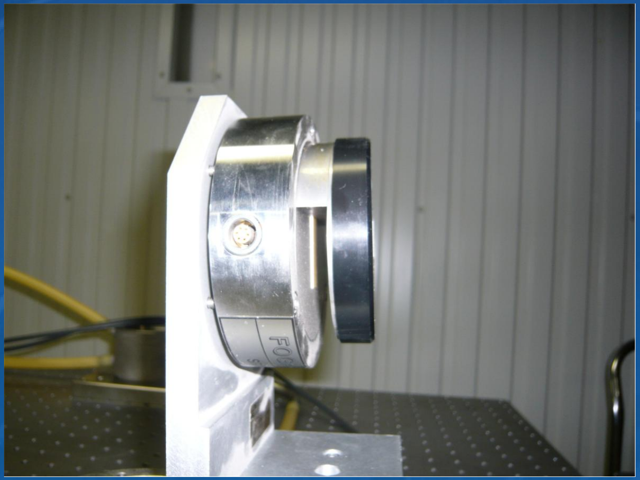
HLS and WPS used at the ESRF

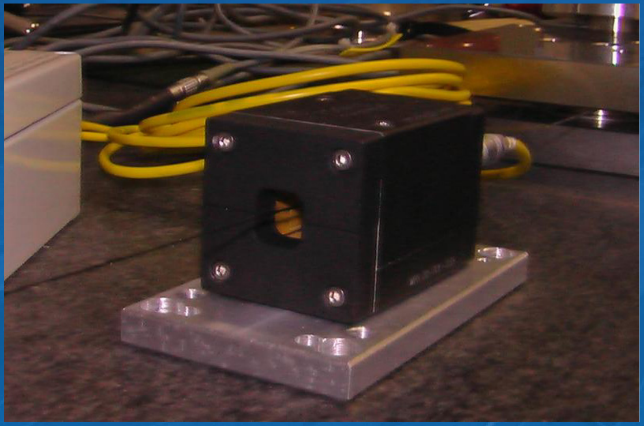
David Martin

- to inventory the existing WPS and HLS sensors (*and what we do with them to establish context*);
- to record the means, methods and conditions of tests on these sensors;
- to define the tests to be performed on these sensors during the inter-comparison;
- to establish a basis for inter-comparison and envisage collaboration with your laboratory on this study.

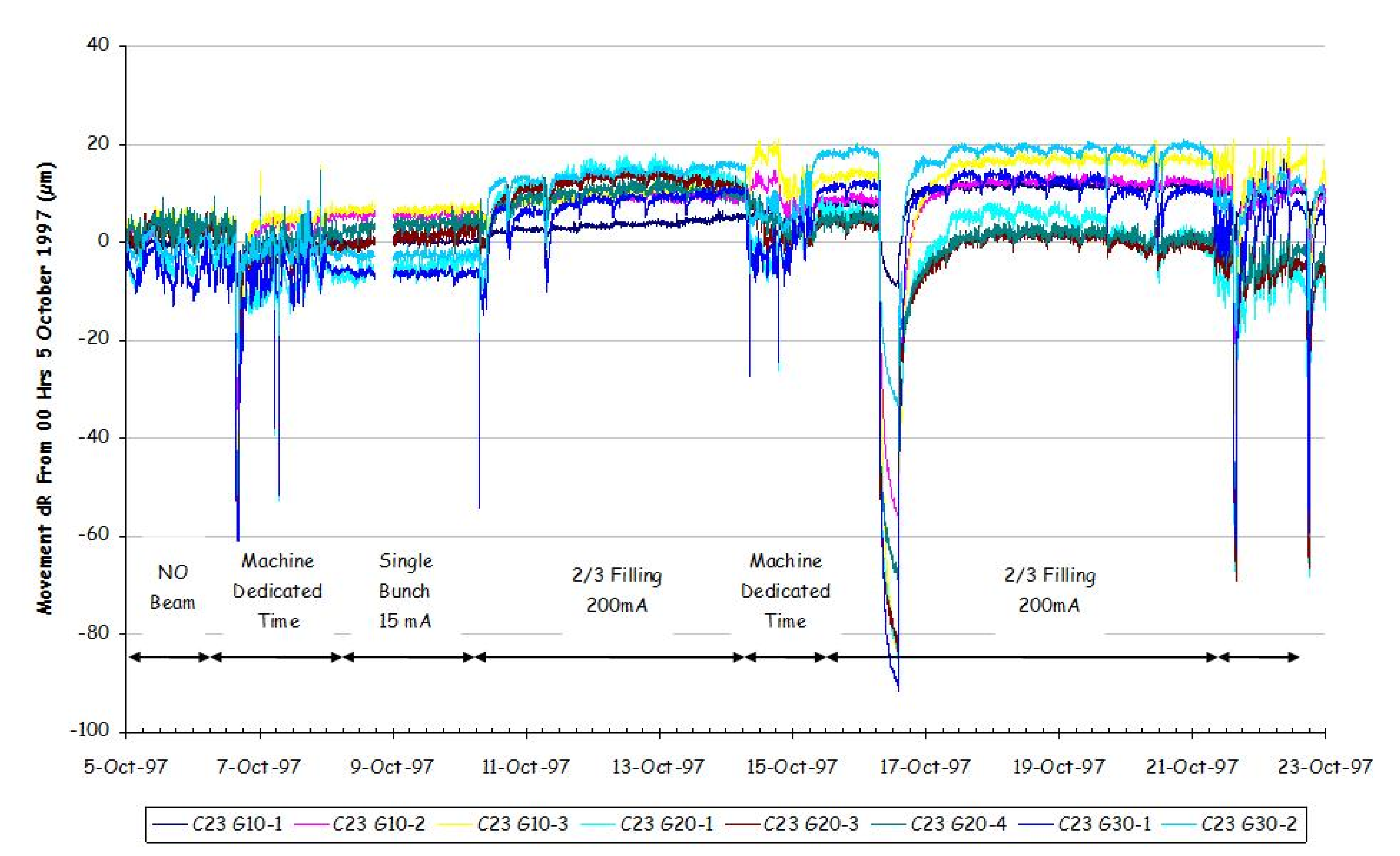
Inventory of existing ESRF WPS sensors

- The ESRF has 18 single axis and 4 bi-axial WPS sensors.
- The single axis system has been used to control planimetric movements of the ESRF SR magnet girders.
- The biaxial system has been used to control the ESRF calibration bench carriage movements.





