Galmon.eu: Open source, crowd sourced GNSS monitoring

bert@hubertnet.nl

tinyurl.com/geobuzz19

NOS NIEUWS · BUITENLAND · MA 15 JULI, 04:35

EU-satellietnavigatiesysteem Galileo plat na 'technisch incident'


NAVSTAR GPS


ГЛОБАЛЬНАЯ НАВИГАЦИОННАЯ СПУТНИКОВАЯ СИСТЕМА
ГЛОНАСС


GALILEO


北斗卫星导航系统
BeiDou Navigation Satellite System

arianespace
service & solutions

LAUNCH KIT

November 2016

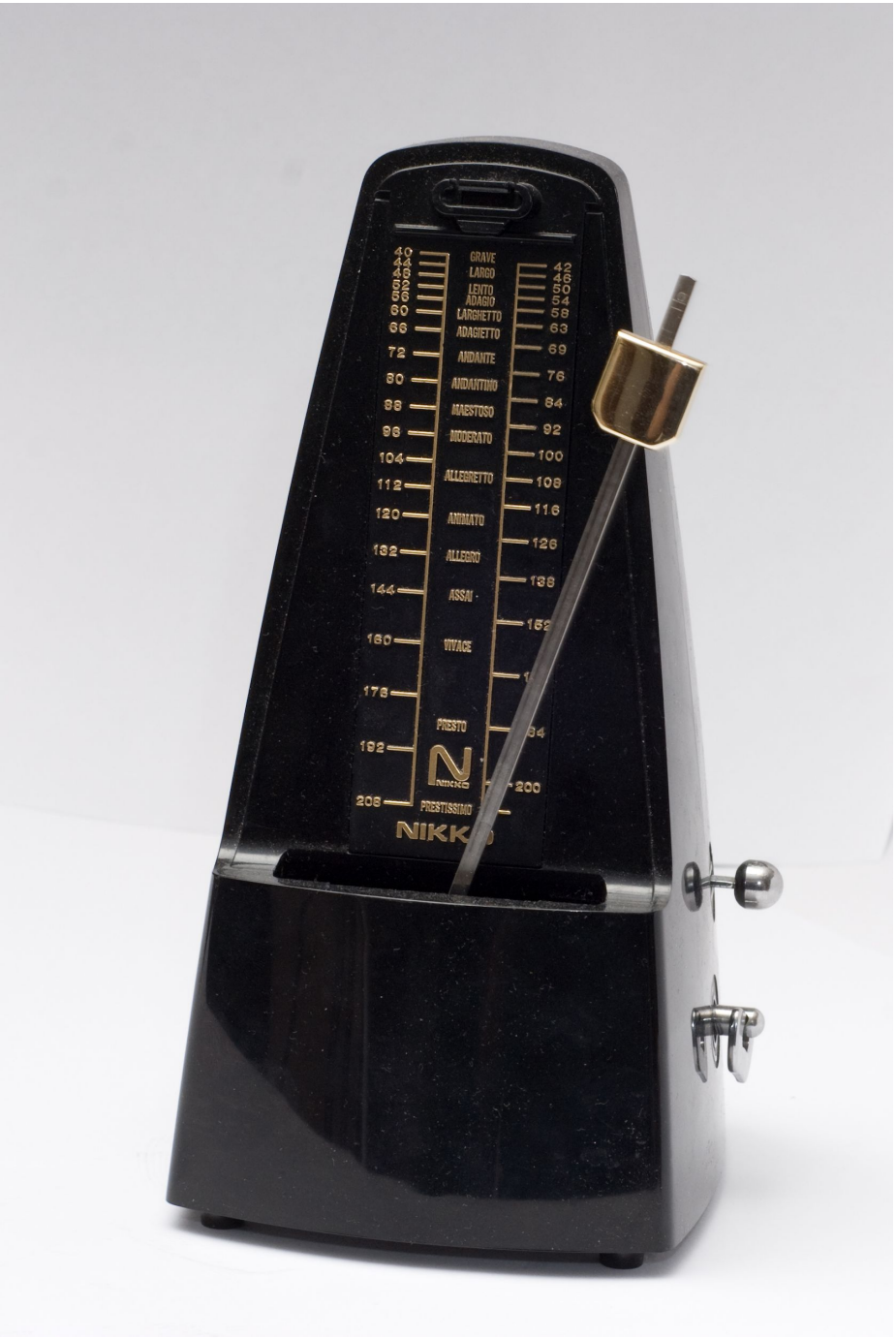
VA233

Galileo FOC-M6
SAT 15-16-17-18

esa

GALILEO
15-16-17-18

cnes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ADAGIO
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ANDANTINO
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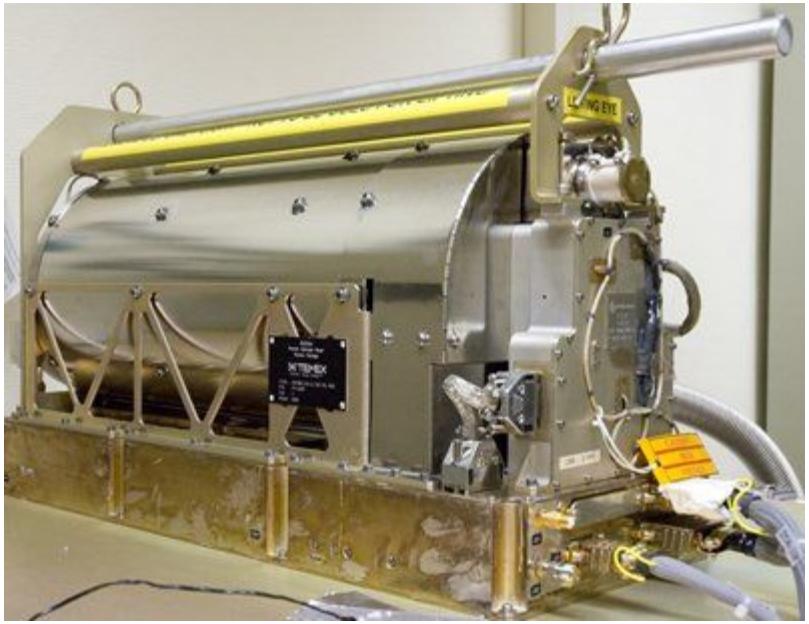
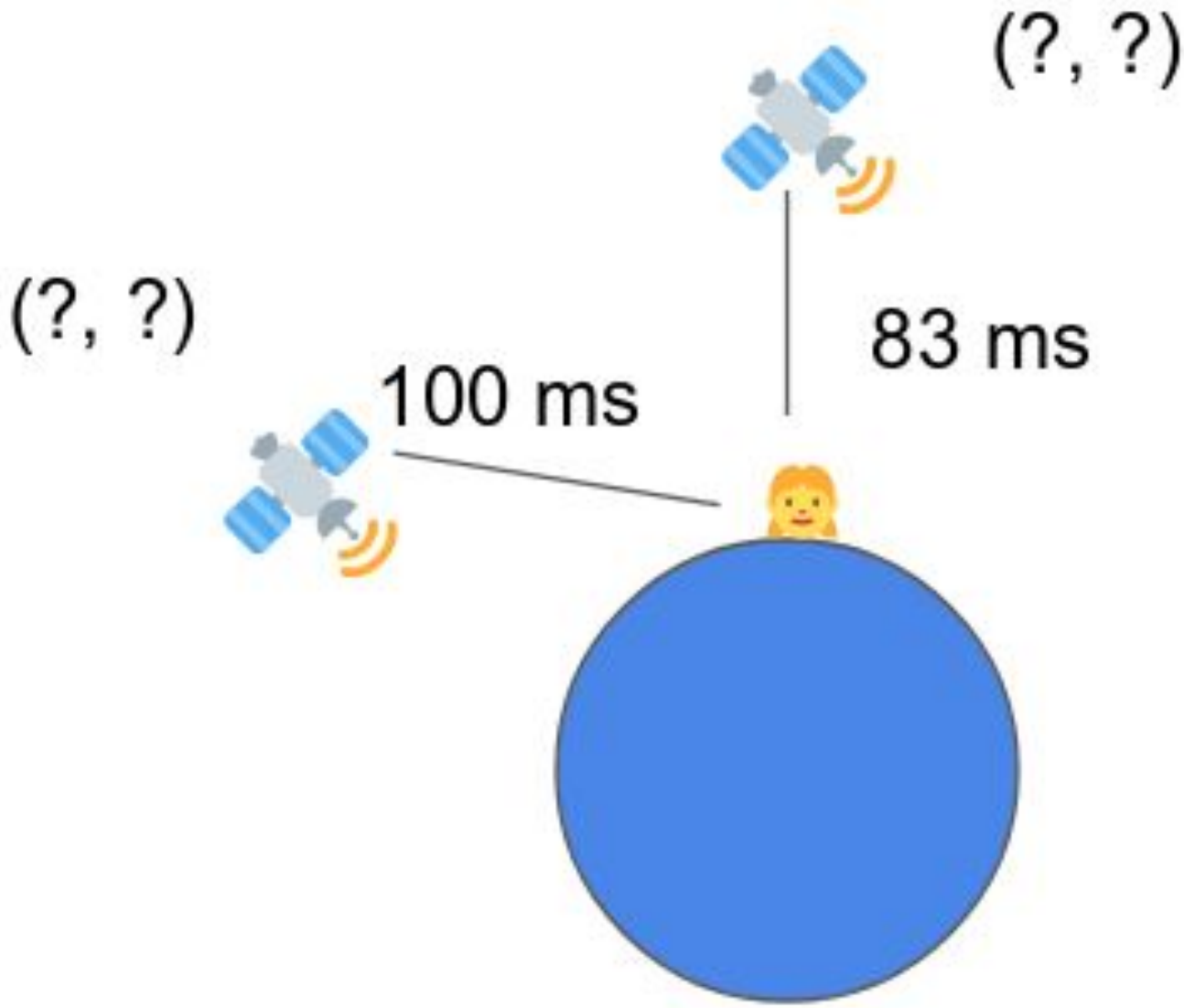
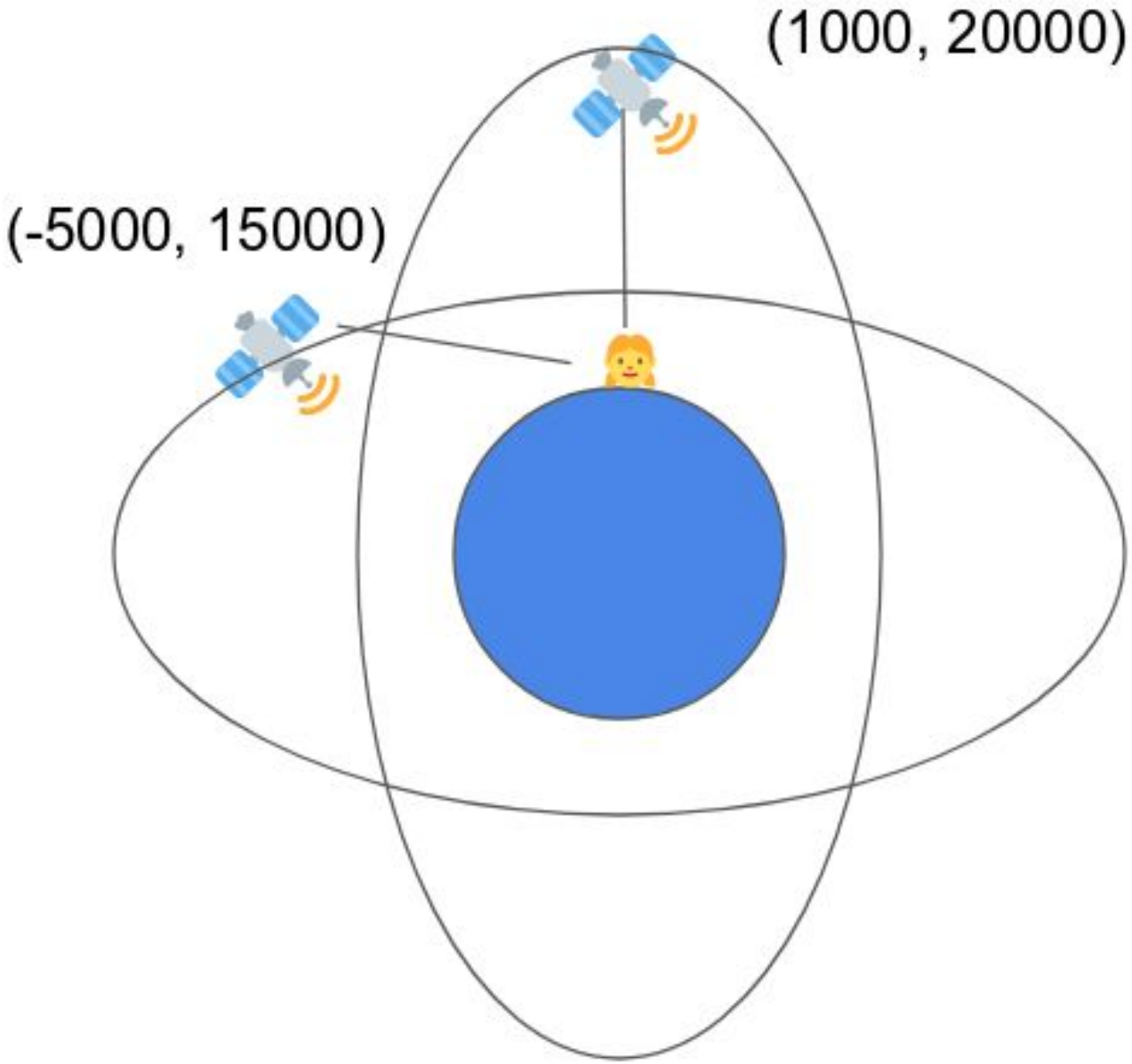
ANIMATO
ALLEGRO
ASSAI
VIVACE
PRESTO
PRESTISSIMO
NIKKO




