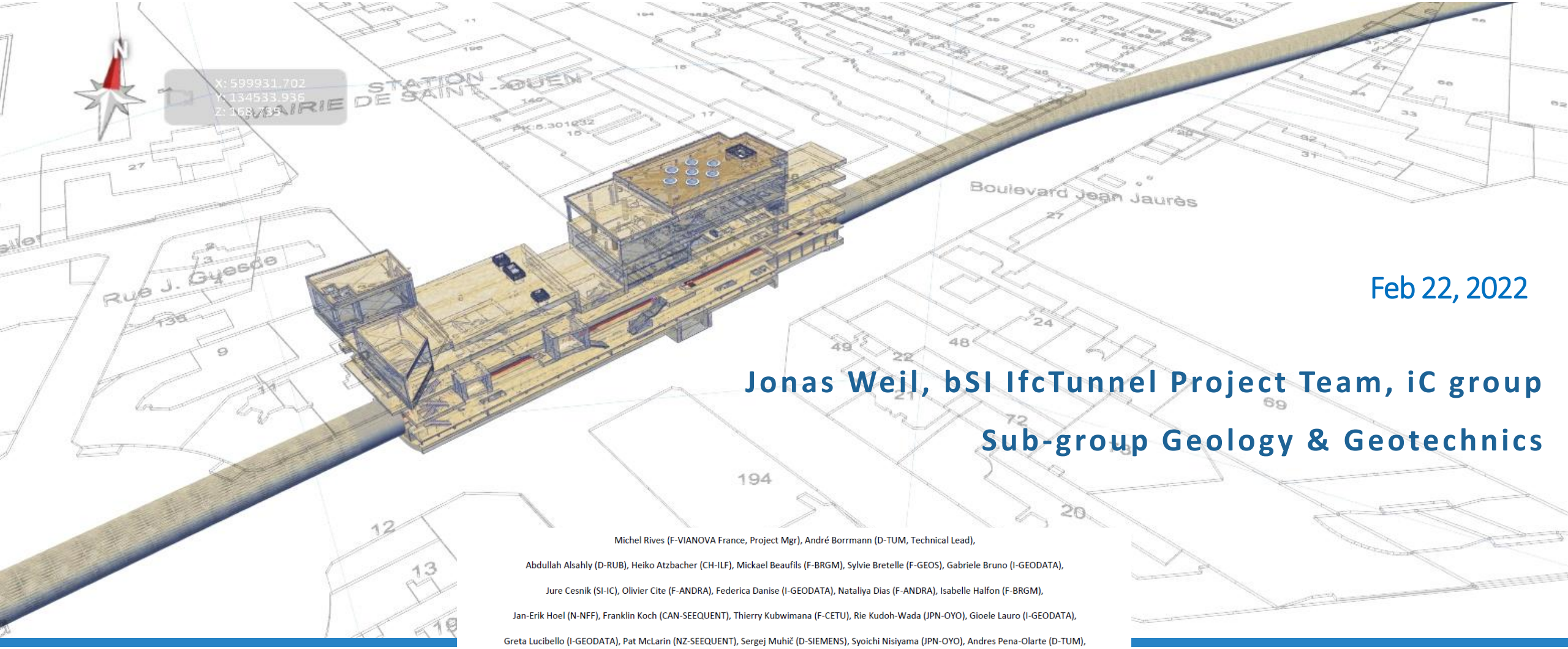
Ground models
Geology & Geotechnics in IfcTunnel



Feb 22, 2022

Jonas Weil, bSI IfcTunnel Project Team, iC group

Sub-group Geology & Geotechnics

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Jan-Erik Hoel (N-NFF), Franklin Koch (CAN-SEEQUENT), Thierry Kubwimana (F-CETU), Rie Kudoh-Wada (JPN-OYO), Gioele Lauro (I-GEODATA),

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IfcTunnel – Deliverables

Phase 1: Requirements

- Geopositioning & geometries
- Soil/rock conditions
- Construction methods
- Systems serving the function

Uses cases (30u)

Requirements refinement (v2)

Phase 2: Specifications (4.3+)

Domains taxonomies (DD)

