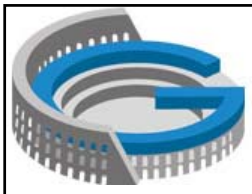

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# Prediction model to identify the significant development periods of the historical objects

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**Czech Republic**

## Syllabus

1. Goal of the project
2. Reconstruction of the historical object
   - materials collection
   - data selection and classification
   - data preparation (reconstruction in MicroStation, geo-referencing in ArcGIS)
   - output in ArcGIS: set of layers in historical periods
3. Design of prediction method
4. Set significant development periods of the historical object
5. Outputs, presentations

# 1. Goal of the project

**To propose a method for the determination of important structural changes of historic buildings**

**Input:**

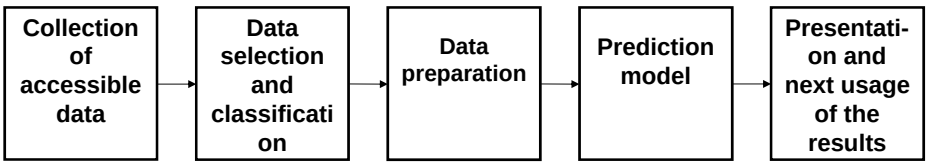
**list of all available layers of structural modifications of the historic building in various stages**

**Output:**

**Set of significant layers only**



# Workflow of the process

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## 2. Reconstruction of the historical object

- **Selection of the historical object**
- **Materials collection**
- **Data selection and classification**
- **Data preparation (reconstruction in MicroStation, geo-referencing in ArcGIS)**
- **Output in ArcGIS: set of all possible layers in historical periods**



## Selection of the historical object

**Špilberk castle – Brno, Czech republic**

Short history: Established under the reign of Přemysl Otakar II, 13th century,
then served as seat of Moravian margraves,
then was as prison and in the end became a national heritage monument in 1962.

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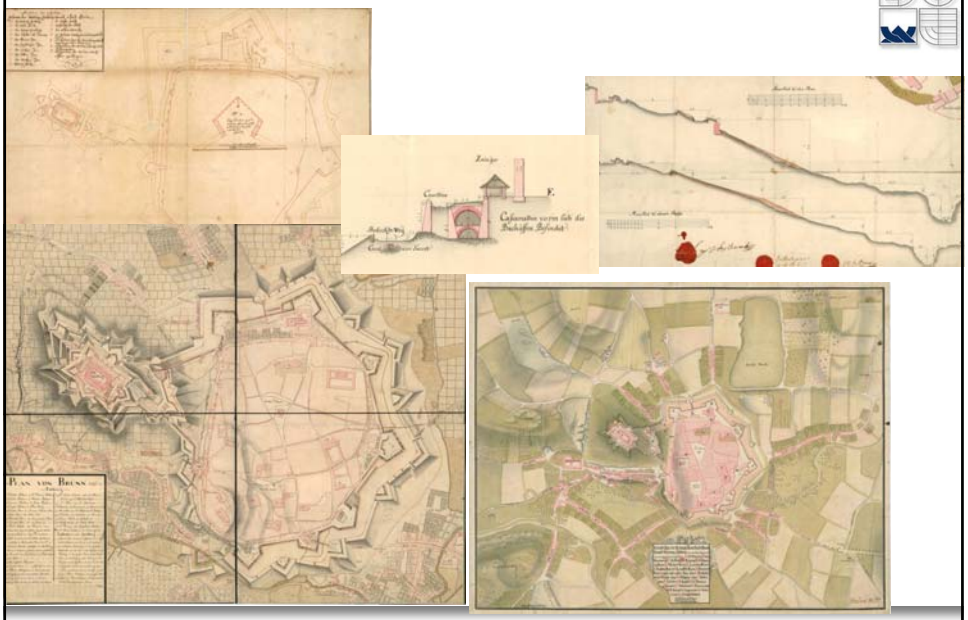
## Materials collection