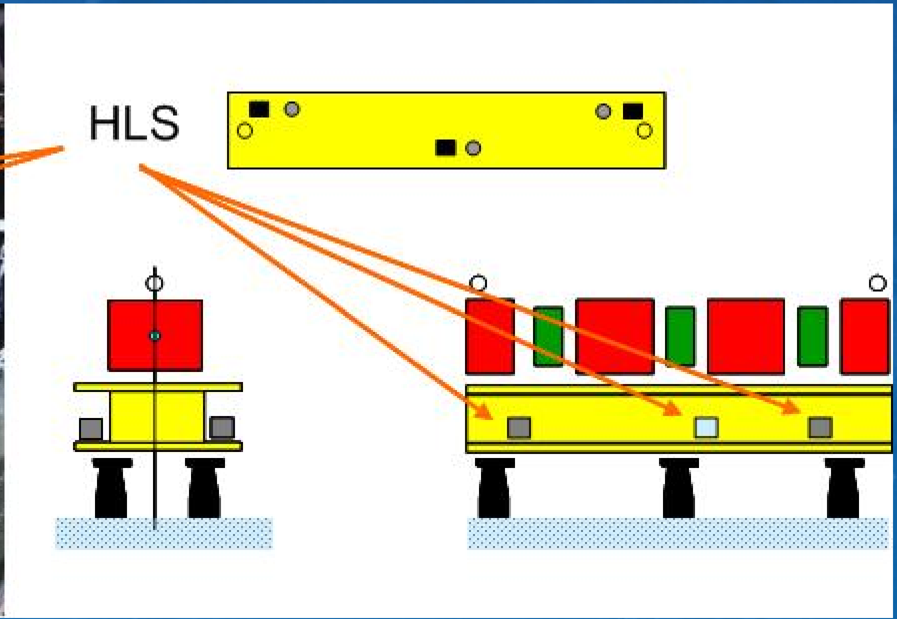
ESRF WPS sensors - SR Girder Movements



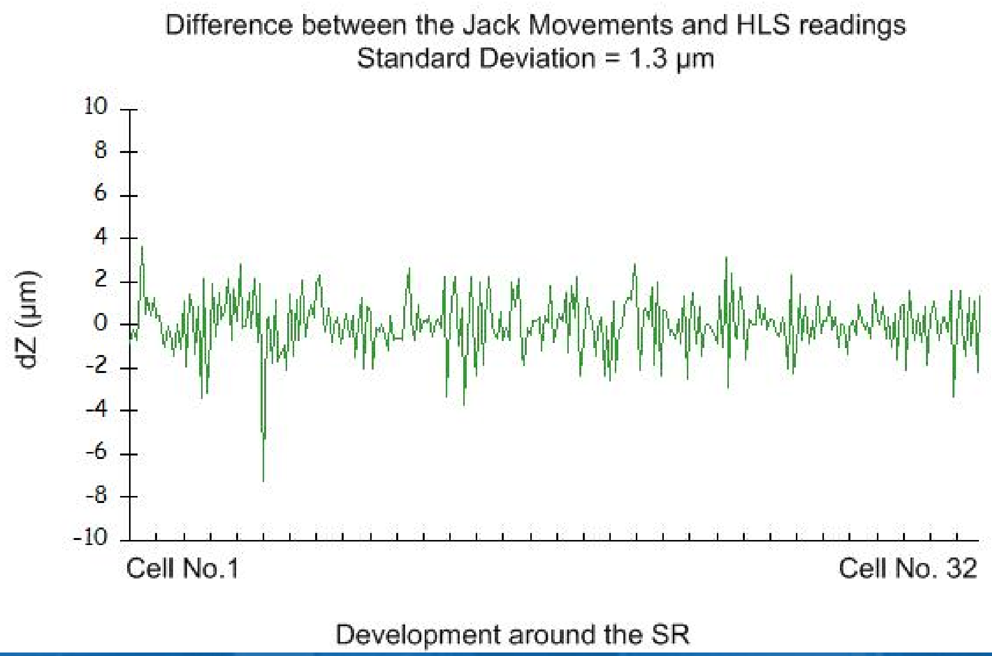
Inventory of existing ESRF HLS sensors

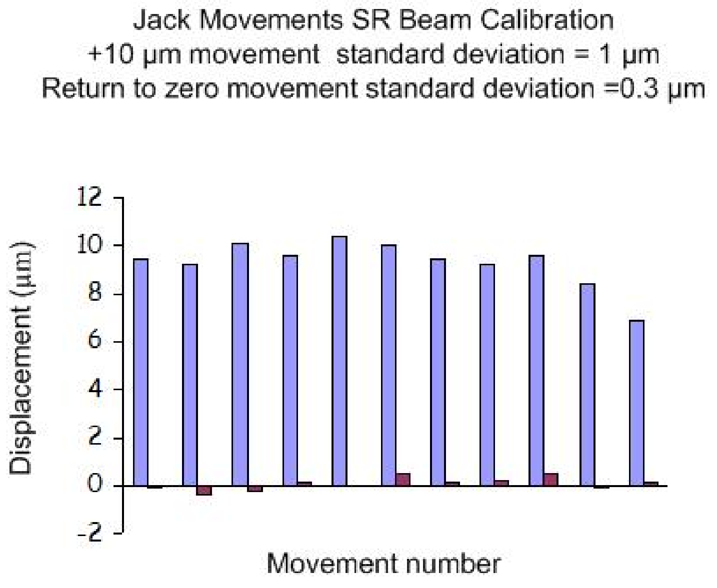
The ESRF has 288 ‘first’ generation HLS sensors installed on the Storage Ring.

This system has been used since 1993 to control the periodic machine vertical realignment.



ESRF HLS sensors – 'first generation' Storage Ring realignment

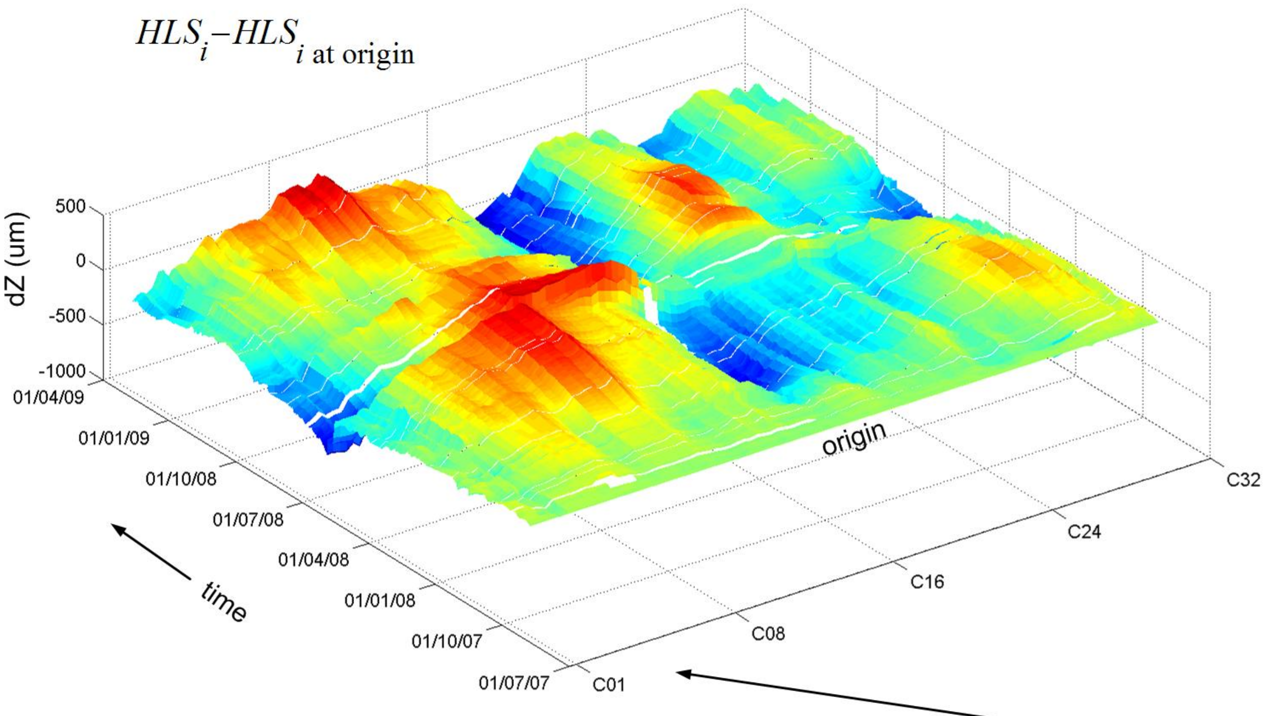


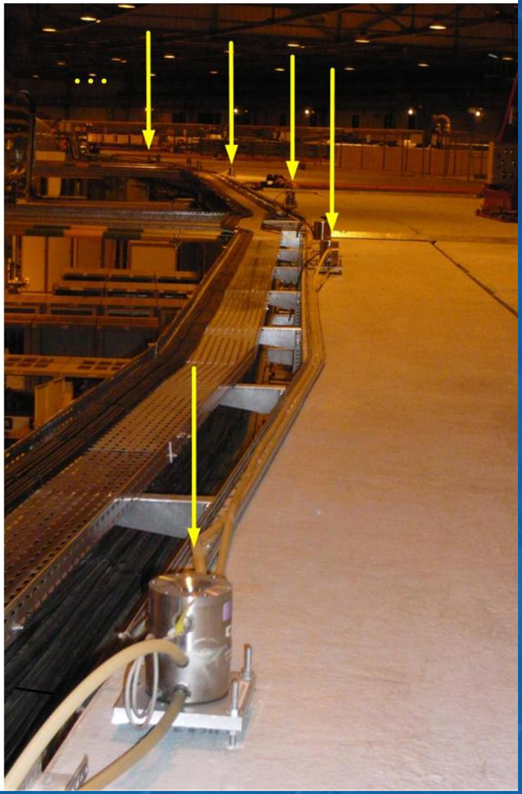


Inventory of existing HLS sensors

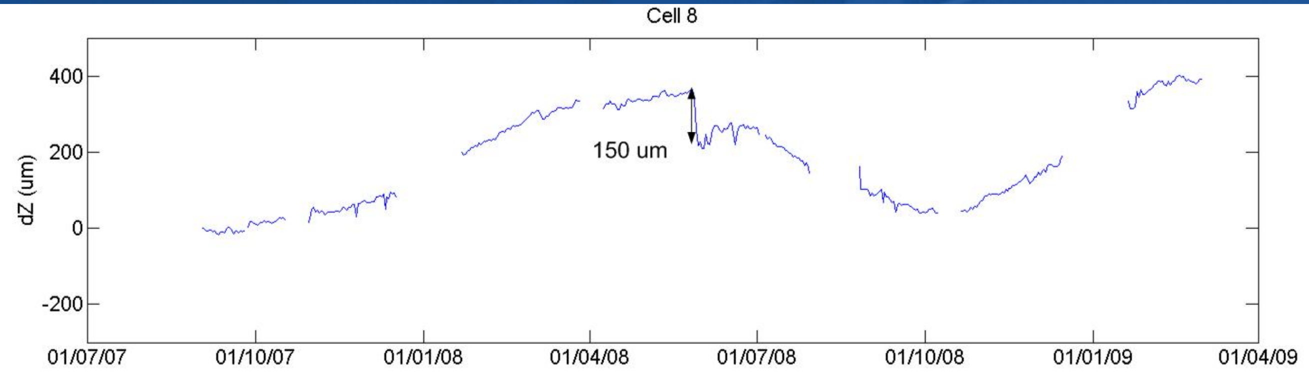
- The ESRF has ~200 'second' generation HLS sensors.
- This system is installed on the ESRF SR tunnel roof and on the beam lines.
- It is used to monitor long term site settlement.

