Annex 1. The Master Course Program

The Program

The modules in italics are mainly devoted to engineering and construction aspects and could be included if the initiative will be jointly developed with and by ITA.
The third column reports the name of the partner institution which was in charge of the teaching activity in the TRUE Project.

Unit	Basic Module	
A1	**Analysis of current use of subsurface utilisation** 1. Introduction 2. Analysis of examples applications 3. Advantages and disadvantages of underground space 4. Benefits and drawbacks of underground facilities	DIGET, POLITO Torino
A2	**Different uses of underground spaces in cities** 1. Underground space in infrastructures services Fresh water supply, waste water services, energy management, multipurpose tunnel, underground waste disposal 2. Underground space for working people Transport, civil defence shelters, storage facilities, industrial and laboratory facilities 3. Underground space for leisure Sporting and recreational space, tourism and culture 4. Modelling and representation of underground environment	HUT, Helsinki
A3	**Benefits and drawbacks of underground facilities** 1. Multi-criteria evaluation methods Introduction, standardisation, quantitative methods, qualitative methods, mixed data methods, literature 2. Practical multi-criteria decision methods Introduction, the decision process, the Analytical Hierarchy Process, a structured decision process, literature 3. Choice of high speed rain route in The Netherlands Introduction, general information, criteria for evaluating alternative solutions, alternative routes, annexes 4. Exercises Multi-criteria evaluations, Using multi-criteria DSS (Basics), Using multi-criteria DSS (Real-World problems), Working with GIS info, using GIS for spatial analysis, choice of high speed rain route	TUE, Eindhoven
A4	**The underground city** 1. City planning: aims and methods Underground city planning: an old idea, Underground city planning: impossible?, Case studies and Annexes 2. Underground ownership: various cases and consequences, costs and value of underground, price formation, future trends Underground utilisation: ownership and management 3. The role of networks in cities Historical approach, the networked city: *réseautique*, Co-ordination Drinking water and sewer systems: contemporary problems 4. Transport: from walking to driving Demand: the growth of mobility, supply. various modes	IFU, Paris

	Problems and solutions: main problems, transport policies Underground utilisation: the pros and cons public transport, parking, roads Effect of transport systems on urbanisation 5. Underground for pedestrians Public facilities Housing 6. Underground cities Conclusions	
A5	**People in underground** *1. The image and the perception of the underground space* The image of underground in the historical, cultural and social background The psychological and physiological effects in underground The orientation and the perception of an underground space 2. ***Identification and classification of subspaces and functions*** Typologies of spaces Specific spaces Analysis of different underground “subspaces The entrances The halls The corridors 3. ***Architectural elements in interior design*** Light in underground space Colours in underground space Sign and information system Materials Commerce and advertising Ventilation grills 4 ***The global project approach*** The art in underground spaces The quality of a public building Architectural programming Guidelines ***Bibliography***	DENER, POLITO Torino
B1.1	*General concepts linked with static underground design criteria*	*DIGET, POLITO Torino*
B1.2	**General geometric settings and construction for urban and no urban sites** The influence and quality of the preliminary investigations on the planning of underground works. An outline of regulative aspects and contractual approaches. Innovation of underground construction in urban area.	DIGET, POLITO Torino
B1.3	**Tunnel adits architectural and design aspects** Influence of geotechnical characteristics on tunnel portals design. Portals in rock masses Tunnel portals in ground Flow chart for tunnel portal design	DIGET, POLITO Torino
B1.4	**Detailed analysis of significant examples to construction and design aspects** Design, monitoring and construction of large tunnels in complex geological formations: Italian examples (Serena Railway tunnel, Avise Motorway Tunnel, Voltri Railway Tunnel).	DIGET, POLITO Torino
B2.1	**Reuse of underground mines and underground waste disposal** Main Aspects of Mine Reuse Design Relevant Examples of Reuse of Mine Openings (mines reused as mining museums, mines reused for civil applications, mines reused	DIGET, POLITO Torino