| Data source (company) | Date | Number of sheets | Content | Format |
|---|---|---|---|---|
| Military Archive Vienna, Austria | 1658 - 1783 | 29 | Plans of Špilberk castle and Brno city | A0 – A1, raster, TIFF, 200 dpi |
| Archive of Brno city, Czech Republic | 1720 – 1944 | 10 | Plans, sketch of Brno city | A3, raster, JPEG |
| Museum of Brno city, Czech Republic | 1749 - 1984 | 4 | Plans in scale 1:1000 | A3, raster, JPEG, TIFF, B/W |
| Archaia ltd., Czech Republic | 1997 - 2004 | 3 | Plans of Špilberk fortification | DGN, DWG |
| ELGEO ltd., CZ. | 2006 | 2 | Digital cadastral map | DGN |
| Facility management of Brno city, Czech Republic | 2006 | 1 | Building structure investigation of Špilberk fortification | Raster, JPEG |
| Czech Office for Surveying and Cadastre | 2002 | 4 | Fundamental Base of Geographic Data (3D) | Raster CIT, vector SHP |
| Geodis Ltd., Brno | 2003 | 2 | Orthophoto 20 cm/pixel | Geo-TIFF, JPEG |



## Materials collection



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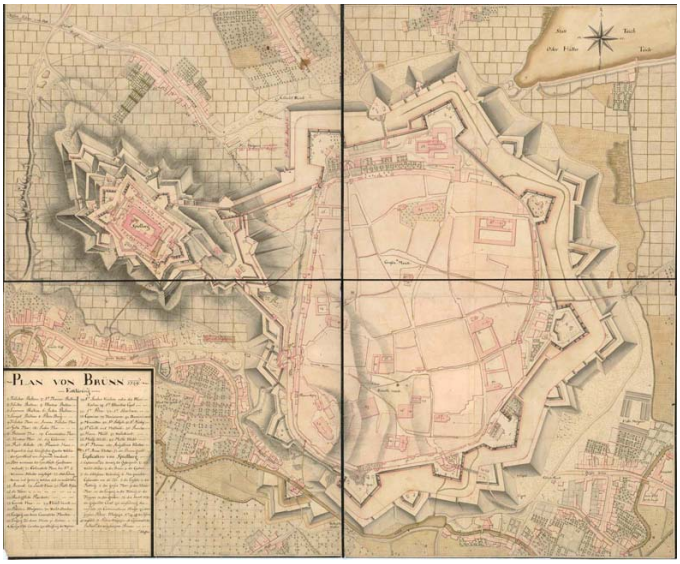
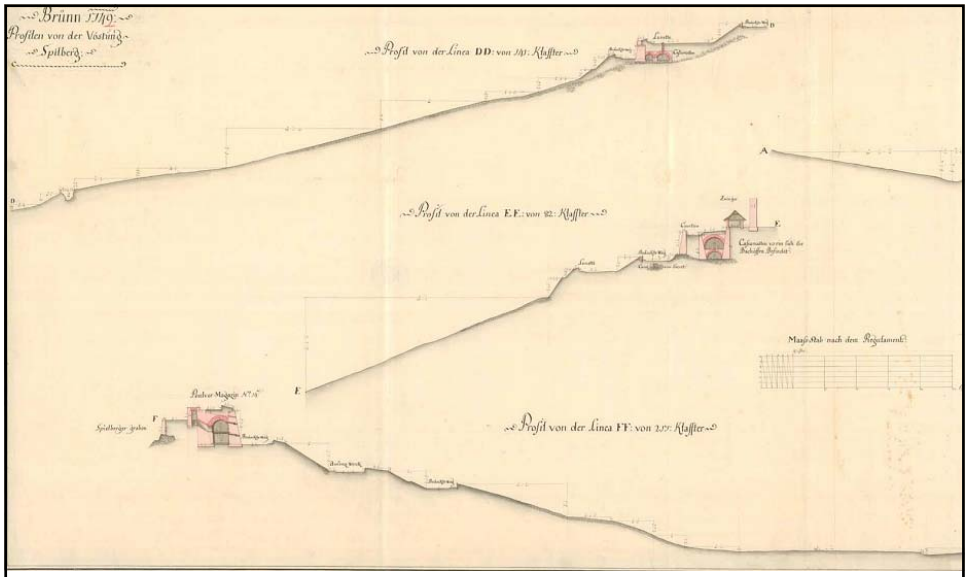
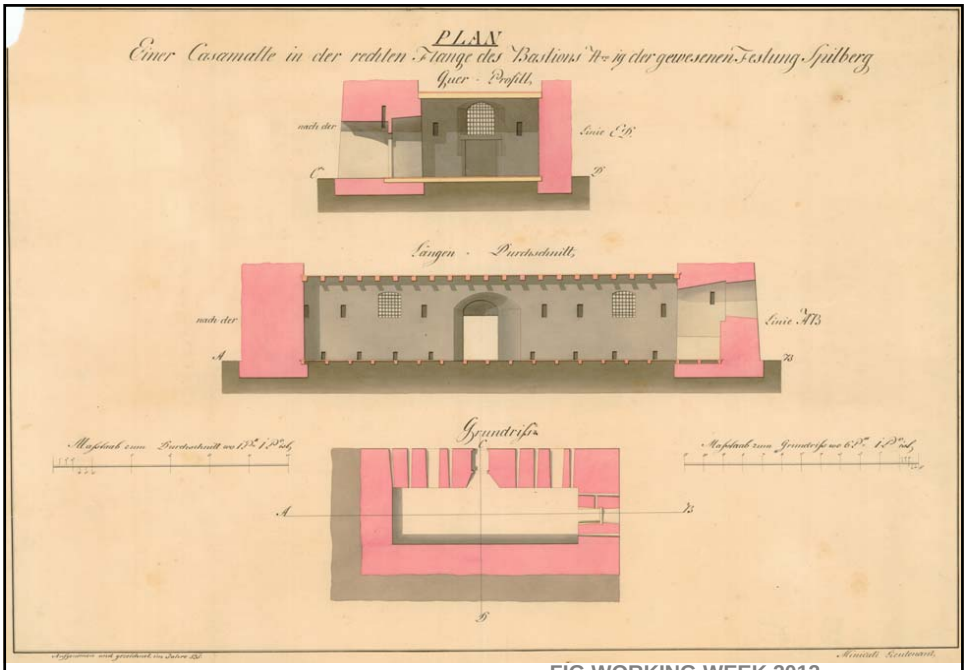



