Galileo Satellite Metadata

Galileo Metadata for scientific products, source and future updates.

Scientific and Fundamental Aspect of GNSS

ETH – 6 September 2019

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Outline

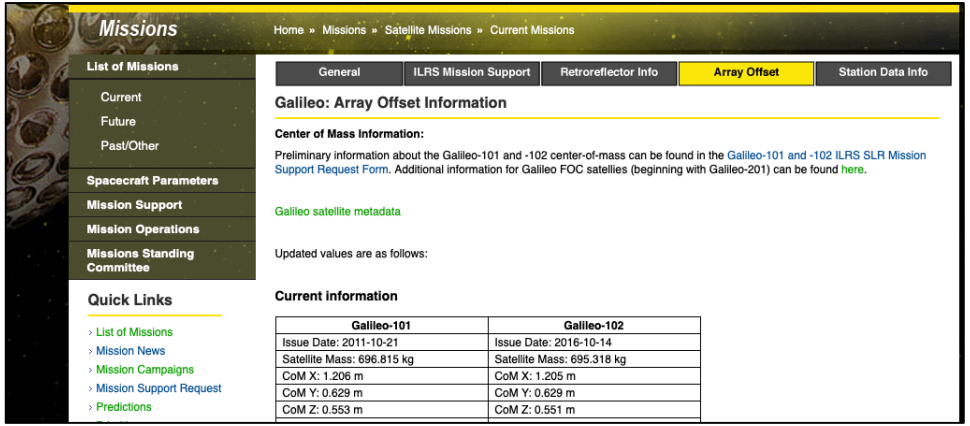
1. Metadata status and history
2. Current content description
3. Future updates
4. Conclusions

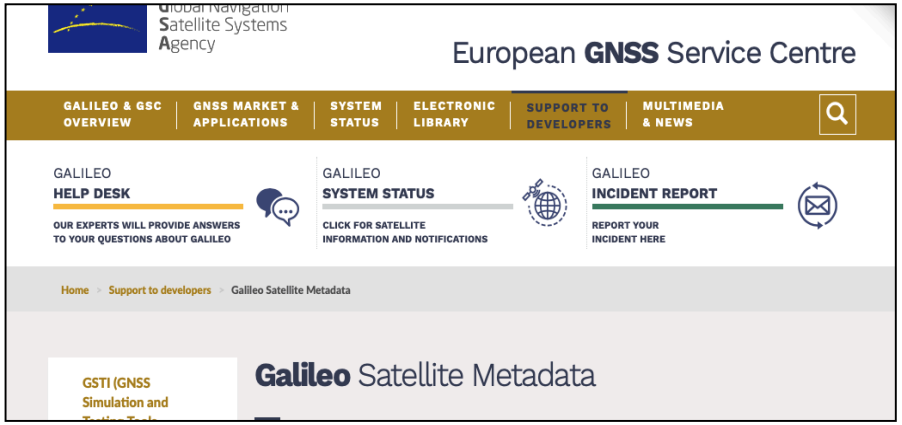
Metada status: released from 2011

Satellite Metadata release through two Web sites

- ILRS web site: Center of Mass and Laser Reflector position
- GSC web site: frame, attitude, navigation antenna, geometry, group delays

https://www.gsc-europa.eu





Metadata status: source

What is the Galileo satellite metadata?

- List of required Galileo information for Scientific Applications
- Requested by Galileo Scientific Advisory Committee in 2011

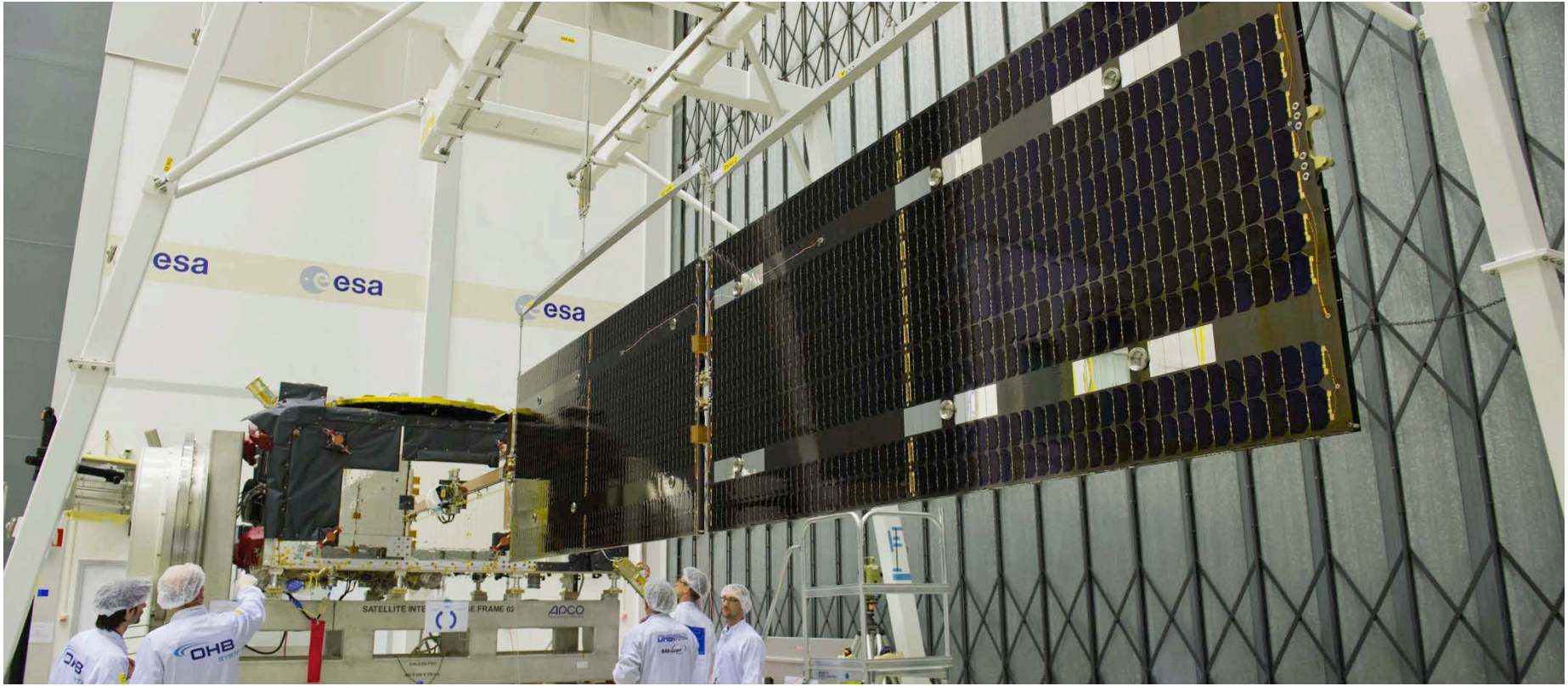
subarea	Information	Format
CoM	mass and CoM evolution w.r.t. origin of mechanical reference frame	web site tables
Frame	Definition of body-fixed coordinate system (X,Y,Z) and view-cone angles (theta, phi)	ANTEX
NAVANT	Nominal CoP for each signal (E1, E5a, E5b, E5AltBOC, E6, ...) w.r.t. origin of the mechanical reference frame PCV for each signal (E1, E5a, E5b, E5AltBOC, E6, ...) as function of the view-cone angles (theta, phi), with respect tthe CoP Source of the CoP and PCV calibrations (e.g. an-echoic chamber measurement)	ANTEX
	Reference point for the Galile navigation data message with respect tthe mechanical reference frame	
	Antenna gain for each signal as function of the view-cone angles	Fix points
Attitude	Nominal spacecraft attitude model, antenna pointing and solar array rotation Description of the satellite orientation during eclipses and "noon" rotations	equations
Geometry	Simplified face model with solar reflectivity, absorption and emission coefficients (e.g. based on configuration drawings including types of materials or surfaces) Dimensions of the main body and extensions (solar panels)	web site tables
HW Delays	Differential instrumental delays	web site tables
Laser	Location of laser retroreflectors w.r.t. the mechanical reference frame	web site tables

