COVER LETTER

Title of the proposal: **TEMPUS: Temperature of urban surfaces assessed by the open-source software toolbox and multispectral satellite data**
The proposal is a resubmission: **NO**
If YES, enter title of initial proposal: **-**

From: ***Pavol Jozef Šafárik University in Košice***

Date: **February 11, 2019**

To: The EUROPEAN SPACE AGENCY (ESA)

The European Space Research and Technology Centre (ESTEC),
Keplerlaan 1,
2201 AZ Noordwijk,
The Netherlands

Att.: Ms Sandy Courtois (IPL-PTS)

Subject: ESA AO/1-9588/18/NL/SC
Invitation to Tender for the Fourth Call for Outline Proposals under the Plan for European Cooperating States (PECS) in Slovakia

Category: ESA Express Procurement Plus – EXPRO+

Our ref.: Proposal No. **1000024234**

Dear Madam,

With reference to the above Invitation to Tender (ITT), we are pleased to present this proposal:

1. The Tenderer (potential Contractor) is:
   Pavol Jozef Šafárik University in Košice, Šrobárova 2, 041 54 Košice, Slovakia

   Fax number: ***+421-55-6222124***
   Telephone: ***+421-55-2347601, +421-55-234-2591, +4215562 226 08***
   Nationality (according to ESA Convention's criteria): ***Slovak***
   VAT Number: ***2021157050***
   ESA Entity Code: ***1000017323***
   ESA Business Unit Number: ***8000013441***

Univerzita Pavla Jozefa Šafárika
v Košiciach
Šrobárova 2, 041 80 Košice

2. The entities participating in the activity and the price breakdown is indicated below:

Table 1: Bidding Team and Price Breakdown Information:

	Prime Contractor	**Sub-contractor 1**
Economic Operator Complete Name and Legal Nature [1]	Pavol Jozef Šafárik University in Košice (Public institution)	Slovak University of Technology in Bratislava (Public institution)
SME (indicate YES or NO)[2]	NO	NO
ESA Entity Code (10000xxxxx) [3]	1000017323	1000017322
ESA Business Unit number (80000xxxxxx)	8000013441	8000035316
Country (ISO Code)	SK	SVK
Firm Fixed Price	142,112	57,408
Currency	EUR	EUR
Total	142,112	57,408
TOTAL PRICE in Euros [4]	142,112	57,408

3. We hereby certify that the legal entities identified in sections 1 and 2 above fully satisfy the requirements, concerning eligibility to submit a tender, that are stated in Appendix 2 to the subject ITT (**"Tendering Conditions for Express Procurement Procedure" - EXPRO/TC**).

4. Our Firm Fixed Price for the activity in accordance with the funding conditions stated in the ITT, amounts to: ***199,520* Euro** all included with the sole exception of any import duties and value added taxes in the Agency's Member States.

5. The subject of the activity is: **Type b**.

6. The proposed contract duration is: ***24 months***.

7. The contact person of the Tenderer to whom all communications relating to this letter should be addressed is the following: ***Michal Gallay (Tel: +421-55-234-2453, e-mail: michal.gallay@upjs.sk).***

8. The contact person of the Tenderer responsible for the technical and contractual management of any resulting contract is as follows: ***Jaroslav Hofierka (tel: +421-55-234-2591, e-mail: jaroslav.hofierka@upjs.sk) for technical and contractual management***

9. With regard to the technical contents, we hereby declare that this Proposal is free from any plagiarism. When use is made of material being quotations or citations from existing public literature such use is clearly indicated and due reference indications (source and author) are provided.

10. We hereby state that we have read and understood all the terms and conditions of the Draft Contract

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[1] Specify here the type of business entity to which the company belongs (e.g Limited Company, Société Anonyme, AG etc)
[2] ESA endorses the definition of Micro, Small and Medium Enterprises provided by the European Commission in Recommendation 2003/361/EC of 6th May 2004 (OJ L 124.20.5.2003 p 36)
[3] The ESA Entity Code corresponds to the esa-p Vendor Code.
[4] Not higher than a) EURO 400.000 for Hardware activities, b) EURO 200.000 for research and development activities, b) EURO 150.000 for space applications, products and services c) EURO 75.000 for preparatory activities and d) EURO 50.000 for awareness and education activities.