ESRF HLS sensors – 'second generation' site movements

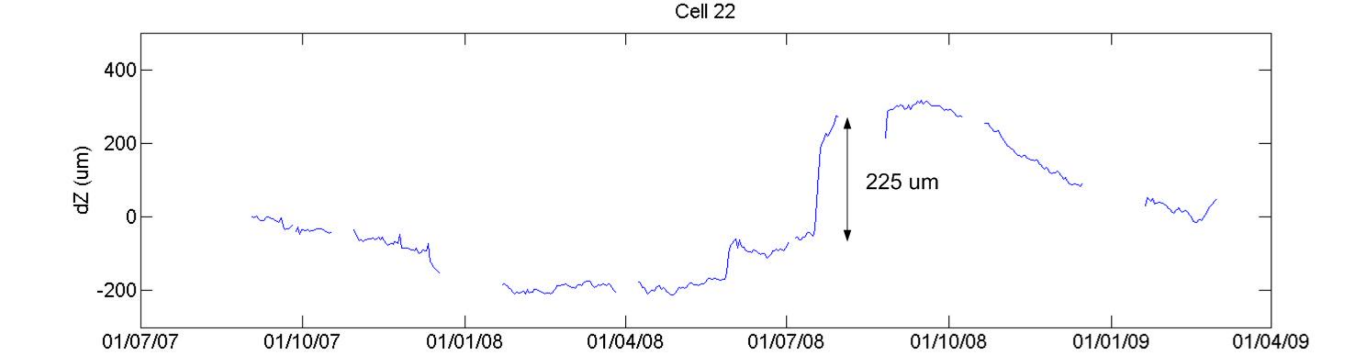




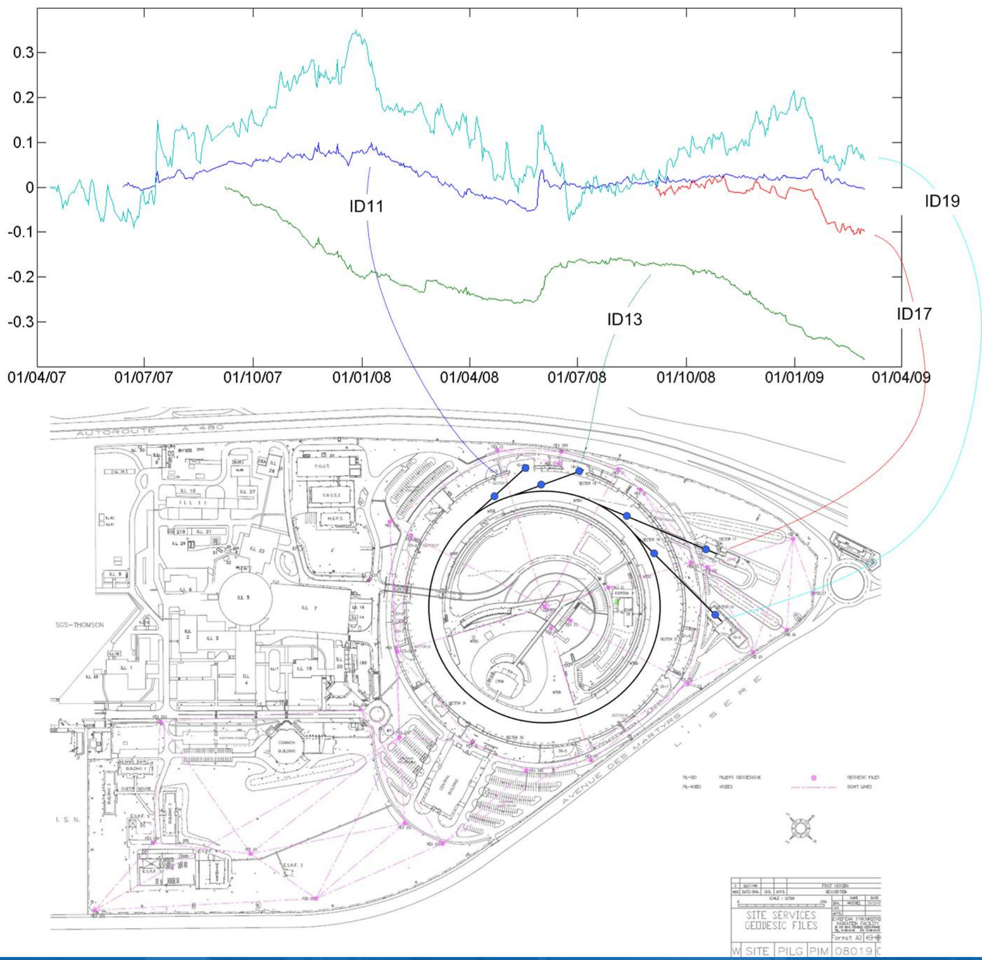
ESRF HLS sensors – ‘second generation’ site movements dam purge

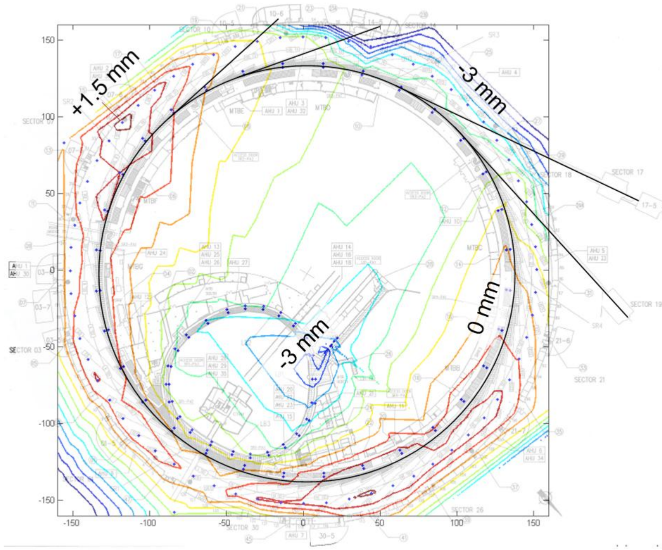


ESRF HLS sensors – ‘second generation’ site movements excavation

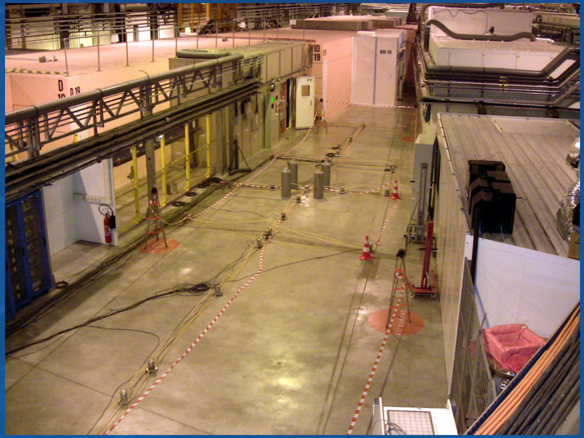


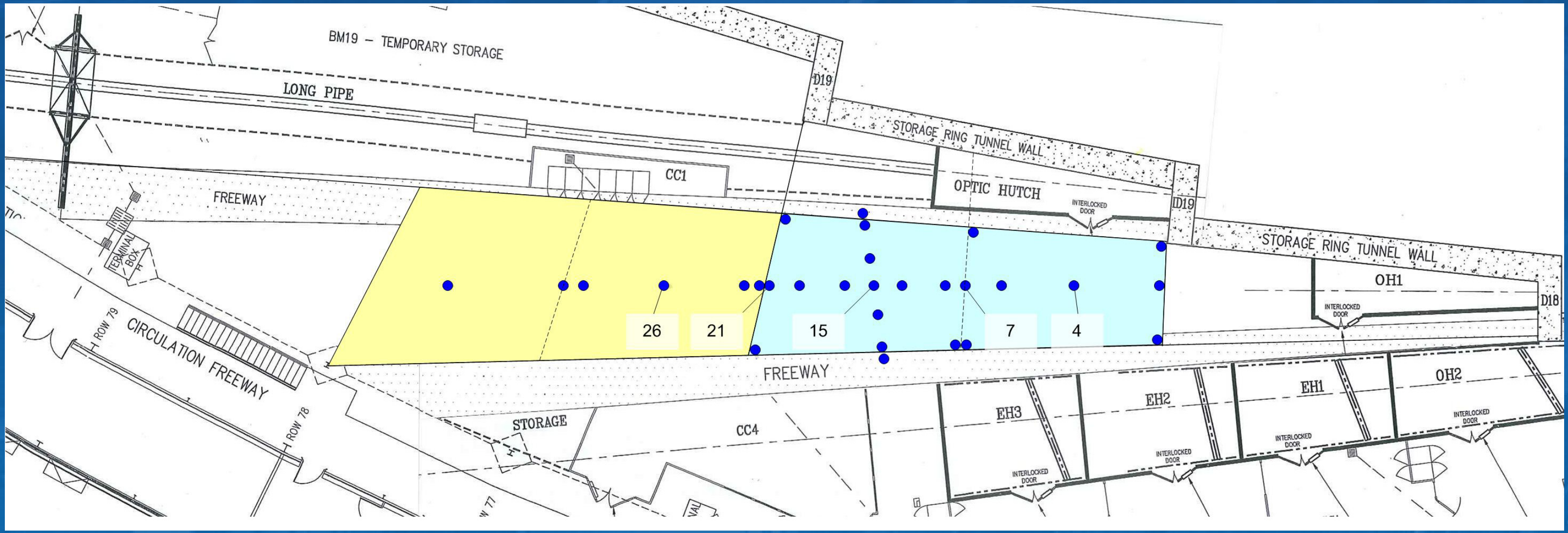
ESRF HLS sensors – 'second generation' long term site movements



