Towards a European community on Accelerators, Detectors and Beamline Alignment

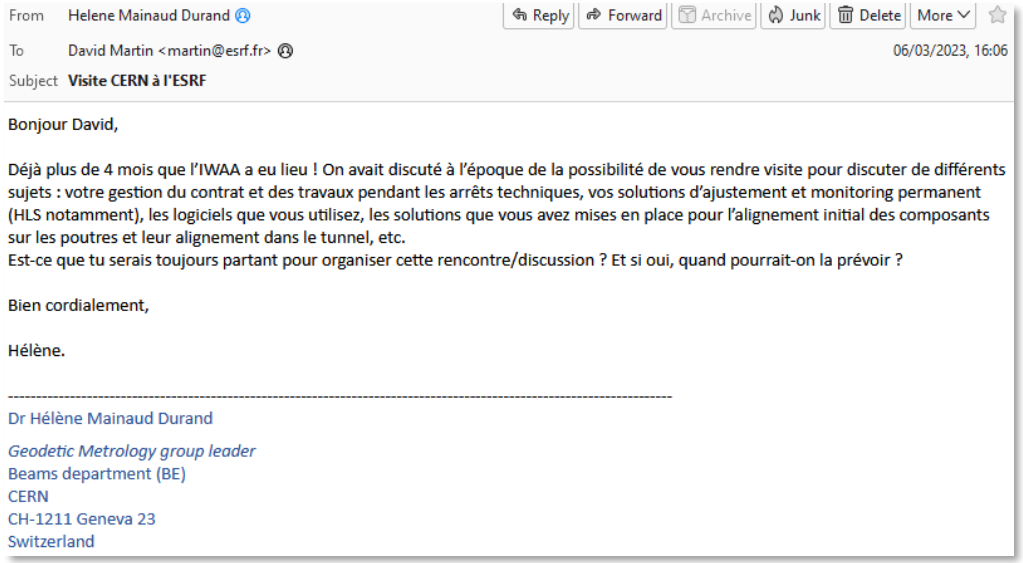
Hélène Mainaud Durand (CERN), David Martin (ESRF)

ORIGINS

Many of you will recall the IWAA held at CERN in November 2022.

During the workshop, we discussed the similarities in our work and our mutual interests. We thought it might be interesting to do an exchange/visit between CERN and the ESRF of some sort to see how we worked.

In early March 2023 Hélène contacted me and we began to discuss how we could make a visit a reality.



From Helene Mainaud Durand — Reply | Forward | Archive | Junk | Delete | More

To David Martin <martin@esrf.fr> — 06/03/2023, 16:06

Subject **Visite CERN à l'ESRF**

Bonjour David,

Déjà plus de 4 mois que l'IWAA a eu lieu ! On avait discuté à l'époque de la possibilité de vous rendre visite pour discuter de différents sujets : votre gestion du contrat et des travaux pendant les arrêts techniques, vos solutions d'ajustement et monitoring permanent (HLS notamment), les logiciels que vous utilisez, les solutions que vous avez mises en place pour l'alignement initial des composants sur les poutres et leur alignement dans le tunnel, etc.
Est-ce que tu serais toujours partant pour organiser cette rencontre/discussion ? Et si oui, quand pourrait-on la prévoir ?

Bien cordialement,

Hélène.

Dr Hélène Mainaud Durand

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Switzerland

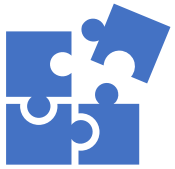
ORGANISATION

Shortly after that we started to formally organize the visit.

Many e-mails and zoom conferences later, we settled on a seminar to be held at the ESRF. Initially there were eleven participants from CERN and seven from the ESRF.

Later Marta and Jon from ALBA and Sebastien from SOLEIL also joined us.

The seminar was held on 27 June 2023 at the ESRF.

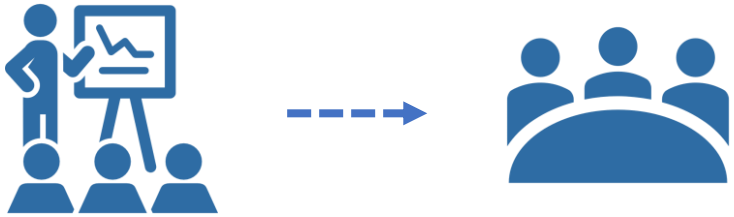


27 JUNE 2023 SEMINAR AT THE ESRF

We wanted to address seven key topics:

- Uncertainty and how to understand and translate physicists' requirements, especially over long distances
- Programs and applications
- Final alignment in the tunnel
- Alignment of magnets etc. on the girders
- Permanent monitoring systems
- Use of exterior company personnel during peak load periods
- Approaches to adjustment and least square calculations.