Metadata content: Centre of Mass (dry)

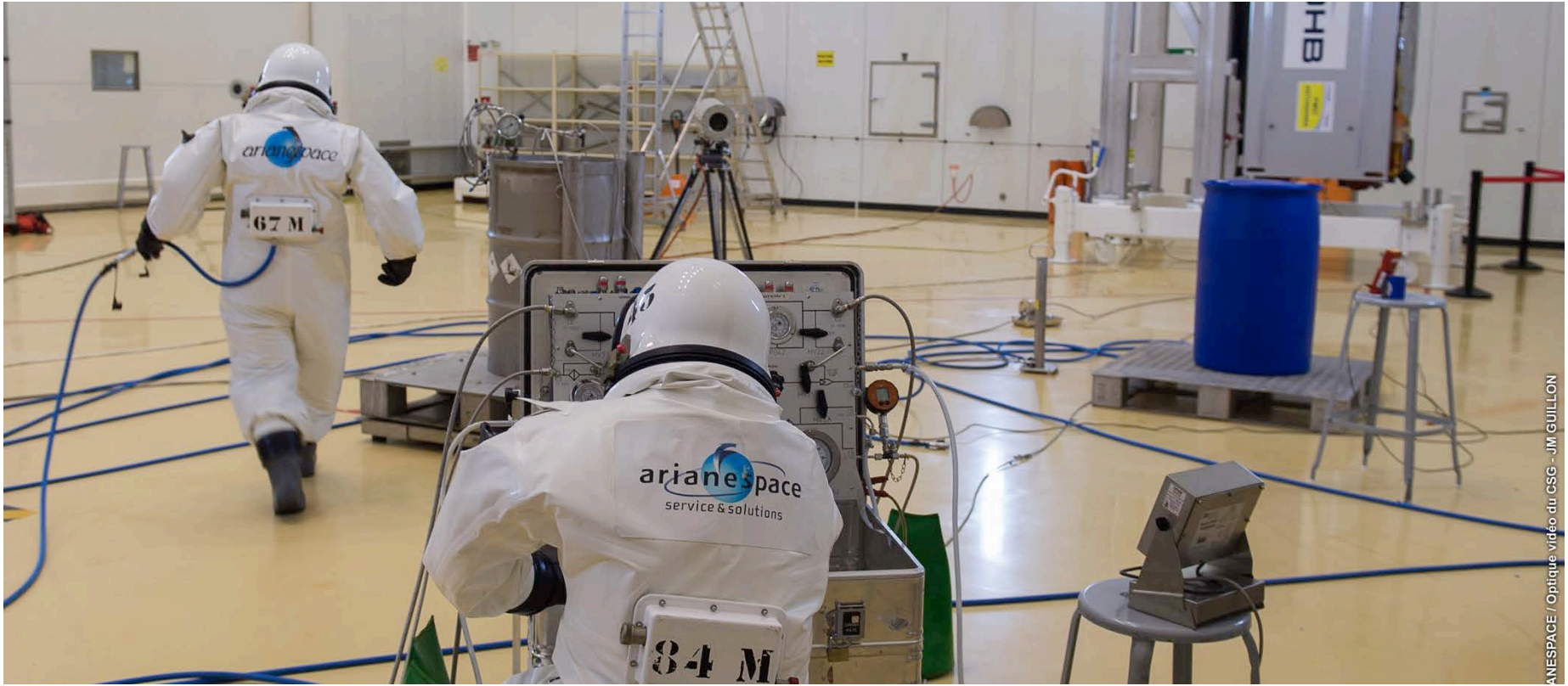
Dry measurement

- Flight configuration
- No propellant
- Stow configuration

Metadata content: Centre of Mass (dry+SA)

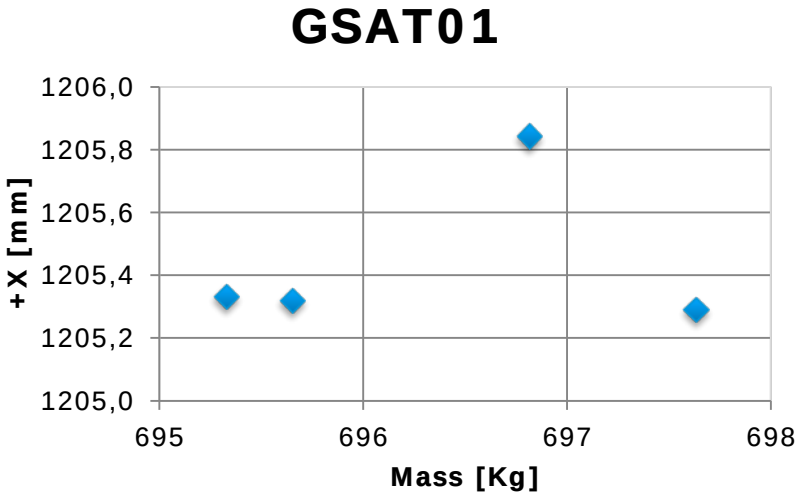


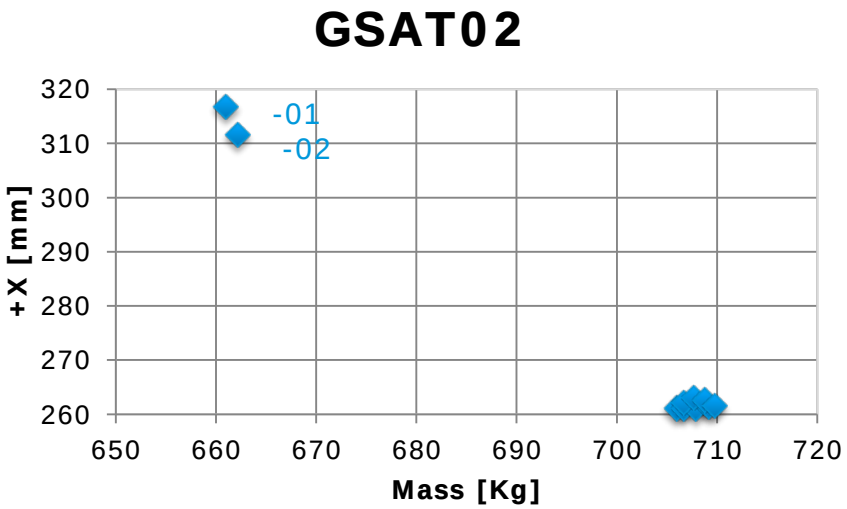
Metadata content: Centre of Mass (dry+SA+prop.)