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included in the subject ITT and that we accept the said terms and conditions without any reservations. We also confirm that any sales conditions of our own shall not apply.

11. Concerning the feasibility to export the deliverable items, of the resulting Contract as that is foreseen in the Draft Contract including its appendices, we hereby declare that we have examined the case and drawn the conclusion that there are no export restriction issues and thus no need to obtain specific licences or authorisations.

12. With regard to the required statements concerning free competition, we hereby certify that:
    a) the prices in this proposal have been arrived at independently without consultation, communication or agreement for the purpose of restricting competition;
    b) unless otherwise required by law, the prices quoted in this tender have not knowingly been disclosed, directly or indirectly, to any other Tenderer or competitor and likewise, will not be disclosed until we have been informed of the results of the ITT;
    c) no attempt has been made or will be made to induce any other Tenderer or competitor to submit or abstain from submitting a tender, for the purpose of restricting competition;
    d) no exclusive teaming arrangement with Third Party(ies) has been made which would restrict competition due to any of the following reasons:
        - where the teaming partner could be considered to be a single source due to technical reasons or other considerations such as legal or geographical (e.g. an extremely limited number of potential participants as a consequence of industrial return requirements),
        - where the industrial category of the teaming partner restricts other choices for industrial policy reasons; for instance when the fact of being an SME is very important and there are few potential participants in this category.

13. The legal representative to sign the resulting Contract on behalf of the Contractor will be:

    prof. RNDr. Pavol Sovák, CSc., rector

14. The proposal is valid for a period of 14 months from the date of tender submission.

15. We hereby acknowledge the right of the Agency during the validity period of this Proposal, to require the Tenderer to provide evidence of any element of his Proposal and to give additional detailed information, including on the price quotation. This includes the right for ESA to perform an audit if ESA deems it appropriate.

16. By submitting the Proposal, I/we the undersigned herewith officially declare that the Proposal fulfils the Key Acceptance Factors, as indicated in section 7 of the subject ITT Cover Letter and in the dedicated section of the "esa-star" system.

Done and signed for, and on behalf of Pavol Jozef Šafárik University in Košice:

Univerzita Pavla Jozefa Šafárika
v Košiciach
Šrobárova 2, 041 80 Košice
-26-

Signature:

Name and title of the signatory: prof. RNDr. Pavol Sovák, CSc., rector, duly authorized to commit the tendering entity and its proposed Sub-contractor(s) if any, for this purpose.

TITLE OF THE PROPOSAL:
TEMPUS: Temperature of urban surfaces assessed by the open-source software toolbox and multispectral satellite data

PART 1 TECHNICAL AND APPLICATION PART

1.0 INTRODUCTION AND SCOPE

Mitigation of urban heat islands (UHIs) requires understanding of the factors affecting the interaction of solar radiation and urban surfaces. Due to this rather complex relationship, two types of UHIs are generally distinguished: surface and atmospheric UHIs (EPA, 2008). Surface UHIs usually develop during hot, sunny summer days. The Sun heats dry, exposed urban surfaces, like roofs, roads and pavements, to temperatures 25 to 50°C higher than the temperature of the ambient air mass. Surface temperatures have a significant influence on air temperatures, especially in the canopy layer, which is closest to the surface. The canopy layer UHIs occur in the layer of air where people live, from the ground to below the tops of trees and roofs. For example, parks and vegetated areas, which typically have cooler surface temperatures, contribute to cooler air temperatures. Dense, built-up areas, on the other hand, typically increase the air temperature. But in general, the air temperature varies less than temperatures of the land surfaces across an area.

