



INC 2019

18-21 November 2019
Edinburgh International Conference Centre, UK



Navigation and Societal Benefits: From Animals to Autonomy

Professor Terry Moore

President

Royal Institute of Navigation



**Working Together For
A More Navigable World**

Royal Institute of Navigation

**Our vision is to be
an inclusive group of diverse disciplines
working together for a more navigable world**

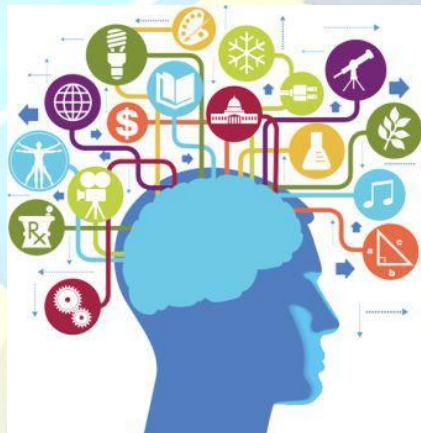
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Working Together For A More Navigable World

1. Learned Society

To enable insights through bringing disciplines and stakeholders together



2. Professional Body

To offer a supportive and straightforward approach to professional engineering registration

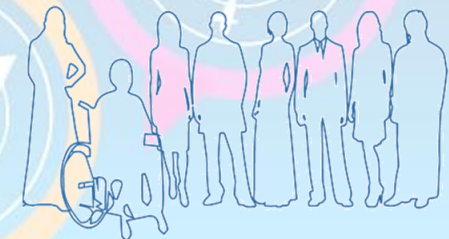
CEng Chartered
Engineer

IEng Incorporated
Engineer

Engineering
EngTech Technician

3. Diverse and inclusive

To offer an environment where everyone is welcome and can contribute and benefit



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Conference Themes



Human Navigation



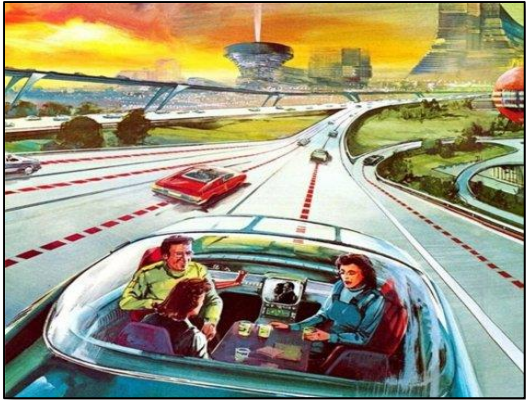
Innovative Navigation Solutions



Animal Navigation



Resilient PNT



Innovation in Land Navigation



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Keynote Presentations



- How the West is Losing the Navigation and Timing War
- How do animals find their way? Birds, compasses and tracking data
- GNSS Radio Frequency Interference Detection from Low Earth Orbit
- Why people get lost: the limits of the brain's map and compass
- View from America: Strengthening PNT Resiliency
- How insect brains perform accurate dead reckoning
- On-Board navigation for LEO, MEO, GEO... and beyond
- Satellite Navigation and Sensing - A Match Made In Heaven
- PNT in UK MoD
- Drones – integration, not segregation



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GPS Status



- 31 operational satellites on-orbit
 - 11 Block IIR, 8 IIR-M, 12 IIF, 2 *Block III*
 - Additional satellites with *Residual Status*, 1 with *Test Status*
- Two new Block III satellites have been launched in the last year
 - Block III launches – 23 Dec 2018, 22 Aug 2019
- Block IR satellites are between 15 and 22 years old!
- GPS Roll-Over
 - 6th April 2019
 - Multiple reports of civilian receiver malfunctions
 - Traffic light timing problems in New York City