**De Rochepine's plan of Brno city of the year 1749**



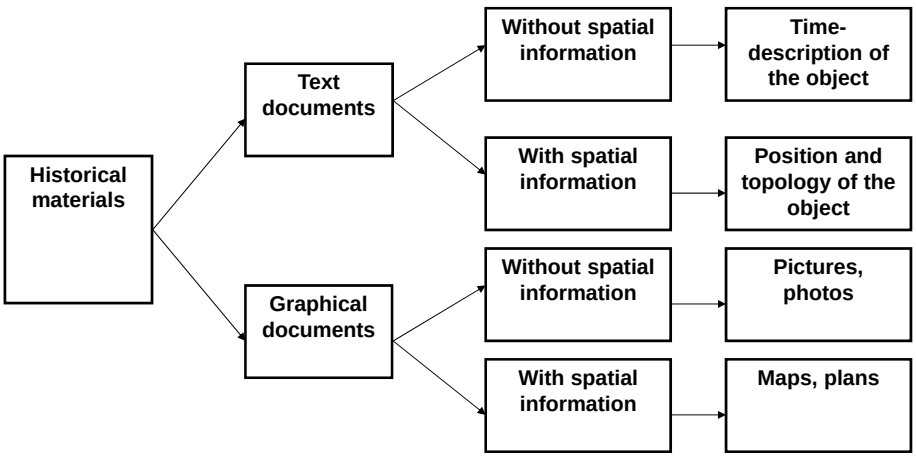



**Example of section of Špilberk castle of 1749**






## Data selection and classification

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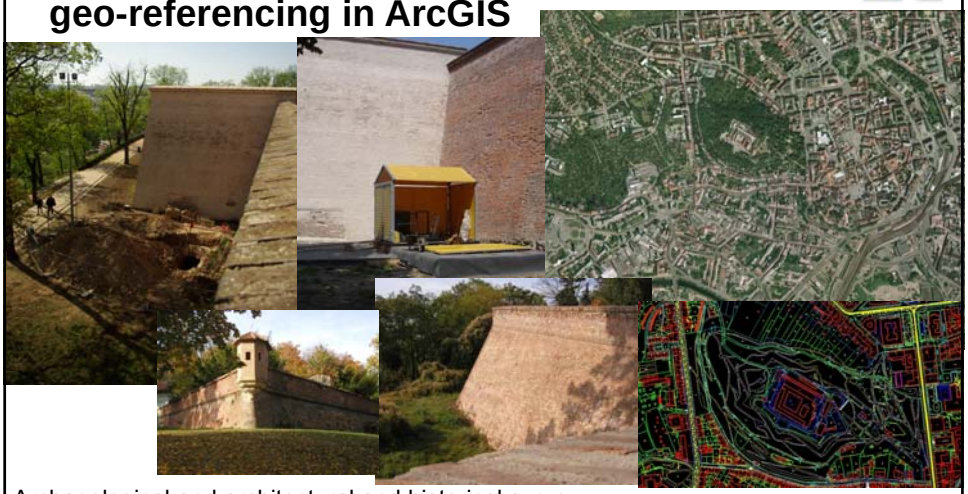
## Data preparation

