FIG WORKING WEEK 2017
Surveying the world of tomorrow – From digitalisation to augmented reality
Helsinki Finland 29 May - 2 June 2017

Applying Geodetic Coordinate Reference Systems in Building Information Modeling (BIM)

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FIG Working Week 2017 in Helsinki, Finland
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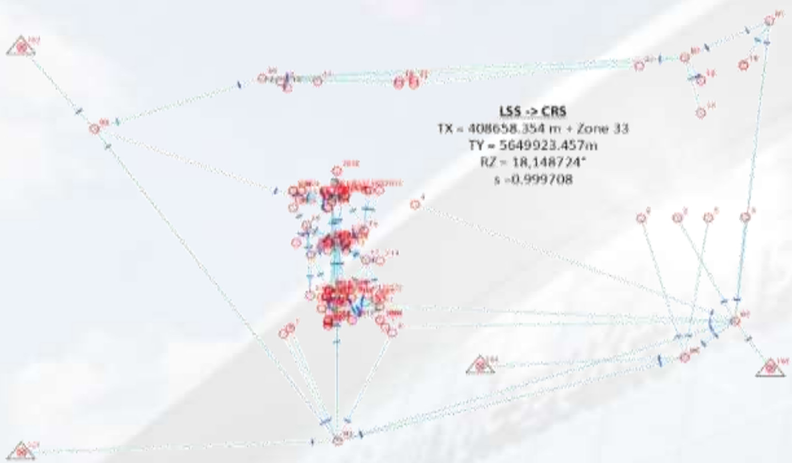
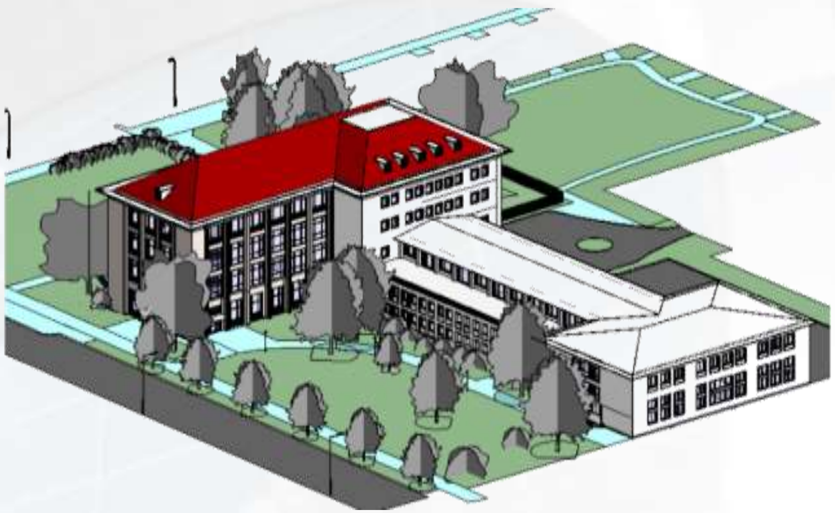
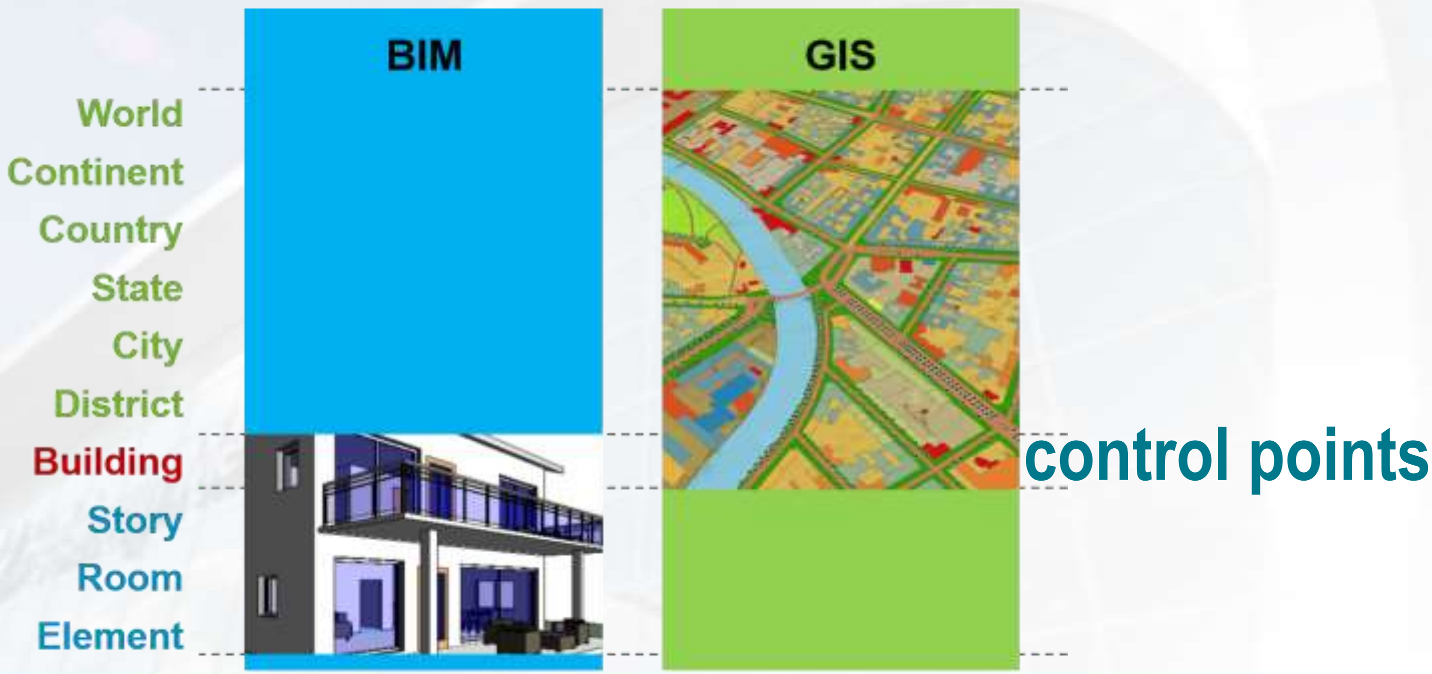