GLONASS Status

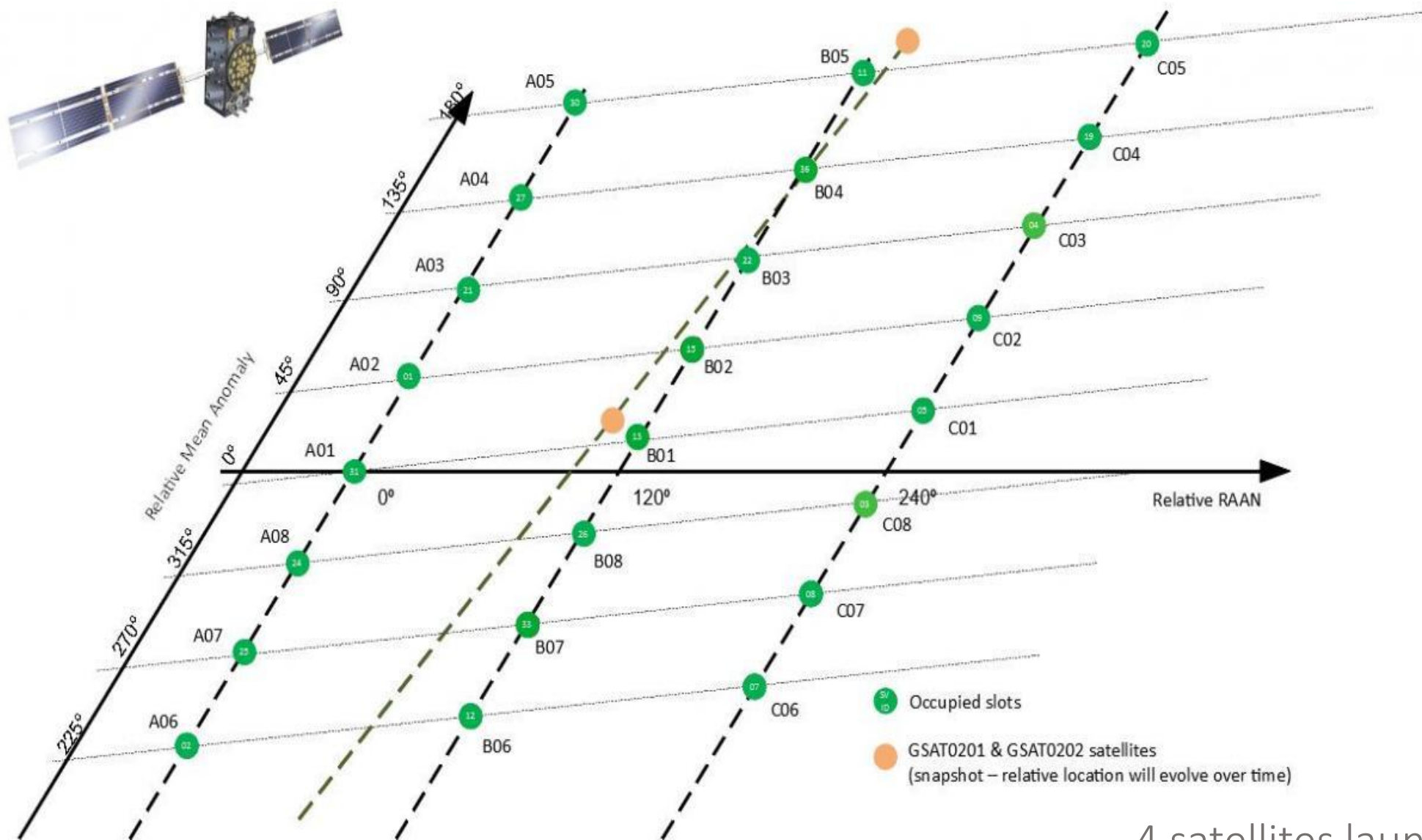
Slot	01	02	03	04	05	06	07	08
Plane 1	01	-4	05	06	01	-4	05	06

Slot	09	10	11	12	13	14	15	16
Plane 2	-2	-5*	00	-1	-2	-7	00*	-1

Slot	17	18	19	20	21	22	23	24	
Plane 3	04	-3	03	02	-6	04	-3	03	02

- 27 in constellation, 23 operational
- *2 maintenance, 1 test satellite, 1 spare*
- Most satellites are GLONASS-M, one GLONASS-K1 (slot 09)
- Last launch, GLONASS-M, 27 May 2019

