



# GALILEO IOV

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Navigation solutions powered by Europe

# Galileo IOV Status and Results - Content

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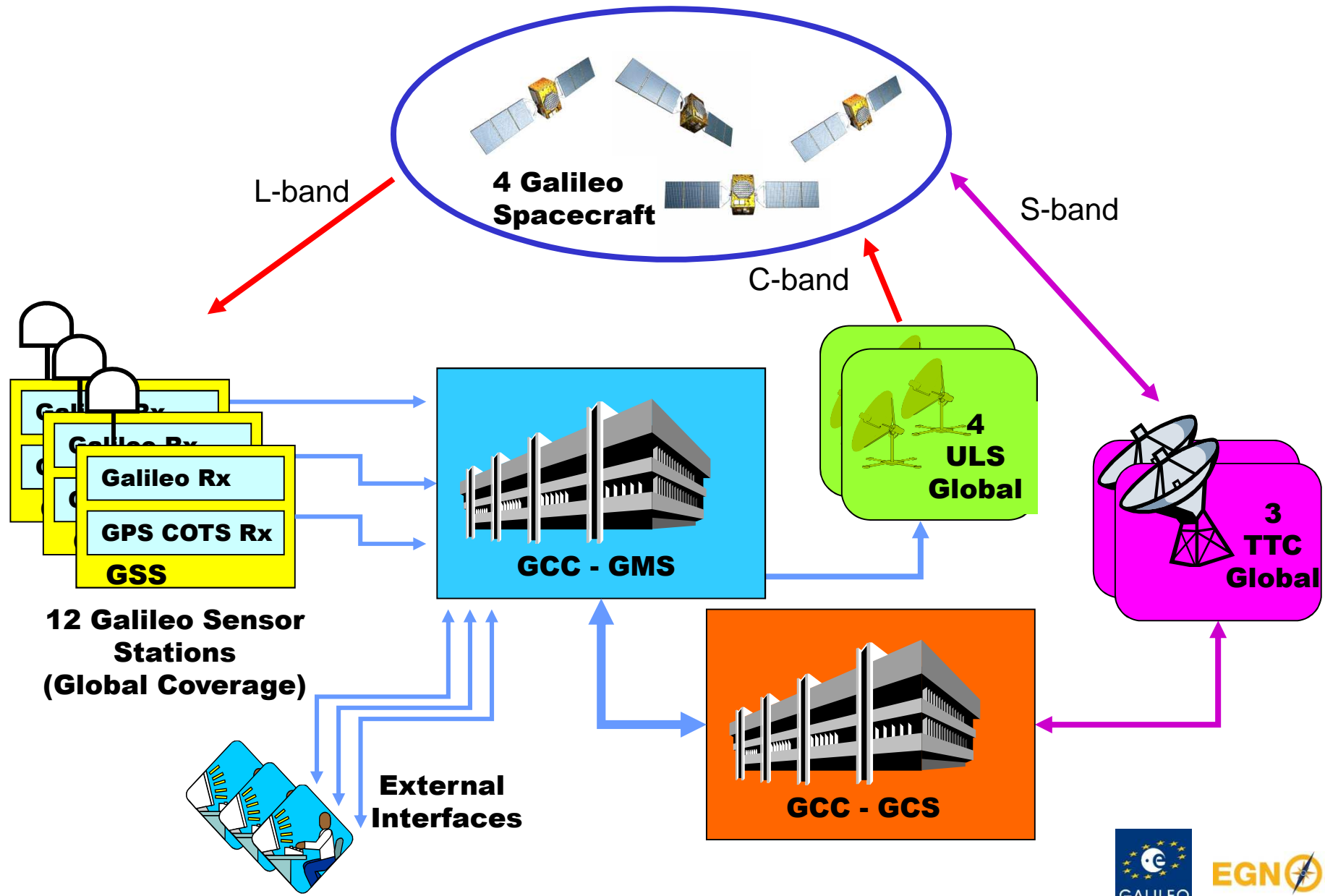


# IOV Mission Objectives

- ★ Verification before full System Deployment:
  - ★ Verification of Space, Ground and User components and Interfaces prior to full system deployment
    - ★ Navigation Processing & Message Dissemination Capabilities
  - ★ Analysis of System Performance with the view to refine the FOC system
    - ★ Signal in Space Ranging Error & User Equivalent Range Error budget
  - ★ Verification of Operational Procedures



