SBUF

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TRANSPARENT UNDERGROUND STRUCTURE (TRUST) - MANAGEMENT

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FÖRORD

Denna rapport presenterar resultat från *Transparent Underground STructure* TRUST – Management (TRUST 1) som pågick mellan 2013 och 2017. TRUST 1 var ett paraplyprojekt som tillsammans med sju andra separata forskningsprojekt bildade TRUST alliansen – ett unikt infrastruktursamarbete ur svensk såväl som internationell synvinkel. TRUST syftade till att utveckla metoder och verktyg för undermarksbyggande i urban miljö med LCC-perspektiv. Det var det första integrerade samarbete med forskare från Sveriges bygguniversitet, Uppsala universitet och specialister från branschen och myndigheter och inkluderade även internationella partners. TRUST finansierades i huvudsak av FORMAS-Trafikverkets forskningsprogram GeoInfra med medfinansiering från SBUF, BeFo och flertalet andra finansiärer.

TRUST 1 har syftat till att (1) samordna delprojekten och kommunicera resultaten from TRUST och (2) stödja innovation och implementering genom kreativ samverkan och nyttiggörande. Resultaten från del 2 av projektet har presenterats i BeFo rapport 183 av Kadefors, Olofsson, Ask (2019). Fokus för denna rapport är att presentera resultaten från del 1 av projektet. Denna rapport publiceras både av SBUF och BeFo.

Maria Ask är huvudförfattare för rapporten. Medförfattare är medlemmar i TRUST 1: Anna Kadefors, Håkan Rosberg, Lars-Olof Dahlström, Mats Svensson och Thomas Olofsson, samt projektledare för övriga TRUST projekt: Torleif Dahlin (TRUST 2.1, 4.2), Alireza Malehmir (TRUST 2.2), Lars O. Ericsson (TRUST 2.4), Fredrik Johansson (TRUST 3.2), Almir Draganovic (TRUST 3.3), och Stefan Larsson (TRUST 4.1).

Stort tack till Formas, SBUF/NCC, BeFo och Nova FoU för finansiering till TRUST 1. Särskilt tack till SBUF (Ruben Aronsson) och medsökare NCC (Lars-Olof Dahlström, Staffan Hinze, med flera kollegor) och BeFo (Per Tengborg, Eva Friedman) för intresse av själva projektet och ert tålamod med försenad rapportering. Tack riktas också till de nationella nätverk som byggts upp via Sveriges bygguniversitet och Svenska djupborrprogrammet.

Vi riktar även ett stort tack till GeoInfras Industriråd för värdefull feedback på vår projektide under sommaren 2012. Slutligen tackar vi mycket kraftigt industrimedlemmarna i referensgruppen: Peter Lundman (Trafikverket), Eva Widing (SKB), Per Tengborg (BeFo) och Lars-Olof Dahlström (SBUF/NCC).

Luleå, 24 juni 2021

SAMMANFATTNING

Med ett växande väg- och järnvägsnät blir det allt viktigare att bygga kostnadseffektiva undermarksanläggningar som är säkra, miljövänliga, energisnåla och lätta att underhålla. Det är därför angeläget att utveckla och implementera nya och förbättrade metoder och tekniker för planering, projektering och byggande av undermarksanläggningar.

TRanparent Underground STructure (TRUST) är en unik forsknings- och innovationsallians ur svensk såväl som internationell synvinkel som syftar till att utveckla metoder och verktyg för undermarksbyggande i urban miljö med LCC-perspektiv. TRUST är det första integrerade samarbetet mellan forskare från Sveriges bygguniversitet (Chalmers, Kungliga tekniska högskolan, Luleå tekniska universitet, Lunds universitet), Uppsala universitet och specialister från branschen, myndigheter och internationella partners. TRUST gruppen omfattade över 40 personer, inklusive doktorander, postdoks, seniora forskare, och specialister. Projektbudgeten uppgår i nära 75 MSEK mellan 2013 – 2017. Projektet finansieras av Formas-Trafikverkets projekt GeoInfra, flera forskningsstiftelser (BeFo, SBUF, Sven Tyréns stiftelse), Sveriges geologiska undersökning, forskningsinstitut och -centra, privata företag och universitet.

TRUST-projektet består av fyra huvudteman med olika delprojekt: Tema 1. *Management*. TRUST Management ansvarar för samordning och spridning av resultat från de olika delprojekten i de olika temagrupperna samt att ge riktlinjer för innovation och implementering av forskningsresultat. Tema 2. *Holistiska undersökningsmetoder* innehåller förslag på olika metoder platsundersökning för att karakterisera tekniska geologiska egenskaper bergmassan. Tema 3. *Smart Underjordsbyggande* använder informationen för att optimera anpassa och styra olika verksamheter i byggfasen. Tema 4. *Informationsmodeller, datastrukturer och visualisering* integrerar informationen och utgör ryggraden för samordning mellan olika aktörer och mellan planering, byggande, drift och underhåll av undermarksanläggningar.

Denna rapport rör paraplyorganisationen för hela TRUST projektet, TRUST- Management (TRUST 1). Som syftar till att (1) samordna delprojekten och kommunicera resultaten, och (2) utveckla innovation och implementering (främja kreativ samverkan och nyttiggörarande). I denna rapport presenteras aktiviteter som genomförts inom samordning och kommunikation. Kadefors et al. (2019) har rapporterat om aspekter av innovation och implementering och resultaten redovisas kortfattat i denna rapport.

TRUST har levererat användarnytta inom tre huvudområden: (1) tekniska innovationer (TRUST 2.1, 2.2, 3.3), (2) riktlinjer, standards (TRUST 2.4, 3.2), och (3) organisatoriska konsekvenser (1, 4.1, 4.2). Vidare har TRUST bidragit till kompetensförsörjning genom att examinera nio tekniska doktorer (nio licentiatavhandlingar, nio doktorsavhandlingar), byggt erfarenhet för tre postdok-forskare, flera masteravhandlingar och många vetenskapliga och populärvetenskapliga publikationer. Utmaningar inom TRUST projektet har varit (1) att hitta gemensamma fallstudier, (2) vi lyckades inte hitta finansiering till två av de tänkta TRUST projekten och ett projekt startade senare än övriga projekt; (3) vi underskattade omfattningen av projektledningen, samt (4) har det varit utmanande att implementera innovationsaspekter (inom TRUST projekt såväl som hos visa organisationer). Samtidigt har ett flertal spinoff projekt etablerats mellan TRUST projekt och mellan flera av delprojekten inom TRUST och dess samarbetspartners, till exempel initierade Tyréns AB ett gemensamt projekt i Varberg och Norges geotekniska institut initierade mätningar i Norge.

Samordning och kommunikation inom TRUST 1 har bidragit till TRUST-alliansens övergripande framgång. Dess huvudsakliga prestationer är: (1) att bidra till nätverksbyggande mellan forskare,

doktorander och experter från TRUST-partnerna, dvs. fem större svenska universitet, myndigheter, industri och internationella partner; (2) sprida kunskap bland projektdeltagare och bredda deras färdigheter inom forskning och innovation i andra delprojekt, och (3) stödja utvecklingen av spin-offprojekt inom både tillämpade projekt och i projekt med mer grundläggande vetenskaplig karaktär.

Resultat och rekommendationer för innovations- och implementeringsaspekter (Kadefors med flera 2019) inkluderar: (1) TRUST har belyst att Trafikverket kan hantera innovation i enskilda mindre forskningsprojekt på mer ad hoc basis men har svårare att hantera innovation på organisationsnivå. Den skenbart perfekta matchningen mellan TRUST och Trafikverket visade sig vara svårt att genomföra i praktiken: Trafikverket hade stora problem att erbjuda en gemensam plats för fältförsök då olika parter involveras och behöver beslutas långt i förväg; (2) System och resurser inom organisationerna behöver stärkas för att dra bättre nytta av den kunskap som tas fram i forskningssamarbeten. Forskare, ledningsfunktioner och tekniska specialister behöver inom organisationer behöver skapa en gemensam förståelse av hur innovationssystemet fungerar, inklusive den legala och kontraktsmässiga kontexten. och (3) Det är också viktigt att branschen investerar i forskning som är längre från implementering. Uppföljningssystem och mätetal behöver anpassas till hur tillämpningsnära forskningsprojektet är, och även ge en bild av behovet av att utveckla kompetens och resurser på mottagarsidan.

Innehåll

1 INTRODUCTION

This report presents results achieved within the project TRransparent Underground STructure (TRUST) – Management (TRUST 1). TRUST 1 is the umbrella project of the TRUST alliance, that consists of eight research projects that worked together and addressed aspects of underground construction.

1.1 The GeoInfra Call

Urbanization is rapidly increasing in Sweden, and is also influencing the underground space, for example by transport infrastructure. In early-mid 2000s to early 2010s, various actors active in underground construction, academia as well as industry, authorities, and public clients, saw the need for research on sustainable development of urban underground infrastructure. As a result, the Swedish research council for sustainable development (Formas) and the Swedish transport authority (STA) issued the joint GeoInfra call from 8 May to 3 September 2012. The GeoInfra call included 50 MSEK funding over five years, of which the Formas funded 74% and STA funded 16%. An additional 50 % of co-funding was required.

Four important, but not exclusive areas were highlighted in the GeoInfra call: (1) Design, operation and maintenance; (2) Efficiency and logistics; (3) Water – interaction with the underground facility; and (4) Risk management. The call required high industry involvement and co-financing, and was heavily supported by the infrastructure industry, especially the Rock Engineering Research Foundation (BeFo) and the Swedish construction industry's organization for research and development (SBUF). Together with the construction companies Skanska, NCC Construction AB (NCC) and Peab, BeFo and SBUF formed an industry-council (*swe: Industriråd GeoInfra*) who offered a service at an early stage to evaluate the industry relevance of the research ideas. The industry-council was coordinated by BeFo.

To inform about the GeoInfra call and to offer opportunities for research support the development of broad researcher projects, the Swedish Centre for Innovation and Quality in the Built Environment (IQS) organized a match-making meeting on 7 June 2012 to support networking between researchers and industry (Figure 1.1A). Proponents had the opportunity to present project ideas and discuss them with industry at the meeting.

1.2 Development of the TRUST alliance

The GeoInfra call encouraged multi-scientific proposals, and came at a good time to test wider-collaboration and alliances. The TRUST-alliance could be formed based on networking within two existing organizations: The Swedish Deep Drilling Program (SDDP) and the SBU researchers active at Swedish universities within civil engineering and geoscientific research started higher level networking activities in early-mid 2000s.

The process leading to the formation of SBU was initiated in 2003 by the SBUF research committee. The committee, with delegates from industry and academia, was concerned with decreasing research funding for the entire building sector, and an uncertain trend for long-term competence supply of teachers and researchers within the sector. A planning group consisting of senior researchers and department heads from the four universities that conducts education and teaching within Civil Engineering or similar (Chalmers University of Technology, Luleå

University of Technology, Lund University and the Royal Institute of Technology), as well as senior executives in some of the largest Swedish construction companies worked together to form SBU that formally was formed in 2011 (see further http://www.sverigesbygguniversitet.se/). Financial and moral support has been given by SBUF since the start until the present. Funding for SBU has also been provided by Formas and Sweden´s innovation agency (Vinnova). SBU conducts research within seven themes: (1) Structural Engineering; (2) Construction and Facilities Management; (3) Building System Design and Performance; (4) Geotechnology; (5) Water and Environmental Technology; (6) Highway Infrastructure and Transport Systems; and (7) Education.

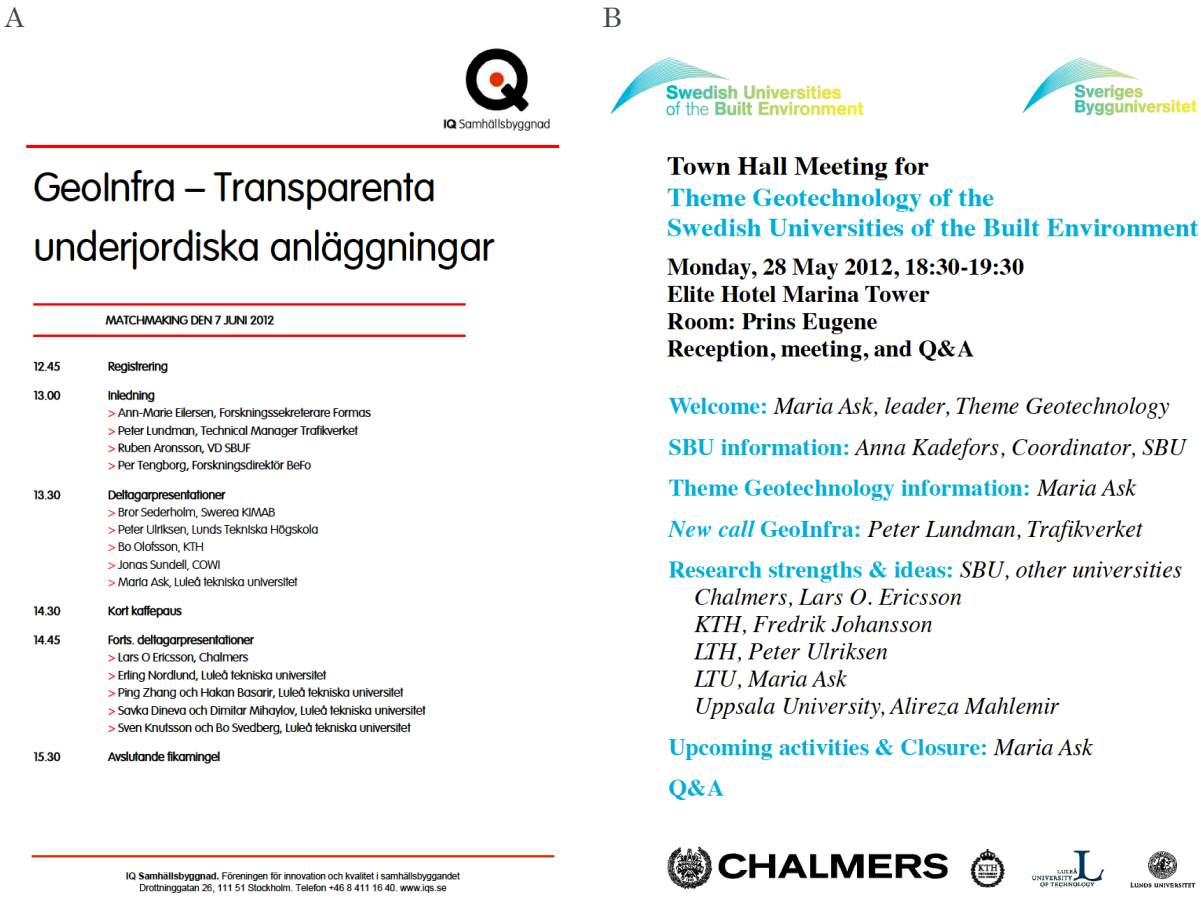

Figure 1.1*. A, Program for match-making at IQS on 7 June 2012. B, Program for townhall meeting of theme Geotechnology of the Swedish Universities of the Built Environment (SBU) on 28 May 2012.*

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themes: (1) Structural Engineering; (2) Construction and Facilities Management; (3) Building System Design and Performance; (4) Geotechnology; (5) Water and Environmental Technology; (6) Highway Infrastructure and Transport Systems; and (7) Education.

SDDP was formed in 2006 through a planning grant from Swedish Research Council (VR) to support scientific continental drilling in Sweden. SSDP members come from Swedish universities that conduct research with high societal relevance that only can be addressed through scientific drilling and borehole observations. In 2013, SDDP was transformed into the Swedish Scientific Drilling Program (SSDP; see further www.ssdp.se) to support Swedish interests in continental- and ocean scientific drilling. Currently, SSDP is led by scientists from Uppsala University, with most active members coming from Luleå University of Technology, Lund University, Stockholm University, and Södertörn University.

Maria Ask was group leader of Theme Geotechnology of the SBU from 2010-2014 and has been a member of SSDP since the start. In her role as group leader for Theme Geotechnology, she organized two open piggy-back activities in association with other meetings to support the formation of GeoInfra proposals. First, a Townhall meeting was arranged at the International Society of Rock mechanics (ISRM) International Symposium EUROCK in Stockholm on 28 May 2012 to spread information about SBU, Theme Geotechnology, and the GeoInfra call (Figure 2.1B). Second, a workshop was arranged on 23-24 August 2012 after the SBU annual conference (*Högskolekonferens*) at Skokloster Wärldshus. Participants came from the SBU member universities, Uppsala University, the Geological Survey of Sweden (SGU) and Tyréns AB.

The outcome of these network activities resulted in the formation of the TRUST alliance. The form of the alliance was controlled by Formas guidelines for proponents (*Formas Handbook 2012*), in which formalities of proposal and their budget are clearly specified.

1.3 The TRUST alliance

A total of ten proposals were submitted to the GeoInfra call. Six of the ten TRUST proposals were approved, corresponding to 67% of total GeoInfra funding within the project (33.6 MSEK). Four of the proposals were not funded through Formas. However, one project (TRUST 4.2) was initiated in 2013, and one project (TRUST 3.2) was initiated in 2014 with funding from other sources. The main part of the TRUST alliance was conducted from 2013 to 2017. The majority of PhD projects were not completed within this time frame, especially for those projects that was initiated later. The final PhD project was defended in 2020.

The TRUST alliance is organized along four themes (Figure 1.2):

- Theme 1, *Management* is responsible for coordinating and disseminate of the different subprojects in the themes and providing guidelines for innovation and implementation of the research result
- Theme 2, *Holistic survey methods* contain proposals on different survey methods to characterize the rock mass.
- Theme 3, *Smart underground construction* use information to optimize, adapt and control the different operations in the construction phase
- Theme 4, *Information models, data structures and visualization*, use and integrate information obtained in Themes 2-3, and is the backbone for coordination between different actors and between planning, construction, operation and maintenance of underground facilities.

Each theme consists of one to three projects, and a more detailed presentation of the individual projects within each theme is given in Section 2.

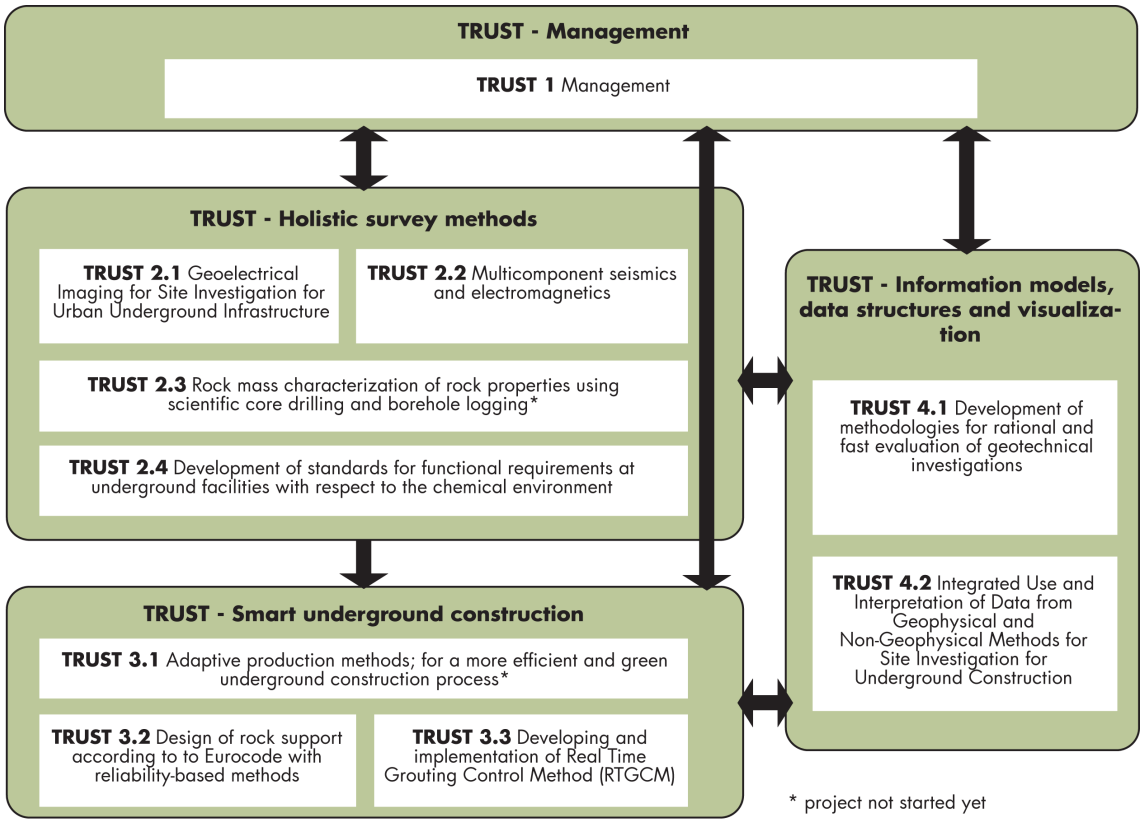

Figure 1.2. *Outline of the TRUST project.*

Two projects (TRUST 2.3 and 3.1) remained unfunded. The aim of TRUST 2.3 was to reduce uncertainties in the prediction of rock conditions encountered by tunnel projects in urban areas in Sweden by investigating and seeking improvements to the rock mass description process currently applied by (1) studying the documented prediction and outcome of earlier Swedish tunnel projects; (2) evaluating and ranking the importance of the obtained parameters and descriptions; and (3) seeking improvements in how key parameters are investigated and assessed by observation and measurement on new drill core- and borehole data. The project had components of scientific drilling with the SDDP infrastructures *Riksriggen* and the *Stress trailer*. The overarching aim of the TRUST 3.1 project was to improve productivity and innovation in the construction industry by applying new technology such as MWD (Measure While Drilling) and machine guiding and concept such as Building Information modelling (BIM) and construction platforms. Especially better management of uncertainties need to be introduced in civil engineering projects. The scope of TRUST 3.1 is to take advantage of these opportunities to optimize underground constructions by using simulation, probabilistic design methods and detailed State-of-the-Art information extraction methods such as MWD (Measure While Drilling). Observations based on MWD data and RTGC (Real Time Grouting Control) will be used to support and optimize front operation (drilling, blasting, loading, reinforcement). Simulation will be used to analyse and optimize the outcomes such as economy, energy use and GHG (Green House Gas) emissions of the selected front operation methods. As a result, the TRUST alliance research effort largely lacks a link between site investigation with geophysical methods (TRUST 2.1 and 2.2) and probability-based design (TRUST 3.2) and the development of the real time grouting method (TRUST 3.3).

The overall vision of TRUST is to enable efficient and sustainable processes for planning, design, construction and management of urban underground facilities by developing:

- New and more holistic survey methods
- Better tools and methods for design and production control
- Integrated information management over the life cycle of the facility

A key factor for achieving TRUST's vision is the integrated and trans-disciplinary platform that enables collaboration between participants from universities, industry and the public sector.

The TRUST alliance has gathered over 40 scientists and experts from the Swedish Universities of the Built Environment (SBU, i.e. Chalmers university of technology, Royal institute of technology, Luleå university of technology and Lund university), Uppsala university, the Geological survey of Sweden (SGU), research institutes (Swedish cement and concrete research institute, CBI, Swerea KIMAB), private companies (ABEM industries, NCC construction Sweden AB, NCC, and Tyréns AB), the regional center for research and development Nova FoU, and international partners (Aarhus university from Denmark, and Leibnitz institute of applied geophysics, LIAG, from Germany).

The total budget of the TRUST alliance is almost 75 MSEK, with funding provided by the Swedish research council for sustainable development, the Swedish transport authority, Rock engineering research foundation (BeFo), the Swedish construction industry's organization for research and development (SBUF), the Sven Tyréns foundation of Tyréns AB, SGU, research institutes (CBI, Swerea KIMAB, Norwegian geotechnical institute, LIAG), research centers (Swedish hydropower centre, Energiforsk, Nova FoU), private companies (Besab AB, Boliden, Cementa AB, First Quantum Minerals Ltd., NCC, Swedish nuclear fuel and waste management company, Swedish consultants environment AB, Thomas concrete group AB), and universities (Aarhus university, Luleå univerdsity of Technology, Lund university, Uppsala university).

The scope of the TRUST alliance is unique from a Swedish- and international view point. By 2017, it was probably the biggest coordinated Swedish research and innovation endeavor within the field of Geotechnology for underground construction. The Väg-Bro-Tunnel (VBT) consortium from the 00s is the only similar existing predecessor, to the author's knowledge. Within VBT, bi-annual meetings were arranged when the PhD students (they were mainly industrial PhD students) presented results (Pers. Comm. Peter Ulriksen, Lund University, 2012-07-03). These meetings offered opportunities to network for PhD students and their supervisors. The integrated collaboration within TRUST is one level above the VBT consortium because of the aim to work on joint case studies. As a result, TRUST could be a new model for integrated collaboration and cooperation that involves the main Swedish universities within civil engineering and applied geosciences, authorities, institutes, private companies, and international partners.

1.4 Objectives and limitations

The TRUST 1 project has two main objectives:

(1) Coordinate TRUST subprojects and communicate results and findings to all partners

(2) Research innovation and implementation aspects of selected subprojects to present models and guidelines for university-industry collaboration.

Because aspects of innovation and implementation is presented in detail in Kadefors et al. (2019), this the focus of this report regards aspects of communication and collaboration, and only brief presentation of the main results of innovation and implementation.

1.5 Outline of the report

The report is organized in five sections and eight appendices:

Section 1 (this section) is an introduction to the TRUST alliance and this report.

Section 2 presents background, objectives, research group, and main results for the subprojects and the four themes

Section 3 gives a summary of the activities within communication and collaboration

Section 4 presents results from innovation and implementation

Section 5 includes concluding remarks

List of appendices

- Appendix 1, Agenda for TRUST workshops 1-8
- Appendix 2, Action items, TRUST workshops 1-7
- Appendix 3, TRUST Publication policy
- Appendix 4, TRUST Partner declaration
- Appendix 5, IT manual
- Appendix 6, User value aspect TRUST – results of workshop 3
- Appendix 7, TRUST final report, Industry meeting of workshop 8

2 TRUST PROJECTS

2.1 TRUST 1 - Management

A well-functioning infrastructure for transporting goods and people is the back-bone of modern society. Extensive investments in the road- and railway systems are planned for, and already being carried out, by the Swedish Transport Administration (STA) to meet the ever increasing societal needs. As urbanization increases the demand for land in central city, it becomes attractive to locate facilities for transportation underground, although this is more expensive. Physical barriers hindering people to move between areas are then minimized and ground level urban space may be used for other city functions.

Infrastructure projects in general, and underground tunneling projects in particular, take long time to complete, and the projects are often associated with large cost increases. A worldwide survey showed that at least 30% and probably more than 50% of underground projects experienced significant cost and schedule overruns (*Reilly & Brown 2004*). The majority of the cost increase in selected Swedish STA projects is related to indirect- and financial costs (*Lundman 2011*). Underground infrastructure projects are especially challenging because they are conducted in a closed room with largely unknown and often highly varying rock mass properties, at the start of the project. In a study of (*Hertogh et al. 2008*), it was mainly tunneling projects encountering unforeseen geological conditions and projects depending on the development of new technology that experienced cost increases and delays during the construction phase. *Lundman* (*2011*) showed that cost increase for the Swedish STA projects due to unique features of underground conditions is substantial (at least 430 MSEK for the Bothnia Line, or 10% of the total cost increase). He concludes: "*STA must take full responsibility of assembling data, information and knowledge on a national basis.*"

Traditionally, stability and water issues have been the two main issues for underground constructions, often resulting in cost increases. Today, Swedish and European energy- and environmental goals and regulations need to be addressed. Thus, with the growing road- and railway network, it is becoming increasingly important to construct cost-effective underground facilities that are safe, environmental-friendly, energy-efficient and easy to maintain. Considering the massive investments planned, there is an obvious potential in proactively developing and implementing new and improved methodologies and technologies for the planning, design and construction of underground facilities. To be successful in bridging the gap between research and practice, such innovation processes require a constructive collaboration between university-based research, R &D functions within government clients and various industry actors, as well as with the managers and specialists involved in the actual construction projects.

The original budget for the period from 2013-2016 was 5 076 kSEK, with funding from Formas (50%, 2538 kSEK), SBUF (23%, 1153 kSEK), BeFo (22%, 1080 kSEK), , and in-kind funding (5%, 305 kSEK) from members of the reference group (industry, universities). Additional funding was provided by Nova FoU (100 kSEK) to support development of the Äspö hard rock laboratory (HRL) case study, and by SBUF (120 kSEK), BeFo (120 kSEK), and Ltu (24 kSEK) to provide salaries in 2017. Thus, the total budget of TRUST 1 was 5 440 kSEK.

The *Management* of the TRUST alliance is responsible for:

1. *coordination* of the subprojects in the TRUST themes
2. *dissemination* of the results and findings to all partners;
3. *innovation* and *implementation* aspects of selected subprojects will be researched with the aim of presenting models and guidelines for university-industry

Table 2.1 lists the participants, their affiliation and role within TRUST 1. The members of the reference group are included in Table 2.2. A forum for internal information management was created in 2013, consisting of Maria Ask, Håkan Rosqvist and Mats Svensson.

Table 2.1. *Research group members of TRUST 1*

Name	Affiliation	Role
Andreas Pauldén	Luleå University of Technology	MSc student
Anna Kadefors	Royal Institute of Technology / Chalmers	Researcher within innovation and implementation
Carl Stureson	Luleå University of Technology	MSc student
Håkan Rosberg	Lund University/Tyréns AB/Rosqvist Resurs AB	Member of steering group
Maria Ask	Luleå University of Technology	Principal investigator, Member of steering group, Researcher within communication and collaboration
Mats Svensson	Tyréns AB	Member of steering group
Thomas Olofsson	Luleå University of Technology	Researcher within innovation and implementation

Table 2.2. *Members of TRUST 1 reference group*

Name	Affiliation
Anna Kadefors	Royal Institute of Technology / Chalmers
Eva Widing	Swedish Nuclear Fuel and Waste Management Company
Lars-Olof Dahlström	NCC AB / Golder Associates AB
Per Tengborg	Rock Engineering Research Foundation
Peter Lundman*	Swedish Transport Administration
Håkan Rosberg	Lund University/Tyréns AB/Rosqvist Resurs AB
Maria Ask	Luleå University of Technology
Mats Svensson	Tyréns AB
Thomas Olofsson	Luleå University of Technology

**, Chair of reference group*

The methods and main results from TRUST 1 - management are presented and discussed in Sections 3 and 4 of this report.

2.2 TRUST 2.1 – Geoelectric mapping as a tool for preinvestigation for underground infrastructure facilities in urban environment

Unstable rock, groundwater inflow and other unforeseen ground conditions is a risk factor not seldom causing delays and large extra costs in underground infrastructure projects. In order to handle such risks better knowledge about the soil-, rock- and groundwater conditions, soil contaminants and unknown underground constructions is needed.

Site investigations prior to large underground infrastructure projects are most often based on drillings. Drillings produce detailed information in single boreholes but no information between those. However, modern geophysical methods can map the underground in 3D in a time and cost-efficient way also between boreholes. Lately especially combined use of the two methods resistivity and time domain induced polarization (DCIP) have shown great potential for underground

infrastructure site investigations. However urban environment is a great challenge due to urban noise and therefore the DCIP technique needs to be further studied and developed.

Formas provided 50% of funding for TRUST 2.1, with additional funding provided by SBUF, BeFo, and Tyréns AB.

The objective is to improve the potential for geophysical methods to interpret ground conditions with respect to geology, groundwater, structures and pollution in urban environment, in order to achieve more cost-effective construction of infrastructure. The aims are to adapt and configure the DCIP technique for use in urban areas, by developing: data collection methodology, instrument (hardware), data processing, inversion techniques and understanding of the relation between geophysical and geotechnical and environmental properties. Table 2.3 lists the participants and members of the reference group and the science advisor group.

Table 2.3. *Members of TRUST 2.1 research group, reference group and scientific advisor group*

Name	Affiliation	Role
Andreas Pfaffhuber	Norwegian Geotechnical Institute, Norway	Member of reference group
Andrew Binley	Lanchester University, UK	Member of ***scientific advisor group***
Charlotte Sparrenbom	Lund University	Researcher, supervisor
Christel Carlsson	Swedish Geotechnical Institute	Member of reference group
David Hagerberg	Tyréns AB	Post doc
Esben Auken	Aarhus University, Denmark	Researcher, supervisor
Geoff Watson*	University of Southampton, UK	Member of scientific advisor group
Gianluca Fiandaca	Aarhus University, Denmark	Researcher, supervisor
Håkan Rosqvist	Tyréns AB	Researcher, supervisor
Johanna Gottlander	Swedish Transport Administration	Member of reference group
Lee Slater	Rutgers University, USA	Member of scientific advisor group
Lena Persson	Geological Survey of Sweden	Member of reference group
Malin Norin	NCC AB	Member of reference group
Mats Svensson	Tyréns AB	R & D responsible
Matteo Rossi	Lund University	Post doc
Mehrdad Bastani	Geological Survey of Sweden	Researcher
Per Hedblom	Guideline Geo AB	R & D engineer
Per Tengborg	Rock Engineering Research Foundation	Member of reference group
Per-Ivar Olsson	Lund University	Doctorate student
Robert Sturk	Skanska AB	Member of reference group
Roger Wisén	Rambøll A/S	Member of reference group
Sara Johansson	Lund University	Doctorate student
Torleif Dahlin	Lund University	Principal investigator, supervisor
Willian Powrie*	University of Southampton, UK	Member of scientific advisor group

*Geoff Watson replaced William Powrie

The work has focused on a number of different tasks:

- Adapting and developing techniques for data acquisition strategies, methodology and data processing in urban environments including handling of urban noise and obstacles.
- Developing interpretation techniques for spectral induced polarisation properties from DCIP data through inverse numerical modelling.
- Develop methodology for 3D surveys in urban area.
- Improve knowledge on how to interpret contamination status of the ground from DCIP data.
- Improve knowledge on how to interpret engineering geological key information from DCIP data.

The work done includes extensive method development, test and evaluation of developed concepts, and application of the methods in field scale. Furthermore, adaptions and development laboratory test procedures has been done.

Field trials have been carried out at several field premises (Table 2.4), with the main objective for testing within brackets. The field trials can be subdivided into three groups:

- Projects planned within TRUST 2.1 (No. 2, 5, 7),
- Spin-off projects as consequence of TRUST collaboration (No. 3, 6), and
- Spin-off project within the research group (No. 1, 4, 8-10).