(?, ?)
(?, ?)
83 ms
100 ms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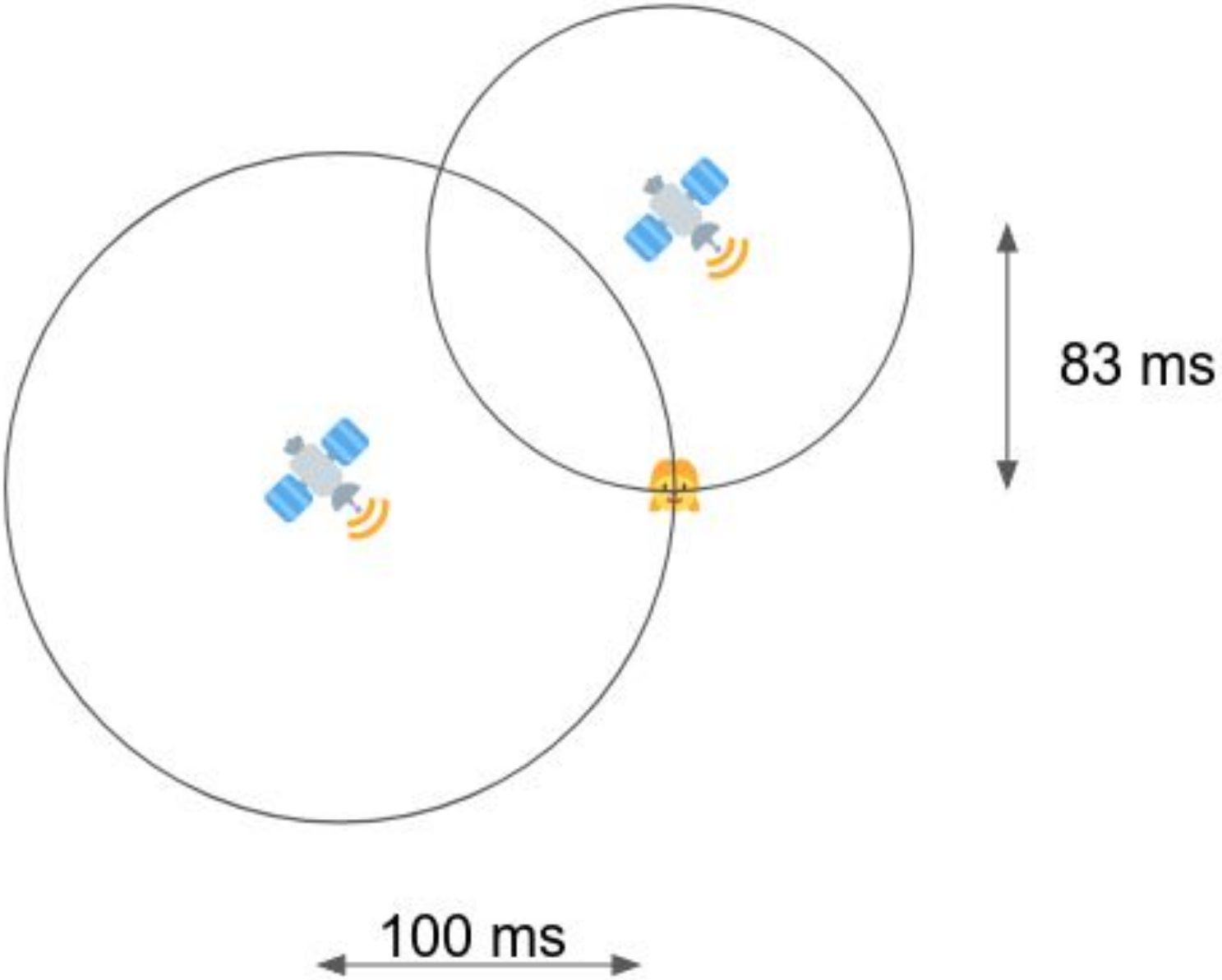
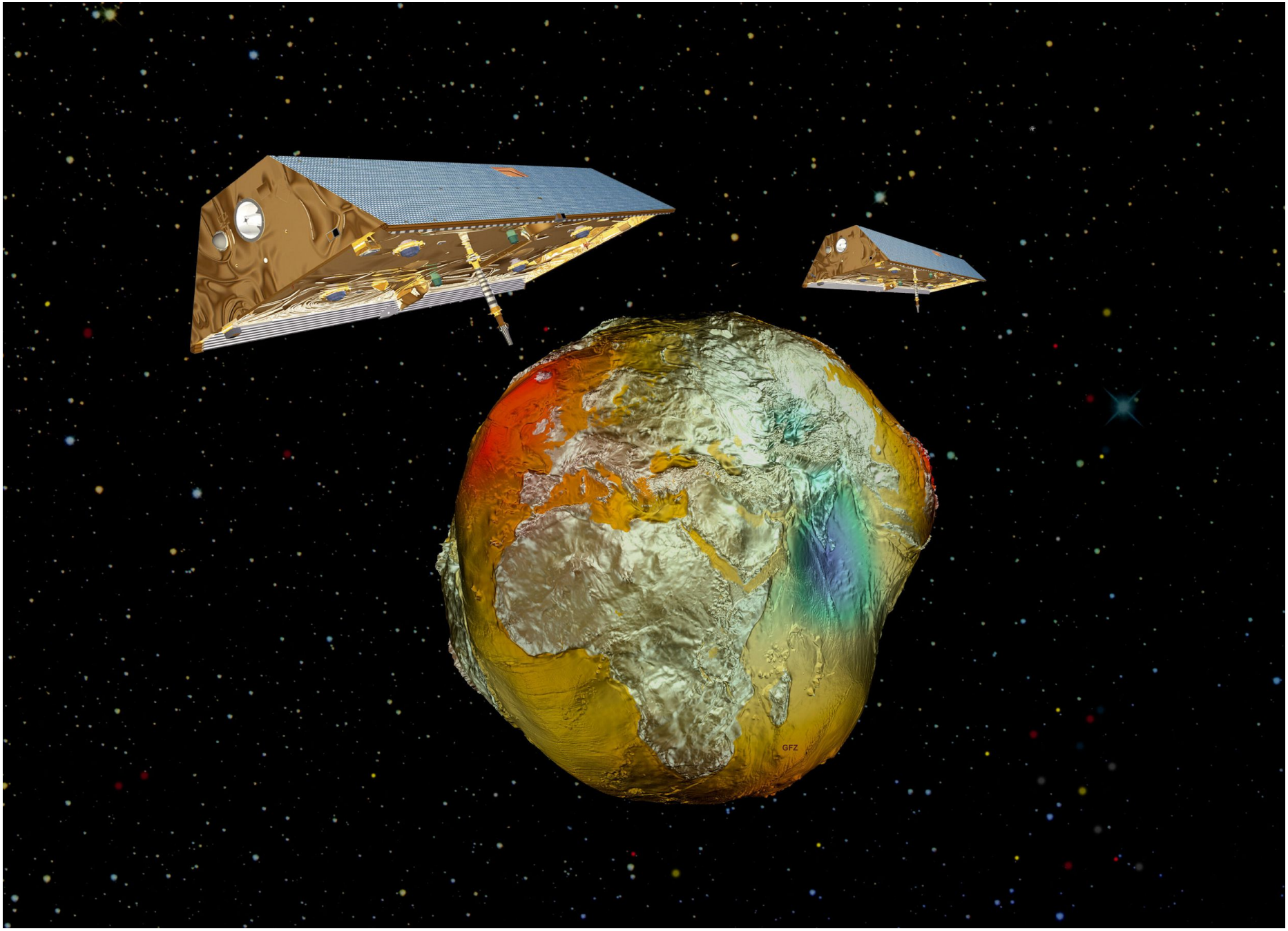

83 ms
100 ms

1. Where is the satellite?

2. How wrong is the atomic clock?

Parameter	Explanation
t_{oe}	Ephemerides reference epoch in seconds within the week
$\sqrt{a}$	Square root of semi-major axis
e	Eccentricity
M_o	Mean anomaly at reference epoch
ω	Argument of perigee
i_o	Inclination at reference epoch
Ω_0	Longitude of ascending node at the beginning of the week
Δn	Mean motion difference
$\dot{i}$	Rate of inclination angle
$\dot{\Omega}$	Rate of node's right ascension
c_{uc}, c_{us}	Latitude argument correction
c_{rc}, c_{rs}	Orbital radius correction
c_{ic}, c_{is}	Inclination correction
a_0	SV clock offset
a_1	SV clock drift
a_2	SV clock drift rate

Table 1: GPS and Galileo broadcast ephemeris and clock message parameters.