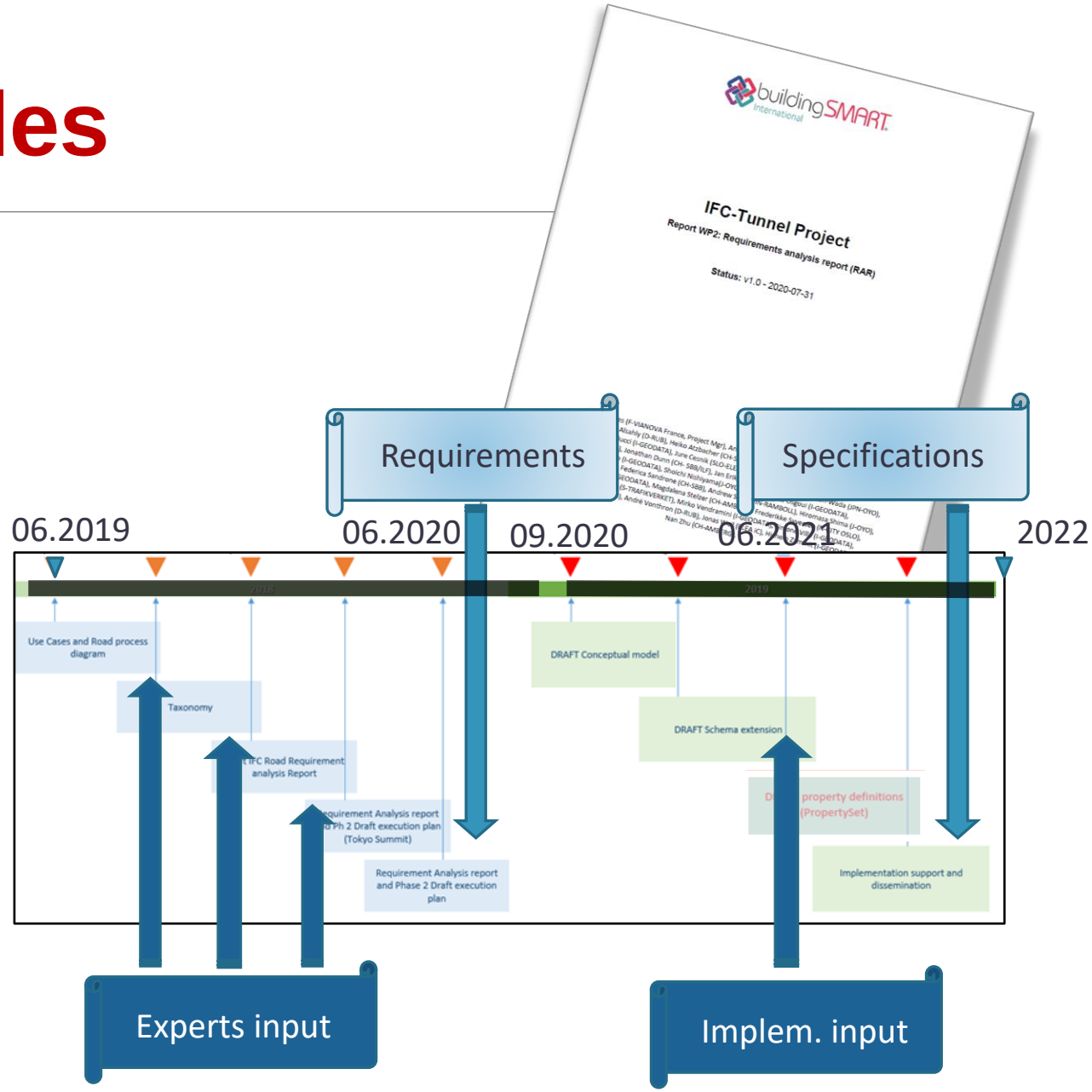
UML Conceptual model

Xpress schema

HTML documentation

Exchange requiremts / Tests ⇦ 2022

SW implementers support ⇦ 2022



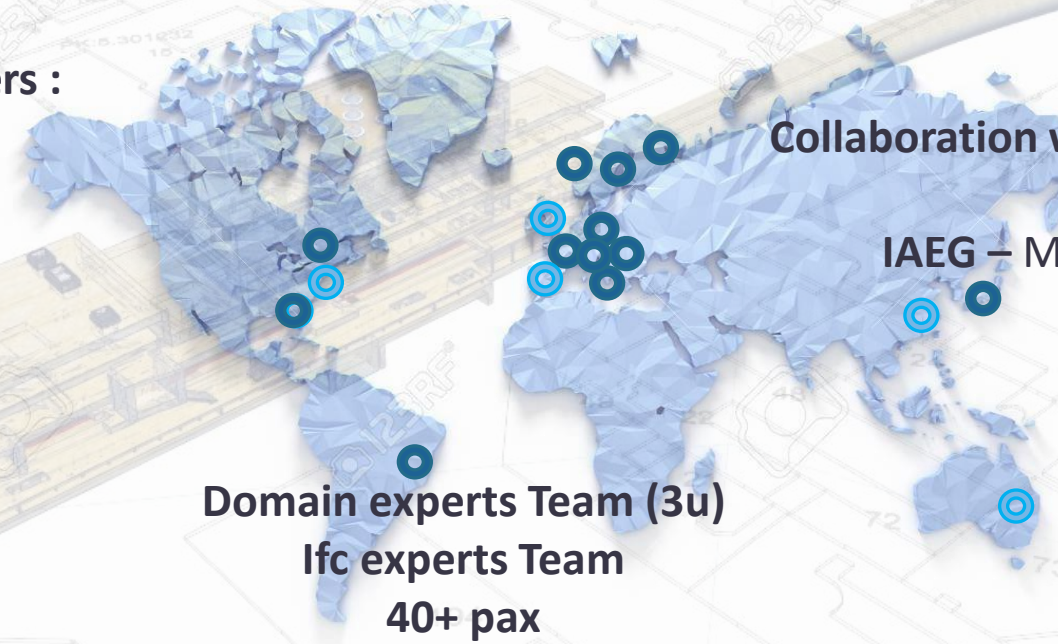
IfcTunnel – Stakeholders 2020-2022

Infrastructures owners :
- ANDRA (F)
- CFF-SBB (CH)
- TVK (S) / FTIA (FIN)

Geotechs, C.E. & systems engineers :
- IC-Group (AUT, SLO)
- GEODATA (I)
- ILF (CH)
- LOMBARDI Grp (CH)
- OYO (JPN)
- SEEQUENT (NZ)

National (prescriptive) agencies :
- DGTIM-CETU (F)
- NFF (N)

Research bodies :
- MINnD (F)
- RUB (D) / TUM (D)
- Univ. of Florida (USA) / Univ. of Loeben (A) / Univ. of SP (BR)



Domain experts Team (3u)
Ifc experts Team
40+ pax
10 sessions/mth x 20 mths = 200 u
200 x 10 pax = 1.000 m*d = 1.2m€

MoU with stakeholders

Budget:
v1 for 2020 & 2021
v2 for 2022

Collaboration with international associations:
ITA – Modelling in tunnelling
IAEG – Modelling in engineering geology

Talks with new partners:
RedBex (A)
Austroads, Aurecon, 12d (AUS)
CCCC (CHN)
Ferrovial (SP)
HS2, NetworkRail (UK)
AASTHO, Bentley Systems (US)
ODA, RDF, GeomG (Int'l)

IfcTunnel – Geology & Geotechnics

Background and motivation

Tunneling requires description of the ground conditions.

Typical challenges in large infrastructure projects:

- Large volumes of geological and geotechnical factual data
- Translation into simplified but representative geotechnical models
- Verification and update based on additional data
- High construction costs / ground conditions as a factor of uncertainty
- Long term storage and access required for operation and maintenance

IfcTunnel – Geology & Geotechnics

Focus

Factual data (observations and measurement results): Standardized exchange format with included geometry required for

- spatial assessment for developing and verifying interpreted models
- visualization in domain-specific software and common BIM systems

Geological models as basis for identifying relevant aspects from engineering perspective

Use case specific geotechnical models

Link to design models (prognosis and as built + encountered conditions)

IfcTunnel – Geology & Geotechnics

Overview: current activities and status

- Use case descriptions (as published 2020 in WP2)
- Taxonomy for conceptual model, UML-model
- Concepts to describe different types of uncertainty
- Geometrical representations: Requirement of voxel models
- Concept to link model of ground conditions to design

Input

ITA AITES

OGC® Making location count.

MND

DAUB

ENG GEOL IAEG AIGI

Etc.

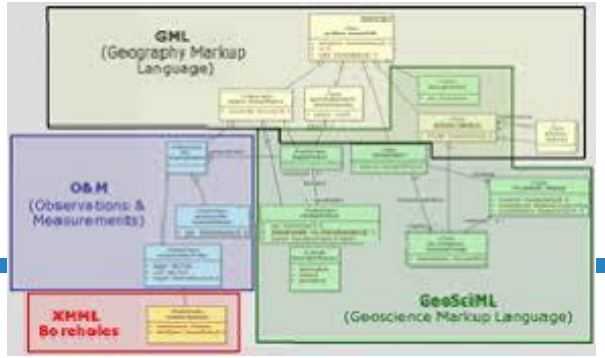
IfcTunnel – Coherence of concepts

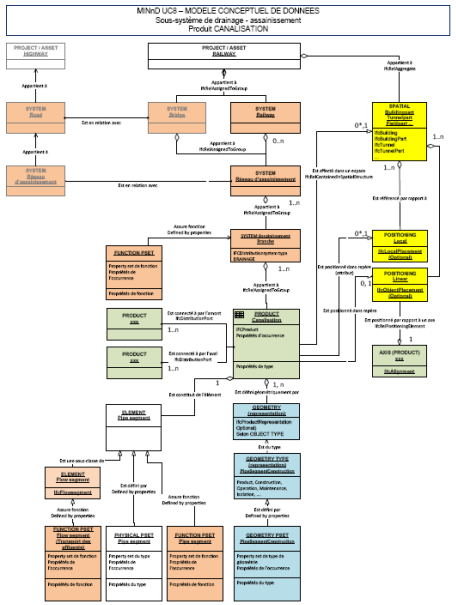
Coordination with OGC :

- Common semantic for Geotechnics ‘objects’
- Implementation into Ifc4.3.x
- Implementation into GeoSciML

IFC 4.3

OGC®
Open Geospatial Consortium, Inc.





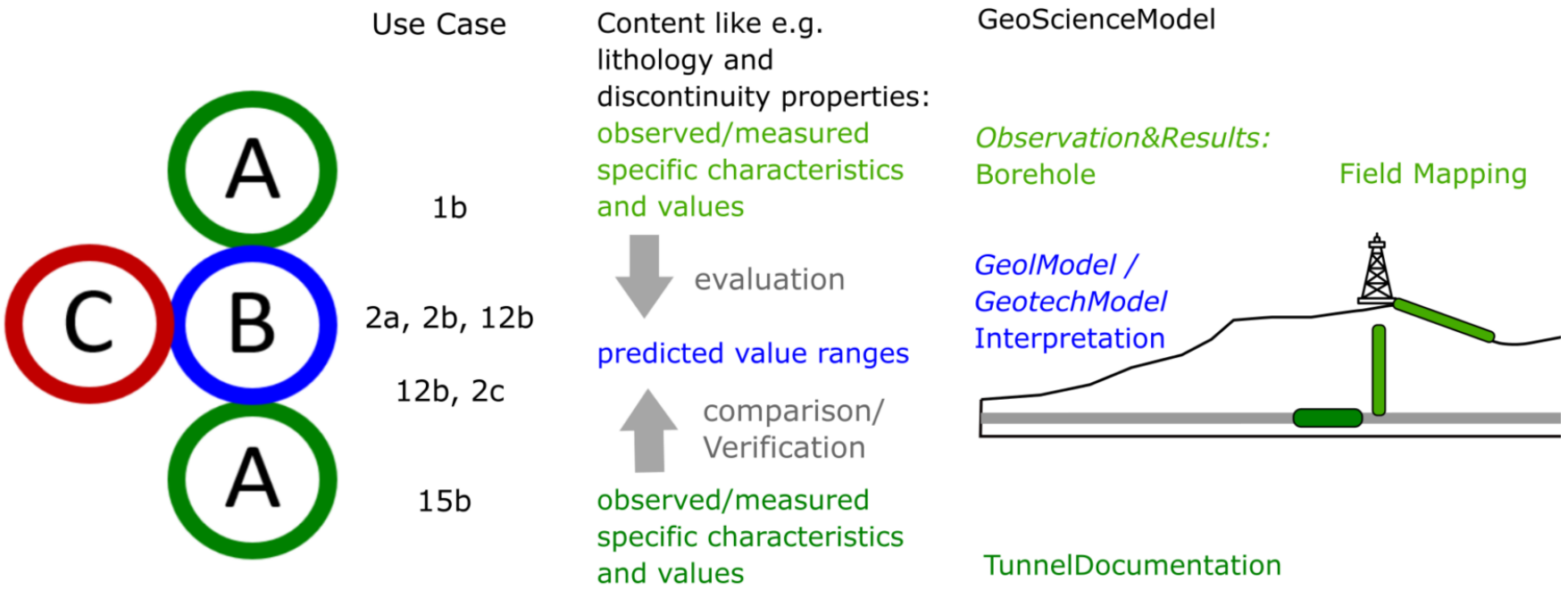
	OGC GeoScience Standards	IFC4.3 Common Schema (bSi)	Requirements of IFC-Tunnel (bSi)
Semantics	**Detailed semantics for various disciplines** **Geotechnics currently not covered (*)**	**Limited** (only one interpreted model)	Formulated in use case descriptions, draft taxonomy and process map
Geometry			
3D geometry – TriangulatedFace or Brep	**Geometry not defined in the standards.** **The semantics can be applied to various geometrical representations** **(OGC and others)**	Covered	Required
3D geometry – Voxel		Covered	Required
2D geometry		Covered	Required
Factual Data, (A), GeoDocu			
Geological mapping	Covered (GeoSciML + GML for 2d geometry)	Not covered	Link/Required
Geotechnical Documentation	Not covered yet (*) GeoSciML: Lab Analysis and Specimens (ISO 19156) Bit not geotechnical tests and parameters	Not covered	Required: Mapping, key outcrops, discontinuities, Test results, Geophysics, Tunnel Docu, Slope Docu,…
Boreholes	GeoSciML: Borehole concept GroundWaterML2: GeologyLogCoverage based on ISO 19156: NO geotechnical properties for log yet (*)	Drilling methods and borehole equipment Representation of interpreted model (SolidStratum) NO original log NO factual data	Required, Including key parameters of Geologic and geotechnical log (factual data) link to external sources

