393467	1750	
2026-08-05	61258	2.57	44.48	11.34	-2.36e-15	1.16e-13	8392157	2550	
2026-08-06	61259	2.50	44.51	20.48	-1.31e-15	1.16e-13	8389374	3042	
2026-08-07	61260	2.49	44.48	10.15	1.24e-15	1.16e-13	8387219	3061	
2026-08-08	61261	2.48	44.50	11.54	1.92e-15	1.16e-13	8386293	2304	
2026-08-09	61262	2.50	44.49	10.64	2.59e-15	1.16e-13	8384213	1985	
2026-08-10	61263	2.50	44.49	10.58	-9.85e-16	1.16e-13	8384415	1866	
2026-08-11	61264	2.42	44.48	10.47	3.35e-15	1.16e-13	8384732	2024	
2026-08-12	61265	2.56	44.49	9.95	2.47e-15	1.16e-13	8384274	2109	
2026-08-13	61266	2.53	44.49	10.47	-1.98e-15	1.16e-13	8383184	3599	
2026-08-14	61267	2.51	44.49	11.65	2.13e-16	1.16e-13	8382645	2126	
2026-08-15	61268	2.54	44.49	14.04	-1.28e-15	1.16e-13	8381732	2189	
2026-08-16	61269	2.43	44.49	11.05	-1.81e-16	1.16e-13	8381959	1654	
2026-08-17	61270	2.55	44.48	11.32	-2.13e-16	1.16e-13	8382111	2140	
2026-08-18	61271	2.52	44.48	11.21	-2.12e-15	1.16e-13	8382858	2054	
2026-08-19	61272	2.61	44.49	11.90	-2.01e-15	1.16e-13	8385473	1883	
2026-08-20	61273	2.45	44.49	10.63	-1.38e-16	1.16e-13	8385174	2053	
2026-08-21	61274	2.46	44.49	14.54	-1.85e-16	1.16e-13	8383314	2586	

2026-08-22	61275	2.56	44.50	10.88	-1.97e-15	1.16e-13	8382277	2032	
2026-08-23	61276	2.51	44.49	11.82	2.98e-15	1.16e-13	8379972	1658	
2026-08-24	61277	2.50	44.48	10.66	-8.47e-16	1.16e-13	8379419	2150	
2026-08-25	61278	2.55	44.50	14.03	2.99e-15	1.16e-13	8380516	2509	
2026-08-26	61279	2.53	44.48	10.94	2.91e-15	1.16e-13	8380017	2025	
2026-08-27	61280	2.48	44.49	16.09	7.48e-16	1.16e-13	8379902	2272	
2026-08-28	61281	2.50	44.50	13.52	-2.91e-15	1.16e-13	8379459	2407	
2026-08-29	61282	2.55	44.49	10.54	-4.16e-15	1.16e-13	8378590	2242	
2026-08-30	61283	2.50	44.50	11.56	3.15e-15	1.16e-13	8377932	2002	
2026-08-31	61284	2.55	44.51	16.46	6.5e-16	1.16e-13	8377953	3149	
2026-09-01	61285	2.50	44.49	10.94	5.46e-16	1.16e-13	8377463	2143	
2026-09-02	61286	2.40	44.49	11.41	2.31e-15	1.16e-13	8377631	2580	
2026-09-03	61287	2.45	44.48	10.69	3.02e-15	1.16e-13	8379265	2113	
2026-09-04	61288	2.57	44.49	13.23	6.18e-16	1.16e-13	8379865	2570	
2026-09-05	61289	2.68	44.50	11.09	2.29e-16	1.16e-13	8378593	2966	
2026-09-06	61290	2.60	44.50	14.13	4.68e-16	1.16e-13	8374387	2723	
2026-09-07	61291	2.56	44.50	13.93	-1.92e-15	1.16e-13	8373545	2623	
2026-09-08	61292	2.51	44.49	10.55	1.83e-15	1.16e-13	8375048	2318	
2026-09-09	61293	2.59	44.49	11.16	4.46e-15	1.16e-13	8376249	2009	
2026-09-10	61294	2.50	44.49	11.40	-1.12e-15	1.16e-13	8375346	2186	
2026-09-11	61295	2.49	44.49	11.43	-2.08e-15	1.16e-13	8373484	2212	
2026-09-12	61296	2.56	44.50	11.17	2.96e-16	1.16e-13	8371521	2936	
2026-09-13	61297	2.50	44.49	11.26	-2.26e-15	1.16e-13	8369694	1464	
2026-09-14	61298	2.51	44.49	10.49	-1.83e-15	1.16e-13	8371470	2027	
2026-09-15	61299	2.56	44.49	10.56	-1.63e-15	1.16e-13	8372075	2020	