**reconstruction in MicroStation, geo-referencing in ArcGIS**



Archaeological and architectural and historical survey



## Data preparation

- Raster and vector data modification (remove redundancy)
- Data selection and evaluation (identical points for geo-referencing, quality of old maps)
- Data completation (geodetic surveying in field)

# Data processing

- Planimetric reconstruction (2D)
  - Geo-referencing of historical maps in ArcGIS into S-JTSK system (Datum of Uniform Trigonometric Cadastral Network in the Czech Republic)
  - Data editing and vectorization
  - Stages of construction work determined (new *.shp layers creating)



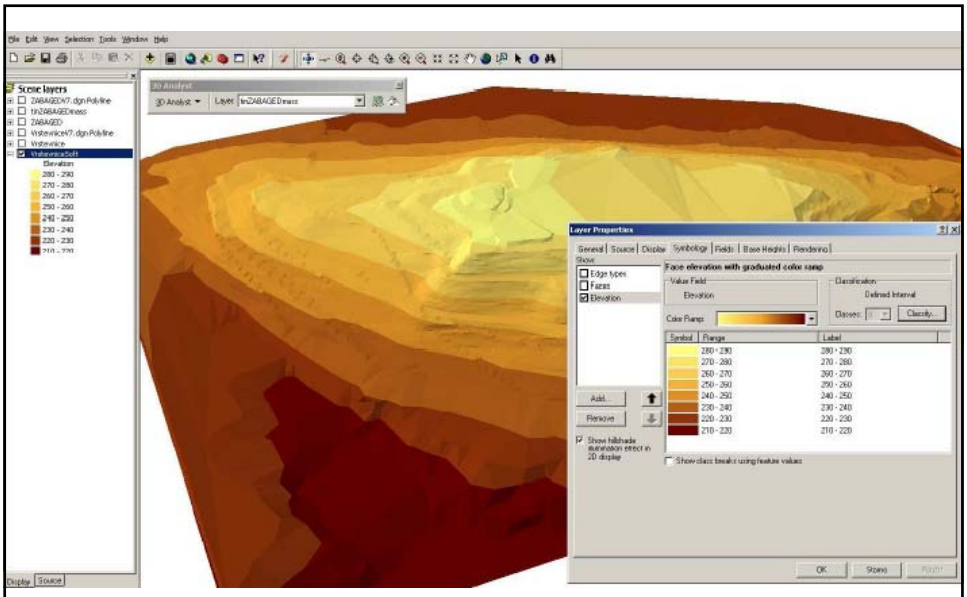
# Data processing

- Altimetry reconstruction (3D) – 2 phases
  1. The creation of digital terrain model (DTM) of Špilberk hill
  2. 3D model of historical reconstruction of Špilberk castle and its fortification
  - materials for DTM have been used (1. phase):
    - A plan of Špilberk castle of 1984 (Brno Museum) in the scale 1:1000 with contour lines with 1 – 0,5 m
    - Altimetry of Špilberk in ZABAGED system (Fundamental Base of Geographic Data)

## 3D model of historical Špilberk castle creation

1. Finding out and drawing approximate position of the section (identical points). Measuring in field (GPS RTK + laser range finder)
2. Marking intersection with current contour of the object (geo-referencing)
3. Profile unification with current condition of the object. Calculate Viennese fathom (1° = 1,896 m), ell (77,8 cm) and inch into metric system
4. Verification of created profile according to contour lines in digital terrain model