	for storage of goods, mines reused for disposal of wastes, mines reused for experimental laboratories and research facilities). New underground usages: problems and projections	
B2.2	**Design of an underground room pillar mine for civil purpose** Introduction Reuse design important aspects Rock mechanics stability aspects Conclusions	DIGET, POLITO Torino
B2.3	*Methods for excavation*	*DIGET, POLITO Torino*
B2.4	*Support techniques*	*DIGET, POLITO Torino*
B2.5	Risk analysis for an underground construction	*DIGET, POLITO Torino*
B2.6	*Numerical design method*	*DIGET, POLITO Torino*
	Geological and structural features of underground excavations	
B3.1	**Detailed analysis of significant examples with special reference to construction and design criteria** The underground tube in Stockholm (Larger population – longer trains). Subway stations: dark and dull under the surface. The world's longest art exhibit). A full-bored waste water tunnel in Stockholm (Technical data of the tunnel). A tunnel for water supply in southern Sweden.	*KTH, Stockholm*
B3.2	*Geoinvestigations*	*KTH, Stockholm*
B3.3	*Rock and soil classifications*	*KTH, Stockholm*
B3.4	*Main geotechnical aspects influencing underground works.*	*KTH, Stockholm*
B3.5	*Hydrological aspects*	*KTH, Stockholm*
B3.6	*Chemical aspects*	*KTH, Stockholm*
B3.7	*Monitoring systems and underground constructions.*	*KTH, Stockholm*
B3.8	**Design of underground nuclear waste repositories: analyses of key points.** Nuclear power: principles. Different disposal of radioactive wastes. The Nordic concept for the storage of low and intermediate level radioactive wastes. The Nordic concept for the storage of high-level radioactive wastes.	KTH, Stockholm
B3.9	**Environmental Impact Assessment** Introduction and principles. The purpose of environmental impact assessment. Historic development. International EIA regulations and conventions. EC directive 85/337 The Espoo Convention. EIA process Screening – is an EIA needed? Scoping. Alternatives Description of the project. Baseline studies Public participation Identification of key impacts. Prediction of the impacts Evaluation of significant impacts. Mitigation measures	KTH, Stockholm

	Presentation of the EIS. Review of the EIS Post-decision monitoring and auditing of predictions and mitigating measures. SEA	

	Specialisation Module	
C	**Risk analysis and safety in the operation of underground space** Analyzing methods used for products and systems (Preliminary Hazard Analysis; Potential hazards for Products; Failure Models and Effects Analysis - FMEA; Fault Tree Analysis - FTA; Event Tree Analysis - ETA; Cause and Consequence Form - CCF; Hazard and Operability Analysis – HAZOP; Operation Fault Analysis – OFA; Systematic Analysis of Wrong Operation Possibilities; Work Safety Analysis – WSA) Road tunnels Traffic safety in tunnels Accidents Tunnel lighting, Emergency Plans, Factors, interiors, interior, length, underground environment, windowless environment, window illusions, entrances, spaciousness, passages, lighting and colouring, …	HUT, Helsinki
D	**Planning of underground transport systems** Role and reason of tunnels Tunnel and transport systems (why to use tunnels, tunnels outside cities including transalpine and subsea, tunnels inside cities and to airports). Supply of underground space (geological supply, urban environment supply). Cavern architecture (uses of caverns, storage, rail stations, power plant, hotels, sport halls; shape of caverns, from general shape to minute details; why is there a taboo on wide spans?). Transport: main topics, main problems. Public transport (costs and advantages of public transport, At or below ground level?) Underground roads	IFU, Paris
E	**Energy utility networks in urban underground** Historical development and current practice for networks and auxiliaries, general problems for underground networks in urban areas (Ancient World, 1800-900, 1900-…, underground urbanism) Network analysis (water cycle, natural gas, electricity, district heating and cooling, RSU management) Underground networks design and management in historical centres Typology, safety and reliability aspects. Cost analysis. Design and construction methods Multi – purpose tunnels	DENER, POLITO - Torino
F	*Mechanized tunnelling*	*DIGET, POLITO Torino*
G	*Organisation and management of a rock engineering project*	*HUT, Helsinki*
M	**Geographical Information System (GIS)** Introduction. (GIS as Information System, component and functions, users and applications) Data and databases (data collection and data storage, maps and spatial objects, databases and data structures) Data manipulations and analyses (data manipulations, selections methods, spatial analysis) Map presentation (map features, thematic maps) Case: high speed train	TUE, Eindhoven
N	*Application of design system for underground development*	*HUT, Helsinki*

