

# EUROPEAN SPACE WEEK

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ONLINE EDITION

## New I/NAV Capabilities Enabling Faster TTFF for Galileo Open Service Users

User Consultation Platform – Mass Market Session

Matteo Paonni - European Commission, Joint Research Centre (JRC)

Organised by:



European  
Global Navigation  
Satellite Systems  
Agency



Under the auspices of:



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# Galileo OS SIS ICD Issue 2.0

- A new issue of the OS SIS ICD being released
- Major update introducing three new features to the I/NAV message transmitted within the Galileo E1 OS signal
  - *Reduced Clock and Ephemeris*
  - *Reed-Solomon Outer Forward Error Correction*
  - *Secondary Synchronisation Pattern*
- Few other minor updates





# Motivation

- Improvement of the Galileo E1 Open Service performance in terms of Robustness and Timeliness
  - Accelerate Clock and Ephemeris Data (CED) retrieval, also in challenging environments
  - Enabling fast reconstruction of the Galileo System Time (GST)
- Backward compatibility guaranteed
  - Introduction of new I/NAV words in addition to the provision of legacy I/NAV words
  - Exploiting currently unused message capabilities
  - No impact on legacy or non-participative receivers



# Optimized Galileo I/NAV Message on E1-B

$T_0$ (GST <sub>0</sub> sync.)	E1-B content ( <i>nominal sub-frame layout*</i> )						E1-B page
1 s	CED 2 (1/2)						Even
2 s	CED 2 (2/2)	Res	SAR	Spare	CRC	SSP1	Odd
3 s	CED 4 (1/2)						Even
4 s	CED 4 (2/2)	Res	SAR	Spare	CRC	SSP2	Odd
5 s	I/NAV Word (1/2)						Even
6 s	I/NAV Word (2/2)	Res	SAR	Spare	CRC	SSP3	Odd
7 s	I/NAV Word (1/2)						Even
8 s	I/NAV Word (2/2)	Res		Spare	CRC	SSP1	Odd
9 s	I/NAV Word (1/2)						Even
10 s	I/NAV Word (2/2)	Res		Spare	CRC	SSP2	Odd
11 s	RS CED 1 or 2 (1/2)						Even
12 s	RS CED 1 or 2 (2/2)	Res	SAR	Spare	CRC	SSP3	Odd
13 s	RS CED 3 or 4 (1/2)						Even
14 s	RS CED 3 or 4 (2/2)	Res		Spare	CRC	SSP1	Odd
15 s	Reduced CED (1/2)						Even
16 s	Reduced CED (2/2)	Res		Spare	CRC	SSP2	Odd
17 s	I/NAV Word (1/2)						Even
18 s	I/NAV Word (2/2)	Res	SAR	Spare	CRC	SSP3	Odd
19 s	I/NAV Word (1/2)						Even
20 s	I/NAV Word (2/2)	Res		Spare	CRC	SSP1	Odd
21 s	CED 1 (1/2)						Even
22 s	CED 1 (2/2)	Res		Spare	CRC	SSP2	Odd
23 s	CED 3 (1/2)						Even
24 s	CED 3 (2/2)	Res	SAR	Spare	CRC	SSP3	Odd
25 s	I/NAV Word (1/2)						Even
26 s	I/NAV Word (2/2)	Res		Spare	CRC	SSP1	Odd
27 s	I/NAV Word (1/2)						Even
28 s	I/NAV Word (2/2)	Res		Spare	CRC	SSP2	Odd
29 s	Reduced CED (1/2)						Even
30 s	Reduced CED (2/2)	Res	SAR	Spare	CRC	SSP3	Odd