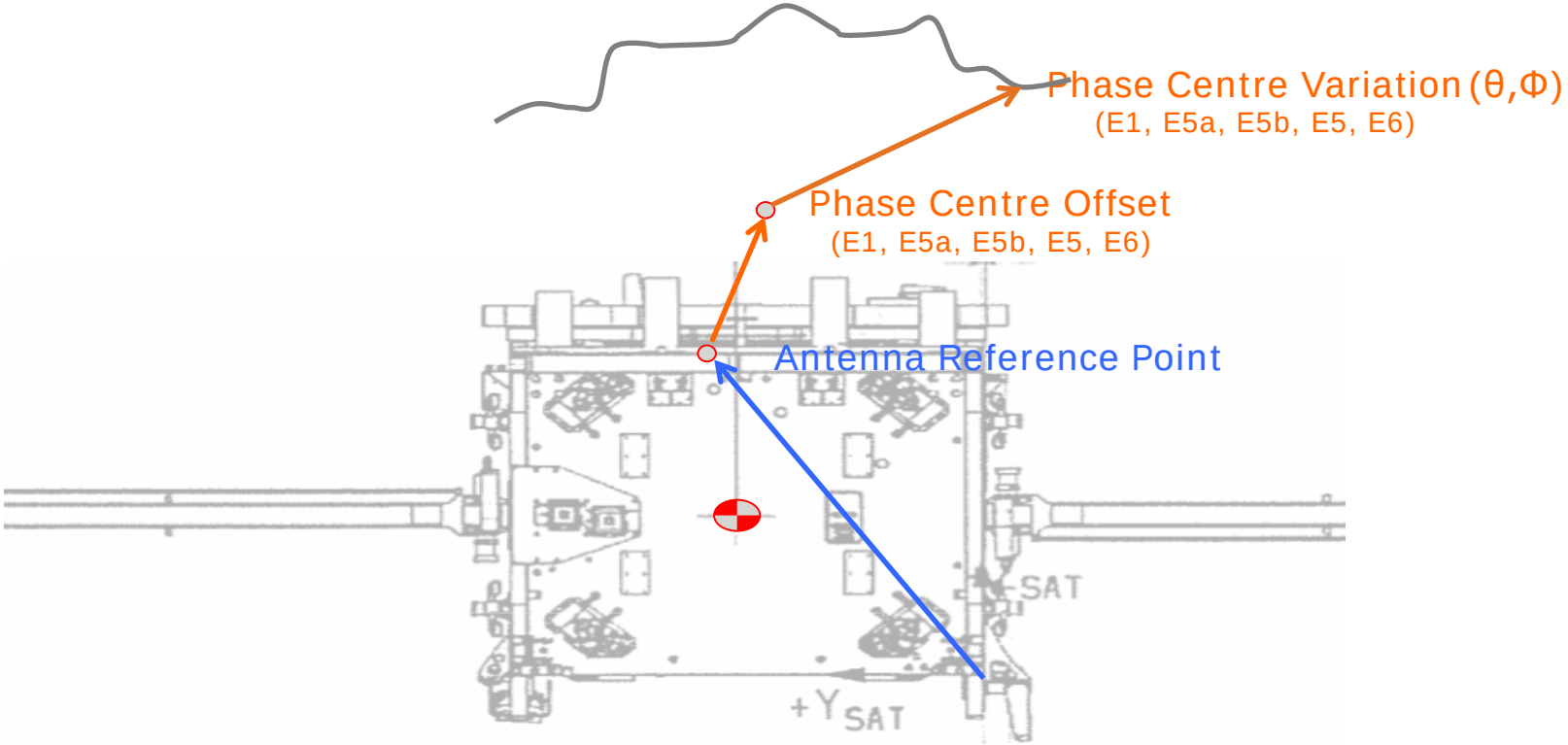
Metadata content: Centre of Mass (final)

- CoM = Measure in stow + (deployed – stowed panels) + (filled – used propellant)
- New CoM value after any maneuver sent to ILRS
- Agreement between S/C well below 1 cm
- GSAT02-01 and -02 in “eccentric” orbit with less propellant show the displacement in + X



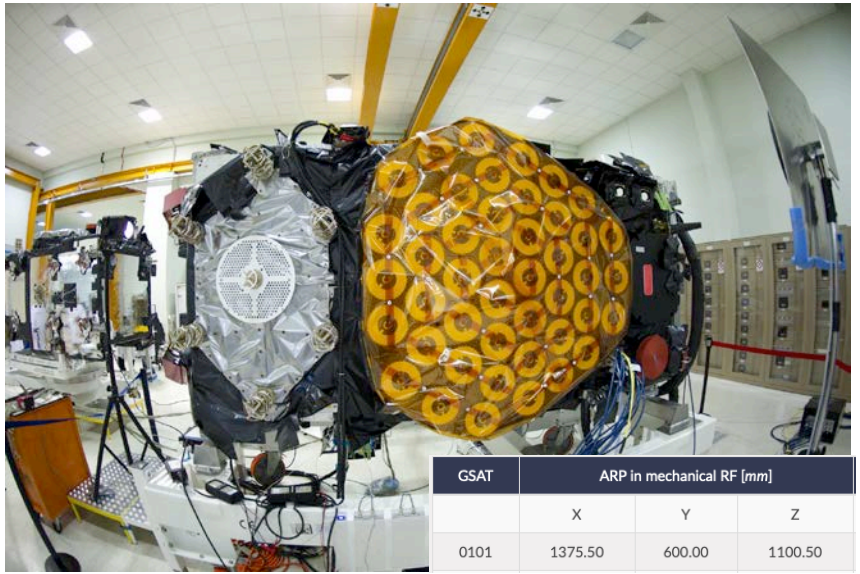


Metadata content: Antenna Phase Center

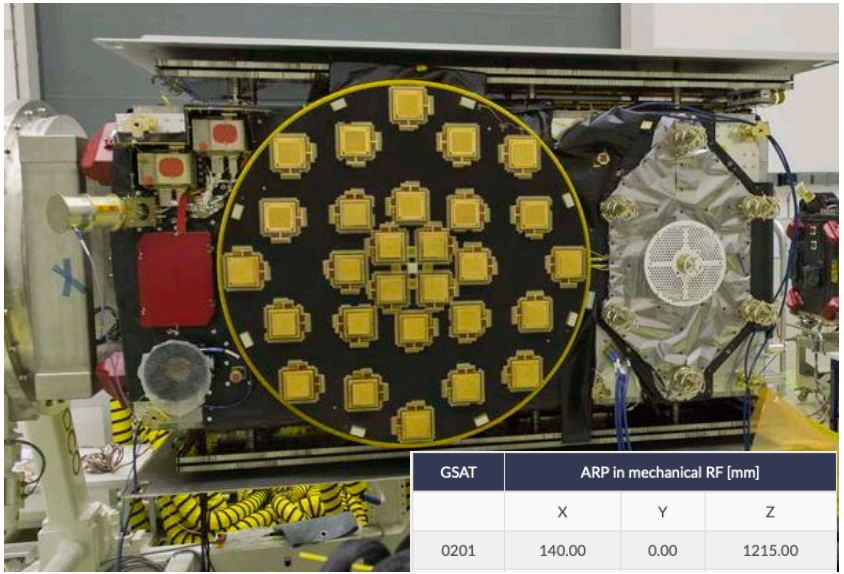


Metadata content: Antenna Phase Center

- Antenna reference point fix in body frame
- Physical point on the satellite [mm]