# System Status: IOV Configuration



# IOV Launch 1 & 2



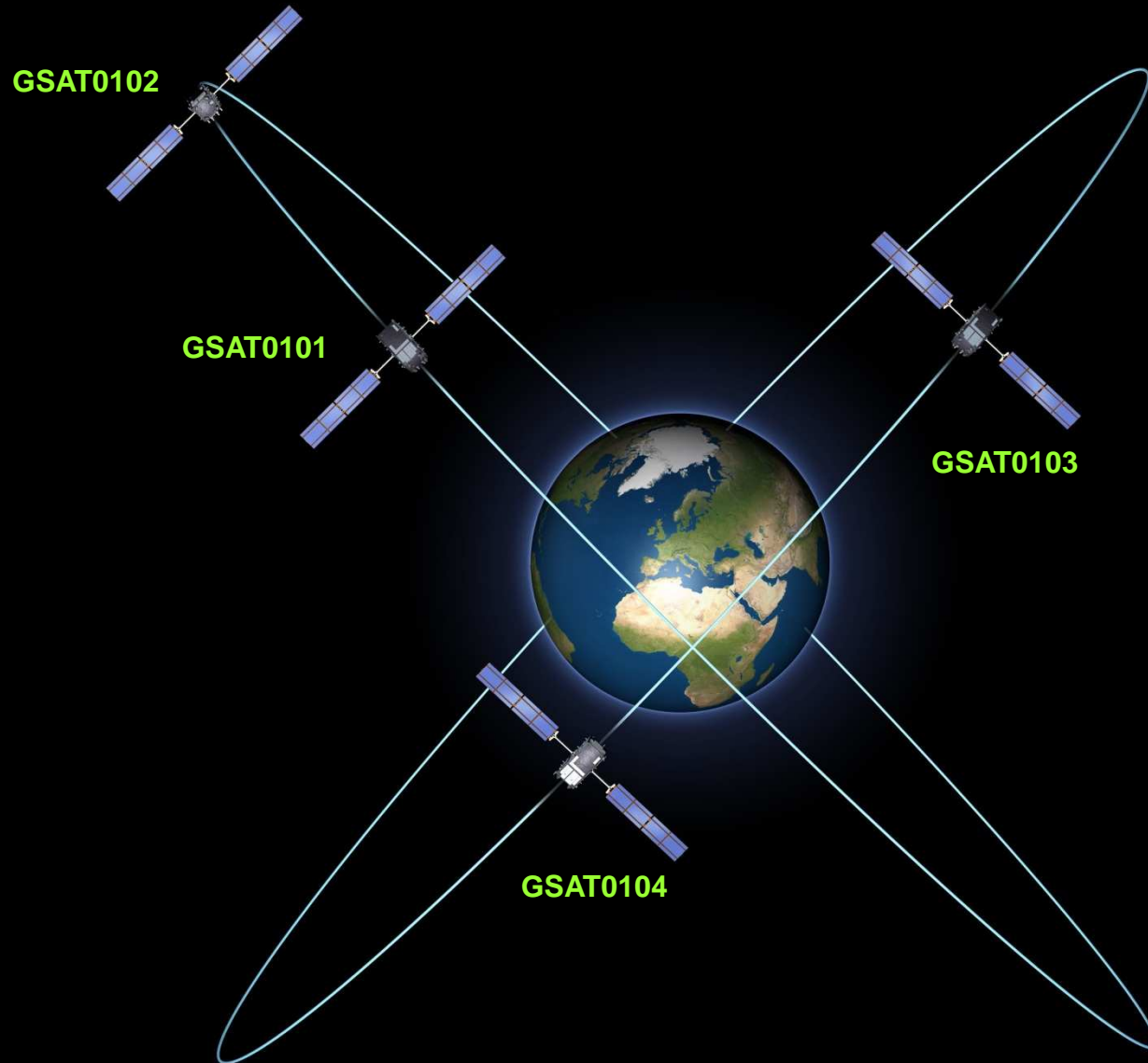
21 October 2011



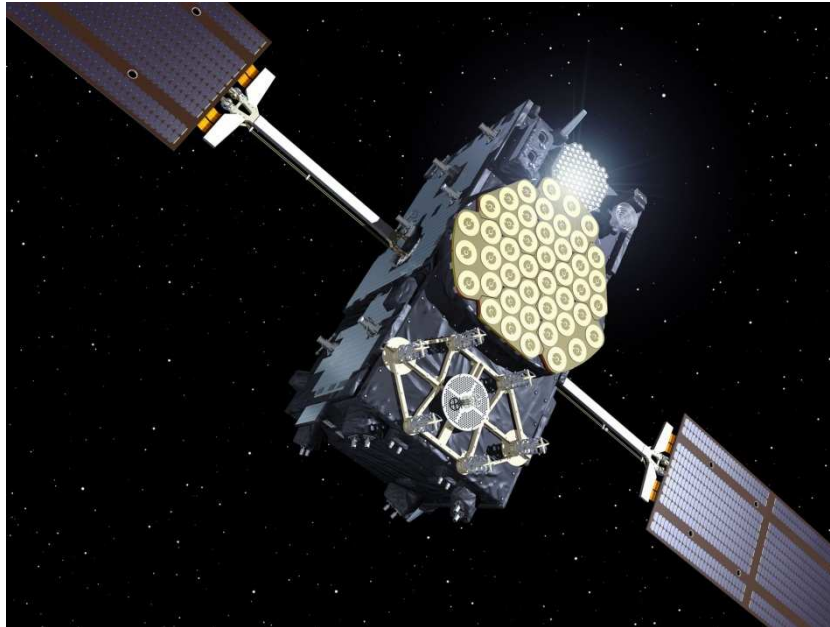
12 October 2012



# Galileo Space Segment for IOV



# IOV Satellites (PFM, FM2, FM3, FM4)



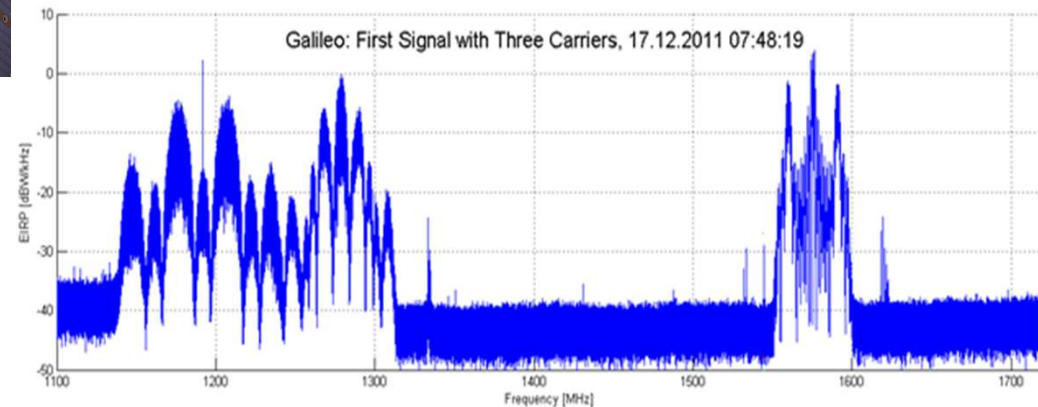
In early 2012 PFM/FM2 underwent a thorough in-orbit testing campaign.

In 2012/13 FM3/FM4 underwent the in-orbit testing campaign.

All four satellite perform well.

## IOV Spacecraft

Mass @ Launch:	~700 kg
Power Consumption:	1420 W
Dimensions:	2.74 x 1.59 x 14.5 m
Lifetime:	12 years
Orbit Injection:	Direct into MEO