**Backward compatibility**  
Provision of “legacy” CED: I/NAV Words 1 to 4

**Time to CED improvement (full accuracy)**  
Provision of RS encoded CED: I/NAV Words 17 to 20

**Time to CED improvement (reduced accuracy)**  
Provision of Reduced CED: I/NAV Word 16

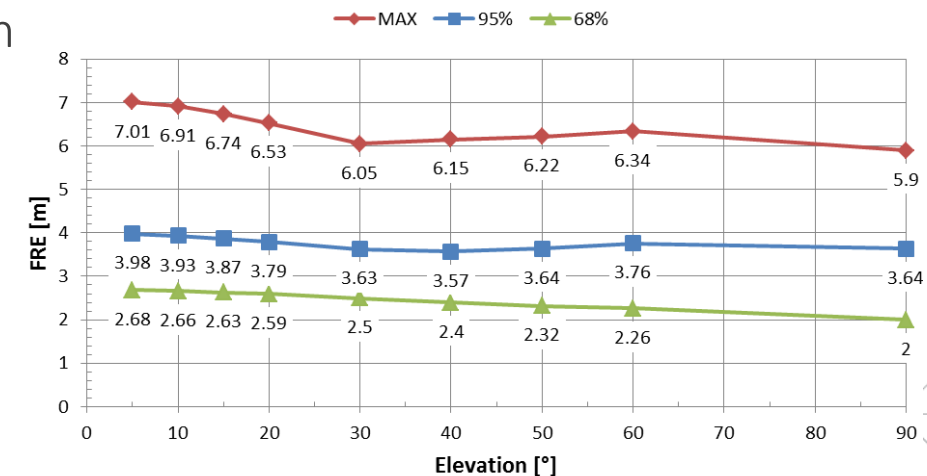
**Time to GST improvement**  
Provision of Secondary Synchronization Patterns



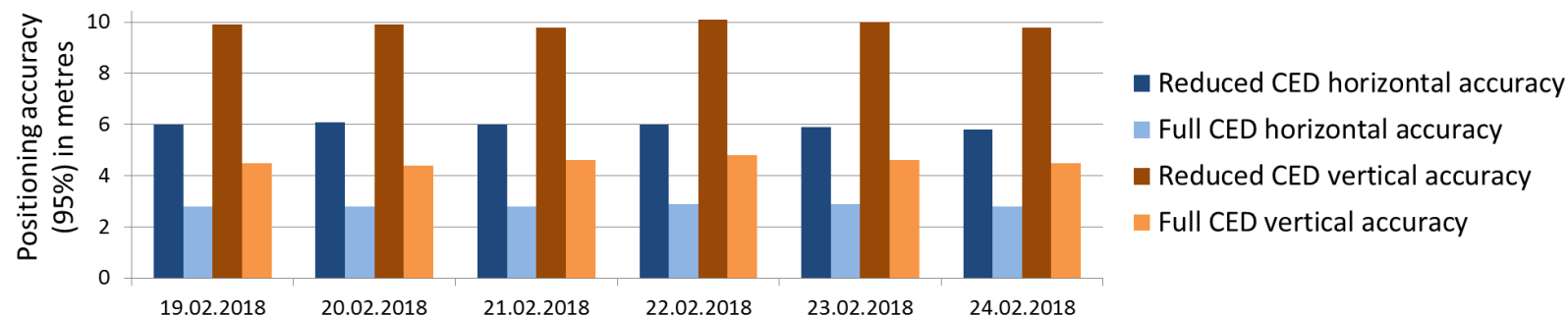
# Reduced Clock and Ephemeris (RedCED)

- RedCED is a compact set of satellite orbit and clock correction information
- Transmitted within 1 single I/NAV word (twice every 30 s)

Type=16	$\Delta A_{red}$	$e_{xred}$	$e_{yred}$	$\Delta I_{ored}$	$\Omega_{ored}$	$\lambda_{ored}$	$a_{f0red}$	$a_{f1red}$	Total [bits]
6	5	13	13	17	23	23	22	6	128



- 10 minutes validity duration with very remarkable ranging and positioning performance