Motivation BIM and GIS Integration

Locate planed buildings within the regional/global context

- To make use of available geodata within the design and planning phase
- To gain correct stake out data for surveying work on the building site



Geometric Representation of 3D Objects

GIS World

Boundary Representation (B-Rep)

Aggregation of all surfaces surrounding the volume

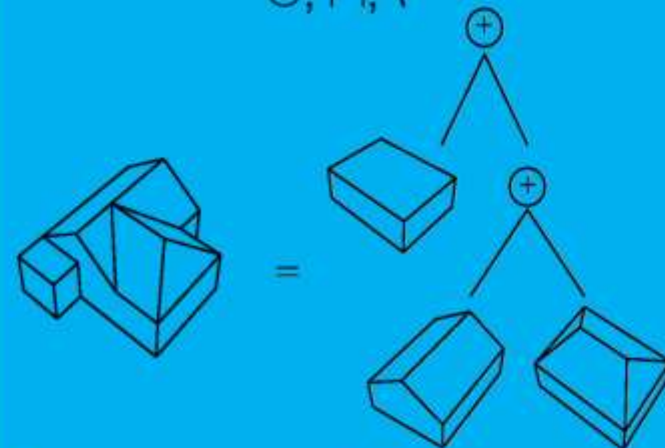
Especially suitable for acquisition from observations (measurement)

BIM World

Parametric, Sweep, CSG

Combination of volumetric objects by Boolean operations

$\cup, \cap, \setminus$



Particularly suitable for design and construction planning

Problem: Different Coordinate Systems

BIM	GIS
• Bottom-up approach: idea for a building → design model/plan → real world (e.g. construction company)	• Top-down approach: real world objects → surveying → 2D/3D model (e.g. by governmental agency)
• The aim is the correct representation of a planned building and construction processes	• The aim is the correct representation of real world objects for general purposes (GDI)
• Representation by relative placement of constructive elements (component-based, generative)	• Representation by absolute positioning of topographic elements located on the earth surface
→ Local Project Coordinate System (PCS, WCS)	→ Regional/global Coordinate Reference System (CRS)