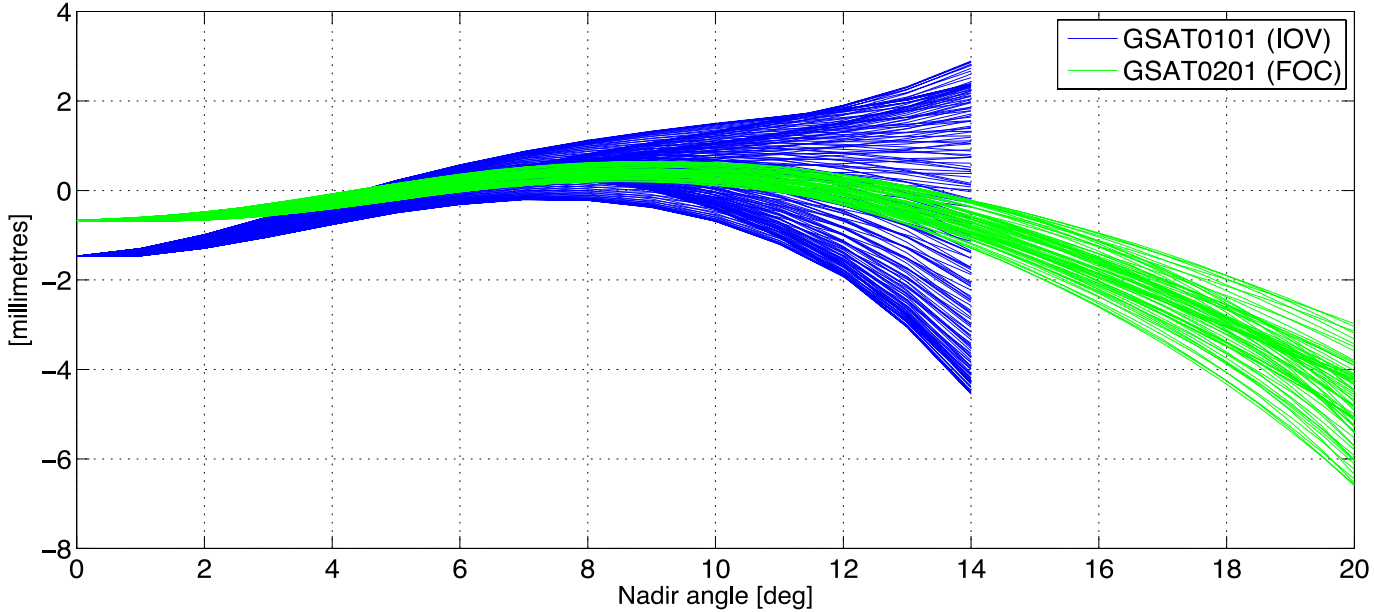
GSAT	ARP in mechanical RF [mm]		
	X	Y	Z
0101	1375.50	600.00	1100.50



GSAT	ARP in mechanical RF [mm]		
	X	Y	Z
0201	140.00	0.00	1215.00

Metadata content: Antenna Phase Center

- Antenna calibrated in Anechoic chamber
- Azimuthal [0°,360°] and Zenith values from 0-14° (GSAT01) and -20° (GSAT02)
- All 5 single frequencies (e.g. E1 signal).



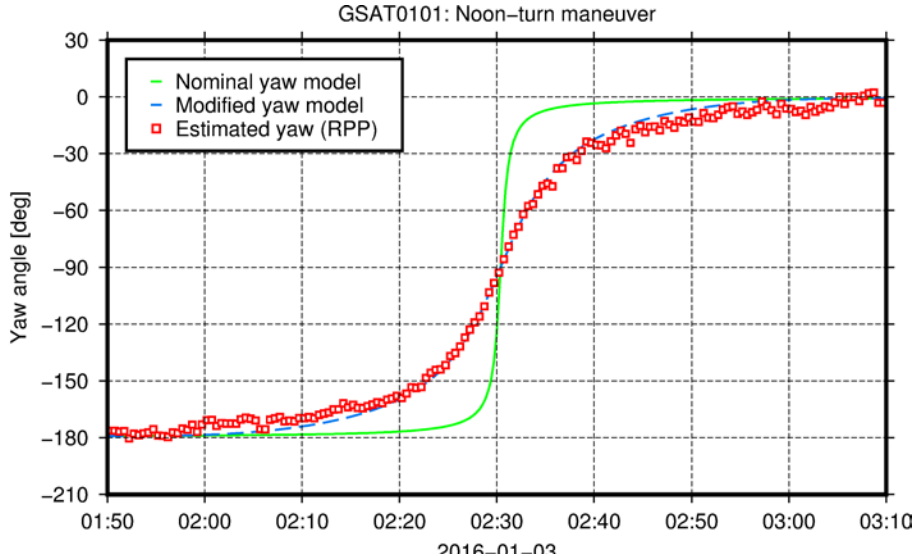
Metadata content: Attitude

Attitude

- Nominal law

$$\psi_r = atan2\left(\frac{-S_Y}{\sqrt{1-S_Z^2}}, \frac{-S_X}{\sqrt{1-S_Z^2}}\right)$$

- Modified law at low beta angles to keep the rate low for reaction wheels



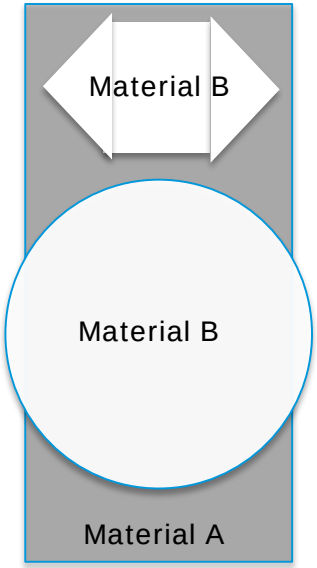
[1] *Source: F.Dilssner, Galileo IOV Spacecraft Metadata and Its Impact on Precise Orbit Determination, EGU2017*

Metadata content: Geometry

- Satellite Dimensions
- Two main materials per area (e.g. +Z face)