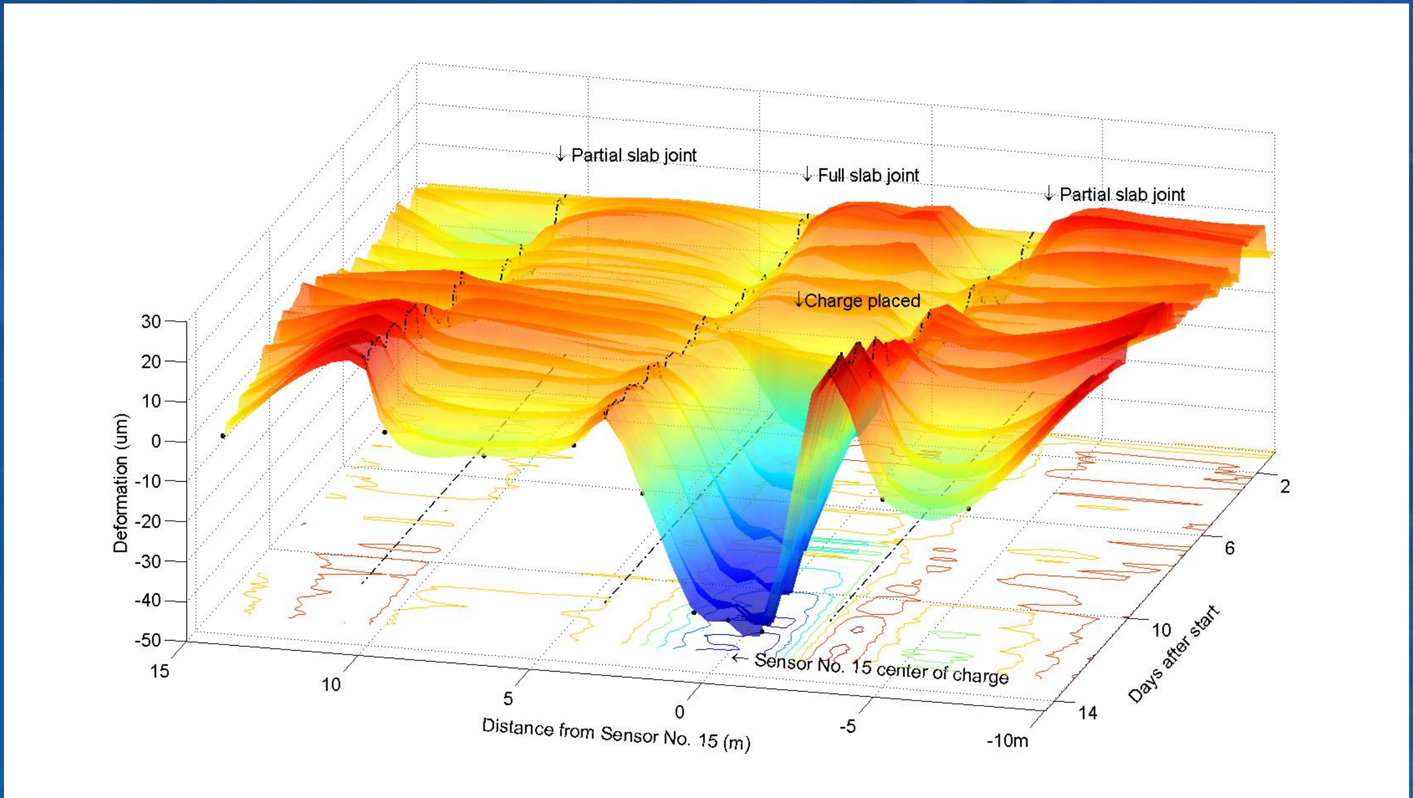


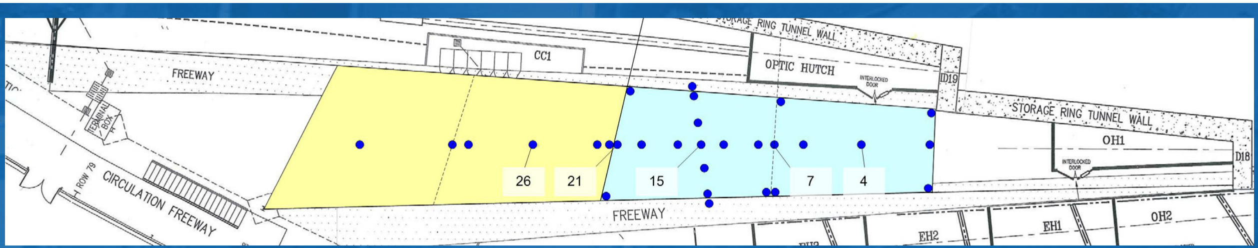
ESRF HLS sensors – 'second generation' BM18 slab study



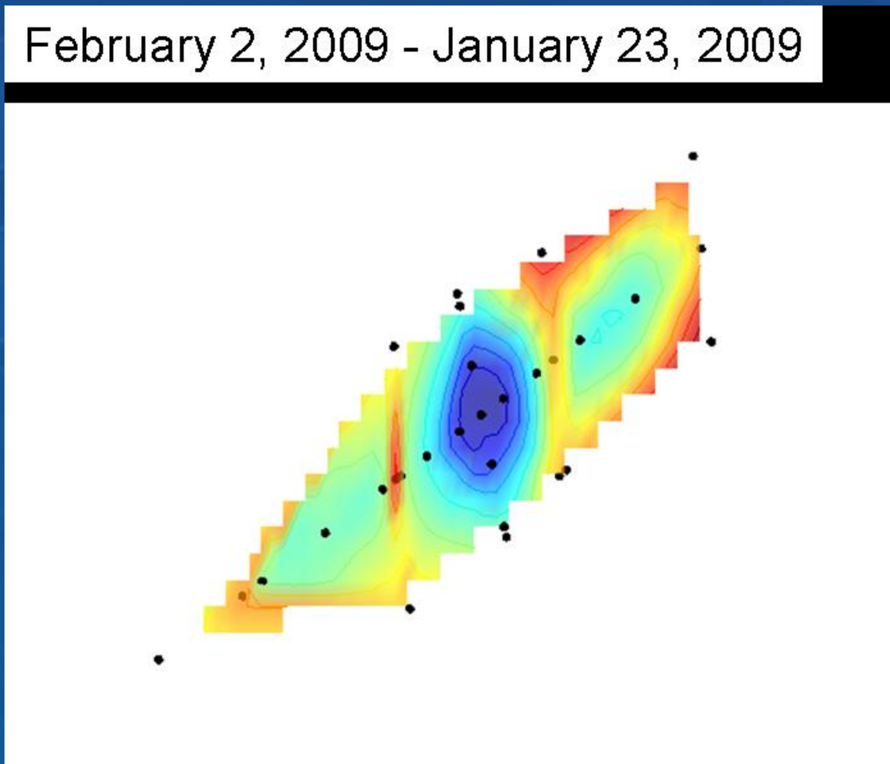


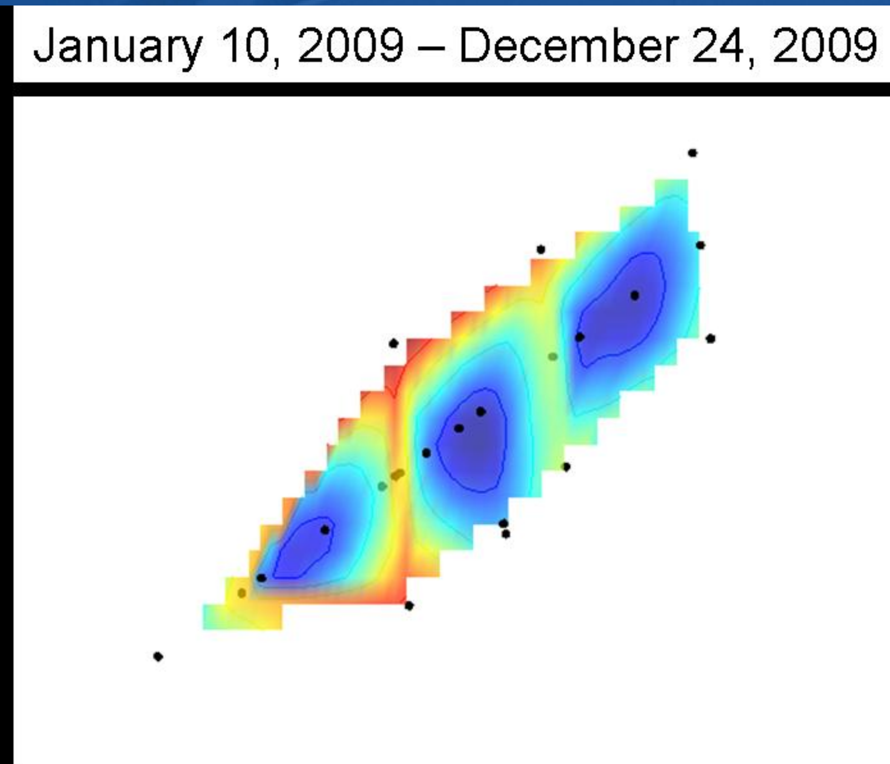
ESRF HLS sensors – 'second generation' BM18 slab study

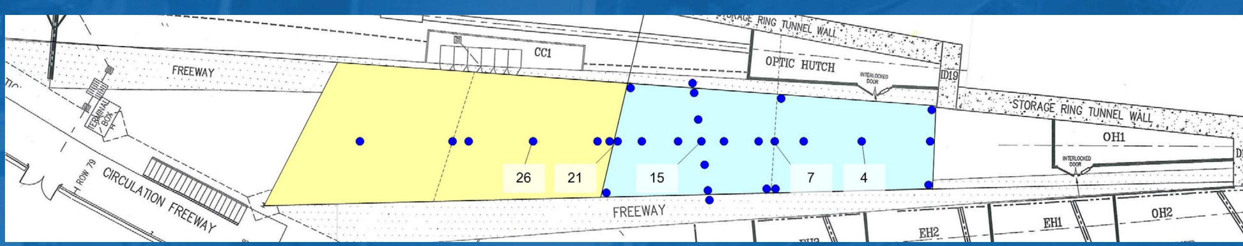




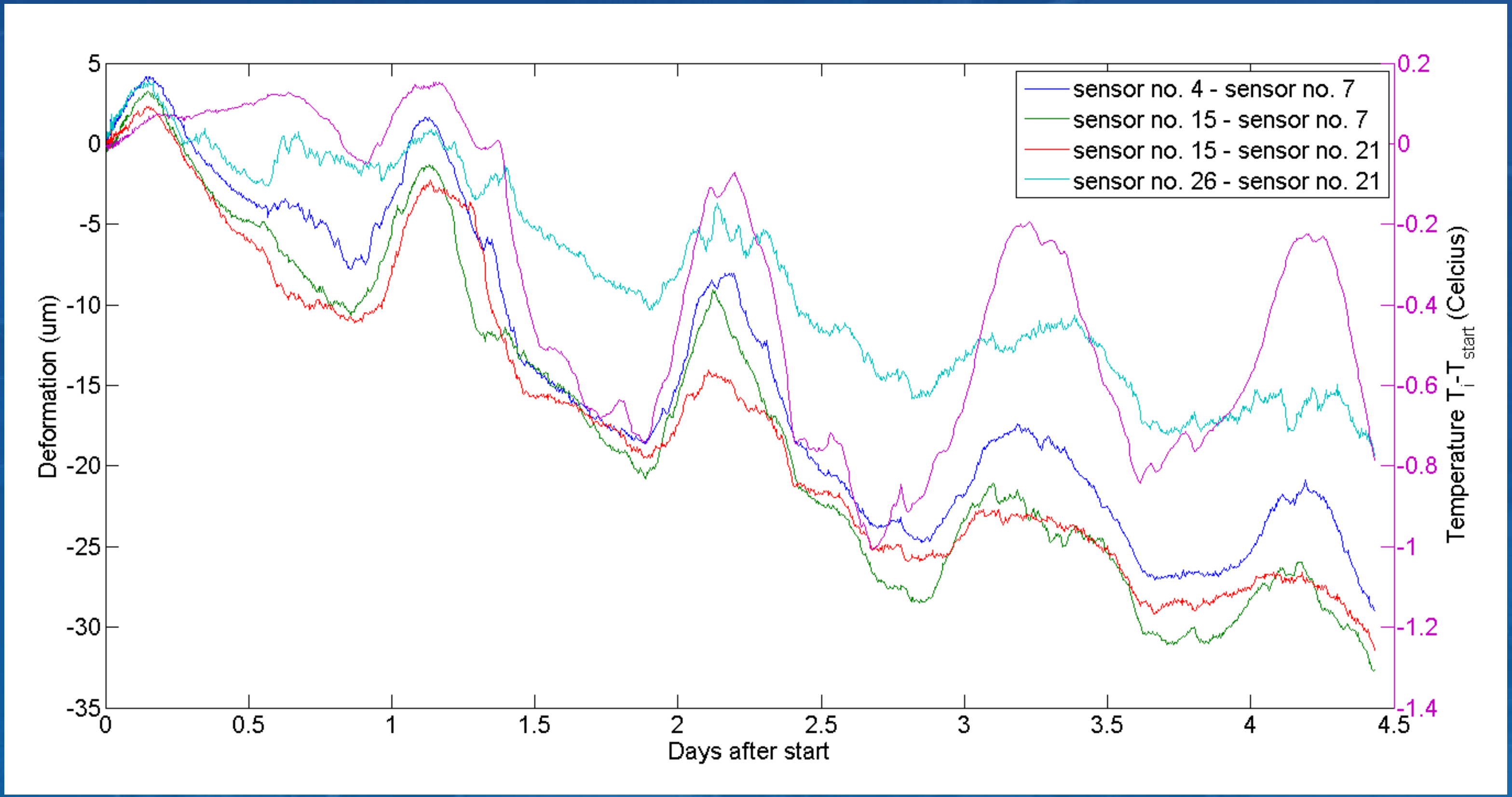
ESRF HLS sensors – ‘second generation’ BM18 slab study

