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Geodetic References for the FCC

Challenge and Opportunity for the French and Swiss Mapping Agencies

D. Willi [1], B. Garayt [2]

[1] swisstopo, [2] IGN

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Geodesy – the science of «where?»

Geodesy is the science that studies the dimensions and shape of the Earth, as well as its gravity field.

Its main objective is to develop and to maintain terrestrial reference systems that any user or creator of georeferenced data can access through networks.

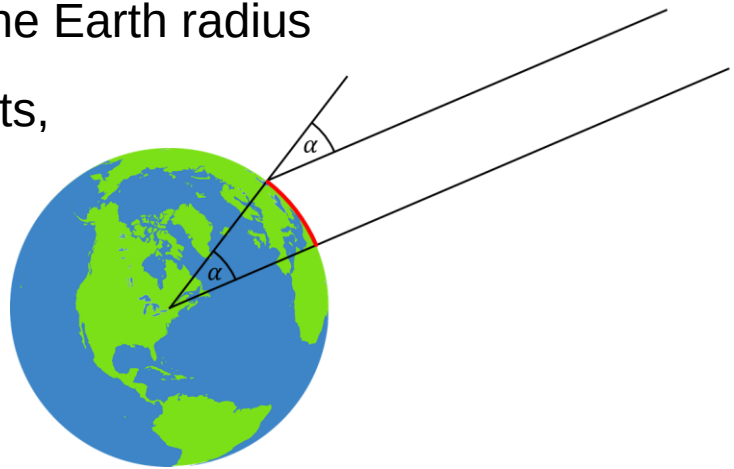
The applications of reference systems

The adoption and implementation of such **reference systems** is essential to:

- **Administer**
  - Normative role of legal coordinates (cadastral systems)
  - Contribution to **security** (basis of a homogeneous cartographic reference system), to **risk prevention**, to **the economy**, etc.
- **Prevent and manage**
  - basis for continuous observation of the territory and repeated observation (aerial imagery, LiDAR, etc.)
- **Know**
  - support for public research on geophysical phenomena, observation of phenomena witnessing climate change effects

Two millenniums of geodesy

- Eratosthenes of Cyrene (Greek mathematician, geodesist, astronomer, …) – 276 BC to circa 195/194 BC
  - First realistic measurement of the Earth radius
- Various meridian arc measurements, from the 17th to the 19th century
  - Determination of the Earth ellipsoid, a mathematical reference surface for cartography