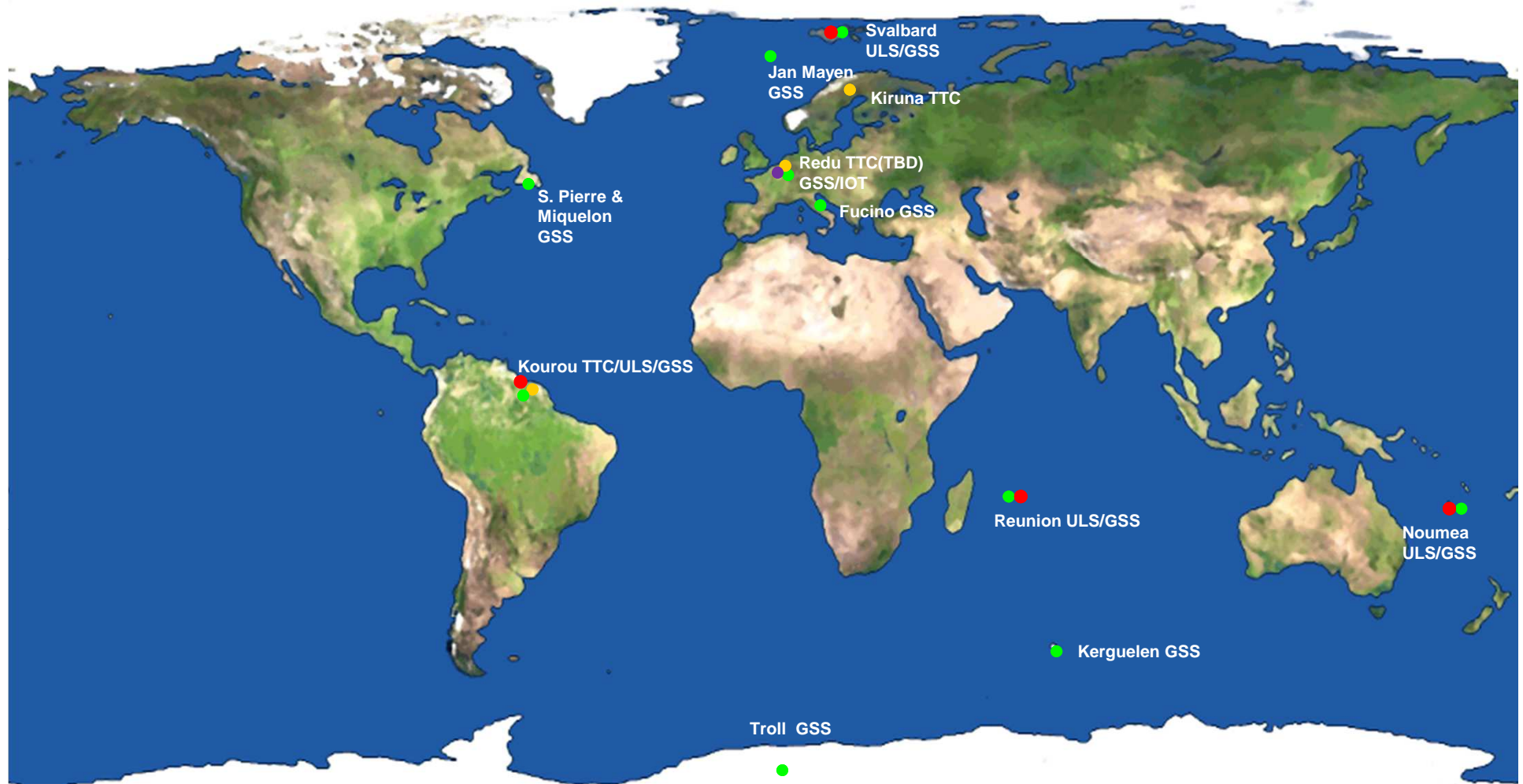


E5 E6

E1



# Galileo Ground Segment for IOV



- 12 GSS
- 4 ULS
- 3 TT&C
- 1 IOT





# Galileo Ground Segment for IOV



**Fucino  
GCC-I & GSS**



**Kerguelen GSS**



**Kourou  
Launch Site**

**ESCC ESOC**



**Noumea  
GSS/ULS/TTC**



**Kiruna TTC**

**ESCC CNES**



**Kourou  
TTC-ULS**

**Oberpfaffenhofen  
GCC-D**

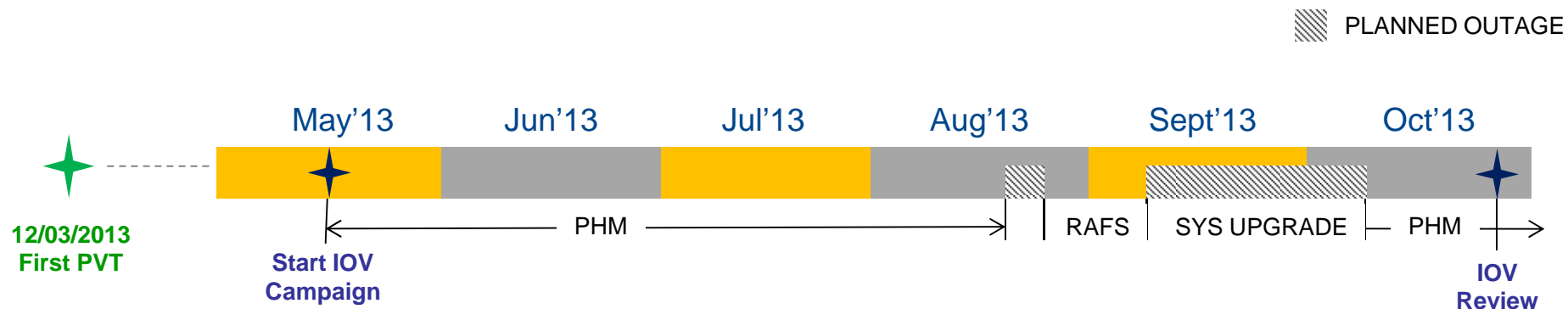


**SAT MANUFATURER**



**Redu IOT**

# IOV SCHEDULE



Satellite	Availability* SIS (%)	Availability* Navigation Message (%)
GSAT0101	100	100
GSAT0102	100	100
GSAT0103	100	100
GSAT0104	86.3**	78.8**

\* Period: 14/05/2013 to 31/07/2013

\*\* Outage on 14/06/13. Resumed signal broadcast 26/06/2013, navigation message on 01/07/13