coordinate characteristics

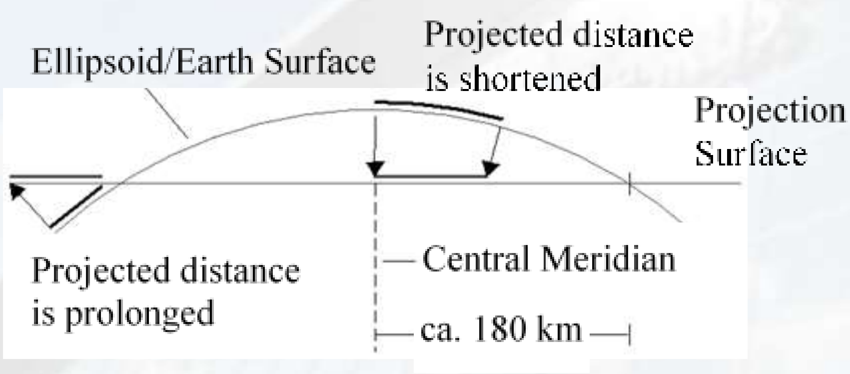
The following coordinate characteristics of the PCS and CRS must be considered when:

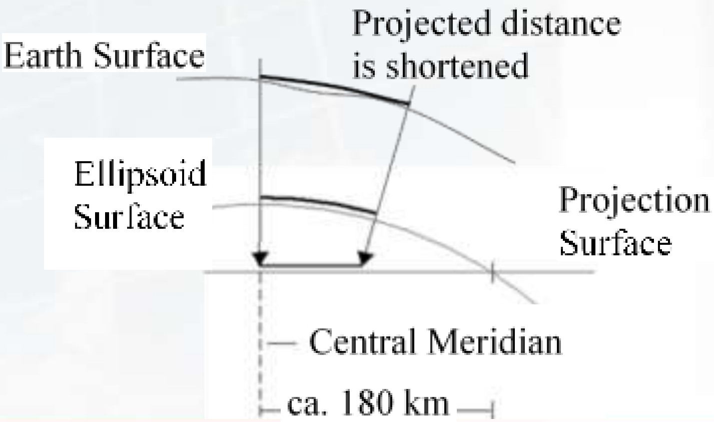
- Integration BIM projects with GIS data
- Obtain survey data from a BIM project

	PCS (e.g. local WCS)	CRS (e.g. ETRS89/UTM)
Linear Unit:	Metric, imperial or none (☹)	scale of national grid (meter)
Scale/Coverage:	Local (limited), project time	World / Country, long term
Zones:	No	Yes, by fixed zones
Number of Digits:	Small numbers (Origin close to the project site)	Large numbers (7-8 before and 2-3 after decimal point)
Distortion map projection:	No (1:1)	Yes (up to ~ 400ppm)
Distortion due to hight:	No	Yes

UTM Projection Distortions

- **Horizontal** distances (x/y-plane) and areas - **distortions** due to:
  - **projection of the curved earth surface into the plane**, e. g. measured distance of one kilometer is up to 40 centimeters longer than calculated between the same points in a GIS
  - **height differences** between the earth surface and the projection surface, e. g. a bridge of about one kilometer which is planned at a height of about 500 meters above sea level is about 8.5 centimeter longer than the surrounding topography in a GIS
- Hence, this distortions have to be considered during the planning and construction phase using a BIM