- Nationwide precise trigonometric measurements starting in the 19th century

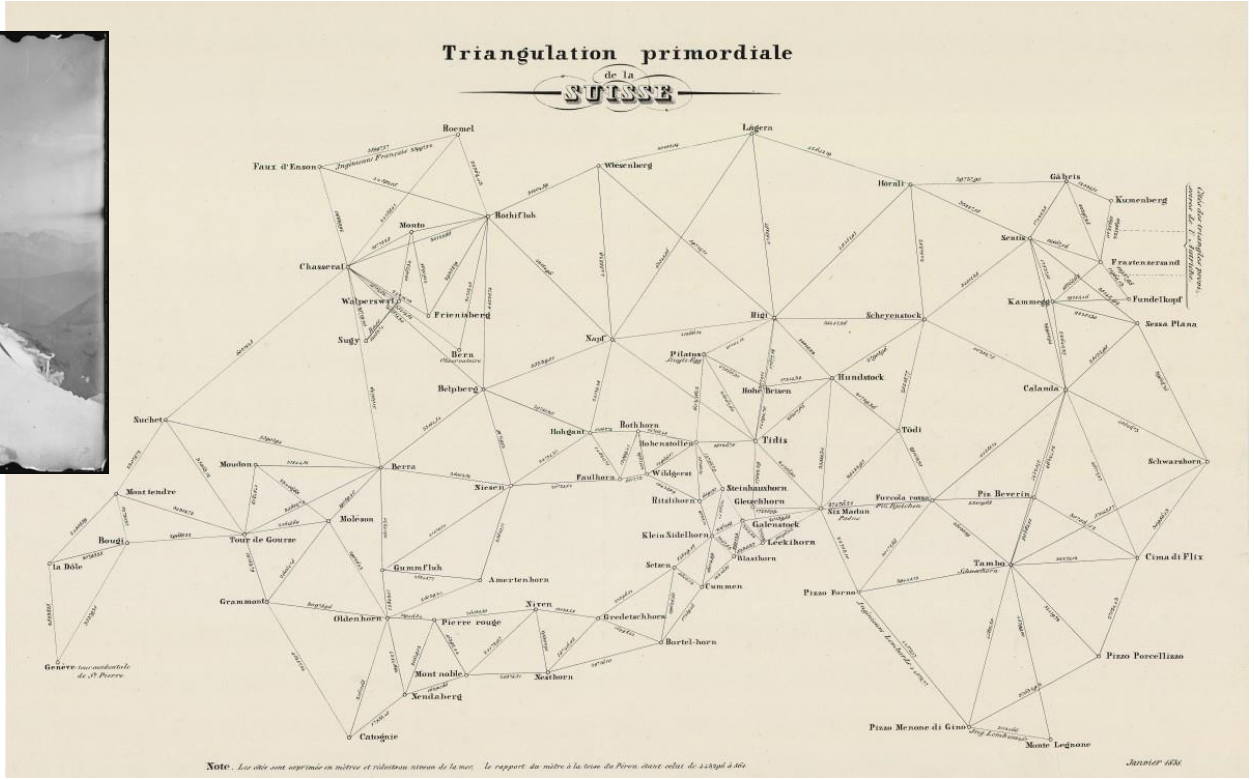
National geodetic infrastructure

- The goal of a triangulation network was to provide precise 2D coordinates (east and west coordinates or longitude and latitude) for:
  - Cartography
  - Cadastral surveying
  - Technical surveying (construction work)
  - Scientific applications
- Beside triangulation networks, many countries built levelling networks, providing accurate heights for:
  - Railway construction
  - Hydrological purposes

La Nouvelle Triangulation de la France

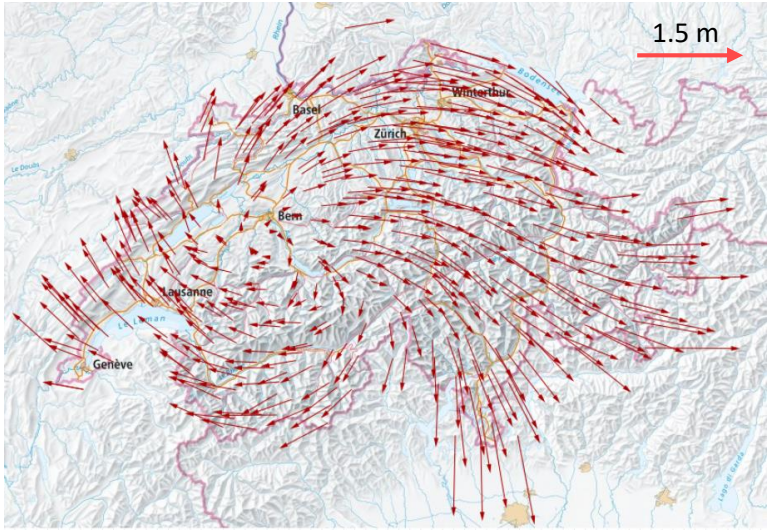
Triangulation net starting from the end of the 19th century. Below: installation of marker in 1938.

Triangulation primordiale 1809 – 1840



The GPS revolution

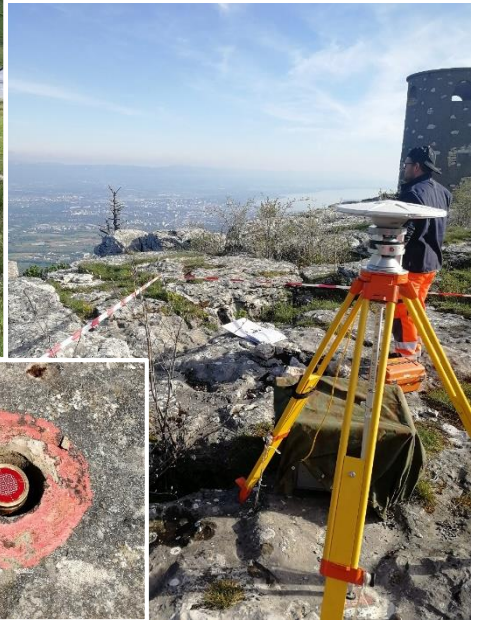
- GPS made triangulation obsolete, because it is more precise and easier to implement
- Many countries modernized their networks with GPS
  - LV95 in Switzerland
  - RGF93 in France
- The change to another system is costly, as many datasets have to be transformed. Thus, such changes are avoided.



Difference between the triangulation and the GPS network in Switzerland. The largest differences are about 3 m

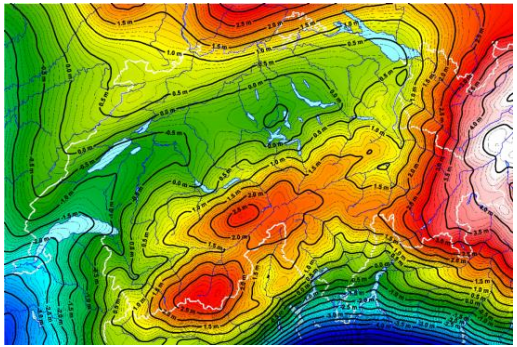
Materialization of modern networks

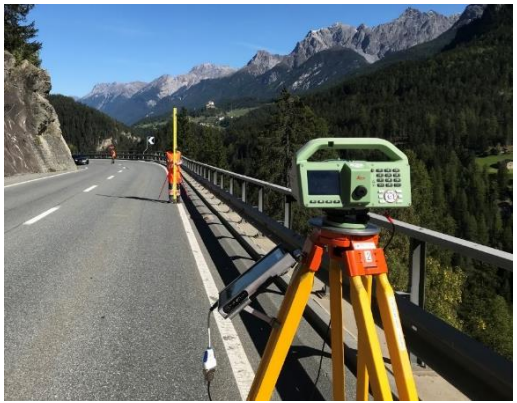
- GPS permanent stations
  - “Continuously Operating Reference Station” (CORS)
  - Main infrastructure to realize reference frames
  - Primary user access
- Campaign points
  - Ground level markers
  - Less expensive
  - Very small visual impact
  - Ideal for densification



What about the 3rd dimension?