Over the last two decades numerous studies have been published analysing the associations between solar radiation, reflectance, emissivity and other heat transfer parameters of urban surface materials (Berdahl and Bretz, 1997; Mirsadeghi et al. 2013). The development and changes in UHIs may vary substantially throughout the day or year depending on radiative and thermal properties of urban surfaces and urban geometry. Land Surface Temperature (LST) is considered to be a reliable indicator of the UHI as there is a strong correlation between the LST and near-surface air temperature due to heat radiation from the surface to the atmosphere (Nichol, 1994; Arrau and Pena, 2010). However, because of atmospheric mixing, the relationship between land surface and near-surface air temperatures is not constant and changes during the day and night (EPA, 2008). LST is generally defined as the radiative skin temperature of the ground. LST is a key parameter in the physics of land surface processes, combining surface-atmosphere interactions and energy fluxes between the atmosphere and the ground. Properties of urban materials, in particular solar reflectance, thermal emissivity, and heat capacity influence the LST and subsequently development of UHIs, as they determine how the Sun's radiation energy is reflected, emitted, and absorbed.

With the advances in thermal remote sensing technology, remote observation of UHIs using satellite and airborne platforms became increasingly popular. Spaceborne thermal sensors such as Landsat 7 ETM+, Landsat 8 TIRS or Terra/Aqua MODIS and ASTER have been frequently used to assess radiometric surface temperature over large areas sometimes coupled with multispectral techniques to perform land cover assessments at the same time as the thermal imagery is obtained (Voogt and Oke, 2003; Li et al., 2013). In these studies much emphasis has been placed on analysis of temperature differences between urban and surrounding rural areas. However, only a few studies were focused on intra-urban analysis (e.g., Onačillová and Gallay, 2018). While temporal resolution of these instruments is relatively high, their spatial resolution of several tens to hundreds of meters poses limitations for monitoring LST of intra-urban environment. The main reason is in the strong heterogeneity of urban areas comprising complex patterns of buildings, road network and urban vegetation. This leads to a strong spatial differentiation of LST over relatively small distances what is still impossible satisfactorily record by current thermal sensors. Airborne thermal sensing provides solution for single mapping but is not cost-effective for monitoring the LST on a long-term basis. The ESA's Sentinel 2 mission provides higher spatial resolution than the mentioned thermal spaceborne sensors and high revisit periodicity of 5 days. Despite not having a thermal sensor, these properties could be exploited for monitoring LST in urban landscape. Recently, 3-D city models became increasingly used as the vertical dimension plays a crucial role in cities (Biljecki et al., 2014). Coupling 3-D city models with Sentinel 2 data can improve our ability to relate small-scale urban structures, spectral properties of urban surface and remotely sensed thermal imagery to assess LST in urban areas (Onačillova and Gallay, 2018). In our previous feasibility study SURGE (ESA contract No. 4000117034/16/NL/NDe), we developed a method and algorithm for physically-based modelling of LST which makes use of 3-D city model, Sentinel 2 multispectral imagery and spatially distributed solar irradiation modelling in GIS environment. In this project, we reached the TRL 3. We demonstrated the potential of the method on a raster input data (2.5D surface models) but the 3D aspect has not been developed further. Moreover, the validation and calibration of the model with respect to higher resolution thermal data was not performed and there was no software plug-in developed.

The goal of the here proposed project is to develop a software toolbox for calculation of LST in an open-source environment of GRASS GIS using the the r.sun and v.sun solar radiation models with a full 3D support, a digital surface model derived from a virtual 3D city model and input data describing the varying properties of urban greenery derived from airborne and terrestrial LiDAR data and Sentinel 2 multispectral imagery. The software product will reach the TRL 6 (Product Release). It will be implemented in an add-on repository of GRASS GIS, thus fully and freely accessible by GRASS GIS users. Later, it can be included in the standard distribution package of GRASS GIS. Our previous experience with a software development of GRASS GIS and on-going activities provides a strong evidence for achieving these goals. prof. Hofierka (project leader) has been a member of the GRASS GIS development team for more than 20 years. His recent contributions are parallelized GRASS GIS modules r.sun, v.surf.rst a r.sim.water using OpenMP recently published in Computers and Geosciences (Hofierka at el., 2017).