Each topic was introduced by a short presentation followed by roundtable discussions.



Uncertainty

The treatment of uncertainty is a major subject of interest – and it remains a key topic in this series of seminars. This session was opened with a presentation by an ESRF physicist Simone Liuzzo: *Error Tolerances, girder errors and long range errors from a beam dynamics point of view*. The propagation of uncertainty using principles outlined in the Guide to Uncertainty in Measurement (GUM) was emphasized.

Programs and applications

We had a good deal of discussion on different applications such Spatial Analyzer, MATLAB and LabVIEW. A number of specialized applications that have been developed over the years by CERN were discussed. We talked about looking for a replacement for SA, but this is no longer a subject of discussion. Nonetheless, SA will continue to be an important subject in this seminar series.

Final Alignment in the tunnel and alignment of magnets on girders

We talked a lot about the ESRF EBS alignment experience how magnets were fiducialised, aligned on girders, and how girders were aligned in the tunnel.

Permanent monitoring systems

HLS/ WPS etc. electronics and data analysis were the main topics of discussion. Although this remains a major topic, our discussions turned to questions about how to manage and analyze large data sets, hence proposed discussions about data bases, data analysis, machine learning in future seminars.

Use of exterior company personnel

This was and remains an important topic. We find it is difficult to find qualified staff. We discussed how exterior company contracts are fashioned and executed. Another subject of interest was and remains staff exchanges between laboratories to see how things are done elsewhere. We can always learn from what others do …

Approaches to adjustment

This was briefly discussed in the first seminar – it was discussed in more detail in the second one.

SEMINAR 9 TO 11 APRIL 2024 AT CERN

In conclusion the seminar was a great success, but it was clear that we had only scratched the surface of our mutual interests.

Almost immediately we started to discuss holding another seminar in 2024, this time at CERN, and this time including colleagues from the other European laboratories.

The second seminar was held 9 to 11 April with an ice breaker on the evening of the 9th and a visit in the afternoon of the 11th.

There were 27 participants from 9 laboratories.

The informal introduction/roundtable discussion format was retained for this seminar. It allows us to delve more freely into topics of mutual interest, but we do have to be very focused.

SEMINAR 9 TO 11 APRIL 2024 AT CERN

This seminar started with an introduction by Rhodri Jones, the Head of the CERN Beams department.

We chose to concentrate on sharing, brainstorming and discussing five principle topics:

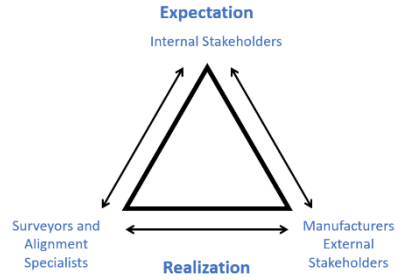
- Alignment techniques
- Error budget and uncertainty
- Workforce
- Programs, applications, analysis and databases
- Towards the future : development & research

There was one additional special topic at the end: *how to build on this seminar*.

The seminar finished with a visit to the Single Component Test bench.

Summary of key actions, conclusions and outcomes from this successful meeting were:

- Communication issues:
  - Use of questionnaire
  - Survey guidelines
  - Specific training for newcomers, especially in design offices
  - Engineering to alignment → How functional geometrical requirements on equipment are handled and transferred into installation drawings (IWAA 2022).
- Tolerances and uncertainty how to build an error budget
  - Propose, train & use the same methodology in the community
  - Establish a state of the art in the labs of what is possible
- Workforce:
  - Strong difficulties in recruitment everywhere
  - → LinkedIn, Mattermost channel for the community, share of universities/schools contacts in Europe
  - Share personnel during peaks (calendar of technical stops peak work load)
  - Invite manufacturers to the next seminar to explain our needs and help influence their developments