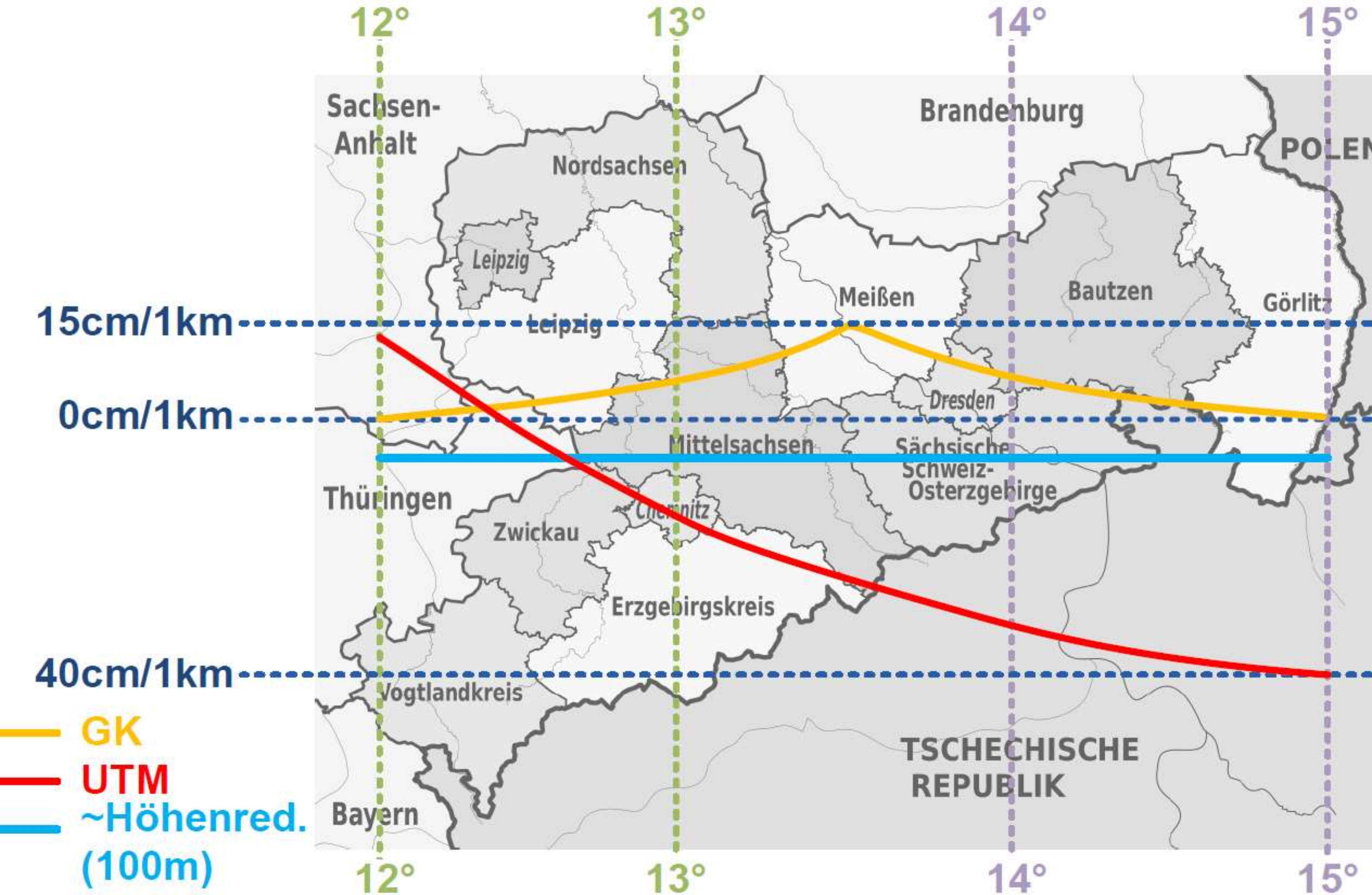




Correction of measured distances for UTM map projection

- Height correction: $$S_{ell} = S_{meas} \cdot \left(1 - \frac{h_{ell}}{R_m}\right)$$
- Projection correction: $$S_{UTM} = S_{ell} \cdot 0{,}9996 \cdot \left(1 + \frac{(E_m - 500\,km)^2}{2R_m^{\,2}}\right)$$
- Combined height and projection correction: $$S_{UTM} = S_{meas} \cdot 0{,}9996 \cdot \left(1 - \frac{h_{ell}}{R_m} + \frac{(E_m - 500\,km)^2}{2R_m^{\,2}}\right)$$
- Where:

S_{meas} …Measured horizontal distance on earth surface
S_{ell} … Horizontal distance on reference ellipsoid
S_{UTM} … Horizontal distance in UTM projected CRS
H_{ell} …Height of earth surface resp. construction/planning site above reference ellipsoid
E_m …Mean easting value of the construction/planning site
R_m …Mean radius of osculating sphere: 6383 km