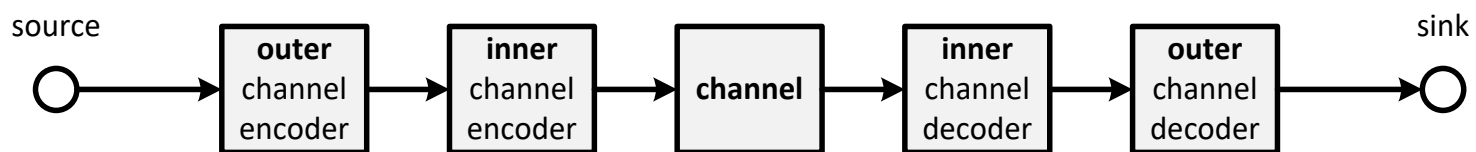




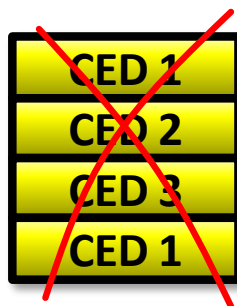


# Reed-Solomon Outer Forward Error Correction

- Outer Forward Error Correction (FEC2) providing correction of residual errors AND recovery of erased information



- “Joker Property”: any set of four different error free received CED words recovers the clock and ephemeris data



- 2 dB improved data demodulation robustness in open sky
- 5 dB improved data demodulation robustness in urban environment

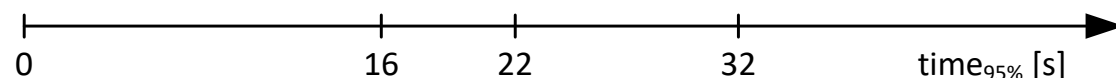


# “Time to Clock and Ephemeris Data” Improvement

legacy I/NAV subframe layout



I/NAV with Reduced CED and Reed-Solomon codes (RS2+RedCED)

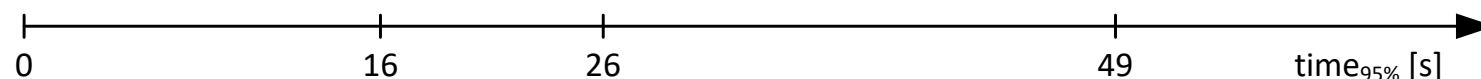


Time to CED (95%) for a user in *open sky*

legacy I/NAV subframe layout



I/NAV with Reduced CED and Reed-Solomon codes (RS2+RedCED)



Time to CED (95%) for a user in *urban environment*



# Secondary Synchronisation Pattern (SSP)

- SSP replaces reserved bits on I/NAV E1-B
- SSP enables the reconstruction of the GST
  - performing a correlation operation on the encoded symbols
  - without the need to demodulate the navigation message
  - using weak signals
- Required level of coarse synchronisation:  $\text{GST} \pm 3 \text{ sec}$

E1-B									
Even/odd=1	Page Type	Data <sub>j</sub> (2/2)	Reserved 1	SAR	Spare	CRC <sub>j</sub>	SSP	Tail	Total (bits)
1	1	16	40	22	2	24	8	6	120





# Implementation roadmap and receivers testing campaign

- The OS SIS ICD Issue 2 is being released now
  - Receiver manufacturers can access all technical details before actual broadcast
- The Programme to support receiver manufacturers with testing campaigns on implementation of new I/NAV capabilities
  - Laboratory tests through simulated signals under realistic scenarios
  - Provided through GSA and supported by JRC in 2021-2022 timeframe
- The system set to transmit the new I/NAV capabilities by **2023**



# Conclusion

- New Galileo OS SIS ICD Issue 2 being released
- Three new technical solutions to be made available to **all Galileo OS users**
  - Improvement of the Galileo E1 Open Service performance in terms of **Robustness** and **Timeliness**
  - Significant **Time To First Fix Improvement** in challenging environments addressing both **unassisted** and **assisted GNSS**
  - **Backward compatibility** guaranteed (no impact on legacy or non-participative receivers)
  - **Low complexity** implementation within OS receivers
- **Testing campaign** supporting receiver manufacturers in 2021-2022
- Broadcast of operational signal with new I/NAV capabilities by 2023



# Additional Information

## Improving the Performance of Galileo E1-OS by Optimizing the I/NAV Navigation Message

*M. Paonni et al., Proceedings of ION GNSS+ 2019*

# Linking space to user needs



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