Galileo Status



4 satellites launched 25 July 2018

Galileo – Batch 3



12 FOC satellites in manufacture

BeiDou (BDS) Status

BeiDou-2 Operational 2012

- Regional, China & nearby areas.
- 12 SVs, 4 MEO, 5 GEO, 3 IGSO

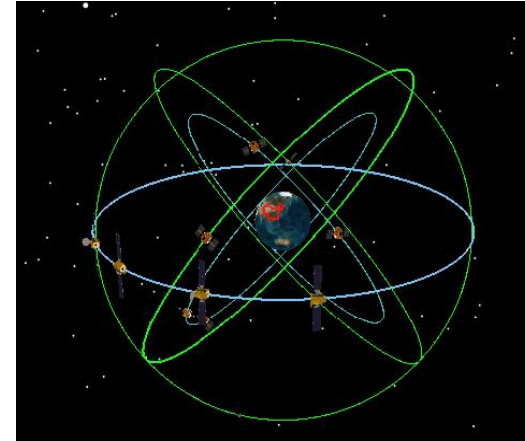
BeiDou-3 Planned for 2020

- Global
- 24 MEO, 3 GEO, 3 IGSO (30 SVs)

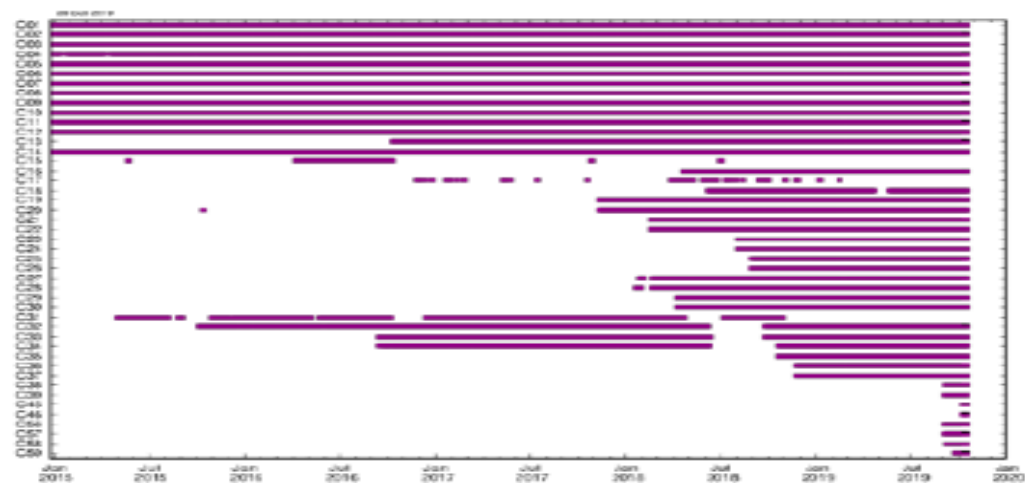
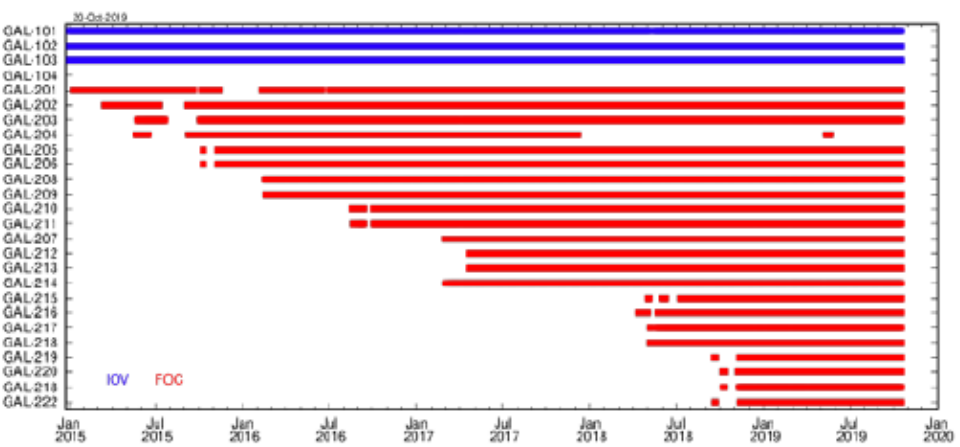
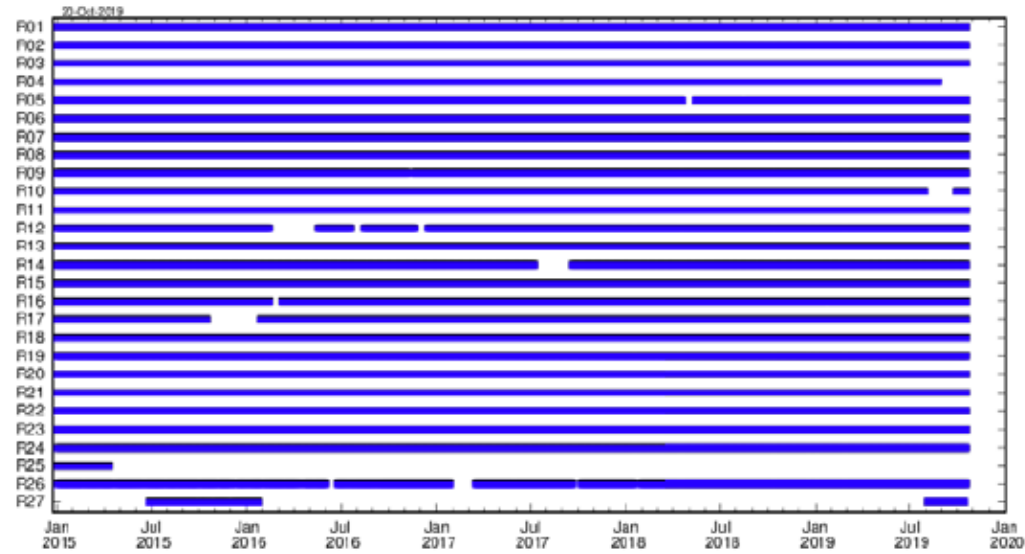
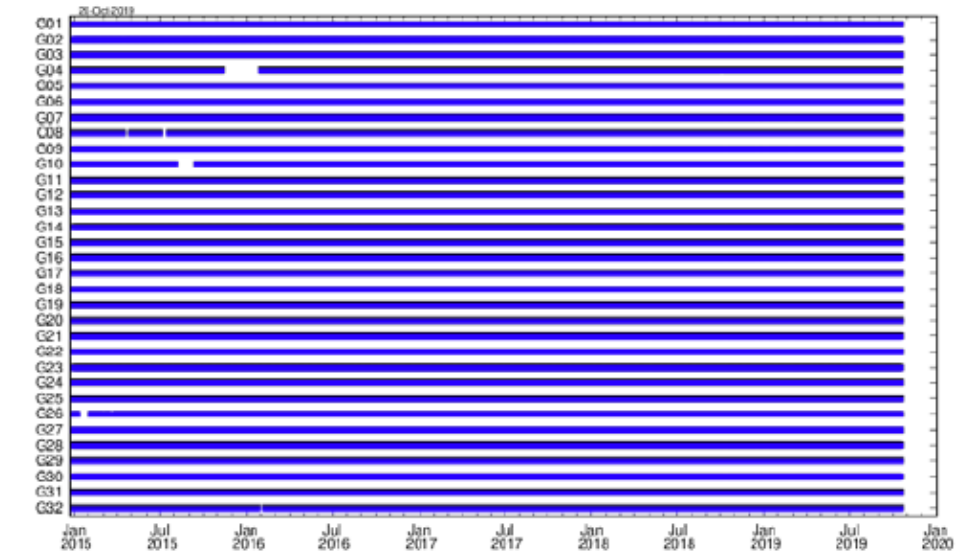
42 satellites in constellation