	OGC GeoScience Standards	IFC4.3 Common Schema (bSi)	Requirements of IFC-Tunnel (bSi)
Interpreted Models (B)			
Geologic Unit	GeoSciML: GeologicUnit concept	Not covered	Required
Geologic Structure	GeoSciML: GeologicStructure concept (including faults, foliation, bedding etc.)	Not covered	Required
Hydrogeologic Unit	GroundWaterML2: HydroGeologicUnit	WaterStratum NO aquifer	Required, Aquifer and piezometric water level
Geotechnical unit	Not covered yet (*)	SolidStratum: Representation of interpreted model Properties NOT sufficient Adequate terminology?	Required, related to design purpose Including link to factual data
Discontinuities (geotechnical)	Not covered yet (*)	Not covered	Required
Properties			
Geological parameters	Stratigraphy, Age, Lithology, Mineralogy,… CGI vocabularies	Not covered	Required
Geotechnical parameters	Not covered yet (*)	Mainly selected soil parameters Hard rock parameters not covered Adequate terminology?	Comprehensive parameter lists for tunnel design - soil, rock (rock mass and intact rock), ground behaviour, TBM-specific
Uncertainty	Not covered yet (*)	Existing in form of properties for geoemetry/extend of geotechnical units, not sufficient	Required for factual and interpreted data, several aspects
Risk	Not covered yet (*)	Intended	Required Interaction with design and general risk register

IfcTunnel – Geology & Geotechnics

Focal points: exchanged geological/geotechnical information and models

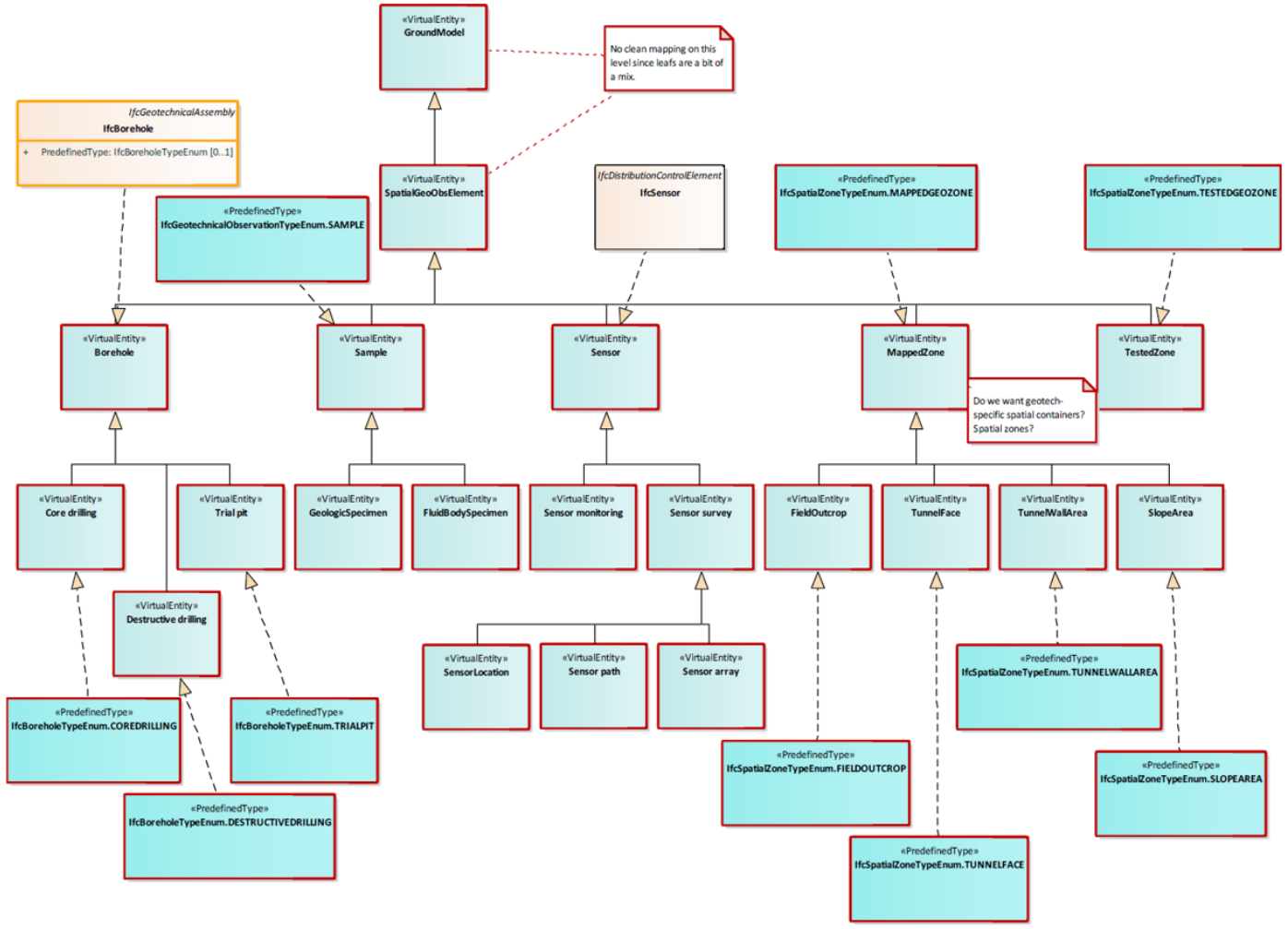
A: Factual Data (measurements and observations, before and during construction)
B: Interpreted models (geological + geotechnical models)
C: Design solutions, applications and risk assessment based on these interpreted models



IfcTunnel – Geology & Geotechnics

Observations / Book A

- Domain-specific collection of typical data sets and classification of different types
- Objects with geometrical representation vs. semantic elements
- Link to external files for extensive datasets (e.g. borehole data, MWD or geophysical logs)



Graphical visualization / UML drafts

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IfcTunnel – Geology & Geotechnics