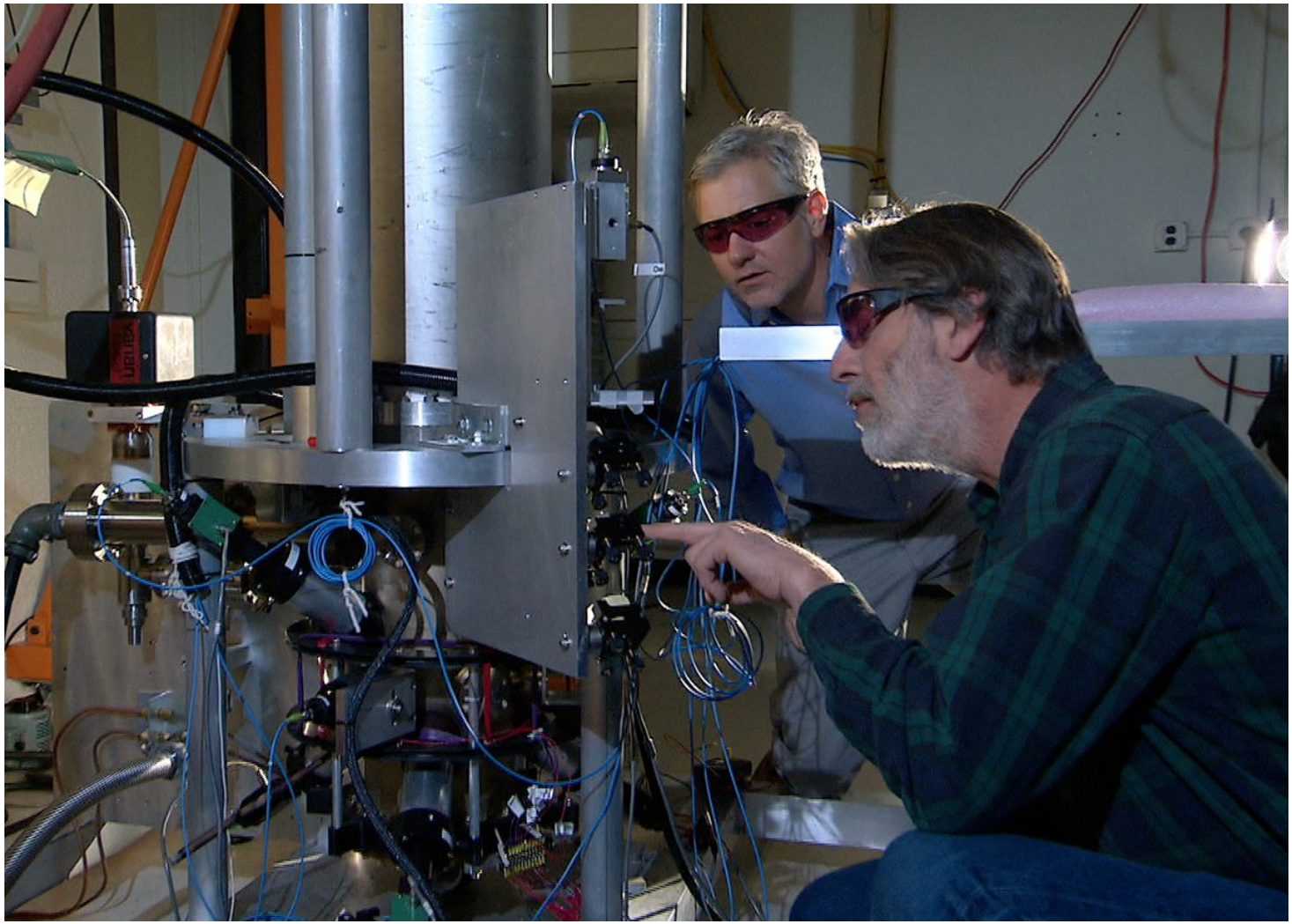

GFZ

Effect of different perturbations on the GPS satellites over 24 h

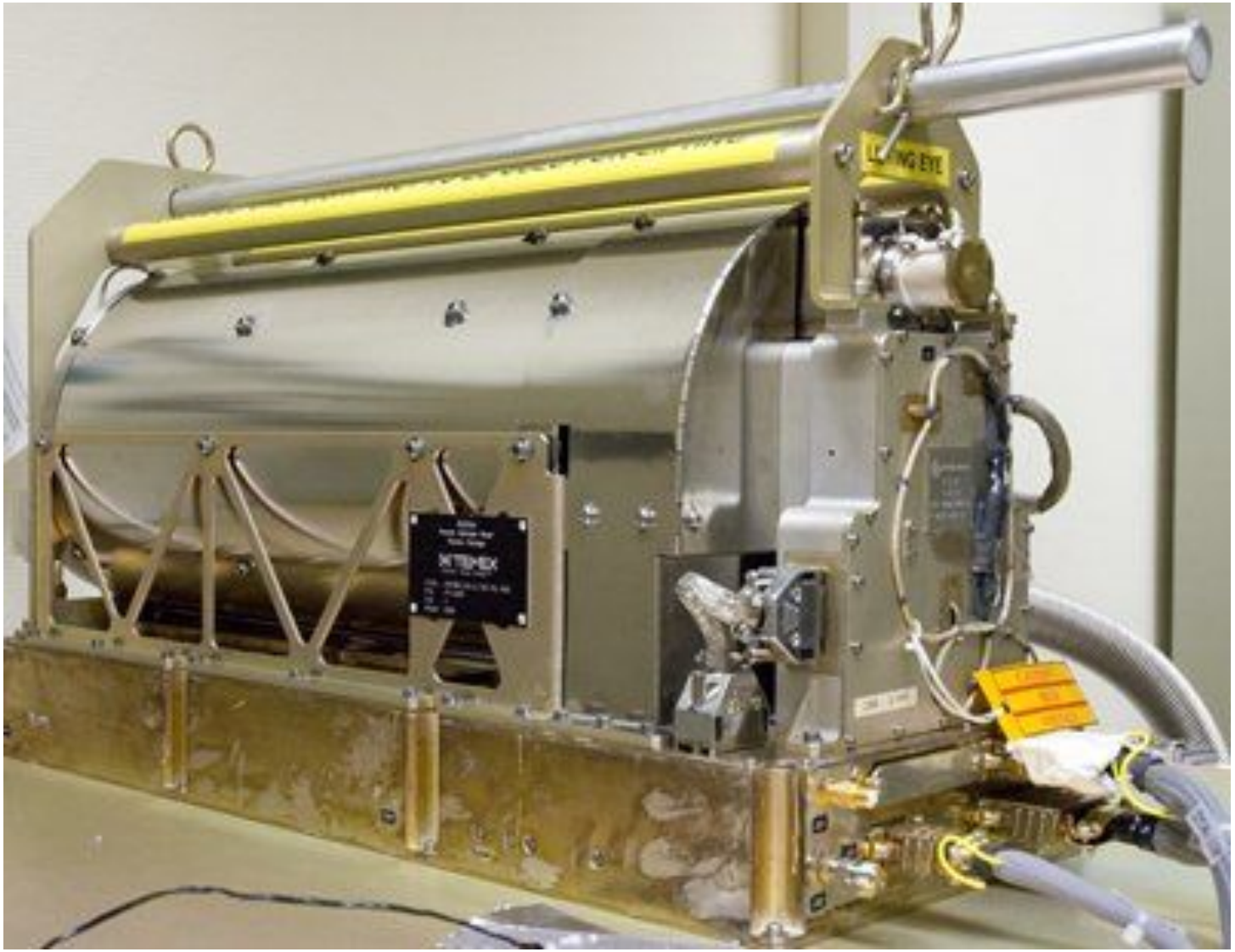
Perturbation	Magnitude (m)			
	Radial	Along	Cross	Total
Earth oblateness	1335	12902	6101	14334
Moon (gravitation)	191	1317	361	1379
Sun (gravitation)	83	649	145	670
C(2,2), S(2,2)	32	175	9	178
Solar Radiation Pressure	29	87	3	92
C(n,m), S(n,m) (n,m=3..8)	6	46	4	46