- BeiDou-2 14 operational
3 MEO, 5 GEO, 6 IGSO
- BeiDou-3 20 operational, *5 testing*
18 MEO, 2 IGSO (*2 MEO, 1 GEO, 2 IGSO*)
- *BeiDou-3S 4 test satellites (not operational)*

Last launch (1 IGSO, BD3) 5 Nov 2019



GNSS Data Availability 2015 - 2019

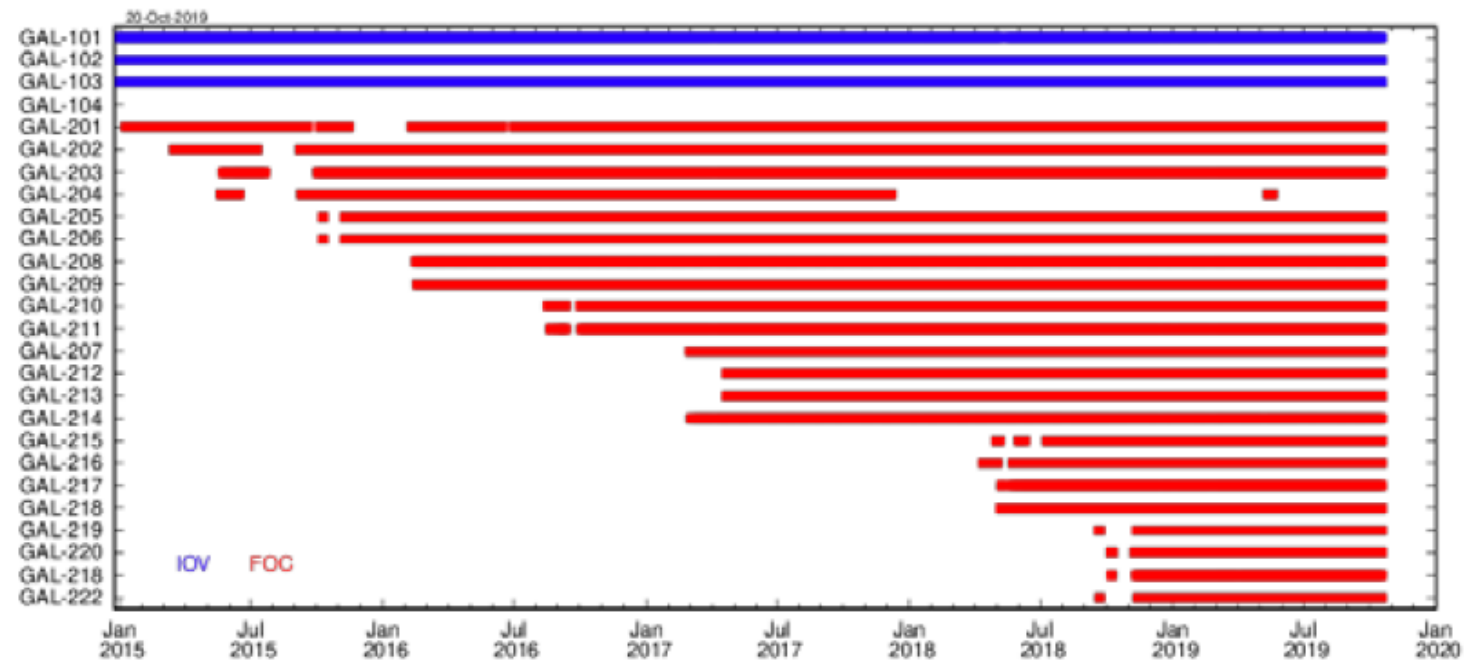
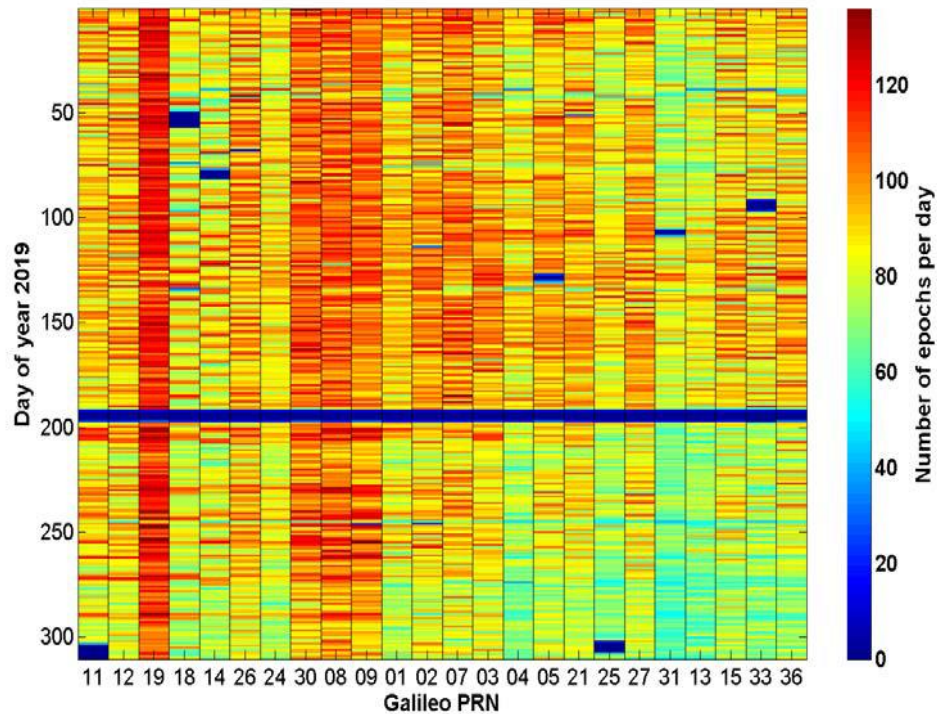