O	*Underground constructions in fractured rocks*	*KTH, Stockholm*
P	***Environmental impacts of underground constructions*** *Impact of vibrations on environment (propagation of wave, blasting, piling, traffic, human perception of vibration.).* *Groundwater modelling (theoretical background)* *Modelling groundwater flow in fractured rock* *Method to predict groundwater flows into underground constructions in hard rocks.* *Objectives and delimitation. Background aspects, environmental problems, technical problem* *Materials and methods- Definitions* *A conceptual model of groundwater flows in underground construction* *Basic questions to be answered in a predicative study* *Classification of predication methods.* ***Qualitative methods*** *Evaluation of existing material* *Use of Remote Sensing images and aerial/satellite photo interpretation* *Outcrop and fracture mapping.* *Airborne and surface based geophysical investigations. Geochemical investigations. Geographic Information System GIS* *Other qualitative methods* *Relation between groundwater inflows and the local rock stress conditions Hydraulic and in-hole investigations.* *Mathematical methods and numerical models* *Impact on groundwater conditions by tunnelling* *Objectives and delimitations.* *Documented environmental effects of tunnelling* *Influence from tunnels on the groundwater balance* *Measures against environmental impact of tunnelling* *Discussion and conclusions* *Underground constructions- monitoring programs. Groundwater monitoring programs*	*KTH, Stockholm*

Annex II
Activities at the Laboratory of Mining and Environmental Technology in Lavrion (Greece)

I. The Laboratory of Mining and Environmental Technology [1]

The Laboratory of Mining & Environmental Technology (LMET) was established in the School of Mining and Metallurgical Engineering (at the National Technical University of Athens - NTUA) in 1983. Professor Dimitris Kaliampakos is the current Director of LMET. The Laboratory of Mining and Environmental Technology (LMET) offers several under- and postgraduate courses, as well as diploma and PhD research opportunities. LMET has an extensive experience of more than 20 years in several fields, namely:

- New developments in underground construction. As urbanization is putting significant pressure on surface land, underground development is gaining ground. Many land-uses that were previously constructed solely on the surface are now being transferred in the subsurface. Research focuses on new methods that offer cost-effective solutions with minimal environmental impact and with minimum nuisance.
- The use of mining techniques in underground space development. Traditional mining techniques such as the “room and pillar method” and the excavation of large underground caverns are the basis of almost every underground construction. LMET has an extensive experience in the design of critical construction parameters of underground developments.
- Underground space ventilation. Usually natural ventilation is not adequate for underground facilities and the installation of an artificial ventilation system is necessary. Designing of such a system requires knowledge and experience as many factors need to be considered. Furthermore, one has to consider how the ventilation system would react in case of a fire incident. LMET uses specialized simulation software and has a vast experience in this field ranging from tunnel ventilation, underground space ventilation as well as dealing with fires in underground space.
- Safety issues and risk assessment and management. The proper operation of an underground facility requires a set of general guidelines, safety procedures and immediate actions both for the personnel and visitors in case of an emergency. Moreover, it is important to assess the risk of various activities in the underground space and produce specific management schemes. LMET was one of the major partners in the EU-funded “Low Risk Disposal Technology” project which aimed at the development of underground storage repositories for hazardous waste.
- The economics of the underground space. The comparison between a surface and an underground facility, based on the construction cost, penalizes the underground alternative. On the other hand, underground facilities offer low utilities and maintenance cost and, most importantly, lower environmental cost. LMET has consistently conducted research in these topics aiming to develop methodologies that estimate the value of underground space and using environmental economics to appraise the advantages of underground development.
- Virtual reality applications in underground space. Virtual reality and 3-D animation techniques are very often used in order to communicate novel ideas to non-experts. LMET has extensively used this technology, in every project, for over 10 years and has recently acquired cutting-edge stereo 3-D projection equipment.

Our proposal suggests the establishment, under the auspices of ACUUS, of a 3-day workshop, where the participants, with the contribution of experts, would receive an

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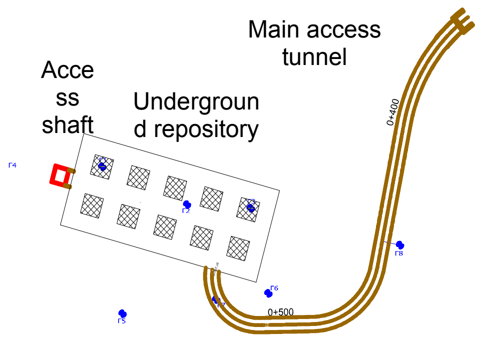
intensive course in selected subjects regarding underground development. The workshop could take place every two years, covering the time between consecutive ACUUS Conferences, and alternate between Italy and Greece.