Main achievements within TRUST 2.1 include:

- Faster data acquisition and better data quality through measurements with 100 % duty cycle; method, hardware and software developments. Test and verification in full scale
- Signal processing and filtering; method and software developments. Major improvements in data quality and spectral content for time-domain IP data
- Better understanding of possible valid IP responses under different conditions
- DCIP data processing; methodology and software
- DCIP SIP inversion in 2D
- 3D data acquisition approaches
- Adaption and development of DCIP laboratory test procedures
- Improved understanding of mechanism behind DCIP responses
- Experience of DCIP responses in different geological materials
- Experience of DCIP responses for contaminants

Table 2.4. *Field trials carried out within TRUST 2.1*

No.	Site	Test objectives	Type of project
1	ESS in Lund	Depth to rock and rock quality	Spin-off research group
2	Kv Färgaren in Kristianstad	Contaminated soil	TRUST 2.1
3	Kv Renen in Varberg	Contaminated soil	TRUST spin-off
4	Arenastaden	Buried waste	Spin-off research group
5	Äspö Hard Rock Laboratory	Depth to rock and rock quality	TRUST 2.1
6	Önneslöv near Dalby	Depth to rock and rock quality	TRUST spin-off
7	Bypass Stockholm in Vinsta	Depth to rock and rock quality	TRUST 2.1
8	Bypass Stockholm accross Lambarfjärden	Depth to rock and rock quality	Spin-off research group
9	Ilstorp	Undisturbed soil material	Spin-off research group
10	Sövde airfield	Undisturbed soil material	Spin-off research group

The project has produced two licentiate thesis (*Johansson 2016; Olsson 2016*) and two PhD thesis (*Olsson 2018; Johansson 2019*), as well as a suite of other publications. The project had generated 15 peer reviewed scientific journal articles, 48 conference proceedings, 5 MSc theses, 2 BSc theses, and 1 popular science article.

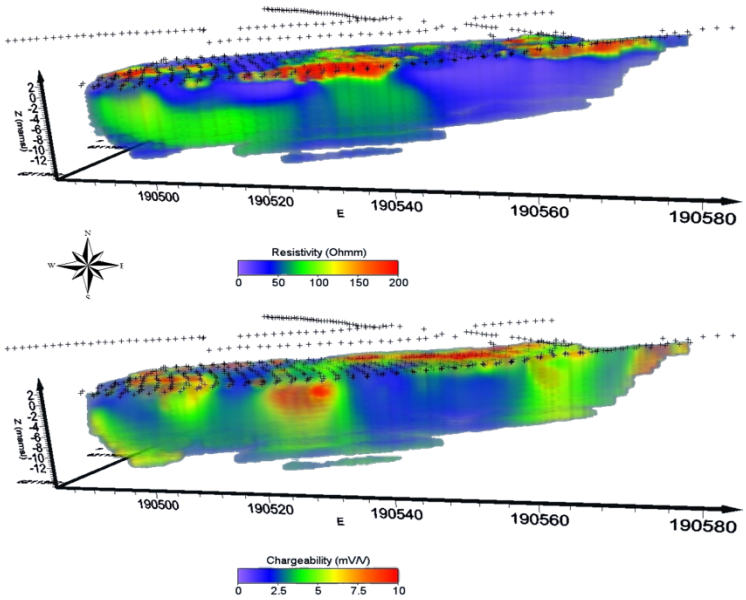

Figure 2.1. *Results from former location of dry-cleaning facility at Färgaren, Kristianstad. View over inverted 3D resistivity model (top) and IP model (bottom). The anomalies (in red and green colours) represent two documented plumes of free-phase PCE (top) and degradation products (bottom) (Johansson et al. 2015).*

2.3 TRUST 2.2 - Development of modern seismic and electromagnetic methods for preinvestigation for underground infrastructure facilities in urban environment

Over the past few years, the demand for urban infrastructures has continuously increased worldwide and in particular, in Sweden. However, there is a lack of knowledge about subsurface geology and structures in the urban environment. Occasionally, information about former or hidden outcrops exists or is available from, for example, municipalities, consultants, and construction companies. Accurate knowledge about near-surface geology and rock quality is important for planning of underground infrastructures because it implies what kind of excavation and rock reinforcement methods should be used. The urban environment is, however, challenging for most geophysical methods due to the multiple sources of noise (e.g., ground vibrations caused by vehicles and electromagnetic noise from power lines) and spatial and temporal restrictions imposed on geophysical surveys by infrastructure. The geophysical survey equipment used needs to be flexible and versatile, and highly insensitive to electromagnetic noise. Geophysical systems and methods have to also be developed top tackle water-bodies covering 7-8% of Swedish land where the need to develop infrastructures in these areas is highly.

Formas provided 50% of funding for TRUST 2.2, Development of modern seismic and electromagnetic methods for preinvestigation for underground infrastructure facilities in urban environment. Additional funding is provided by Uppsala University, SGU, NGI, SBUF, BeFo, First Qunrum Minerals Ltd., and Boliden AB.

To overcome issues with the electromagnetic noise and also to provide sensors that are of higher amplitude dynamic compared with common geophones, we developed a multicomponent broadband seismic landstreamer based on the micro-electromechanical systems (MEMS) sensors and tested and employed it during the course of the project for planning of several major urban underground infrastructures inside and outside Sweden. A boat-towed RMT system was constructed and used at several test sites in Sweden to show case its potential for delineating structures that are crucial for planning of under-water tunnels. Along the equipment developments, several methods and

algorithms were developed to extract rock quality information and proxies that can be directly linked to tunneling design or compared with parameters obtained using static tests.

The project comprised of 4 main steps:

- Brainstorming and backyard tests on instrumentations
- Small-scale tests and quality control against known targets
- Larger-scale and becoming involved in major running urban infrastructure projects
- Developing algorithms and methodologies to maximize the results and their impacts with a particular focus on either extracting dynamic mechanical properties or quantifying uncertainty in the results.

The working team had two separate objectives (seismic landstreamer and boat-towed RMT, Figure 2.2) but met and discussed and provided ways to integrate these approaches. TRUST 2.2 also provided support and input to other projects.

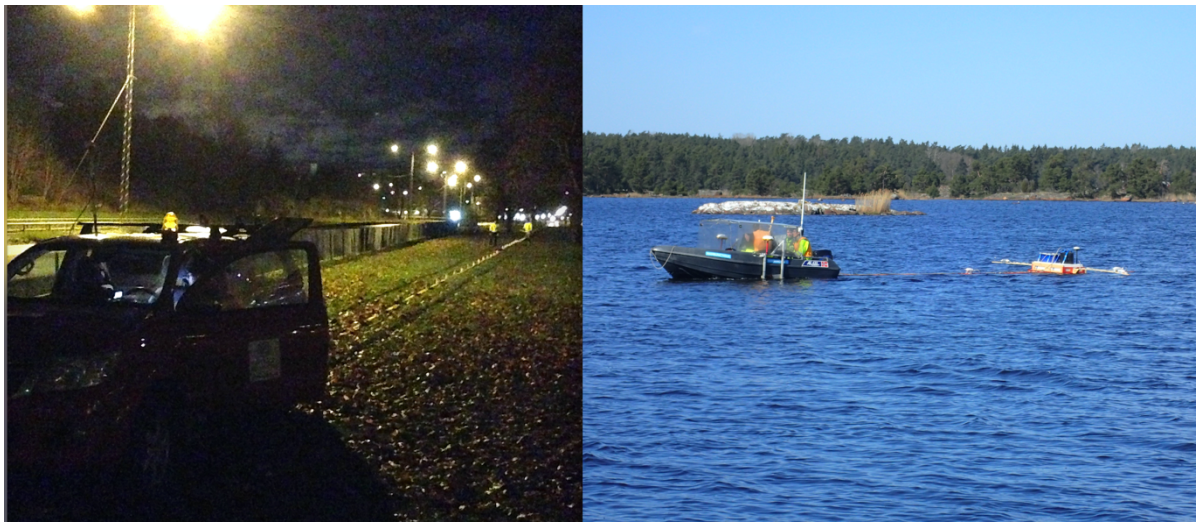

***Figure 2.2**. Left: Seismic landstreamer when tested in the Vinsta access ramp (Bypass Stockholm). Right: the boat-towed RTM when tested over the Äspö HRL facility.*

The core institutions worked actively on the project were Uppsala University and the Geological Survey of Sweden. The project however benefited from additional experts and advisors who provided feedbacks and supports but also organized sites and knowledge to improve data acquisition and methods used in the project. Table 2.5 lists the participants, their affiliation and role within TRUST 2.2, and the members of the reference group.

A workflow was designed to follow-up progress within TRUST 2.2. This included:

- Brainstorming on ideas and methods
- Discussion and planning
- Execution and data working and discussion on the results
- Interpretation, discussion and improvement for future studies.
- Presentation locally and externally and eventually peer-reviewed publications

Advisory team and working group members were informed about activities, field plans and publications through emails and meetings and help and suggestions were sought were needed or when provided by any of the members. Trust 2.2 members actively participated in all meetings, workshops and field activities planned within the project.

TRUST 2.2 had a late start due to co-funding issues but quickly managed to recover when the potentials of the instrumentations and ideas became clear to several partners inside and outside of the project. The landstreamer system for example has been and is being used in various projects hence meeting the main objective of the Geo-infra call by Formas on being truly innovative. The applications are enormous. Table 2.6 is a list where TRUST 2.2 has contributed with the instrumentations and methods. They can be subdivided into three groups:

(1) Projects planned within TRUST 2.2 (No. 1, 2, 6),
(2) Spin-off projects as consequent of TRUST collaboration (No. 3, 4, 10, 11), and
(3) Spin-off project within the research group (No. 5, 7-9, 12-14).

Table 2.5. *Members of TRUST 2.2 research group and reference group*

Name	Affiliation	Role
Alireza Malehmir	Uppsala University	Principal investigator, supervisor, researcher
Andre Pugin	Natural Resources Canada	Member of reference group
Andreas Pfaffhuber	Norwegian Geotechnical Institute	Member of reference group
Bojan Brodic	Uppsala University	Doctorate student
Cecilia Montelius	NCC AB	Member of reference group
Chris Wijns	First Quantum Minerals Ltd.	Member of reference group
Christer Andersson	Rambøll A/S	Member of reference group
Christopher Juhlin	Uppsala University	Supervisor, researcher
Joachim Place	Uppsala University	Post doc
Lars Dynesius	Uppsala University	Research engineer
Laust B. Pedersen	Uppsala University	Supervisor, researcher
Lena Persson	Geological Survey of Sweden	Researcher
Mats Svensson	Tyréns AB	Member of reference group
Mehrdad Bastani,	Geological Survey of Sweden	Supervisor, researcher
Nils Rydén	PEAB AB	Member of reference group
Pasanen Antti	Geological Survey of Finland	Member of reference group
Philip Curtis	Geological Survey of Sweden	Researcher
Robert Sturk	Skanska AB	Member of reference group
Roger Wisén	Rambøll A/S	Member of reference group
Sara Bazin	Norwegian Geotechnical Institute	Member of reference group
Shunguo Wang	Uppsala University	Doctorate student
Suman Mehta	Uppsala University	Doctorate student
Sverker Olsson	Geological Survey of Sweden	Researcher
Tomas Kalscheuer	Uppsala University	Supervisor

The project has produced two licentiate thesis (*Brodic 2015; Mehta 2015*) and three PhD thesis (*Brodic 2017; Mehta 2017; Wang 2017*). By 2018, more than 15 peer-reviewed publications, 20 conference abstracts, 10-15 oral presentations nationally and internationally, contribution to popular science publications and promotional videos, and several reports have come out of TRUST 2.2 project. In-kind contributions provided particularly by UU and SGU significantly over-exceeds what were provided by our sponsors without which we would not have been at the position where we are now.

Table 2.6. *Field trials carried out within TRUST 2.2*

No.	Site	Test objectives	Type of project
1	Laisvall, Sweden (2014)	Mineral exploration and geological mapping	TRUST 2.2
2	Stockholm, Sweden (2013)	Bypass Stockholm, site characterization and equipment quality control	TRUST 2.2
3	Kristianstad, Sweden (2014)	Contaminated site and test work	TRUST spin-off
4	Varberg, Sweden (2014)	Planning of a double-track train tunnel	TRUST spin-off
5	Bollnäs, Sweden (2014)	Post-glacial fault imaging	Spin-off research group
6	Äspö, Sweden (2015)	Tunnel-surface seismics for fracture mapping and rock quality estimations	TRUST 2.2
7	Ludvika, Sweden (2015)	Mineral exploration and geological mapping	Spin-off research group
8	Möra, Sweden (2015)	Geological mapping	Spin-off research group
9	Malmberget, Sweden (2015)	Mine planning	Spin-off research group
10	Dalby, Sweden (2015)	Geological energy storage	TRUST spin-off
11	Oslo, Norway (2015)	Planning of E18-Oslo tunnel	TRUST spin-off
12	Turku, Finland (2014)	Esker structures and water management	Spin-off research group
13	Siilinjärvi, Finland (2014)	Mineral exploration/mine planning	Spin-off research group
14	Stevns chalk group, Denmark (2016)	PhD school	Spin-off research group

2.4 TRUST 2.4 - Development of standards for functional requirements at underground facilities with respect to the chemical environment

Constructions in underground space represent interventions in the surrounding environments. This concerns mainly the hydrology but also other aspects such as the release of ion species from the host rock during and after excavation. During and after constructions, which go hand in hand with the excavations, further factors needs to be considered, which concerns mainly the new construction materials brought into the underground space:

- Functionality of the new materials
- Interaction of the new materials with subsurface water
- Durability of the new materials

All three factors are strongly influenced by the underground environment with the underground water constituting the transport media between the environment and the materials. The construction materials are mostly either cementitious or reinforcement for shotcrete and concrete parts (either as mesh, bars or fibers) as well as steel for rock bolts. The STA publishes technical requirements that regulate and give advices concerning construction and dimensioning of a tunnel in a road and railroad environment. Even though the authority STA launched new requirements for tunnel construction and revised guidance for dimensioning TRVK Tunnel 11 and TRVR Tunnel the TRUST 2.4 project aimed at proposing a further development of the standards.

Formas provided 50% of funding for TRUST 2.4, *Development of standards for functional requirements at underground facilities with respect to the chemical environment*. Additional funding is provided by is provided by SBUF, Cementa AB, SKB, BeFo, Energiforsk AB, NCC Construction AB, Nova FoU, Besab AB, STA, SGU, CBI Betonginstitutet AB, Swerea KIMAB AB, Thomas Concrete Group AB, and Sweco Environment AB.

By means of integrated activities and studies on underground hydrochemistry, cement-based materials and corrosion processes, the general objective of the project has been to further develop standards to meet functional requirements at underground facilities with respect to the chemical environment in terms of groundwater chemistry and vault atmosphere composition.

The project has also provided a basis for improving the content of environmental impact assessments in conjunction with underground projects. Furthermore, the project aimed to provide a basis for constructing safer tunnels with cost-effective maintenance.

The project has comprised three sub-projects interacting with each other: (1) Prediction of underground hydrochemistry due to excavation, (2) Hydrochemical effects on resistance of shotcrete and grout to leaching and chemical degradation, and (3) Hydrochemical effects on the corrosion rate of rock bolts. R&D activities have encompassed literature compilations, database analyses, laboratory testing, field investigations (e.g. Äspö HRL) and computational modelling.

The Division of GeoEngineering, Chalmers University of Technology (Chalmers) represented the hydrogeological knowledge. The Swedish Cement and Concrete Research Institute (CBI) was mainly responsible for activities regarding cementitious materials and concrete issues. Swerea/KIMAB (KIMAB) covered subjects related to corrosion processes. Partners in the project were the Swedish Geological Survey (SGU), Nordic Construction Company AB (NCC), Cementa, Thomas C G AB and NOVA, Oskarshamn.

Several researchers have been involved in the three subprojects. Table 2.7 lists the participants, their affiliation and role within TRUST 2.2.

Table 2.7*. Research group members of TRUST 2.4*

Name	Affiliation	Role
Anders Selander	Swedish Cement and Concrete Research Institute (CBI)	Researcher
Arezou Baba Ahmadi	Swedish Cement and Concrete Research Institute (CBI)	Researcher
Arvid Taube	Swedish Transport Administration	Researcher
Bror Sederholm	Sweden's Corrosion & Metals Research Institute (Swerea KIMAB)	Researcher
Elisabeth Helsing	Swedish Cement and Concrete Research Institute (CBI)	Researcher
Frederic Mathurin	NOVA FoU / Swedish Nuclear Fuel and Waste Management Company (SKB)	Researcher
Fredrik Mossmark	Chalmers / Geological Survey of Sweden (Sweco AB)	Doctorate student, researcher
Ingemar Löfgren	Thomas C G AB	Researcher
Jan Trägårdh	Swedish Cement and Concrete Research Institute (CBI)	Researcher
Johan Ahlström	Sweden's Corrosion & Metals Research Institute (Swerea KIMAB)	Researcher
Lars-Olof Dahlström	Golders Associates AB (NCC AB)	Researcher
Lars O Ericsson	Chalmers	Principal investigator, supervisor, researcher
Lars-Ove Lång	Geological Survey of Sweden	Researcher
Leif Fjällberg	Swedish Cement and Concrete Research Institute (CBI)	Researcher
Malin Norin	Chalmers / NCC AB	Researcher
Marcus Laaksoharju	NOVA FoU	Researcher
Mariusz Kalinowski	Swedish Cement and Concrete Research Institute (CBI)	Researcher
Mikael Westerholm	Cementa AB	Researcher
Monica Lundgren	Swedish Cement and Concrete Research Institute (CBI)	Researcher
Nils Davant	Swedish Cement and Concrete Research Institute (CBI)	Researcher
Urban Åkesson	Swedish Transport Administration	Researcher
Urs Mueller	Swedish Cement and Concrete Research Institute (CBI)	Researcher

According to the scope of work and the three sub-projects the main result covers:

– A methodology, with three steps, for predicting the hydrochemical conditions that will exist during the construction and operation phase for constructions that are being built in crystalline bedrock in areas that have been subjected to recent glaciation and thereby provide a basis for material selection.
– A comprehensive compilation regarding shotcrete composition characteristics. For Sweden and the rest of Europe the report discusses: material choice, mix design, environmental aspects, durability aspects, damage mechanisms, standards, guidelines, requirements.
– Material choice recommendations for shotcrete based on sulfate exposure and performance tests. The recommendations cover: influence of binders, temperatures, accelerators, concentrations of sulfate solution and other hydrochemical constituents.
– Recommendations regarding use of carbon steel in the context of underground corrosion problems due to inappropriate groundwater chemistry. Focus on potential impacts considering: flow velocity, microbial activity and the water constituents Fe^{2+}, Cl^{-}, SO_4^{2-} Ca^{2+}, HCO_3^{-}, H^{+}.

The project has resulted in one PhD dissertation (*Mossmark 2014*).

2.5 TRUST 3.2 - Design of rock support according to Eurokod using reliability-based design methods

Design of rock tunnels and rock caverns will since 2009 be carried out according to SS-EN 1997-1 in combination with SS-EN 1990. The basis is that every single design/load case will be verified to such an extent that no relevant limit state will be reached. According to SS-EN 19901-1 limit states have to be verified by one or a combination of methods, where one of the available methods is reliability-based methods. Because of the large uncertainties in geotechnical and rock mechanical design, and the fact that limit states are complex and based on integration of rock reinforcement and rock mass, design methods based on reliability-based methods are often welcome. Guidelines for how to use reliability-based design according to Eurocode 7 is however missing in the building industry, and hence there is a need for research aiming to clarify in which design/load cases reliability-based design methods are useful and how to carry out the design according to this.

TRUST 3.2, Design of rock support according to Eurocode using reliability-based design methods is funded by SBUF, BeFo, BESAB, SKB and SVC. It consists of two subprojects, a Senior research project and a PhD project, with the objectives:

– Study which rock mechanical problems that are most suitable for reliability-based design (senior research project)
– Study which rock mechanical problems that are most suitable for reliability-based design (PhD project); and
– Develop applicable methods for design of rock reinforcement according to Eurocode 7 using reliability-based methods (PhD project).

Table 2.8 lists the participants, their affiliation and role within TRUST 3.2.

The work within TRUST 3.2 consists of:

– Review of the limit states presented in the traffic administrations guidelines for the design of tunnels (senior research project)
– Review of research performed within the area of reliability-based design of tunnels (PhD project)
– Use literature review and the results from the senior research project as a basis for further research within identified areas of improvement (PhD project)
– Publish the results from the research in international peer-reviewed journals and conferences (PhD project)

Table 2.8. *Research group members of TRUST 3.2*

Name	Affiliation	Role
Fredrik Johansson	Royal Institute of Technology	Principal investigator, supervisor, researcher
Håkan Stille	Royal Institute of Technology	Researcher in the Senior research project
Johan Spross	Royal Institute of Technology	Researcher
Mats Holmberg	Tunnel Engineering	Researcher in the Senior research project
Stefan Larsson	Royal Institute of Technology	Supervisor, researcher
William Bjureland	Royal Institute of Technology	Doctoral student

In the senior research project, the applicability of using reliability-based design has been assessed for all limit states in the traffic administrations guidelines. A seminar was organized with the industry at which the different design methods were discussed. The results of the study have been published in a BeFo-report (reference) along with suggestions for further research. The discussions from the seminar can be found on BeFo:s website (link).

The project has produced one licentiate thesis (*Bjureland 2017*) and one PhD thesis (*Bjureland 2020*). By 2018, i.e. at the half-time of the PhD project, 1 journal paper had been submitted, 2 conference papers (EUROCK 2015 and Geo-Risk 2017) and 2 Master of Science thesis´s had been published.

2.6 TRUST 3.3 - Grouting need predicted by the Real Time Grouting Control Method (RTGCM)

Determination of the smallest crack width the cement could possibly penetrate is today based on readings from a filter press or a filter pump. Both these methods give conservative results, which strongly effect the calculated depth of penetration and grouting time. Without knowledge on which fractures that could be grouted with a certain grout, it is hard to predict how large a volume that will be grouted. This is hence a crucial knowledge in order to carry out an optimal grouting procedure.

In this project a new measuring method for measuring penetration ability of cement –based grout, long slot with varied aperture size (VALS), is developed. This method helps us to decrease uncertainty in measuring of penetration ability of cement –based grouts. The project tested also using dynamic pressure with low frequency in grouting and showed that that there is a large potential for improving grout penetrability of a grout and increase sealing effect. Decreasing uncertainty in measurements of penetration ability of a cement-based grouts and improved penetrability of cement based grout due to use of low frequency dynamic pressure give as possibility to use cement-based grouts to seal also more fine fractures instead to use chemical grout for this purpose. Cement based grout is both more economical and environmental friendly. It is also a more sustainable product compared to grouts based on amorphous silica for example. Initial developments of the RTGC method was made by Professors Håkan Stille and Gunnar Gustafson (Chalmers).

STA provided 50% of funding for TRUST 3.2, *Grouting need predicted by the Real Time Grouting Control Method (RTGCM).* Additional funding was provided by is provided by SBUF and BeFo

The objective of the project was verification of penetration length of grout in field estimated with RTGC method, decrease uncertainty in measuring of penetration ability of cement –based grouts and improve of penetrability of the grout. Table 2.9 lists the participants, their affiliation and role within TRUST 3.3.

Table 2.9. *Research group members of TRUST 3.3*

Name	Affiliation	Role
Almir Draganović	Royal Institute of Technology	Principal investigator, supervisor, researcher
Ali Nejad Ghafar	Royal Institute of Technology	Doctoral student
Håkan Stille	Royal Institute of Technology	Researcher in the Senior research project
Stefan Larsson	Royal Institute of Technology	Supervisor, researcher

A new measuring method for measuring penetration ability of cement –based grout, long slot with varied aperture size (VALS) is developed. Uncertainty in measurements of penetration ability of cement-based grouts could be reduced by using this device. The device gives also opportunity to develop new grouts with better penetration ability and opportunity to choose a more proper grout. A new low frequency dynamic grouting pressure is developed in lab. It gives opportunity to develop new grouting equipment and method for field application and improve grouting i.e. increase sealing efficiency.

The project has produced one licentiate thesis (*Nejad Ghafar 2016*) and one PhD thesis (*Nejad Ghafar 2017*).

2.7 TRUST 4.1 – Development of methodologies for rational and fast evaluation of geotechnical investigations

TRUST 4.1 consists of two subprojects. In Subproject A, the objective is to improve data management tools regarding geotechnical data within ongoing projects and for long time maintenance of data. Today data is stored in a badly organized way – different servers and computers, binders etc. and comes in many different data formats. The GeoBIM concept aims at developing a database that can handle ALL data formats in order to make joint interpretation much easier in the future. In Subproject A, the GeoBIM concept has been developed. It has been developed within Tyréns AB (Mats Svensson, Olof Friberg, Pär Hagberg, Pål Hansson, Peter Alstorp). The GeoBIM concept organizes all geotechnical data (including contaminated soil data from 2017) in a project or an organization. The data is accessible via a web inlog and an interactive map interface from any unit (computer, smartphone or "läsplatta") and requires no software installed on your unit. Data and reports can be downloaded via the interface depending of rigths in the projects. This main feature/tool is up and running and implemented in the industry in approximately 10 projects or organizations (Nov 2016). In Subproject B, the objective is to highlight, develop and improve methods to assess the quality and value of geotechnical site investigations. Statistical evaluations of geotechnical parameters have been conducted and reliability-based design readily accessible to the industry. This naturally includes a discussion on how to make the definition of the EN 1997 partial-factor method to better harmonise with the risk-based approach of reliability-based design.

The project is funded by Formas (50%) and Tyréns AB (50%). Table 2.10 lists the participants, their affiliation and role within TRUST 4.1.

The TRUST 4.1 subproject B has produced one licentiate thesis (*Prästings 2016*) and one PhD thesis (*Prästings 2019*).

Table 2.10. *Research group members of TRUST 4.1*

Name	Affiliation	Role
Anders Prästings	Royal Institute of Technology	Doctoral student, Subproject B
Mats Svensson	Tyréns AB	Researcher, Subproject A
Olof Friberg	Tyréns AB	Researcher, Subproject A
Pål Hansson	Tyréns AB	Researcher, Subproject A
Pär Hagberg	Tyréns AB	Researcher, Subproject A
Peter Alstorp	Tyréns AB	Researcher, Subproject A
Stefan Larsson	Royal Institute of Technology	Principal investigator, supervisor, Subproject B

2.8 TRUST 4.2 – Integrated use and interpretation of data from geophysical and non-geophysical methods for site investigation for underground construction

Unforeseen ground conditions is a risk factor often leading to large delays and extra costs in large underground infrastructure projects. Integrated use and interpretation of data from different types of investigations, generating geophysical as well as non-geophysical data, is crucial for all infrastructure planning and construction in rocks for risk reduction. This means to decrease the risk for delays, costs and claims.

Boreholes and geotechnical sounding and sampling give point information with high geometrical resolution, whereas geophysics can create information in 2D or 3D, however with higher uncertainty than the point investigations. Furthermore, the geophysical techniques do not provide the primary information needed for the engineering design. By combining the different sources in a joint interpretation procedure, the overall uncertainty can be lowered and point information integrated into 2D or 3D. Hence more precise and relevant geo models can be obtained.

The ultimate objective is a prognosis model of the soil and rock properties that can be used as better information basis for decision makers resulting in more cost-efficient infrastructure projects. The aim of this project is to develop tools that can create geological and geotechnical models in an objective, robust and repeatable way by using the different sources of information in a statistically optimized way. It aims at developing methodology and tools for an integrated use of all relevant geotechnical data used in large underground infrastructure projects, for example geophysics, in situ methods and core drillings. It also includes test and demonstration of these tools. The joint interpretation will be used for designing a methodology, a workflow, on how to investigate the soil and rock volume for optimal overall efficiency starting from planning field surveys over data inversion to interpretation. The methodology is tested in selected infrastructure projects.

Table 2.11 lists the participants, their affiliation and role within TRUST 4.2, Integrated use and interpretation of data from geophysical and non-geophysical methods for site investigation for underground construction. The members of the reference group is common with that of TRUST 2.1, and presented in Table 2.3.

The work focuses on a number of different tasks:

- Development of methodology for efficient field data acquisition with combined DC resistivity and time-domain induced polarization (DCIP) tomography and seismic refraction.
- Development of algorithms and software for joint interpretation, using joint inverse numerical modelling (inversion) and cluster analysis. The work with joint inversion algorithms is within the Geophysical Inverse Modelling Library (GIMLi) package in close cooperation with the international researchers who created the software library.

– Calibration of algorithms and models against synthetic models and real data from infrastructure projects.
– Pilot tests and full-scale implementation in real projects.
– Development of a methodology for predicting hydraulic and mechanical properties from geophysical and other data.

Table 2.11. *Research group members of TRUST 4.2*

Name	Affiliation	Role
Kristofer Hellman	Lund University	Research assistant
Mathias Ronczka	Lund University	Post doc
Roger Wisén	Lund University	Researcher, supervisor
Thomas Günther	Leibniz Institute for Applied Geophysics (LIAG)	Researcher, supervisor
Torleif Dahlin	Lund University	Principal investigator, supervisor

The work focuses on a number of different tasks:

– Development of methodology for efficient field data acquisition with combined DC resistivity and time-domain induced polarization (DCIP) tomography and seismic refraction.
– Development of algorithms and software for joint interpretation, using joint inverse numerical modelling (inversion) and cluster analysis. The work with joint inversion algorithms is within the Geophysical Inverse Modelling Library (GIMLi) package in close cooperation with the international researchers who created the software library.
– Calibration of algorithms and models against synthetic models and real data from infrastructure projects.
– Pilot tests and full-scale implementation in real projects.
– Development of a methodology for predicting hydraulic and mechanical properties from geophysical and other data.

The work done includes extensive method development, test and evaluation of developed concepts, and application of the methods in field scale. Furthermore, adaptions and development laboratory test procedures has been done. TRUST 4.2 also has participated and conducted field trials (Table 2.12). The field tests include land based and underwater measurements as well as borehole measurements. Figure 2.3 shows joint inversion result from the Äspö Hard Rock Laboratory (HRL).

Table 2.12. *Field trials carried out within TRUST 4.2*

No.	Site	Type of project
1	ESS in Lund	Spin-off research group
2	Kv Färgaren in Kristianstad	TRUST 4.2
3	The Varberg tunnel	TRUST spin-off
5	Äspö Hard Rock Laboratory	TRUST 4.2
6	Önneslöv near Dalby	TRUST spin-off
8	Bypass Stockholm accross Lambarfjärden	Spin-off research group
9	Östlig förbindelse in Stockholm	Spin-off research group
10	Sewage tunnel	Spin-off research group

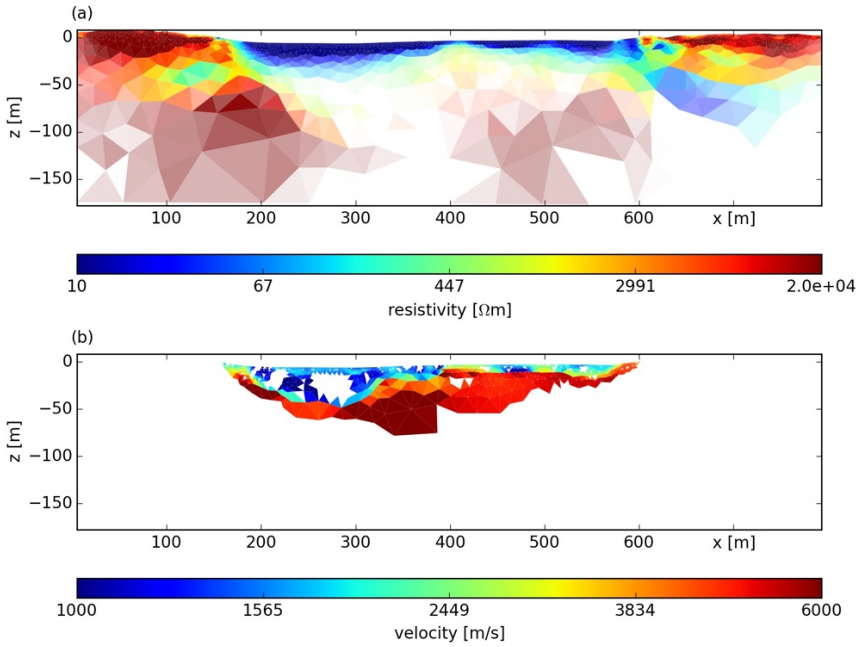

Figure 2.3. *Joint inversion result from the Äspö Hard Rock Laboratory test with resistivity (top) and velocity (bottom) distribution. The shading is based on the coverage of each model cell.*

Main results include:

- Methodology for joint data acquisition of DCIP and seismic refraction data on land and in water passages.
- Establishment of functionality for inversion of resistivity, IP and seismic refraction data in GIMLi for land-based and underwater data in the numPy (numerical Python[1]) environment.
- Development and optimisation of coupled inversion in GIMLi.
- Development and adjustment of methodology for quantification and visualisation of data coverage for inverted models.
- Identification and assessment of different methods for cluster analysis.
- Testing and evaluation of the above developments by synthetic modelling and in full scale on the test sites.
- Integration of borehole measurement data together with surface based measurement data in the inversion.

By 2018, the project had generated 4 peer reviewed scientific journal articles, 13 conference proceedings, 1 MSc thesis, 1 BSc thesis, and 1 report.

[1] Python, is open source software which is available for many operating systems, allowing Python code to run on a wide variety of systems

3 COORDINATION AND COLLABORATION

In this section, main activities within coordination and collaboration are presented, in the order presented in Table 3.1.

Table 3.1. *Proposed coordination and dissemination activities outlined in the TRUST 1 Formas proposal*

No.	Coordination and dissemination activities ("quoted text from proposal")	
1	Virtual meeting room	… "If the project will be funded, communication and data exchange will be enhanced by expanding the virtual project room to provide information to the wider scientific and engineering community and general public, but will also provide an essential means of communication between the different subprojects of the TRUST consortium in a password-protected, internal part of the project room." …
2	Regular telephone and online meetings	"Telephone and online meetings will be arranged for the project leaders and participants at regular intervals, at minimum, at a specified date and time each month when current- and planned activities are being discussed, with focus on the project deliverables, budget and time line."
3	Organizations of workshops and participation at national- and international meetings	"A workshop will be organized for the participants in TRUST once a year by the management project. The reference group for the different sub-projects will also be invited for the exchange of knowledge between industry and university."
4	Research school for graduate students	"The senior researchers within the project will develop PhD courses and meetings for graduate students within the TRUST project. The research school will also be open for other graduate students within the GeoInfra call."
5	The GeoBIM database	"All data collected by TRUST project will be incorporated in the database and the visualization tool. " …

3.1 Virtual meeting room

Two types of virtual meeting rooms were set up online, the TRUST website and Webforum. While the TRUST website was intended for external information, Webforum was intended for internal use, and represents a form of data base of the project.