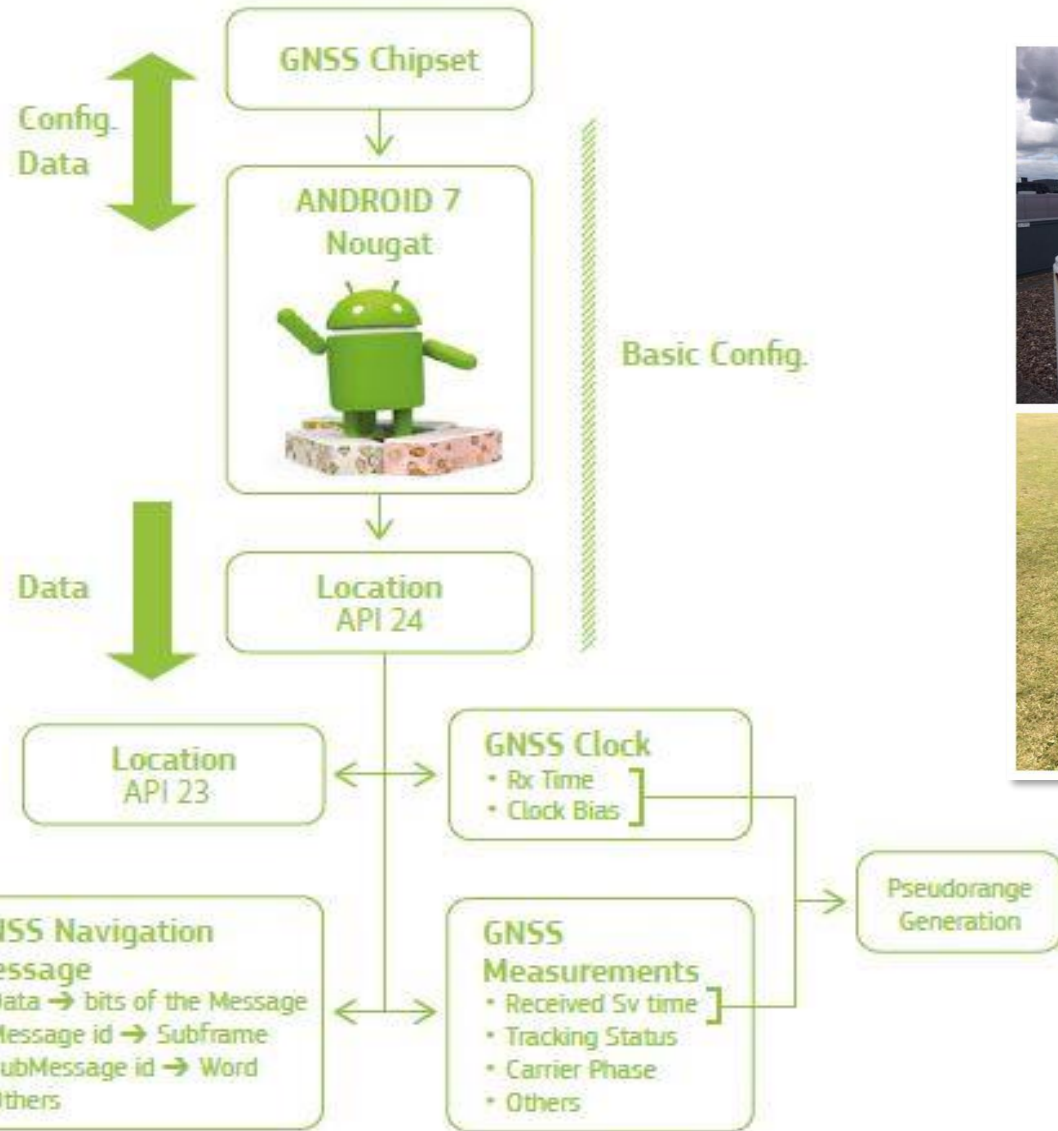
Galileo Outage

- Galileo Out of Service July 11 to July 18 2019
- Gap in Broadcast Ephemeris data
- No interruption to broadcast signals
- Problems in ground segment