# POSITIONING PERFORMANCE

# Accuracy of 1st Position Fix at ESTEC

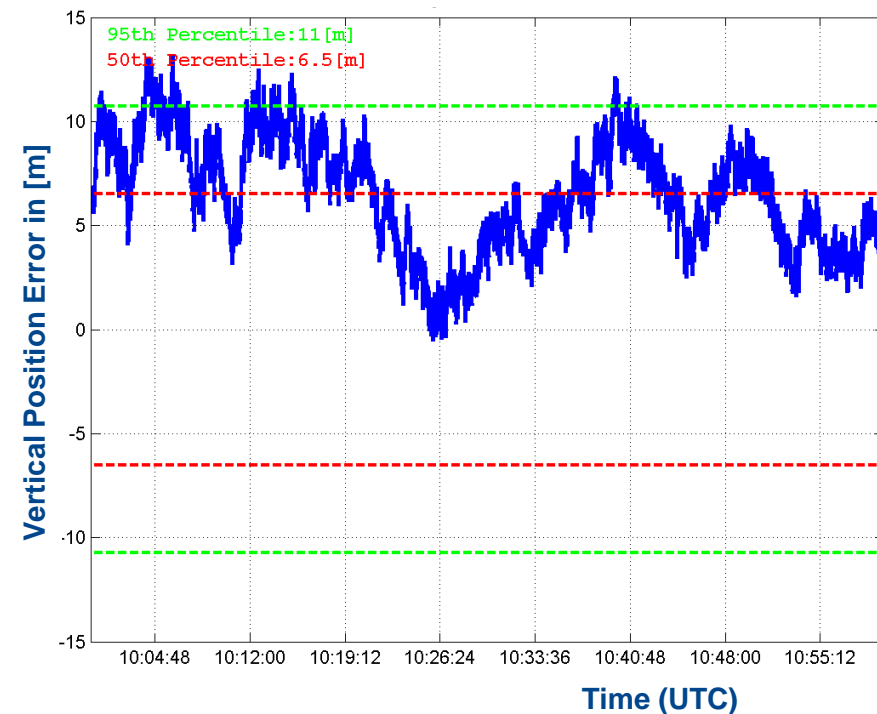
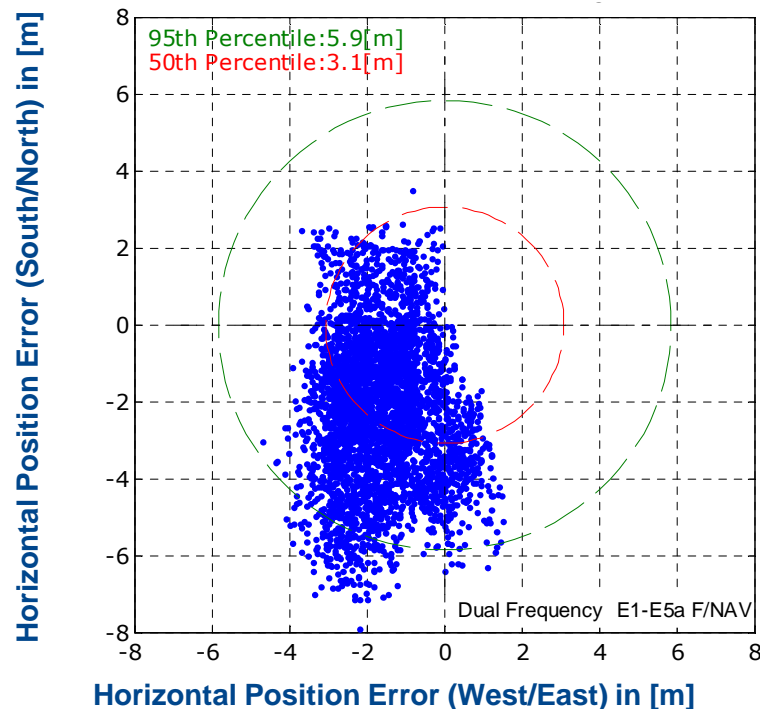
## Standalone Galileo Position Solution

E1/E5a Dual Frequency Receiver

12<sup>th</sup> March 2013 10:00 – 11:00 UTC

Horizontal Accuracy: 5.9 m (95<sup>th</sup> Percentile)

Vertical Accuracy: 11 m (95<sup>th</sup> Percentile)



Position Fix established with Test User Receivers in real-time  
and with TGVF Reference Receivers off-line.



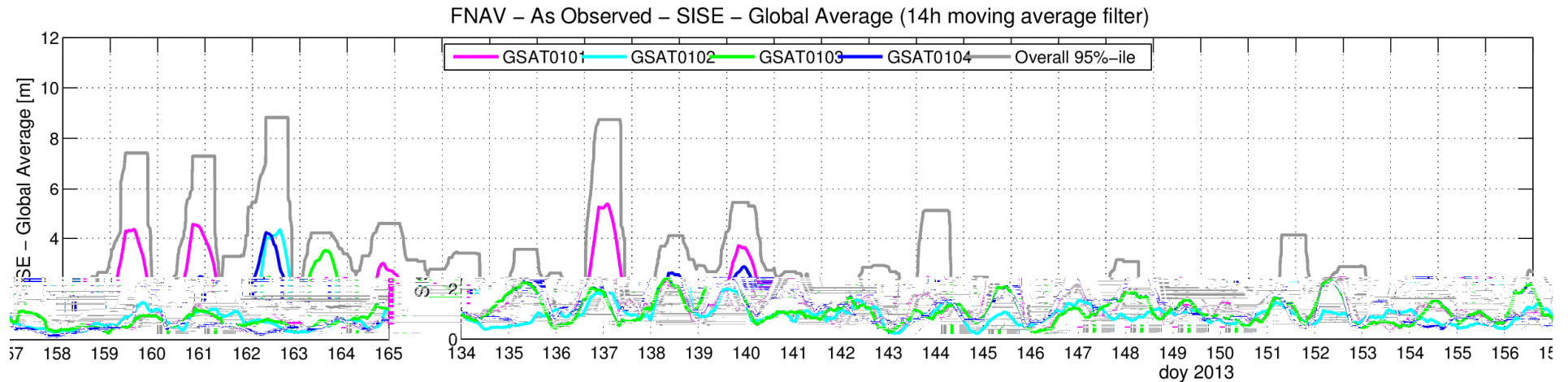
# Visibility of Satellites to Support PVT

	Number Satellites	Availability of 1 satellite visible worldwide (expected)	Availability of 1 satellite visible worldwide (measured)	Availability of PDOP < 5 (Expected)	No. PVT windows over 10 days	Average window duration (min)	Maximum window duration (min)
<b>IOV</b>	4	67 %	65.3 %	5.5 %	9	88.3	152.1
	6	96%	-	9.6%	18	77	152.1
	8	100%	-	15.5%	32	67.6	152.3
	10	100%	-	32.2%	53	87.5	324.1
	14	100%	-	72.3%	90	115.7	383.3
	26	100%	-	100%	1	14400	14400