**TIN of Špilberk hill in 3D Analyst (ArcGIS)**

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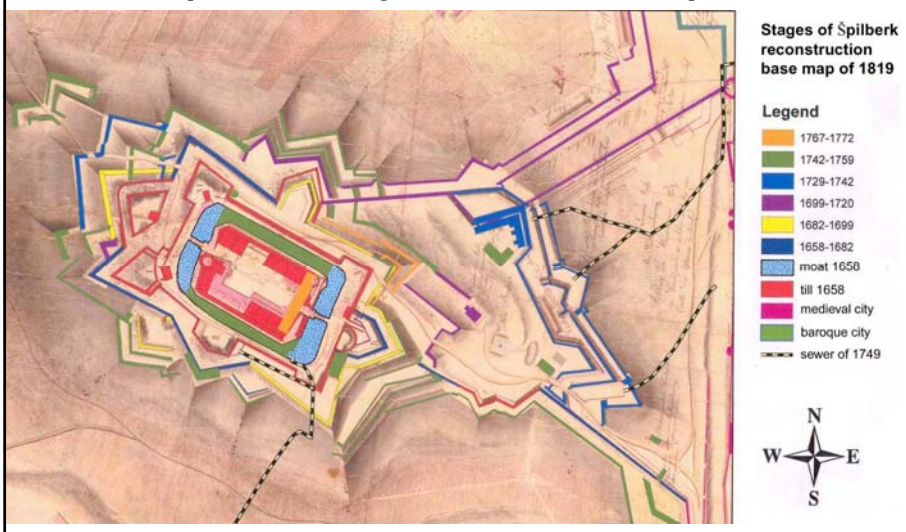
## Output in ArcGIS

**create all possible layers in historical periods**



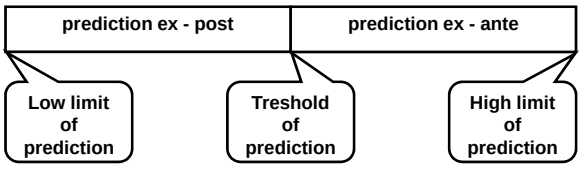



## 3. Metod of prediction

### Typology of prediction models (in general)

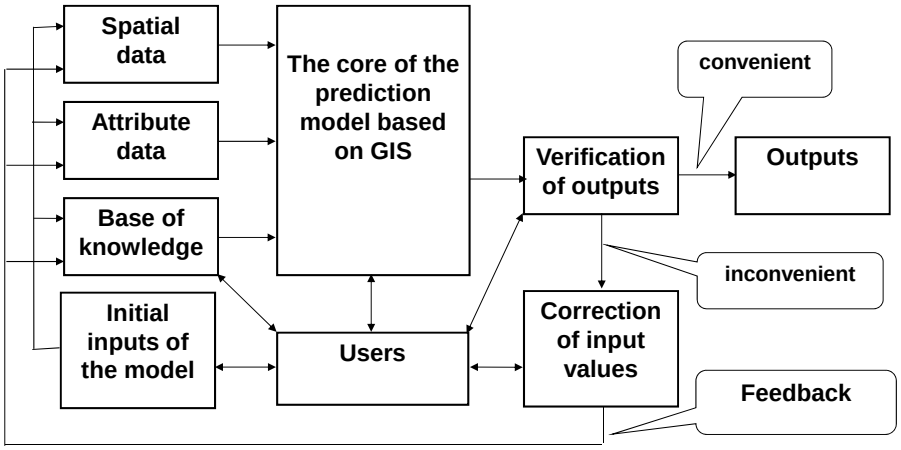
Stand-points:

1. Temporal (pre- or post-introduction)




2. Methodology (experimental, simulation, inductive, deductive)
3. Technical processing
   - statistic analysis (analysis of time series, regression analysis)
   - artificial intelligence (neural networks, genetic algorithms)
   - GIS
4. Determination/purpose (marketig, finance, economy, medicine,…)

## Conception of the prediction model






## Prediction model based on Markov chain

the conditional distribution of any state $X_{n+1}$, given the past states $X_1, X_2, \ldots, X_n$, $n$ 1 and the present state $Xn$, is independent of the past states and depends only on the present state.

$$P\{X_{n+1} = j | X_n = i, X_{n-1} = i_{n-1}, \ldots, X_2 = i_2, X_1 = i_1\} = P\{X_{n+1} = j | X_n = i\} = P_{ij}$$

$$P_{ij} \geq 0, i, j \geq 0; \sum_{j=1}^{\infty} P_{ij} = 1, i = 1,2,\ldots$$

## Prediction model based on Markov chain

If the process has a finite number of states, which means the state space S={1,2,y, i, j, … s}, then the Markov chain model can be defined by the matrix of one-step transition probabilities:

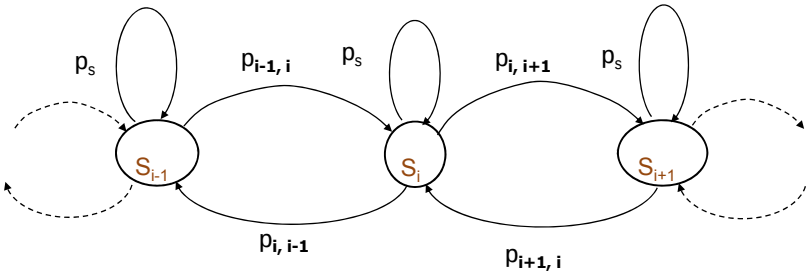
$$P = \begin{bmatrix} P_{11} & P_{12} & P_{1s} \\ P_{21} & P_{22} & P_{2s} \\ P_{s1} & P_{s2} & P_{ss} \end{bmatrix}$$

$$P_{ij} = \frac{N_{ij}}{N_i}$$

The initial probability $P_{ij}$:
$N_{ij}$ denotes the transition times from state *i* to state *j* and $N_i$ denotes the number of random variables $\{X_n, n=1,2, \ldots, m\}$ belonging to state *i*.



## Prediction model based on Markov chain




| | |
|---|---|
| $p_s$ | is probability of remaining in the current state |
| pi, i-1 | is probability of transition to previous state |
| pi, i+1 | is probability of transition to next state |

## Prediction model based on Markov chain

Interpretation of states in Markov chain:

Changes in position between objects in neighboring layers in ArcGIS
Procedure scans by window and computes the probability to the differences between position of the object in various periods
Interpretation: changes ⟺ uncertainity ⟺ accuracy
Accuracy estimation: approximatelly 0,4 m
Changes: > 0,5 m in position



## 4. Set significant development periods of the historical object

| | Main stages of construction work | Used historical maps (year) |
|---|---|---|
| 1 | until 1658 | 1658 |
| 2 | 1658 – 1682 | 1658, 1678, 1682 |
| 3 | 1682 – 1699 | 1699 |
| 4 | 1699 – 1720 | 1699, 1720 |
| 5 | 1720 – 1742 | 1729, 1742 |
| 6 | 1742 – 1759 | 1742, 1749, 1756, 1759 |
| 7 | 1759 – 1772 | 1759, 1767, 1772, 1783 |

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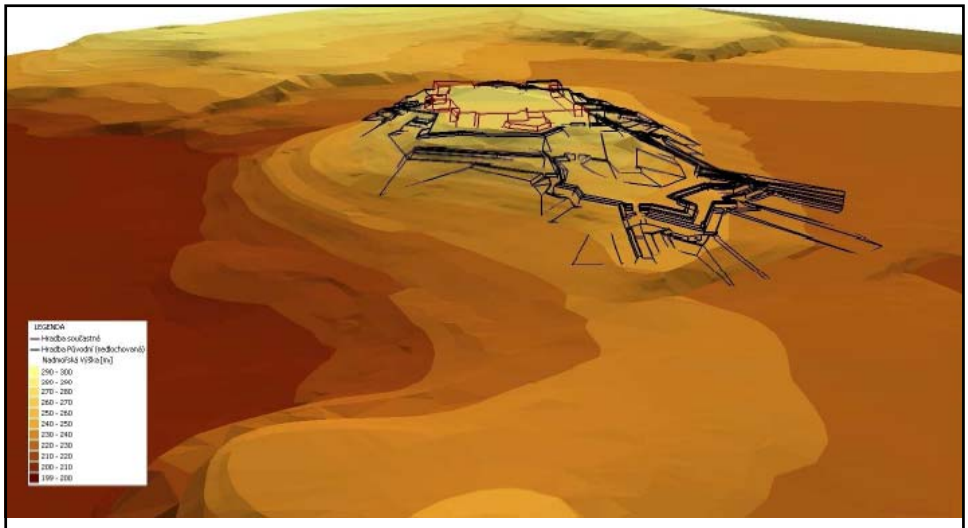
## 5. Outputs, presentations

- **Historical wireframe model of Špilberk castle**
- **Stages of Špilberk castle construction work, TIN base**
- **3D model of Špilberk castle of 1759 in Sketch-Up program**





