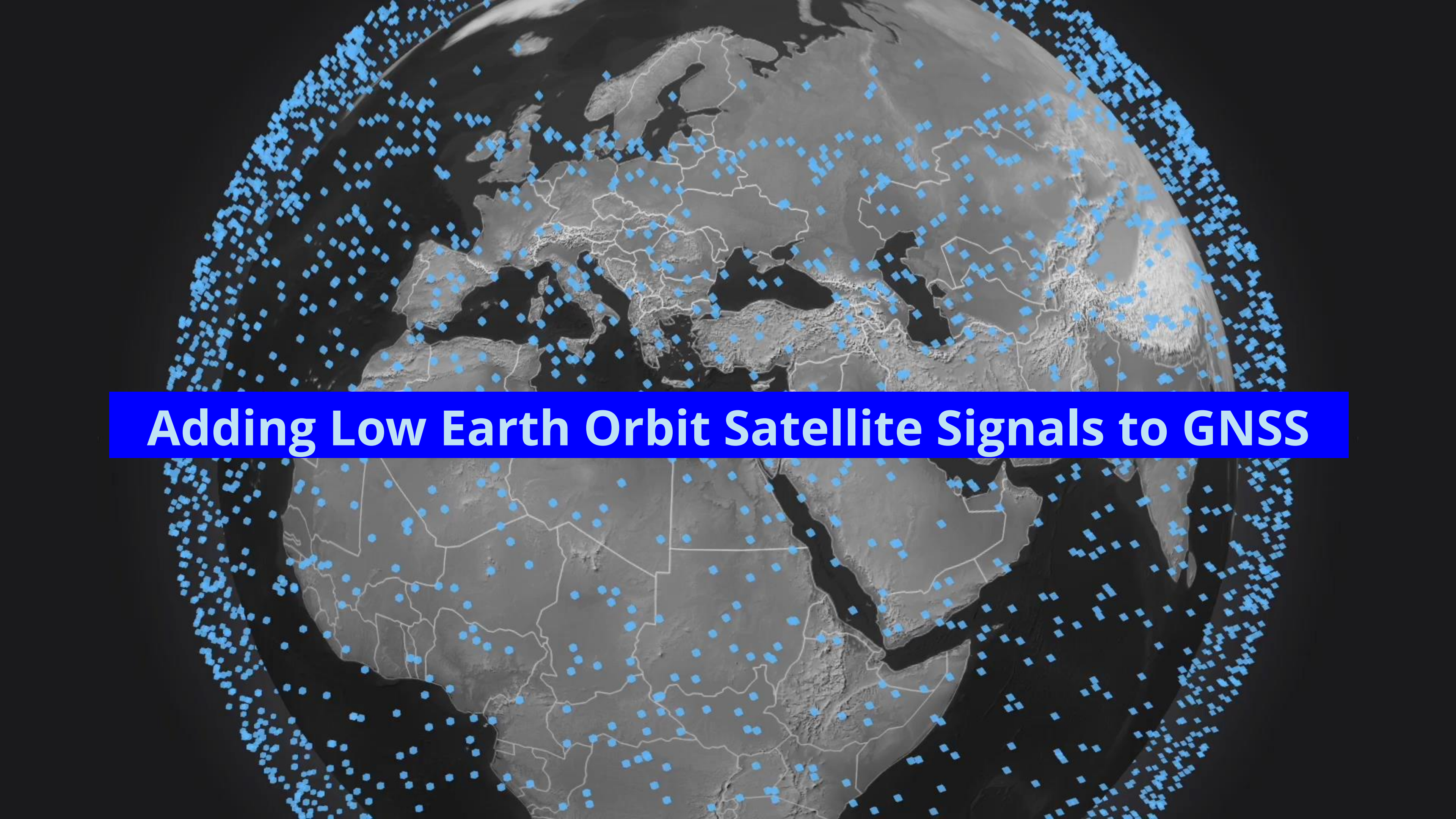
Accelerating the future of aerospace


Adding Low Earth Orbit Satellite Signals to GNSS

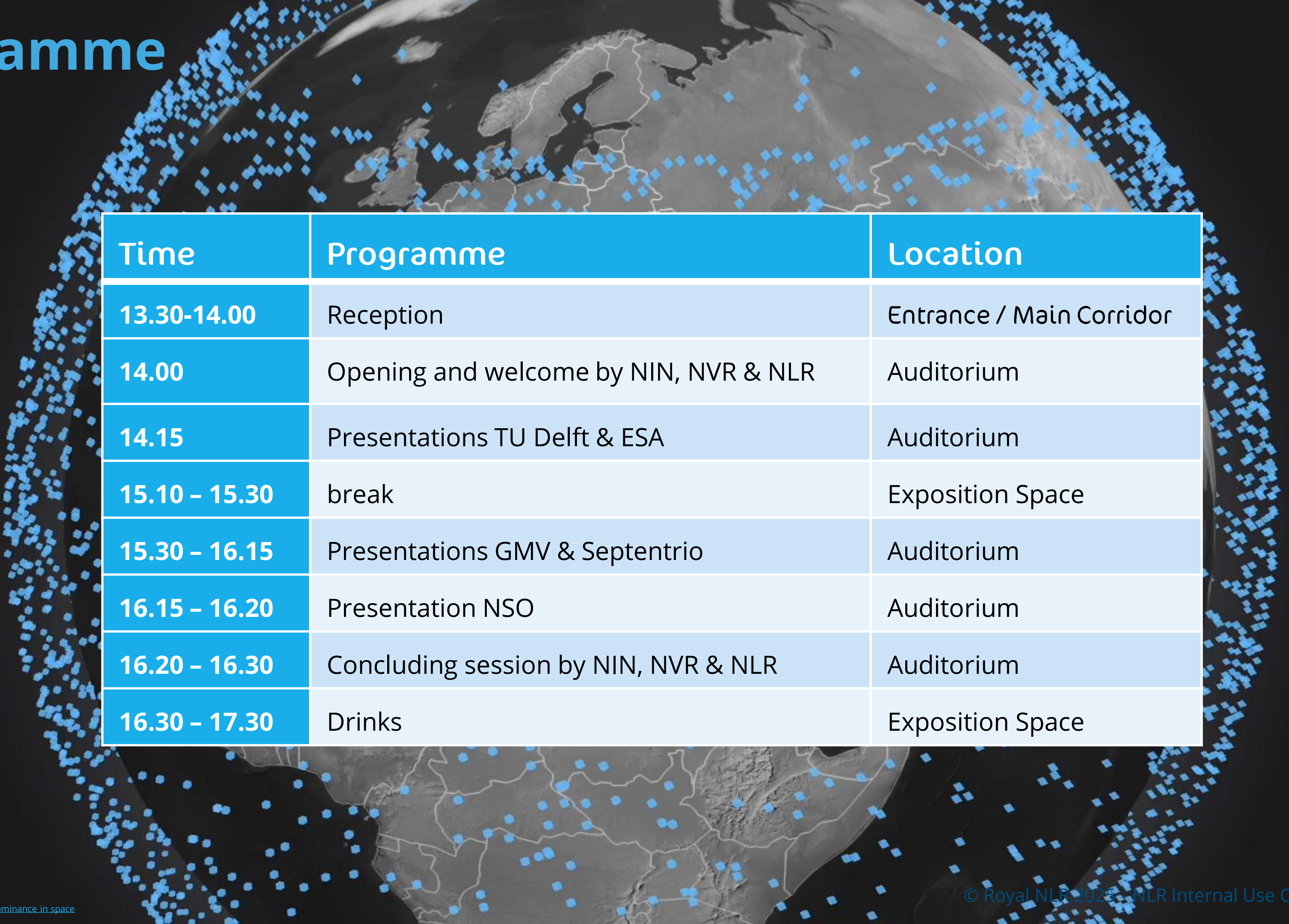
Accelerating the future of aerospace

Nederlands Instituut voor Navigatie

Adding Low Earth Orbit satellite signals to GNSS

NETHERLANDS SPACE SOCIETY

Programme



Time	Programme	Location
13.30-14.00	Reception	Entrance / Main Corridor
14.00	Opening and welcome by NIN, NVR & NLR	Auditorium
14.15	Presentations TU Delft & ESA	Auditorium
15.10 – 15.30	break	Exposition Space
15.30 – 16.15	Presentations GMV & Septentrio	Auditorium
16.15 – 16.20	Presentation NSO	Auditorium
16.20 – 16.30	Concluding session by NIN, NVR & NLR	Auditorium
16.30 – 17.30	Drinks	Exposition Space