The TRUST website was launched in mid-2013. This first version was published in Swedish. The site was reconstructed in 2016, when it also was published in English. The aim of the web site is to present information about TRUST in a succinct and informative way. Figure 3.1. shows the home view of the website. The construction of the web site was led by Mats Svensson (Tyréns AB), who together with the TRUST group agreed upon the content. The web site was designed by Emma Larsson of Studio Sueca AB. Studio Sueca AB is experienced in working interdisciplinary in the fields of landscape architecture, urban design, architecture and communication.

The website contains information about the TRUST project as a whole, and the individual subprojects, and is the main channel for outreach activities. The development of eight videos were led by Johan Nyman (Mirage media) and Mats Svensson (Tyréns AB) posted at the website (Table 3.2).

Additional outreach was obtained through presentations at meetings (see below), and through publications in peer-reviewed and popular scientific journals, and interviews (i.e. article in *Ny Teknik,* Nr 3, 2016: "*Fler metoder samtidigt ger billigare tunnel*").

Leaflets in Swedish and English can be downloaded about the TRUST project as a whole (Figure 3.1) and for the individual subprojects. Also listed are publication and presentations.

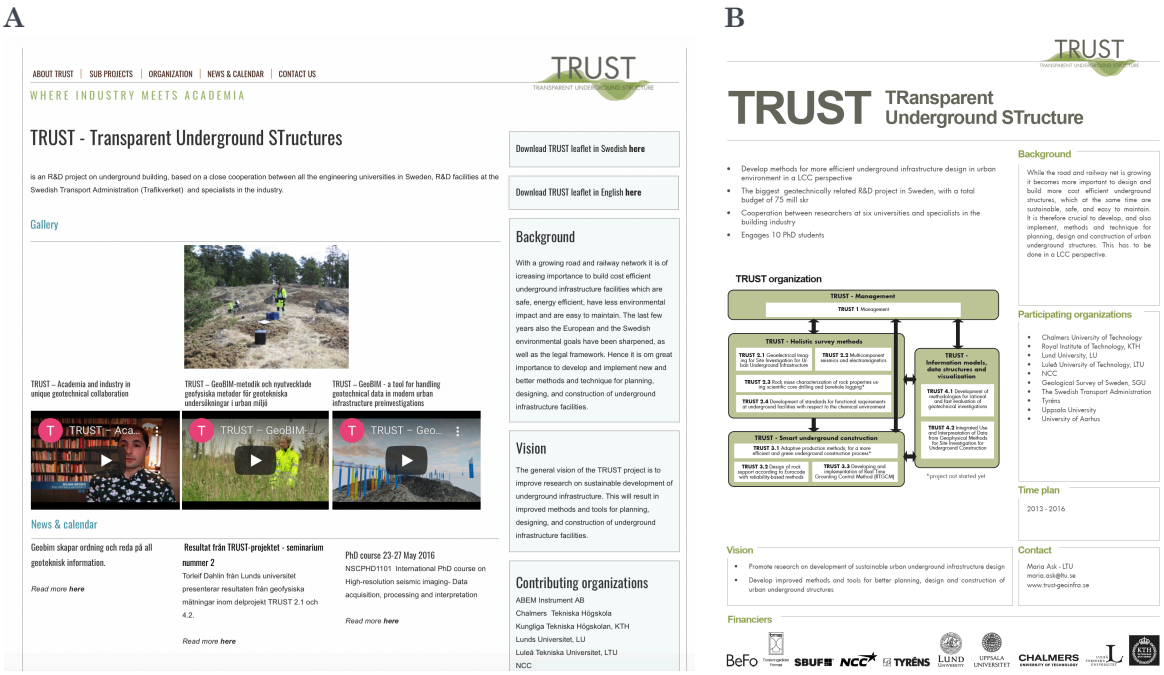

Figure 3.1. *A, The front page of the TRUST website, www.trust-geoinfra.se, screen shot from 30 September 2020. B, Information leaflet about the TRUST project (available at www.trust-geoinfra.se).*

Table 3.2, *TRUST presence on YouTube*

No.	Title	Address
1	TRUST – Utveckling av undersökningsmetoder inför tunnelbyggen	https://youtu.be/0dUZ2qvA65w
2	TRUST 2.1 – Geoelektriska metoder	https://youtu.be/ylc1fyFt0ss
3	TRUST 2.2 – Utveckling av moderna seismiska och elektromagnetiska metoder för förundersökning av underjordisk infrastruktur i urban miljö	https://youtu.be/xjK8EhkGpEc
4	TRUST 4.1 – Utveckling av metoder för rationell och snabb utvärdering av geotekniska undersökningar	https://youtu.be/08AeTxBIhqY
5	Äspö	https://youtu.be/vHQunJpT5rY
6	TRUST – GeoBIM-metodik och nyutvecklade geofysiska metoder	https://youtu.be/NmXicev0coQ
7	TRUST – Academia and industry in unique geotechnical collaboration	https://youtu.be/yOTkbqzXWco
8	TRUST – GeoBIM- a tool for handling geotechnical data	https://youtu.be/3i_kdFv2IGc

Webforum is the selected portal for internal communication. TRUST adapted the webportal of Tyréns AB because is secure, affordable and easy to use. It was in operation from mid 2013 to the end of 2017. Figure 3.2 shows the home view of Webforum. Access to the Webforum is reached via a personal user name and password.

TRUST used Webforum as an internal archive of meetings, publications and data. Webforum for TRUST 1, Management included data archiving of project administration, workshops, case study,

marketing material, website (www.trust-geoinfra.se), user-values, partnering declaration, publications and presentations, IT manual, Spin-off projects, and the final report.

Figure 3.2. *The TRUST internal website, Webforum, on 15 December 2017., https://secure.webforum.com /formasprojekt/page.aspx*

3.2 Regular telephone and online meetings

Telephone and online meetings were arranged for the project leaders and participants at regular intervals, once a month during the semester. A total of 36 telephone meetings were arranged, from February 2012 to December 2016. The meetings were held the first Monday each month, from 15:00-16:30. Typically, project investigators and members of TRUST 1 participated at the meeting. Current- and planned action items that had been discussed and agreed upon in person during biannual workshops (see Section 3.3) were followed-up, status of individual TRUST project as well as web site activities and future plans were discussed.

3.3 Meetings and workshops

Various types of meetings and workshops were arranged during the course of the project. In order to foster internal collaboration and networking, biannual workshops were arranged for TRUST members. Meetings also were arranged to regarding the case study and TRUST-1. Members of the TRUST alliance also arranged one international workshop, and TRUST 1 members were invited to give presentations of TRUST at various national meetings and workshops.

3.3.1 TRUST biannual workshops

Eight TRUST biannual workshops were arranged from March 2013 to August 2016 (Table 3.3). Apart from the 1-day first TRUST workshop (WS#1), the remaining were 2-day workshops. The agenda and action items of each workshop are listed in Appendices 1 and 2, respectively. Some standing agenda items were the same for all workshops, others were revisited over a number of meetings. In addition, some agenda items were focused on innovation aspects, these are further discussed in Section 4, *Innovation and implementation*.

A total of 18 participants came to TRUST workshop 1 (WS#1), that was held at KTH, Stockholm, on 27 March 2013 (Figure 3.3). The focus of the meeting was to give an overview of approved and not-

yet approved projects, and to discuss how to organize coordination and communication within the project. All sub-projects in the TRUST consortium presented their scientific goals and deliveries during TRUST WS#1. In connection with the presentation, the innovation aspects of the sub-projects were also discussed as important recipients of project results and how to normally interact between research practitioners and internships.

Table 3.3. *Place, date and number of participants at TRUST biannual workshops.*

WS No.	Place	Date	No. participants
WS#1	KTH, Stockholm	27 March 2013	18
WS#2	Tyréns AB, Malmö	20-21 August 2013	27
WS#3	BeFo, Näringslivets hus, Stockholm	3 February 2014	60
	Tyréns AB, Stockholm	4 February 2014	28
WS#4	LTU, Luleå	19-20 August 2014	35
WS#5	Uppsala University, Uppsala	3-4 February 2015	35
WS#6	Sweco AB, Gothenburg	25-26 August 2015	33
WS#7	Lund University, Lund	2-3 February 2016	33
WS#8	KTH, Stockholm	30 August 2016	19
	SBUF, Näringslivets hus, Stockholm	31 August 2016	41

A total of 18 participants came to TRUST workshop 1 (WS#1), that was held at KTH, Stockholm, on 27 March 2013 (Figure 3.3). The focus of the meeting was to give an overview of approved and not-yet approved projects, and to discuss how to organize coordination and communication within the project. All sub-projects in the TRUST consortium presented their scientific goals and deliveries during TRUST WS#1. In connection with the presentation, the innovation aspects of the sub-projects were also discussed as important recipients of project results and how to normally interact between research practitioners and internships.

Figure 3.3*, Participants at Workshop 1. Insert photos, from the left: Philip Curtis (SGU), Torleif Dahlin (LU), Lars O. Ericsson (Chalmers), Peter Jonsson (LU), Johan Spross (KTH). Back row, from the left: Mats Svensson (Tyréns AB), Esben Auken (AArhus University), Håkan Rosqvist (LU, Rosqvist resurs), Olof Friberg (Tyréns AB), Maria Ask (LTU), Almir Draganovic (KTH), Fredrik Johansson (KTH), Mehrdad Bastani (SGU), Catrin Edelbro (LTU), Stefan Larsson (KTH). Front row, from the left: Anna Kadefors (Chalmers), Alireza Malehmir (Uppsala University), Thomas Olofsson (LTU).*

The second workshop was held at Tyréns AB, in Malmö, 20-21 August 2013, and gathered 27 participants (Figure 3.4). Much of the workshop was devoted to getting to know each other and the subprojects. Additional goals were to (1) identify criteria for joint field studies; and (2) examine synergies and risks with cooperation between the various subprojects.

***Figure 3.4**, Participants at Workshop 2. Back row, from the left: Peter Jonsson (LU), Mats Svensson (Tyréns AB), Malin Norin (NCC/Chalmers), Anna Gustavsson (LU), Almir Draganovic (KTH), Charlotta Sparrenbom (LU), Thomas Olofsson (LTU), Håkan Rosqvist (LU/Rosqvist Resurs), Per-Ivar Olsson (LU), Marcus Wennermark (LU), Torleif Dahlin (LU), Maria Ask (LTU), Olof Friberg (Tyréns AB), Fredrik Johansson (KTH), Stefan Larsson (KTH), Mehrdad Bastani (SGU), David Hagerberg (Tyréns AB) Joachim Place (UU), Suman Mehta (UU). Front row, from the left: Lars-Olof Dahlström (NCC), Anna Kadefors (Chalmers), Sara Johansson (LU/Tyréns AB), Ali Nejad Ghafar (KTH), Alireza Malehmir (UU), Bojan Brodic (UU). Not in photo: Gianluca Fiandaca (Aarhus University) and Pål Hansson (Tyréns AB).*

The third TRUST workshop was held in Stockholm on 3-4 February 2014. BeFo hosted the first day of the meeting at Näringslivets hus (Figure 3.5). The participants collectively covered a wide range of competence within financing, planning, production and operation of underground infrastructure. The second day was hosted by Tyréns AB with 28 participants (Figure 3.6). The focus was of the workshop was to: (1) increase the participants knowledge of other subprojects in TRUST; (2) identify criteria for joint field studies; and (3) develop the TRUST partnering charter, by examine synergies and risks with cooperation between the various subprojects.

***Figure 3.5,** Snapshot of some industry- and academia participants at day 1 of WS#3.*

***Figure 3.6**, Views from day 2 of WS#3.*

Workshop 4 was held at LTU in Luleå, 19-20 August 2014 with 35 participants (Figure 3.7). The unique goals of the workshop were to: (1) Sign the TRUST partnering declaration; (2) Develop guidelines for the TRUST publication policy; (3) Discuss aspects of site selection – find the locales for joint field studies; (4) Investigate aspects of implementation, and (5) Allocate own time for PhD students.

***Figure 3.7**, Participants at WS#4. Back row, from the left: Fredrik Johansson (KTH), Almir Draganovic (KTH), Mikael Lumetzberger (LU), Torleif Dahlin (LU), Esben Auken (Aahus university). Second row from back: Anders Prästings (KTH/Tyréns AB), Carl Stureson (LTU), Ali Nejad Gahfar (KTH), Joachim Place (UU), Per-Ivar Olsson (LU), Håkan Rosqvist (LU/Tyrens AB), Eva Widing (SKB), Ove Lagerqvist (LTU). Second row from front: Mats Svensson (Tyréns AB), Suman Mehta (UU), Shunguo Wang (UU), Thomas Olofsson (LTU), Charlotta Sparrenbom (LU), Anna Kadefors (Chalmers), David Hagerberg (Tyréns AB), Malin Norin (NCC/Chalmers), Marcus Laaksoharju (Nova FoU). Front row: Sara Johansson (LU), Gianluca Fiandaca (Aarhus University), Maria Ask (LTU), Bojan Brodic (UU), Alireza Malehmir (UU), Mehrdad Bastani (SGU), William Bjureland (KTH), Marcus Wennermark (LU), Lars O. Ericsson (Chalmers). Not in photo: Johan Hedin (Rock Tech Centre).*

The fifth workshop was hosted by Uppsala university on 3-4 February 2015 in Uppsala with 35 participants (Figure 3.8). The objectives of WS#5 was to (1) present results; (2) discuss aspects of implementation; (3) decide the publication policy; (4) Discuss the status of case studies; (5) allow own time for PhD students. Mats Svensson presented the infrastructure design process to give all TRUST participants a basic knowledge of the process. Three different actors presented their R&D implementation. The TRUST publication policy was presented (Appendix 3).

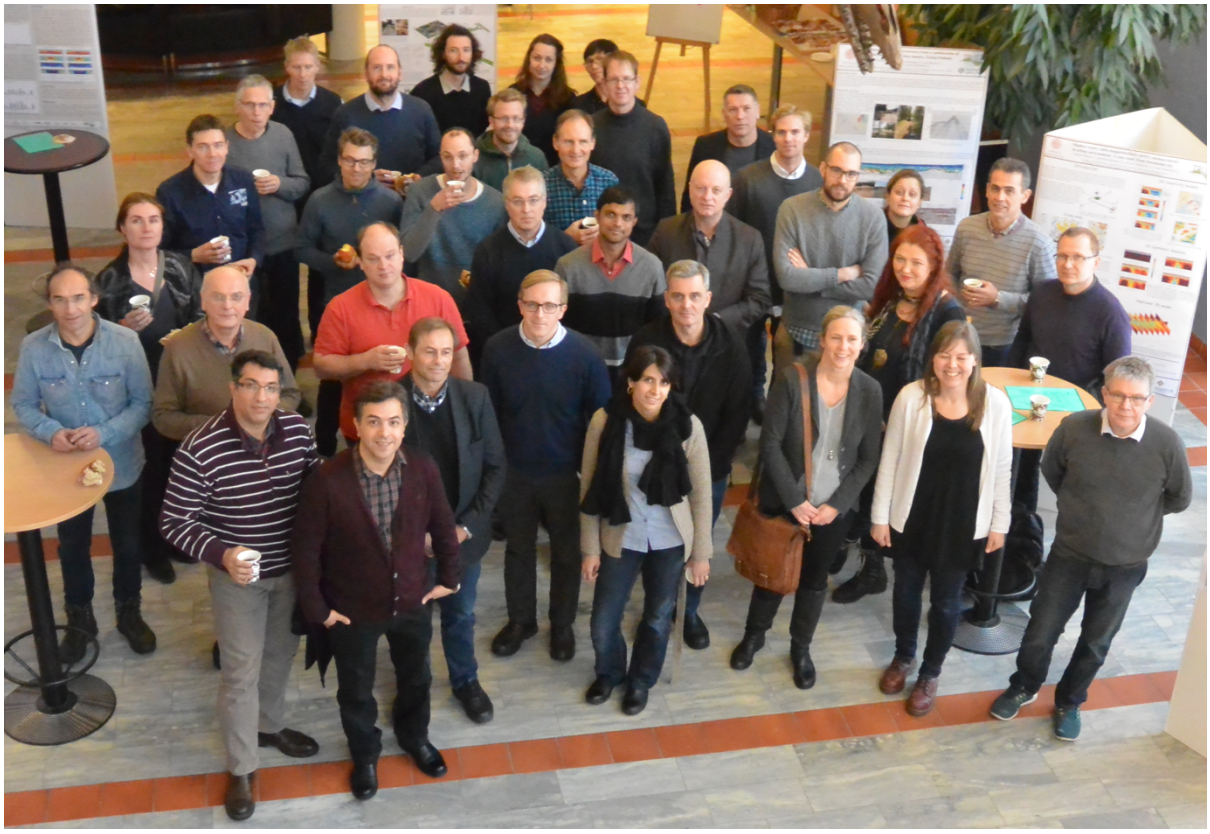

***Figure 3.8**, Participants at WS#5. **Back, from the left**: Mats Lundkvist (SKB), Robert Sturk (Skanska), Andreas Pfaffhuber (NGI), Joachim Place (UU), Emil Lundberg (UU), Georgiania Maries (UU), Shunguo Wang (UU), Fredrik Mossmark (Chalmers/Sweco). **Row two from the back**: Roger Wirsén (Ramböll/LU), Marcus Wennermark (LU), Per-Ivar Olsson (LU), Mats Olsson (SKB), Torleif Dahlin (LU), Suman Mehta (UU), Anders Berntsson (STA), Almir Draganovic (KTH), Andreas Pauldén (LTU?), Carl Stureson (LTU), Charlotta Sparrenbom (LU), Mehrdad Bastani (SGU).). **Row two from the front**: Mats Svensson (Tyréns AB), Laust Pedersen (UU), David Hagerberg (Tyréns AB), William Bjureland (KTH), Håkan Rosqvist (LU/Tyrens AB), Malin Norin (NCC/Chalmers), Jöni Makinen (Turku University). **Front row, from the left**: Ali Nejad Gahfar (KTH), Alireza Malehmir (UU), Per Tengborg (BeFo), Azita Dehghannejad (UU), Anna Kadefors (Chalmers), Maria Ask (LTU), Thomas Olofsson (LTU). **Not in photo:** Phil Curtis (SGU), Stefan Larsson (KTH), Marcus Laaksoharju (Nova FoU).*

TRUST WS#6 was conducted on 25-26 August 2015 with 33 participants (Figure 3.9). The first day was hosted by Chalmers, during which the topics of discussion were to (1) present new results, from Äspö HRL and elsewhere, and (2) planning for the upcoming measurements at Vinsta, the Bypass Stockholm field site. The second day was hosted by Sweco AB, with focus on the renewal of TRUST. Per Tengborg (BeFo) and Ulf B Eriksson (STA) presented their view of future research needs. The main part of day 2 was devoted to a large group work focusing on renewal or TRUST, and lead by Kari Österling (Facilitator at Mötesverkstan).

***Figure 3.9**, Snapshots from WS#6. A, Andreas Pfaffhuber (NGI) & Alireza Mahlemir (UU), B, Fredrik Mossmark & Lars O. Ericsson (Chalmers), Roger Wirsén (Rambøll). C, Torleif Dahlin (LU), D, Per Tengborg (BeFo), E, Ulf B. Andersson (STA), F, Kari Österling, G, Charlotta Sparrenbom (LU), Joachim Place (UU), Esben Auken (Aarhus University), Amlir Draganovic (KTH), H, Ali Najad Gahfar (KTH), Shunguo Wang (UU), Bojan Brodic (UU), Anders Prästings (KTH) and William Bjureland (KTH).*

There were 33 participants at the seventh TRUST Workshop, which was hosted by Lund University from 2-3 February 2016. The focus of the workshop was to present results and to discuss plans about the future. An excursion to the Dalby quarry was conducted (Figure 3.10). This excursion was conducted as a result of the Skanska-funded spinoff project regarding site investigation for underground heat/cold storage, a spin-off project of the TRUST alliance.

***Figure 3.10**, Participants at WS#7. **From the left**: Torleif Dahlin (LU), Per-Ivar Olsson (LU), Sara Johansson (LU/Tyréns AB), Matteo Rossi (LU), David Hagerberg (LU/Tyréns AB), Fredrik Mossmark (Chalmers/SGU), Maria Ask (LTU), Suman Mehta (UU), Laust Pedersen (UU), Andreas Pfaffhuber (NGI), Alireza Malehmir (UU), Shunguo Wang (UU), Bojan Brodic (UU), Mehrdad Bastani (SGU), Almir Draganovic (KTH), Lars O. Ericsson (Chalmers), Mathias Ronczka (LU), Leif Jonsson (LU), Mikael Jakobsson (LU), Charlotta Sparrenbom (LU).*

TRUST WS#8 was conducted from 30-31 August 2016 in Stockholm. Results and future plans were presented and discussed during Day 1, which was hosted by KTH, with 19 participants. Members of TRUST 3.3 also showed their new laboratory equipment, the varying aperture long slot rig that is designed to test injection of grout (Figure 3.11). Day 2 was conducted at Näringslivets hus, and hosted by SBUF. The most important results from TRUST were presented at the final seminar, with 41 participants, of which 22 came from industry.

Standing agenda items

There were three main standing points of each agenda: First, the progress of individual TRUST subprojects was discussed. The form varied, for example, through power point presentations of PIs or other project members, poster presentations, as well as student presentations of their Licentiate thesis. Second, specific action items were agreed upon (Appendix 2). All action items had an identified responsible investigator and a delivery date. The progress was followed up during subsequent monthly telephone meetings and biannual workshops. Third, general networking was also included at all workshops, mostly during coffee breaks and joint dinners, bur also through scheduled time in the agenda (e.g. own planning time for PhD students).

***Figure 3.11**, Participants at WS#8 during Day 1 (A-B) and Day 2 (C-D), A, Alireza Malehmir (UU), Mehrdad Bastani (SGU), and Shunguo Wang (UU); B, Håkan Rosqvist (LU/Tyréns AB) and Almir Draganovic (KTH); C, Ruben Aronson (SBUF), the host of the Day 2 of the meeting, giving the opening address; and D, Discussion from the poster session.*

Revisited agenda items

Several agenda items were revisited over several workshops:

- Terms of internal collaboration were developed during the initial workshops in the form of a partnering declaration, rules for data collection, publication policy, and education.
- Because STA contributed with a big part of the GeoInfra funding, its project Bypass Stockholm was identified as the ideal target for case studies. However, the site selection process turned out to be more complex than initially expected, much related to delays in the Bypass Stockholm project and unforeseen technicalities of the STA procurement process. As a result, contact was taken with the Swedish Nuclear Fuel and Waste Management Co (SKB) and their underground research laboratory, Äspö Hard Rock Laboratory (HRL), near the city of Oskarshamn.
- It was recognized that it might be valuable to schedule own time for PhD students at the workshops, where they could discuss different aspects of their studies and exchange experiences from their process. Own time for PhD networking was scheduled from WS#4 and onwards.
- As indicated, not all of the envisioned TRUST projects were funded from the start of the project by the Geoinfra call (Figure 1.2). Therefore, strategies for securing funding for those projects were developed during initial workshops. The process was partly successful, with the approval of subprojects TRUST 3.2 and 4.2. However, two of the envisioned projects never got approved (TRUST 2.4 and 3.1). This resulted in that the full vision of the TRUST alliance could not be fulfilled. Towards the end of the project, discussions focused on possibilities for a continuation of TRUST, the main work was made at day two of the TRUST WS#6, mentioned above.

Unique agenda items

Unique agenda items mainly consisted of invited speakers who gave thematic talks to TRUST workshops. Table 3.4. lists invited speakers and the title of their talks.

Table 3.4. *List of talks.*

WS No.	Title of talk	Invited speaker
WS#3	User value aspects of the Swedish Transport Administration (STA)	Peter Lundman, STA
WS#3	GeoFuture and user value aspects	Idar Kirkhorn, ViaNova Systems A/S
WS#4	Rock Tech Centre	Johan Hedlin, Rock Tech Centre
WS#4	The Bygginnovationen	Ove Lagerqvist, LTU/Pro Development
WS#5	R&D Implementation by Large Clients – STA	Anders Berntsson, STA
WS#5	R&D Implementation by Contractors – Skanska AB	Robert Sturk, Skanska AB
WS#5	R&D Implementation by Consultanta – Tyréns AB	Håkan Rosqvist, Tyréns AB
WS#5	Äspö HRL	Mats Ohlsson, Swedish
WS#5	Nova FOU status	Marcus Laaksoharju, Nova FOU
WS#6	BeFo outlook on research needs within rock engineering research	Per Tengborg, BeFo
WS#6	Status of Förbifart Stockholm and future research needs	Ulf B. Eriksson, STA
WS#8	TRUST from the view of the funding organizations – SBUF	Ruben Aronsson, SBUF
WS#8	TRUST from the view of the funding organizations – BeFo	Per Tengborg, BeFo
WS#8	TRUST from the view of the funding organizations – SKB	Eva Widing, SKB
WS#8	TRUST from the view of the funding organizations – Tyréns AB	Bengt Hansson, Tyréns AB

3.3.2 Reference group meetings of TRUST 1

The progress of the TRUST 1 project was discussed during six reference group meetings (RGM; Table 3.5). The reference group was composed of members (Table 2.2) of the funding organizations, with Lars-Olof Dahlström (NCC) representing SBUF and Peter Lundman (STA) being the chair.

Table 3.5. *Place, date and number of participants at TRUST biannual workshops.*

RGM No.	Place	Date
RGM#1	STA, Solna	12 April 2013
RGM#2	SKB, Stockholm	26 February 2014
RGM#3	BeFo, Stockholm	19 November 2014
RGM#4	NCC, Stockholm	16 April 2015
RGM#5	Tyréns AB, Stockholm	5 October 2015
RGM#6	SKB, Stockholm	12 April 2016

The standing points of meetings were status updates of the TRUST projects, and how the progress of the main two objectives of TRUST 1 were discussed. The reference group provided advice and opinion on the progress of TRUST, and also shared their network when needed. This was especially valuable during the site selection process, but also during the planning of the open workshops (WS#3 and WS#8), as well as WS#6 when the future of TRUST was discussed. The work within the reference group also led to spreading results from TRUST to the reference groups members organizations, for example, SKB initiated contacts with TRUST 4.1 about their data base GeoBIM).

3.3.3 Near Surface Geoscience 2017 in Malmö

A plan for two scientific conferences was outlined in the TRUST 1 proposals to Formas, BeFo and SBUF. However, as a result of delays in identifying suitable joint case studies, the plan was changed to organize one large conference after the official end of the project.

Thorleif Dahlin led the work within TRUST that resulted in a submission of a proposal to arrange a Near Surface Geoscience (NSG) conference and exhibition of the European Association of Geoscientists and Engineers (EAGE) in Sweden in 2017, to favor large national and international impact. The EAGE approved the proposal: NSG'17 was arranged from 4-6 September 2017 in Malmö, with 500 participants and three parallel, conferences and an exhibition (Appendix 4):

- 23rd European Meeting of Environmental and Engineering Geophysics (23EEG)
- 2nd European Airborne Electromagnetics Conference (2EAE)
- 4th Sustainable Earth Sciences Conference (4SES)

Table 3.6 lists the members of the local advisor- and scientific committees, which comprise strong TRUST member representation. On Sunday 3 September, two workshops and one short course were offered: (1) Workshop: Geophysics in support of infrastructure planning; (2) Workshop: Geophysics for mapping and monitoring of contaminated ground and buried waste; and (3) Short course: A practical introduction on how to apply ground-based transient electromagnetic (TEM) for mapping of groundwater resources. On Thursday 7, two field trips were offered: (1) Application of high-resolution geophysical Methods for mapping bedrock Structures and variation in rock quality within the Tornqvist Zone; and (2) Challenges and site investigations for the particle Accelerators MaxIV and ESS in Lund

3.3.4 Other meetings

The plan for joint case studies in the Formas proposal was expressed as "*coordinate the different research projects in TRUST in case studies along sections of Förbifart Stockholm selected in consultation with the Swedish Transport Administration*". This approach proved to be quite complicated, could not be achieved at the beginning of the project, and is discussed in more detail in Kadefors et al. (2019). Prior to any detailed STA discussions had commenced, preliminary data acquisition was made by TRUST 2.2. (Uppsala University). First, RMT measurement was conducted on Lake Mälaren across the lake passages of Bypass Stockholm from both sea- and ice surfaces before the start of TRUST. Table 3.7 shows two STA presentation of TRUST in 2014. In addition, a number of meetings were arranged during the second half of 2014 to discuss how to fit in TRUST measurements into the Bypass Stockholm schedule. At these meetings, TRUST communicated wishes that the STA would provide: (1) A designated contact person (Ulf B. Eriksson); (2) Clear conditions and rules (communicated at the meetings); and (3) Updates on changes in the time schedule (e-mail list "*Nytt från E4 Förbifart Stockholm*"). TRUST informed about the survey at Vinsta / Lövstavägen and STA approved that additional test could be conducted there. TRUST projects 2.1 and 2.4 conducted a joint campaign (electromagnetic data collection and water geochemistry) in 2015. It was also concluded that the more production-focused projects (TRUST 3.2, 3.3 and non-funded projects 2.3 and 3.1) were not suitable because the progress of Bypass Stockholm was too slow (no underground activities had started).

To get access to an underground testbed, discussions were started with SKB and Nova FoU by TRUST WS#4 (in 2014). A number of meetings were arranged to discuss the plan forward (Table 3.7). The largest joint campaign was launched, including TRUST 2.1, 2.2, 2.4, 3.3, 4.1 and 4.2 projects in first half of 2015. Data acquisition was conducted on- and offshore, as well as within the

tunnel. While high-quality results were obtained for TRUST 2.1 and 2.2, the outcome of TRUST 3.3 was unsuccessful. The TRUST project in general and TRUST 1 in particular has been presented at a range of conferences and meetings, and also has been invited to give presentations, see Table 3.7.

Table 3.6. *Members of Local Advisory Committee & Scientific Committee*

23EEG: Local Advisory Committee	23EEG: Scientific Committee
Torleif Dahlin (Chair), Lund University*	Niklas Linde (Chair), University of Lausanne
Esben Auken, Aarhus University*	Mehrdad Bastani, Geological Survey of Sweden*
Jesper Emilsson, Guideline Geo AB	Ahmad Ali Behroozmand, Stanford University
Jaana Gustafsson, Tyréns AB	Albert Casas, University of Barcelona
Alfredo Mendoza, Sweco AB	Anders Vest Christiansen, Aarhus University
Lars Nielsen, University of Copenhagen	Ranajit Ghose, TU Delft
Lena Persson, Geological Survey of Sweden*	Isabelle Lecomte, University of Bergen
Mathias Ronczka, Lund University*	Majken Looms, University of Copenhagen
Leif Stenberg, SKB*	Alireza Malehmir, Uppsala University*
Mats Svensson, Tyréns AB*	Manuel João Senos Matias, University of Aveiro
	Ingelise Møller, GEUS
	Thomas Ingeman Nielsen, Technical University of Denmark
	Andreas Pfaffhuber, NGI*
	Thorkild M. Rasmussen, Luleå University of Technology
	Matteo Rossi, Lund University*
	Nils Rydén, Lund University*
	Roger Wisén, Rambøll Denmark A/S & Lund University*
2EAE: Scientific Committee	23EEG: Scientific Committee
Esben Auken (Chair), Aarhus University*	Philip Ringrose (Chair), NTNU/Statoil
Andreas Pfaffhuber (Chair), NGI*	Maria Ask, Luleå University of Technology*
Kristoffer Andersen, Aarhus University	Peter Bergmann, GFZ
Mehrdad Bastani, Geological Surevy of Sweden*	Isabelle Czernichowski-Lauriol, BRGM/ENeRG
Vikas Baranwal, NGU	Mikael Erlström, Geological Survey of Sweden
Cyril Schamper, Paris 6 University	Jean-Charles Ferran, CGG
Anders Vest Christiansen, Aarhus University	Birgit Müller, KIT
Guillaume Martelet, BRGM	Lars Henrik Nielsen, GEUS
Jim Hodgson, GSI	Jan-Erik Rosberg, Lund University
Pierre-Alexandre Reninger, BRGM	Constantin Sava, GeoEcoMar/ENeRG
Bernhard Siemon, BGR	Iain Stewart, Plymouth University
Robert Supper, GBA	Tim Tambach, Shell
Kurt Sørensen, SkyTEM Surveys	Sylvain Thibeau, Total
Andrea Viezzoli, Aarhus Geophysics ApS	Ton Wildenborg, TNO/ CO2GeoNet

*, TRUST project and reference group members

Table 3.7. *Presentations of TRUST project at project meetings, workshops and conferences*

Date	Title	Meeting / Workshop / Conference
2013-04-24	TRansparent Underjordsinfra-STruktur (TRUST)	STA, Solna
2013-12-02	Erfarenheter av samverkansprojekt (TRUST)	SBU Externa råd, Stockholm
2014-03-13	TRUST – Sveriges största Geo-FoU någonsin	Grundläggningsdagen, Stockholm
2014-03-18	TRUST	SKB- Nova FOU, Äspö
2014-05-26	TRansparent Underground Structure (TRUST)	SKB- Nova FOU, Äspö
2014-06-10	TRUST	STA, Solna
2014-08-21	Forskarmiljön TRUST – ett GeoInfraprojekt	SBU Högskolekonferens
2014-11-03	TRUST – a new model for research collaboration	NGL Annual Science Meeting, Oskarshamn
2015-11-02	TRUST – a new model for research collaboration	Singapore-Sweden Excellence Seminar
2016-93-14	Om TRUST – Transparent Underground Structure	Bergmekanikdagen, Stockholm
2017-10-06	Forskningsbaserad innovation i infrastrukturbyggande: Erfarenheter och lärdomar från TRUST GeoInfra	Samhällsbyggardagarna, STockholm
2017-10-17	Utveckling av metoder för undermarksbyggande i urban miljö med LCC-perspektiv	Betongdagen, Stockholm

3.4 Research school and meetings for graduate students

The following plans for a research school for graduate students was included in the proposal: "*The senior researchers within the project will develop PhD courses and meetings for graduate students within the TRUST project. The research school will also be open for other graduate students within the GeoInfra call*."