- GPS alone is not sufficient for height determination.
- A **geoid model** is needed.
- Levelling is still widely used to establish and maintain national height reference systems to provide heights to the users.
- Unification of height systems is more challenging than the unification of coordinate reference systems.





International unification efforts

- European **Terrestrial** Reference System
- International **Terrestrial** Reference System

- European **Vertical** Reference System
- International **Height** Reference System

- All these efforts are based on:
  - Exchange of data (permanent stations)
  - Numerical standards and models
  - Common methods

Permanent stations that contribute to the European Terrestrial Reference System (Source: EUREF)

- National networks in Europe are typically linked to the European Terrestrial Reference Frame

Is everything solved? No!

- Even though different systems are compatible in theory, differences in the realisation (= the practical implementation) lead to inconsistencies in the **centimetre** or **decimetre** range
- Typically, those differences are not perfectly known neither modelled
- Large infrastructure projects with very high accuracy demands require a project-specific geodetic infrastructure
  - As of today, this is the only possibility to ensure consistent coordinates over the whole site
  - As all geometric works rely on those coordinates, highly accurate and consistent coordinates are crucial

Geodetic infrastructure for the FCC

Proposition of the Geodesy Advisory Board

- 1 – 2 continuously CORS
- 1 pillar in the vicinity of each access shaft

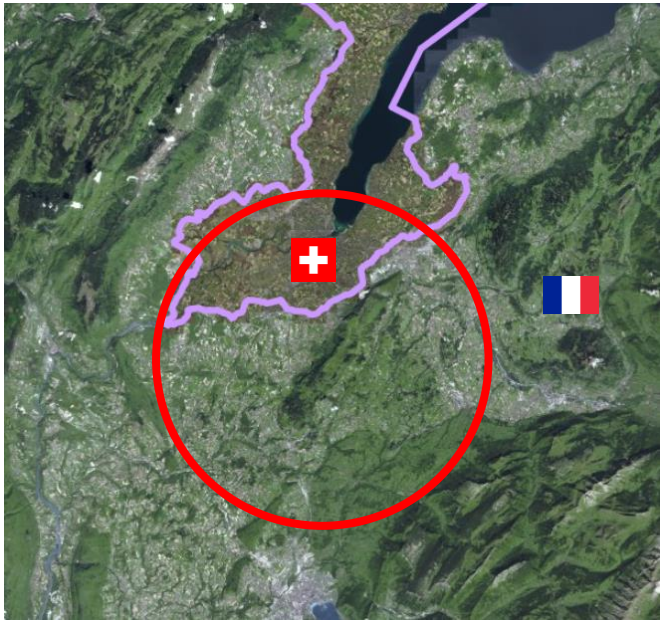
→ To be installed as soon as possible. Needed for the “realisation” of the system.

- 1 – 2 more pillars per shaft
- 3 – 4 additional ground level markers
- Possibly, some height benchmarks

→ Before the start of construction work.

Role of IGN and swisstopo

- As official mapping agencies, IGN in France and swisstopo in Switzerland support the geodetic activities related to FCC
- Both IGN and swisstopo provide access to existing data and models
- Future CORS will be operated in a joint effort and be integrated in the existing geodetic infrastructures in France and in Switzerland



Benefit for the FCC project

- The surface network (CORS, pillars and ground level points) are essential to compute the coordinate reference system for the FCC project
  - Ensures a precise reference for all underground infrastructure
  - Serves also for the long term monitoring of surface movements
- The data from the CORS are made available for positioning and for specific applications (for instance high accuracy GPS post-processing)
  - Primary access to the reference system
- The pillars and the ground level points are accessible and their coordinates are available
  - Secondary access to the coordinate reference system

Socio-economic benefit I

- Between 60 and 80 percent of all political, economic and private decisions are spatially oriented
- Geoinformation (data with a spatial component) is essential to enable decision making
- Geodesy and reference systems are the basis for any geodata and for long-term surveying and territorial monitoring

Socio-economic benefit II

- Densification of existing networks
  - Professionals can have access to more control points for increased efficiency and reliability in daily work
- Freely available CORS data
  - Higher data availability will lead to added value, for instance more accurate GPS positioning

- Enhanced models
  - Eventually, the community will benefit from better surface displacement models and other models (for instance geoid model)

Conclusions

- For the FCC, a project specific reference systems is needed
- The geodetic infrastructure for the FCC will consist of:
  - of 1 – 2 GPS permanent stations
  - 2 – 3 pillars in the vicinity of each shaft
  - 3 – 4 ground control points in the vicinity of each shaft
- This infrastructure is crucial for the project, as it provides the geometrical reference for all construction and alignment work
- The socio-economic benefits are mainly generated through freely available data and models

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