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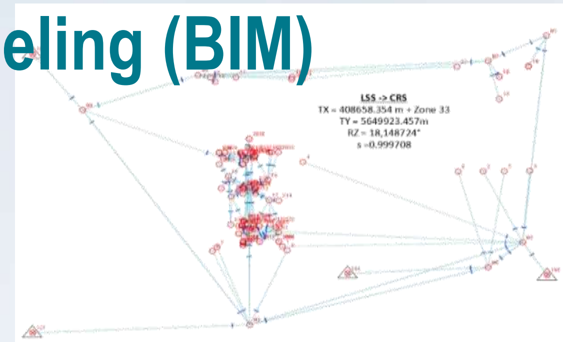
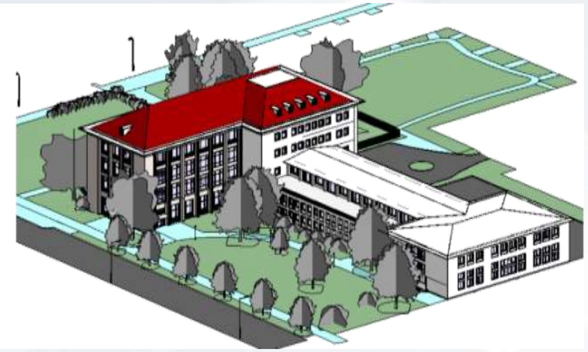




- for each building
- in BIM Software

- scale (projection, elevation above ellipsiod)
- „long" geo-coordinates, zone
- GIS / Surveying Software (COGO)

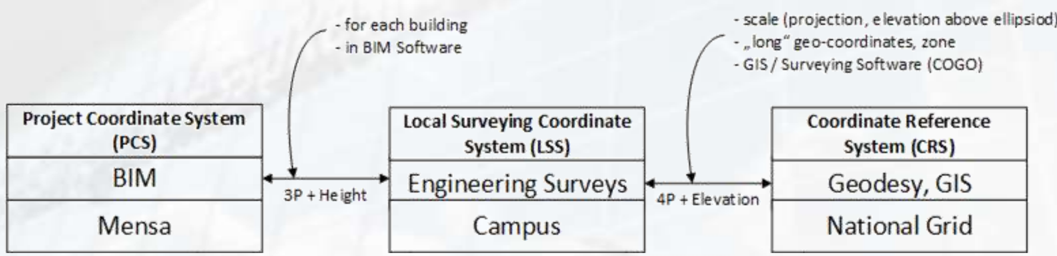
Project Coordinate System (PCS)		Local Surveying Coordinate System (LSS)		Coordinate Reference System (CRS)
BIM	← 3P + Height →	Engineering Surveys	← 4P + Elevation →	Geodesy, GIS
Mensa		Campus		National Grid

identical object points

identical survey points

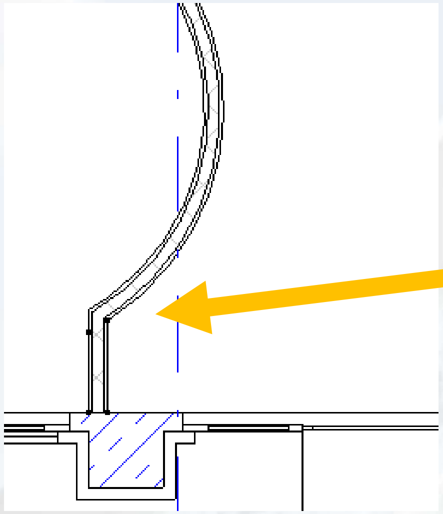
Example: Georeferencing in Autodesk Revit

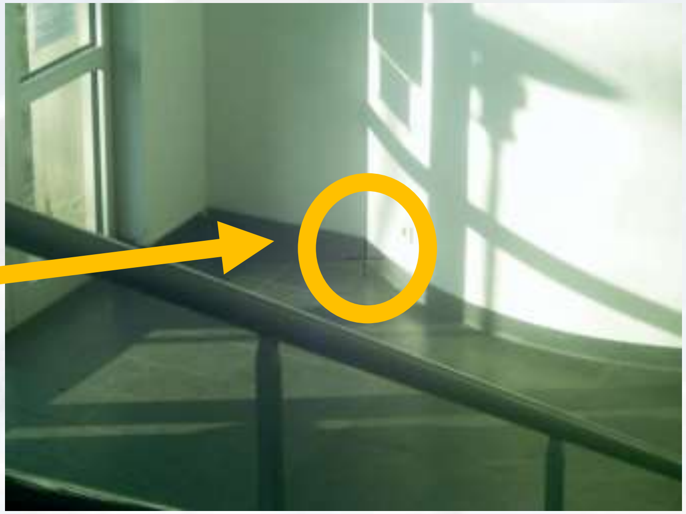
- Given: Autodesk Revit BIM project of the university (**Mensa building**)
- The **Intermediate Local Surveying Coordinate System** (LSS) between the BIM PCS and the national CRS has been introduced
  - Provides a common reference system and frame with scale=1 and short coordinate values
  - Allows to integrate multiple BIM projects (e.g. Mensa building, Building A, Building B)
  - The LSS is than georeferenced to a national CRS