Observations / Book A

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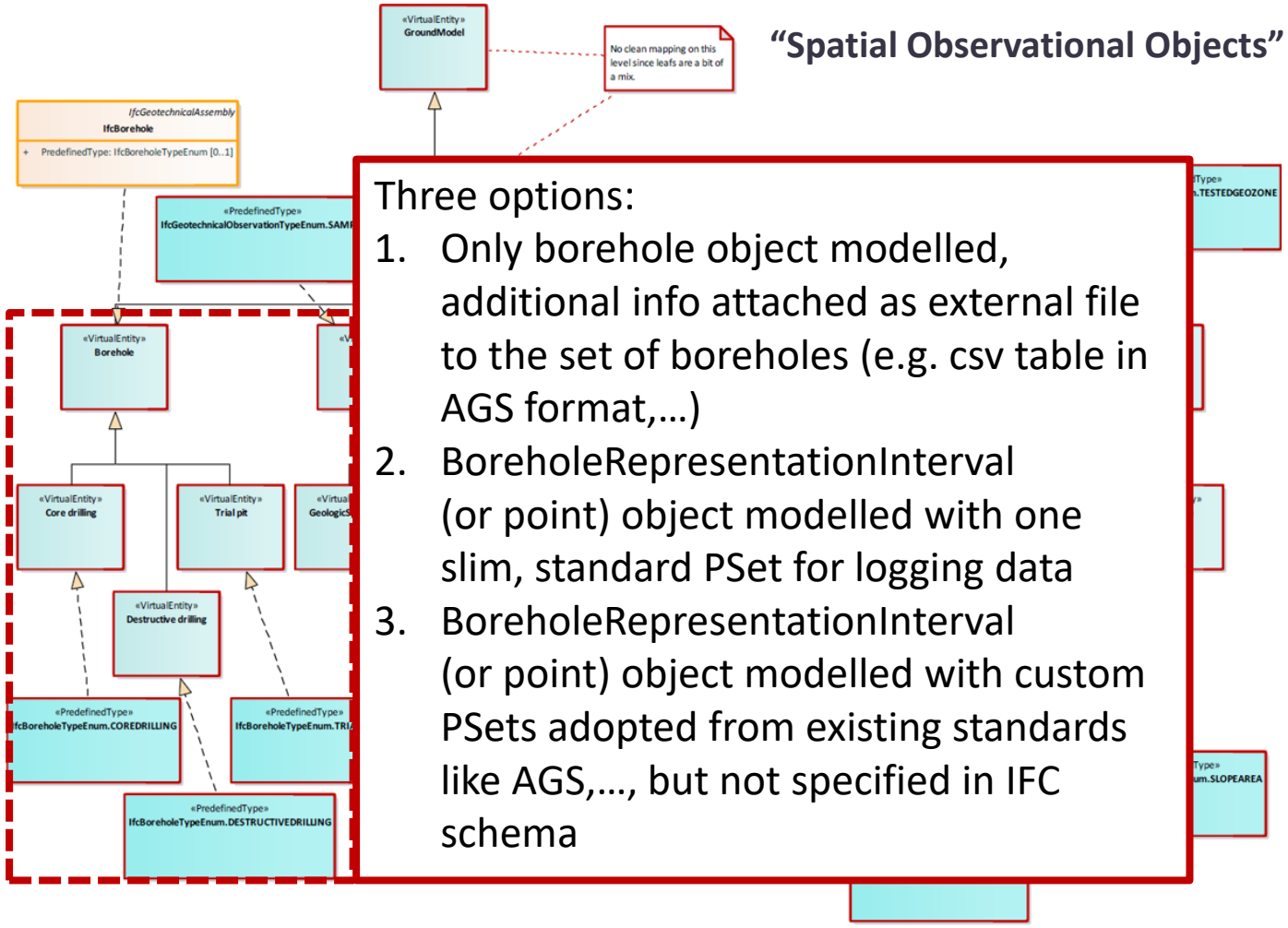
Example: borehole data

“Spatial Observational Objects”



Graphical visualization / UML drafts

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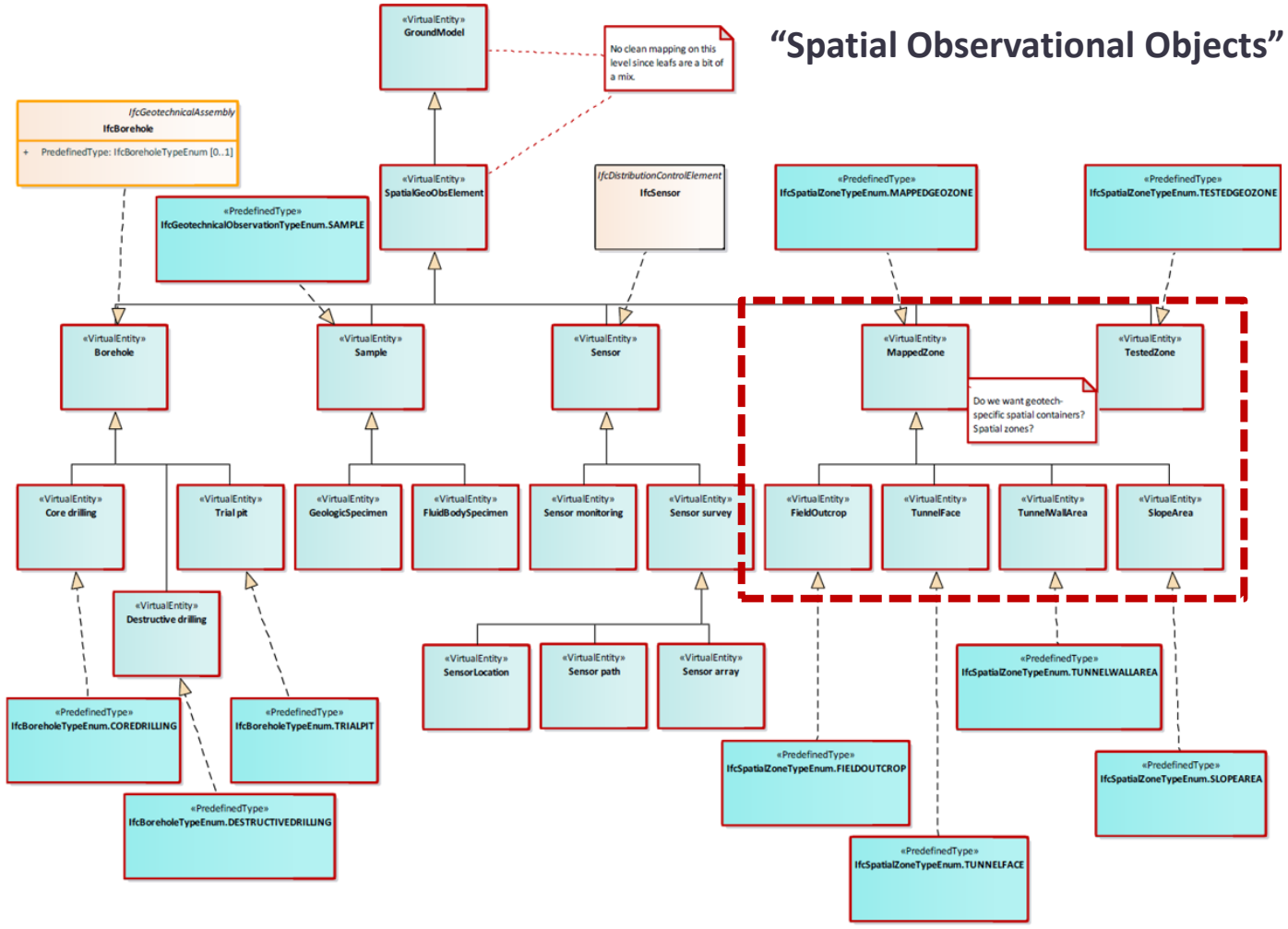
Example: geological outcrop and tunnel documentation

“Spatial Observational Objects”