Source: China seeks to break Starlink's dominance in space

Accelerating the future of aerospace

LEO-PNT: An Introduction

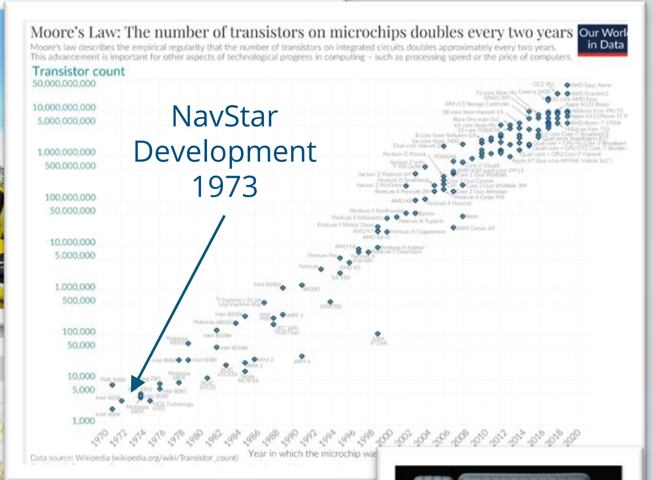
Heiko Engwerda, 05-02-2025

Why LEO PNT

Service benefits:
- Resilience to interference and cyber threats
- Improved Accuracy, availability, continuity, integrity
- Reduced dependency on GNSS

Technical benefits
- Reduced latency
- Increased Power
- Frequency diversity
- Spatial diversity and coverage
- Improved converge

Market benefits
- Development of the space economy
- Competitiveness and innovation
- Integrated services
- Shorter development cycle
- A fresh start



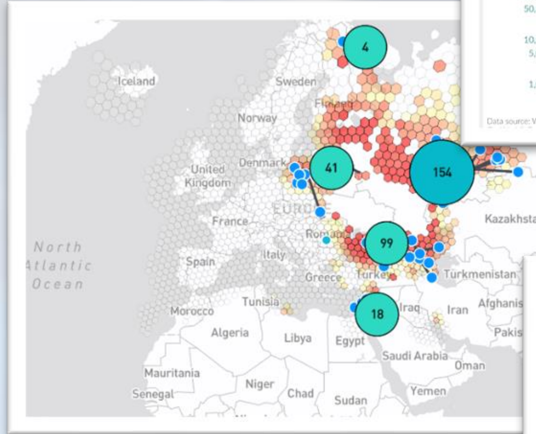


Image source:

Data source: https://spoofing.skai-data-services.com/

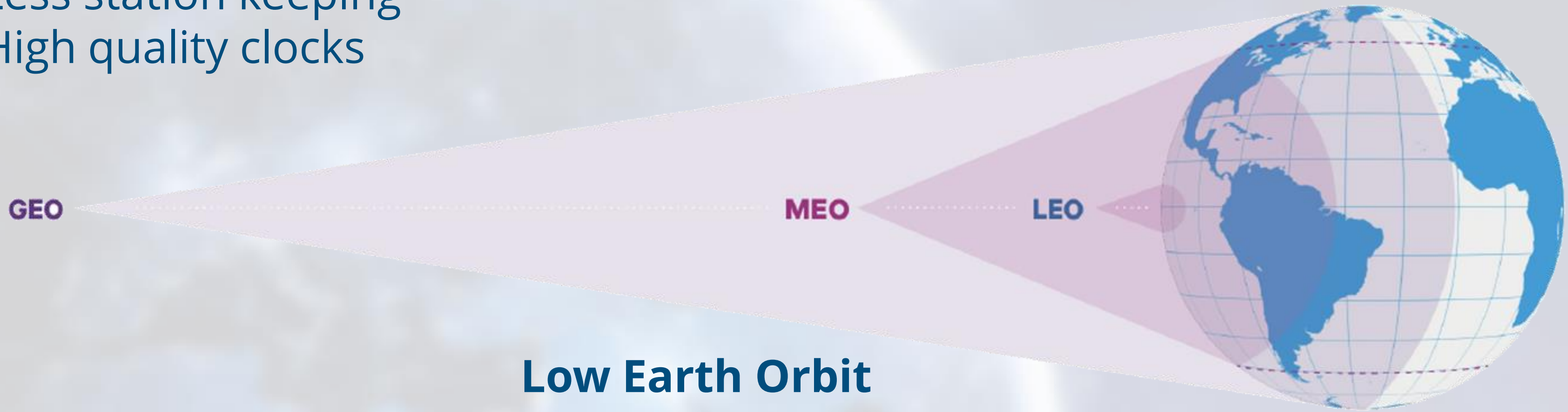
Magellan NAV 1000 GPS receiver
Credit: National Museum of American History