Reality

Box-Wing



6.2 FOC Satellites

Dimensions of the Box with respect to the mechanical RF	Surface areas of the Box
$\Delta X = 2.530m$	$\pm X - panel = 1.320m^2$
$\Delta Y = 1.200m$	$\pm Y - panel = 2.783m^2$
$\Delta Z = 1.100m$	$\pm Z - panel = 3.036m^2$

Material	Area $[m^2]$	$\alpha[-]$	$\varrho[-]$	$\delta[-]$
A	1.053	0.93	0.00	0.07
B	1.969	0.57	0.22	0.21

Metadata content: Differential code bias

Measured on ground by manufacturer

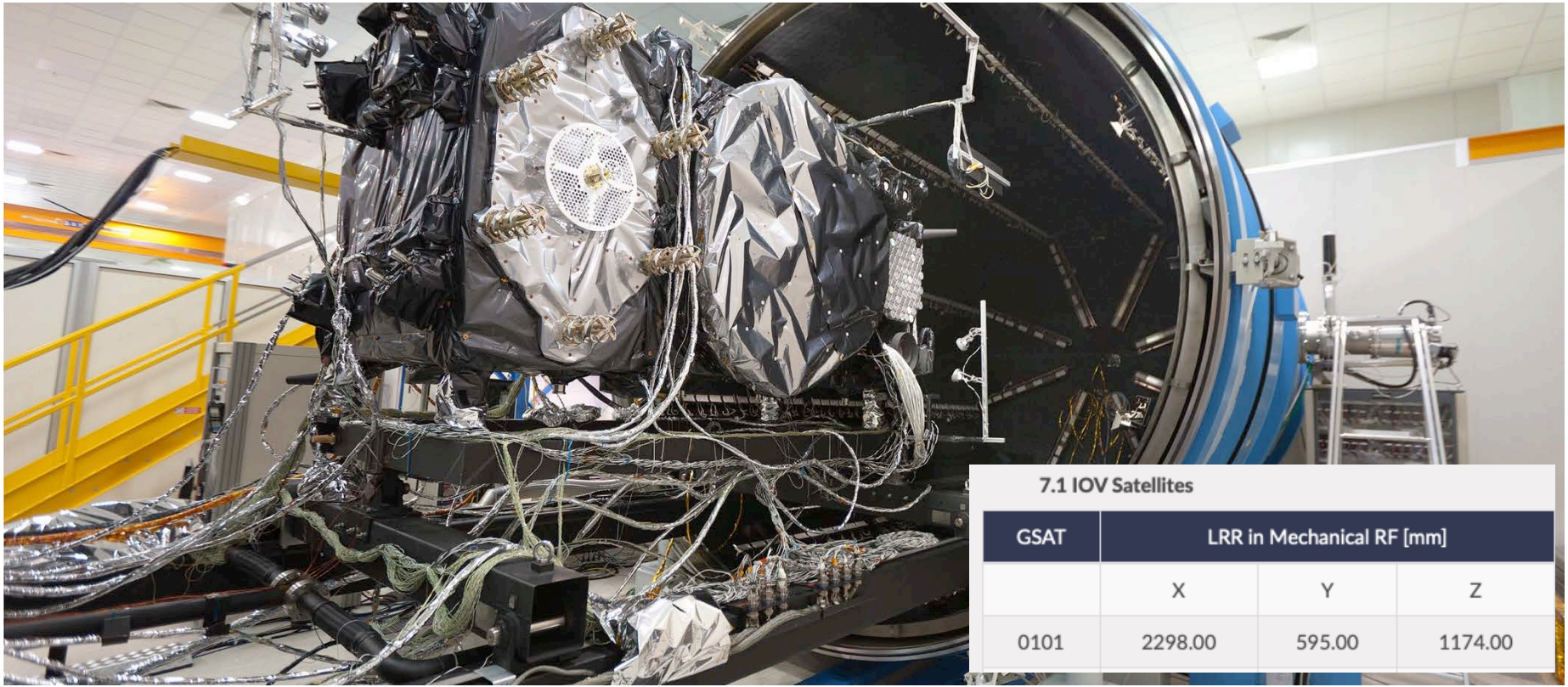
- Calibration performed in ambient up to Antenna input
- Sensitivity to temperature measured on thermal chamber
- IOV provided as tables for each central frequency

8.1 Measured Satellite Group Delay

The Galileo IOV satellite group delays have been measured on-ground by the spacecraft manufacturer for all three signal bands (E1, E5, and E6) and both on-board subsystems ("primary" and "redundant"). The results are listed in the table below.

GSAT	Primary *[ns]*			Redundant *[ns]*		
	E1	E5	E6	E1	E5	E6
0101	1214.8	1205.1	1208.9	1215.2	1204.9	1206.7
0102	1218.9	1212.0	1211.2	1218.9	1212.5	1211.7
0103	3149.3	3146.9	3149.8	3150.3	3149.3	3150.1
0104	3150.1	3148.1	3148.3	3151.9	3150.7	3149.8

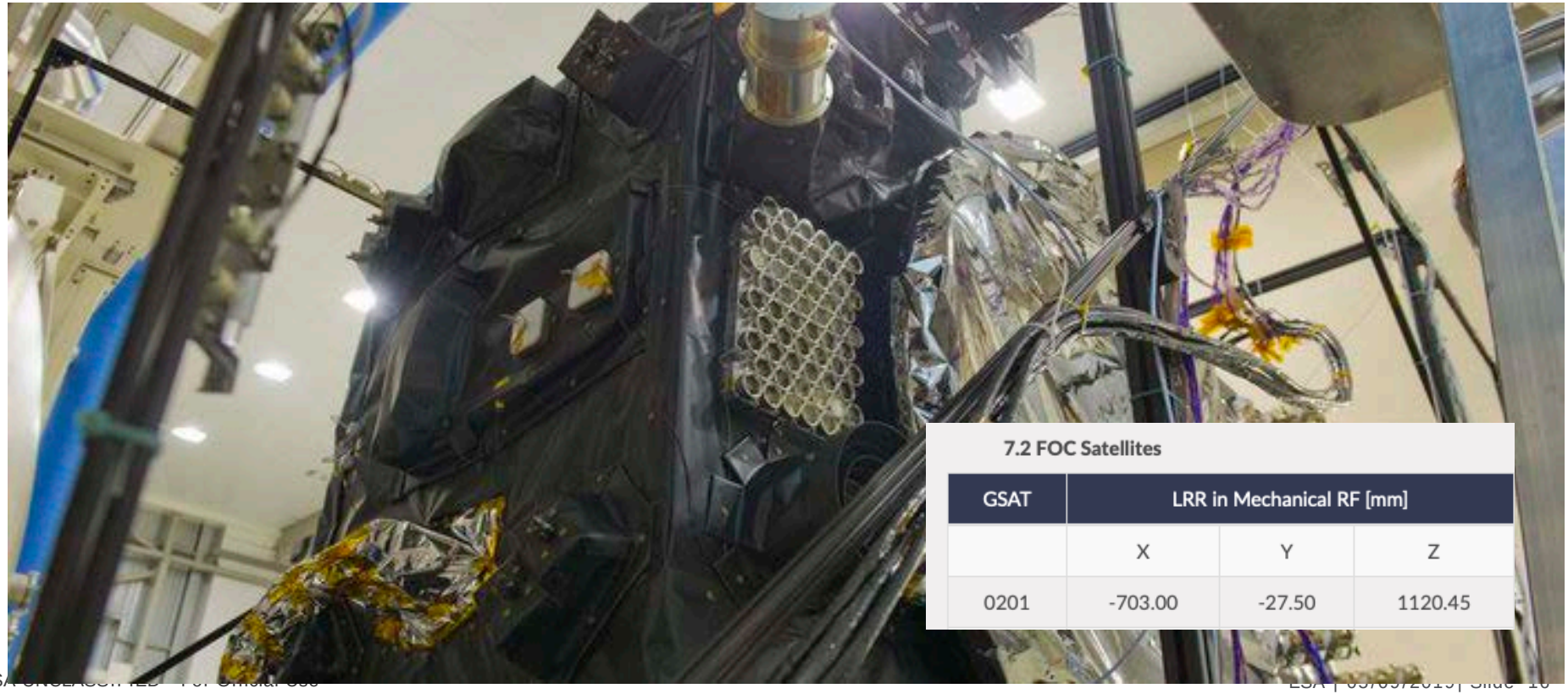
Metadata content: Laser reflector (IOV)