Graphical visualization / UML drafts

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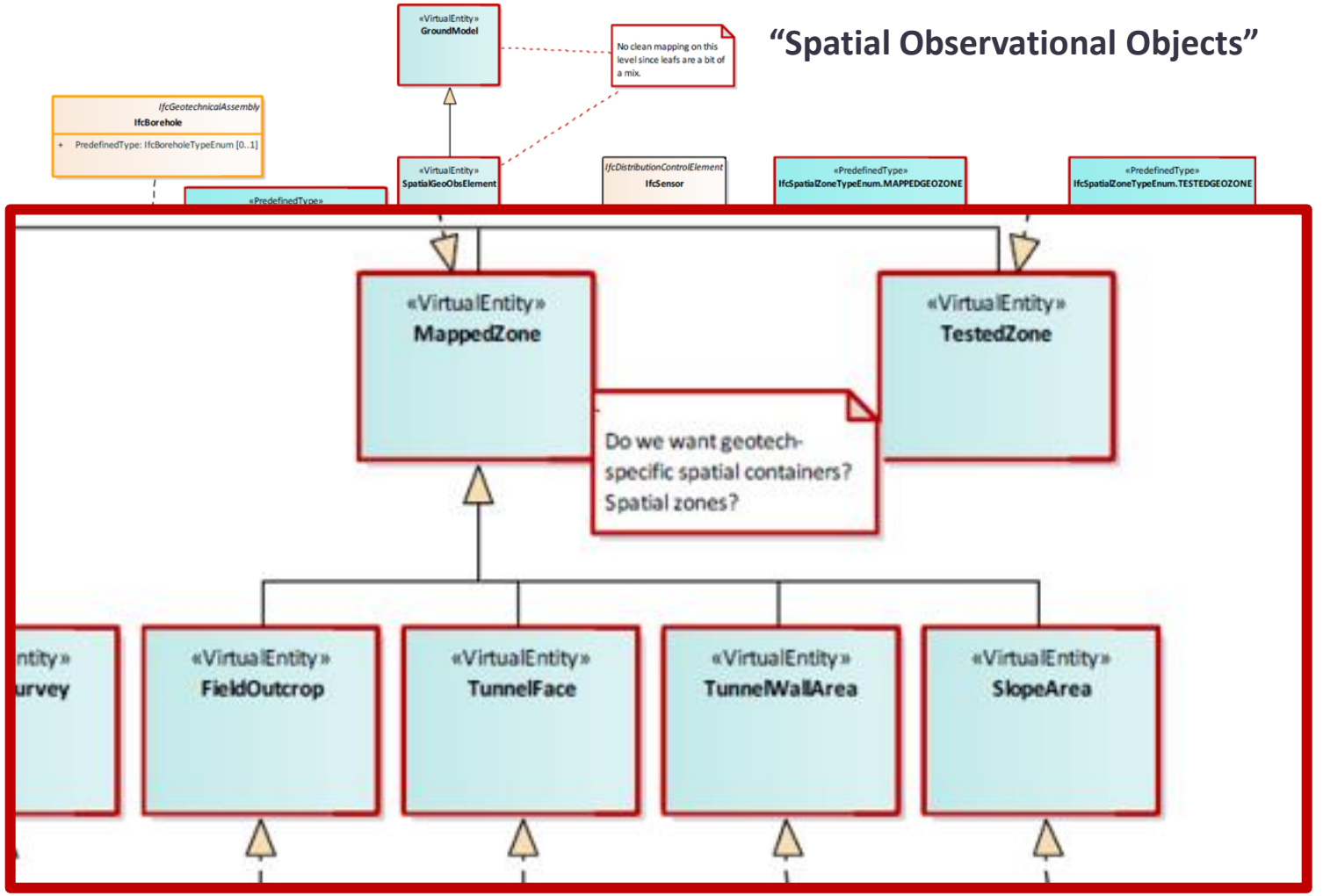

Graphical visualization / UML drafts

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IfcTunnel – Geology & Geotechnics

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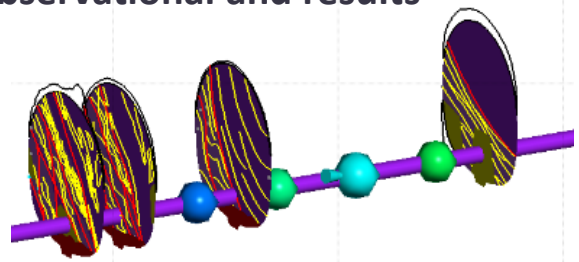
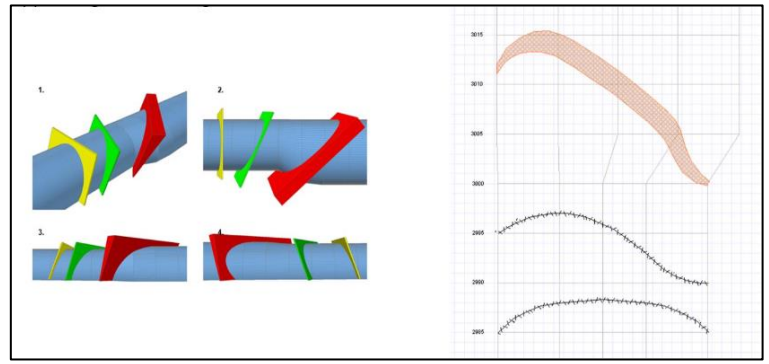
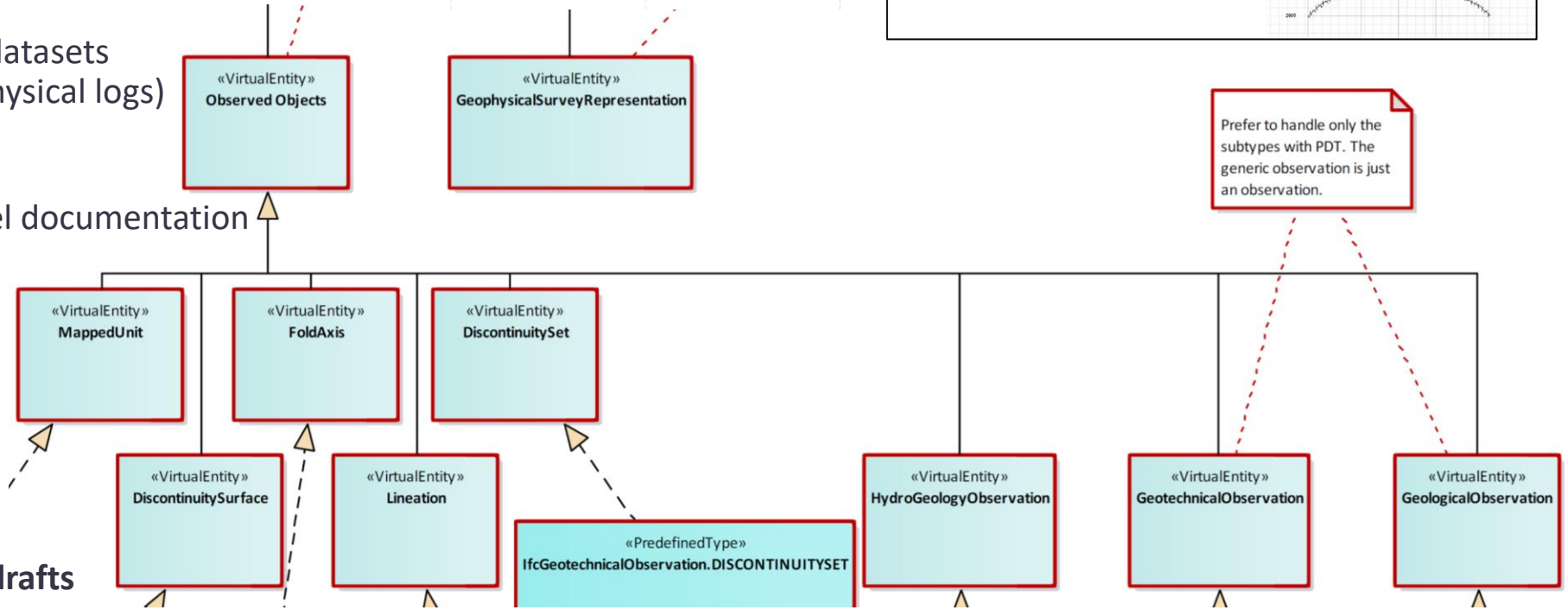
Example: geological outcrop and tunnel documentation

“Observational and results”