THE FUTURE OF EUROPEAN COMPETITIVENESS — PART A | CHAPTER 4

Strengthening industrial capacity for defence and space

Medium Earth Orbit

- ~30 satellites for good global coverage
- Up to multiple hours in view
- Less station keeping
- High quality clocks



Low Earth Orbit

- >200 satellites for good coverage
- Only minutes (<20) in view
- Higher doppler shifts, lower latency
- Lower path loss

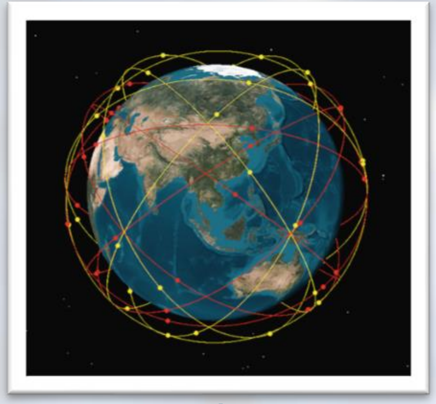
- Lower SWaP
- Increased autonomy
- Increased drag and gravity
- Cheaper to launch (per sat.)

Image source: https://www.satellitetoday.com/content-collection/ses-hub-geo-meo-and-leo/

SoOp

Iridium Next[1]

Augmentation



Beidou[2]

Dedicated Service

Iridium STL[3]

1) source: insidegnss.com
2) Wang, D., Jia, X. and Li, J., 2020. Simulation Analysis of LEO Satellite Navigation-Augmented Property Based on Beidou-3. In China Satellite Navigation Conference (CSNC) 2020 Proceedings: Volume III (pp. 124-133). Springer Singapore.
3) Iridium STL Fact Sheet

LEO PNT Initiatives

Space Infrastructure

Europe
- ESA's FutureNAV
  - Deimos, TASI, TASF, GMV, OHB
- Fergani Space

USA
- Xona Space
- ✓ Iridium® STL
- TrustPoint

Japan
- JAXA
- ArkEdge Space

China
- Centispace
- Geely
- SatNet LEO
- Beidou

UAE
- GNSSaS

Receiver Manufacturers

Receiver Manufacturer	LEO PNT Provider Support
NovAtel	Xona
Septentrio	Xona
StarNav	Xona, Globalstar
Syntony GNSS	Xona
STMicroelectronics	Xona
Furuno	Xona
Etherwhere	Xona
Auroxat	Xona
Qascom	Xona
Qinetiq	Xona
Parsons Corporation	Globalstar
Safran	Iridium® STL
Adtran	Iridium® STL
Viavi Solutions	Iridium® STL
NAL Research Corp.	Iridium® STL

Data source: FrontiersSI, State of the market report, Low Earth Orbit Positioning Navigation and Timing (LEO PNT), 2024