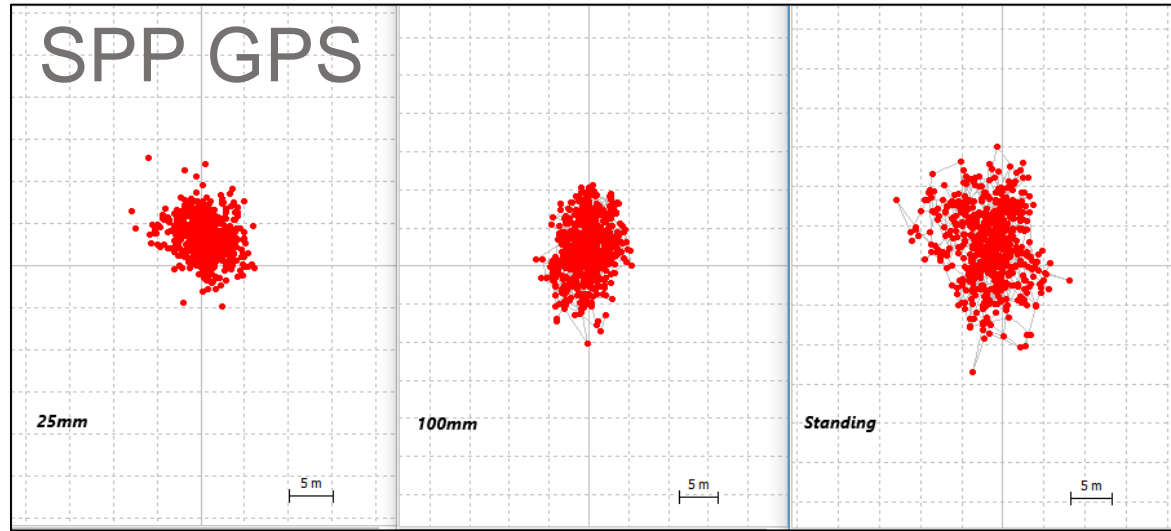
Galileo BCE availability



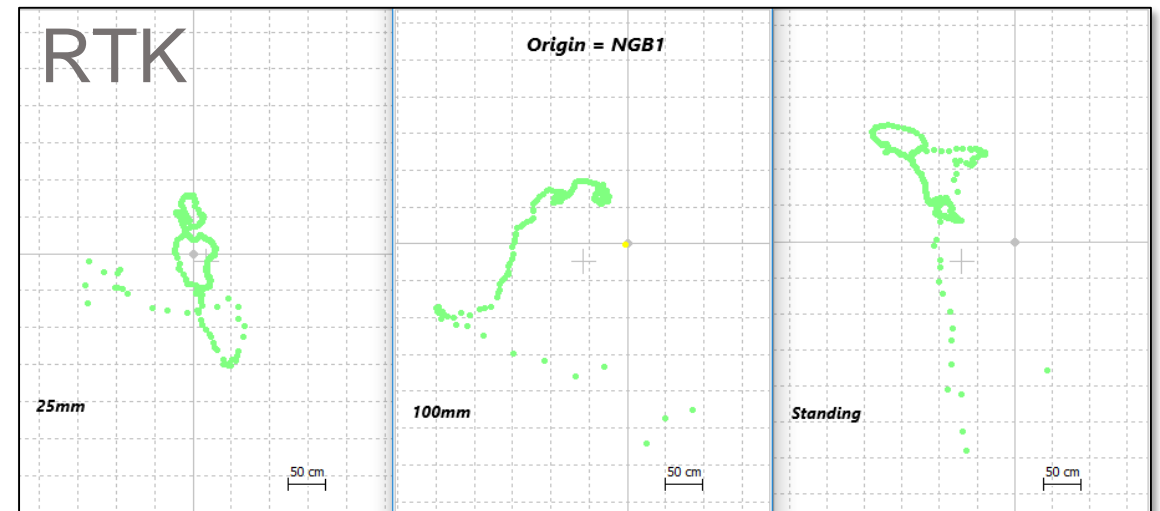
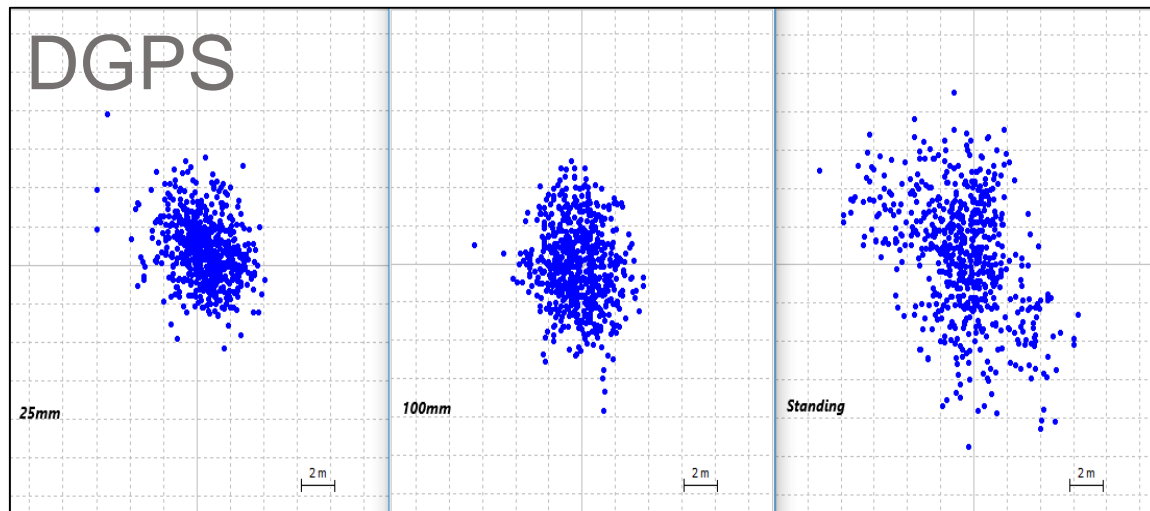
Mobile Phone GNSS



Mobile Phone GNSS



- Xiaomi Mi8
- Single frequency GPS
- Antenna shielding





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