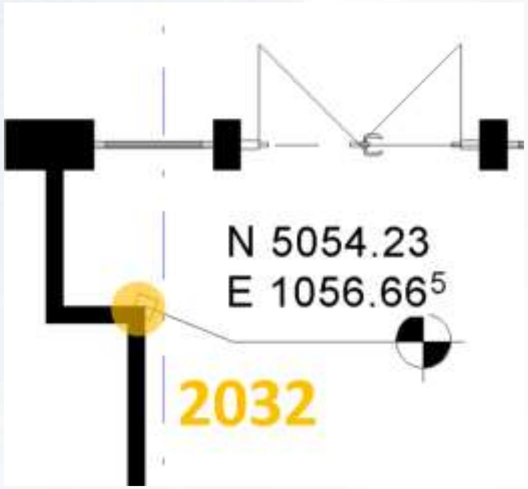


Control points

- In order to spatially link the LSS and the PCS, a set of identical points was defined and measured
- This control points are specified in the BIM model and as natural targets of the engineering survey outside and inside the building



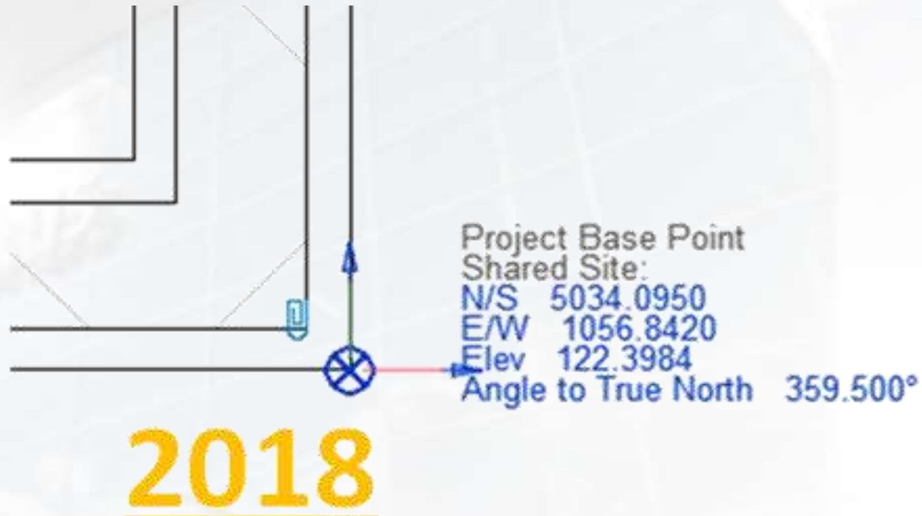




Georeferencing Using Revits Project Base Point

A BIM model can be georeferenced by moving the **Project Base Point** (PBP) to a control point with known coordinates

1. Unclip and move the PBP to the well identifiable corner within the building model which corresponds to the pre-measured control point #2018 using the point snapping function
2. Clip the PBP and assign the LSS coordinates of the point #2018 to the PBP properties
3. Insert the pre estimated azimuth angle of 359.5° to the PBP properties



Georeferencing Using a CAD File

A BIM model can be georeferenced by acquiring the LSS coordinates from a CAD file containing measured lines and polygons of the building elements

1. Link the CAD file to the Revit project using Revit linking functions
2. Placed the CAD elements (yellow) in the BIM Model (black) graphically by using the “move” and “rotate” tools as well as “Line Snapping” tool
3. Use “AcquireCoordinates” to assign transformation parameters between the Revit PCS and the LSS to the Project Base Point

Georeferencing Using the Plug-In Point Layout

Plug-in “Autodesk Point Layout” (APL) provides functionalities for the surveyor’s work within the BIM, i.e. assigning the transformation parameters from the Revit PCS to the LSS