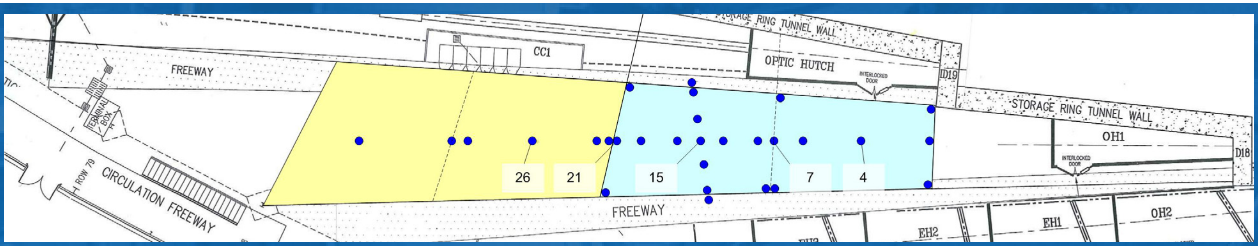




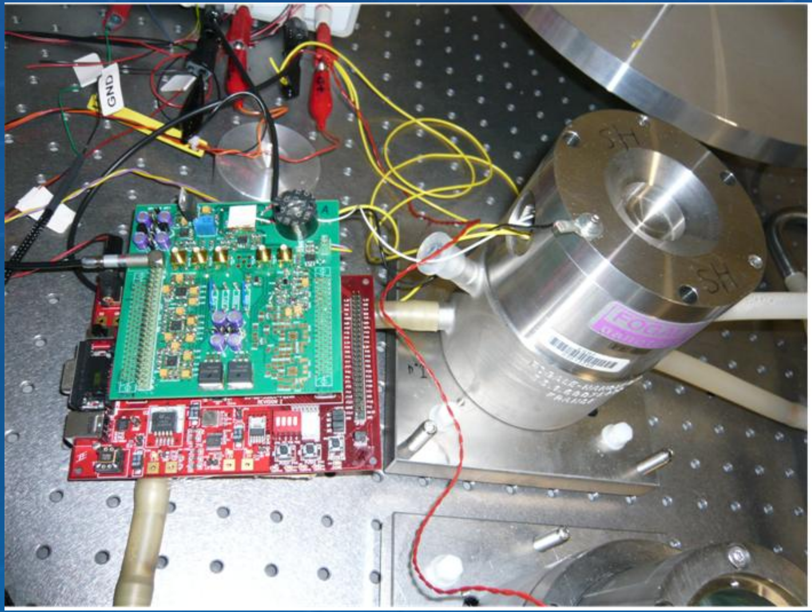


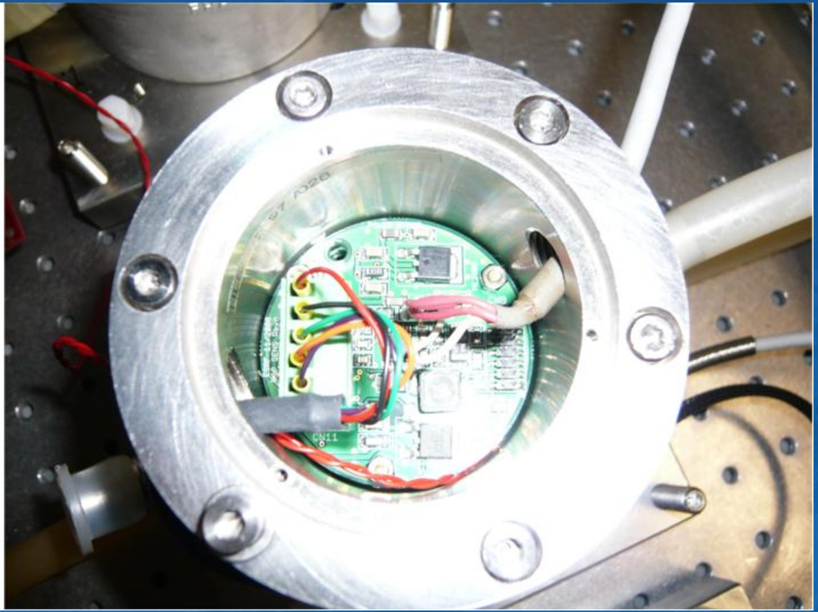
ESRF HLS sensors – 'second generation' BM18 slab study





ESRF HLS sensors – ‘next generation’ digital capacitance electronic





Methods and conditions of tests on these systems - questions

How reliable are the measurements issued from these systems?

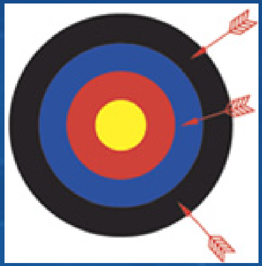
How can we test or calibrate them?

What is their uncertainty?

Are we speaking the same language?

What is our standard?

Methods and conditions of tests on these systems - uncertainty



Low accuracy
Low precision

Low accuracy
High precision

High accuracy
High precision

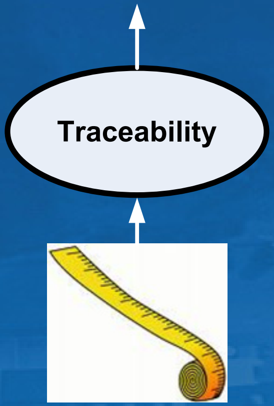
Error and Uncertainty

Error is the difference between the measured value and the true value of a measurement

Uncertainty of measurement is the doubt that exists about the result of any measurement. It is an expression of our confidence in it.

Methods and conditions of tests on these systems - traceability

... NIST F1, the world's best clock...



One of the pillars of instrument calibration and all legal metrology is the notion of traceability.

Traceability is a method of ensuring that a measurement (even with its uncertainties) is an accurate representation of what it is trying to measure.

Methods and conditions of tests on these systems - traceability


BIPM

JCGM 100:2008
GUM 1995 with minor corrections

Evaluation of measurement data — Guide to the expression of uncertainty in measurement

Évaluation des données de mesure — Guide pour l'expression de l'incertitude de mesure

ΜΕΤΡΩ ΧΡΩ

First edition September 2008

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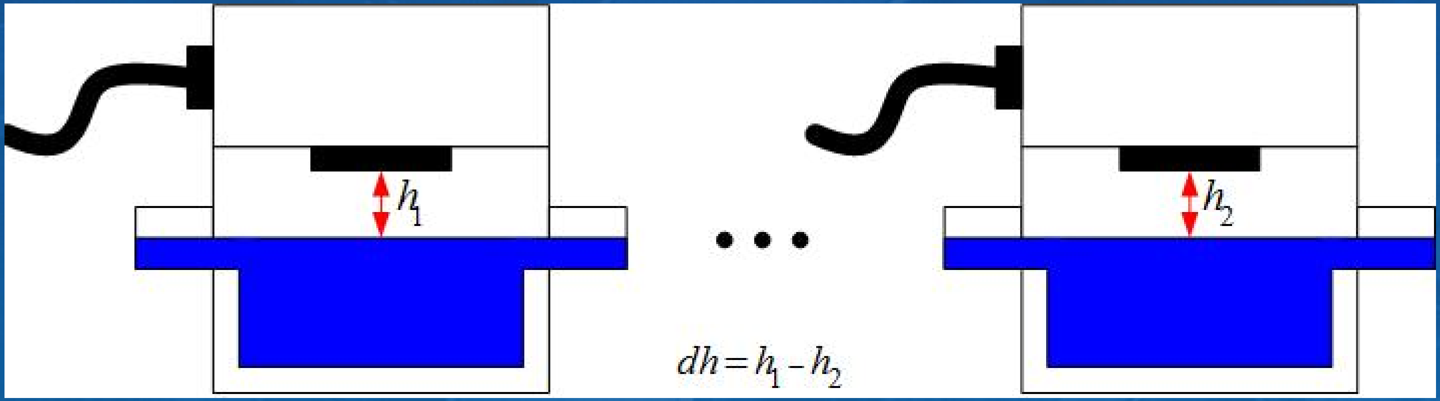
- The commonly accepted way to go about determining uncertainty in the metrology world follows the 'GUM' uncertainty framework.
- This requires a *standard* or *etalon*.
- Uncertainties are divided into two categories: *Type A* and *Type B*.
- Type A : method of evaluation of uncertainty by the statistical analysis of series of observations,
- Type B: method of evaluation of uncertainty by means other than the analysis of series of observations.