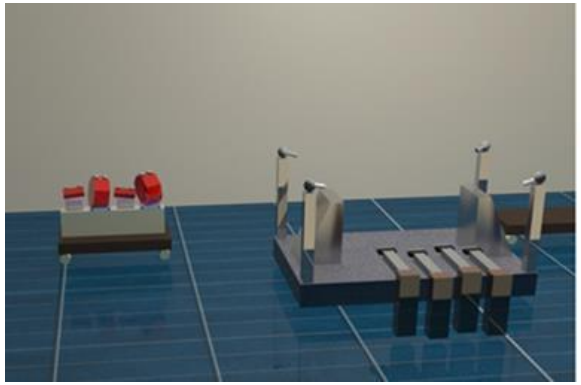
Machine	U(L) [µm]	U(R) [µm]	U(Z) [µm]
Long. Varying field dipoles	1000	>100	>100
High gradient quadrupoles, Combined function dipoles	500	60	60
Medium gradient quads	500	100	85
Sextupoles	500	70	50
Octupoles	500	100	100

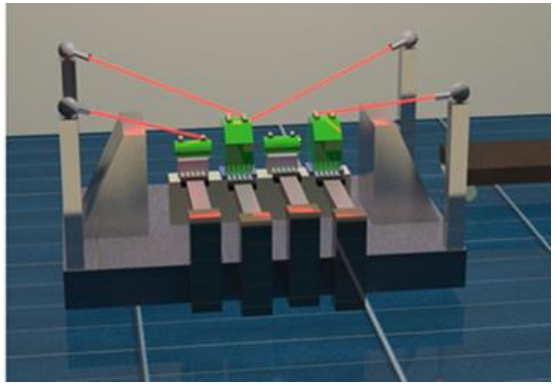
Cont. summary of key actions, conclusions and outcomes from this successful meeting were:

- Negotiate/share specific software licenses between the 9 labs represented at the meeting we have 51 licenses in total.
- Strong interest to use SurveyPad/LGC for least square calculations:
  - Open Software under preparation
  - Discussions with NPL for the traceability of the calculation modules
  - An opportunity to standardize the calculations on uncertainties in the community
  - Possibility to share developments between labs on the input/output formats
  - Introduction and training to the software under preparation
- Different axes of developments discussed (automated measurements, sensors developments adjustment solutions, etc.).
  - Strong interest for FSI solutions and UAP platform
  - Interesting developments on automated and integrated measurements in different labs