# SIS Ranging Error

## (Period 14/05/13 – 14/06/13)



Parameter	Case	Unit	IOV Value	FOC1 Target
ODTS E1-E5a	GSAT0101 (67%)	m	1.26	< 0.65
BGD Accuracy E1-E5a	All satellites (95%)	m	0.32	< 0.5
Maximum Age of Broadcast Message	GSAT0101 (Average)	min	35.1	< 100
Ionospheric Error Correction Performance (single frequency users)	Average all stations	%	98.19	> 68





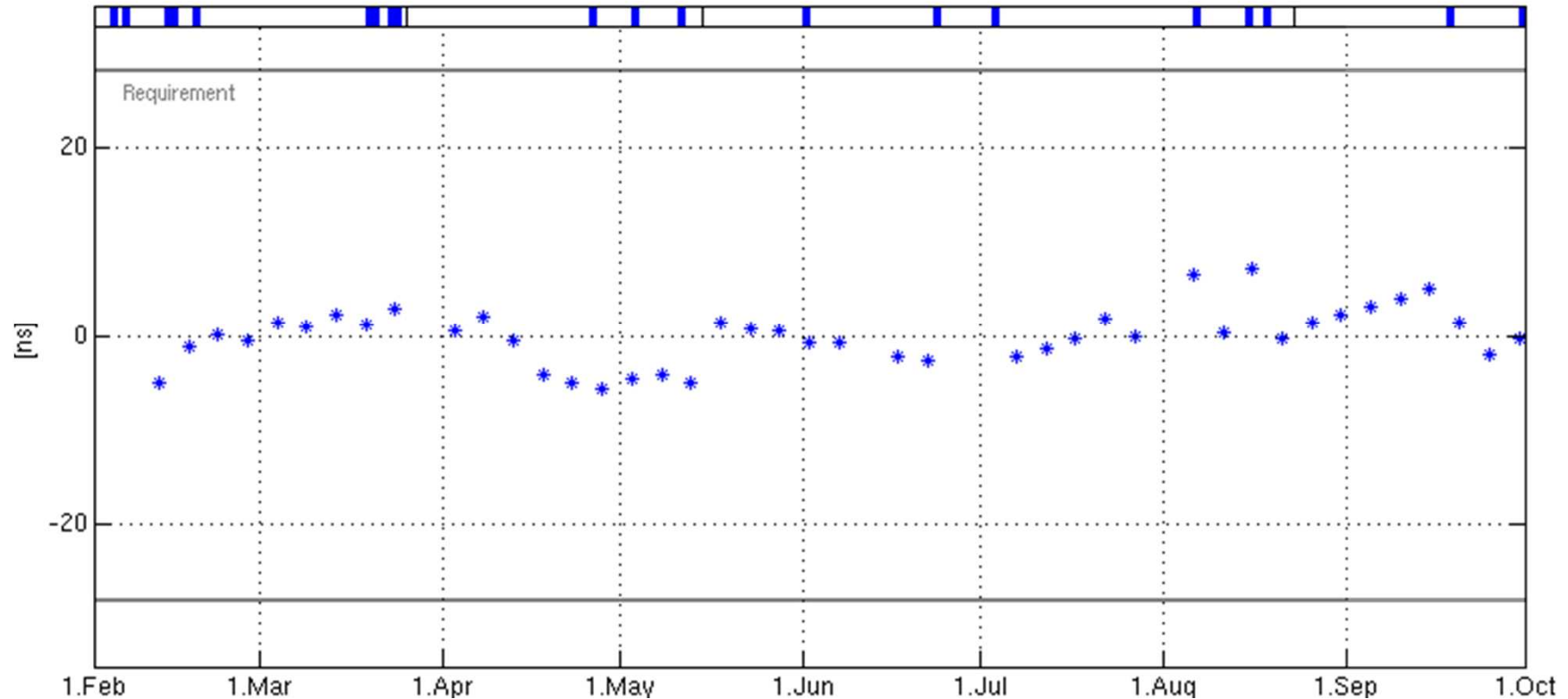
# TIMING PERFORMANCE

# UTC-GST(MC) Prediction Error

early results