Methods and conditions of tests on these systems – HLS measurand

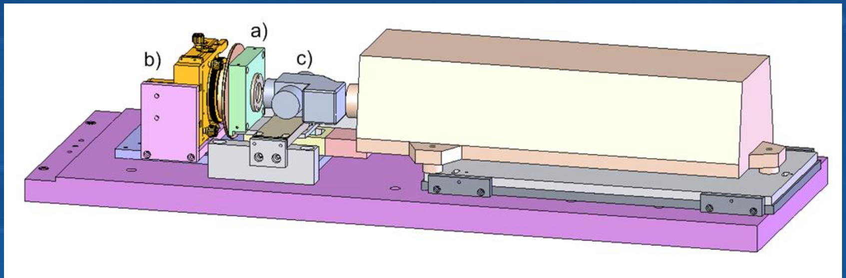
First what are we measuring - what is the measurand†?

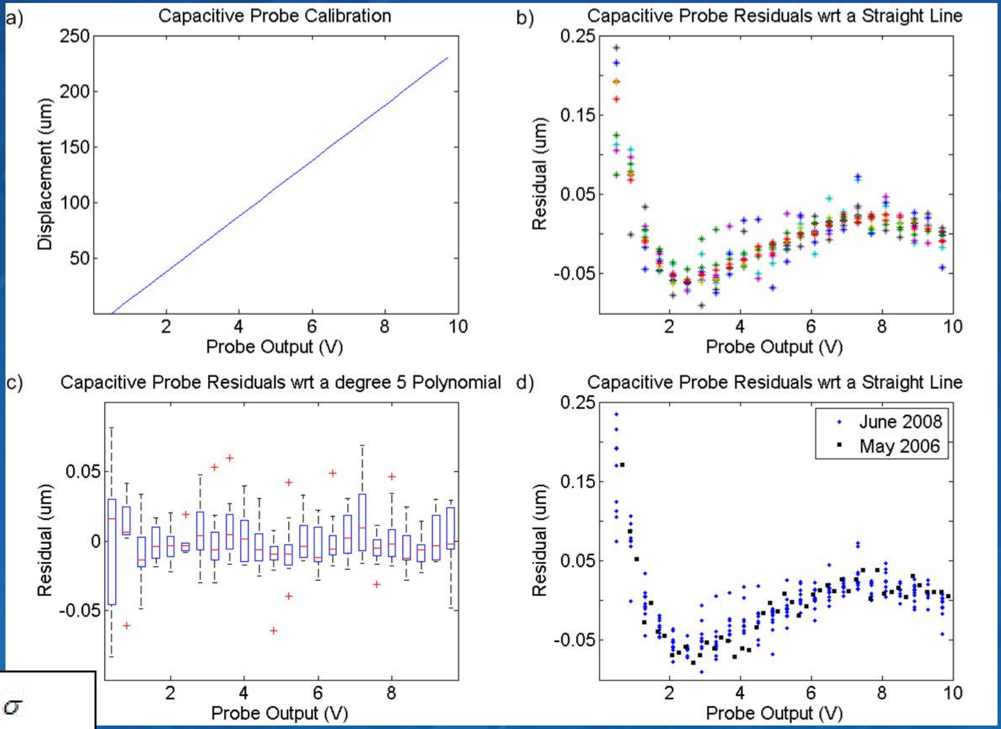
What is the principle of the measurement?



†Measurand: the quantity intended to be measured (VIM)

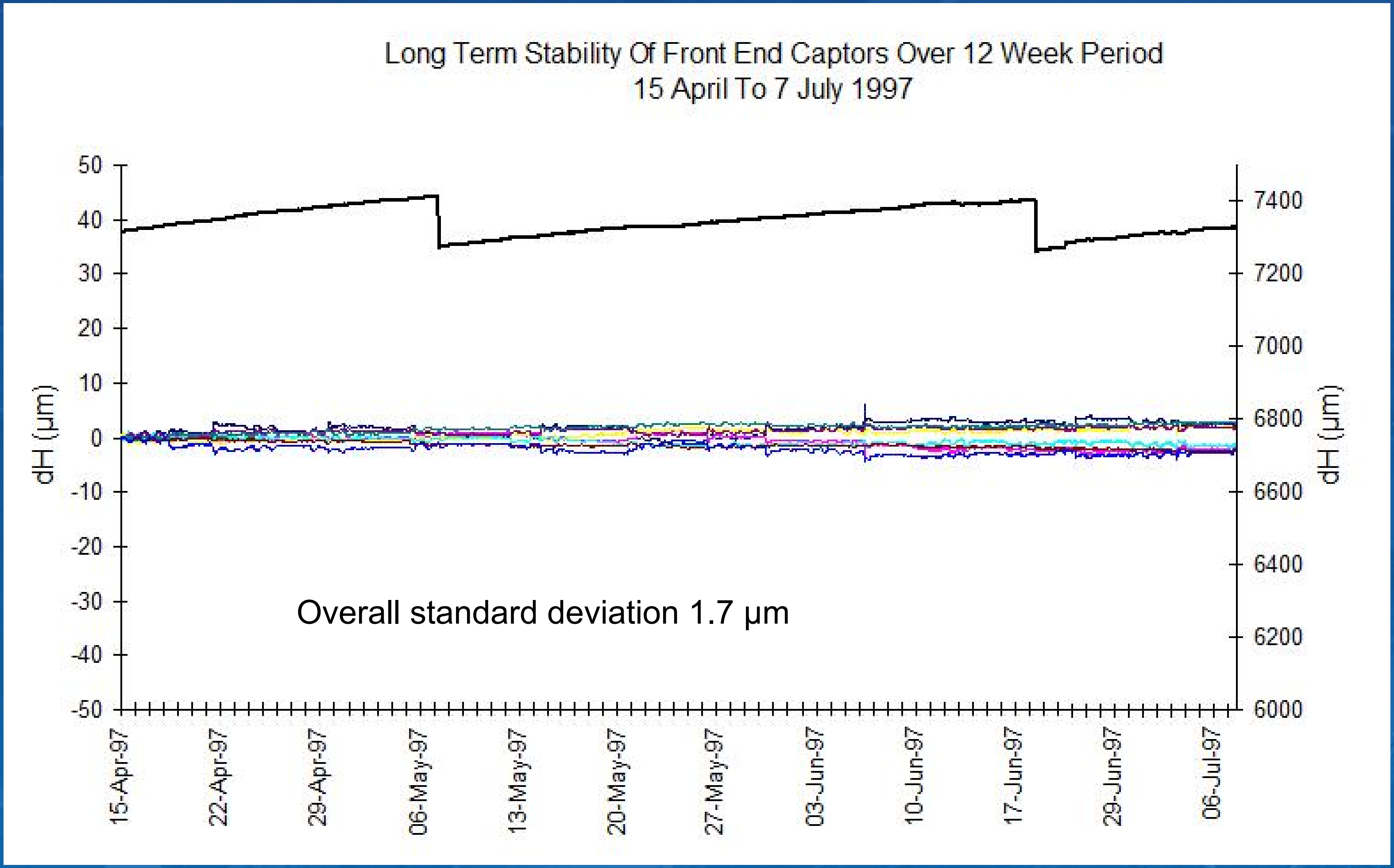
Uncertainty - example Type B for HLS probe calibration



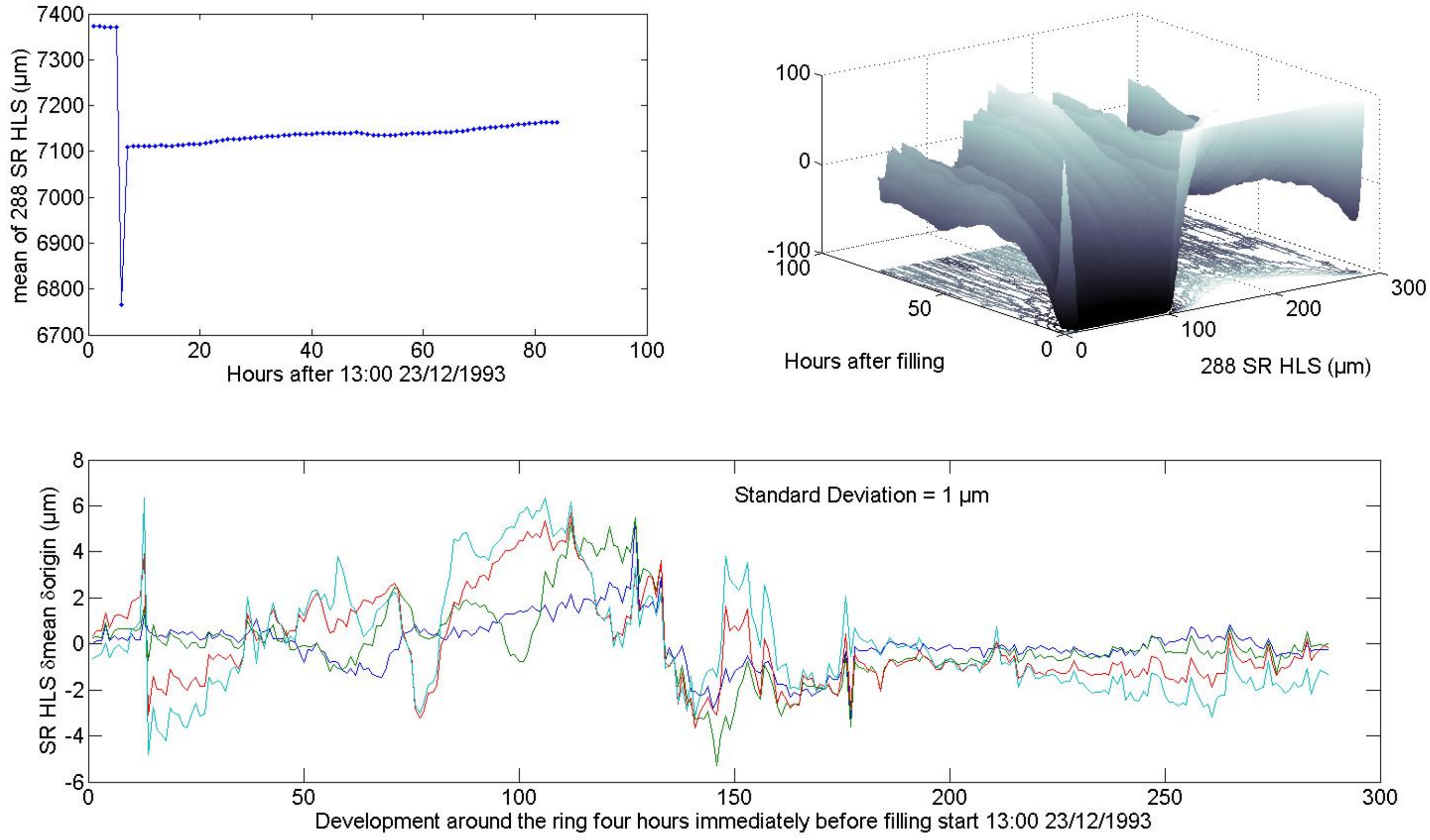


Quantity	*PDF*	μ	σ
Intrinsic Uncertainty	$N(\mu,\sigma^2)$	0	0.013 µm
Calibration of probe	$N(\mu,\sigma^2)$	0	0.014 µm
Repeatability of calibration	$N(\mu,\sigma^2)$	0	0.022 µm
Final probe calibration uncertainty	$N(\mu,\sigma^2)$	0	0.029 µm