7.1 IOV Satellites

GSAT	LRR in Mechanical RF [mm]		
	X	Y	Z
0101	2298.00	595.00	1174.00

Metadata content: Laser reflector (FOC)



7.2 FOC Satellites

GSAT	LRR in Mechanical RF [mm]		
	X	Y	Z
0201	-703.00	-27.50	1120.45

Metadata status: time-line

Satellite Metadata release

- 2011-Oct release of CoM and LRR positions
- 2016-Dec release of IOV (GSAT101-104)
- 2017-Oct release of FOC (GSAT201-214) values for NAVANT, Geometry, Delays, attitude
- 2019-Mar update of FOC (GSAT215-222) values for NAVANT
- 2019-Q4 release completed with FOC Group Delays in new SINEX bias

Scientific community usage

- CoM and LRR values used nominally for POD
- Antenna (ANTEX) adopted in IGS and used in REPRO activities.
- Attitude implemented in POD SW
- Geometry properties used for Box-wing models
- Differential Code Bias has a limited use (but released only for IOV satellites).

Metadata possible improvements

subarea	Information	Format
Frame	Definition of body-fixed coordinate system (X,Y,Z) and view-cone angles (theta, phi)	#N/A
CoM	mass and CoM evolution w.r.t. origin of mechanical reference frame	SINEX METADATA?
Geometry	~~Simplified~~ **Detailed** face model with solar reflectivity, absorption and emission coefficients based on configuration drawings for surfaces.	
	Mean radiation emissions from NAVANT and radiators	
Laser	Location of laser retroreflectors **cubes** w.r.t. the mechanical reference frame	
Antenna	Nominal CoP for each signal (E1, E5a, E5b, E5AltBOC, E6, ...) w.r.t. origin of the mechanical reference frame PCV for each signal (E1, E5a, E5b, E5AltBOC, E6, ...) as function of the view-cone angles (theta, phi), with respect tthe CoP	ANTEX
	Code (group) delays	
Attitude	Nominal spacecraft attitude model, antenna pointing and solar array rotation Description of the satellite orientation during eclipses and "noon" rotations	equations
HW Delays	Differential instrumental delays for each signal (E1, E5a, E5b, E5AltBOC, E6, ...) and component (pilot,data)	SINEX BIAS

Metadata future updates: Group delays

- Release in SINEX BIAS format instead of tables
- Values per date
- FOC Values by signal components (C1A,C1B,...)

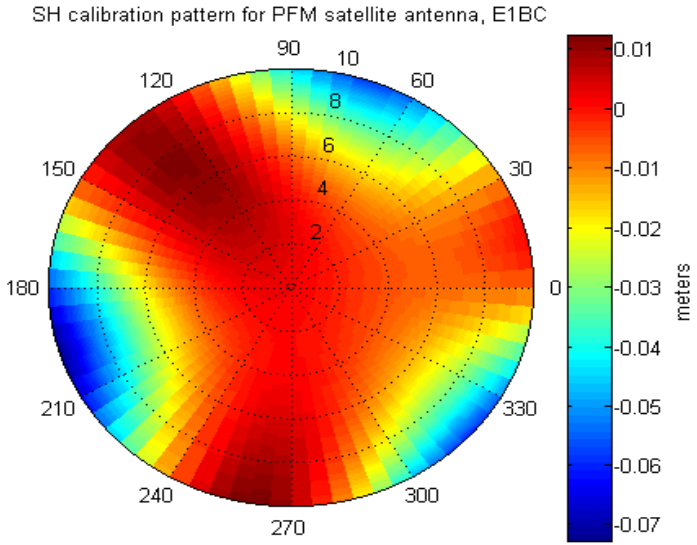
```
%=BIA 1.00 GAL 18:058:00000 GAL 10:001:00000 10:001:00000 R        0
*-------------------------------------------------------------------------------
* Solution INdependent EXchange Format (SINEX)
*-------------------------------------------------------------------------------
+BIAS/SOLUTION
*BIAS SVN_ PRN STATION__ OBS1 OBS2 BIAS_START___ BIAS_END_____ UNIT __ESTIMATED_VALUE___ _STD_DEV__
 OSB  E101 E11           C1   C5   2010:140:00000               ns                 9.7000      0.0000
 OSB  E101 E11           C1   C6   2010:140:00000               ns                 5.9000      0.0000
 OSB  E201 E18           C1C  C1B  2015:009:28575               ns                -0.3998      0.0000
 OSB  E201 E18           C1C  C5I  2015:009:28575               ns               -15.5244      0.0000
 OSB  E201 E18           C1C  C5Q  2015:009:28575               ns               -15.6547      0.0000
 OSB  E201 E18           C1C  C7I  2015:009:28575               ns               -15.5364      0.0000
 OSB  E201 E18           C1C  C7Q  2015:009:28575               ns               -15.3040      0.0000
 OSB  E201 E18           C1C  C6B  2015:009:28575               ns                -5.9228      0.0000
 OSB  E201 E18           C1C  C6C  2015:009:28575               ns                -6.0184      0.0000
```

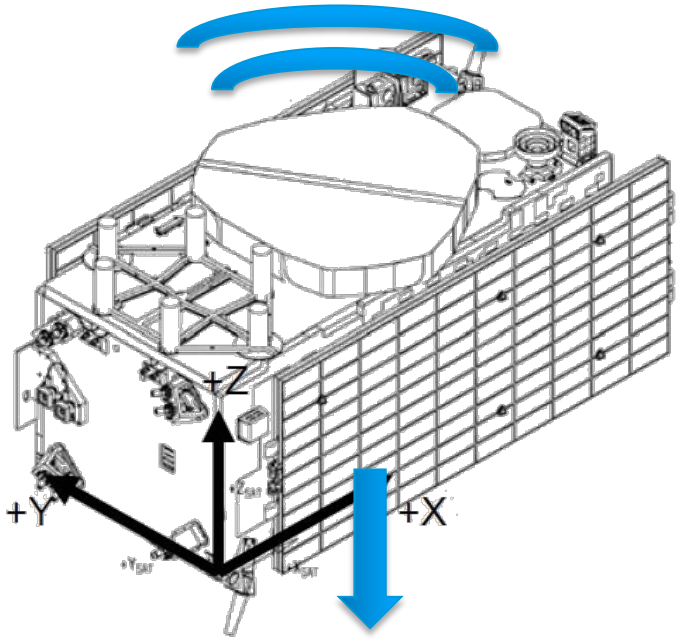
current

FOC update

Metadata future updates: Antenna

- Antenna code (or group) delays from calibrations
- Antenna average power transmitted in Z direction for antenna thrust modeling