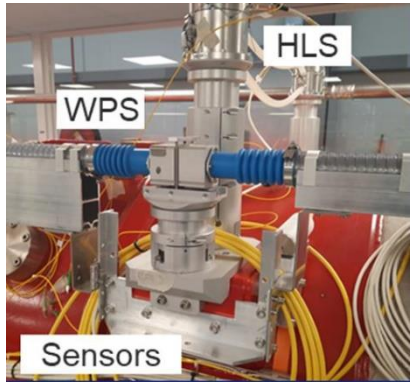
Towards the future …

AI, Machine Learning, Digitization …

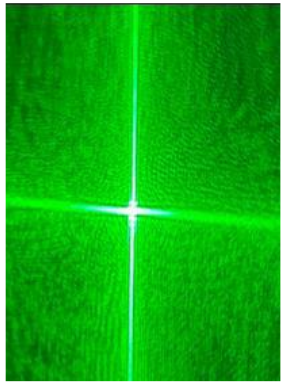




Low cost sensors



Alignment solutions



Sustainability

Automation

Adjustment

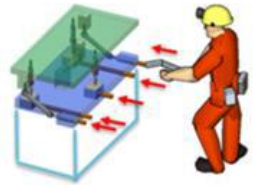


Fig. 8a. Manual adjustment: the operator turns adjustment knobs

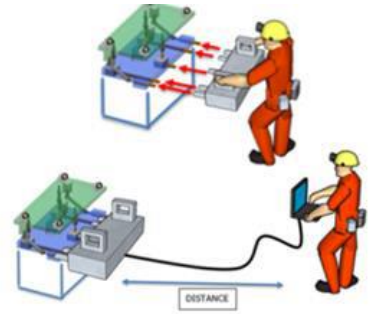
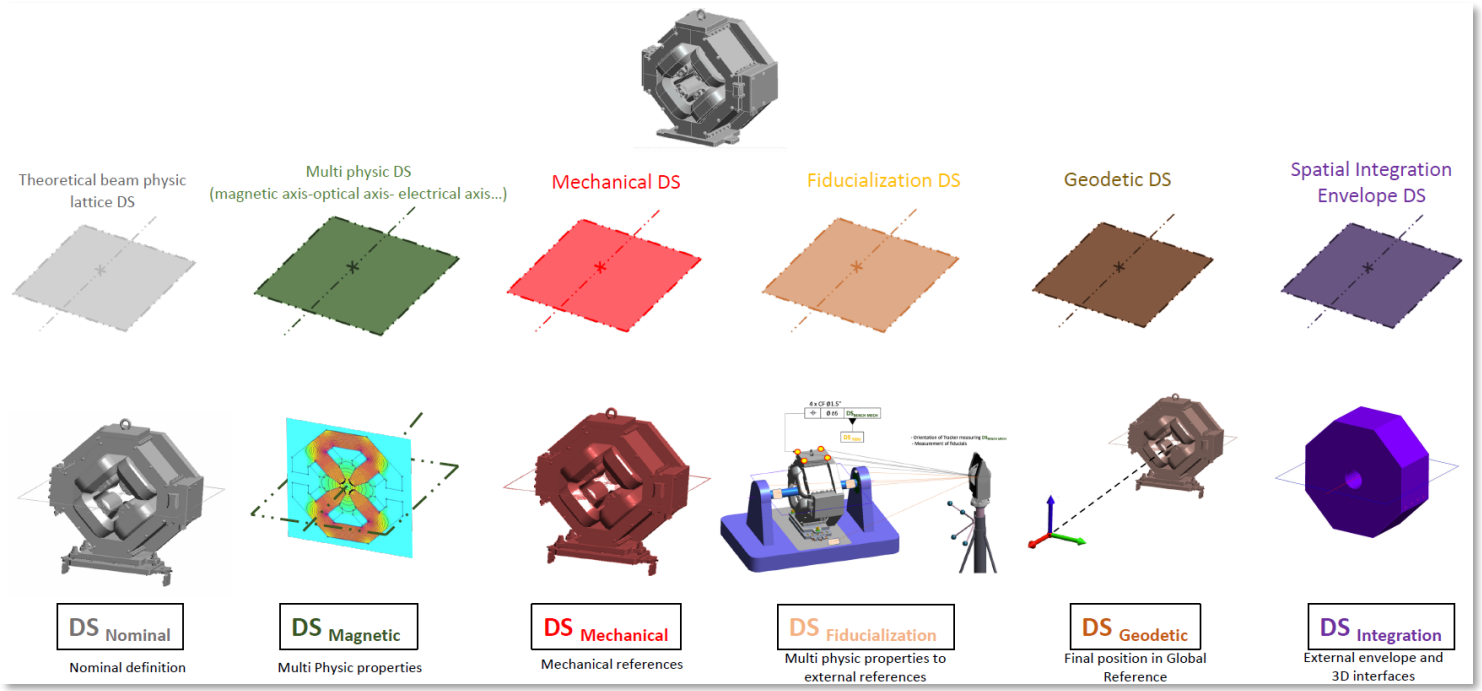


Fig. 8b. Semi/manual adjustment using temporary plug-in motors

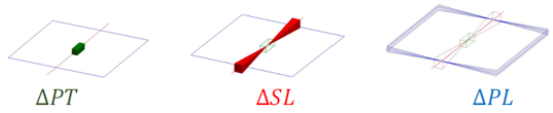
Towards the Future: Engineering to Alignment (E2A)

We are quite keen to investigate E2A, which declares Datums Systems (DS) and attaches them to Coordinate Systems contained in the CAD skeleton.



A **datum system** can always be reduced to:
- A theoretically exact plane **[PL]**
- A straight line **[SL]** in this plane
- A point **[PT]** on this straight line

locking all degrees of freedom or a subset thereof with respect to which geometrical specifications are referenced. With this you can fully express positioning requirements using tolerance zones with respect to the DS.



ISO 5459:2011 Geometrical product specifications (GPS) – Geometrical tolerancing – Datums and datum systems

Nicquevert B, Rey F, *From Engineering to Alignment - How functional geometrical requirements on equipment are handled and transferred into installation drawings*. IWAA2022.

Towards the Future:

We would also like to investigate the interplay between E2A and the expression of uncertainty in measurement

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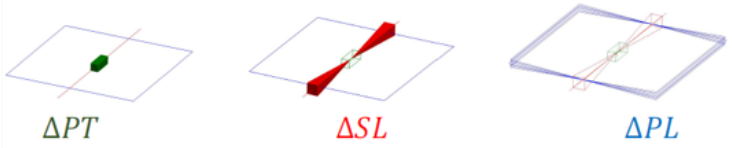

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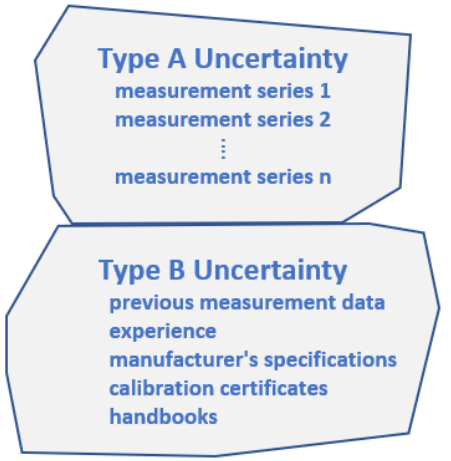


measurement uncertainty
non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

$$U = \sqrt{Type\ A^2 + Type\ B^2}$$

SEMINAR 9 TO 11 APRIL 2024 AT CERN

How to build on this seminar?