Graphical visualization / UML drafts

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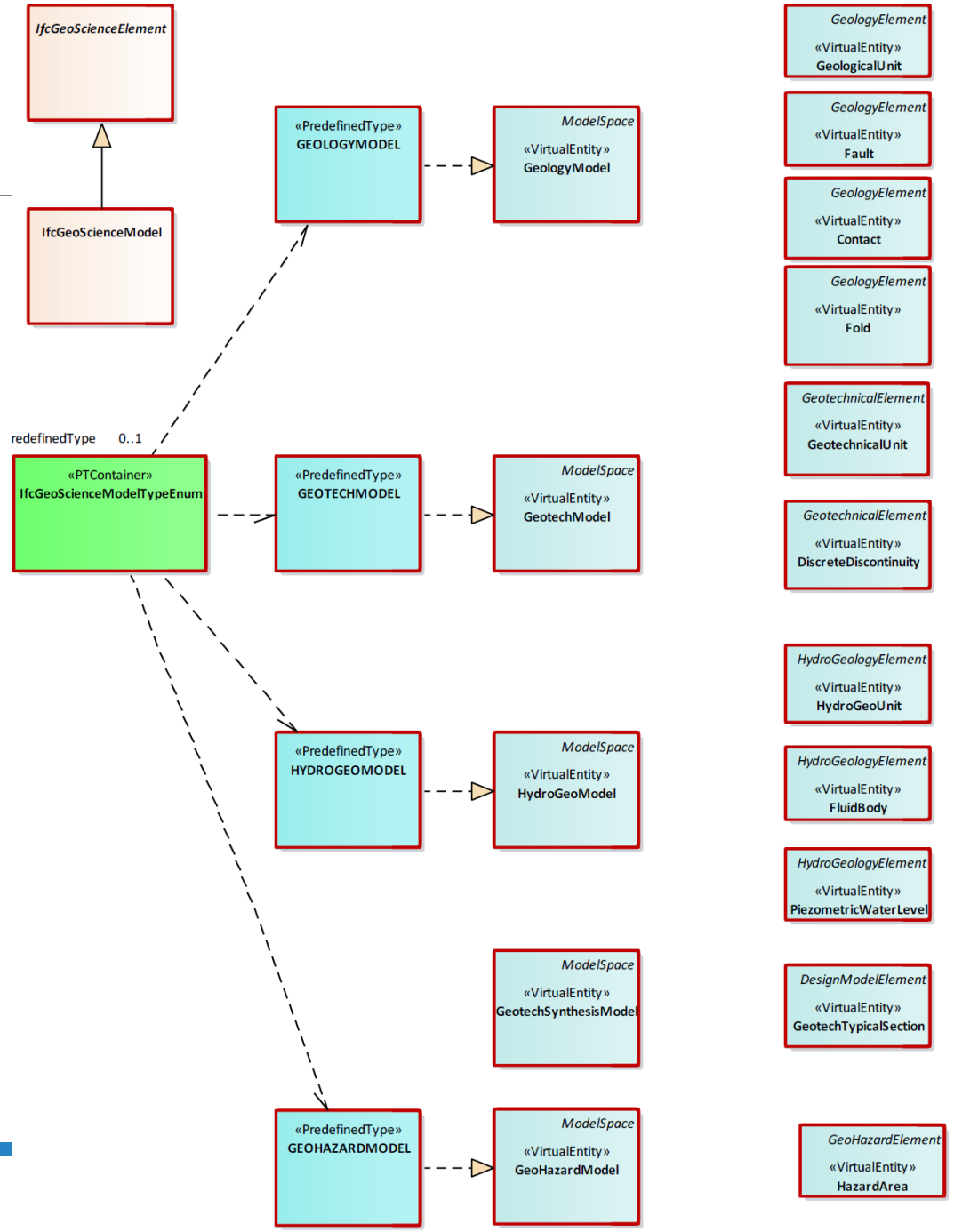
IfcTunnel – Geology &

Interpreted models / Book B

- Several models, representing specific classifications of the ground conditions as well as uncertainty and methodological info
- “GeotechSynthesisModel” as a link to building structure: e.g. representation of Geotechnical Baseline Report and Longitudinal Section

Example: Alternative approach for geotechnical models with different granularity



Graphical visualization / UML drafts

IfcTunnel – Geology &

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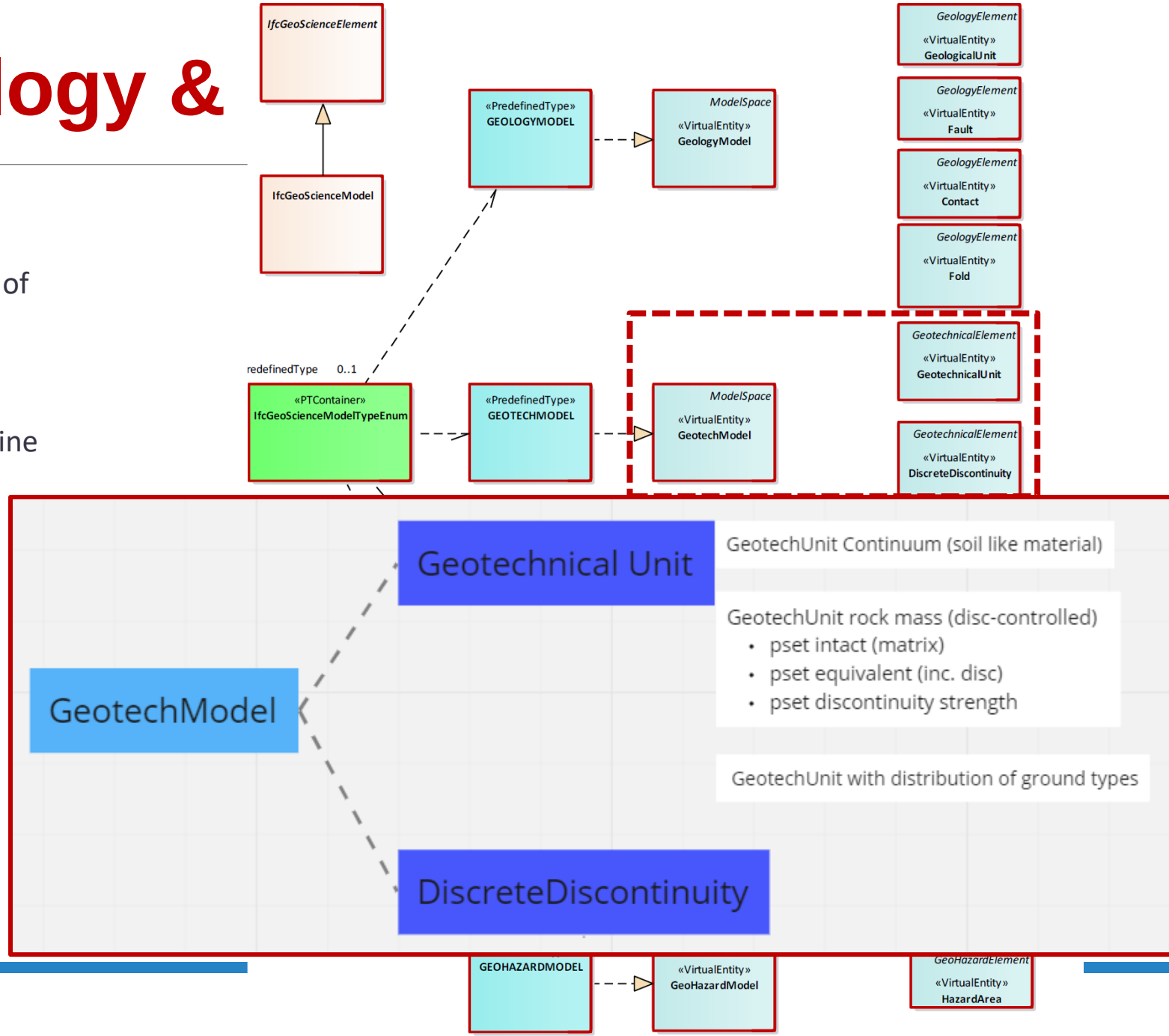
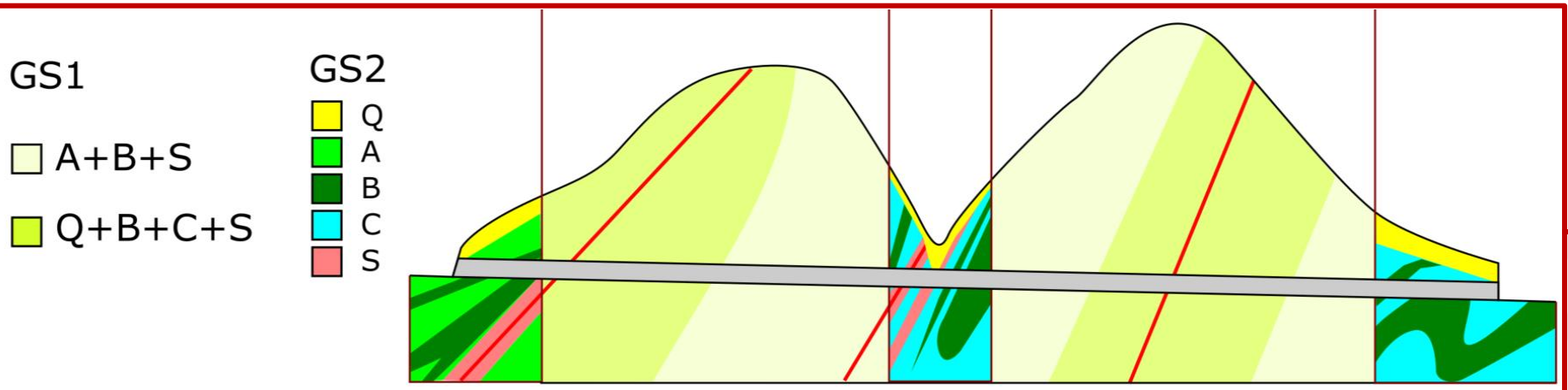


Graphical visualization / UML drafts

IfcTunnel – Geology & Geotechnics

Interpreted models / Book B



Geology Model		One single model				
Knowledge / Site invest. Density		high	low	high	low	high
Geotechnical Model	Model approach *	2	1	2	1	2
	Partial model (name)	Portal W	T1	T2	T3	Portal O
	Resolution	3m	10m	3m	10m	3m
	Allowed uncertainty	1m	5m	1m	5m	1m