Frequency Spectrum

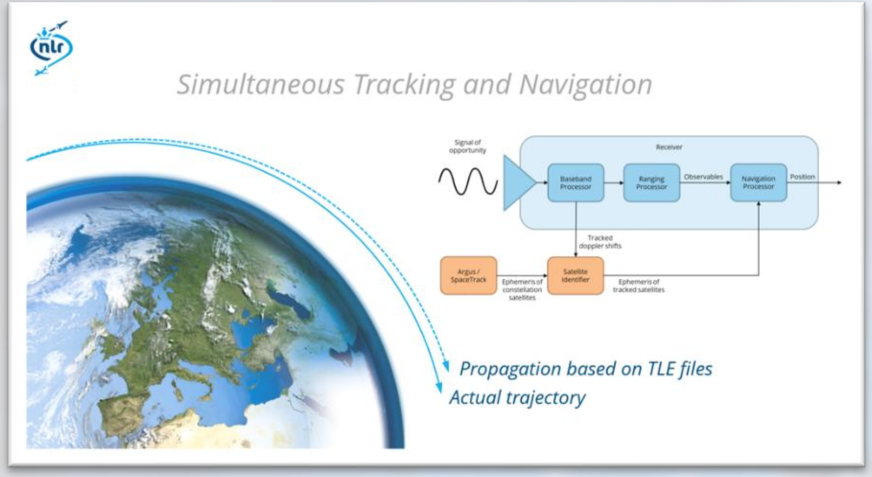
Design Trade-off:
- ❖ Signal power, distortion and penetration
- ❖ System complexity
- ❖ Compatibility
- ❖ Spectrum congestion

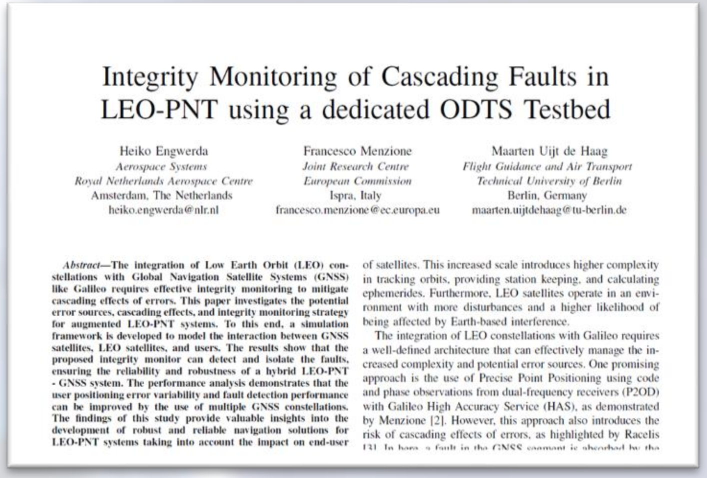
⇩ Low data rates
⇧ Less susceptible to weather
⇧ Better penetration depth

⇧ High data rates and bandwidth
⇩ Very susceptible to weather
⇩ Low penetration depth

Image source: FrontiersSI, State of the market report, Low Earth Orbit Positioning Navigation and Timing (LEO PNT), 2024

NLR Activities





Integrity Monitoring of Cascading Faults in LEO-PNT using a dedicated ODTS Testbed

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***Abstract*—The integration of Low Earth Orbit (LEO) constellations with Global Navigation Satellite Systems (GNSS) like Galileo requires effective integrity monitoring to mitigate cascading effects of errors. This paper investigates the potential error sources, cascading effects, and integrity monitoring strategy for augmented LEO-PNT systems. To this end, a simulation framework is developed to model the interaction between GNSS satellites, LEO satellites, and users. The results show that the proposed integrity monitor can detect and isolate the faults, ensuring the reliability and robustness of a hybrid LEO-PNT - GNSS system. The performance analysis demonstrates that the user positioning error variability and fault detection performance can be improved by the use of multiple GNSS constellations. The findings of this study provide valuable insights into the development of robust and reliable navigation solutions for LEO-PNT systems taking into account the impact on end-user**

of satellites. This increased scale introduces higher complexity in tracking orbits, providing station keeping, and calculating ephemerides. Furthermore, LEO satellites operate in an environment with more disturbances and a higher likelihood of being affected by Earth-based interference.

The integration of LEO constellations with Galileo requires a well-defined architecture that can effectively manage the increased complexity and potential error sources. One promising approach is the use of Precise Point Positioning using code and phase observations from dual-frequency receivers (P2OD) with Galileo High Accuracy Service (HAS), as demonstrated by Menzione [2]. However, this approach also introduces the risk of cascading effects of errors, as highlighted by Racelis

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Thank you for your attention!

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