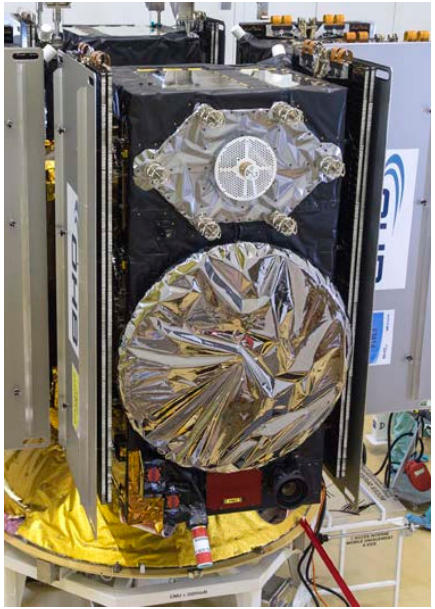




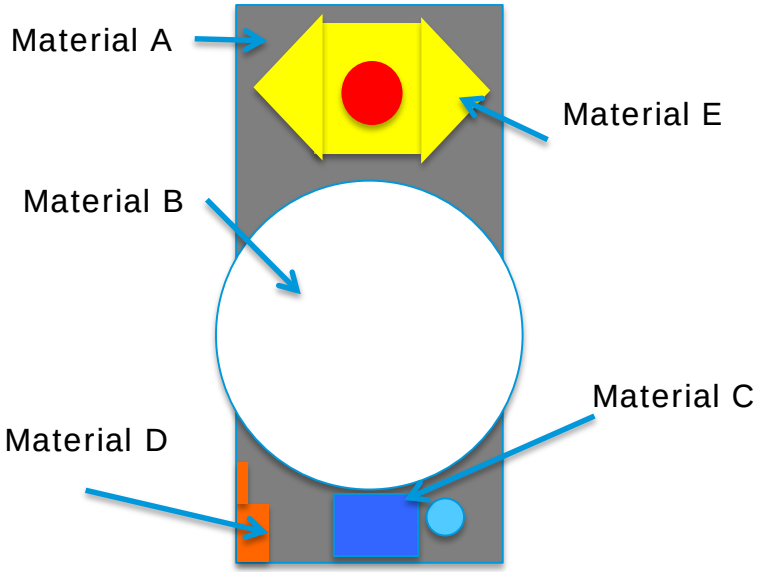
Metadata future updates: materials box

- Infrared band properties
- More than 2 materials for surface (e.g. +Z)