* 1: Enveloping geometry for similar units (materials) with expected %-distribution

2: Explicitely modelled units

GeotechUnit Continuum (soil like material)

GeotechUnit rock mass (disc-controlled)
- pset intact (matrix)
- pset equivalent (inc. disc)
- pset discontinuity strength

GeotechUnit with distribution of ground types

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IfcTunnel – Geology & Geotechnics

Uncertainty

conceptual model includes some aspects that help treating uncertianty:

- alternative subtypes of "GeotechUnits" (previous slide)
- "ParameterDistributionModel" that can be used to quantify or rate different types of uncertainty in model
- GeotechSynthesisModel that defines expected ranges and variations for key-aspects along the alignment (next slide)
- Uncertianty description in definition of a property (ranges for recommended/characteristic parameters,…)

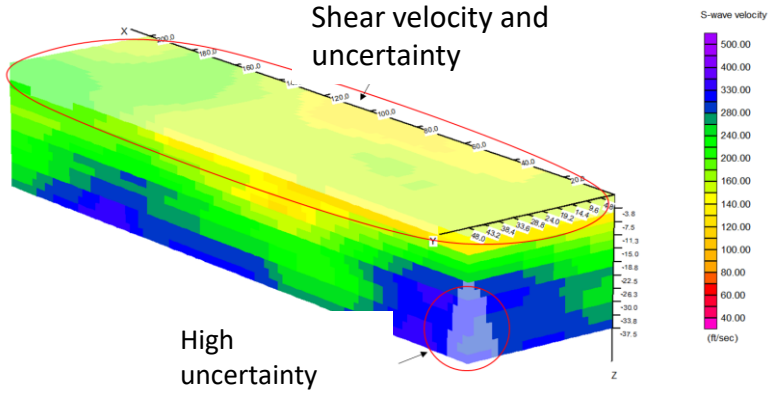
Currently ongoing:

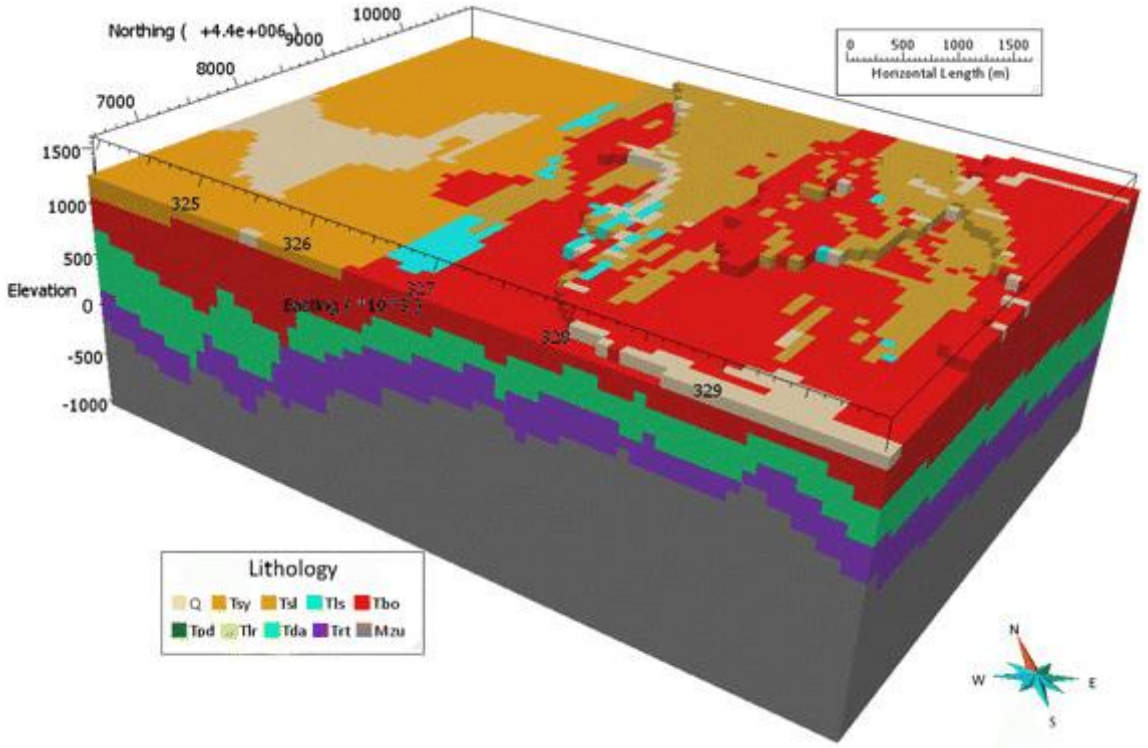
- Listing types and sources of uncertainty
- Definition of “Uncertainty Pset (s)” with
  - types and rating of uncertainty
  - geometrical uncertainty (e.g. +/- 1m, optional specific for certain directions like in IFC 4x3-concept)
  - geometrical resolution (e.g. referring to triangle mesh or voxel model)

IfcTunnel – Voxels (varying properties)

Background

- Voxel representation required for modelling spatial variation of soil / rock properties **without defining explicit boundaries**
- Facilitates representation of uncertainties
- IFC solution under development





Source: Witter et al. 2016

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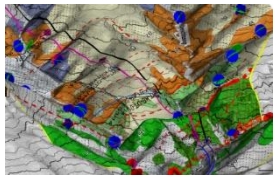
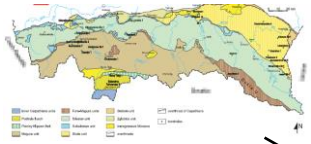
„GeotechSynthesisModel“

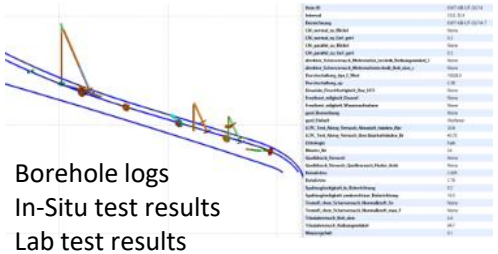
Book A
Observations / Factual data



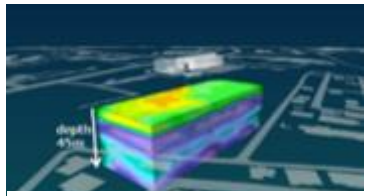
Field mapping



Maps and Literature



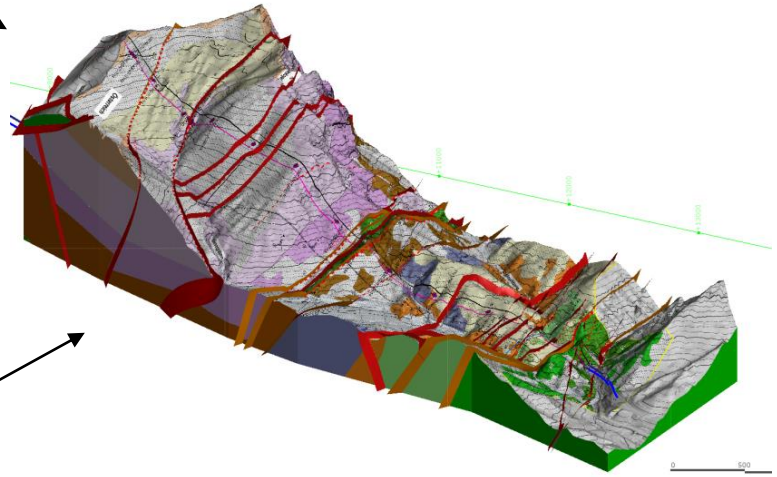
Borehole logs
In-Situ test results
Lab test results
Groundwater monitoring



Geophysical Survey

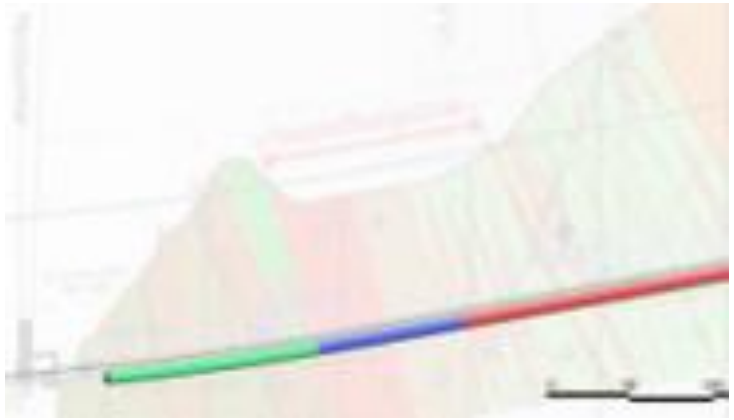
Book B
Interpreted Models

Geological and Hydrogeological conditions
Geomechanical properties



Design-related prognosis model

- interpretation of conditions described in Book A and B with regard to the tunnel alignment
- Definition of intervals along the alignment with similar expected conditions, described by key-properties for tunnel design