GST vs. UTC (modulo 1 second) prediction accuracy

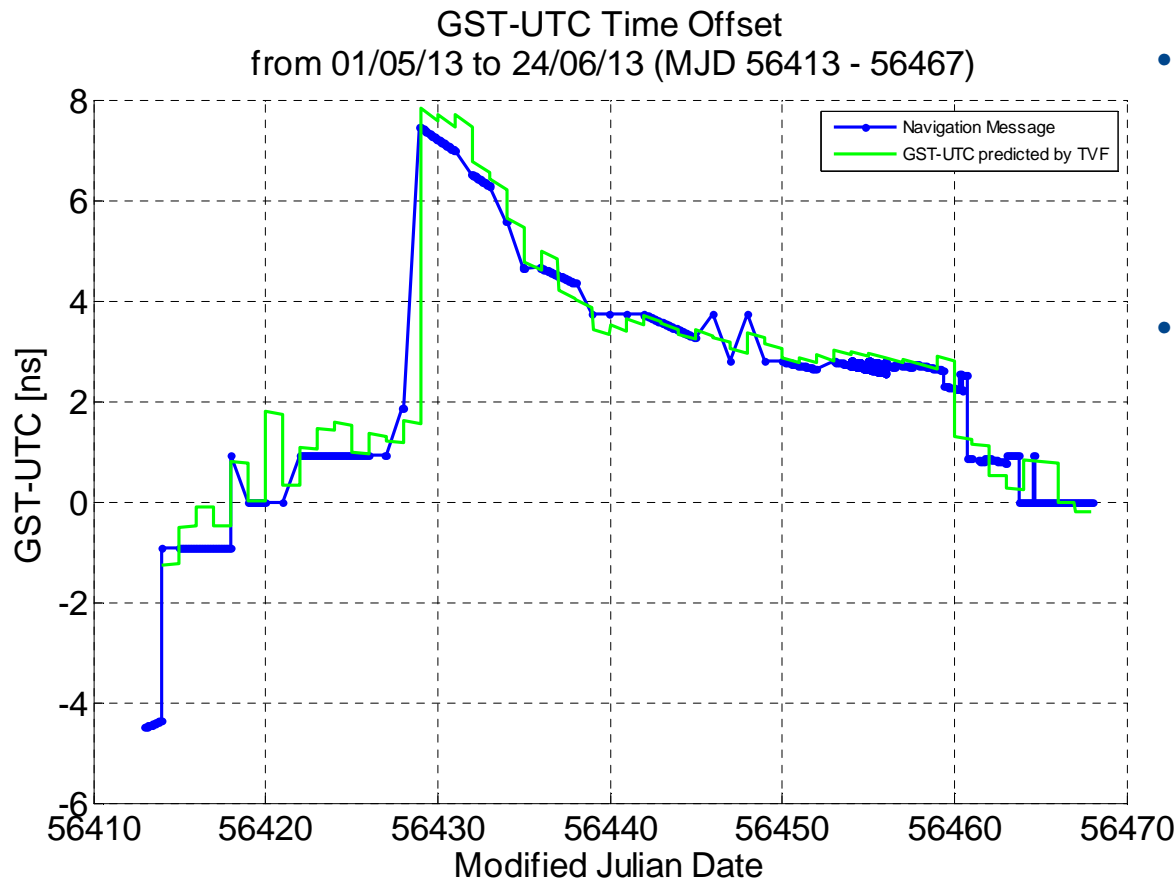


- TVF daily evaluates a prediction value for UTC-GST(MC) time offset. The prediction is broadcast in the Galileo navigation message.
  - The UTC-GST(MC) prediction error is evaluated by TVF monthly when CircularT is available.
  - Through-out the IOV campaign, UTC-GST(MC) prediction error remains within +/- 5 ns