1. Start the APL tool “Coordinates”
2. Select the desired unit (e.g. meter, millimeter, feet)
3. Click on two control points and enter the corresponding LSS coordinate values
4. The azimuth of the transformation is determined from coordinates

Our aproach with students:

- at least 4 control points
- proper adjustment (reliability!)
- Set transformation (North, East, Azimuth, Hight) in PBP

Export Georeferencing Using IFC

Software: Georeferencing a IFC project using the **IfcSite:LocalPlacement**

```
#1184287= IFCCARTESIANPOINT((1084.59446826616,5057.05699179754,116.6499));
#1184289= IFCDIRECTION((0.999977162717487,0.00675825742964856,0.));
#1184291= IFCAXIS2PLACEMENT3D(#1184287,#19,#1184289);
#1184292= IFCLOCALPLACEMENT($,#1184291);
#1184293= IFCSITE('1LROFPV2z2_wtYyzyn1ZUH',#41,'Default',$,'',#1184292,$,$,.ELEMENT.,(51,2,2,97821
```

Standard (IFC4): **IfcCoordinateReferenceSystem** *and*
IfcCoordinateReferenceSystem -> IfcProjectedCRS

- Name (e.g.: EPSG1234), GeodeticDatum (e.g. ETRS89), VerticalDatum (e.g. AHD)
- Unit, MapProjection, MapZone

```
#17=IFCPROJECTEDCRS('EPSG:31467','EPSG:31467 - DHDN / 3-Degree
Gauss- Krueger Zone 3','EPSG:31467',$,'Gauss-Krueger','3',#18);
```

More Information:André Borrmann, *IFC Infra Overall Architecture Project Documentation and Guidelines*, buildingSmart (2017)

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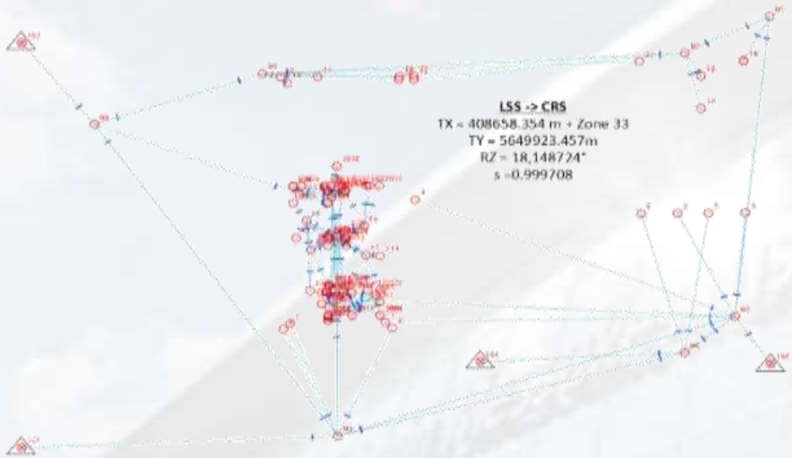

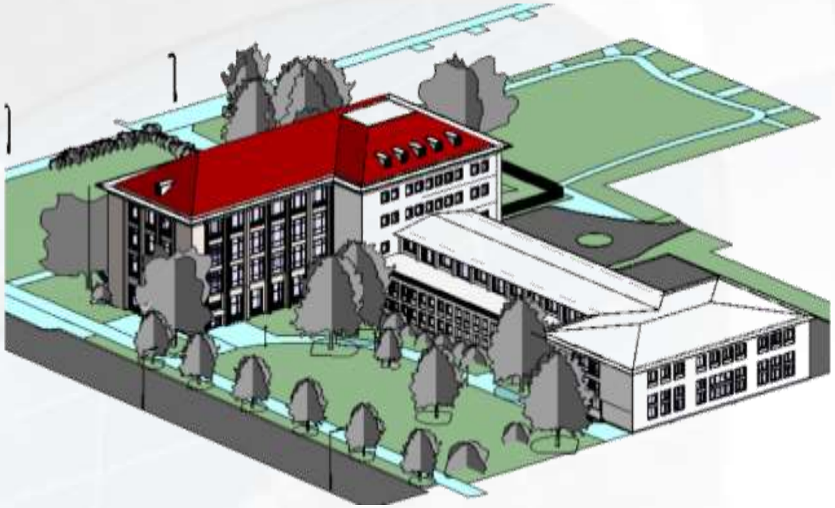

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