Fredrik Johansson (KTH) approved to act as contact person for developing the research school. It was discovered that each university own designs on obligatory courses resulting in very limited space for courses within a TRUST research school. After an initial survey among the supervisors, on needs /requirements of courses, it was recognized that a better solution would be to organize individual courses rather than an entire curse program. Fredrik Johansson developed a joint geostatistics course; Anna Kadefors and Thomas Olofsson drove the process to develop a joint research business course; and Alireza Malehmir and colleagues gave the course "Physical properties of rocks".

As mentioned above, starting from TRUST WS#4, time was allocated for separate PhD student meetings during the biannual workshops. At the end of each WS, the PhD students gave a summary of important items discussed.

3.5 Results of coordination and collaboration

In order to enhance the opportunities from working in a large group and to reduce the risk for misunderstandings, the members of TRUST developed a partnering declaration document, defined needs and requirements for data collection, and agreed upon a publication policy.

3.5.1 Partnering declaration

An important aspect in the TRUST project has been to enhance collaboration between the research projects. This issue was brought up at the TRUST WS#1 (February 2013), and project members decided to use inspiration and tools from partnering in construction projects. Such tools include development of joint goals, documenting them as a "Partnering Declaration", and follow-up workshops (Appendix 5). At WS#2 (August 2013), an introduction about partnering methods was followed by a group work session was organized, where groups discussed behaviors and synergies associated with research collaborations. The two questions to groups were:

1) Which behaviors and other circumstances may produce trust and distrust in research collaborations?
2) Which potential advantages/synergies do you see in the TRUST collaboration? (for yourself, the research community and society?)

The group discussions were summarized and it was decided to devote more time at WS#3 to further discussions about joint goals as a basis for developing a Partnering Declaration.

Opportunities and risks were identified during group discussions during day 2 of WS#3 (February 2014). The four groups were assigned a unique subject to discuss:

- Group 1, General collaboration issues
- Group 2, Data sharing and quality
- Group 3, Publication and impact on the research field
- Group 4, Impact on society

Four types of opportunities were identified within Group 1, general collaboration issues: (1) Higher creativity and cross-fertilization of ideas; (2) Opportunities for future research collaboration; (3) Better quality of problem formulation and results; and (4) Individual satisfaction by opportunities for making new friends, expanding professional networks and having a good time. Risks within collaboration, in general are: (1) Free-riding as participants want to have benefits without contributing; (2) Too much time is spent on meetings, communication and coordination; (3) Unclear division of responsibility; (4) Relationships to relevant partners outside the network suffer; and (5) Ideas developed in the project are used in applications or publications with other partners in an unfair way.

Three main opportunities are identified within Group 2, data sharing and quality: (1) More and better results for the same money by collaboration in data collection and sharing of data; (2) Discover new uses of results for other projects and purposes; and (3) Better quality of data and improved methods by collaboration and peer review. The identified risks are: (1) Opportunities for data use are lost due to insufficient communication between projects; (2) Different groups and individuals have different quality standards and requirements; some may have to do additional work to benefit others; (3) Results and data are published without consent and coordination; and (4) Mismatched time schedules.

The identified opportunities of Group 3, publication and impact in the research field are: (1) More and higher quality publication by collaboration and peer review; (2) More co-publications; and (3) More citations and higher h-index of participant researchers. The identified risks are: (1) Contributions are not acknowledged by co-authorship; (2) Results and data are published without consent and coordination; and (3) Unintended plagiarism due to lack of communication.

The work by Group 4, impact on society identified five types of opportunities: (1) More and better results/tools for the same money; (2) Improved understanding between academia and industry; (3) Better opportunities to get questions important to practice addressed; (4) Influence design standards (norms); and (5) Contribute to more efficient and sustainable construction technologies. No risks were identified.

3.5.2 IT manual

In order to support organized handling of data in a systematic way that could be incorporated in the GeoBIM concept of TRUST 4.1, aspects of data was handled in three steps.

In the first step, a questionnaire was developed by Peter Jonsson (LU) to survey what data types will be used in the TRUST project and, as far as possible, from what sources the data emanate. The survey considered four types of data:

- Own measurements: Data that are a result of measurements produced in own subproject. Examples: Measurements of grout density, profiles from reflection seismic.
- Data from other TRUST participants: Data that is produced in another TRUST subproject, but also are used in own project. Examples: Measurements of grout density used by the seismology group, Synthetic seismic velocity profiles used by the co- ordination group.
- Modeling: This is data emanating from modeling activities in own subproject. Example: Results from finite element modeling of grout in a fracture, Results from finite difference modeling of a seismic wavefield.
- Other data: This is data from general sources, public databases, model data publicly available or from project not within the TRUST framework. Example: Maps, terrain models.

In the second step, a *TRUST Field Measurement Form* was developed by Olof Froberg (Tyréns AB) and co-workers. The form was developed to give other members of TRUST (in other subprojects) opportunity to see planned field surveys.

As the third step, an IT manual was developed by Olof Friberg and Mikael Lumetzberger (Tyréns AB, see Appendix 7). The IT manual contains guidelines for naming conventions and data storage structuring and specifies the metadata that should accompany uploaded material. The manual generally describes how data and documents are to be structured within the entire TRUST project, with specific instructions regarding TRUST 2.1. The IT manual covers the following main subjects: (1) Software and formats; (2) Coordinate systems; (3) Webforum; (4) Drawings & maps; (5) Collected & processed data; (6) Documents; (7) Naming conventions; (8) Delivery specifications

3.5.3 Publication policy

A publication policy was developed with the goal to offer means for internal review and to ensure a fair process for publishing data. Mehrdad Bastani (SGU) led this work that was adapted at TRUST WS#5 (Appendix 3)

The publication policy contains general overview about the policies related to the publications made during and after the termination of the TRUST project. All the partners/project leaders (PP/PL) involved in the TRUST project should be familiar with the policy. We have mainly used the Vancouver Protocol (VP, https://www.google.se/#q=vancouver+protocol+download) to form the publication policies within the TRUST project. We have also taken into account some of the experiences gained from our previous collaborations with other research projects. During the discussions made in the TRUST WS# 4, the authorship was of main focus and it is therefore emphasized here that authorship credit should be based only on substantial contributions to:

- conception and design, or analysis and interpretation of data
- drafting the article or revising it critically for important intellectual content
- final approval of the version to be published.

3.6 The GeoBIM database

Plans for a GeoBIM data base was outlined in the proposal: "*All data collected by TRUST project will be incorporated in the database and the visualization tool.*" This topic part of TRUST 4.1, thus not a topic of TRUST 1.

The establishment of WebForum allowed possibility to upload and store data and documents generated by the subprojects.

4 INNOVATION AND IMPLEMENTATION

In this section, we present aspects of innovation and implementation from three aspects: Academic work, Aspects of innovation and implementation from biannual workshops, and Spin-off projects.

4.1 Academic work

The academic work has been presented in two separate publication, the MSc thesis of Pauldén and Stureson (2015) and the BeFo report of Kadefors et al. (2019). As the result, we refer to these publications for the full results and present the main results below.

4.1.1 Pauldén and Stureson (2015): MSc thesis

Pauldén and Stureson (2015[2]) compiled a joint MSc thesis entitled "Project based organizations' challenges when absorbing knowledge from joint Research and development projects between industry and academia: A case study from the perspective of a construction contractor firm". The study investigated how project-based organizations (PBOs) in the construction industry absorb and implement new knowledge from research projects with the academy, by identifying challenges related to the absorptive capacity of the industry (ACAP). Qualitative data was collected through a case study in the construction industry, where both primary and secondary data were used. Primary data consisted of 14 semi-structured interviews, while secondary data consisted of reports and documents from actors involved in the case study.

The results of show that the ACAP process among PBOs faces many challenges in research collaboration projects between industry and academia. Furthermore, PBOs do not see the concept of ACAP as an important part of creating competitive advantages, which leads to missed opportunities as resources are not used in the most efficient way. The ACAP process must be adapted to match the type of R&D project being run. Identified recipients must be present at each R&D project to increase the chances of implementing the results. Therefore, it is of great importance to have a clear implementation and marketing strategy from the start of the projects.

The challenges when absorbing knowledge from was further investigated. Regarding challenges in research and development the following observation was made:

- Type of R&D: industry more interested in development projects (more easy to implement, less risky and result quicker) and the academic more interested in basic and applied research
- Priorities differ: Industry interested in solutions, academy interested in publications
- Lack of incentives, no demand of new solution or innovations from the client

4.1.2 Kadefors et al. (2019): BeFo report

Kadefors et al. (2019[3]) compiled the report Innovation processes and dissemination of research-based knowledge in Swedish rock engineering - experiences in the TRUST GeoInfra project. It summarized and discussed results of interviews and workshops conducted with representatives of clients, contractors, consultants, researchers and funding agencies in the TRUST project. The report also describes the innovation processes and the dissemination of knowledge in Swedish rock engineering research in general and within the TRUST project in particular

[2] http://ltu.diva-portal.org/smash/get/diva2:1020072/FULLTEXT02.pdf
[3] https://www.befoonline.org/publikationer/r-183__1313

Innovation in the project-based construction industry is perceived as complex and poorly understood. The authors discussed and analysed the innovation system within the underground construction area with a focus on dissemination and implementation of research-based knowledge in business projects. The result is primarily based on interviews performed with representatives of clients, contractors, consultants, researchers and funding bodies within the TRUST project. There are two main focus areas: the innovation system level and the TRUST project. The innovation system level describes drivers, organization and processes for engaging in R&D and implementing results within the Swedish Transport Administration (STA), contractor companies and consultancy firms, but also interviewee opinions about the innovation culture in Swedish rock engineering and construction more generally.

Underground construction is an area where comparatively much research is carried out and university-industry collaboration is lively. The results confirm many of the observations made by previous researchers: the small resources within companies devoted to research and innovation, the importance of champions at the project level, problems as innovation drivers, and the difficulties to disseminate knowledge and implement company level initiatives. The contractor interviews illustrate how sensitive their innovation processes are to chance factors such as timing of new relevant business projects and the experiences and knowledge of the individuals that happen to be assigned to a specific project. In this respect, the client is more in control. However, the interviewed client representatives from STA express the same kind of difficulties in driving innovation more strategically on the organizational level and convince their project managers to open up for R&D tests and new knowledge in their business projects.

There are many drivers for firms to engage in R&D collaborations with public funding. R&D collaboration provided access to knowledge networks by enabling participation in reference groups and communities such as BeFo. Another important goal, both of companies and of SBUF, was to support MSc and PhD education for future recruitment. Thus, the individuals themselves were often the most important research output. Implementation of results was not found a primary motivation although a more strategic approach was emerging among public organizations and private companies, who put more emphasis than they used to on application in practice of research results. The consultancy company Tyréns AB was especially active in developing their R&D strategy to support a business model based on premium services. Knowledge development for underground construction was in large part driven by individual specialists based on their contacts in business projects. Centrally defined R&D strategies did not deal explicitly with such technical disciplines, but tended to focus on general goals such as sustainability, or on participation in high profile research collaborations.

Most specialists within academia as well as industry were involved in several networks and perceived these to provide useful interaction platforms. Research funding was governed by BeFo and SBUF, and these peer networks thus strongly influenced research strategy on a national level. The number of PhDs in industry had increased over the last years, and important informal networks developed over time between these and their former university departments. Such relationships formed the basis for gaining research funding, which is often dependent on industry co-funding.

When establishing TRUST, the assumption was that a large coordinated R&D project would be better for communicating with industry and implementing results than several smaller projects. However, it turned out to be more or less the other way around. The existing system could handle innovation in projects, but not innovation on the organizational level. This became apparent when trying to find a joint test site. In smaller research projects, access to business projects is provided by project-based individuals with an R&D background and personal contacts. This often requires that site work is going well and that site measurements are found not to cause too much disturbance. Large programs for site measurements involving numerous actors, such as TRUST, call for planning and upfront commitment. However, there was no system on the receiver side – and here the STA

was the primary actor – that was able to take the step from a bottom up, ad-hoc, individual based regime to an organizational strategy with national level implications. Thus, the large size of the TRUST project turned out to be a major disadvantage.

In general, the internal innovation capabilities of companies and client authorities need to be developed in order for these to benefit from the collaborative research programs and act upon the knowledge developed. One aspect is that measures should be taken to more explicitly involve business project managers in both R&D and implementation. Innovation capability development is needed especially on the client side, since long term strategies in supplier organizations will not develop if the strategies of the dominant clients is not clear. However, assuming that the geo area in general is largely an open innovation environment, it also seems useful to explore if different actors could perform complementary activities in an industry innovation system. For example, specialist networks both within organizations and on the industry level may be more formally mobilized in external monitoring, strategy development and evaluation. In the future, top management, technically oriented specialists and researchers need to be more aware of how the innovation system works, including the regulatory and contractual environment.

There is also a need to invest also in research that is relatively far from application. Thus, evaluation processes and output measurement systems should be adapted to how close to implementation the research project is and also assess the need to build capabilities on the receiver side.

4.2 Aspects of innovation and implementation from biannual workshops: Identifying user-values

The first day of TRUST #WS3 was hosted by BeFo and devoted to identify user-value aspects for underground construction projects from academic- and industry point of views, both in general, and in particular for the TRUST project. This was achieved by presentations in plenum and through group work by invited experts who collectively cover a wide range of competence within financing, planning, production and operation of underground infrastructure. The following organizations were present, organized with respect to their type:

- Swedish and Danish universities (Chalmers, KTH, LTU, LU, UU, Aarhus University),
- Governmental agencies (SGU, STA),
- Large clients (Boliden, STA, SKB),
- Contractors (BESAB, NCC, Skanska),
- Research institutes (CBI, KIMAB, LIAG, NGI, SGI),
- Consultants (ABEM instruments AB, Golder Associates, NCC Teknik, Norrkonsult, Ramböll, Rosqvist Resurs AB, SWECO, Tunnel Engineering AB, Tyréns AB, ViaNova Systems AS), and
- Research foundation (BeFo).

In plenum, the TRUST project as a whole was presented, user-values of the individual projects were presented, and two invited speakers presented user value aspects with focus on their respective organizations. Peter Lundman (STA) presented the task and strategic challenges of STA, information about major ongoing projects, various aspects of prognoses and accuracy. Peter Lundman presented user values that would be valuable for the STA: (1) Improved awareness of uncertainties – a better standpoint; (2) Improved prognoses (Better contract; More correct solution at the “first shot”); and (3) Better design and production methods (Faster, cheaper and safer…). Idar Kirkhorn (ViaNova Systems A/S) presented a subproject on the development of an open data model with 3D representation within the Norwegian project Geofuture, which is coordinated by NGI (https://www.ngi.no/eng/Projects/Geofuture). Idar Kirkhorn presented a number of general

challenges, for example, how to handle various versions of the model, review control, as well as errors and error lists of the model. He presented four specific challenges for open model project: (1) How to gather all disciplines into one single intelligent model? (2) How to make all disciplines to work together - using one shared model? (3) How to get all work together at the same time within only one model? and (4) How to present the model to all actors in a simple way?

Appendix 7 present the results from the group work. In brief, anticipated results from TRUST may be exploited as innovations sorted in three different categories:

- The result from TRUST 2.1, TRUST 2.2 and TRUST 3.3 can all be encapsulated in technology innovations – surveying geophysical instruments, 2.1 and 2.2, or grouting rigs as in 3.3. However, the use of the product innovations requires at the same time access to trained staff implicating that in order to introduce the technology to the market the innovation needs to be provided as a service. The key question for implementation is weather the new innovations really can provide better service and quality for the customer compared to traditional technologies and that these qualities (values) are requested and recognized by the customer (STA). As it was commented at the workshop "Clients should be more interested to predict the grouting", "Better knowledge of possibilities needed among clients in order to ask for the right pre-investigation methods" and "Better quality of site investigation results at an affordable cost" needs to be quantified, i.e. "how much better" and what is "affordable".
- A value can also be utilized in the form of a law, policy or a standard. TRUST 2.4 and TRUST 3.2 are developing standards that can be applied by the owners/developers of underground facilities after the end of the project. Therefore, the implementation "needs linkage to purchase & contractual aspects of the underground construction project". The client (STA) needs to require the design according to the standard.
- The result of TRUST 4.1 and TRUST 4.2 have organizational implications. The GeoBIM consisting of object-oriented 3D models can be used to predict performance metrics. Especially, gains in clarification of project objectives for stakeholders and resolving of coordination issues between different design disciplines can justify the investments in the design phase, "estimated saving ~5% of production cost". However, the commercial relationships between the many specialists involved must be resolved to encourage sharing of information between stakeholders in the projects. Therefore, the implementation requires some incentive in the contract supporting collaboration and information sharing. In BIM supported building projects 3D models are often aggregated in digital mock-ups on a regular basis in a concurrent engineering design process.

Common implementation issues are:

- The client (STA) is an important player in the implementation of the result in all projects. The client needs to require the use of the method, standard or technology or procure the construction project to facilitate the implementation and use of the specific innovation.
- The main driver for researchers in many of the research projects is the academic values, i.e. Scientific publications, PhD examinations, research network, etc. Hence, other (industry) partners need to be involved that will make use of the result and take the innovation to the market.

4.3 Discovery of innovation and implementation

Implementation of results were discussed at all workshops. Implementation requires some incentive in the contract supporting collaboration and information sharing.

External speakers gave presentations aimed at educating TRUST members. Aspects of implementation were presented during TRUST WS#4 by two invited speakers: Johan Hedlin (Nordic Rock Tech Centre AB) presented "Rock Tech Centre: Moving theory into practice" and Ove

Lagerqvist (Pro Development AB/LTU) presented "Implementation aspects of the *Bygginnovationen"*.

Two external speakers and one internal speaker gave presentations during TRUST WS#5: (1) Anders Berntsson (STA) presented R&D Implementation by large clients; (2) Robert Sturk (Skanska AB) presented R&D Implementation by contractors; and (3) Håkan Rosqvist (Tyréns AB/TRUST 1, 2.1) presented R&D Implementation by consultants.

General issues and barriers that were discussed in WS#5 regarding the implementation of research result were:

- Doing research on the wrong problems (no user value)
- No connection between implementation in real project and investment in research.
- Fragmented project processes lead to routine information collection not adapted to the decision-making gates and the life cycle perspective of the project outcome.

Challenges in collaboration and knowledge sharing were discussed in WS#5:

- External collaboration and knowledge sharing: No strategies for external sharing and initiatives tied to individuals. However, the TRUST network provides an opportunity for knowledge sharing of R&D in underground construction
- Internal collaboration and knowledge sharing: Company ICT system for knowledge sharing have bad reputation. Knowledge sharing mostly through mouth-to-mouth => strongly connected to individuals. The real use of a PhD project is in the competence of the PhD not in the result of the research

Two invited speakers gave presentations of research needs during TRUST WS#6. Per Tengborg (BeFo) presented "BeFo outlook on future research needs within rock engineering research" and Ulf B. Eriksson (STA) presented "Status of Bypass Stockholm and future research needs".

A larger group from industry was also invited to the final day of TRUST WS#8 that was hosted by SBUF. This day started with presentations in plenum, with a final report of the TRUST project by Maria Ask (Appendix 8), and presentation of of results from the case study at Äspö HRL by Mats Svensson, Charlotte Sparrenbom, Alireza Malehmir, Fredik Johansson, Almir Draganovic and Torleif Dahlin. Ruben Aronsson for SBUF, Per Tengborg for BeFo and STA, Eva Widing for SKB and Bengt Hansson for Tyréns AB presented TRUST from their views as funding organizations. This was followed by a porter session entitled Innovation and user-value of TRUST sub-projects (posters are also included in Appendix 8). The different subprojects in TRUST have results that can be exploited as:

- Technology innovations (e.g. surveying instruments, grouting rigs)
- New standards and regulations
- Methods and tools for data aggregation, coordination and communication of information (e.g. GeoBIM, Eurocode)
- Barriers also have been identified:
- The client (STA) needs to require the use of the method, standard or technology or procure the construction project to facilitate the implementation and use of the specific innovation
- The use of new innovations also requires access to trained staff, i.e., to introduce new technology, the innovation needs to be provided as a service
- The main driver for researchers often is academic values. Other (industry) partners who will make use of the result are needed, to take the innovation to the market

4.4 Spin-off projects

The development of the TRUST network has resulted in the development of spin-off projects. There are two types, (1) science-driven and (2) implementation-driven spinoff projects.

It was very clear that a number of science-driven spin off between the different TRUST sub projects were discussed, all in different stages. All from Joachims presentation of the seismic – grouting cooperation to the new idea of a collaborative project between the PhD students William, Anders P and the geophysical projects around the question "How sure are we on the level of the bedrock?". We could identify several potential ideas on collaborative spin off projects formed during this TRUST period. It is very important, because these spin-offs was what the TRUST umbrella was dreaming of in the Formas application. Hence, these ideas should be taken a step forward and be defined, to be used for marketing and as a result of an outcome for future "unexpected" research (addressing Formas and similar). The science driven spin-offs that culminated with a proposal are listed in Table 4.1, of which all but the support letter has led to funded projects. The support letter was intended to be part of a proposal to EU innovation support, but the proposal was never submitted m the lead PIs (SKB and Nova FoU).

There has also been a number of spin-off projects that are implementation-driven. These are listed in Table 4-2. All these projects have been conducted.

Table 4-1, *Science-driven spin-off projects*

No.	Title	Responsible
1	Grout spread detection using ultrasonic frequencies	Joachim Place (UU), Ali Nejad Gahfar (KTH)
2	Letter of support to the ERUF application for further development of the Äspö laboratory	Maria Ask (LTU), Torleif Dahlin (LU), Alireza Malehmir (UU), Lars O. Eriicsson (Chalmers), Fredrik Johansson (KTH), Almir Draganivic (KTH), Stefan Larsson (KTH), Anna Kadefors (Chalmers/KTH)
3	Combined survey methods in underground construction - monitoring of water quality changes with geoelectric	Charlotte Sparrenbom (LU), Malin Norin (NCC) & Fredrik Mossmark (SWECO)
4	Characterisation and monitoring of in-situ remediation of chlorinated hydrocarbon contamination using an interdisciplinary approach (MIRACHL), see http://mirachl.com/	Torleif Dahlin & Charlotta Sparrenbom (LU), Mats Svensson (Tyréns AB), Esben Auken (ÅU),
5	Rock characterization in 3D in Dalby quarry	Torleif Dahlin, Sara Johansson, Per-Ivar Olsson, Leif Johansson (LU)

Table 4-2, *Implementation-driven spin-off projects*

No.	Title	Responsible for new project / client, contact
1	Kristianstad – Färgaren – TRUST 2.1	Alireza Malehmir (UU) / TRUST 2.1
2	Varberg - STA	Torleif Dahlin (LU), Alireza Malehmir (UU) / Mats Svensson (Tyréns AB)
3	Östlig förbindelsen - STA	Torleif Dahlin (LU) / STA
4	Oslo –tunneling, Norway	Alireza Malehmir (UU) / Statens veivesen, Andreas Pfaffhuber (NGI)
5	Siilijärvi open pit mine, Finland	Alireza Malehmir (UU) / Yara Oy
6	Turku water management project, Finland	Alireza Malehmir (UU) / Geological Survey of Finland, University of Turku
7	Site investigation for underground thermal storage facility in Dalby, Skåne	Torleif Dahlin (LU), Alireza Malehmir (UU) / Robert Sturk (SKANSKA)
8	Ostlänken	Mats Svensson (Tyréns AB) / STA / Tyréns AB

5 Concluding remarks

The TRransparent Underground STructure (TRUST) is a unique interdisciplinary research and innovation project alliance and a new model for collaboration with the ambition to create an internationally competitive research cluster within underground construction in Sweden. The main part of the project was conducted from 2013-2017, but some PhD projects running until 2020. The alliance has gathered over 40 scientists and experts from the SBU, Uppsala university, the SGU, research institutes, private companies, a regional center for research and development, and international partners. The total budget of the TRUST alliance is almost 75 MSEK, with funding provided by Formas, STA, research foundations (BeFo, SBUF, Sven Tyréns foundation), SGU, research institutes and -centers, private companies, and universities.

The overall aim of the TRUST alliance is to improve methods and tools for planning, design and construction of underground facilities. The TRUST alliance is composed of eight subprojects that cover four themes, (1) Management (TRUST 1), (2) Holistic survey methods (TRUST 2.1, 2.2, 2.4), (3) Smart underground construction (TRUST 3.2, 3.3), and (4) Information models, data structures and visualization (TRUST 4.1, 4.2). This report presents results achieved within subproject TRUST 1, the umbrella project of the TRUST alliance. The focus of this report regards coordination of the subprojects and communication of results. Kadefors et al. (2019) has reported aspects of innovation and implementation, and is only briefly presented in this report.

The seven subprojects in Themes 2-4 have contributed to technical innovations (TRUST 2.1, 2.2, 3.3), influences policies and standards (TRUST 2.4, 3.1, 4.1), and influence organization of data (TRUST 4.1, 4.2). Subprojects TRUST 2.1 and 2.2 have developed and optimized data acquisition and analyzing techniques for geoelectric, electromagnetic, and multicomponent seismic methods for urban areas. Subproject TRUST 2.3 has analyzed the evolution hydrogeochemistry of groundwater during underground tunnel construction, and its effect on cement-based materials and corrosion of tunnel reinforcement. Subproject TRUST 3.2 has developed reliability-based design methodology for shotcrete in rock tunnels, and a design methodology for shotcrete lining based on a combination of the observational method and reliability-based methods in accordance with Eurocodes. Subproject TRUST 3.3 has explored penetrability properties of cement-based grout for existing methodologies, measured penetrability more realistically, improved grout spread using dynamic pressure impulses, and applied real time grouting control theory to predict the grout spread in an artificial fracture with variable aperture. Subproject TRUST 4.1 has developed a framework for statistical evaluation of geotechnical parameters, explored limitations of the partial-factor method in Eurocode (EN 1997), and integrated this method with risk-based approach of reality-based design. TRUST 4.1further developed the web-based Geo-BIM, which is a database for gathering various types of geotechnical site investigation data, in 2D and 3D. GeoBIM allows interpretation and visualization of data for a wide range of users. Subproject TRUST 4.2 has integrated different types of data with respect to resolution and scale of investigation for improved reliability of geophysical subsurface models. The TRUST alliance contribute to knowledge building within underground construction, nine technical licentiate thesis, nine doctoral thesis, two postdoctoral fellows, several MSc thesis projects, and numerous peer-reviewed and popular scientific publications. Because two subprojects focusing on engineering geology site investigation methods (TRUST 2.3) and adaptive construction methods (TRUST 3.1), the TRUST alliance never reached its full envisioned potential.

Five activities were planned to support coordination and communication. Activities (1) *Virtual meeting room*, (2) *Regular meetings*; (3) *Organizations of workshops and participation at meetings* developed according to plan. Especially activities (2) and (3) has been critical for sharing knowledge, building networks and initiation spin-off projects. In turn, during meetings, development of a joint

partnering declaration, IT manual, and publication policy has proven to be important for achieving a well-functioning collaboration among the scientists and experts from the different subprojects. Activity (4) *Research school* never reached its full potential, because local requirements at the different universities left limited space for developing a joint research school for graduate students. Likewise, activity (5) *The GeoBIM database* was not further developed because it was part of the TRUST 4.1 project. The internal virtual meeting room Webforum offered a site where data and documents from the subprojects could be uploaded.

Management have been more extensive than anticipated. A steering group was founded to act as a sounding board for the progress of the project and the design of workshops. Project management has required significantly more extensive coordination than planned, especially as a result of the identification of joint case studies being more extensive than planned. Unforeseen obstacles (e.g. political, project-related delays, legal aspects) resulted in that the original joint case study in the Bypass Stockholm project led to the development of the alternative case study in the Äspö hard rock laboratory. These factors motivated extension of the project and application of extra funding.

The coordination and communication provided by TRUST 1 has contributed to the overall success of the TRUST alliance. Its main achievements are: (1) contributing to network-building between researchers, doctoral students and experts from the TRUST partners, i.e. five major Swedish universities, authorities, industry, and international partners; (2) disseminating knowledge among project participants and broadening their skills within the research and innovation of other subprojects, and (3) supporting the development of spin-off projects within both applied projects and in projects with a more basic scientific character.

The innovation and implementation aspects has been presented in detail by Kadefors et al. (2019) who presents results from interviews and workshops conducted with representatives of clients contractors, consultants, researchers, and funding agencies. In short, their main findings and recommendations were: (1) Industry (i.e. the Swedish transport authority) can handle innovation in individual construction projects but has a harder time to handle innovation on the organizational level (i.e. large coordinated TRUST alliance). While access to business projects is provided by individuals (often through their personal contacts) on the client or supplier side in smaller research projects, large programs with many actors call for more planning and upfront commitment. TRUST has demonstrated difficulties to advance from a bottom-up, ad-hoc, individual-based regime to an organizational strategy with national level anchoring and implications. Thus, the apparent ideal match between TRUST and the Swedish transport agency in theory proved to be a major disadvantage in practice; (2) Internal innovation capabilities of companies and client authorities need to be developed for organizations to benefit from large collaborative research programs. Top management, technically oriented specialists and researchers need to develop a joint understanding on how the innovation system works, including the regulatory and contractual environment; and (3) There is a need to invest in research that is relatively far from application. Evaluation processes and output measurement systems should be adapted to how close to implementation the research project is, and also assess the need to build capabilities on the receiver side.

It was recognized at an early stage that the focus and interest of the different TRUST members varied. While many university scientists have focus on developing research with the end product being a publication, industry experts often have a more applied focus, where the end product may be a completed project such as a tunnel. To raise the understanding of different point of views, specialists from different fields (e.g. consultants, entrepreneurs, funding organization, owners) were invited speakers to biannual workshops. The result is a general increase in understanding of different roles and needs, and that slight expansion of scope can allow fulfillment of ore than one need.

6 Appendices

Appendix 1, Agenda, TRUST workshops 1-8
Appendix 2, Action items, TRUST workshops 1-7
Appendix 3, TRUST Publication policy
Appendix 4, TRUST Partner declaration
Appendix 5, IT manual
Appendix 6, User value aspect TRUST – results of workshop 3
Appendix 7, TRUST final report, Industry meeting of workshop 8

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Agenda for TRUST Workshop No. 1

March 26, 2013, 18:30
Dinner: Elite Hotel Arcadia, Stockholm

March 27, 2013, 08:30 – 16:00
Workshop: Sal B25, Brinellvägen 23, KTH

1. Welcome (Larsson)	08:30 – 08:35
2. Introduction (Ask)	08:35 – 08:45
3. Project presentations, please refer to questions below	08:45 – 11:15
2.1, Geoelectric site investigations (Dahlin)	08:45 – 09:00
2.2, Multicomponent seismics and electromagnetics (Malehmir)	09:00 – 09:15
2.4, Development of standards for functional requirements at underground facilities with respect to the chemical environment (LOE)	09:15 – 09:30
3.2, Optimization of Reinforcement (Johansson)	09:30 – 09:45
3.3, Real Time Grouting Control (Draganovic)	09:45 – 10:00
COFFEE	10:00 – 10:30
4.1, Development of methodologies for rational and fast evaluation of geotechnical investigations (Larsson)	10:30 – 10:45
4.2, Integrated use and interpret. of data from geophysical and non-geophysical methods for site investigation for underground construction (Dahlin)	10:45 – 11:00
1, Transparent Underground STructure (TRUST) – Management (Ask, Kadefors)	11:00 –11:15
4. Remaining TRUST projects & funding issues	11:15 – 12:00
2.3, Rock mass characterization (Ask)	11:15 – 11:30
3.1, Adaptive production methods (Olofsson)	11:30 – 11:45
Plan further	11:45 – 12:00
LUNCH *Syster och Bror*	12:15 – 13:00
5. Coordination and communication	13:15 – 14:45
a. Coordination - case study	
1. Coordination of fieldwork and test sites	
2. Data deliveries	
3. Co-publications	
4. Joint research PhD courses	
b. Communication	
1. Web site	
2. Meetings and Workshops (Monthly – Biannual)	
3. Conferences (Annual)	
4. Reference groups	
COFFEE	14:45 – 15:00
6. Letter to Trafikverket (Ask)	15:00 – 15:30
7. Concluding remarks	15:30 – 16:00
Timing for upcoming meetings	15:30 – 15:45
Action items	15:45 – 16:00
8. Closure	16:00

Project presentations (15 min presentation including questions)

Please address the following issues in Item 3, project presentations:

1. Project participants; their roles and contact information. Also please list required new personnel
2. What are the scientific goals
3. What are the largest challenges in the project
4. What are the largest threats for the project
5. What are your anticipated deliveries
    a. Data
    b. Papers (number of papers, where to publish, titles, authors)
6. Time planning, including potential data deliveries
7. Collaboration needs within TRUST
8. For the innovation and implementation part of TRUST 1, please address the following questions:
    a. Who are the most important actors for implementing results within your research area?
    b. How is communication and collaboration between research and practice within your area?
    c. Can you give examples of research results which previously have been implemented in your area?