- Present this initiative and its outcome at IWAA 2024 @ SLAC, beginning of October.

During IWAA 2024:

- Propose talks on AI & ML and discuss/brainstorm on how to integrate them in our field
- Propose peer review for IWAA papers → the idea is to peer review those papers that request it to ensure the highest quality. They would be marked *peer reviewed*.
- Propose a dedicated session on uncertainty calculations.

Minutes finalized, with a complete list of actions that will be followed closely.

- *2023 - https://indico.cern.ch/event/1347319/*
- *2024 - https://indico.cern.ch/event/1382382/overview*

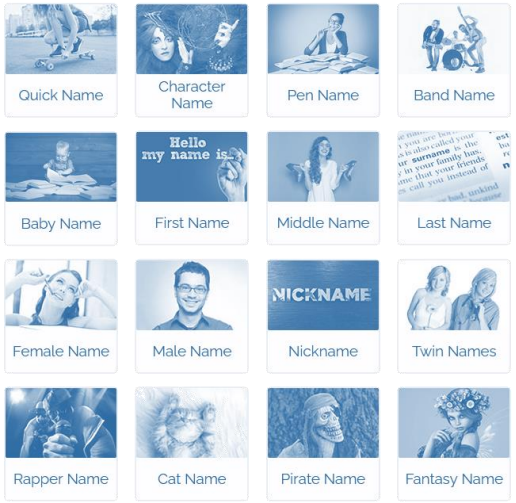
ID	Action	Resp	Due
S1	Communication with equipment owners and physicists: share guidelines, questionnaire and documents available. *Documents to be inserted into the Indico page – session 1.*	All	June 24
S2a	Familiarization with the propagation error techniques: Propose a process. Prepare a table on reference values for the uncertainty contributions	David Hélène	Sept. 24
S2b	Collect the values for each lab on the uncertainty contributions	David Hélène	Sept. 24
S3a	Provide a schedule with technical stops and potential peaks of workload. *Format to be prepared.*	All Hélène.	Sept. 24
S3b	Create a LinkedIn for the community of lab surveyors		
S3c	Database with surveyors' universities and schools from Europe: Share CERN link and info. Propose new contacts	 Hélène All	 June 24 Sept. 24
S3d	Implement a Mattermost channel	Camille	Sept. 24
HTBa	SA licenses: Contact procurement services to see what is possible between labs. Explore different options: token-based, cloud-based, floating	Jean-Frédéric	 Sept. 24 June 24
HTBb	IWAA 2024: Propose a presentation on the outcome of the seminar	Hélène	June 24 (abstract)
HTBc	IWAA 2024: Propose a session / training on uncertainty and GUM, another a discussion or presentation on future trends, including AI and Machine Learning	David Hélène	June 24
HTBd	IWAA 2024: Propose a possibility of peer review for the papers.	David Hélène	June 24
HTBe	Propose a date for the next iteration of the seminar at ESRF	David	June 24
HBTf	Invite Hexagon and SA at the next alignment seminar	David	Jan. 25
S4a	Clarify the timeline (and conditions if any) to have LGC (and SurveyPad) open source	Francis	June 24
S4b	Propose an introduction to LGC to all interested labs. Export the LGC user guide and documentation	Guillaume	Sept. 24
S4c	Least square adjustment using LGC: send measurement files to Guillaume to have a preliminary idea of the software	All	Dec. 24
S5a	Prepare a timeline to propose the UAP platform as an open hardware	Mateusz	Sept. 24

NEXT SEMINAR 3 TO 5 JUNE 2025 AT THE ESRF

Next iteration will be 3 to 5 June 2025 at the ESRF. Topics we would like to discuss are:

- Uncertainty in measurement
- E2A
- LGC open source
- 3D scanning
- Manpower issues
- …

And, we would like to find a name for this recurring *shindig*…



We would also like to attract other European labs who couldn't attend the 2024 seminar…

Thank you for your attention …