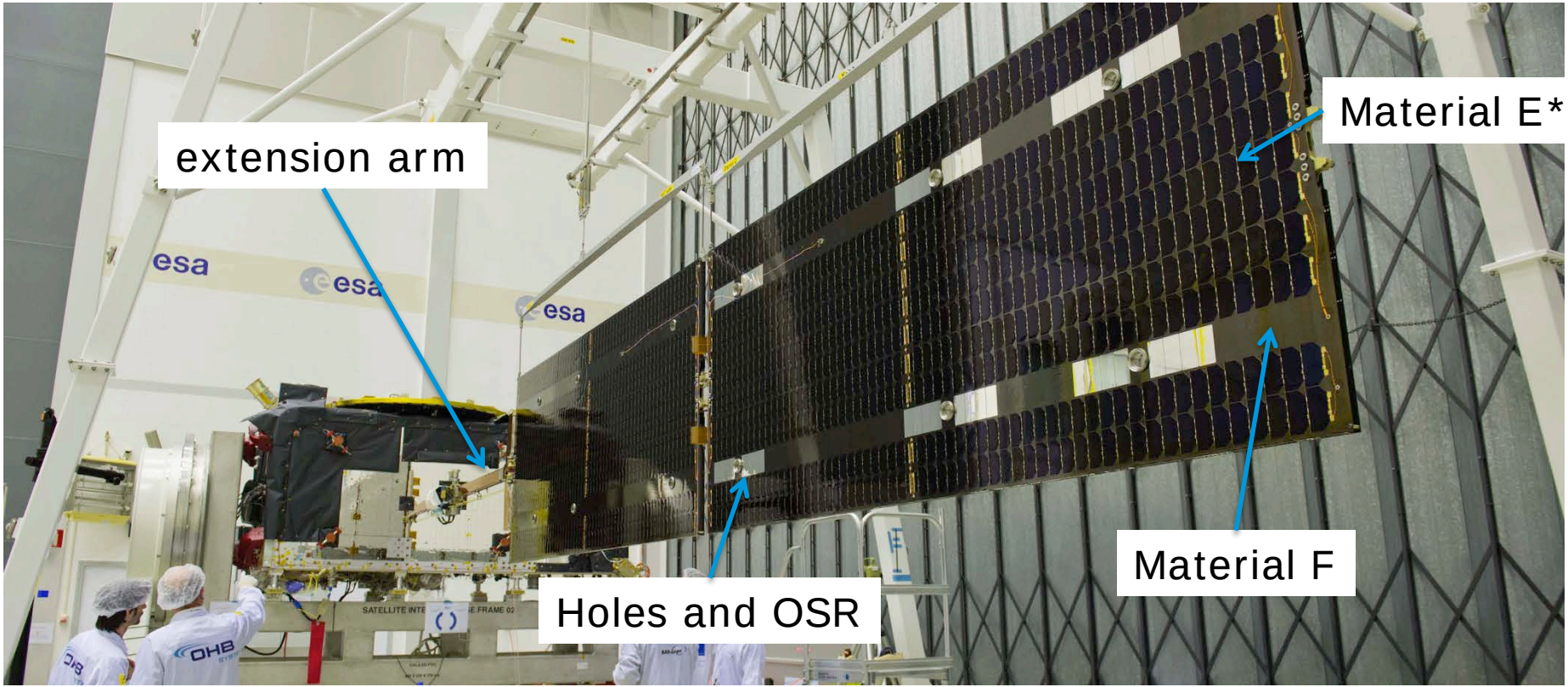
Reality



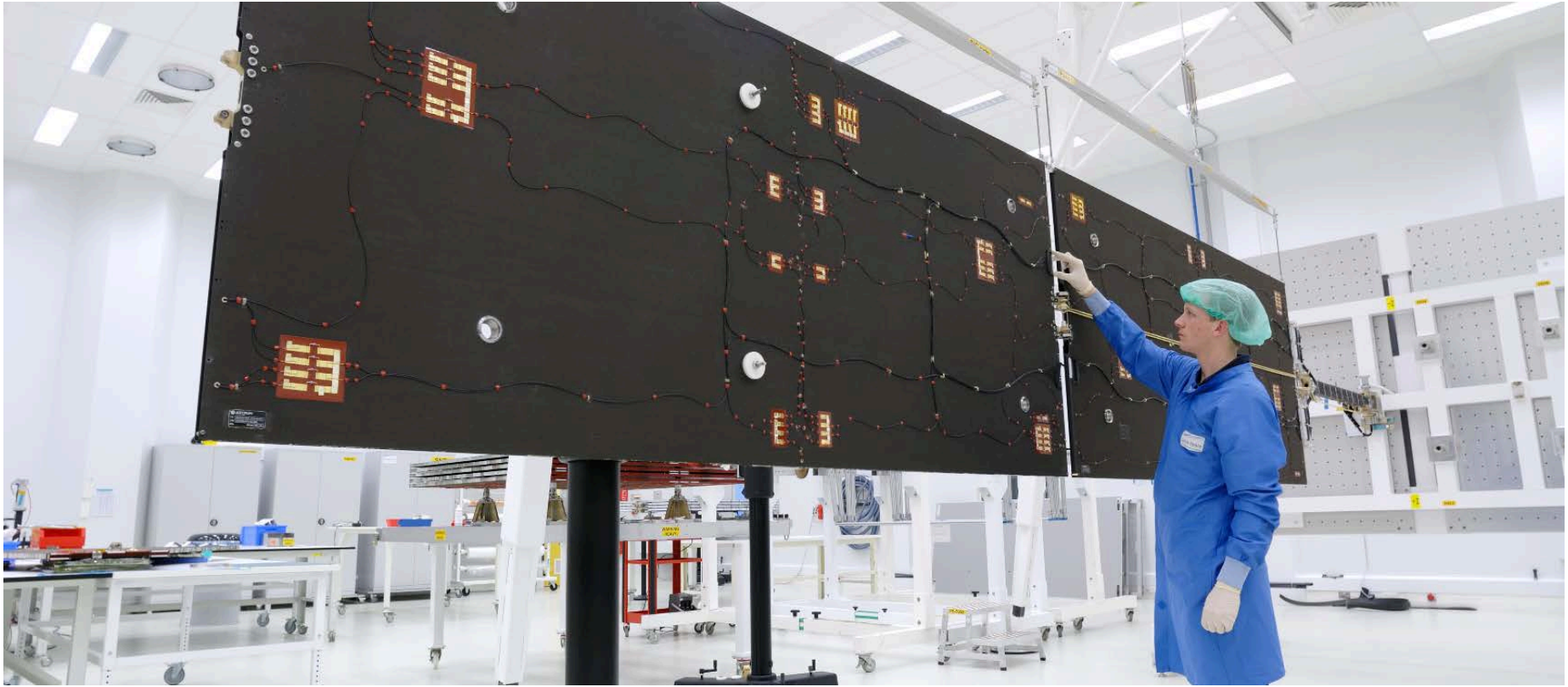
Box-Wing improvements



Metadata future updates: materials SA



Metadata future updates: materials SA rear side

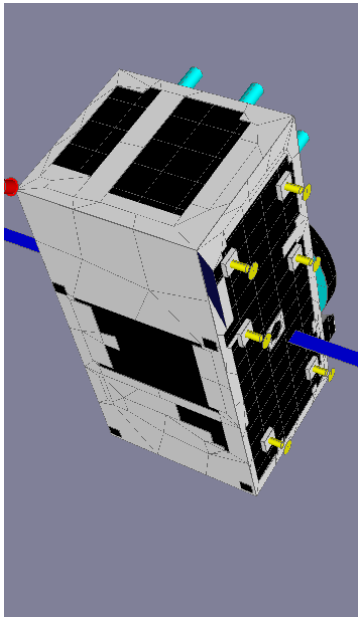


Metadata future updates: radiators emission

Metadata future updates: radiators emission

- -Z, -X, ±Y contain radiators emitting energy absorbed from solar panels
- Radiation active during eclipse
- Mean radiated values could be of interest for SRP box-wing models.

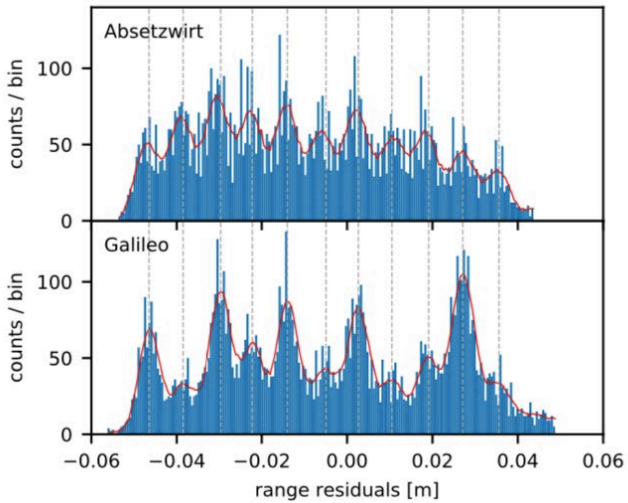
RTMM data (2014)

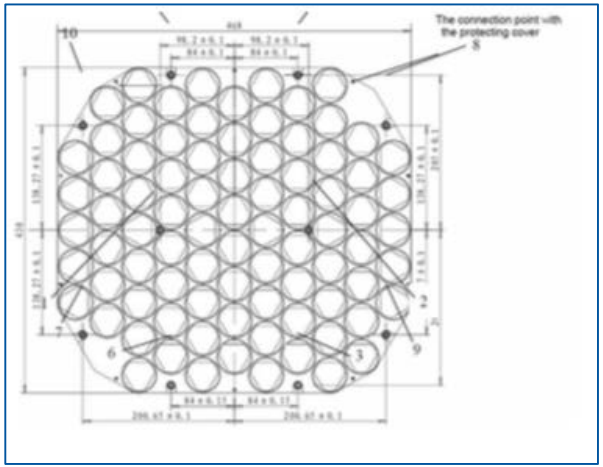


Reality (2017)

Metadata future updates: Laser Reflector geometry

- PCO the Phase Center of the Array
- Knowledge on individual cube phase centers can be beneficial to science users
- Example from Graz SLR station[1]





Source[1] : Attitude determination of Galileo satellites using high-resolution kHz SLR, Michael A. Steindorfer, 2019

Galileo Metadata conclusions

Status

- Data set with the relevant Satellite properties for POD and derivation of Science products.
- Defined in 2011 by the Scientific community through the Galileo Scientific Advisory Committee (GSAC)
- Released through ILRS and GSC web sites

Scientific community usage

- Most of the values adopted by the Scientific community for POD (e.g. Antex)
- Feedback awaited from Scientist on benefits and possible improvements.

Future

- Updates under preparation for IOV/FOC and new FOC satellites under production.
- Feedback and input from scientific community crucial for improvements.