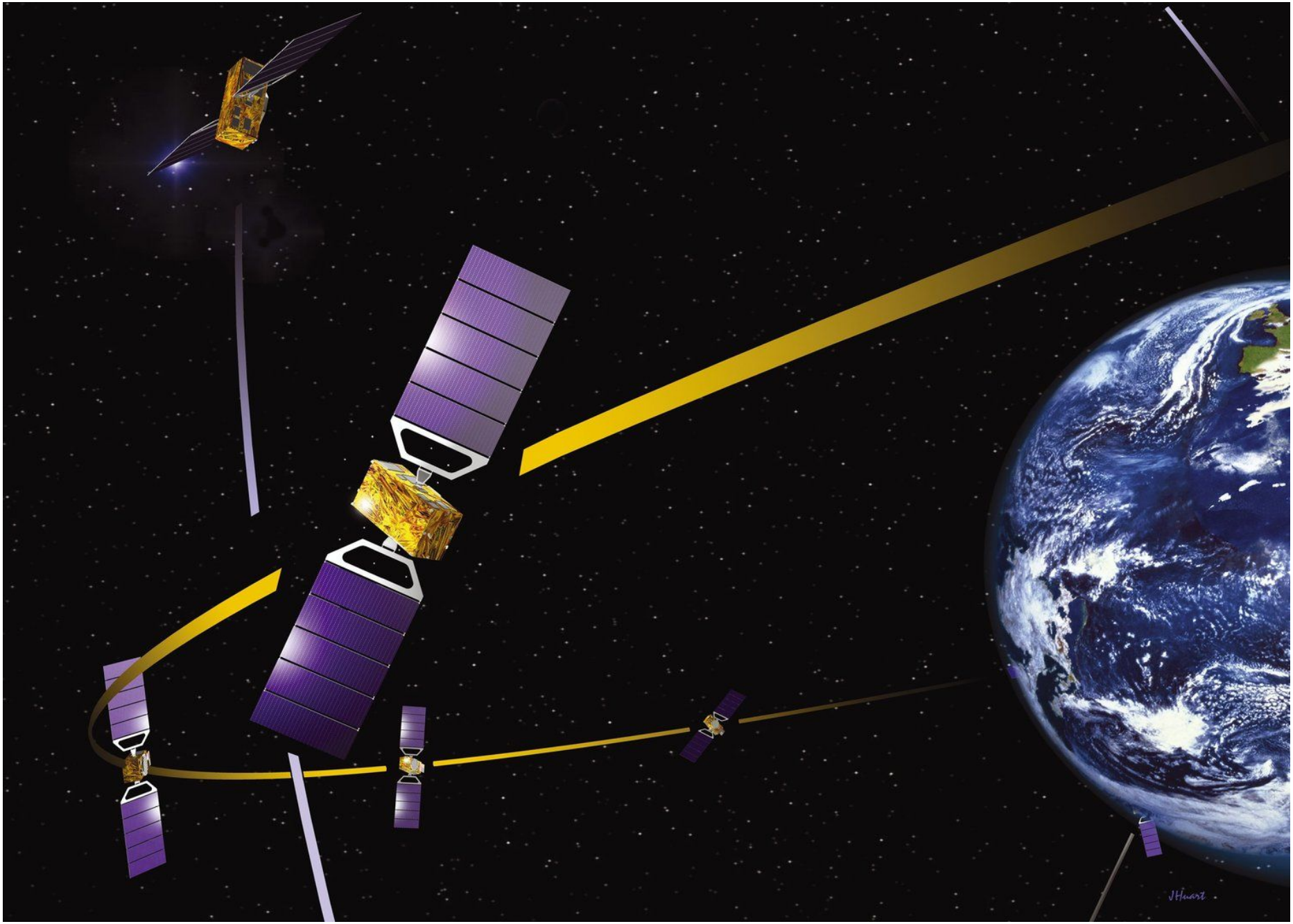
1 nanosecond = 30 centimeters

0.1 nanosecond/day: NIST F-2



1 nanosecond/day.. CORRECTED: Passive Hydrogen Maser

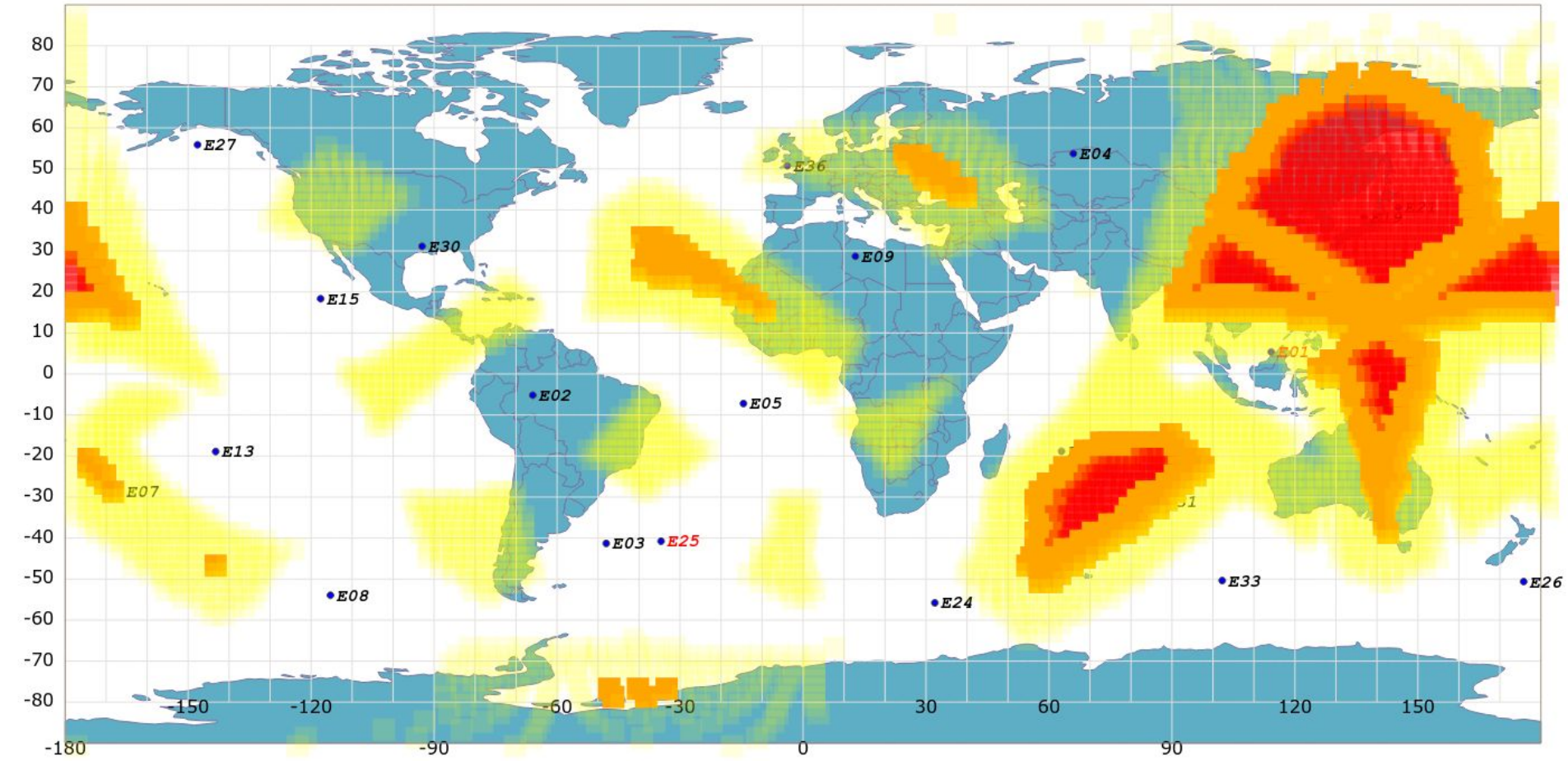


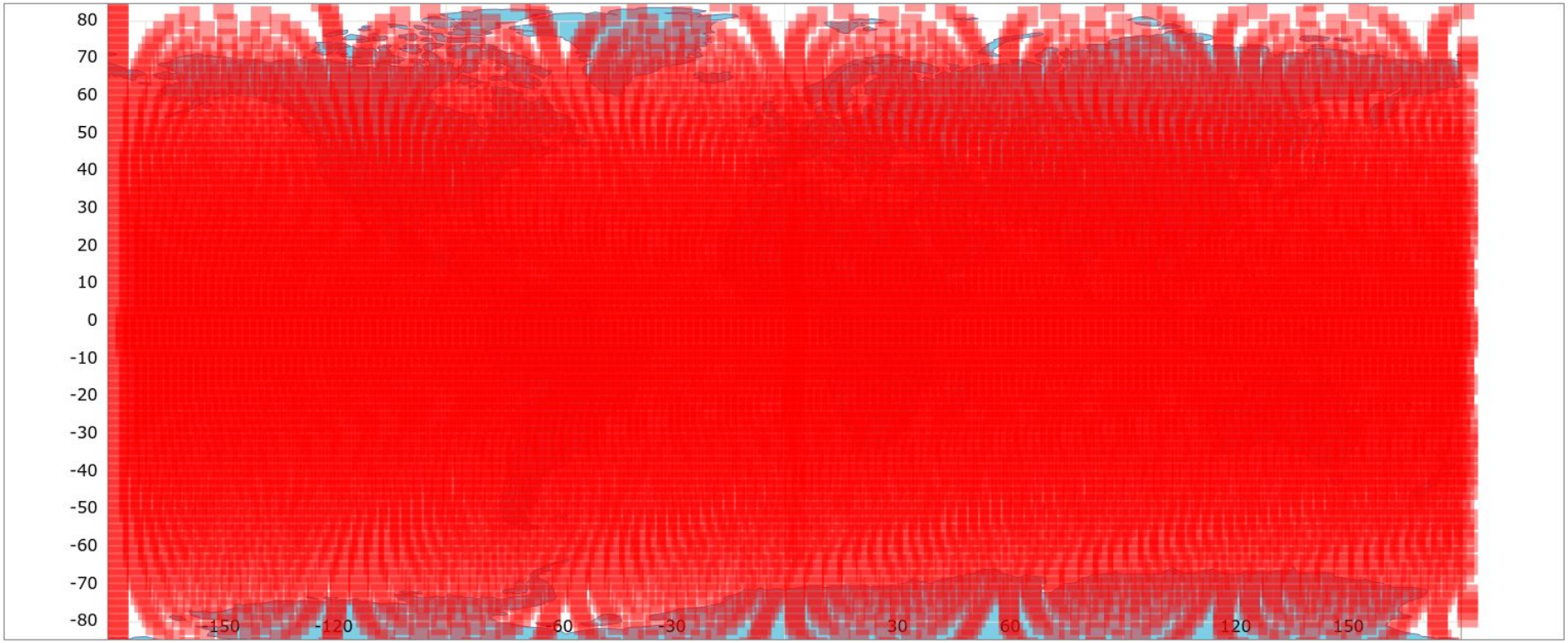

JHuart

1. Where is the satellite?

2. How wrong is the atomic clock?

This is 24/7 hard work!


E27
E30
E15
E13
E07
E08
E02
E03
E25
E36
E04
E09
E05
E01
E24
E33
E26
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150


80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-150
-120
-60
-30
30
60
120
150

Europe's version of GPS suffers major outage

By Bianca Britton, CNN Business

Updated 1359 GMT (2159 HKT) July 15, 2019

POLITICO

EU goes dark on Galileo satellite outage

'We can't provide a running commentary,' official says after EU forced to take satellite navigation system offline.

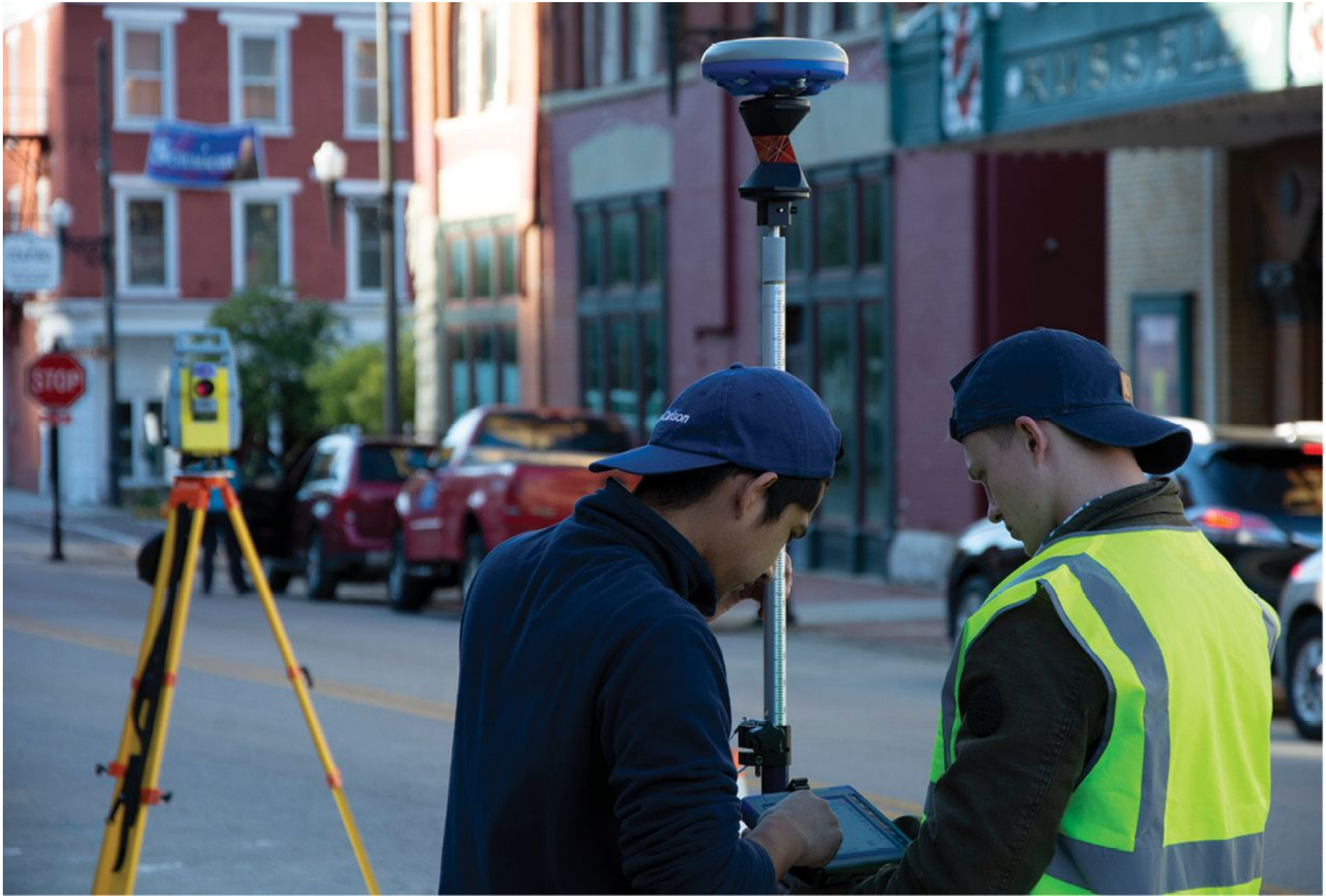
By **JOSHUA POSANER** | 7/17/19, 7:00 PM CET | Updated 7/18/19, 8:29 AM CET