2026-09-16	61300	2.51	44.48	11.06	2.17e-15	1.16e-13	8373088	2009	
2026-09-17	61301	2.50	44.49	12.83	-3.83e-15	1.16e-13	8372991	2348	
2026-09-18	61302	2.53	44.50	13.55	-5.84e-16	1.16e-13	8371750	2732	
2026-09-19	61303	2.56	44.49	12.83	3.64e-18	1.16e-13	8370508	2110	
2026-09-20	61304	2.52	44.49	12.13	2.07e-15	1.16e-13	8367911	1903	
2026-09-21	61305	2.59	44.49	12.20	-1.51e-15	1.16e-13	8367386	2290	
2026-09-22	61306	2.48	44.49	12.40	4.18e-15	1.16e-13	8368616	1991	
2026-09-23	61307	2.58	44.49	12.29	-1.23e-15	1.16e-13	8368844	1768	
2026-09-24	61308	2.58	44.49	10.53	6.7e-16	1.16e-13	8369299	2137	
2026-09-25	61309	2.51	44.49	11.80	1.49e-15	1.16e-13	8369596	1957	
2026-09-26	61310	2.52	44.49	12.82	-1.56e-15	1.16e-13	8366287	3769	
2026-09-27	61311	2.56	44.49	13.42	-5.91e-16	1.16e-13	8363091	2061	
2026-09-28	61312	2.52	44.49	10.47	2.15e-15	1.16e-13	8363469	2791	
2026-09-29	61313	2.53	44.50	23.86	-6.54e-16	1.16e-13	8362685	3023	
2026-09-30	61314	2.46	44.49	12.06	-1.24e-15	1.16e-13	8359435	1849	
2026-10-01	61315	2.56	44.48	10.85	2e-15	1.16e-13	8358983	1841	
2026-10-02	61316	2.53	44.49	10.92	1.9e-15	1.16e-13	8358255	2033	
2026-10-03	61317	2.57	44.49	10.83	-9.84e-16	1.16e-13	8359631	1976	
2026-10-04	61318	2.55	44.49	11.16	1.96e-15	1.16e-13	8359350	1847	
2026-10-05	61319	2.52	44.49	10.87	-5.61e-16	1.16e-13	8359674	2298	
2026-10-06	61320	2.42	44.51	13.63	-2.09e-17	1.16e-13	8360959	3213	
2026-10-07	61321	2.49	44.50	15.34	2.36e-15	1.16e-13	8362618	2651	
2026-10-08	61322	2.61	44.49	10.90	2.2e-15	1.16e-13	8363186	1868	
2026-10-09	61323	2.51	44.49	12.55	-7.11e-16	1.16e-13	8363069	1770	
2026-10-10	61324	2.57	44.50	11.36	-1.43e-15	1.16e-13	8359842	2558	

2026-10-11	61325	2.45	44.50	11.24	-2.77e-15	1.16e-13	8357042	2114	
2026-10-12	61326	2.52	44.48	11.80	1.57e-15	1.16e-13	8355801	2410	
2026-10-13	61327	2.52	44.49	11.04	-3.26e-15	1.16e-13	8354815	1808	
2026-10-14	61328	2.48	44.51	16.90	-8.19e-16	1.16e-13	8354176	2878	
2026-10-15	61329	2.51	44.51	15.48	9.73e-17	1.16e-13	8354313	3056	
2026-10-16	61330	2.51	44.49	10.18	5.38e-16	1.16e-13	8353298	1854	
2026-10-17	61331	2.49	44.50	16.16	-2.51e-15	1.16e-13	8353177	2892	
2026-10-18	61332	2.52	44.49	14.64	-4.79e-16	1.16e-13	8352396	2205	
2026-10-19	61333	2.44	44.49	9.94	-1.96e-15	1.16e-13	8353543	2207	
2026-10-20	61334	2.47	44.53	21.94	2.26e-15	1.16e-13	8355579	4394	
2026-10-21	61335	2.53	44.49	11.16	-9.53e-16	1.16e-13	8358738	1688	
2026-10-22	61336	2.44	44.48	11.25	-3.92e-15	1.16e-13	8358728	1994	
2026-10-23	61337	2.46	44.49	10.75	-4.79e-16	1.16e-13	8357195	1921	
2026-10-24	61338	2.39	44.49	10.81	1.41e-15	1.16e-13	8354231	2340	
2026-10-25	61339	2.46	44.49	10.89	1.22e-15	1.16e-13	8349481	1539	
2026-10-26	61340	2.49	44.49	10.63	-1.49e-15	1.16e-13	8349441	2375	
2026-10-27	61341	2.41	44.49	10.95	4.44e-15	1.16e-13	8349179	2949	
2026-10-28	61342	2.43	44.50	10.94	-2.4e-16	1.16e-13	8349538	1949	
2026-10-29	61343	2.48	44.49	11.56	6.87e-16	1.16e-13	8351394	1952	