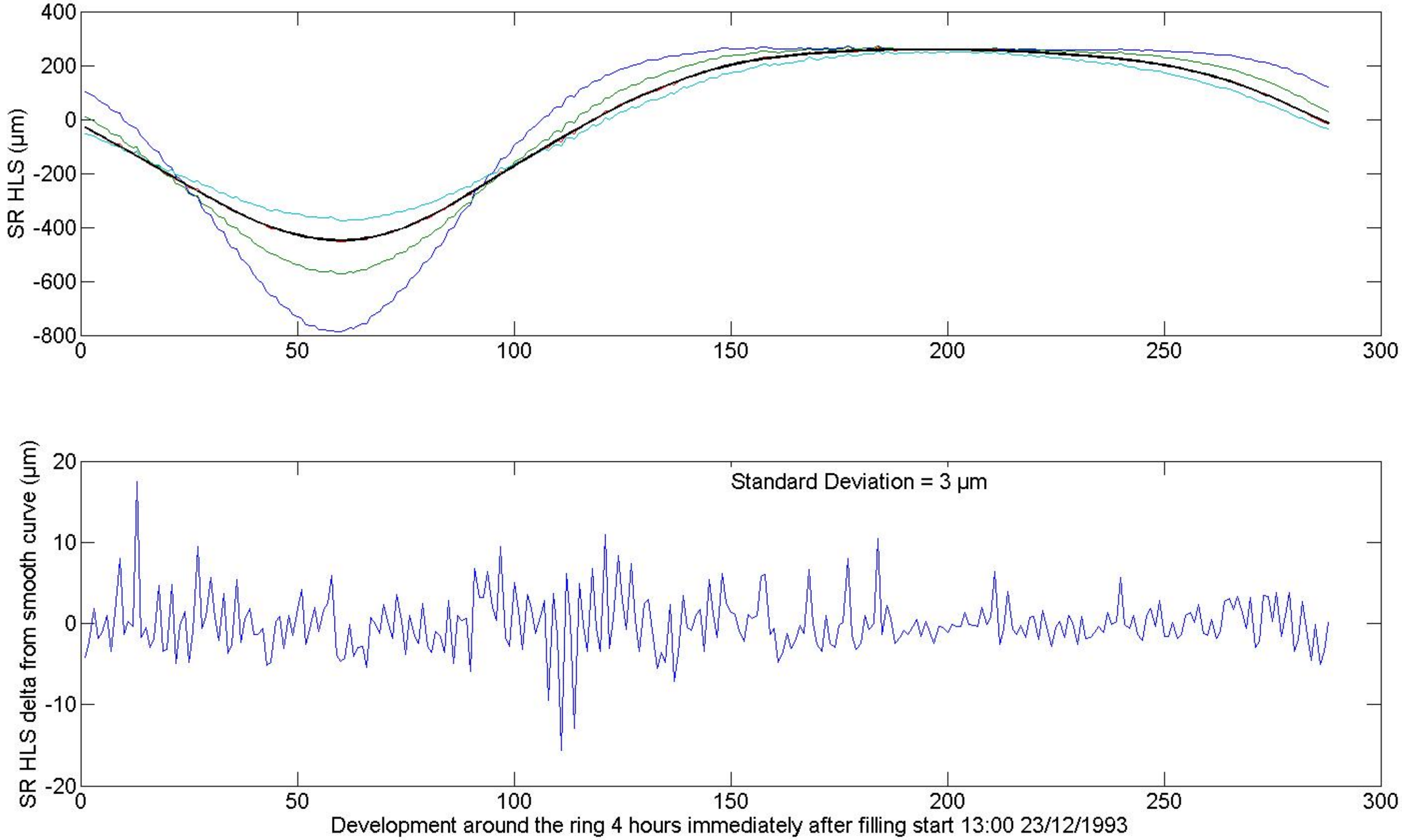
Uncertainty - example Type B for HLS probe laboratory temporal stability



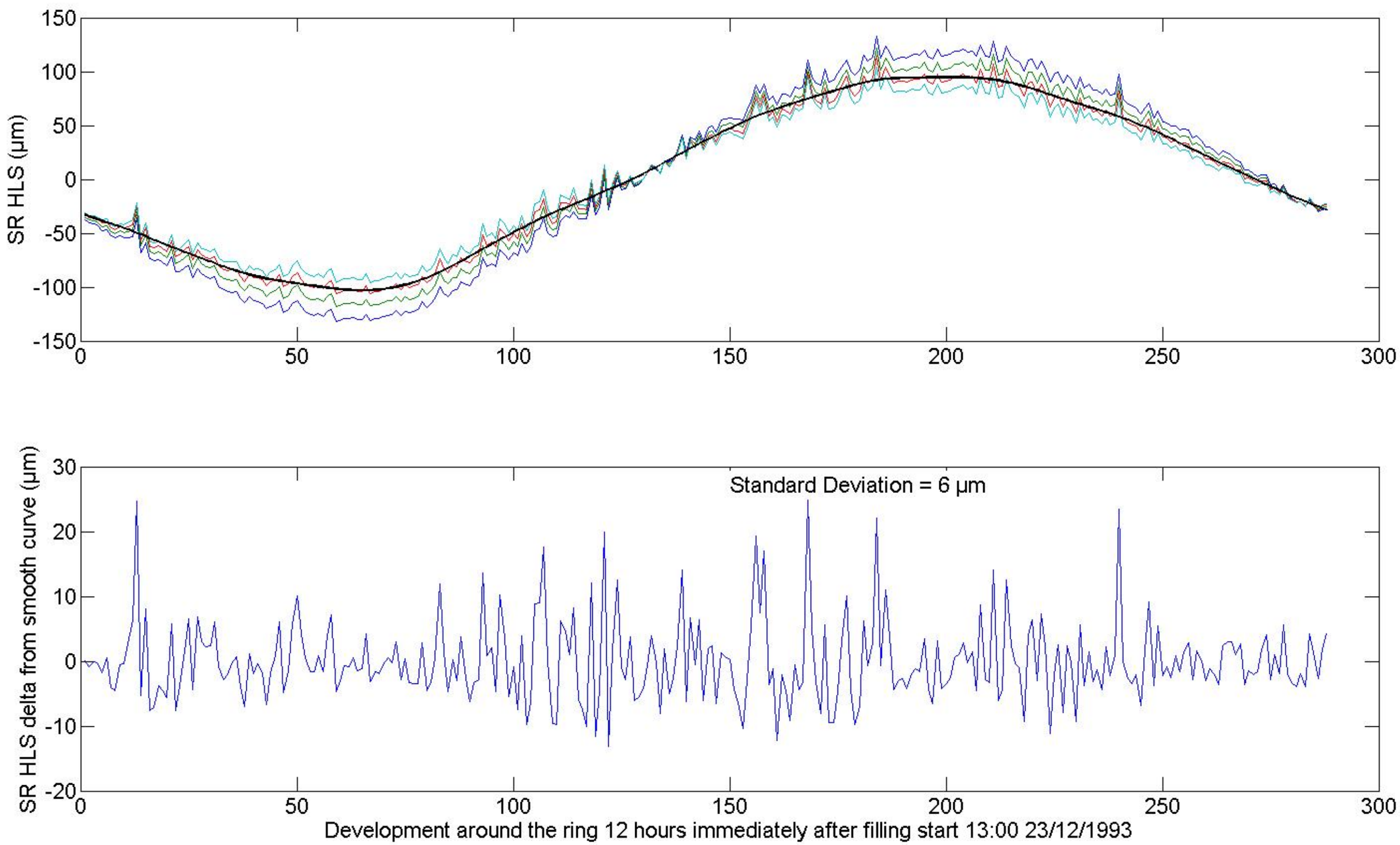
Uncertainty - example Type B for HLS system filling/purging behaviour