The EU's multibillion-euro satellite navigation system Galileo has been down for almost a week — with little explanation.

The Galileo constellation, a €10 billion investment aimed at giving Europe an independent and more accurate alternative to the U.S. Global Positioning System (GPS) system, has been offline after first experiencing problems on Thursday, with no timeline for bringing the navigation service back into operation.

While the agency responsible insists the problem stems from a ground-based station and not the orbiting satellites, it has been quiet on the precise cause.

These guys care



Galileo Reference Centre, Noordwijk

sv	best-tle	iod	eph-age-m	latest-disco	time-disco	sisa	health	tle-dist	alma-dist	ΔUTC ns	ΔGPS ns	sources	db	ΔHz	prres
E01@1	GSAT0210 (PRN E01)	16	64 minutes ago	4.8 cm	-0.2 ns	312 cm	ok/ok/val/val	2.0 km	1.6 km	0.0 +0.0/d	-3.3 -0.8/d	8 28	28 20	_ _	20 -10
E02@1	GSAT0211 (PRN E02)	21	14 minutes ago	4.8 cm	0.0 ns	312 cm	ok/ok/val/val	1.9 km	1.5 km	0.0 +0.0/d	-3.3 -0.8/d	1 3 4 13 18 26 27 31 32 33 37 41	29 47 33 20 33 23 41 16 25 35 41 17	_ _ 0 4 1 _ _ _ _ _ 8	0 -0 2 -24 -5 0 0 -35 -11 2 -4 -16
E03@1	GSAT0212 (PRN E03)	18	44 minutes ago	7.8 cm	0.2 ns	312 cm	ok/ok/val/val	11.5 km	0.8 km	0.0 +0.0/d	-3.3 -0.8/d	17 23 25	25 44 44	_ _ _	5 1 1
E04@1	GSAT0213 (PRN E04)	15	74 minutes ago	7.4 cm	0.1 ns	312 cm	ok/ok/val/val	4.9 km	2.1 km	0.0 +0.0/d	-3.3 -0.8/d	7 8 24 28	33 29 34 20	_ _ _ _	-3 -14 -1 -25
E05@1	GSAT0214 (PRN E05)	21	14 minutes ago	4.4 cm	-0.1 ns	312 cm	ok/ok/val/val	7.8 km	1.6 km	0.0 +0.0/d	-3.3 -0.8/d	17 28	22 40	_ _	-7 -1
E07@1	GSAT0207 (PRN E07)	16	64 minutes ago	10.4 cm	0.1 ns	312 cm	ok/ok/val/val	10.3 km	3.1 km	0.0 +0.0/d	-3.3 -0.8/d	3 4 5 13 16 18 22 27 31 32 33 37 39 41	44 10 40 29 19 17 24 37 29 29 40 25 19 30	_ _ _ -1 _ _ _ _ _ _ _ -1	1 -9 0 6 4 -9 0 0 -14 -1 -1 -34 -11 7
E08@1	GSAT0208 (PRN E08)	21	14 minutes ago	2.3 cm	-0.0 ns	312 cm	ok/ok/val/val	15.1 km	1.5 km	0.0 +0.0/d	-3.3 -0.8/d	1 3 4 13 15 17 18 23 25 27 31 32 33 39 41	15 24 10 14 11 33 14 12 11 18 30 26 7 8 24	_ _ _ -1 _ _ -7 _ _ _ _ _ _ _ -4	110 -15 62 14 63 1 15 7 7 0 4 -23 31 -17 -34
E09@1	GSAT0209 (PRN E09)	19	34 minutes ago	4.5 cm	-0.0 ns	312 cm	ok/ok/val/val	6.9 km	2.2 km	0.0 +0.0/d	-3.3 -0.8/d	6 7 24 28	27 26 26 21	_ _ _ _	18 2 -4 -24
E11@1	undefined						ok/ok/val/val			0.0 +0.0/d	0.0 +0.0/d	3 26 37	36 37 39	_ _ _	0 0 0
E12@1	GSAT0102 (PRN E12)	21	14 minutes ago	4.1 cm	0.0 ns	312 cm	ok/ok/val/val	3.3 km	1.5 km	0.0 +0.0/d	-3.3 -0.8/d	5 16 41	23 18 9	_ _ _	-15 -8 59
E13@1	GSAT0220 (PRN E13)	20	24 minutes ago	7.6 cm	-0.2 ns	312 cm	ok/ok/val/val	15.6 km	1.1 km	0.0 +0.0/d	-3.3 -0.8/d	17 23 25 28	29 39 40 34	_ _ _ _	-3 -2 -0 0
E14@1	GSAT0202 (PRN E14)	21	14 minutes ago	4.1 cm	0.3 ns	312 cm	test/test /val/val	12.5 km		0.0 +0.0/d	-3.3 -0.8/d	1 3 4 18 26 27 33 37	26 46 27 28 40 28 25 44	_ _ 1 1 _ _ _ _	0 0 0 0 0 0 0 0
E15@1	GSAT0221 (PRN E15)	18	44 minutes ago	8.0 cm	0.2 ns	312 cm	ok/ok/val/val	13.3 km	1.9 km	0.0 +0.0/d	-3.3 -0.8/d	17 23 25	39 42 43	_ _ _	1 -1 -0
E18@1	GSAT0201 (PRN E18)	15	74 minutes ago	5.6 cm	-0.0 ns	312 cm	test/test /val/val	5.3 km		0.0 +0.0/d	-3.3 -0.8/d	8 23	36 36	_ _	0 0
E19@1	GSAT0103 (PRN E19)	15	74 minutes ago	3.0 cm	-0.0 ns	312 cm	ok/ok/val/val	3.1 km	1.7 km	0.0 +0.0/d	-3.3 -0.8/d	5 16 31 32 41	37 23 19 25 43	_ _ _ _ -1	-1 6 10 -12 -2
E21@1	GSAT0215 (PRN E21)	19	34 minutes ago	9.5 cm	-0.1 ns	312 cm	ok/ok/val/val	2.5 km	1.0 km	0.0 +0.0/d	-3.3 -0.8/d	5 8 16 22 23 28 31 41	31 30 25 30 12 25 23 26	_ _ _ _ _ _ _ -1	3 6 3 0 21 -9 0 13
E24@1	GSAT0205 (PRN E24)	18	44 minutes ago	3.9 cm	0.1 ns	312 cm	ok/ok/val/val	2.3 km	2.4 km	0.0 +0.0/d	-3.3 -0.8/d	6 7 24 28	32 28 19 21	_ _ _ _	-7 -7 2 -2
E25@1	GSAT0216 (PRN E25)	21	14 minutes ago	4.7 cm	0.1 ns	312 cm	ok/ok/val/val	4.5 km	0.5 km	0.0 +0.0/d	-3.3 -0.8/d	1 3 4 7 15 17 18 26 27 33 37	32 31 33 25 25 27 39 38 34 22 40	_ _ -0 _ _ _ 2 _ _ _ _	-1 10 0 15 -5 -1 2 0 0 15 -0
E26@1	GSAT0203 (PRN E26)	15	74 minutes ago	2.8 cm	-0.1 ns	312 cm	ok/ok/val/val	4.4 km	0.9 km	0.0 +0.0/d	-3.3 -0.8/d	5 8 16 22 28	12 28 14 30 34	_ _ _ _ _	31 6 13 0 8
E27@1	GSAT0217 (PRN E27)	21	14 minutes ago	4.6 cm	-0.0 ns	NO SISA AVAILABLE	ok/ok/val/val	3.1 km	1.8 km	0.0 +0.0/d	-3.3 -0.8/d	3 5 13 16 22 23 25 27 31 32 39 41	42 38 30 25 29 14 14 29 38 35 26 34	_ _ -1 _ _ _ _ _ _ _ -1	1 5 9 2 0 20 20 0 4 -1 -3 10
E30@1	GSAT0206 (PRN E30)	19	34 minutes ago	7.7 cm	0.1 ns	312 cm	ok/ok/val/val	3.9 km	2.8 km	0.0 +0.0/d	-3.3 -0.8/d	3 4 5 13 16 18 22 26 27 31 32 33 37 39 41	46 16 28 38 26 27 29 21 28 38 37 44 43 24 44	_ -0 _ -1 _ 1 _ _ _ _ _ _ _ -1	0 -7 -4 -1 -2 -67 0 0 0 3 -1 1 0 -9 -1
E31@1	GSAT0218 (PRN E31)	21	14 minutes ago	3.9 cm	-0.0 ns	312 cm	ok/ok/val/val	2.7 km	0.8 km	0.0 +0.0/d	-3.3 -0.8/d	8 24 28	32 30 29	_ _ _	-1 -3 0
E33@1	GSAT0222 (PRN E33)	21	14 minutes ago	2.1 cm	0.0 ns	312 cm	ok/ok/val/val	3.6 km	1.3 km	0.0 +0.0/d	-3.3 -0.8/d	5 8 16 24 28	11 35 15 8 31	_ _ _ _ _	23 -1 7 -145 -2
E36@1	GSAT0219 (PRN E36)	19	34 minutes ago	5.8 cm	0.1 ns	312 cm	ok/ok/val/val	11.9 km	0.9 km	0.0 +0.0/d	-3.3 -0.8/d	1 3 4 7 13 18 26 27 33 37	29 44 35 13 28 33 36 36 33 42	_ _ -0 _ -1 2 _ _ _ _	-0 -1 -0 17 -4 5 0 0 2 -1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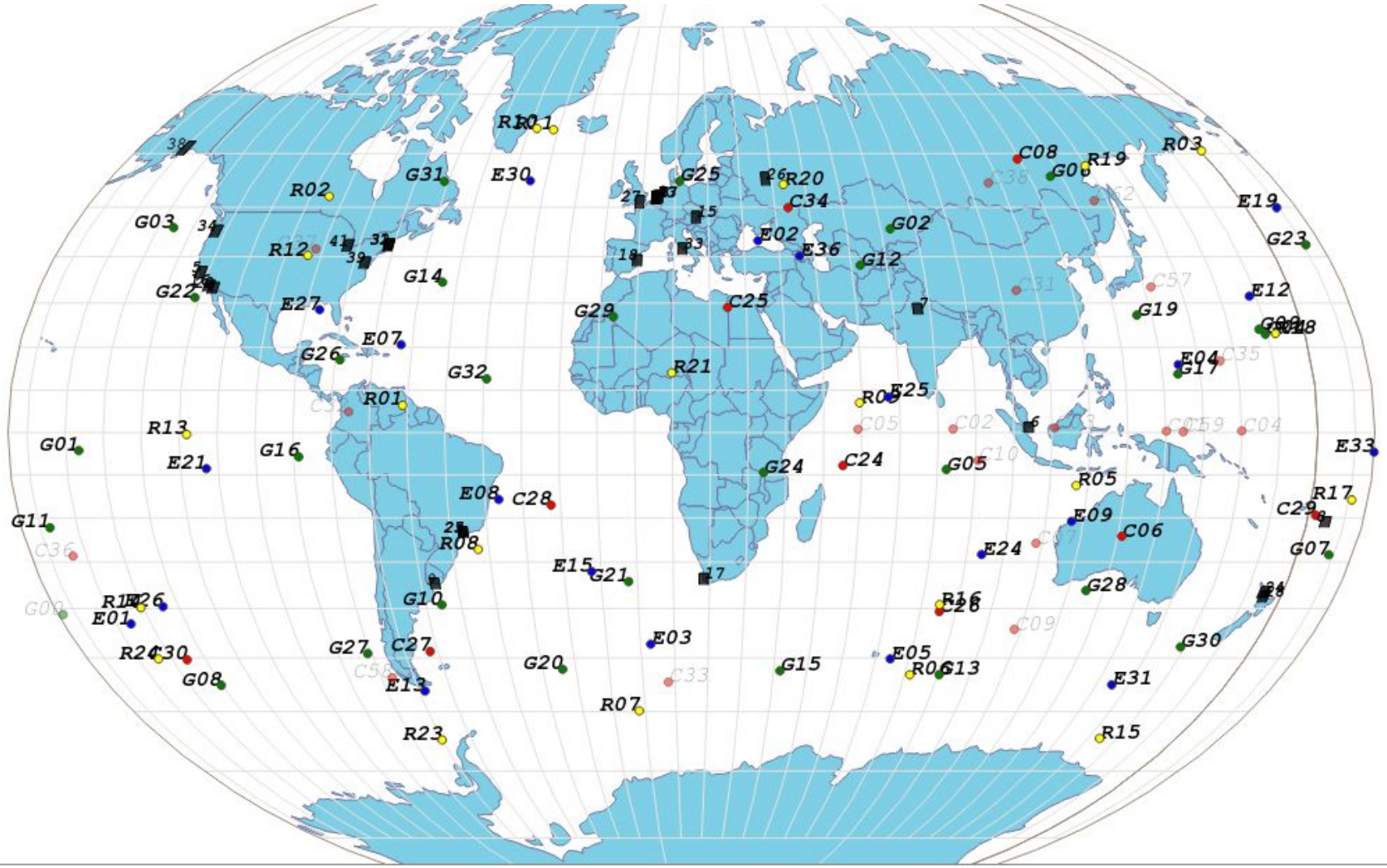
R01
R03
C08
R19
G06
E19
G23
R02
G31
E30
G25
R20
C34
G03
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E36
G12
R12
G14
G22
E27
G29
C25
G19
E12
E07
G26
G32
R21
E04
G17
R01
R25
R13
G01
G16
E21
G24
C24
G05
R05
E33
E08
C28
E09
C06
R17
G11
R08
E24
G07
E15
G21
G28
G10
R16
E01
E03
G30
R24
C30
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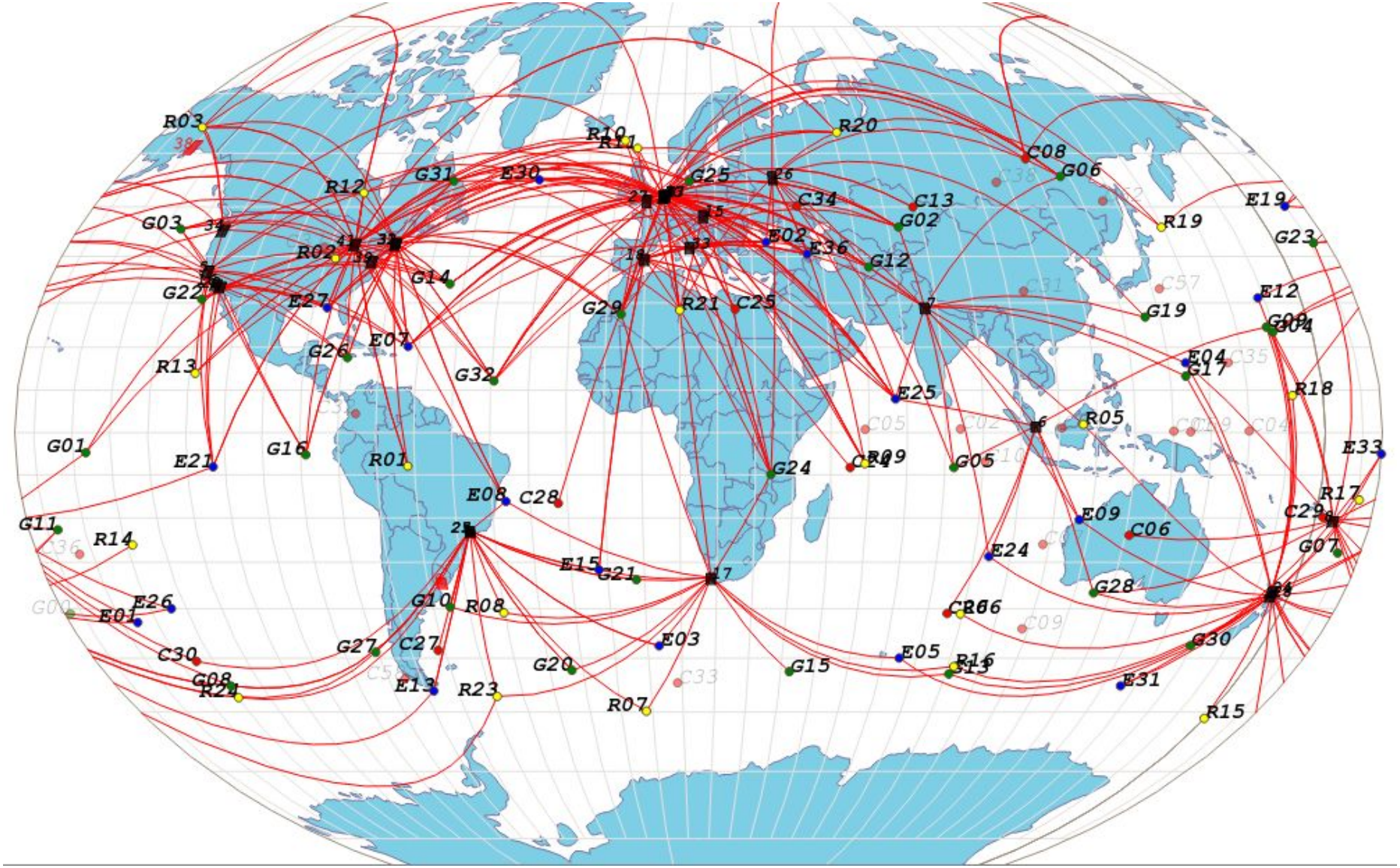
G08
E13
R07
R23
R15