**Historical wireframe model of Špilberk castle**

MicroStation V8, altimetry system Bpv (Baltic Vertical Datum after Adjustment)

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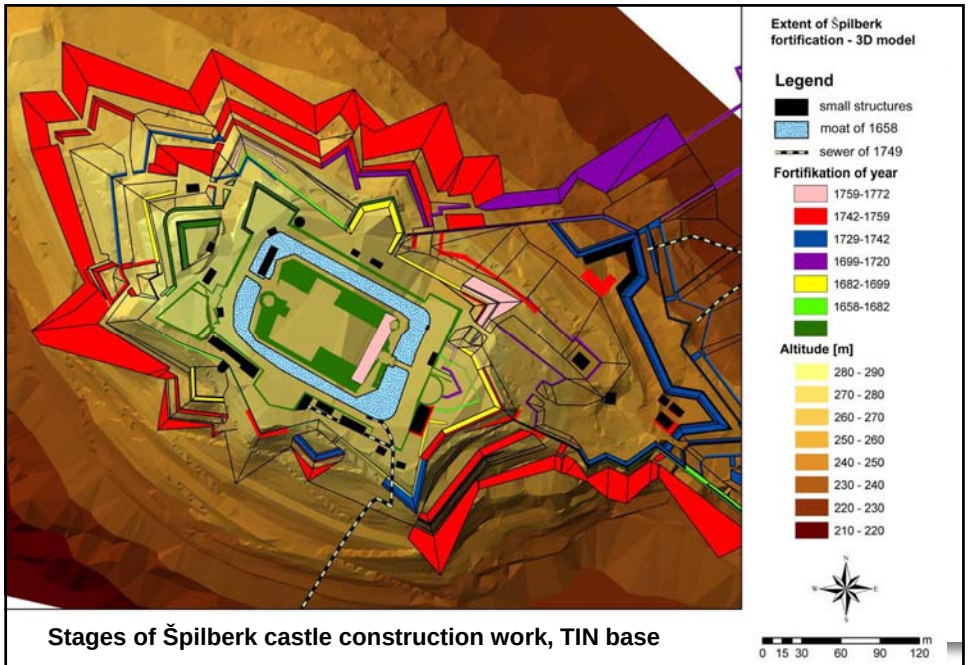
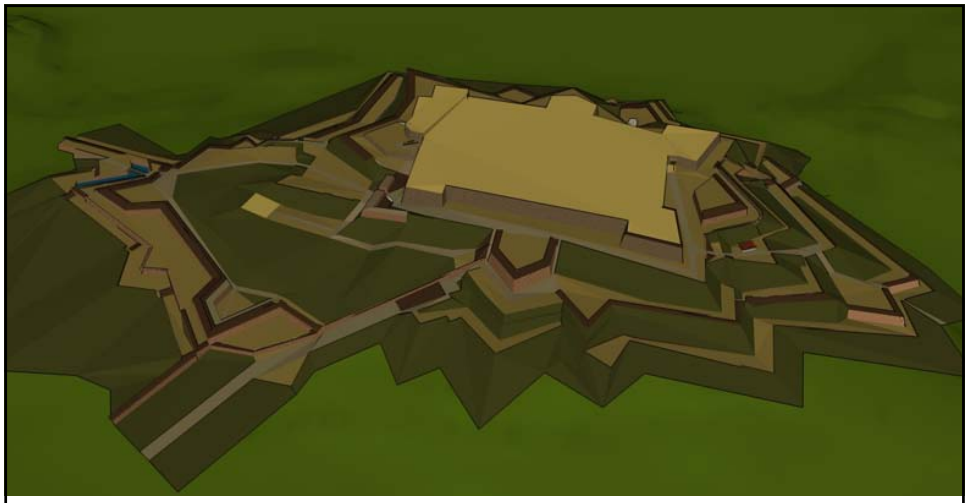



**Stages of Špilberk castle construction work, TIN base**





**3D model of Špilberk castle of 1759 in Sketch-Up program**

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# Conclusions

- Creation of 3D model today non-existing baroque fortification of Špilberk castle (will be improved)
- It will be historically the first 3D digital model of the citadel taking original shape the one in the second half of 18th century (baroque)
- Significance both for specialists and general public




**Thank you for your attention**