II. The Lavrion Technological and Cultural Park

The Lavrion Technological and Cultural Park (LTCP) is located in the same area where the ancient Greeks started the underground exploitation of silver in 5th century BC. These deposits along with the ancient mining residues (off-grade ores) were further exploited for lead extraction from the 19th century until the early 90's. The complex bears a significant mining history and constitutes a unique monument of industrial archaeology. The effort for its restoration began in the past decade and it was decided to establish a science and cultural park in the area. Nevertheless, even if the building's restoration has progressed rapidly, land remediation only focused on the most critical areas so as to mitigate immediate risks. Most of the ground is covered with waste and slug materials, while the grade of the contamination varies, because of the successive transfer and deposition of the wastes that took place during the lifespan of the metallurgical plant.
Thus, solutions pursuing the rehabilitation of the contaminated land and the polluted buildings have been implemented for more than 10 years. The 7.5 MEuro project consists of the following constructions (all within the premises of the LTCP):

- a specially designed repository for the contaminated soils (approx. 3.5 MEuro)
- an underground repository of 2,000 m^2 for the hazardous wastes (approx. 2 MEuro)
- a state-of-the-art environmental laboratory that will monitor and support the restoration activities (approx. 1.5 MEuro).



The hazardous waste that will be deposited in the underground repository consists mainly of polluted materials, having unusually high concentrations of heavy metals and toxic metalloids, such as arsenic, lead, cadmium and zinc. The effective area of the repository is approximately 2,000 m^2 with a maximum capacity at about 5,000 tons of wastes.

Fig. 1. LTCP underground hazardous waste repository (a) general layout of the underground complex, (b) main area of the repository after the completion of the excavation works.

The construction is made within the marble formation between the levels of +12m and +17.5 m, and the development adopted the principles of the room-and-pillar mining method. In this manner the development of 7-m wide parallel and transverse galleries is made, leaving 7-m wide pillars of the host rock to support the opening, resulting to an overall mined space utilisation of more than 75%. The space of the facility is around 1,900 m^2 that was developed out of a total area of 2,475 m^2. Furthermore, a 10% steep tunnel is constructed for the waste transportation and

general access to the repository along with a 35 m deep shaft that will be used for safety reasons and for ventilation purposes.
The permeability of the host marble formation is an issue that mandates the implementation of an efficient engineering barrier system that would ensure the waste containment and mitigate impacts from possible major accidents to water and ground/soil system. The technical barriers adopted suggest the use of special shotcrete mixtures (ELKEM Microsilica 920 D) for the waterproofing of the roof and sidewalls of the complex, along with the installation of chemically resistant, impermeable, industrial flooring. The design standards, in particular, aimed at attaining a permeability coefficient in the roof and sidewalls in the order of 10^{-9} m/s. In addition, in case of emergency, where water infiltration occurs, special pumping units are installed so as to collect any polluted run-offs and thus block their diffusion to the water table. These measures, in addition to the special drums that are used for the waste storage, are capable of achieving the long-term safety of the underground repository.

III. Educational and Research activities in the Underground Facility of L.T.C.P.

The underground facility in LTCP could be used for various educational and research activities. In particular, we have the potential to develop a part of the facility into an underground research laboratory. Some indicative research fields are listed below:

- α Ventilation. Fire and smoke incidents, toxic gas leakage etc.
- α Monitoring systems – Automatic control systems. An integrated system involving sensors, loggers and transponders/actuators that will provide real time monitoring of certain environmental quality parameters and in case of emergency would trigger an alarm and isolate certain compartments of the underground facility.
- α Virtual reality applications. Production of educational VR material (interactive video, animations etc.) dealing with various aspects of the underground space. Installation of a Cave Automatic Virtual Environment (CAVE). The concept is to use this immersive virtual environment in order to familiarise the public with underground development and stimulate politicians and stakeholders interest in underground alternatives.