R03
R10
R11
R20
C08
G06
R12
G31
E30
G25
C34
C13
E19
G03
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R19
G23
R02
E02
E36
G12
G22
G14
E27
G29
R21
C25
G19
E12
E07
R13
G26
G32
E04
G17
R18
E25
R05
G01
E21
G16
R01
G24
G05
E33
E08
C28
R17
G11
E09
C06
R14
E24
G07
E15
G21
G28
E26
G10
R08
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C27
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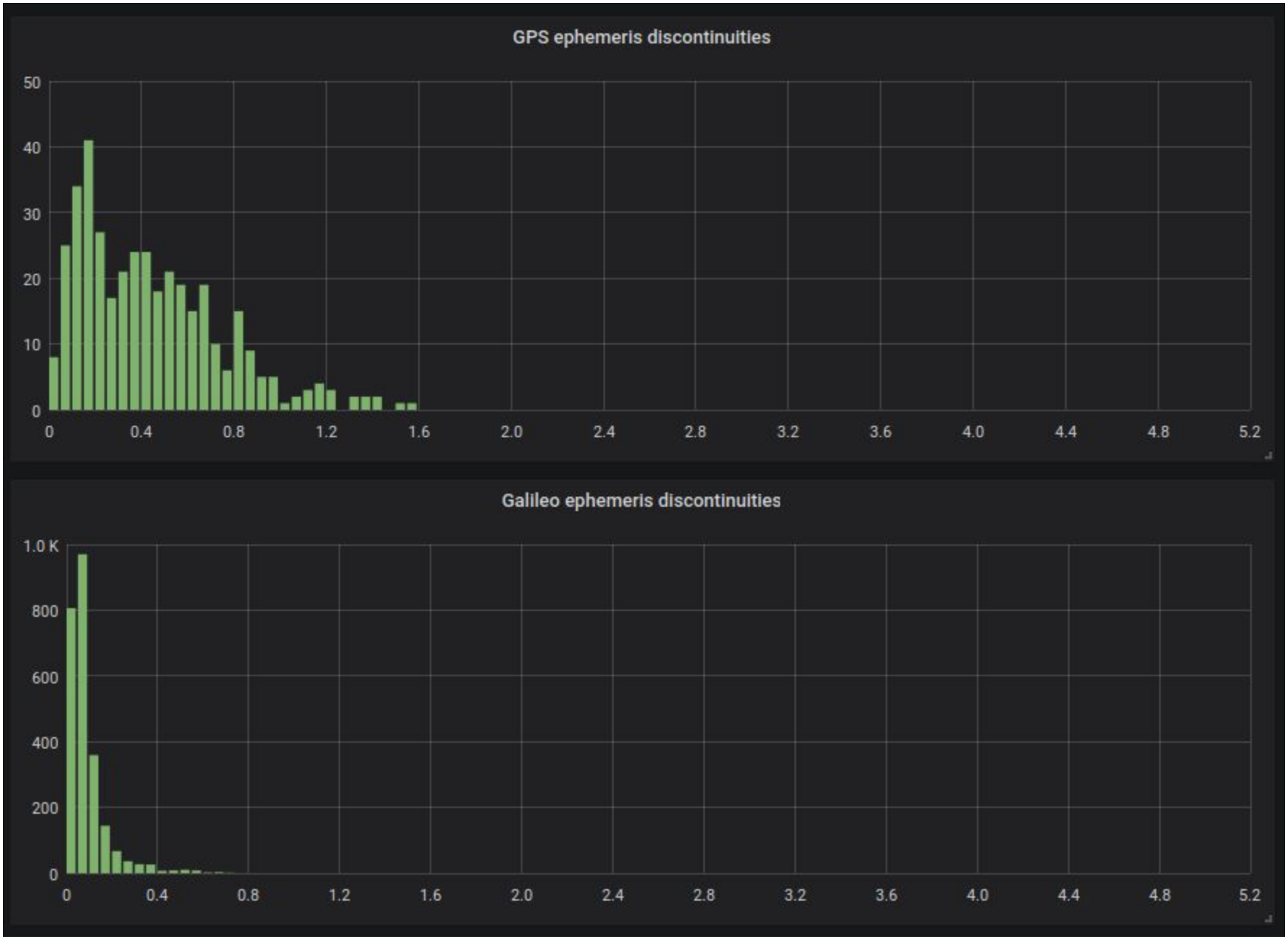
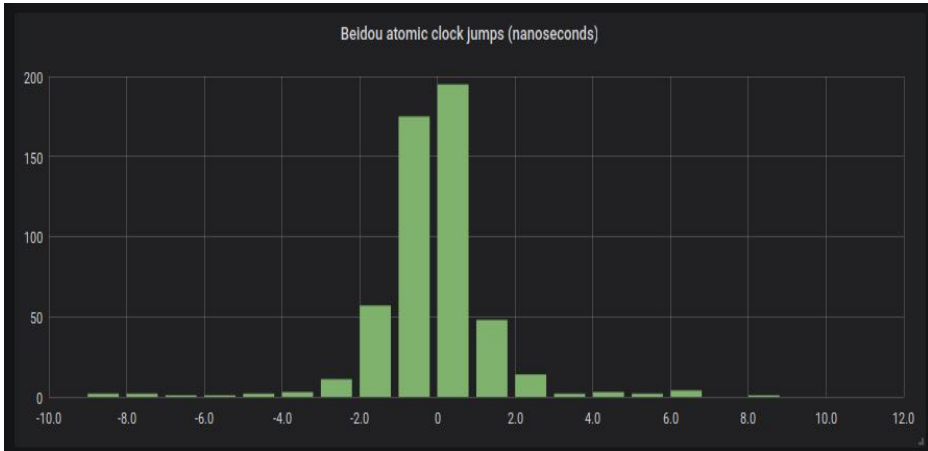
E05
G30
C30
G20
G15
E31
E13
R23
R07
R15