# Broadcast GST(MC)-UTC offset

## early results

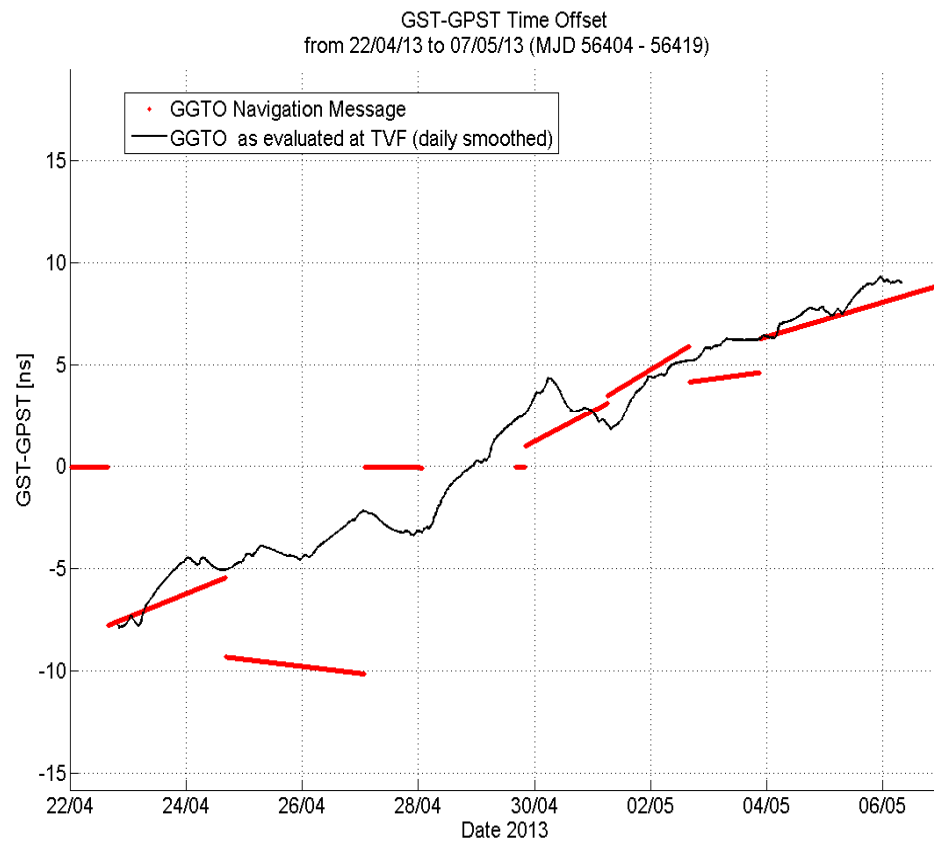


- TVF evaluates the offset between GST(MC)-UTC offset computed from the broadcast GST(MC)-UTC conversion parameters and the one predicted by TVF.
- The broadcast and the computed GST(MC)-UTC offset are in a very good agreement.



# Broadcast GPS-Galileo Time Offset (GGTO)

early results



- The TVF estimates GGTO and compares its value with the GGTO transmitted in the navigation message (evaluated by PTF).
- The TVF's GST(MC)-GPSTime estimate is based on the PTF GPS receiver directly connected to GST(MC) and retrieving GPSTime from GPS Signal In Space.
- GGTO is not always updated daily.
- The broadcast value is mainly in good agreement with the TVF estimate





# Beyond IOV: FOC satellites

- ★ 22 satellites procured to OHB (D).
- ★ First two satellites already built and undergoing tests at ESTEC.
  - ★ Several System Compatibility Tests passed successfully already.
  - ★ Thermal Vacuum Tests to take place in November 2013.
- ★ Third and Fourth satellites already integrated in factory.
- ★ Rest of satellites in different stages of manufacturing.



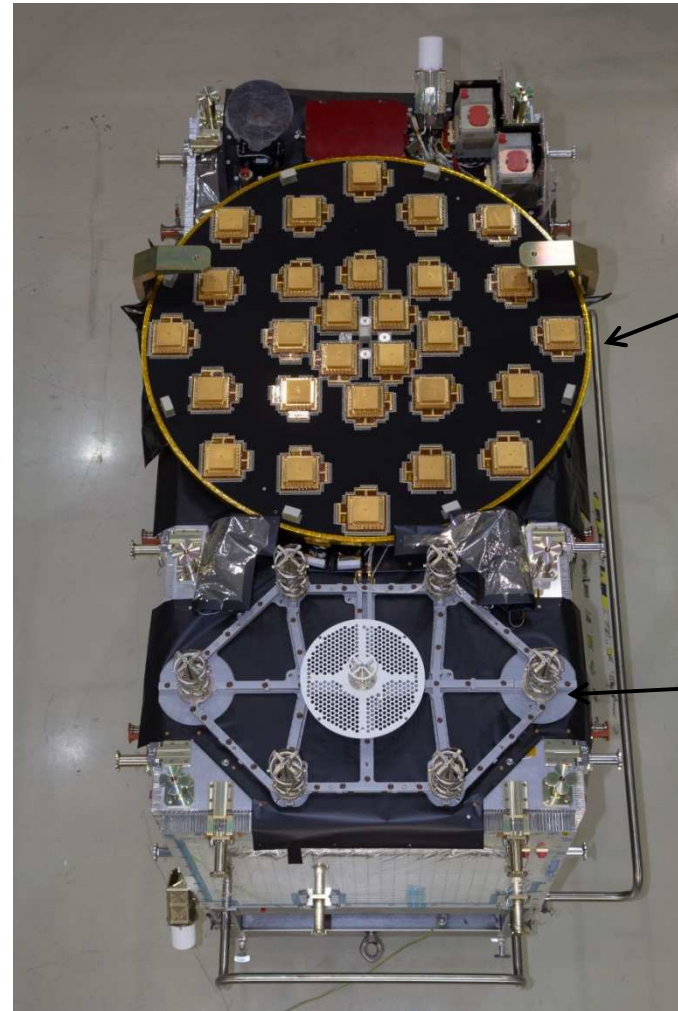
# FOC FM-01 Being Ready for Tests



November 11, 2013



# FOC FM-01 Front view



Navigation Antenna

Search and Rescue  
Antenna





# Beyond IOV: Ground Segment Being Extended to FOC1 Capability (2015)



- 16 GSS
- 5 ULS
- 5 TT&C
- 3 MEOLUT



# Conclusions

- ★ The first position fix with Galileo was obtained on the 12 March 2013.
- ★ The in-Orbit Validation Campaign of Galileo was initiated in May 2013 and will be completed in October 2014
- ★ Almost 1 window of about 2 hours each day during which PVT calculation based on Galileo-only is possible
- ★ IOV results are very satisfactory:
  - ★ Ranging error < 3 m
  - ★ GST-UTC offset < 11.77 ns
  - ★ UTC dissemination accuracy < 12.16 ns
  - ★ Horizontal, Vertical positioning error < 10 m
- ★ Availability and performance will increase as space and ground segment are completed
  
- ★ The preparation for Early Services has started