Draft Agenda for TRUST Workshop No. 2

Tyréns AB, Isbergs gata 15, 211 19 Malmö

August 20, 2013, 08:00 – 19:30+

0. Arrival & Coffee	08:00
1. Welcome (Svensson)	08:30 – 08:35
2. Introduction (Ask)	08:35 – 08:45
3. Project presentations (15 min project; 5 min/PhD + poster)	08:45 – 11:45
1. TRUST – management (Ask)	08:45 – 09:00
2.1, Geoelectric site investigations (Dahlin, 2 PhD)	09:00 – 09:25
2.2, Multicomponent seismics and electromagnetics (Malehmir, 3 PhD)	09:25 – 09:55
COFFEE	10:00 – 10:30
2.4, Development of standards for functional requirements at underground facilities with respect to the chemical environment (Norin, 1 PhD)	10:30 – 10:50
3.3, Real Time Grouting Control (Draganovic, 1 PhD)	10:50 – 11:10
4.1, Development of methodologies for rational and fast evaluation of geotechnical investigations (Larsson)	11:10 – 11:25
4.2, Integrated use and interpret. of data from geophysical and non-geophysical methods for site investigation for underground construction (Dahlin, 1 PhD)	11:25 – 11:45
LUNCH	11:45 – 13:00
4. Bypass Stockholm (FS) (Svensson) Discussion	13:00 – 14:00
5. Introduction to Group work Site selection (Rosqvist) Synergies and risks (Kadefors)	14:00 – 14:30
6. Group work:	14:30 – 16:45
Site selection (Discussion leaders: Dahlin, Malehmir, Noren)	14:30 – 16:00
Synergies and risks (Discussion leaders: Kadefors, Olofsson, Dahlström)	16:00 – 16:45
COFFEE	15:00 – 15:30
7. PhD courses (Johansson)	16:45 – 17:00
9. Concluding remarks Initial reports of group work by group leaders	17:00 – 17:30
10. Poster Session & Dinner preparation	18:30 – 19:30
DINNER	19:30

August 21, 2013, 08:00 – 13:00

11. Agenda (Ask)	08:00 – 08:10
12. Upcoming meetings Dates (Ask) Theme WS3: User value aspects (*nyttoaspekter*) (Olofsson)	08:10 – 08:25
13. Update on TRUST projects not yet funded (Ask, Olofsson, Johansson)	08:25 – 08:45
14. Synergies and risks Group work presentations (discussion leaders)	08:45 – 09:15
15. Site Selection Group work presentations (discussion leaders)	09:15 – 11:15 10:30 – 11:15
COFFEE	10:00 – 10:30
Discussion	10:30 – 11:15
16. PhD courses (Johansson)	11:15 – 11:30
17. Webforum (Svensson)	11:30 – 11:45
18. TRUST website – www.trust-geoinfra.se (Svensson)	11:45 – 12:00
19. Concluding remarks (Ask) Action items	12:00 – 12:15
20. Closure	12:15
LUNCH	12:30

Draft Agenda for TRUST Workshop No. 3

Stiftelsen Bergteknisk Forskning (BeFo), Styrelserummet, Sabis AB, Näringslivets Hus, Storgatan 19, Stockholm
February 3, 2014, 09:30 – 19:30+

0. Arrival & Coffee	09:30
1. Welcome (Tengborg)	10:00 – 10:10
2. Introduction (Ask)	10:10 – 10:25
3. TRUST (Ask)	10:25 – 10:45
4. Project presentations – user value aspects (10-12 min project) 1. TRUST – management (Olofsson) 2.1, Geoelectric site investigations (Dahlin) 2.2, Multicomponent seismics and electromagnetics (Malehmir) 2.4, Development of standards for functional requirements at underground facilities with respect to the chemical environment (Norin) 3.2, Optimization of rock support in design according to Eurocode with reliability-based methods (Johansson) 3.3, Real Time Grouting Control (Draganovic) 4.1, Development of methodologies for rational and fast evaluation of geotechnical investigations (Larsson) 4.2, Integrated use and interpretation of data from geophysical and non-geophysical methods for site investigation for underground construction (Dahlin)	10:45 – 12:15
LUNCH	12:15 – 13:15
5. User value aspects - invited presentations User value aspects of the Swedish Transport Administration (Peter Lundman, STA) GeoFuture and user value aspects (Idar Kirkhorn, ViaNova Systems A/S)	13:15 – 14:15 13:15 – 13:45 13:45 – 14:15
6. User value aspects - group work (Olofsson) Introduction (Olofsson) Group work	14:15 – 16:45 14:15 – 14:25 14:25 – 16:45
COFFEE	from 16:00
7. Concluding remarks in plenum (Ask) Initial reports of group work (group leaders, all) Conclusions of group work (Tengborg, Widing)	16:45 – 18:00 16:45 – 17:45 17:45 – 18:00
DINNER at Tyréns headquarters (Peter Myndes Backe 16, Stockholm)	19:30+

Tyréns AB, Peter Myndes Backe 16, Stockholm
February 4, 2014, 08:15 –16:15

8. Arrival & Coffee	08:15
9. Agenda	08:30 – 08:35
10. Upcoming meetings	08:35 – 09:00
TRUST Conference #1 / Workshop #4 (Ask)	08:35 – 08:45
Near Surface Geoscience in Sweden (Dahlin)	08:45 – 08:55
Dates (Ask)	08:55 – 09:00
11. Partnering charter (Kadefors)	09:00 – 10:30
Introduction (Kadefors)	09:00 – 09:15
Group work	09:15 – 10:30
COFFEE	from 10:00
12. TRUST results - PhD- and post-doc students (10-30 minuter/project)	10:30 – 11:40
TRUST 2.1 (Johansson, Olsson, Fiandaca)	10:30 – 11:00
TRUST 2.2 (Brodic, Place, Mehta, Wang)	11:00 – 11:30
TRUST 2.4 (Mossmark)	11:30 – 11:40
TRUST 3.3 (Gahfar)	11:40 – 11:50
TRUST 4.1 (Prästings)	11:50 – 12:00
TRUST 4.2 (Wennemark)	12:00 – 12:10
LUNCH	12:10 – 13:10
13. Partnering charter report (Kadefors)	13:10 – 13:25
14. Site Selection Process (Rosqvist)	13:25 – 14:15
Status report (Rosqvist)	13:25 – 13:45
Report on data form survey (Jonsson)	13:45 – 13:55
Discussion (Rosqvist)	13:55 – 15:00
COFFEE	15:00 – 15:30
15. Action items (Ask)	15:30 – 16:00
Partnering charter	
Site selection	
Others	
16. Concluding remarks	16:00 – 16:15
17. Closure	16:15

Draft Agenda for TRUST Workshop #4, Day 1

Multistudio, F-huset, Luleå University of Technology
August 19, 2014, 08:30 – 19:00+

0. Arrival & Coffee & Poster mounting	08:30*
1. Welcome (Ask)	08:45 – 08:50
2. Introduction (Ask)	08:50 – 09:00
3. TRUST – introduction to posters (5 or *10* min per poster) (Ask)	09:00 – 12:20
1. Management (Ask&Olofsson**,** *Kadefors***)**	09:00-09:15
2.1, Geoelectric site investigations (Sparrenbom, Johansson, Olsson, Fiandaca, Lumetzberger)	09:15-09:40
2.2, Multicomponent seismics and electromagnetics (Malehmir, Mehta, Wang, Brodic)	09:40-10:00
2.4, Development of standards for functional requirements at underground facilities with respect to the chemical environment (Norin)	10:00-10:05
Discussion	*10:05 – 10:15*
COFFEE	10:15 – 10:45
3.2, Optimization of rock support in design according to Eurocode with reliability-based methods (Johansson)	10:45-10:50
3.3, Real Time Grouting Control (Draganovic, Nejad Ghafar, Place)	10:50-11:05
4.1, Development of methodologies for rational and fast evaluation of geotechnical investigations (Svensson, Prästings)	11:05-11:15
4.2, Integrated use and interpretation of data from geophysical and non-geophysical methods for site investigation for underground construction (Wennermark, Lumetzberger)	11:15-11:25
Discussion	*11:25-11:45*
LUNCH at Wibergsgården including photo session	11:45 – 13:00
4. Implementation (Rosqvist)	13:00 – 14:30
– Rock Tech Centre (Hedlin) including discussion	13:00-13:45
– The *Bygginnovationen* (Lagerqvist) including discussion	13:45-14:30
5. Äspö HRL – Nova FoU (Laaksoharju)	14:30 – 14:45
6. Status of Äspö HRL – campaigns (Rosqvist)	14:45 – 16:45
– Introduction (Ask)	14:45-14:50
– Brief overview of Äspö (Svensson)	14:50-16:10
– Planning – group work	16:10-16:45
COFFEE	from 16:00
7. Partnering declaration (PD) (Kadefors)	16:45 – 17:00
– Routine for signing the PD (5 min)	16:45-16:50
– Publication policy (Bastani) (10 min)	16:50-17:00
8. Concluding remarks in plenum (Ask, all)	17:00 – 17:30

9. TRUST – Poster session	17:30 – 19:00
DINNER at F-house Fika room *Lab tour after dinner*	19:00+

*Requires arrival at LLA on 18 Aug.

Draft Agenda for TRUST Workshop #4, Day 2

Multistudio, F-huset, Luleå Tekniska Universitet, Luleå
August 20, 2014, 08:30 – 14:30

10. Arrival & Coffee with Agenda of Day 2	08:30
11. Upcoming meetings – TRUST Workshop #5 – Uppsala (Malehmir) – TRUST Conference #1 / WS #6 (Ask) – TRUST Conference #2 / Near Surface Geoscience in Sweden (Dahlin)	08:45 – 09:00 08:45-08:50 08:50-08:55 08:55-09:00
12. Status of site selection processes (Rosqvist) – Äspö HRL (project leaders) – Förbifart Stockholm (Rosqvist)	09:00 – 10:00 09:00-09:45 09:45-10:00
COFFEE	10:00 – 10:30
14. Group work: Management / PhD students – Management • Publication policy (Bastani & Ask) • User value & implementation (Kadefors & Rosqvist) – PhD student internal discussions	10:30 – 11:45
LUNCH at F-house Fika room	**11:45 – 12:45**
14. Report of group work – Publication policy (Bastani & Ask) – User value & implementation (Kadefors & Rosqvist) – PhD student internal discussions	12:45 – 13:30 12:45-13:00 13:00-13:15 13:15-13:30
15. Action items (Ask)	13:30 – 14:00
16. Concluding remarks	14:00 – 14:30
17. Closure	14:30**

**OK with departure w/ SAS from LLA at 15:50 and arrival at MMX 18:15 /CPH 19:15

Draft Agenda for TRUST Workshop #5, Day 1

Hambergsalen, Geocentrum, Uppsala University, Villavägen 16, Uppsala
February 3, 2015, 09:00 – 19:00+

0. Arrival & Coffee & Poster mounting	09:00
1. Welcome (Malehmir)	09:30 – 09:35
2. Introduction (Ask)	09:35 – 09:45
3. TRUST – introduction to posters (5 min per poster) (Ask)	09:45 – 12:20
4.2, Integrated use and interpretation of data from geophysical and non-geophysical methods for site investigation for underground construction (Dahlin, Wennermark)	09:45-09:55
4.1, Development of methodologies for rational and fast evaluation of geotechnical investigations (Larsson, Svensson)	09:55-10:05
3.3, Real Time Grouting Control (Draganovic, Nejad Ghafar)	10:05-10:15
3.2, Optimization of rock support in design according to Eurocode with reliability-based methods (Bjureland)	10:15-10:20
Comments	*10:20-10:30*
COFFEE	10:30 – 11:00
2.4, Development of standards for functional requirements at underground facilities with respect to the chemical environment (Norin, Mossmark)	11:00-11:10
2.2, Multicomponent seismics and electromagnetics (Bojan, Shunguo, Makinen, Azita)	11:10-11:30
2.1, Geoelectric site investigations (Sparrenbom, Dahlin, P.-I. Ohlsson)	11:30-11:50
LUNCH at EBC restaurant	11:50 – 13:00
4. The infrastructure project design process – what is done when? (Svensson)	13:00 – 13:30
5. R&D Implementation by different actors (Ask)	13:30 – 14:15
– Large Clients – Swedish Transport Administration (Anders Berntsson)	13:30-14:00
– Contractors – Skanska AB (Robert Sturk)	14:00-14:30
– Consultants – Tyréns AB (Rosqvist)	14:30-15:00
– Introduction to group work (Svensson)	15:00-15:15
COFFEE	15:15 – 15:45
6. Group work implementation (Session 1) – The infrastructure project design process – R&D Implementation by different actors	15:45 – 17:00
7. Concluding remarks in plenum (Ask, all) – Draft action items day 1	17:00 – 17:30
8. TRUST – poster session	17:30 – 19:00
DINNER at Norrland II	19:00+

Draft Agenda for TRUST Workshop #5, Day 2

Hambergsalen, Geocentrum, Uppsala University, Villavägen 16, Uppsala
February 4, 2015, 09:00 – 16:00

9. Arrival & Coffee with Agenda of Day 2	08:30
10. Upcoming meetings	09:00 – 09:40
– TRUST Workshop #6 – Gothenburg, tentative 25-26 August 2015 (Norin/Dahlström)	09:00-09:10
– TRUST Workshop #7 – Lund/Malmö, tentative 2-3 February 2016 (Dahlin)	09:10-09:20
– TRUST Conference #1 / BeFo Bergmekanikdagen 14 March 2016 (Ask)	09:20-09:30
– TRUST Conference #2 / Near Surface Geoscience in Sweden (Dahlin)	09:30-09:40
11. TRUST renewal process (Ask)	09:40 – 10:15
– Formas call 150219, Hållbart samhällsbyggande (Ask)	09:40-09:45
– Äspö HRL (M. Ohlsson)	09:50-10:15
COFFEE	10:15 – 10:45
12. Group work implementation (Session 2)/ PhD students own time 1. Renewal process – The infrastructure project design process – R&D Implementation by different actors 2. PhD students own time	10:45 – 12:00
LUNCH at EBC restaurant	**12:00 – 13:00**
13. Status of site selection processes (Rosqvist)	13:00 – 14:00
– Äspö HRL ○ Nova FoU status (Laaksoharju) ○ Project leaders report ○ Coordination	13:00-13:45
– Förbifart Stockholm	13:45-14:00
14. Publication policy (Ask)	14:00 – 14:30
– Publication policy document (Bastani)	14:00-14:15
– Discussion & decision	14:15-14:30
COFFEE	14:30 – 14:45
15. Report of group work	14:45 – 15:30
– Implementation (the infrastructure project design process & R&D Implementation by different actors)	14:45-15:00
– Renewal process	15:00-15:15
– PhD students	15:15-15:30
16. Action items (Ask)	15:30 – 15:50
17. Concluding remarks	15:50 – 16:00
18. Closure	16:00

Agenda for TRUST Workshop #6, Day 1

Chalmers sal VK, Sven Hultins gata 6, Gothenburg
August 25, 2015, 09:30 – 20:00+

0. Arrival & Coffee	09:30
1. Welcome (Mossmark)	10:00 – 10:05
2. Introduction (Ask) (Agenda, Agreements, News including the new TRUST web)	10:05 – 10:20
3. TRUST, Theme 2 – status reports on Äspö HRL field work (Ask)	10:20 – 11:45
Film Äspö measurements	10:20-10:25
2,1, Geoelectric site investigations (Ohlsson)	10:25-10:45
2.2, Multicomponent seismics and electromagnetics (Brodic/Wang)	10:45-11:05
2.4, Development of standards for functional requirements at underground facilities with respect to the chemical environment (Mossmark)	11:05-11:25
Discussion	*11:25-11:45*
4. TRUST – status reports on Innovation & implementation (Ask)	11:45 – 12:15
1 Management (Olofsson)	11:45-12:05
Discussion	12:05-12:15
LUNCH	12:15 – 13:30
5. TRUST, Theme 3 – status reports on Äspö HRL field work (Ask)	13:30 – 14:30
3.2, Optimization of rock support in design according to Eurocode with reliability-based methods (Johansson)	13:30-13:50
3.3, Real Time Grouting Control (Draganovic)	13:50-14:10
Discussion	*14:10-14:30*
6. TRUST, Theme 4 – status reports on Äspö HRL field work (Ask)	14:30 – 15:05
4.1, Development of methodologies for rational and fast evaluation of geotechnical investigations (Svensson)	14:30-14:35
4.2, Integrated use and interpretation of data from geophysical and non-geophysical methods for site investigation for underground construction (Dahlin)	14:35-14:55
Discussion	*14:55-15:05*
Coffee	15:05 – 15:30
7. Status of site selection processes (Rosqvist)	15:30 – 16:15
– Förbifart Stockholm	
○ Project leaders report (Dahlin, Malehmir/Bastani, Norin/Sparrenbom)	15:30-16:00
○ Coordination	16:00-16:15
8. TRUST – additional status report (Ask)	16:15 – 17:45
– Additional short reports (5 min/project)	
9. Upcoming meetings	17:45 – 18:00
– TRUST Workshop #7 – Lund/Malmö, tentative 2-3 February 2016 (Dahlin)	17:45-17:50
– TRUST Workshop #8 – Stockholm, tentative 30-31 August 2016 ((Johansson)	17:50-17:55
– TRUST Conference – Near Surface Geoscience in Sweden 2017 (Dahlin)	17:55-18:00
10. Concluding remarks (Ask, all)	18:00 – 18:30
– Reflections from today's activities	
– Draft Action Items	
DINNER at Sweco, Skånegatan 3, Gothenburg	20:00+

Agenda for TRUST Workshop #6, Day 2

Sweco, Skånegatan 3, Gothenburg
August 26, 08:00 – 16:00

11. Arrival & Coffee with Agenda of Day 2	08:00
12a. TRUST renewal process, session 1 (Kari Österling) – The objective is to identify benefits from the TRUST project, to explore these benefits, identify why and what added value they represent and to give suggestions as to how develop future projects – During the morning session, we will focus on finding out the benefits of the TRUST projects and what societal needs may be addressed by TRUST.	8:30 – 10:00
COFFEE	10:00 – 10:30
12b. TRUST renewal process, session 2 (Österling)	10:30 – 12:00
LUNCH	12:00 – 13:00
13. Research needs (Svensson) – BeFo outlook on research needs within rock engineering research (Per Tengborg) – Status of Förbifart Stockholm and future research needs (Ulf B. Eriksson, TRV) – Discussion	13:00 – 14:15 13:00-13:30 13:30-14:00 14:00-14:15
COFFEE	14:15 – 14:30
14. TRUST renewal process, session 3 (Österling) – During the afternoon session, we will focus on finding out the possibilities for a continued TRUST after 2016/2017. What are the research & innovation needs? We will discuss how to meet them.	14:30 – 15:30
15. Concluding remarks (Ask, All) – Reflections from workshop activities – Draft Action Items	15:30 – 16:00
16. Closure	16:00

Agenda for TRUST Workshop #7, Day 1

LU konferens, G Biskopshuset, G Biskopsgatan 1, Lund
February, 2016, 09:15 – 19:30+

0. Arrival & Coffee	09:15
1. Welcome (Sparrenbom)	09:45 – 09:50
2. Introduction (Ask)	09:50 – 10:05
3. Celebrating Licentiate thesis presentations (Ask) 20-10 minute	10:05 – 11:05
2.2, Multicomponent digital-based seismic landstreamer for urban underground infrastructure planning (Brodic)	10:05-10:35
2.2, Boat-towed RMT for urban underground infrastructure planning: Stockholm Bypass (Förbifart) case study (Mehta)	10:35-11:05
4. Project status - Theme 4 (Ask) 10-5-5 minute presentation – bee hive – discussion	11:15 – 11:55
4.2, Ronczka	11:15-11:35
4.1, Svensson	11:35-11:55
LUNCH	11:55 – 13:00
5. Project status – Theme 3 (Ask) 10-5-5 minute presentation – bee hive – discussion	13:00 – 13:40
3.3, Nejad Ghafar	13:00-13:20
3.2, Johansson	13:20-13:40
6. Project status – Theme 2 (Ask) 10-5-5 minute presentation – bee hive – discussion	13:40 – 15:05
2.4, Mossmark	13:40-14:00
2.2, Malehmir	14:00-14:05
2.2, Wang	14:05.14:25
2.1, Johansson	14:25-14:45
2.1, Olsson	14:45-15:05
Coffee	15:05 – 15:35
7. TRUST 2.0 (Rosqvist)	15:35 – 16:00
8. Active work towards TRUST 2.0 (Rosqvist) Opportunity to ad hoc group work on topics concerning TRUST 2.0. Each group appoints a lead who presents the outcome of the work in Item 16.	16:05 – 17:30
9. Upcoming meetings	17:30 – 18:00
– TRUST Workshop #8 – Stockholm, 30-31 August 2016 (Draganovic)	17:30-17:45
– TRUST Conference – Near Surface Geoscience in Sweden 2017 (Dahlin)	17:45-18:00
10. Concluding remarks (Ask, all) – Reflections from today's activities – Draft Action Items	18:00 – 18:15
CELIBRATION & DINNER at Geologen, Sölvegatan 12,	18:30+
11. Congratulations Licentiates – Suman Metha according to Bastani – Bojan Brodic according to Malehmir	

Agenda for TRUST Workshop #7, Day 2

LU konferens, G Biskopshuset, G Biskopsgatan 1, Lund
August 26, 08:00 – 16:00

12. Dalby Excursion, Departure from *Hotell Finn* (kind reminder: dress for the weather)	08:00
13. Arrival LU konferens	10:30
COFFEE	10:30 – 11:00
14. TRUST results, Äspö HRL (Malehmir)	11:00 – 11:30
15. TRUST results, Bypass Stockholm (Sparrenbom/Mossmark/Dahlin)	11:30 – 12:00
LUNCH	12:00 – 13:00
16. Results "Active work towards TRUST 2.0 " (Rosqvist) – Group leaders presents results – Panel discussion.	13:00 – 15:00
COFFEE	15:00 – 15:30
17. Concluding remarks (Ask, All) – Reflections from workshop activities – Draft Action Items	15:30 – 16:00
18. Closure	16:00

Agenda for TRUST Workshop #8, Day 1

Stora konferensrummet, KTH, Brinellvägen 23, Stockholm
August 30, 2016, 10:00 – 17:00

1.0. Arrival & Coffee	09:30
1.1. Welcome (Draganovic)	10:00 –10:10
1.2. Introduction (Ask)	10:10 – 10:30
1.3. Celebrating Licentiate thesis presentations (Ask) – Sara Johansson: *From microstructure to subsurface characterization. Spectral information from field scale time domain induced polarization* – Per Ivar Ohlsson: – Ali Nejad Gahfar: *An experimental study to measure and improve the grout penetrability* – Anders Prästings: *Aspects on probabilistic approach to design: From uncertainties in pre-investigation to final design* *Discussion*	10:30 – 12:30
LUNCH	12:30 – 13:30
1.4. In preparation for day 2 of TRUST WS#8	13:30 – 14:00
1.5. Upcoming meeting – NGL conference, Kalmar, 10-11 October 2016. Deadline abstract submission & registration 160901 – Grundläggningsdagen, Stockholm, 17 March 2017. Deadline abstract submission: 160911 – TRUST Conference – Near Surface Geoscience in Sweden 2017 (Dahlin)	14:00 – 15:15
Coffee	15:15 – 15:45
1.6. TRUST 2.0 *Discussion*	15:45 – 16:30
1.7. Congratulations Licentiates – Sara Johansson, Per Ivar Ohlsson (Torleif, Lotta) – Ali Nejad Gahfar (Almir) – Anders Prästings (Stefan) –	16:30 – 17:15
1.8. Concluding remarks (Ask, all) – Reflections from today's activities – Draft Action Items	17:15 – 17:30
DINNER (TBD)	17:30

Program: TRUST final seminar (workshop #8)

Näringslivets hus, Wallenbergaren, Stockholm
August 31, 09:30 – 16:30

0. Arrival & coffee	09:30
1. Plan for the day (Maria Ask)	10:00 – 10:05
2. Introduction (Ruben Aronsson)	10:05 – 10:15
3. TRUST Final report (Maria Ask) *Discussion*	10:15 – 10:45
4. Sustainable underground construction with GeoBIM – Äspö HRL case (Mats Svensson) – GeoBIM (Mats Svensson) – Geophysical data (Charlotte Sparrenbom, Alireza Malehmir) – Eurocode, Uncertainties (Fredrik Johansson, Mats Svensson) – Grouting (Almir Draganovic) – Joint data interpretation (Torleif Dahlin) *Discussion*	10:45 – 12:00
LUNCH	12:00 – 13:00
5. TRUST from the view of the funding organizations (Ask) – SBUF (Ruben Aronsson) – BeFo (Per Tengborg) – SKB (Eva Widing) – Tyréns AB (Bengt Hansson) *Discussion*	13:00 – 14:30
COFFEE	14:30 – 15:00
6. Poster session: Innovation & user-value of TRUST sub-projects	15:00 – 16:15
7. Thank you & closure	16:15 – 16:30

ACTION ITEMS TRUST WORKSHOP #1

No.	What	Who	When
1	Clarify why *Bypass Stockholm* main site?	Ask	2013-06-15
2	Resubmit TRUST 2.3 to FORMAS in April	Ask (PI), Edelbro, Curtis, among others	2013-04-16
3	Resubmit TRUST 3.1 to FORMAS in April	Schunnesson (PI), Olofsson, among others	2013-04-16
4	Specification of field site needs for each subproject.	Rosqvist responsible for site selection for entire TRUST. Ask is coordinating. All subproject leaders.	2013-06-15
5	Informal lunch/meeting with Project *Bypass Stockholm*.	Ask, Ericsson, Kadefors, Olofsson	2013-05-31
6	A project internal communication platform up and running 1st June.	Svensson, Ask	2013-06-01
7	Outline of a PhD course program for the first telephone meeting	Johansson	2013-05-06
8	Vision, goals etc for the whole TRUST project.	Ask	2013-06-01
9	Web site up and running	Svensson, Ask	2013-06-01
10	Who will have access to data produced within TRUST? Has to be clarified before first field campaign, autumn 2013.	Ask	2013-08-15
11	Every project prepare names for reference group	Ask coordinates, All project leaders	2013-05-06

ACTION ITEMS TRUST WORKSHOP #2

No. WS2-	**What**	**Who**	**When**
1	There will be a special session on the development of a partnering charter (P. 2, App M) during TRUST WS3, 3-4 February 2014. A draft partnering charter will be sent out 2 weeks before WS3.	Anna Kadefors, Thomas Olofsson, L-O Dahlström	20 Jan. 2014
2	A vision for the entire TRUST project should be formulated. The vision is to be developed during the autumn, discussed during monthly telephone meetings, and decided at WS3.	Maria Ask, Mats Svensson, Håkan Rosqvist, Thomas Olofsson	Monthly telephone meetings ➔ 3 Feb. 2014
3	TRUST is linked to TrVs time planning. Ask will contact Nils Outters, TrV and request access to TrV time planning for FS.	Maria Ask	2 Sep 2013
4	TRUST project 4.1 needs information about 3D models. Maria Ask shall contact Nils Outters TrV and ask for a meeting between TrVs BIM-personnel (e.g. Johan Asplund) and Olof Friberg.	Maria Ask	2 Sep 2013
5	Coordinated pre-investigation is to be conducted by TRUST projects 2.1 and 2.2 in Johannelund before WS3. The two PIs shall give a preliminary report during the workshop. These results may provide input to Action Item 8.	Torleif Dahlin, Alireza Malehmir	3 Feb. 2014
6	TRUST Information (1): Each project shall present, in a simplistic way, the methods they are planning to use, and this should be presented at the TRUST website. A model from LDEO, NY, was distributed by Ask.	PI	21 Sep. 2013
7	TRUST Information (2): Peter Jonsson will produce a form that will help each project to identify potential synergies (in-data needed and out-put data produced) in three classes: (i) must know, (ii) good-to-know, and (iii) not critical to know.	Peter Jonsson PI respond	9 Sep 2013 21 Sep. 2013
8	TRUST Information (3): A site selection group with representatives from each project has been formed to define site selection criteria and field sites. Håkan Rosqvist is chair. The group is active during the autumn, reports its progress during the monthly telephone meetings, and present results during WS3.	Ask, Rosqvist, Bastani, Ask, Norin, Olofsson, Johansson, Draganovic, Svensson, Dahlin	Monthly telephone meetings ➔ 3 Feb 2014?
9	On 130809, Fredrik Johansson distributed two questions for the establishment of joint PhD courses. PIs are requested to respond to these questions and Johansson is requested to compile a summary of the need and interest for organizing joint PhD course.	PI Fredrik Johansson	9 Sep 2013 7 Oct. 2013

TRUST Workshop # 3 –Action Items

Action Item 3-1: All participants provide written feedback about the group work.

Responsibility of: All participants to fill in the form. Maria Ask is in charge of evaluating the feedback.
Deadlines: (1) 12 February 2014 via e-mail[1] to or uploaded at TRUST project place[2] or
(2) 14 February 2014 via normal post (Maria Ask, Inst. för samhällsbyggnad och naturresurser, Luleå tekniska universitet, SE-971 87 Luleå)
Background: Feedback is needed for improving our performance with respect to planning and content of workshops. Workshop #3 consisted of two group works, user-value aspects and partnering charter. A feedback form for each workshop day has been circulated among all workshop participants.

Action Item 3-2: Compiling a report on the group work on user-values

Responsibility of: Tomas Olofsson
Deadline: 20 February 2014
Background: The results of the group work should be collected, analyzed and distributed to all workshop participants. The results should be distributed to all workshop participants no later than 20 February 2014.

Action Item 3-3: Drafting the suggested goals/behavioral rules under Section 2 "*Data sharing and quality*" for the Partnering charter according to group discussions, and developing draft Guidelines for this area.

Responsibility of: Olof Friberg
Deadline: A progress report is to be given at TRUST telephone meeting No. 10, 3 March 2014 at 15:00
Background: The group work at TRUST Workshop #2 resulted in draft of the Partnering charter[3]. The outcome of the group work on *Partnering charter – Data sharing and quality* at this workshop should be forwarded to Action Item 3-5.

Action Item 3-4: Drafting the suggested goals/behavioral rules of Section 3 "*Publication and impact on the research field*" of the Partnering charter according to group discussions, and developing draft Guidelines for this area.

Responsibility of: Mehrdad Bastani
Deadline: A progress report is to be given at TRUST telephone meeting No. 10, 3 March 2014 at 15:00
Background: The group work at TRUST Workshop #2 resulted in draft of the Partnering charter[4]. The outcome of the group work on *Partnering charter – Publication and impact on the research field* at this workshop should be forwarded to Action Item 3-5.

Action Item 3-5: Preparing the Partnering charter, Version 1.0

Responsibility of: Anna Kadefors
Deadlines: (1) Progress reports are to be given at TRUST telephone meetings TM No. 10-14.
(2) The Partnering charter should be ready for signing at TRUST at TRUST Workshop #4 (19-20 August 2014)
Background: The group work at TRUST Workshop #2 resulted in the draft of the Partnering charter[5]. *Partner charter, version 1.0* depends on input to Chapters 1 and 4 (*General collaboration*

[1] Maria.Ask@ltu.se
[2] https://secure.webforum.com/formasprojekt/doc/?dfRefID=254
[3] https://secure.webforum.com/formasprojekt/doc/getdoc.ashx?refID=4246
[4] https://secure.webforum.com/formasprojekt/doc/getdoc.ashx?refID=4246
[5] https://secure.webforum.com/formasprojekt/doc/getdoc.ashx?refID=4246

and *Impact on society*, respectively) via e-mail comments from TRUST PIs, and Action Items 3-3 and 3-4.

Action Item 3-6: Identification of a joint TRUST test sites for summer of 2014 – Äspö HRL

Responsibility of: Maria Ask and Lars O. Ericsson
Deadline: TRUST telephone meeting TM No. 10
Background: Trafikverket will not be ready to provide a test site for summer 2014 for all TRUST projects. As the result, TRUST will investigate if the ramp of the Äspö Hard Rock is a suitable alternative site. Contacts will be made with Nova FoU.

Action Item 3-7: Identification of a joint TRUST test sites for summer of 2014 – Nacka

Responsibility of: Håkan Rosqvist and Almir Draganovic
Deadline: TRUST telephone meeting TM No. 10
Background: Trafikverket will not be ready to provide a test site for summer 2014 for all TRUST projects. As the result, TRUST will investigate if the test mine of Atlas Copco in Nacka is a suitable alternative site. Contacts will be made with Atlas Copco.

Action Item 3-8: Identification of a joint TRUST test sites for summer of 2014 – Tanumshede

Responsibility of: Lars O. Ericsson and Malin Norin
Deadline: TRUST telephone meeting TM No. 10
Background: Trafikverket will not be ready to provide a test site for summer 2014 for all TRUST projects. As the result, TRUST will investigate if the road tunnel in Tanumshede is a suitable alternative site.

Action Item 3-9: Upload material on the TRUST website

Responsibility of: All TRUST members
Deadline: Progress reports are given at TRUST telephone meetings
Background: An attractive and updated website is important for spreading information about TRUST to external actors. All TRUST members are responsible to report presentations, posters, publications, PhD courses etc. to the website. Uploaded your contributions to the folder 05 Website / 0502 New Contributions[6] at the TRUST project place. Mats Svensson should be notified via e-mail[7] about all uploads.

Action Item 3-10: Contribution to the draft agenda for TRUST Workshop #4

Responsibility of: TRUST primary investigators (PI)
Deadline: TRUST telephone meeting TM #14, Monday 4 August 2014, at 15:00
Background: In order to get a well-balanced agenda for the TRUST Workshops and Conferences, TRUST PI are requested to actively contribute to the draft agenda so that ample time is allowed for presenting results and other activities (e.g. group work).

Information 3-1: Date, place and host for upcoming meetings

Workshop #4: Dates: 19-20 August 2014; Place: LTU, Luleå; Host: Maria Ask
Workshop #5: Dates: 3-4 February 2015; Place: UU, Uppsala; Host: Alireza Malehmir
Workshop #6/Conference #1: Dates: 24-26 August 2015; Place: Skokloster; Host: Maria Ask

[6] https://secure.webforum.com/formasprojekt/doc/?dfRefID=258
[7] Mats.Svensson@tyrens.se

TRUST Workshop # 4, Luleå 19-20 August 2014

Decision Items

Decision Item 4-A: The first version of the Partnering Declaration has been signed

Background: TRUST members worked on developing the partnering declaration during TRUST Workshops (WS) #2 and #3, and the text was approved by PIs in a advance of TRUST WS#4. All TRUST members present at TRUST WS #4 signed version 1.0 of the document. Signatures from remaining TRUST members will be collected, and obedience of the document will be followed-up in subsequent meetings.

Decision Item 4-B: Äspö HRL case study: where and when

Background: TRUST members have made two important decisions regarding where and when the upcoming joint case study at Äspö HRL will be conducted.

1. Where: All TRUST projects involved at Äspö HRL shall make investigations +/- 100 m on either sides of the NE1-fracture zone in the tunnel (other places OK as well).
2. When: In order to optimize collaboration it has been decided that measurements will be conducted in spring 2015.
3.

Decision Item 4-C: Date & Place for TRUST WS#5

Background: Alireza Malehmir, Uppsala University will host TRUST WS#5, **3-4 February 2015**

Decision Item 4-D: New routine for travel planning

Responsibility of: TRUST WS participants, Maria Ask

Background: The current routine for travel support has been modified in two aspects to avoid paying expensive transport and unused hotel rooms. In order to receive travel support from TRUST 1.0, reservations must be completed 1 month in advance of the activity.

Action Items

Action Item 4-1: Äspö HRL case study, part 1: TRUST target and time plan

Responsibility of: Maria Ask.