sv	best-tle	iod	eph-age-m	latest-disco	time-disco	sisa	health	tle-dist	alma-dist	A
E01@1	GSAT0210 (PRN E01)	16	74 minutes ago	4.8 cm	-0.2 ns	312 cm	ok/ok/val/val	2.0 km	1.3 km	
E02@1	GSAT0211 (PRN E02)	22	14 minutes ago	5.3 cm	-0.0 ns	312 cm	ok/ok/val/val	1.9 km	1.4 km	
E03@1	GSAT0212 (PRN E03)	18	54 minutes ago	7.8 cm	0.2 ns	312 cm	ok/ok/val/val	11.3 km	0.9 km	
E04@1	GSAT0213 (PRN E04)	15	84 minutes ago	7.4 cm	0.1 ns	312 cm	ok/ok/val/val	4.9 km	2.1 km	
E05@1	GSAT0214 (PRN E05)	22	14 minutes ago	4.4 cm	-0.0 ns	312 cm	ok/ok/val/val	7.6 km	1.7 km	
E07@1	GSAT0207 (PRN E07)	16	74 minutes ago	10.4 cm	0.1 ns	312 cm	ok/ok/val/val	10.5 km	2.4 km	
E08@1	GSAT0208 (PRN E08)	22	14 minutes ago	6.0 cm	-0.1 ns	312 cm	ok/ok/val/val	15.0 km	1.5 km	
E09@1	GSAT0209 (PRN E09)	19	44 minutes ago	4.5 cm	-0.0 ns	312 cm	ok/ok/val/val	6.8 km	1.7 km	
E11@1	undefined						ok/ok/val/val			


GPS ephemeris discontinuities
50
40
30
20
10
0
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
Galileo ephemeris discontinuities
1.0 K
800
600
400
200
0
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2


Beidou atomic clock jumps (nanoseconds)
200
150
100
50
0
-10.0
-8.0
-6.0
-4.0
-2.0
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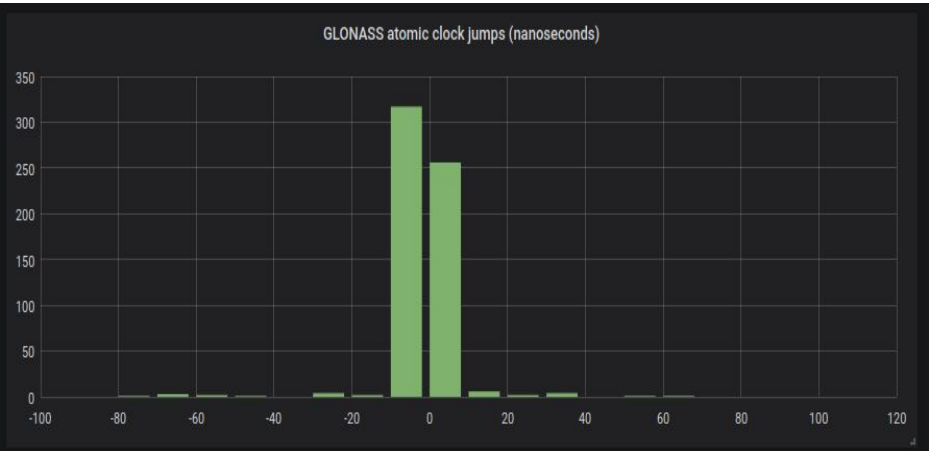
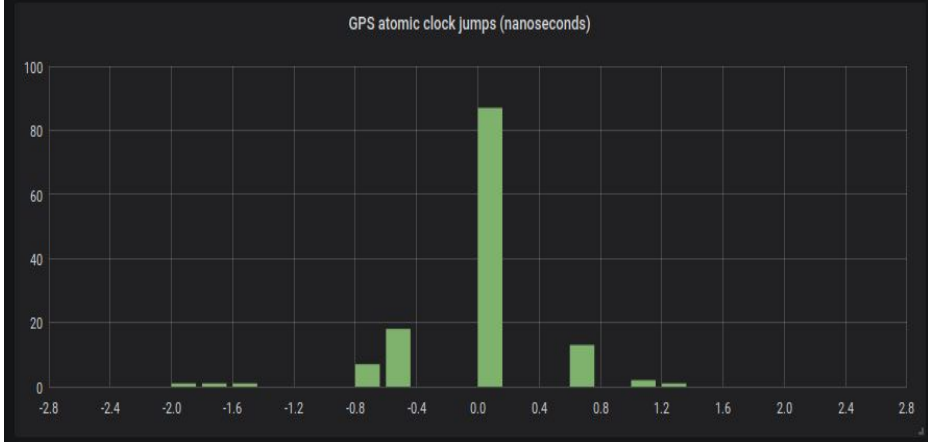
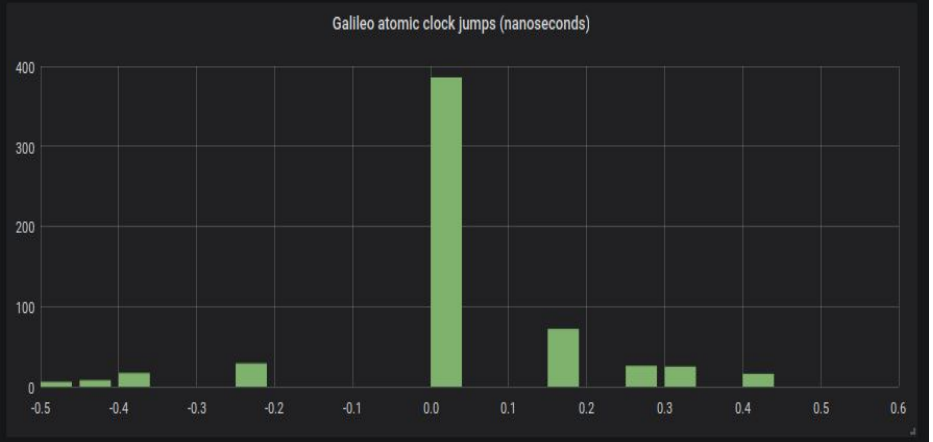
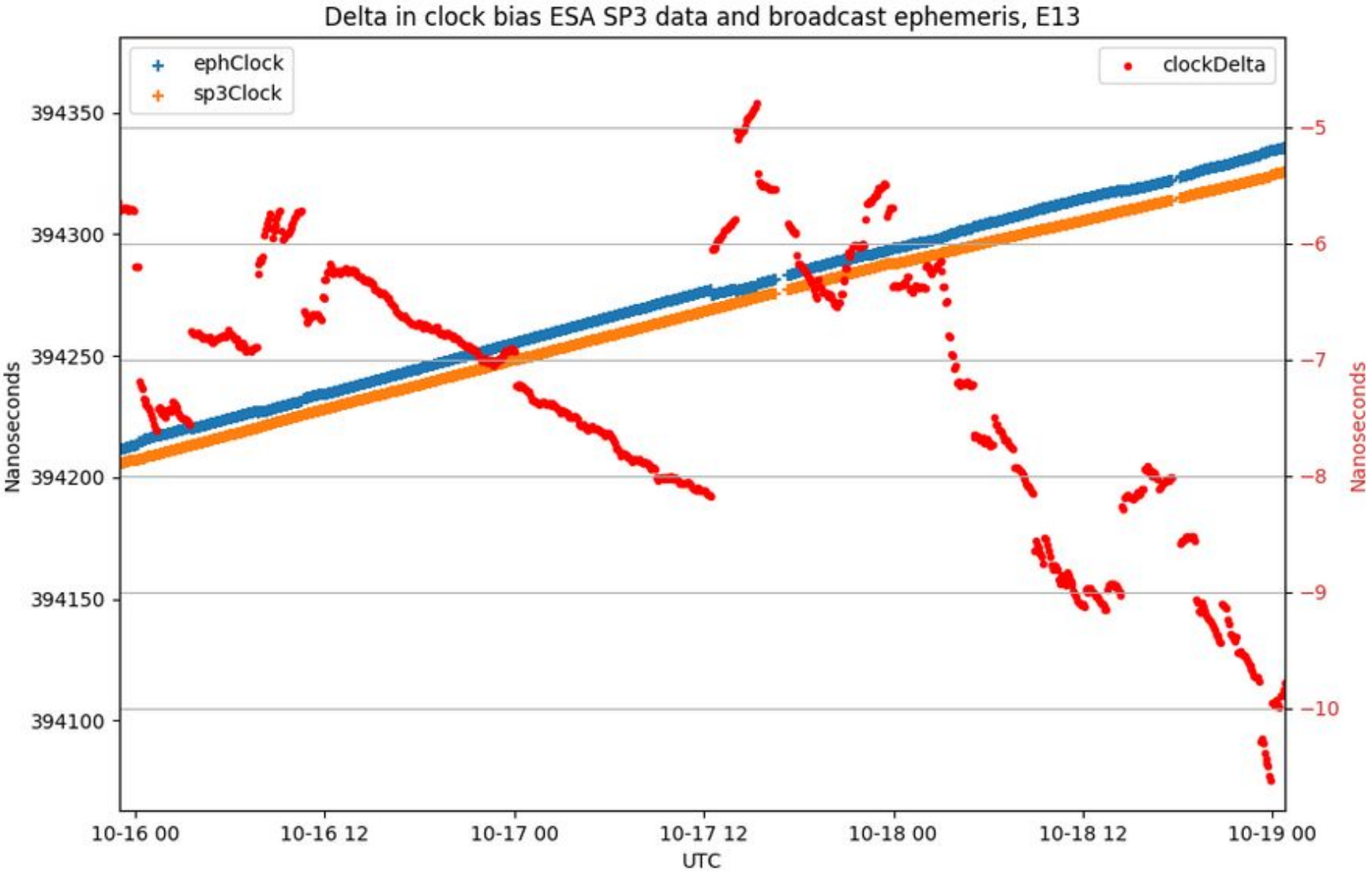
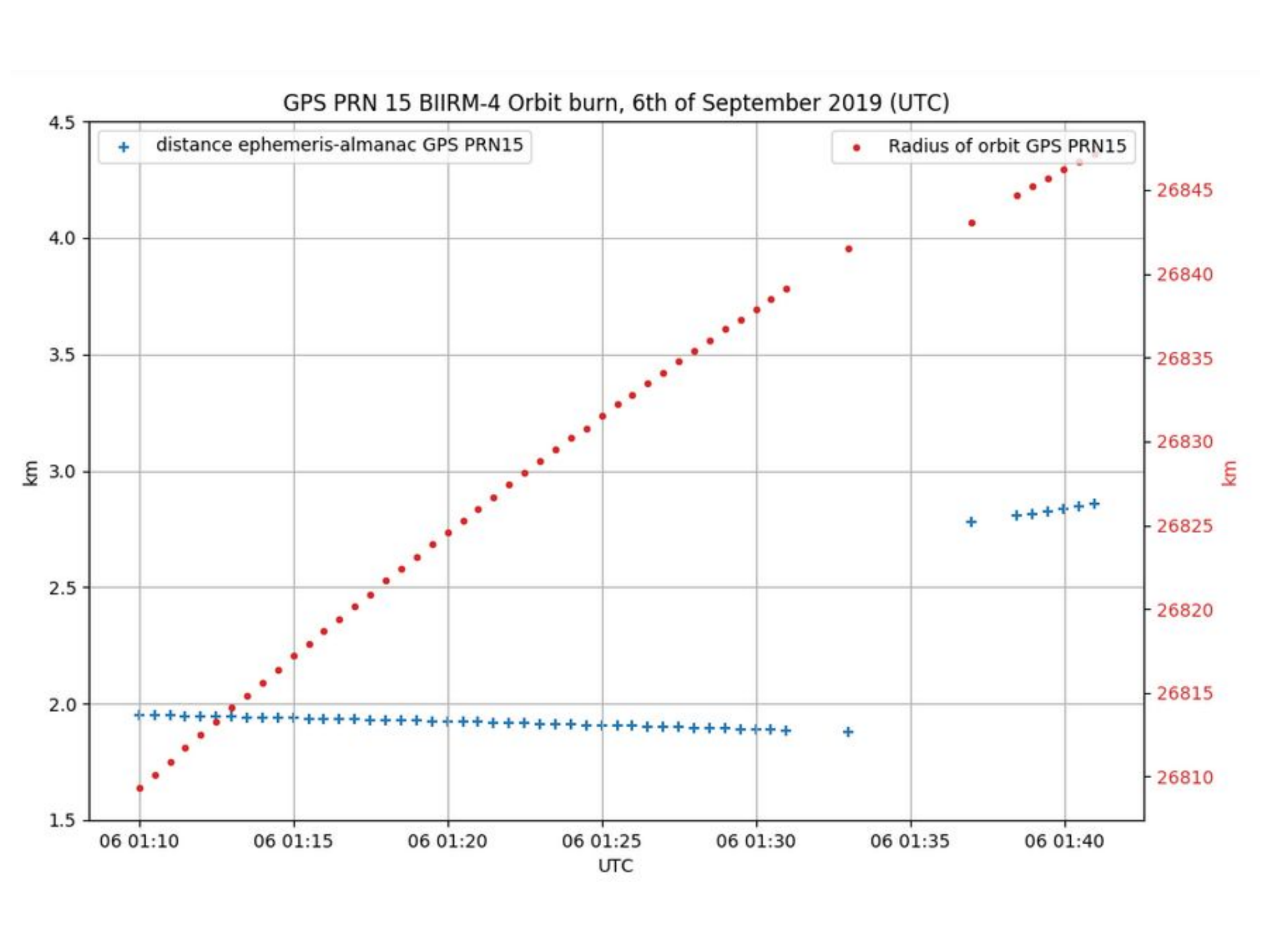
2.0
4.0
6.0
8.0
10.0
12.0