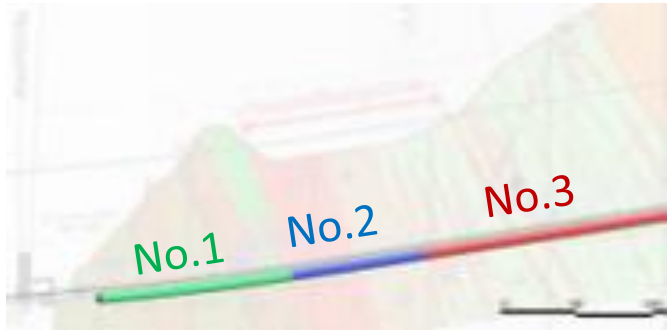


BIM-representation:
Alignment-based „Dummy Geometry“ with key-properties

→ *GeotechTypicalSection*

„GeotechSynthesisModel“

Geotechnical prognosis model



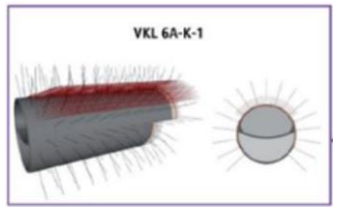
BIM-representation:
Alignment-based „Dummy Geometry“ with key-properties

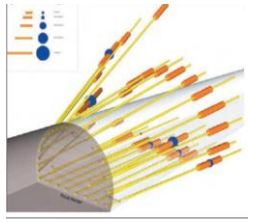
GeotechTypicalSection		No.1	No.2	No.3	No.4
Geotech key properties	Expected distribution of **ground types**	GT A: 70% GT B: 30%	GT B: 50% GT B: 50%	GT A: 70% GT B: 30%	GT A: 50% GT D: 50%
	Discontinuity setting	1	1+2	2+3	4
	Groundwater conditions	1	2	3	4
	Geogene hazards	1	1	1	1
	Contaminations	1	-	-	1
	…				

ExcavationModel		No.1	No.2	No.3	No.4
Design solution	Expected distribution of **support types**	ST 1: 40% ST 2: 30% ST 3: 30%	ST 3: 70% ST 4: 30%	ST 2: 30% ST 4: 30% ST 5: 30%	ST 1: 50% ST 4: 50%
	Excavation methods	A	A	A	B
	Injections	1	1	1	
	Health&safety measures				
	Material management	A	A	B	A
	…				

Prognosis model of Tunnel Design

Design solution developed for the required tunnel space based on expected ground conditions

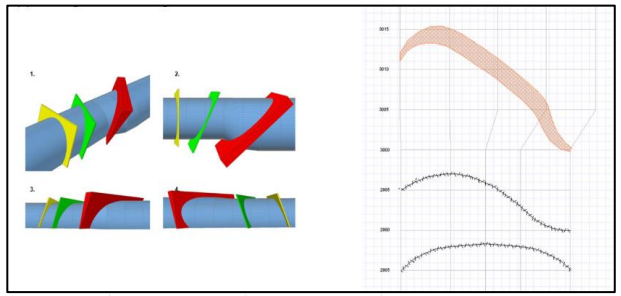


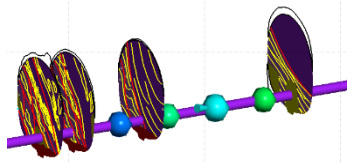


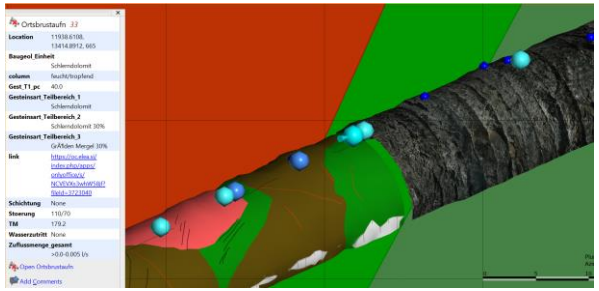
„GeotechSynthesisModel“

Book A
Observations / Factual data

Geological documentation during construction

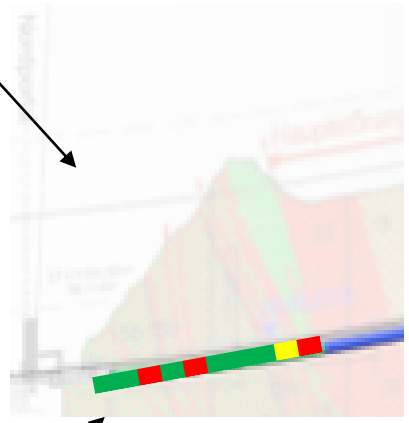






Book B
Geotech Synthesis Model

- Check of documented encountered conditions against prediction
- High granularity „As Built“Model for comparison and accounting



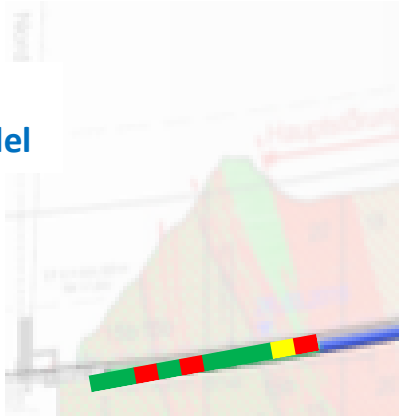
GeotechTypicalSection		No.1	No.2
PROGNOSIS Geotech key properties	Expected distribution of ground types	GT A: 70% GT B: 30%	GT B: 5(GT B: 5(
	Discontinuity setting	1	1+2
	Groundwater conditions	1	2
	Geogene hazards	1	1
	Contaminations	1	-
	…		

	Chainage / Round No.	1	2	3	4	5	6	7	8	9	10	No.2
ENCOUNTERED Geotech key properties	Expected distribution of ground types	A	A	A+ B	B	A+ B	A	A	B	C	B	GT B: 5(GT B: 5(
	Discontinuity setting	1	1	1	1	1	2	1	1	1	1	1+2
	Groundwater conditions	1			1			1	1	1		2
	Geogene hazards	1	1	1			1	1	1			1
	Contaminations	1		1					1			-
	…											

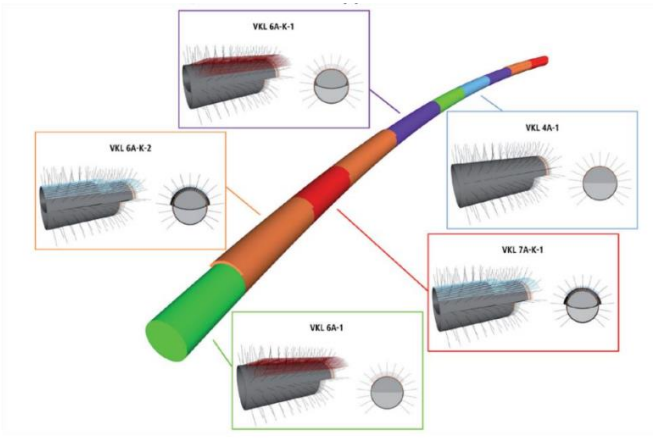
buildingSMART International

„GeotechSynthesisModel“

Book B:
High granularity „As Built“ Ground Model



Book C:
„Active Design / As Built“ Design Model
Construction and support measures executed as required from encountered ground conditions



	Chainage / Round No.	1	2	3	4	5	6	7	8	9	10	No.2
ENCOUNTERED Geotech key properties	Expected distribution of ground types	A	A	A+ B	B	A+ B	A	A	B	C	B	GT B: 5 GT B: 5
	Discontinuity setting	1	1	1	1	1	2	1	1	1	1	1+2
	Groundwater conditions	1			1			1	1	1		2
	Geogene hazards	1	1	1			1	1	1			1
	Contaminations	1		1					1			-
	…											

	Chainage / Round No.	1	2	3	4	5	6	7	8	9	10	No.2a	
APPLIED Design solution	**Applied support types**	ST3	ST3	ST2	ST2	ST2	ST1	ST1	ST1	ST5	ST5	ST 1: 70% ST 3: 30%	S S
	Excavation methods	A	A	A	A	A	A	A	A	A	A	A	
	Injections	1	1	1	1	1				1	1	1	
	Health&safety measures									1	1		
	Material management	A	A	A	A	A	A	A	A	A	A	A	
	…												