Deadlines: 1 September 2014

Background: Maria will inform Nova FoU about Dectioon Item 4-B.

Action Item 4-2: Äspö HRL case study, part 2: Handling agreements with Nova FoU

Responsibility of: All PIs and Maria Ask.

Deadlines: (1) PIs should submit concerns regarding the Nova FoU agreement before Thursday 28 August to Maria Ask (e-mail)
(2) Maria Ask will compile and forward TRUST comments and concerns to Nova FoU before 1 September (TM14)

Background: In order to get access to the first joint TRUST case study at Äspö HRL, subprojects must sign an agreement and submit a commissioning inquiry to Nova FoU and SKB.

Action Item 4-3: Äspö HRL case study, part 3: Signing agreements with Nova FoU

Responsibility of: PIs that not yet have signed an agreement (TRUST 2.2, 3.2, 4.1)
Deadlines: TRUST projects working at Äspö HRL should sign an agreement with Nova FoU. The agreement
Background: In order to get access to the first joint TRUST case study at Äspö HRL, subprojects must sign an agreement and submit a commissioning inquiry to Nova FoU and SKB.

Action Item 4-4: Äspö HRL case study, part 4: Submitting commissioning inquiry to Nova FoU

Responsibility of: PIs that not yet have signed an agreement (TRUST 3.2)
Deadlines: TRUST projects working at Äspö HRL should submit commissioning inquiry to Nova FoU to initiate planning of their project
Background: In order to get access to the first joint TRUST case study at Äspö HRL, subprojects must sign an agreement and submit a commissioning inquiry to Nova FoU and SKB.

Action Item 4-5: Äspö HRL case study, part 5: Appoint project- and activity leader

Responsibility of: PIs
Deadlines: 1 October 2014
Background: PIs must appoint project leader and activity leader for the case study at Äspö HRL.

Action Item 4-6: Äspö HRL case study, part 6: Application for additional geophysical site investigation

Responsibility of: Torleif Dahlin
Deadlines: 24 December 2014
Background: There is an opportunity to collect additional geophysical data at Äspö HRL (which was not a possibility in the Geoinfra proposal). An application for additional geophysical investigations will be submitted.

Action Item 4-7: Äspö HRL case study, part 7: Application for rock mass characterization (TRUST 2.3)

Responsibility of: Maria Ask
Deadlines: 10 September 2014
Background: A proposal regarding a focused TRUST 2.3 project focusing on rock mechanic testing and its link to sonic velocities will be submitted to BeFo.

Action Item 4-8: Äspö HRL case study, part 8: Application for rock mass characterization (TRUST 2.3)

Responsibility of: Thomas Olofsson
Deadlines: 1 October 2014
Background: The work of developing a focused proposal for TRUST 3.1 regarding the damaged blasting zone will be initiated.

Action Item 4-9: *Förbifart Stockholm* case study (Vinsta)

Responsibility of: Håkan Rosqvist and Maria Ask
Deadlines: 1 October 2014
Background: The planning of the case study along *Förbifart Stockholm*, Vinsta exit should be continued.

Action Item 4-10: Application for groundwater geochemistry

Responsibility of: Malin Norin and Charlotte Sparrenbom
Deadlines: 10 October 2014
Background: There is a gap in funding for collecting groundwater geochemistry data. A joint application for a joint groundwater geochemistry sampling program for TRUST projects 2.1 and 2.4 in the *Förbifart Stockholm* case study (Vinsta) should be submitted.

Action Item 4-11: Application for groundwater geochemistry

Responsibility of: Malin Norin and Charlotte Sparrenbom
Deadlines: 10 October 2014
Background: There is a gap in funding for collecting groundwater geochemistry data. A joint application for a joint groundwater geochemistry sampling program for TRUST projects 2.1 and 2.4 in the *Förbifart Stockholm* case study (Vinsta) should be submitted.

Action Item 4-12: TRUST publication policy

Responsibility of: Mehrdad Bastani
Deadlines: 5 September 2014
Background: The draft TRUST publication policy will be updated following the group work during TRUST WS#4, and the updated version will be to all project leaders and WS participants who get to comment and/or approve the policy. TRUST project members then sign the approved policy that gets published on the web.

Action Item 4-13: Innovation and Implementation of TRUST WS#5

Responsibility of: Mats Svensson
Deadlines: 24 December 2014
Background: There will be a presentation of the STA design and decision process at TRUST WS#5 in February. The presentation will be organized and personnel from STA will be invited. Report of progress will be given before the dead line

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Action Item 4-14: Development of joint PhD courses

Responsibility of: Fredrik Johansson, Anna Kadefors and Thomas Olofsson
Deadlines: 2 February 2015
Background: PhD students have identified a number of PhD courses. Fredrik Johansson will drive the process to develop a joint statistics course. Anna Kadefors and Thomas Olofsson will drive the process to develop a joint research to business course.

Action Item 4-15: Internships for PhD students

Responsibility of: Supervisors and PhD students
Deadlines: 2 February 2015
Background: PhD students have reported interest in internships in companies. Supervisors and their respective PhD students should pursue the process. They also should investigate the opportunities to share field works.

Action Item 4-16: Posting ongoing activities at the trust-geoinfra.se

Responsibility of: PIs
Deadlines: Ongoing
Background: The TRUST website is important for spreading information about TRUST. All are responsible for posting ongoing activities. Information should be sent to Mats Svensson.

Action Item 4-17: Next phase of TRUST

Responsibility of: PIs, Maria Ask
Deadlines: 2 February 2015
Background: It is time to start thinking of the next phase of TRUST, beyond 2016. Strategies for lobbying and developing new research issues, and possible new partners should be developed.

TRUST Workshop # 5, Uppsala 3-4 February 2015

Decision Items

Decision Item 5-A:	**TRUST publication policy has been approved**

Background: TRUST members worked on developing the partnering declaration during TRUST Workshops (WS) #2 and #3, and the text was approved by PIs in a advance of TRUST WS#4. All TRUST members present at TRUST WS #4 signed version 1.0 of the document. Signatures from remaining TRUST members will be collected, and obedience of the document will be followed-up in subsequent meetings.

Decision Item 5-B:	**Activity leaders at Äspö HRL of TRUST 2.1, 2.2, 3.3 and 4.2**

Background: TRUST project 2.2 has assigned Emil Lundberg, Uppsala University as activity leader for the Äspö HRL campaign. TRUST project 3.3 has assigned Almir Draganovic, KTH as activity leader for the Äspö HRL campaign. TRUST projects 2.1 and 4.2 have assigned Marcus Wennermark, Lund University as activity leader for the Äspö HRL campaign. Emil Lundberg is assigned as overall coordinator, and his costs will be shared by participating TRUST projects.

Decision Item 5-C:	**Date & Place for TRUST WS#6**

Background: LOE, Chalmers and Malin Norin, NCC will host TRUST WS#5, **25-26 August 2015.**

Decision Item 5-D:	**PhD provides input to trust-geoinfra.se**

Background: Per Ivar 2.1, Bojan 2.2, 4.2, 3.2, 3.3, Anders (Mats tf) 4.1 & Olof Marcus 4.2 The TRUST website is important for spreading information about TRUST. All participants are requested to upload ongoing activities. Information should be sent to Mats Svensson. Information requested include publications, abstracts, posters, presentations, fotos, animations, etc.

Action Items

Action Item 5-1:	**Implementing R&D in infrastructure projects**

Responsibility of: Thomas Olofsson & Anna Kadefors

Background: The invited speakers Anders Berntson (STA), Robert Sturk (Skanska) and Håkan Rosqvist (Tyréns) presented how R&D results are implemented from client, entrepreneur and consultants perspectives, respectively. A MSc thesis project by Andreas and Carl has been being initiated to investigate implementation aspects of R&D implementation in infrastructure projects. Thomas is the main adviser and will report in August.

Action Item 5-3: Äspö HRL: Signing Nova FoU agreement

Responsibility of: Fredrik Johansson, Almir Draganovic and Stefan Larsson

Background: KTH lawyers have contacted Nova FoU regarding the agreement due to the fees stated in the agreement. Nova FoU will respond that TRUST will not pay any fees.

Action Item 5-2: Äspö HRL: Submitting commissioning inquiry to Nova FoU

Responsibility of: Fredrik Johansson and Almir Draganovic

Background: In order to get access to the first joint TRUST case study at Äspö HRL, subprojects must sign an agreement and submit a commissioning inquiry to Nova FoU and SKB. The PIs of TRUST projects 3.2 and 3.3 must submit commissioning inquiry to Nova FoU get access to the Äspö HRL.

Action Item 5-4: Äspö HRL: Appoint project- and activity leader

Responsibility of: Fredrik Johansson and Stefan Larsson

Background: PIs of TRUST projects 3.2 and 4.1 must appoint project leader and activity leader for the case study at Äspö HRL.

Action Item 5-5: *Förbifart Stockholm* case study (Vinsta) – time & date

Responsibility of: Håkan Rosqvist

Background: TRV has informed TRUST that testing may be commenced 1 May 2015. Håkan Rosqvist will maintain the communication with TRV about timing of measurements that the TRUST projects will conduct measurements at the end of the allocated time window.

Action Item 5-6: *Förbifart Stockholm* case study (Vinsta)

Responsibility of: Torleif Dahlin, Alireza Malehmir, Lars O. Ericsson

Background: TRV has informed TRUST that testing may be commenced 1 May 2015. The planning of the field work should be continued.

Action Item 5-7: Nova FoU annual report

Responsibility of: Maria Ask, Lars O. Ericsson

Background: The PIs of TRUST projects 1 and 2.4 are requested to submit requested text to the Nova FoU annual report as soon as possible.

Action Item 5-8: TRUST participation in the ERUF application (Oskarshamn Labs initiative)

Responsibility of: Maria Ask, PIs

Background: TRUST wants to take an active role in the ERUF application to allow inclusion of the TRUST vision regarding sustainable development of underground structure, and to develop improved methods and tools for planning, construction, and operation and maintenance of underground constructions.

Action Item 5-9: Posting ongoing activities at the trust-geoinfra.se

Responsibility of: All TRUST participants

Background: The TRUST website is important for spreading information about TRUST. All participants are requested to upload ongoing activities. Information should be sent to Mats Svensson. Information requested include publications, abstracts, posters, presentations, fotos, animations, etc.

Action Item 5-8: Application for groundwater geochemistry (Action Item 4-10)

Responsibility of: Malin Norin and Charlotte Sparrenbom

Background: There is a gap in funding for collecting groundwater geochemistry data. A joint application for a joint groundwater geochemistry sampling program for TRUST projects 2.1 and 2.4 in the *Förbifart Stockholm* case study (Vinsta) should be submitted.

Action Item 5-17: Next phase of TRUST

esponsibility of: PIs, Maria Ask
Deadlines: 2 February 2015
Background: It is time to start thinking of the next phase of TRUST, beyond 2016. Strategies for lobbying and developing new research issues, and possible new partners should be developed.
Target Vinnova and Formas
TRUST – UK conference, Mats
TRUST – renewal phase, MA, HR, MS, AD
Has TRUST done a substantial work.
Where are we – self evaluation What have TRUST achieved?

Action Item 5-13: Innovation and Implementation of TRUST WS#5

Responsibility of: Mats Svensson
Deadlines: 24 December 2014
Background: There will be a presentation of the STA design and decision process at TRUST WS#5 in February. The presentation will be organized and and personell from STA will be invited. Report of progress will be given before the dead line

.

Action Item 5-14: Development of joint PhD courses

Responsibility of: Fredrik Johansson, Anna Kadefors and Thomas Olofsson
Deadlines: 2 February 2015
Background: PhD students have identified a number of PhD courses. Fredrik Johansson will drive the process to develop a joint statistics course. Anna Kadefors and Thomas Olofsson will drive the process to develop a joint research to business course.

Action Item 5-15: Internships for PhD students

Responsibility of: Supervisors and PhD students
Deadlines: 2 February 2015
Background: PhD students have reported interest in internships in companies. Supervisors and their respective PhD students should pursue the process. They also should investigate the opportunities to share field works.

TRUST Workshop #6
Draft Action Items

Action Item 6 – 1: Äspö HRL: field work part 2

Action: Primary analyses of the Äspö HRL measurements during spring 2015 show that there is a need to conduct complementary measurements. A plan for securing additional funding as well as coordination and planning of additional fieldwork should be coordinated.

Responsibility of: PIs TRUST 2.1 & 2.2 /representatives.

Deadline: Updates are provided in subsequent monthly telephone meetings (TM)

Action Item 6 – 2: Äspö HRL: SICADA data

Action: It is challenging to obtain the correct data from the SKB SICADA data base and also the conversion formula for the local Äspö HRL and national coordinate systems. The TRUST stakeholders shall compile a list and submit that to TRUST 4.1 who will obtain the requested data. We shall take help from SKB personnel and get data.

Responsibility of: Mats Svensson is the contact person towards SKB.

Deadline: October TM

Action Item 6 – 3: Äspö HRL: Develop one joint integrated model

Action: Site investigations of TRUST 2.1, 2.2, 4.2 projects have collected different types of geophysical data. A joint inversion of the various data should be made. These results should be integrated and a joint model should be identified.

Responsibility of: PIs TRUST 2.1 & 2.2

Deadline: Presentation at TRUST WS #7

Action Item 6 – 4: Identify spin-off projects from TRUST collaboration.

Action: Several spin-off projects have been generated during the course of TRUST umbrella project. It is important to keep track of this aspect of TRUST.

Responsibility of: All TRUST members are requested to submit the spin of projects that have been generated until date.

Deadline: October TM, the results should be posted on www.trust-geoinfra.se

Action Item 6 – 5: Bypass Stockholm project – understanding TRV objectives

Action: TRUST has been granted access to *Trafikplats Vinsta* for site investigation. TRUST recognize that there is a need to further our understanding on what are the objectives for TRV to grant us access to the site. TRUST should set up a meeting with TRV to discuss TRV objectives. All TRUST PIs are welcome to the meeting.

Responsibility of: Håkan Rosqvist

Deadline: October TM

Action Item 6 – 6: Bypass Stockholm project – explore funding possibilities.

Action: The original plan for TRUST was to use the Bypass Stockholm project as the joint case study for our projects. However, due to delays in that project, we have been forced to explore alternate sites for case studies, further away and at different locations compared to the original plan. In order to conduct fieldwork in Bypass Stockholm, more funding is needed.

Responsibility of: Håkan Rosqvist and PIs TRUST 2.1, 2.2, 2.4, 3.2, 4.1, 4.2

Deadline: October TM

Action Item 6 – 7: Bypass Stockholm project – planning
Action: TRUST needs to plan for field measurements, TRUST 2.1, 2.4 (and 2.2).
Responsibility of: PIs TRUST 2.1, 2.2 & 2.4
Deadline: October TM

Action Item 6 – 8: Plan for outreach activity
Action: The achievement of TRUST is poorly known in many groups. It is important to spread information about TRUST achievements. An outreach program should be developed with presentations that all TRUST members can present. Explain that site investigation is important. Not an identified TRV & BeFo list.
Responsibility of: Maria Ask, Håkan Rosqvist, Mats Svensson will develop a presentation. TRUST PIs provide input
Deadline: November TM

Action Item 6 – 9: Contribution for the research bill in February 2016
Action: TRUST should provide input to the upcoming research bill. It is suggested to channel our contribution through SBU. It is suggested that all TRUST members provide a text describing suggestions, maximum six lines long (Times 12, A4). There is documented material on IQS. UU is welcome & can send their own.
Responsibility of: All TRUST members, Coordinated by Maria Ask
Deadline: November TM

Action Item 6 – 10: Outcome of the TRUST #6 work regarding the renewal process of TRUST
Action: The documentation from the workshop will be posted on the TRUST Webforum project place. The results will be further analyzed in three rounds: (1) Svensson and Rosqvist make a first summary of results; (2) Österling, Ask, Svensson and Rosqvist reviews the summary and propose all TRUST members to contribute in the third round. This will form a basis in the renewal process discussions.
Responsibility of: Håkan Rosqvist, Mats Svensson and Maria Ask
Deadline: October TM

Action Item 6 – 11: TRUST WS#7 – open time in the agenda
Action: To allow development of spin-off projects and to enhance opportunities for collaboration, there shall be time crafted out for his in the Agenda for WS #7.
Responsibility of: Maria Ask
Deadline: TRUST WS #7

Action Items TRUST Workshop #7

Action Item WS7-1	TRUST WS-7: All presenters that presented material at the meeting should make sure to upload their presentations at Webforum, at https://secure.webforum.com/formasprojekt/doc?dfRefID=619 Dead line: 160307 (TRUST TM#29)	Presenters
Action Item WS7-2	All members of TRUST that have been first authors of published paper (scientific, popular scientific), conference papers, thesis (PhD, Lic., MSc, BSc), and abstracts should upload their published material at Webforum, at https://secure.webforum.com/formasprojekt/doc?dfRefID=268. A structure will be set-up at Webforum. Background**:** It is important to share the results within the group as well as keeping a library that is available for marketing the results of TRUST. Dead line: 160307, (TRUST TM#29)	Rosqvist, All first authors
Action Item WS7-3	Äspö HRL 1, TRUST projects involved in Äspö HRL measurements in 2015 shall provide input to the Nova FoU requested input to their annual report, using the distributed document. Background: Nova FoU requested input to the annual report no later than 22 January, and also has distributed a reminder of their request on 28 January. Dead line: 160208	Dahlin, Malehmir, Ericsson, Draganovic, Svensson, Ask
Action Item WS7-4	Äspö HRL 2, TRUST projects who have collected new data from Äspö HRL are requested to contact Mats Svensson on how to upload the data tp GeoBIM. Dead line: 160304	Dahlin, Malehmir, Ericsson, Draganovic
Action Item WS7-5	Äspö HRL 3, TRUST 4.1 shall contact SKB to verify the SICADA delivery. Background: SKB has delivered SICADA data to TRUST 4.1, with the delivery including data files and a list of what data files were delivered. However, there are discrepancies between the listed and delivered files. Dead line: 160403	Svensson
Action Item WS7-6	Äspö HRL 4, The first draft of a GeoBIM database including relevant SICADA data and TRUST data from Äspö HRL should be completed. Dead line: 160415	Svensson
Action Item WS7-7	Äspö HRL 5, Presenting and discussing the draft GeoBIM model with SKB personnel (i.e. Assen Simeonov, Fredrik Mathurin, Eva Widing, Mats Ohlsson) during 1-2 meetings, before commencing the work with the joint model. Dead line: 160830	Dahlin, Malehmir
Action Item WS7-8	TRUST 2.1 will submit an environmental extension to the special FORMAS call "*Targeted call within the program Sustainable Building and Planning – fifth call*" Dead line: 160218	Sparrenbom, Rosqvist, Dahlin
Action Item WS7-9	Marketing 1: TRUST 1 and 2.1 are to be giving 3-minute presentation at the BeFo Medley on the 50th anniversary of *the Bergmekanikdagen*. They will distribute their pptx presentations in advance, before 160301. Dead line: 160314	Ask, Dahlin

Action Item WS7-10	Marketing 2. A TRUST 1.0 achievement executive brochure should be produced before *the Bergmekanikdagen*. TRUST members will be asked to contribute Dead line: 160314	Ask with support from TRUST members
Action Item WS7-11,	Marketing 3. A TRUST 1.0 achievement executive report should be produced. TRUST members will be asked to contribute. The idea is to adapt the form of ocean drilling program evaluation reports, e.g. http://www.ecord.org/pub/ECORD_evaluation-report.pdf Dead line: Summer 2016, draft 1 of the report	Ask with support from TRUST members
Action Item WS7-12	Marketing 4: TRUST 2.2 has been invited by Bastani to present their project at SGU – Uppsala. It is intended that this presentation is the first in a series, and that other TRUST projects will be invited. Dead line: Spring 2016	Bastani, Malehmir
Action Item WS7-13	Marketing 5 TRUST 1 will organize presentations of TRUST for TRV, during which other TRUST members will be invited to participate/contribute. Dead line: 2016, exact timing to be determined during TRUST 1 reference group meeting 160303	Ask, Rosqvist et al
Action Item WS7-14	Marketing 6: TRUST 1 will organize presentations of TRUST for SKB, during which other TRUST members will be invited to participate/contribute. Dead line: 2016, exact timing to be determined during TRUST 1 reference group meeting 160303	Ask, Rosqvist et al
Action Item WS7-15	TRUST 2.1 and 2.2 should submit a proposal to update the practical book for getoechnicians, Triumf, 1992, *Geofysik för geotekniker: metoder och tillämpningar*, Byggforskningsrådet, Stockholm. T31:1992, 84 pp. Dead line: Proposal for funding should be submitted in 2016	TRUST 2.1, 2.2
Action Item WS7-16	The VINSTA area has not been sufficiently investigated. Ask is taking the lead in submitting a proposal to Formas, VINNOVA, SGU or other organizations. Dead line: Spring 2016	Ask with support from TRUST members
Action Item WS7-17	The Dalby excursion resulted in an idea to capture the 3D nature of the bedrock by capturing images of the quarry over time. A proposal should be submitted to BeFo Dead line: Spring 2016	Sara Johansson, Leif Jonsson
Action Item WS7-18	The webmaster of the TRUST website www.trust-geoinfra.se is overloaded with work. It is decided that Ask will organize a move of the website to an LTU actor. Dead line: 160307 (TRUST TM#29)	Ask
Action Item WS7-19	During TRUST WS#7, Johan NYMAN, Mirage Media / LU interviewed and filmed TRUST participants for follow-up videos of the earlier TRUST videos. Svensson is responsible for supporting the editing and future publication of the video. Dead line: Date for desired publishing date: 160531	Svensson
Action Item WS7-20	TRUST WS#8 will be the last workshop in the current TRUST project. More industry participation is required, and TRUST members are requested to actively participate in this process. Dead line: 160307 (TRUST TM#29) and subsequent TMs	TRUST PIs

POLICIES REGARDING THE PUBLICATIONS WITHIN THE TRUST PROJECT

This document contains general overview about the policies related to the publications made during and after the termination of the TRUST project. All the partners/project leaders (PP/PL) involved in the TRUST project are supposed to read the contents of the document and send their feedback to Mehrdad Bastani (mehrdad.bastani@sgu.se) not later than 20140415. No respond is interpreted as a full agreement of the project partner(s) to the contents of the document. Mehrdad Bastani will later send the final version of the document to Maria Ask for further actions. All PPs and PLs should sign an agreement regarding the Publication Policies pointed out in the final version of this document.

We have mainly used the Vancouver Protocol (VP,see the link: https://www.google.se/#q=vancouver+protocol+download) to form the publication policies within the TRUST project. The text in italic face shown in Appendix A represents the material extracted from the VP. We have also taken into account some of the experiences gained from our previous collaborations with other research projects. During the discussions made in the TRUST workshop # 4 in Luleå the authorship was of main focus and it is therefore emphasized here that:

Authorship credit should be based only on substantial contributions to:

- conception and design, or analysis and interpretation of data
- drafting the article or revising it critically for important intellectual content
- final approval of the version to be published.

For the TRUST project all the partners agreed upon that:

"Conditions 1 and 2 must be met and the third one is considered as a consequence of the first two when any version of the paper is submitted after it is posted in the project homepage (see section 2)."

"Participation solely in the acquisition of funding or the collection of data does not justify authorship."

1. PUBLICATION CATEGORIES:

Publications may be in any of the following forms:

- Abstract: Usually limited to page submitted to a conference, workshop, etc. for an oral or poster presentation. They are not usually counted as a full publication but can be referenced later. May have reference list but rarely have acknowledgements.

- Extended abstract: Are sent for the same purpose as an abstract but may have several pages (up to 6 pages) and are usually counted as an ISI publication. They include reference list and acknowledgements.

- Full paper: A manuscript is sent to a journal and contains many sections such as abstract, introduction, etc. The format of the manuscript changes and is mainly based on the guidelines issued by each journal.

- Reports: The reports sent to supporting organizations or clients that have funded the project(s). They may have similar structure as a full paper but are usually much longer describing many other details than a scientific paper. Acknowledgments are also made in such publications.

- Popular science articles: A short article that **d**isseminates the latest achievements of science in a form that is easily understandable for its intended audience

2. PUBLICATION POLICIES RELATED TO TRUST PROJECT

The TRUST is an umbrella project which involves several partners from academia, industry and state-running organizations. This implies that the research carried out in the frame of TRUST project spans over a wide range of group of researchers with a variety of expertise and disciplines. Most of the disciplines have overlapping tasks and interests that may lead to issues such as conflicts of interests when it comes to publication of the results in the form of one the above mentioned categories (see section 1). This therefore demands a clear policy regarding publications made in the frame of the TRUST project. Considering the fact that TRUST project has constructed modern and functional communication tools, namely a homepage and a project-place it can be used as a basis and effective tool to use for the actions regarding the posting of the publications.

All the TRUST members have the possibility to log in, either read the posts/notices/announcements etc. made by the other partners or make their own. We therefore suggest the following steps to take before submitting the planned publications in any forms mentioned in section 1:

- Please read Appendix A in this document before you post the publication note.

- Post an announcement in the project-place regarding the planned publication to get feedback (e. g. regarding authorship, relevant referencing, etc). Make sure that the posting is made in proper time which means that it does not conflict with submission deadline. A requirement of at least 10 days before the submission deadline should be standard. However, it is compulsory to post all publications (including last minute ones).

- It must be considered by all the partners that receive the posted documents are circulated JUST within the TRUST members who has signed this policy (BEFORE PUBLICATION).

- Copy the publication file in pdf format in the folder specified by the webmaster (see section 3).

- Specify a deadline (if applicable) both in the form of number of days and date (e.g. 5 day from the date posted or 20150115). A minimum of one week deadline is a requirement.

- Send a message to all TRUST project members using the facilities available at the project-place.

- The author(s) MUST abide the agreements made with clients that are involved in any form (e.g. property owners, consultant companies, etc).

- Two days prior to the announcement deadline send a last-notification message to all the project members regarding the approaching deadline.(Ask the webmaster for the automatic message on the publication submission.)

Conflicts of interest have to be solved by the project management (TRUST 1) via telephone contact/meeting with the parties involved.

Acknowledgements: A standard text for the funding organizations MUST be included in the publication. Please read the following two examples provided by Torleif Dahlin and Alireza Malehmir.

Torleif: Funding for the work was provided by Formas, The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, (ref. 2012-1931), BeFo, Swedish Rock Engineering Research Foundation, (ref. 331) and SBUF, The Development Fund of the Swedish Construction Industry, (ref. 12719). The project is part of the Geoinfra-TRUST framework

Alireza: The survey was carried out within the frame of Trust2.2-GeoInfra (http://trust-geoinfra.se) project sponsored by Formas, BeFo, SBUF, SGU, Boliden, Skanska, FQM, and NGI.

3. PROJECT-PLACE FACILITIES FOR PUBLICATION ANNOUNCEMENTS IN THE TRUST PROJECT

The webmaster of the TRUST project is responsible to provide the:

- Possibility of using the tools for posting announcements that are automatically sent to all the project members.

- Information about the location on the project's homepage where the members can copy the materials related to their publications.

Appendix A: Vancouver Protocol

Redundant or Duplicate Publication

Redundant or duplicate publication is publication of a paper that overlaps substantially with one already published. Readers of primary source periodicals deserve to be able to trust that what they are reading is original unless there is a clear statement that the article is being republished by the choice of the author and editor. The bases of this position are international copyright laws, ethical conduct, and cost-effective use of resources.

Most journals do not wish to receive papers on work that has already been reported in large part in a published article or is contained in another paper that has been submitted or accepted for publication elsewhere, in print or in electronic media. This policy does not preclude the journal considering a paper that has been rejected by another journal, or a complete report that follows publication of a preliminary report, such as an abstract or poster displayed for colleagues at a professional meeting. Nor does it prevent journals considering a paper that has been presented at a scientific meeting but not published in full or that is being considered for publication in a proceedings or similar format. Press reports of scheduled meetings will not usually be regarded as breaches of this rule, but such reports should not be amplified by additional data or copies of tables and illustrations.

Authorship

All persons designated as authors should qualify for authorship. Each author should have participated sufficiently in the work to take public responsibility for the content.
Authorship credit should be based only on substantial contributions to 1) conception and design, or analysis and interpretation of data; and to 2) drafting the article or revising it critically for important intellectual content; and on 3) final approval of the version to be published. Conditions 1, 2, and 3 must all be met. Participation solely in the acquisition of funding or the collection of data does not justify authorship. General supervision of the research group is not sufficient for authorship. Any part of an article critical to its main conclusions must be the responsibility of at least one author. All members of the group who are named as authors, either in the authorship position below the title or in a footnote, should fully meet the above criteria for authorship. Group members who do not meet these criteria should be listed, with their permission, in the Acknowledgments or in an appendix (see Acknowledgments).
The order of authorship should be a joint decision of the coauthors. Because the order is assigned in different ways, its meaning cannot be inferred accurately unless it is stated by the authors. Authors may wish to explain the order of authorship in a footnote. In deciding on the order, authors should be aware that many journals limit the number of authors listed in the table of contents.

Acknowledgments

At an appropriate place in the article (the title-page footnote or an appendix to the text; see the journal's requirements), one or more statements should specify 1) contributions that need acknowledging but do not justify authorship, such as general support by a departmental chair; 2) acknowledgments of technical help; 3) acknowledgments of financial and material support, which should specify the nature of the support; and 4) relationships that may pose a conflict of interest (see Conflict of Interest). Persons who have contributed intellectually to the paper but whose contributions do not justify authorship may be named and their function or contribution described-for example, "scientific adviser", "critical review of study proposal," "data collection," or "participation in clinical trial." Such persons must have given their permission to be named. Authors are responsible for obtaining written permission from persons acknowledged by name, because readers may infer their endorsement of the data and conclusions.
Technical help should be acknowledged in a paragraph separate from that acknowledging other contributions.

Conflict of Interest

Conflict of interest for a given manuscript exists when a participant in the peer review and publication process-author, reviewer, and editor-has ties to activities that could inappropriately influence his or her judgment, whether or not judgment is in fact affected. Financial relationships with industry (for example, through employment, consultancies, stock ownership, honoraria, expert testimony), either directly or through immediate family, are usually considered to be the most important conflicts of interest. However, conflicts can occur for other reasons, such as personal relationships, academic competition, and intellectual passion.
Public t rust in the peer review process and the credibility of published articles depend in part on how well conflict of interest is handled during writing, peer review, and editorial decision making. Bias can often be identified and eliminated by careful attention to the scientific methods and conclusions of the work. Financial relationships and their effects are less easily detected than other conflicts of interest. Participants in peer review and publication should disclose their conflicting interests, and the information should be made available so that others can judge their effects for themselves. Because readers may be less able to detect bias in review articles and editorials than in reports of original research, some journals do not accept reviews and editorials from authors with a conflict of interest.

Authors

When they submit a manuscript, whether an article or a letter, authors are responsible for recognizing and disclosing financial and other conflicts of interest that might bias the ir work. They should acknowledge in the manuscript all financial support for the work and other financial or personal connections to the work.

TRUST Partnering Declaration

Version 1.0 (TRUST Workshop #4, Luleå, 19-20 August 2014)

Vision: The overall vision of the TRUST project is to enable efficient and sustainable processes for planning, design, construction and management of urban underground facilities by developing:

- New and more holistic survey methods
- Better tools and methods for design and production control
- Integrated information management over the life cycle of the facility

A key factor for achieving TRUST's vision is the integrated and trans-disciplinary platform that enables collaboration between participants from universities, industry and the public sector. This national collaboration will leverage output from research and facilitate implementation of results by rethinking relationships within and between industry and academia.

Joint goals and core values: This partnering declaration has been developed during two TRUST workshops, in August 2013 and February 2014. Four important aspects have been considered: (1) General collaboration; (2) Data collection & sharing; (3) Publications & impact on the research field; and (4) User-values & societal impact.

As TRUST partners we have jointly agreed to commit to excellence at personal and professional levels to foster a creative environment. We will:

- Have a positive and supportive attitude, characterized by trust, generosity and openness
- Become familiar with fellow TRUST partners and their projects
- Participate constructively in collaborative activities and tasks
- Respect joint agreements, deadlines and budgets, and inform early about delays
- Plan data collection and sharing to serve joint goals and societal value along with project-specific and individual goals
- Strive for transparency and fairness in publication planning and co-authorship by respecting the TRUST project publication policy
- Initiate and seize opportunities for extended research collaboration, during the lifetime of the TRUST project and in the future
- Be open about plans for relevant funding applications and research collaborations outside of TRUST
- Be attentive to user-value aspects and show commitment in communicating and implementing research outcomes
- Engage in developing innovative collaborative relationships between academia, industry and the public sector

Signatures of project leaders (fully funded projects)

TRUST 1: Maria Ask (Luleå University of Technology)

TRUST 2.1: Torleif Dahlin (Lund University)

TRUST 2.2: Alireza Malehmir (Uppsala University)

TRUST 2.4: Lars O. Ericsson (Chalmers University of Technology)

TRUST 3.2: Fredrik Johansson (Royal Institute of Technology)

TRUST 3.3: Almir Draganovic (Royal Institute of Technology)

TRUST 4.1: Stefan Larsson (Royal Institute of Technology)

TRUST 4.2: Torleif Dahlin (Lund University)

TRUST Partnering Declaration

Version 1.0 (TRUST Workshop #4, Luleå, 19-20 August 2014)

Signatures of additional project participants present at TRUST Workshop #4

Name (organization)	TRUST Project No.
Ali Nejad Gahfar (Royal Institute of Technology)	3.3
Anders Prästing (Royal Institute of Technology/Tyréns AB)	4.1
Anna Kadefors (Chalmers University of Technology)	1
Bojan Brodic (Uppsala University)	2.2
Charlotte Sparrenbom (Lund University)	2.1
David Hagerberg (Tyréns AB)	2.1
Esben Auken (Aarhus University)	2.1, 4.2
Gianluca Fiandaca (Aarhus University)	2.1
Håkan Rosqvist (Lund University/Tyréns AB)	1, 2.1
Joachim Place (Uppsala University)	2.2
Malin Norin (NCC/Chalmers University of Technology)	2.4
Marcus Wennemark (Lund University)	4.2
Mats Svensson (Tyréns AB)	1, 2.1, 4.1
Mehrdad Bastani (Geological Survey of Sweden)	2.1, 2.2
Per-Ivar Olsson (Lund University)	2.1
Sara Johansson (Lund University/Tyréns AB)	2.1
Shunguo Wang (Uppsala University)	2.2
Suman Mehta (Uppsala University)	2.2
Thomas Olofsson (Luleå University of Technology)	1
William Bjureland (Royal Institute of Technology)	3.2

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TYRÉNS

REPORT

IT MANUAL TRUST 2.1

TRUST
Transparent Underground Structure

DRAFT
2014-05-30

Assignment:	921457, 3.82 TRUST 4.1 Developments of methods for rational and rapid evaluation of geotechnical surveys.
Title:	IT Manual TRUST 2.1
Status:	Draft
Date:	2014-05-30

Authors

Consultant:	Olof Friberg & Mikael Lumetzberger
Quality control:	S. Johansson, M. Svensson, C. Sparrenbom

Revisions

Date	2014-10-10
Version:	English translation
Name:	Mikael Lumetzberger, Tyréns

Author:

Date: ÅR-MÅN-DAG

Quality control by:

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Summary

The IT manual contains guidelines for naming conventions and data storage structuring and specifies the metadata that should accompany uploaded material.