GLONASS atomic clock jumps (nanoseconds)
350
300
250
200
150
100
50
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
120


GPS atomic clock jumps (nanoseconds)
100
80
60
40
20
0
-2.8
-2.4
-2.0
-1.6
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8


Galileo atomic clock jumps (nanoseconds)
400
300
200
100
0
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6


Delta in clock bias ESA SP3 data and broadcast ephemeris, E13
ephClock
sp3Clock
clockDelta
394350
394300
394250
394200
394150
394100
Nanoseconds
−5
−6
−7
−8
−9
−10
Nanoseconds
10-16 00
10-16 12
10-17 00
10-17 12
10-18 00
10-18 12
10-19 00
UTC


GPS PRN 15 BIIRM-4 Orbit burn, 6th of September 2019 (UTC)
distance ephemeris-almanac GPS PRN15
Radius of orbit GPS PRN15
km
km
UTC
4.5
4.0
3.5
3.0
2.5
2.0
1.5
26845
26840
26835
26830
26825
26820
26815
26810
06 01:10
06 01:15
06 01:20
06 01:25
06 01:30
06 01:35
06 01:40

```
Report on 21 SVs from Mon, 11 Nov 2019 22:50:00 +0000 to Mon, 18 Nov 2019 22:40:00 +0000
E01:   0.00% unobserved,   0.00% unhealthy,  72.42% healthy,   0.00% testing,  27.58% napa
E02:   0.10% unobserved,   0.00% unhealthy,  99.90% healthy,   0.00% testing,   0.00% napa
E03:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E04:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E05:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E07:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E08:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E09:   0.00% unobserved,   0.00% unhealthy,  99.90% healthy,   0.00% testing,   0.00% napa
E12:   0.60% unobserved,   0.00% unhealthy,  99.31% healthy,   0.00% testing,   0.00% napa
E13:   0.00% unobserved,   0.00% unhealthy,  72.32% healthy,   0.00% testing,  27.68% napa
E15:   0.00% unobserved,   0.00% unhealthy,  72.12% healthy,   0.00% testing,  27.88% napa
E19:   0.99% unobserved,   0.00% unhealthy,  98.71% healthy,   0.00% testing,   0.00% napa
E21:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E24:   0.10% unobserved,   0.00% unhealthy,  99.90% healthy,   0.00% testing,   0.00% napa
E25:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E26:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E27:   0.00% unobserved,   0.00% unhealthy,  89.19% healthy,   0.00% testing,  10.81% napa
E30:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E31:   0.00% unobserved,   0.00% unhealthy,  72.02% healthy,   0.00% testing,  27.98% napa
E33:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
E36:   0.00% unobserved,   0.00% unhealthy, 100.00% healthy,   0.00% testing,   0.00% napa
-------------------------------------------------------------------------------------------
Tot:   0.09% unobserved,   0.00% unhealthy,  94.09% healthy,   0.00% testing,   5.81% napa
```

GNSS.Store

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USB GPS GLONASS receiver
EA

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− 1 + 955 pieces availa

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to Netherlands via AliExpres

Estimated Delivery on 12/01

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Cable length: 4.50 m

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€18,21 / m

incl. VAT. excl. shipping costs

in stock, delivery time: 1-2 business days

Quantity | add to cart

Mark to compare

Raspberry Pi Zero W

galmon

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Live website: https://galmon.eu/

Theoretically multi-vendor, although currently only the U-blox 8 and 9 chipsets are supported. Navilock NL-8012U receiver works really well, as does the U-blox evaluation kit for the 8MT. In addition, many stations have reported success with this very cheap AliExpress sourced device. The best and most high-end receiver, which does all bands, all the time, is the Ublox F9P, several of us use the ArdusimpleRTK2B board.

Highlights

- Processes raw frames/strings/words from GPS, GLONASS, BeiDou and Galileo
- All-band support (E1, E5b, B1I, B2I, Glonass L1, Glonass L2, GPS L1C/A) so far, GPS L2C and Galileo E5a pending).
- Calculate ephemeris positions
- Comparison of ephemerides to independent SP3 data to determine SISE
  - Globally, locally, worst user location
- Record discontinuities between subsequent ephemerides (in time and space)
- Compare doppler shift as reported by receiver with that expected from ephemeris
- Track atomic clock & report jumps
- Coverage maps (number of satellites >5, >10, >20 elevation)
- HDOP/VDOP/PDOP maps
- Compare orbit to TLE, match up to best matching satellite
- Tear out every bit that tells us how well an SV is doing
- Full almanac processing to see what *should* be transmitting

So.. how good are GPS, Galileo, GLONASS and BeiDou?

- When Galileo works, it is likely the best
  - Currently down 1 satellite, plus on average 0.5 more

- GPS is “old faithful”, not as precise, but with new band, may also be very good. Ground system very old. Also down 2 satellites now, but has enough spares.

- GLONASS: Well.

- BeiDou: Highly dynamic, changing faster than receivers can cope with. Manual incorrect. Still very impressive launch speed & change rate.

Why GALMON.EU?

- For “PNT Customers”:
  - Double check - is it just me or is something going on?
  - Assurance that conditions are good for precision measurements

- For GNSS operators:
  - Totally independent monitoring solution, written by people who have no reason to make it look better than it is
  - **(Official monitoring, sadly, is being performed by Galileo-vendor itself)**

- For public order:
  - Spoofing detection
  - Jamming detection

- For researchers / hobbyists / GNSS operators:
  - Access to all our recorded data, every message, raw, since August 2019
  - Interim level data: Grafana graphs
  - InfluxDB of all recorded statuses, ephemerides, atomic clock parameters
    - Gateway to Pandas/Matplotlib/Jupyter

Galmon.eu: Open source, crowd sourced GNSS monitoring

bert@hubertnet.nl

tinyurl.com/geobuzz19