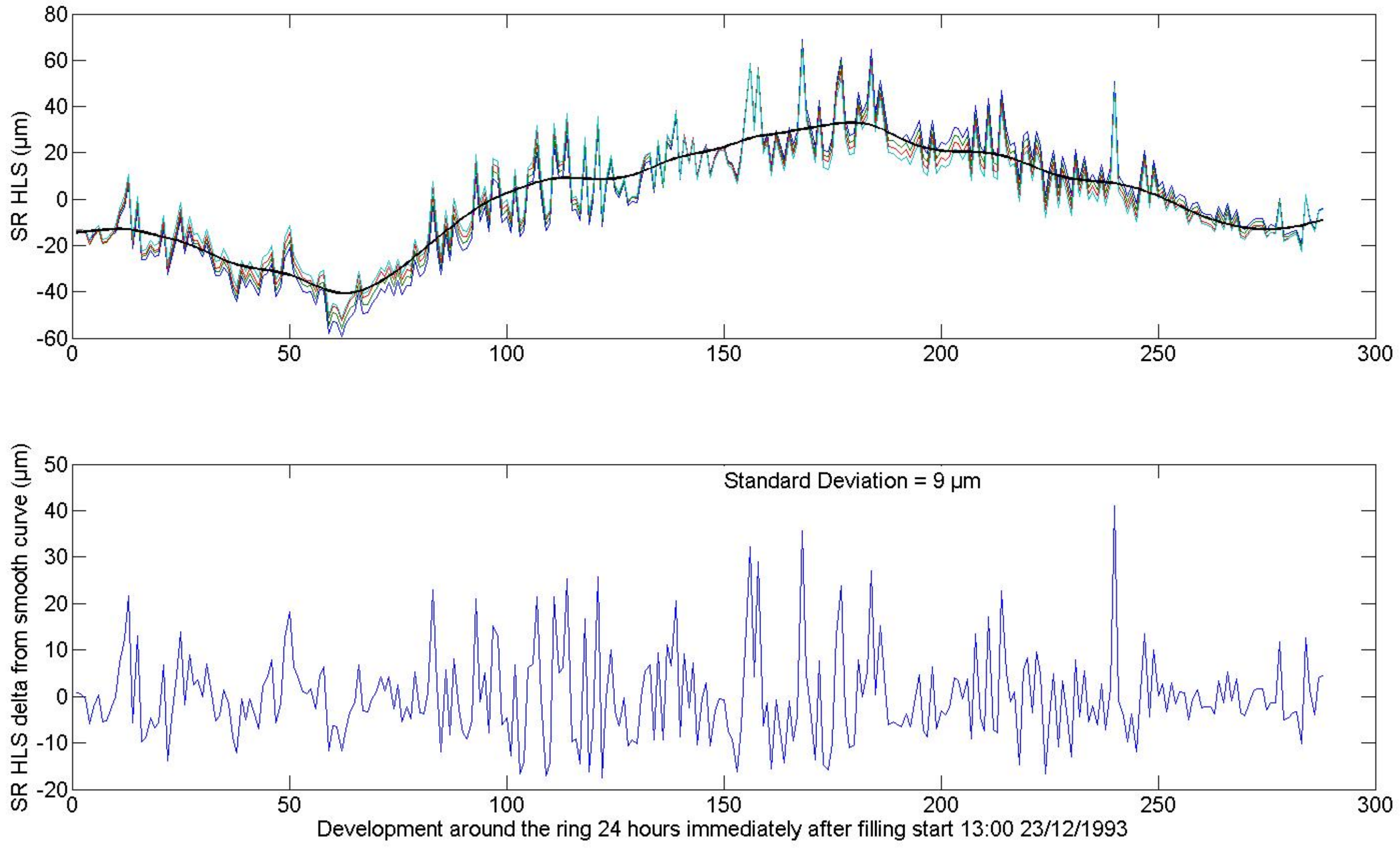
Uncertainty - example Type B for HLS system filling/purging behaviour



Uncertainty - example Type B for HLS system filling/purging behaviour



Uncertainty - example Type B for HLS system filling/purging behaviour

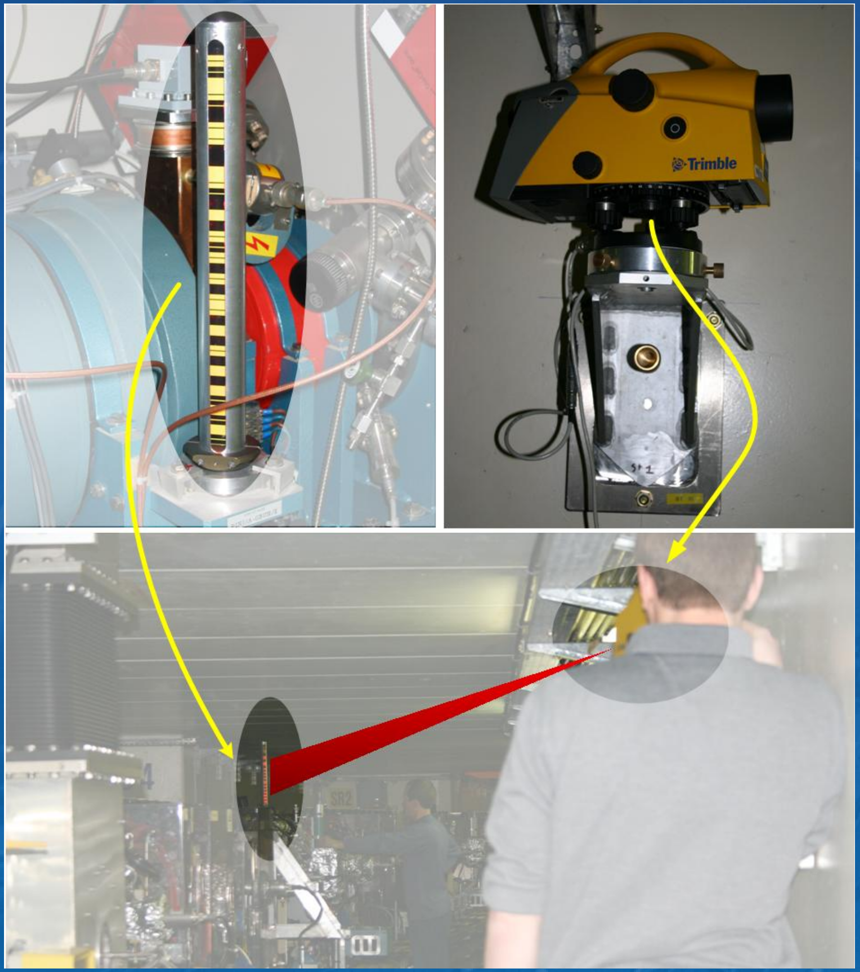


Uncertainty - example Type B for HLS other contributions

There are certainly other Type B contributions to the uncertainty of the HLS …

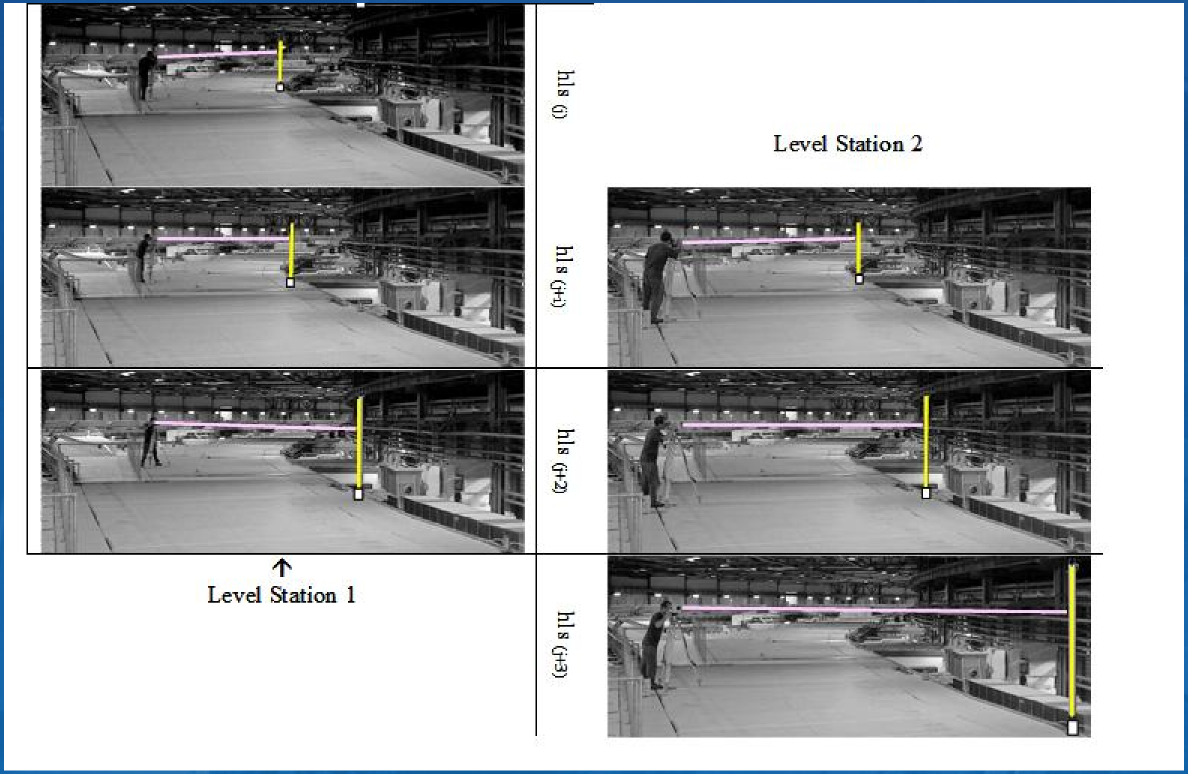
Uncertainty - Type A for HLS

- Recall Type A uncertainty evaluates uncertainty statistical analysis of series of observations.
- Implicitly there is a comparison with a 'traceable' standard or etalon.
- What is the standard?
- One reasonable standard for the qualification of an HLS is the level.
- This implies levelling the HLS.



Uncertainty - Type A for HLS

- Qualifying an HLS by levelling is discussed in my 2004 IWAA paper.
- It is shown there that we can expect an uncertainty in the height differences determined between the level network and the HLS of between 30µm and 60µm.



Methods and conditions of tests on these systems – uncertainty calculation

$$U(dH) = \sqrt{(\text{Type A})^2 + \sum (\text{Type B})^2}$$

Uncertainty contribution		Type B (µm)
Calibration	U(c)	0.029
Temporal Stability	U(s)	1.7
Filling – non-linearity	U(nl)	6

$$U(dH) = \sqrt{45^2 + 96 \times \left(0.03^2 + 1.7^2\right) + 6^2} = 48.4\ \mu m$$

Conclusion

From what we have seen in these last slides, it is considered of primal importance to establish a clear set of tests, guidlines and related uncertainties for the HLS and WPS.

The ESRF is open to any inter-laboratory comparison and collaboration with this study

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