The manual generally describes how data and documents are to be structured within the entire TRUST project, with specific instructions regarding TRUST 2.1.

The IT manual covers the following main subjects:

- Software and formats
- Coordinate systems
- Webforum
- Drawings and maps
- Collected and processed data
- Documents
- Naming conventions
- Delivery specifications

Table of contents

1 Introduction

The IT manual aims to provide guidelines for how digital information should be organized and made accessible for the TRUST database. The IT manual will also make quality assurance of information more efficient, and ensure that uploaded and delivered material meet qualitative and structural standards set by the TRUST project.

1.1 General software and formats

Documents are to be produced in programs directly readable by the Microsoft Office suite.

Storage of conventional geotechnical survey data should comply with Sveriges Geotekniska Förening's SGF standard. The software GS Arkiv, version 2008 or later, are to be used for storage.

Coordinate transformation are to be carried out in Lantmäteriet's GTRANS software or alternatively in FME using the GTRANS engine.

Survey coordinates are to be uploaded in .csv format.

Resistivity and IP data are uploaded to TRUST during the steps of data processing outlined in the figure below. Se chapter 2 for further details regarding uploading of resistivity and IP data.

1.2 Coordinate system

Plane and elevation systems are dependent on project and are determined at the start of every test project. All material is to be delivered in this coordinate system regardless of any other systems used during data collection and processing.

1.3 Project portal Webforum

During the course of the TRUST project, a customized project portal from Webforum is to be used (administrated by Tyréns AB). The Project portal is intended to be a gathering point of information that will promote the cooperative effort in the project.

The Project portal will streamline data distribution between different subprojects and project phases. It will also allow project management, project staff and clients continuous, easy access to data and results. Se chapter 2.2 and 5 for more details regarding the Project portal.

1.4 Document

Final versions of documents are generally delivered in Word or Excel format, or alternatively in pdf format. During ongoing work, documents are to be managed inside their respective subproject catalogue. At the final delivery, quality reviewed documents are to be moved to a corresponding location in a specified delivery catalogue.

Naming of documents is to be made according to the project specific naming convention. See chapter 3.1 for a detailed description.

1.5 Data, drawings and plane maps

Project specific symbols, drawing frames and drawing title blocks that are generated should be distributed through the Project portal.

Drawings and maps are to be produced in A1 or A3 formats unless necessities require a smaller format. Naming and numbering of drawings and maps are to be made according to the project specific naming convention. See chapter 3.1 for a detailed description.

2 General structures

2.1 Subproject structure

The TRUST subprojects form main units which project information is designated to:

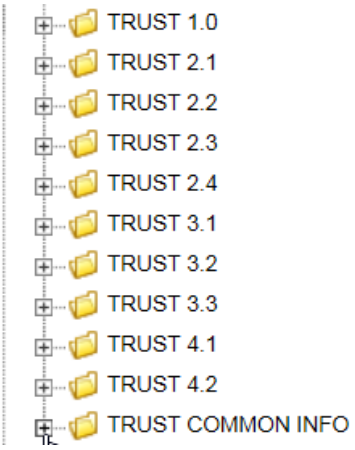
Subproject	Designation*
1	P10
2.1	P21
2.2	P22
2.3	P23
2.4	P24
3.1	P31
3.2	P32
3.3	P33
4.1	P41
4.2	P42

* Designation is used for naming of material.

2.2 Catalogue TRUST webforum

2.3 General catalogue structure

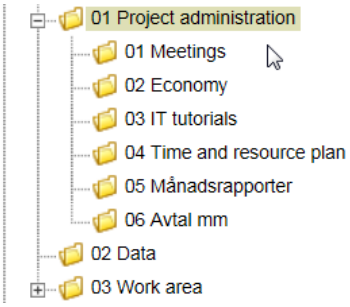
TRUST Webforum catalogue folders are subdivided according to the TRUST subprojects. There is an exchange of information between documents and data from different subprojects (with accompanying descriptions and metadata). Final delivery of quality reviewed material is made through the *TRUST COMMON INFO* catalogue. *TRUST 1.0* contains material that is distributed through TRUST coordination projects, e.g. TRUST workshops and background literature for the common TRUST field sites:



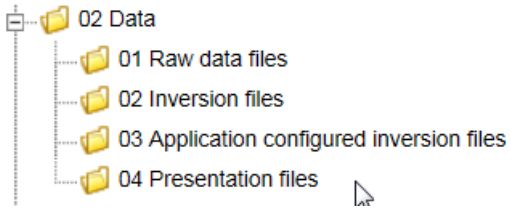
The subproject catalogue contains the catalogues *01 Project Administration*, *02 Data* and *03 Work Area*.

In the catalogue *03 Work Area,* each subproject is free to create their own catalogue structure. All catalogues (except *Doktorandkataloger)* are common in the sense that all project staff on the web platform has read access to all project catalogues. All project staff has write access to their respective subproject catalogue as well as *TRUST 1.0* and *TRUST COMMON DATA*.

The catalogue *01 Project Administration* is partly open for structuring by respective subprojects but is to contain the catalogues *01 Meetings* (meeting notes), *02 Economy* (follow-up), *03 IT Tutorials* (contains this IT manual, and eventual subproject additions) and *04 Time and Resource plan.*



The structure in the 02 Data catalogue will vary between the different subprojects due to the different data types and file formats that are generated. Below is a section showing subproject 2.1:



01 Raw data files contain files read by Terrameter software to generate data for inversion modelling.

02 Inversion files contain inversion modelling output files.

03 Application configured inversion files contain files processed to be input into various presentation and visualization software

04 Presentation files contain presentation material from visualization software e.g. 3D-engines such as Voxler, or GIS.

The catalogue destination for uploaded data is specified in the list below (bolded formats are obligatory for 2.1 projects):

Processteg	Filtyp
01 Raw data files	**terrameter, db, raw, txt, dat**
02 Inversion files	**inv,** xyz, vtk
03 Application configured inversion files	xlsx, txt, dat
04 Presentation files	pdf, shp, dxf, dwg, voxb

3 Naming convention

3.1 Naming convention of documents

Naming of TRUST documents are to be made according to the following principle, left to right:

Subproject Designation	Site Number	Status	Document Class	Serial Number	File Extension

Subproject Designation: Respective subproject designation according to chapter 2.1.

Site Number: Survey sites are coded with CS for common TRUST sites (i.e. more than one active subproject at any one site) or PS for subproject-specific sites, followed by a serial number. The sites are assigned numbers by the project management in Subproject 1.0 and are shown in the table below:

Common sites	Site number
Förbifart Stockholm	CS1
Kv Färgaren Kristianstad	CS2
Varbergstunneln	CS3
Äspölaboratoriet	CS4

Subproject sites	Site number
Delprojektsite 1	PS1
Delprojektsite 2	PS2
Delprojektsite 3	PS3

Status: Consists of a letter indicating document status:

STATUS	Designation
Not applicable	D
Arbetsmaterial	C
Granskningshandling	B
Final delivery	A

Document Class: Abbreviation of document types listed below:

DOCUMENT CLASS	DESIGNATION	DEFINITION
MSc thesis	MTHE	
Lic thesis	LTHE	
PhD thesis	PTHE	
Scientific journal paper	SPAP	
Conference paper	CPAP	
Postal presentation	PPRE	
Oral presentation	OPRE	
General report	GERE	
Site report	SIRE	Conducted surveys on site
Annual report	ANRE	
Final report	FIRE	

Serial Number: A number ranging between 01-99.

File Extension: E.g. .doc, *.xls* or *.pdf*.

Example of a file: An initial field report in pdf format for the Varberg project is named P21CS3SIRE01.pdf

Protocols and other miscellaneous work in progress uploaded during the project but not included in the final delivery are to be named after the principle Subprojectdesignation_Date_DescriptiveText.

Example of a file: A meeting protocol from the 8:th of January 2013 for Subproject 2.1 is named P21_2013-01-08_StartMeeting

3.2 Metadata documents

When uploading documents to the project portal, metadata are to be included in the document description according to the below table:

METADATA	DESCRIPTION
Uppladdad av/Uploader	Signature*
Handlingsnamn/Document name	Naming convention**
Handlingstyp/Document type	Descriptive text
Uppladdningsdatum/Date	Date uploaded*
Delprojekttillhörighet/Subproject	Designation**
Tillhörande Bilagor/Appendices	Appendix name
Kontaktperson/Contact	Document author

* Added automatically
** In compliance with TRUST naming conventions

3.3 Naming convention of data

The naming conventions described in this manual are confined to cover only data actively processed or produced within the TRUST project. Background information, previous survey results, GIS and CAD data etc… should be managed in the structure and format it is being supplied in.

3.4 Naming convention of resistivity and IP data

The naming of TRUST resistivity and IP data are to be made according to the below principle:

Subproject Designation	Site Number	Process Step	Survey Line Number	Presentation Type	Serial Number	File Extension

Subproject Designation: Respective subproject designation according to chapter 2.1.

Site Number: Survey sites are coded with CS for common TRUST sites (i.e. more than one active subproject) or PS for subproject-specific sites, followed by a serial number. The sites are assigned numbers by the project coordination in Subproject 1.0 and are shown in the table below:

Common sites	Site number
Förbifart Stockholm	CS1
Kv Färgaren Kristianstad	CS2
Varbergstunneln	CS3
Äspölaboratoriet	CS4

Subproject sites	Site number
Delprojektsite 1	PS1
Delprojektsite 2	PS2
Delprojektsite 3	PS3

Process Step: Consists of number designating the process step below:

Process Step	DESIGNATION
Non applicable	00
Raw data	01
Inversion data	02
Processed inversion data	03
Presentation	04

Survey Line Number: Survey line naming varies depending on the field methods, but will generally be recorded on a line-to-line praxis as shown in the below table:

Line numbering	DESIGNATION
Non applicable	LXX_LXX
Line 1	L01_L01
Line 2 – Line 4	L01_L04

Presentation type: Abbreviation designating the visualization type of resistivity data file according to the below table:

Presentation Type	DESIGNATION
Non applicable	--
2D profile model	-P
2D section model	-S
Volymer (3D-model)	-V
Interpretation	-T
Visualization	-W
Coordinates	-Z
Planes	-O

Serial number: A number ranging between 01-99.

File extension: Format type suffix.

Example 1: If subproject 2.1 delivers a .db raw data file of resistivity survey line 01-03 from the Varbergstunneln field site it is named P21CS3L01_L03-01.db

Example 2: If subproject 2.1 delivers a .voxb (voxler) visualization file of resistivity survey line 01-010 from the Äspö field site it is named P21CS404L01_L10-W01.voxb

3.4.1 Positioning naming convention

Electrode positions are to be given an electrode-id containing the survey line and serial number, e.g. for line 1 electrode 5 the electrode-ID would be L01.05
Several lines can be collected in the same coordinate file, and the file in turn is to be named according to the described TRUST conventions.

Example: If subproject 2.1 uploads a coordinate file with positions collected in the Varbergstunneln field site of electrodes in resistivity profiles 03-05. A previous file also containing coordinates for line 03-05 has already been uploaded, so this second file is named P21CS301L03_L05-Z02.csv

3.5 Metadata

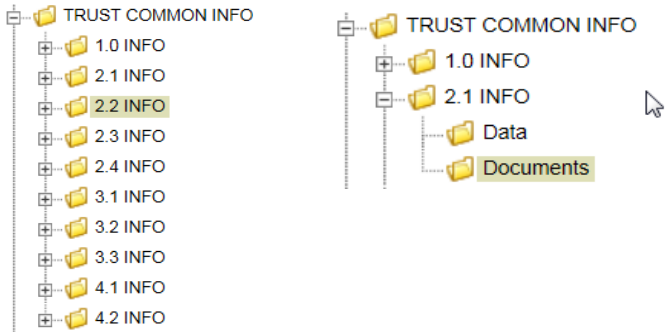
Data uploaded into the TRUST database is to be accompanied with metadata entered into the file description:

METADATA	Designation
Uppladdad av/Uploader	Signature*
Drawing number	Naming**
Drawing type	Descriptive text
Uppladdningsdatum/Date	Date uploaded*
Delområdestillhörighet/Subproject	Designation**
Tillhörande filer/Attached files	Naming**
Mätningsperiod/Field period	Survey Date
Kontaktperson/Contact	Surveyor

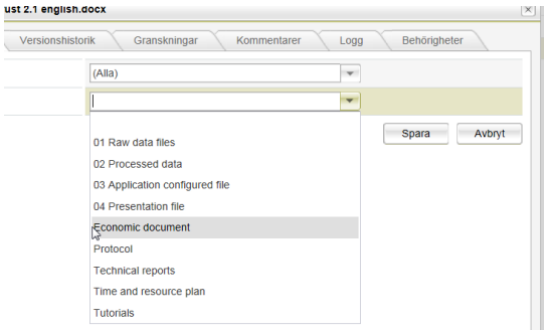
* Added automatically
** In compliance with TRUST naming conventions

4 Delivery of material

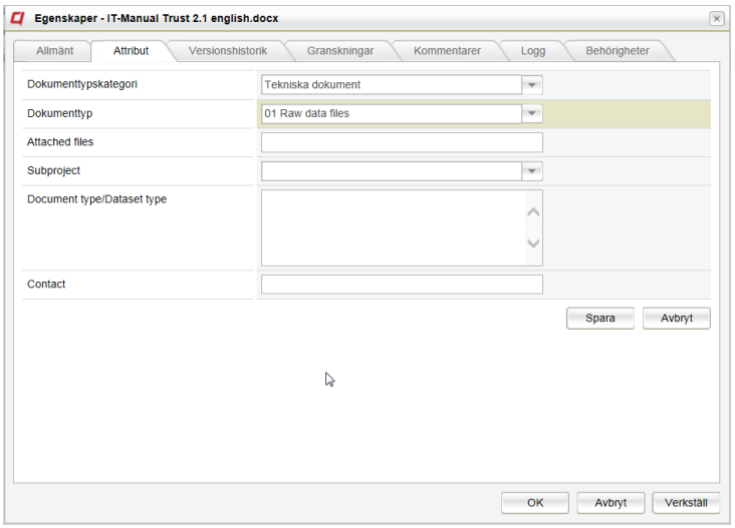
Delivery of material to other subprojects should be carried out through Webforum and the *TRUST COMMON INFO* catalogue: Each subproject has a corresponding delivery catalogue containing folders for Data and Documents. After placement in the delivery catalogue, the material is distributed to be used freely by all subprojects.



During uploading to Webforum, material is to be assigned a document type from predefined options shown in the attributes window below.



Relevant metadata is then to be added in the respective fields:



INTRODUCTION

The overall vision of TRUST is to enable efficient and sustainable processes for planning, design, construction and management of urban underground facilities by developing:

- New and more holistic survey methods
- Better tools and methods for design and production control
- Integrated information management over the life cycle of the facility

A key factor for achieving TRUST's vision is the integrated and trans-disciplinary platform that enables collaboration between participants from universities, industry and the public sector.

One of the goals of any applied research project is to implement the results in practice, therefore the user value aspects of the research projects has been investigated in workshop 3. Each funded project in the TRUST consortium, (Project 1, 2.1, 2.4, 3.2, 3.3, 4.1 and 4.2 in Fig. 1), was asked to specify the anticipated result and the use(r) values of the project. The values should also include for whom and at what stage in the life cycle underground facility the values are of benefit and the time horizon when the values of the project can be harvested in practice.

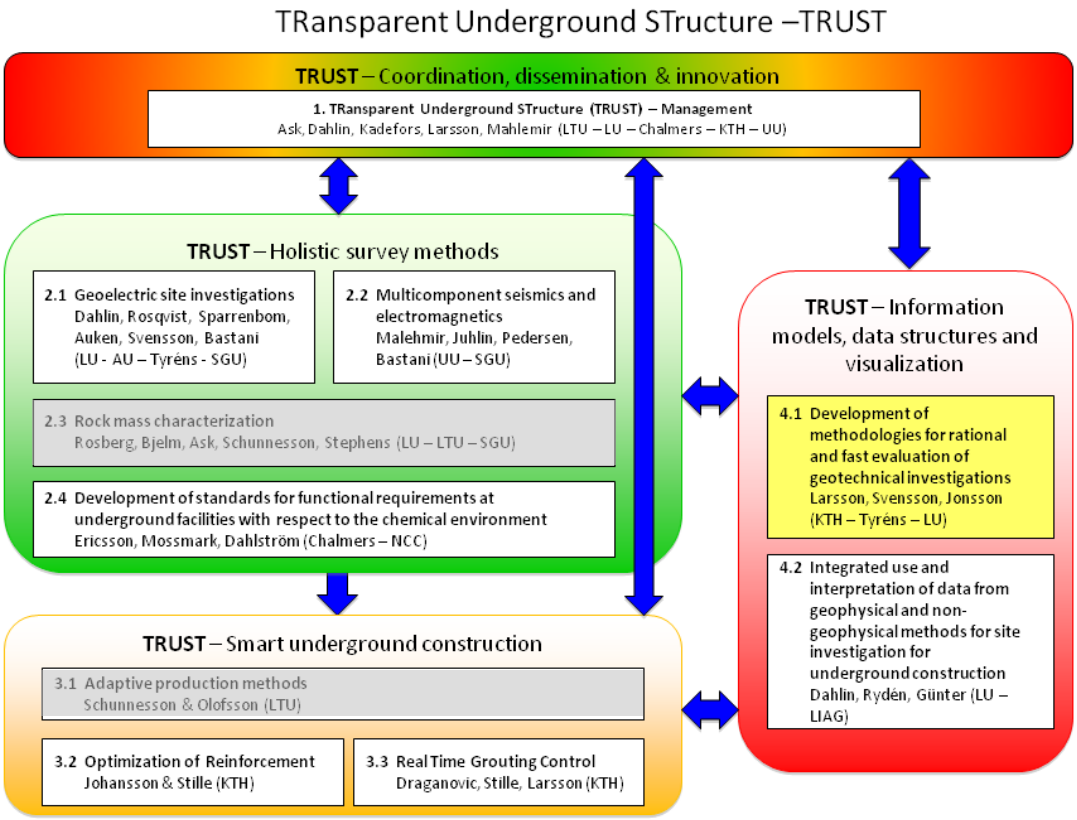


Fig 1: Projects within the TRUST consortium. Projects 2.3 and 3.1 are still not fully funded and have not started.

RESULT AND USER VALUES

Project 1: TRUST – management

The management project coordinates the different projects in the TRUST themes and disseminates the results and findings to all partners. It is also responsible for investigation of research innovation and implementation aspects. The anticipated result consists of:

- Dissemination activities of results and findings
- Models and guidelines for university-industry collaboration
- Implementation of result in civil engineering projects and the infrastructure construction industry

The user value for society lies in the anticipated result which is a synthesis from all the subprojects in the TRUST themes. At the workshop it was pointed out that a requirement is that the same test site is used in order to find interaction and synergies between different projects in TRUST. Also, if the TRUST concept is successful, the cooperation will glue the different knowledge islands together increasing the possibilities to compete with large research projects. Also, involved PhD students get exposed to future employers.

Project 2.1: Geoelectrical Imaging for Site Investigation for Urban Underground Infrastructure

The project intends to improve the potential of geo-electrical tomography for the interpretation of ground conditions with respect to geology, groundwater, structures and pollution in urban environments. The main result of the project is

- DCIP[1] tomography that is adapted to urban environments. Data acquisition strategies, methodology and data processing adapted for use in urban environments.
- Prototype instruments. DCIP equipment for time and cost efficient 3D data acquisition.
- 3D inversion of DCIP data. Algorithms for 3D inversion of DCIP data incorporating IP decay curves.
- Correlations between geophysical and engineering/environmental key parameters.

The results are going to be disseminated to authorities, industry and academy and integrated with the result from other TRUST sub-projects.

The values from the project are believed to be

- Better quality of site investigation results at an affordable cost
- Lower quotations thanks to better tender documents and reduced risk premiums (less uncertainty)
- Reduced environmental disturbances thanks to better engineering geological model

[1] DCIP = DC resistivity and induced polarisation

- Competence building and networking between academy and industry opens new possibilities for cooperation

The foreseen requirements of the new technology is believed to be access to instrumentation and knowledge on how to carry out investigations. Also, the knowledge of links between geophysical and engineering/environmental parameters is believed to be a requirement for its use.

A prototype will be available before the project ends. The step from prototype to commercially available is expected to be short if prioritized (roughly 1 year). Further test and demonstration probably required before full acceptance in the industry.

The comments from workshop indicated that the statement “Better quality of site investigation results at an affordable cost” needs to be quantified, i.e. “how much better” and what is “affordable”.

Project 2.2: Multicomponent seismic and electromagnetics

The project intends to develop two new systems particularly suited for noisy environments: (1) Multicomponent seismic streamer system and (2) radio-magnetotelluric system (RMT).

By imaging and characterizing of fault, fracture, dykes, and mineralized zones, their mechanical properties, anisotropy, depth to bedrock, layering above the bedrock etc., will give a better results for a lower cost that will decrease uncertainty and risks for contractors.

The result of the project can be implemented in practice

Some of the comments from the workshop were:

- What about refraction seismic in TRUST 2.2? - Answer this kind of data is collected in 2.2 (according to AM).
- It would be a success if 50 % of the goals could be reached in the project
- Values can be site dependent. Testing needed for each site to be able to derive the correct parameters which. Specialized operators needed
- Start of a research phase. Not clear how it can be applied in practices.
- Better knowledge of possibilities needed among clients in order to ask for the right pre-investigation methods.
- Instead of require methods – tell us What need to be answered
- Researchers (theoretical) need to meet industry (practical) somewhere half way. Find out what can be used commercially and give important results for the society. Optimize method for industrial purposes.

Project 2.4: Development of standards for functional requirements at underground facilities with respect to the chemical environment

The project is to develop standards for functional requirements at underground facilities with respect to the chemical environment. The anticipated result is:

- Prediction of underground hydrochemistry due to excavation
- Hydrochemical effects on resistance of shotcrete and grout to leaching and chemical degradation
- Hydrochemical effects on the corrosion rate of rock bolts

The values with the project are standards to meet functional requirements at underground facilities with respect to the chemical environment in terms of groundwater chemistry and vault atmosphere composition. It will also provide a basis for improving the content of environmental impact assessments (MKB) in conjunction with underground projects and the constructing of safer tunnels with cost-effective maintenance.

The developed standards can be applied by the owners/developers of underground facilities after the end of the project.

Some of the comments from the workshop were:

- Explosives could be more highlighted as affecting the boundary conditions.
- Link between geochemical properties and geophysical properties – possible combination of result from 2.4 and 2.1/2.2?
- Numerical flow and chemistry models can be used to predict the chemical environment around the tunnel and also the environment impact.
- Model should be the tool for setting the standards for the materials to be used for the construction.
- Requirement. Important to have base chemistry data and follow it through the construction and maintenance phase. Follow sites in different geological environments. Hydrogeological model. Requirements on the water sampling process.
- Should reduce the maintenance costs by choosing the correct material in the first place. Specific corrosion protection, long time behavior of shotcrete and grout.

Project 3.2: Design of rock support according to to Eurocode with reliability-based methods

The project objective is to identify suitable reliability-based design methods for rock mechanical problems in general and of rock support in tunnels in particular. The result of the project is anticipated to be:

- Improved design guidelines, especially for when and how reliability based design methods should be used.
- A clarification under which conditions and for which failure modes reality based design is relevant for design in rock.
- A better way to incorporate uncertainties in the design.

The values are believed to be a more optimal design of rock support, lower construction cost, better verified safety and eventually an increased competitiveness of Swedish consultants (who will use the methods).

The requirements are knowledge and experience of reliability based design methods, access to good data of the rock conditions and (eventually) access to design software.

Some of the comments from the workshop were:

- The values from 3.2 need linkage to purchase & contractual aspects of the underground construction project. Somebody (TRV) need to require “design according to Eurocode”
- When is it suitable to use reliability based design?
- Improved design guidelines, which conditions, which failure modes.
- Normal reliability has to trust on a lot of data.
- Connection between geophysics and design parameters in 3.2 important
- Interpretation. Normal that Rock mass has fewer samples, and also other kinds of uncertainties, e.g. joint geometry and persistence etc.

Project 3.3: Developing and implementation of Real Time Grouting Control Method (RTGCM) for rational tunneling – with focus on grout penetration ability and real spread

The project has two objectives to verify the penetration length and the determination of penetration ability of cement based grout. The result is anticipated to be:

- Verification of penetration length in field estimated with RTGCM
- Better measurement of penetration ability of grout related to real fractures

The values of the project are more effective (faster and cheaper) grouting with better reliable estimate of the grouting result, better choice of grout and possibility to develop better (cement) grout.

The requirements to utilize the values of the project are access to developed equipment (grouting rig) and trained crew. The results from the project can be implemented short after TRUST has finished.

Some of the comments from the workshop were:

- Optimizing the grouting process – reducing time and cost, including maintenance. Safety – Water so important => better durability gives better safety. The optimization is also important from an environmental point of view. Sustainable grouting.
- But do we need to grout? To predict grouting needs is as important as being good at doing it.
- Other threats (against cement based technique)? – Other chemicals.
- Clients should be more interested to predict the grouting.

- Final vision is that the rig helps the operator to perform the grouting. For example indicate hydraulic fracturing. The crew should not need very extensive training.
- There are connections between 2.4 and 3.3. For example hydrogeological characterization and the site and chemical interaction between cement and water.

Project 4.1: Development of methodologies for rational and fast evaluation of geotechnical investigations

The project will develop methods and tools to store, visualize and reduce uncertainties of geotechnical data and to optimize geotechnical test programs. The result of the project are anticipated to be

- Geo BIM with a visualization modulus through all project phases
- Visualize uncertainties
- Reduce uncertainties by the combination of test methods
- Optimization of test program at every single stage

The values of the Geo BIM module will provide a fast and more objective evaluation of soil and rock properties and the associated uncertainties. The visualization module will improve the communication between the client, consultants, contractors, authorities, politicians etc. To be able to turn and twist, turn on and off, color code uncertainties … in a 3D-world is enormously powerful.

Requirement are that we get sufficient amount of data from one large infrastructure project in order to test and develop Geo-BIM with all occurring types of data (geotechnical, cores, geophysics, production data, blasting etc.). The results from the project can be implemented ? after TRUST has finished.

Some of the comments from the workshop were:

- The first conceptual model don´t have to be perfect but a better model would gain a lot. We are getting into more and more complex areas (urban, contaminants…)
- A combination of 2D/3D methods (geophysics) and sampling and sounding is optimum
- You need to visualize the right kind of data for different purposes and actors – design, politicians, other type of engineers
- Data keeping necessary in a LCC perspective. Who should maintain the data gained in a project?
- Are the identified values useful?
    - Estimated cost saving ~5% of production cost in Norway, due to better communication, clash detection
    - Missing As built documentation costs a lot of money
    - Could improve the tender document
- Who is taking over data after the project is finished?

- Obstacle? Developing of existing commercial software may cause legal problems using it as "freeware"
- Other values that were identified: Tool for data analysis that can be implemented in the visualization programs, the optimization of site investigation program is also a tool for planning, how can it be used for reliability based design (3.2)

Project 4.2: Integrated Use and Interpretation of Data from Geophysical and Non-Geophysical Methods for Site Investigation for Underground Construction

The project deals with the merging of data from several methods measuring different physical properties with different resolution characteristics into a comprehensive model of the primary sought properties. The results of the project are:

- Methods for joint interpretation of different geophysical and non-geophysical data via joint inversion and cluster analysis, for realistic conditions with topography integrated.
- Methodology for analysis and presentation of reliability in models
- Prediction of rock mechanical parameters (E.g. water leakage and rock stability, based on geophysical data combined with other data)

The results are going to be disseminated to authorities, industry and academy and integrated with the result from other TRUST sub-projects. The values from the project are believed to be better quality of site investigation results at an affordable cost and lower quotations thanks to better tender documents and reduced risk premiums. Reduced environmental disturbances thanks to better engineering geological model and competence building and networking between academy and industry opens new possibilities for cooperation are also believed to be values of the project.

Access to software plus knowledge to carry out integrated interpretation is needed as well as new technology used for interpretation of site investigation data. We also need to develop new methods for linking geophysical and primary parameters and finally access to competence to make use of the results and interpret it in the organizations involved.

Prototype software will be available before the project ends. The step from prototype to commercially available is expected to be medium (depending on if resources are allocated). Further test and demonstration probably required before full acceptance in the industry

Some of the comments from the workshop were:

- How can we calibrate indirect- and direct measurement?
- What are the relevant rock mechanics parameters?
- How can we reduce uncertainty?
- How can we improve rock unit characterization?
- We need to be quantify better quality of site investigation

DISCUSSION

The different projects in TRUST with the exception of TRUST 1 –management have results that can be exploited as innovations sorted in three different categories:

- The result from TRUST 2.1, TRUST 2.2 and TRUST 3.3 can all be encapsulated in technology innovations – surveying geophysical instruments, 2.1 and 2.2, or grouting rigs as in 3.3. However, the use of the product innovations require at the same time access to trained staff implicating that in order to introduce the technology to the market the innovation needs to be provided as a service. The key question for implementation is weather the new innovations really can provide better service and quality for the customer compared to traditional technologies and that these qualities (values) are requested and recognized by the customer (TRV). As it was commented at the workshop "Clients should be more interested to predict the grouting", "Better knowledge of possibilities needed among clients in order to ask for the right pre-investigation methods" and "Better quality of site investigation results at an affordable cost" needs to be quantified, i.e. "how much better" and what is "affordable".

- A value can also be utilized in the form of a law, policy or a standard. TRUST 2.4 and TRUST 3.2 are developing standards that can be applied by the owners/developers of underground facilities after the end of the project. Therefore the implementation "needs linkage to purchase & contractual aspects of the underground construction project". The client (TRV) needs to require the design according to the standard.

- The result of TRUST 4.1 and TRUST 4.2 have organizational implications. The Geo BIM consisting of object oriented 3D models can be used to predict performance metrics. Especially, gains in clarification of project objectives for stakeholders and resolving of coordination issues between different design disciplines can justify the investments in the design phase, "estimated saving ~5% of production cost". However, the commercial relationships between the many specialists involved must be resolved to encourage sharing of information between stakeholders in the projects. Therefore the implementation requires some incentive in the contract supporting collaboration and information sharing. In BIM supported building projects 3D models are often aggregated in digital mock-ups on a regular basis in a concurrent engineering design process.

Common implementation issues are:

- The client (TRV) is an important player in the implementation of the result in all projects. The client needs to require the use of the method, standard or technology or procure the construction project to facilitate the implementation and use of the specific innovation.

- The main driver for researchers in many of the research projects is the academic values, i.e. Scientific publications, PhD examinations, research network, etc. Hence, other (industry) partners need to be involved that will make use of the result and take the innovation to the market.

- Many of the projects can strengthen each order and some project can use the result from other project as input. Therefore a requirement is that the same test site is used in order to find interaction and synergies between different projects in TRUST.

Finally, one feedback from the workshop was the more time should have been available to “to really go in depth”. Future group work like this should allow participants to elaborate more and allow the different projects to reflect and clarify the different views.

APPENDIX 1 – WORKSHOP NOTES

Group 1

General

Why do we investigate at all? What are we looking for? (GE)

What info should you tell who, and when?

Who is taking over data after project is finished.

Reflection: How many of the researchers know about the different stages? (MS)

The good things you produce – SHARE IT, earn the money on being best to use it

Communicate the risk in an understandable and priceable way

Should we connect contract issues with TRUST projects?

Do we spend the money in the right stages?

We must never forget the purpose why we are doing things

Which are the important things to know? – Ultimate state, Servicability state (Brott, bruksgräns)

More project specific discussion

Trust 2.2

Have we forgot refraction seismic in TRUST?

- We get the data for that in TRUST 2.2. (AM)

Better knowledge about available possibilities needed among clients in order to do the right preinvestigation methods

We must be better at marketing

Instead of require methods – tell us What to be answered.

Trust 2.4

More values? – Explosives could be more highlighted as affecting the boundary conditions.

Link between geochemical properties and geophysical properties – combine 2.4 and 2.1/2.2?

Any obstacle to harvest? It is a matter of marketing, communication…

Trust 3.3 Developing tool/machine for predicting grout length

Important for us: 1. Improved knowledge must be used in industry – reducing time and cost, including maintenance. 2. Safety – Water so important => better durability gives better safety 3. Time – Result can be used right after finished project. All is about communication.

But do we need to grout? (GE)

- How to predict grouting need is as important as being good at doing it.

What are the threats (against your cement based technique)? – Other chemicals (with a much higher environmental impact).

Clients should be more interested to predict the grouting.

Trust 4.1 Geo- BIM

The first conceptual model don´t have to be perfect but a better model would gain a lot. We are getting into more and more complex areas (urban, contaminants…)

Too much data gets "too much". You need to use the right data at the right time. (SL)

A combination of 2D/3D methods (geophysics) and sampling and sounding is optimum (AM)

You need to use the right and very different data for different purposes – design, politicians, other type of engineers… - COMMUNICATION

Data keeping necessary in a LCC perspective. Who should maintain the data gained in a project?

Are the identified values useful?

- Cost saving…5% in Norway, communication, know the quality
- Missing As built documentation costs a lot of money
- Could improve the tender document

What info should you tell who, and when?

Who is taking over data after project is finished.

Obstacle? Developing an existing commercial software may cause legal problems using it as "freeware" (small risk)

Group 2

TRUST 1.0

The projects should be tested at one site. It would be easier to make interactions between the projects then. Important to find synergies and how to make it happens on the operational level.

TRUST 2.2

Goals high (vision) with realistic background. It would be a success if 50 % could be reached.

Values are site dependent. Testing needed for each site to be able to derive the correct parameters.

Specialized operators needed.

Start of a research phase. Not clear how it can be applied.

Researchers (theoretical) need to meet industry (practical) somewhere half way. Find out what can be used commercially and give important results for the society. Optimize method for industrial purposes.

TRUST 2.4
Numerical flow and chemistry models used to predict the chemical environment around the tunnel and also the environment impact.

Model should be the tool for setting the standards for the materials to be used for the construction.

Requirement. Important to have base chemistry data and follow it through the construction and maintenance phase. Follow sites in different geological environments. Hydrogeological model. Requirements on the water sampling process.

Should reduce the maintenance costs by choosing the correct material in the first place. Specific corrosion protection, long time behavior of shotcrete and grout.

TRUST 3.3
Calculate and follow the penetration of the grout in the fracture. Objective to be able to stop the grouting when the penetration length is reached. Stop using grouting time, stop pressures etc. as markers.

Optimizing the grouting process, saving time? and material. At least the result of the grouting will be more reliable estimated. The optimization is also important from an environmental point of view. Sustainable grouting.

Final vision is that the rig helps the operator to perform the grouting. For example indicate hydraulic fracturing. The crew should not need very extensive training.

There are connections between 2.4 and 3.3. For example hydrogeological characterization and the site and chemical interaction between cement and water.

Group 3

TRUST project	Results	‘	Construction stage, for who	Requirement, condition	Time horizon
2.1	Is it possible to quantify how much better	Direct value – and quantitative New equipment New codes			
4.2		Calibrating indirect- and direct measurement Determining the relevant rock mechanics parameters			

		Reducing uncertainity Improve rock unit characterization			
3.2		The full value of the project needs linkage to purchase & contract aspects			
1		If you has a success with approach, better universities to compete about large contracts. More joint papers. PhD students get exposed to future emplyers Cooperation will glue the small islands together			

Interaction between projects. Find synergies. Make it happen on operational level.

Group 4

TRUST 2.1. Geoelectrics, IP

Results.
When you say better. Quantify. Give it a number. Where do you have substantial possibilities. Way to find out where we have the real big values.
Consultants wants to be better, see risks, suggests, we can fill in the gaps. We can produce better prediction of this parameter. More specific. Fill in gap for water, parameter.
Express like 3-times more information for the same cost in terms of …
The question, what more do you need. TRUST, the project is related to 4.2. You need additional information to put parameters. Coupled to parameter.
AH, methods, most geophysics within geophysics developed. THE INTEGRATION NEEDED. DIFFERENT MAPS, GEOTECHNICAL REPT, GEOLOGICAL MAP. MUCH ISOLATED.
RC, PROVOCATIVE QUESTION, the equipment get better. How you tackle noice in the project.
SJ, Noise handling
LP, Urban environments. Major problem, electrical properties meet problems. Existing infrastructure. Goal to handle railway noises. Structure induction difficult to model. Hard to deal with. Serious problem.
AH, Geophysicist. Does not mean not much. More valuable result would be to make geophysics understandable.
MH, black box. When to use it, how to interpret and what is the box.
RC, Nothing until the data has been calibrated with in situ data. When does this advance geophysical methods have a hreak-through in the projects.
Innovation is not successful until it is implemented. How to get it from research into consultant. How do you sell it.
IK, is it R&D, improving of existing things.
LP, 3D application not used before. IP parameter has great focus, more difficult to measure in urban environment. Information how to handle these things.
RC, Norway. Site investigations in Norway. Planned.
AH, getting better. More used. Not always right but mostly. Partially urban. What is the resolution. Difficult to communicate. What exact question do you need to control. Bedrock under clay, ground water flow.
MA; finding
AH, how to IP and resistivity measurement handbook fr Swedish problems.
MH, tunnel. Bedrock quality. Combining methods. Limitations. Accuracy, write simple. Create a trigger to talk to geophysics. ETH, Switzerland, geology, problem, limitations,. What is there.

LP, uncertainities, combine uncertainity with scale. Small scale, large uncertainity. Big scale, smaller uncertainity.
MH, Scale seldom discussed.
RC, heared about the table. User value. Highlight more geophysical method. Time horizon is medium, long
MA; contaminated grounds.
RC, calibration
MA,

RC, 3.2 Design parameters. How much geophysical data can be trabsfered to design parameters.
FJ, not good in geophysics, joint persistence, young modulus. Etc.
PL, seismic methods may have portential.
RC, dynamic and static. Geophysics. Screen large areas, Sceen large areas. Help to develop a conceptual model of a site. Do core sampling, do testing.
AH, not so difficult to challenge. Academic challenge.
RC, bh information what is needed to support seisics.

IK, mentioned, Norway, cost effect of new way of designing, new 3D models and BIM. Road authorities, more eager in measuring what happens. Nine categories of change, what is changing on site. Try to find where are the problems now. Wait for problem with not knowing where the rock is. Any way. Can TRUST go into real life projects. Can be related to lack of investigations.
There is a project on grouting, take running on real. 2.2 has plans to carry on going measurements. Changed order, real money from . Build up motivation.
David.

<u>3.2 Eurocode</u>

When is it suitable to use reliability based design.
Improved design guidelines, which conditions, which failure modes.
Interpretation. Rock has fewer samples, other uncertainity. Joint percistence. Not included in the classification systems
MA, getting the right parameters,.
GG, improved design guidelines, own guidelines. TRV has “projekteringshandbok”
MH, not a table. Guidelines.
How will you improve the desgn guidelines.
FJ, depends of the results. We do not know when to sue it. The observational method, Eurocode says the acceptebla limits of the technical construction. Risk that the behavior will be different.
MH, something else, normal reliability has to trust on a lot of data. You will not get realistic data. Own, you do not actually not need. Similar projects. Q_system, rock support chart. Try to fond out what is the most important parameter. Not site specific. When you are uncertain of the conditions.
MA, TRUST, Aiming at
AH, 3.2, Q-value. Some relevant. Do you seek correlations between, next step looking at different factors. Which factor is relevant in. Which method for which site. Tunnel support, geophysics.
FJ,
MA,
IK, Important to look together at the same site, but different.
LP, using historical data? New data.
FJ, depend on failure mode. Shear strength of the joints is the critical parameter. In situ stresses. Someone will measure.
FJ, what needs do you see. Verification is very important. Bring it further away from just relying in empirical methods. Gold development & university of Alberta. Lats Jacobsson, spalling strength. Reliability in the design. You can always be conservative; required design method.

MH, Wedge-detection. 10-60 m rock cover. Fracture geometry and persistence. Normal mapping not accurate enough. Subjective.
LP, if using geophysics,
Norway.
Table values:

Table.
New design possibility in the tool box
How to implement it. What are the requirement. How well are we ready to implement it. Not so difficult from geophysical methods. Communication and education. Compute programs.
Implementation is that you have a client that request Eurocode.
Good enough, different point of view.
MA; stress
MH, management issue rather than technical challenge. Corporate memory. Model.

Trust 4.2,

Integrate data and use it over the entire project.
MH, purchase issues are not included in TRUST. Method of sharing risks is not important.
MA, MH, RC: looking into how to expand TRUST with these aspects. Avoid disputes.
Require good site investigation, data. Requires report. Promote writing geotechnical base lines.
Good enough, risk of loosing money.
Could you multiply all quantities with 5-6% more.
Payment form adaped to those ocnditions would be good. Biased risk sharing. Take too much risk to take the contract.

Trust 1

Read it two ways, risk to be. Intersting package. Many players. Diversion of funding. Several problem.

TRUST

TRANSPARENT UNDERGROUND STRUCTURE

Maria Ask & TRUST gruppen
31 augusti 2016
TRUST slutseminarium, Näringslivets hus, Stockholm

TRansparent Underground STructure

- Ett unikt infrastrukturprojekt ur svensk såväl som internationell synvinkel
- Utvecklar metoder och verktyg för undermarksbyggande i urban miljö med LCC-perspektiv
- Omfattar en stor del av den design- och byggtekniska processen för ett infrastruktur-projekt under mark
- Första integrerade samarbetet mellan forskare från Chalmers*, KTH*, LTU*, LU*, Uppsala universitet och specialister från branschen & myndigheter
- TRUST gruppen >40 personer (10 doktorander, 3 postdoks, 20-tal seniorer, 10-tal specialister)
- Projektbudget >70 MSEK från 2012 – 2017/8

*SBU, Sveriges bygguniversitet

Sveriges Bygguniversitet

TRUST
TRANSPARENT UNDERGROUND STRUCTURE

Bakgrund

GEOINFRAUTLYSNINGEN (3 september 2012)

- Mång- och tvärvetenskapligt angreppssätt
- Hållbart- och urbant underjordsbyggande

TRUST

- Existerande nationella nätverk
  - Sveriges bygguniversitet (SBU)
  - Svenska djupborrprogrammet (SDDP)
- Planeringsmöten
  - SBU Townhall meeting, EUROCK 2012 (28 maj)
  - IQ Samhällsbyggnad match-making (7 juni)
  - Tema Geo-möte, SBUs Högskolekonferens (23-24 augusti)
- ENGAGEMANG FRÅN INDUSTRIN
  - Näringslivets industriråd gav feedback på projektidéer till Geoinfrautlysningen (sommaren 2012)

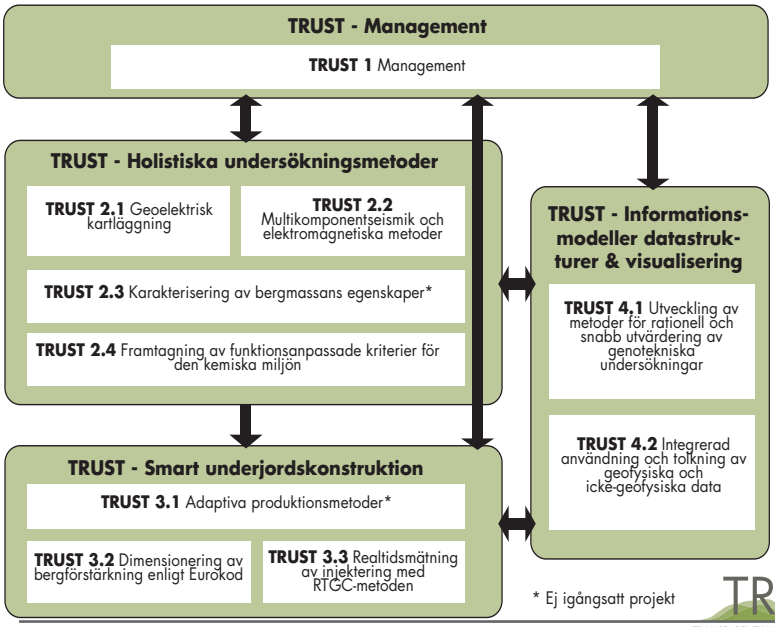
Town Hall Meeting for
Theme Geotechnology of the
Swedish Universities of the Built Environment
Monday, 28 May 2012, 18:30-19:30
Elite Hotel Marina Tower
Room: Prins Eugene
Reception, meeting, and Q&A

Welcome: *Maria Ask, leader, Theme Geotechnology*
SBU information: *Anna Kadefors, Coordinator, SBU*
Theme Geotechnology information: *Maria Ask*
New call GeoInfra: *Peter Lundman, Trafikverket*
Research strengths & ideas: *SBU, other universities*
- *Chalmers, Lars O. Ericsson*
- *KTH, Fredrik Johansson*
- *LTH, Peter Ulriksen*
- *LTU, Maria Ask*
- *Uppsala University, Alireza Mahlemir*

Upcoming activities & Closure: *Maria Ask*
Q&A

CHALMERS

TRUST
TRANSPARENT UNDERGROUND STRUCTURE



* Ej igångsatt projekt

TRUST
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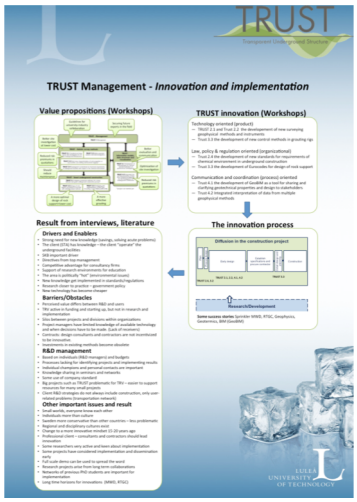
TRUST 1 – Management



SYFTE

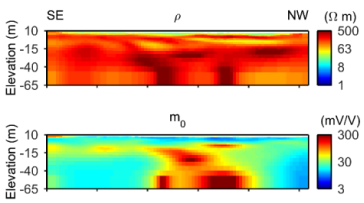
- Samordna delprojekten och kommunicera resultaten
- Innovation och implementering (främja kreativ samverkan och nyttiggörande)

POSTER

- *TRUST Management - Innovation and implementation*

Kontakt: Maria Ask, maria.ask@ltu.se

TRUST 2.1 – Geoelektrisk kartläggning



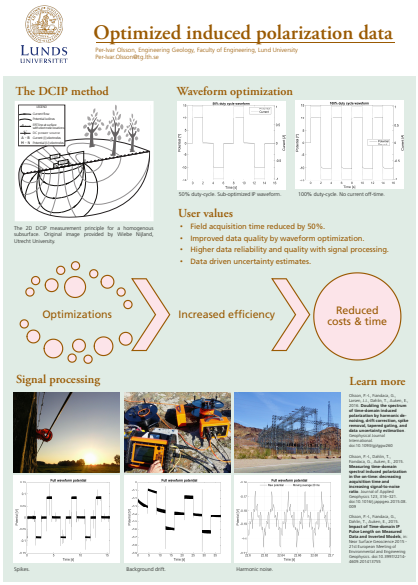
SYFTE

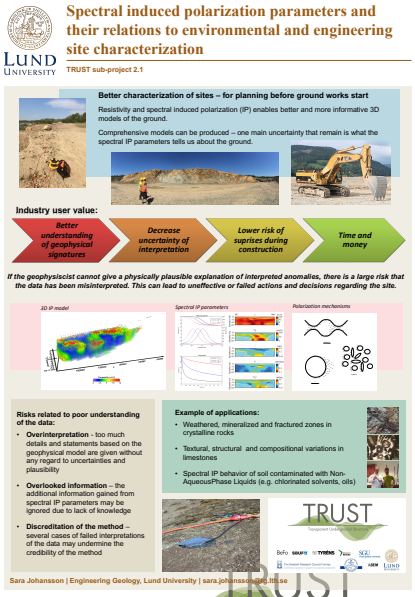
- Att anpassa geoelektriska undersökningar för urbana miljöer

POSTERS

- *Optimized induced polarization data*
- *Spectral induced polarization parameters and their relations to environmental and engineering site characterization*

Kontakt: Torleif Dahlin, torleif.dahlin@tg.lth.se





Kontakt: Torleif Dahlin, torleif.dahlin@tg.lth.se

TRANSPARENT UNDERGROUND STRUCTURE

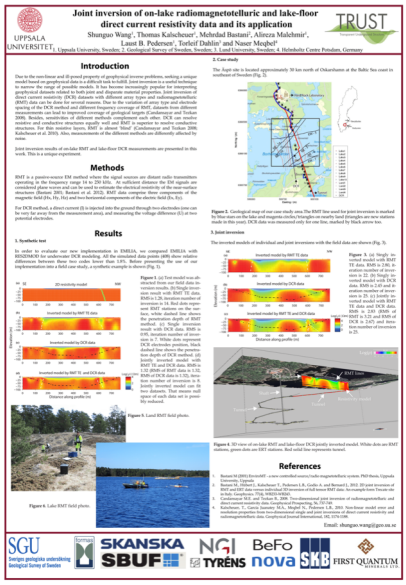
TRUST 2.2 – Multikomponentseismik & elektromagnetiska metoder

SYFTE

- Att utveckla mätmetoderna multi-komponentseismik och radiomagneto-tellurik (RMT) i urbana områden

POSTERS

- Joint inversion of on-lake RMT and lake-floor direct current resistivity data and its application
- Shallow water RMT measurement in urban environment
- Multicomponent broadband digital-based seismic landstreamer for urban infrastructure planning



Kontakt: Alireza Malehmir, alireza.malehmir@geo.uu.se

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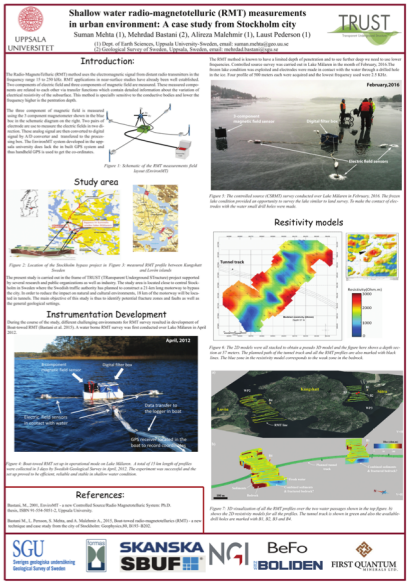

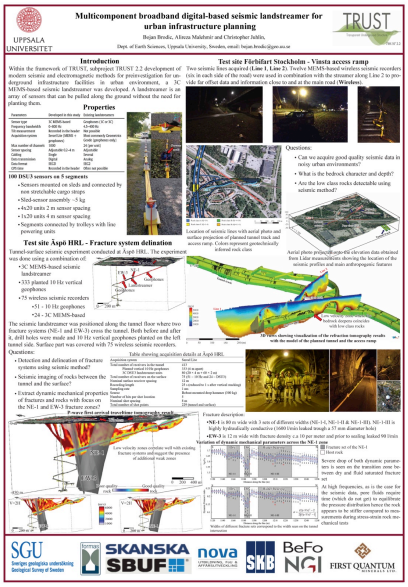

Kontakt: Alireza Malehmir, alireza.malehmir@geo.uu.se

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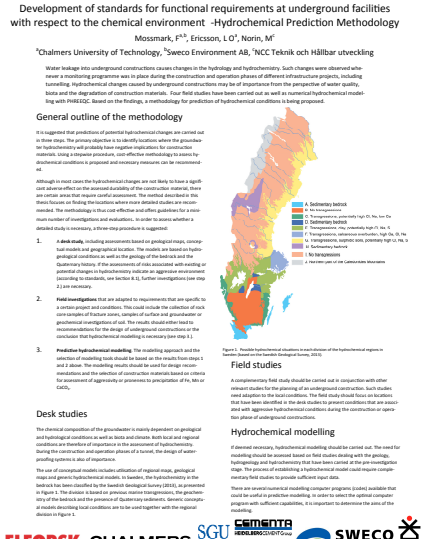


TRUST 2.4 – Framtagning av funktionsanpassade kriterier för den kemiska miljön

SYFTE

- Att vidareutveckla standarder för att uppfylla funktionella krav på underjordsanläggningar med avseende på den kemiska miljön

POSTERS

- *Development of standards for functional requirements…*

Kontakt: Lars Ericsson, lars.o.ericsson@chalmers.se

TRUST

TRANSPARENT UNDERGROUND STRUCTURE

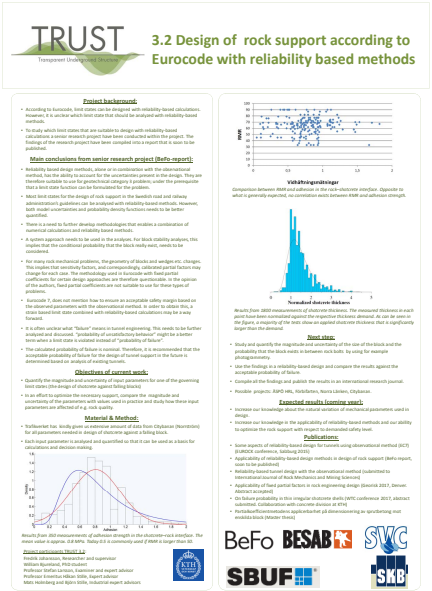
TRUST 3.2 – Dimensionering av bergförstärkning enligt Eurokod

SYFTE

- Minska osäkerheterna vid geoteknisk och bergmekanisk dimensionering m.h.a. tillförlitlighetsbaserade metoder

POSTER

- *Design of rock support according to Eurocode with reliability based methods*



Kontakt: Fredrik Johansson, fredrik.johansson@byv.kth.se

TRANSPARENT UNDERGROUND STRUCTURE

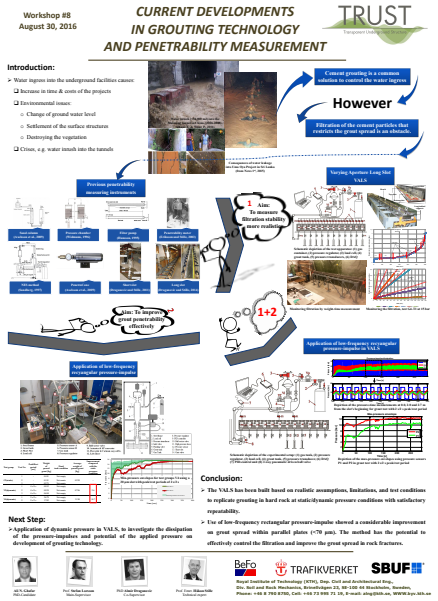
TRUST 3.3 – Realtidsmätning av injektering med RTGC*–metoden

SYFTE

- Att studera injekteringsmedlens inträngningsförmåga och verkliga spridning

POSTER

- *Current developments in grouting technology and penetrability measurements*



Kontakt: Almir Draganovic, almir.draganovic@byv.kth.se

*RTGC, Real-Time Grouting Control

TRANSPARENT UNDERGROUND STRUCTURE

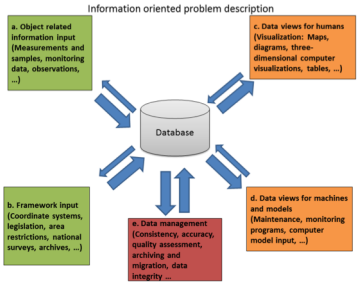
TRUST 4.1 – Integrerad användning och tolkning av geofysiska &icke geofysiska data

SYFTE

- Verktyg för kvalitetssäkring (multivariatanalys av geodata)
- Databas för att visualisera geomodell (2D, 3D)
- Visualiseringsverktyg för tolknings- och kommunikationsändamål av/med olika användare/brukare

POSTERS

- *How to use the GeoBIM concept*
- *Multivariate assessment of geotechnical parameters – A foundation for reliability based design*



Kontakt: Stefan Larsson, Stefan.Larsson@byv.kth.se

TRUST
TRANSPARENT UNDERGROUND STRUCTURE

TYRÉNS TRUST

How to use the GeoBIM concept

Mats Svensson, PhD, Tyréns AB

The fundamental idea of the GeoBIM concept is to supply a database that can store ALL georelated data which is used in an urban underground infrastructure project. The data can then be exported for use in further applications in the infrastructure design and building process, using standard softwares.

Stages in the infrastructure process
- Planning and field work
- **Data storage** (in project)
- **Geo modelling**
- Design - road, railway
- Visualization
- **Uncertainty modelling**
- Data archiving (lifecycle, maintenance)

Data storage
All data produced is imported to the GeoBIM database via certain script
- For full QA and source control a number of meta data is compulsory - date, XYZ coordinates, coordinate and levelling system, engineer, company etc

GeoBIM database Östlänken project, OLP4, TRV
- 1246 investigations (August 2016)
- 37 Geotechnical methods available
- 7 Geophysical methods available

Geo modelling
- Choose your data for a certain application, i.e. Jb2, refraction seismics and core drilling for bedrock modelling
- Via the Export function chosen data is exported to applicable modelling software (i.e. Micromine, GoCAD)
- After interpretation the model is further exported to the road och railway design software, i.e. Civil3D, Microstation, Novapoint

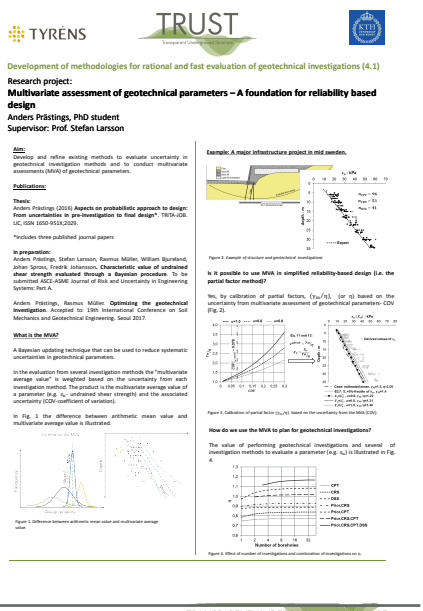
Examples of different data sets combined in different geo modelling softwares, ready for interpretation
- Seismics and RMT in Åspö HRL
- Jb2, resistivity and geological mapping in Varberg railway tunnel
- Rock cores and laboratory uniaxial tests, Helsingborg railway tunnel

Uncertainty modelling
- All data in the database and intepreted data/surface/model has an uncertainty value (still to be implemented)
- Data and uncertainties are exported for uncertainty modelling and reliability based design in certain softwares (see TRUST 3.2, 4.1 Anders P)

Example of how uncertainties can be applied to different geotechnical Parameters, and connected to the data in the GeoBIM database (Anders P, TRUST 4.1)

Example of uncertainty model applied to interpreted bedrock surface. The uncertainty model can be calculated, among other parameters, by using the uncertainties given to each data point in the GeoBIM database.

(This part is still to be implemented)



TYRÉNS TRUST

Development of methodologies for rational and fast evaluation of geotechnical investigations (4.1)

Research project:
Multivariate assessment of geotechnical parameters – A foundation for reliability based design
Anders Prästings, PhD student
Supervisor: Prof. Stefan Larsson

Aim:
Develop and refine existing methods to evaluate uncertainty in geotechnical investigation methods and to conduct multivariate assessments (MVA) of geotechnical parameters.

Publications:

Thesis:
Anders Prästings (2014) **Aspects on probabilistic approach to design: From uncertainties in pre-investigation to final design*.** TRITA-JOB. LIC, ISSN 1650-9514;2029.

*Includes three published journal papers

In preparation:
Anders Prästings, Stefan Larsson, Rasmus Müller, William Bjureland, Johan Spross, Fredrik Johansson, **Characteristic value of undrained shear strength evaluated through a Bayesian procedure**. To be submitted ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems: Part A.

Anders Prästings, Rasmus Müller. **Optimizing the geotechnical investigation**. Accepted to: 19th International Conference on Soil Mechanics and Geotechnical Engineering. Seoul 2017.

What is the MVA?

A Bayesian updating technique that can be used to reduce systematic uncertainties in geotechnical parameters.

In the evaluation from several investigation methods the "multivariate average value" is weighted based on the uncertainty from each investigation method. The product is the multivariate average value of a parameter (e.g. s_u- undrained shear strength) and the associated uncertainty (COV-coefficient of variation).

In Fig. 1 the difference between arithmetic mean value and multivariate average value is illustrated.

Figure 1. Difference between arithmetic mean value and multivariate average value.

Example: A major infrastructure project in mid sweden.

Figure 2. *Example of structure and geotechnical investigations*

Is it possible to use MVA in simplified reliability-based design (i.e. the partial factor method?

Yes, by calibration of partial factors, (γ_{su}/η), (or η) based on the uncertainty from multivariate assessment of geotechnical parameters- COV (Fig. 2).

Figure 3. Calibration of partial factor (γ_{su}/η) based on the uncertainty from the MVA (COV).

How do we use the MVA to plan for geotechnical investigations?

The value of performing geotechnical investigations and several - of investigation methods to evaluate a parameter (e.g. s_u) is illustrated in Fig. 4.

Figure 4. Effect of number of investigations and combination of investigations on η.

TRANSPARENT UNDERGROUND STRUCTURE

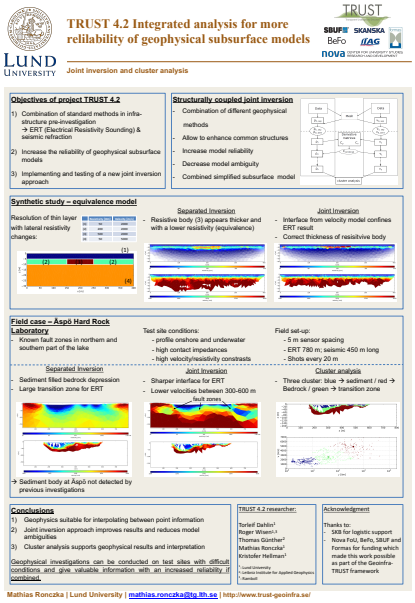
TRUST 4.2 – Integrerad användning & tolkning av geofysiska & icke geofysiska data

SYFTE

- Bygga en ingenjörsgeologisk modell med eftertraktade egenskaper genom att integrera data från flera olika fysikaliska mätmetoder där skala och upplösning varierar

POSTER

- *Integrated analysis for more relilability of geophysical subsurface models*



Kontakt: Torleif Dahlin, torleif.dahlin@tg.lth.se

TRANSPARENT UNDERGROUND STRUCTURE

Projektledning - en viktig del

FYSISKA MÖTEN

- Telefonmöte (33 st)
- Workshops (8 st)
- Workshops öppna (referens-gruppernas medlemmar, inbjudna talare)

VIRITUELLA MÖTESPLATSER

- Hemsida, www.trust-geoinfra.se
- Projektplattform (internt bruk)

TRUST

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Utmaningar

1. Gemensam fallstudie
2. Finansieringsaspekter
   - Två projekt har inte finansierats (2.3, 3.1)
   - Ett projekt startades senare än övriga
   - Vi underskattade omfattningen av projektledning
3. Implementera innovationstänk
   - TRUST-projekten
   - Organisationerna

Äspö HRL (SKB); Förbifart Stockholm (TRV), med flera

TRANSPARENT UNDERGROUND STRUCTURE

Förväntad användarnytta

TRUST WS#3

1. **60 deltagare**
2. **Varje projekt presenterade:**
   - *förväntade resultat*
   - *upplevd användarnytta*
   - *skede i livscykeln*
   - *förväntad tidshorisont*
3. **Gruppdiskussioner**

TEKNISKA INNOVATIONER (2.1, 2.2, 3.3)

- Kräver utbildad personal
- Erbjuder en service
- Leder till innovationen till bättre service & kvalitet?
- Behöver kunden detta?

POLICIES, STANDARDS (2.4, 3.2).

- Implementering behöver kopplas till upphandling& kontraktsaspekter i projektet
- Kunden måste anpassa designen till en standard

ORGANISATORISKA KONSEKVENSER (4.1, 4.2)

- GeoBIM kan användas för att prediktera performance metrics.
- Viktigt att dela data (även mellan konkurrenter)

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Presterad användarnytta så här långt

TEKNISKA INNOVATIONER

- Införande av ny teknik
- Förbättrad datakvalitet
- Effektiviserade mätmetoder

POLICIES, STANDARDS, PROCESSER

- Vattenkvalitet
- Injektering
- Databaser (GeoBIM)

SPIN-OFFS

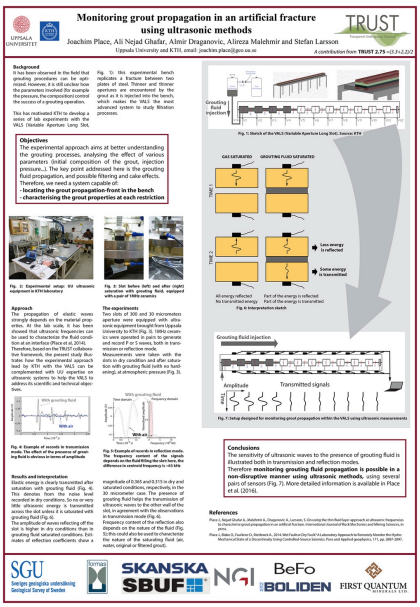
- Utveckling av nya projekt (vetenskapliga & tillämpade)
  - TRUST-medlemmar
  - Referensgruppmedlemmar (t.ex. Andreas Pfaffhuber, NGI; Robert Sturk, SKANSKA)
- Utveckling av nätverk (speciellt bland doktorander & yngre forskare)

TRUST
TRANSPARENT UNDERGROUND STRUCTURE

Spinoffs

Science-driven spin-off projects	Responsible
Grout spread detection using ultrasonic frequencies	Joachim Place (UU), Ali Nejad Gahfar (KTH)
Kombinerade undersökningsmetoder vid undermarksbyggande - övervakning av vattenkvalitetsförändringar med geoelektrik	Charlotte Sparrenbom (LU), Malin Norin (NCC) & Fredrik Mossmark (SWECO)
MIRACHL (Formas Hållbar samhällsbyggande)	Torleif Dahlin & Charlotta Sparrenbom (LU), Mats Svensson (Tyréns AB), Esben Auken (ÅU),
Bergkaraktärisering i 3D i Dalby stenbrott	Torleif Dahlin, Sara Johansson, Per-Ivar Olsson, Leif Johansson (LU)

TRUST
TRANSPARENT UNDERGROUND STRUCTURE



Monitoring grout propagation in an artificial fracture using ultrasonic methods

Joachim Place, Ali Nejad Ghafar, Almir Draganovic, Alireza Malehmir and Stefan Larsson

Uppsala University and KTH, email: joachim.place@geo.uu.se

A contribution from TRUST 2.75 v1.1+2.2/2

TRUST

TRANSPARENT UNDERGROUND STRUCTURE

Implementation-driven spin-off projects	Responsible
Kristianstad – Färgaren – TRUST 2.1	Alireza Malehmir
Varberg - TRV/Tyréns AB	Torleif Dahlin Alireza Malehmir Mats Svensson
Östlig förbindelsen - TRV	Torleif Dahlin
Oslo –tunneling- Statens veivesen (Andreas Pfaffhuber, NGI)	Alireza Malehmir
Siilijärvi open pit mine, Finland – Yara Oy	Alireza Malehmir
Turku water management project – GTK/University of Turku	Alireza Malehmir
Dalby – SKANSKA (Robert Sturk)	Torleif Dahlin Alireza Malehmir
Ostlänken – TRV/Tyréns AB	Mats Svensson

TRUST

TRANSPARENT UNDERGROUND STRUCTURE

Slutord

- Ny modell för samarbete
  - SBU + UU
  - Industri
  - Myndigheter
- Korta tiden för att demonstrera & implementera nya metoder & standards
- Kompetensförsörjare
  - 10 doktorander
  - 13 MSc
  - 4 BSc
- Nätverksbyggare
- FoU-plattform för framtida forskning, utveckling och demonstration