ESA is a strong supporter of open-science philosophy with open-source software development being an important part of this. ESA's Advanced Concepts Team (ACT) has developed github and gitlab channels for ESA and programmes such as SOCIS (the ESA summer of code in space). Now it maintains a number of open source projects that are put at the service of a wider community (https://www.esa.int/gsp/ACT/resources/software.html). Our project will benefit these ESA activities thus providing further evidence that ESA supports open-source software development. The proposed software toolbox will be accessible for users of ESA satellite products such as Sentinel 2, thus directly supporting the use of the ESA products by a very wide community. Mitigation of UHI is a part of SmartCity agenda worldwide, including Slovakia. Our project will show that the acute problems of climate change are addressed also by Slovak researchers with a product that can be freely used by urban planners, city managers or public administration in Slovakia or elsewhere. The test data will be prepared for Kosice city, the second largest city in Slovakia for which valuable datasets originated in our previous ESA/SURGE study. We expect that results of our project will be presented not only at scientific conferences but also during our regular activities such as European Researchers' Night science fair or in public media.

1.1 TECHNICAL OBJECTIVES:

In this project, we propose a specialized software simulating land surface temperature based on publicly available data such as the products of the ESA's Sentinel 2 missions, various municipal, national data or even Open Street Map data. Using this software, we can assess the effects of urban greenery (especially trees) on land surface temperature thus also directly influencing the air temperature in urban areas leading to a creation of UHIs. To make it even more accessible for public, we decided to propose an open-source software module - toolbox for GRASS GIS (grass.osgeo.org) called *r.lst* (raster-based module for land surface temperature geospatial modelling for 2-D representation of cities) and *v.lst* (vector-based module for land surface temperature geospatial modelling dedicated for 3-D city models). The mitigation of UHIs requires understanding of the factors affecting the land surface temperature during hot sunny days as well as proper tools to simulate various scenarios for urban planning and city management. This software toolbox consists of various software modules implemented in the open-source GRASS GIS. The proposed toolbox will be available for users as a single GRASS GIS module with one, integrated user interface, software and data documentation. The advantage of this approach is the open-source software and free data concept beneficial for the citizens of the cities and countries as well as stimulating further development under free/open-source software licence. Therefore, the implementation phase includes the code submission to GRASS GIS distribution that assures a wider software validation and later sustainable and continuous development and improvement. Our previous active involvement and experience in the development of other GRASS GIS modules such as r.sun and v.sun, and others supports this decision (Hofierka, 1997), (Šúri and Hofierka, 2004), (Hofierka and Zlocha, 2012).

The positive micro-climate effects of urban greenery are well-known. During hot summers they reduce high temperatures caused by urban heat islands but also provide numerous other positive environmental effects, such as higher humidity and reduction of dust. The primary root of heat islands in cities is due to the absorption of solar radiation by mass building structures, roads and other hard surfaces. The absorbed heat is subsequently re-radiated to the surroundings and increases ambient temperatures. The vegetation can stop and absorb most of incoming solar radiation mostly via photosynthesis and evapotranspiration process. Moreover, the cooling effect of urban greenery goes beyond its boundary, in many cases in several hundreds of meters. The key components of the simulation representing these processes are: 3-D city model representing the morphology and building materials absorbing the solar radiation, solar radiation model

capable of assessing the spatial distribution of solar radiation in a complex urban environment and urban vegetation model representing the varying properties of plants throughout the year.

These parameters can be efficiently managed within the environment of geographic information systems (GIS) which enable integration of diverse spatial data and their analysis. We developed a new sophisticated solar radiation model v.sun (Hofierka and Zlocha, 2012) providing necessary methodological framework to assess spatial distribution of solar radiation in the 3-D city environment. The structure of the model is based on experience and applications of earlier solar radiation model r.sun dedicated for 2.5-D surfaces (terrain) and raster datasets (Šúri and Hofierka, 2004) which is integrated in the open-source GRASS GIS. The v.sun model was also developed for the GRASS GIS platform but it has not been fully implemented yet. However, the effects of urban greenery are still rather poorly represented either in the v.sun model or r.sun models. The reason is the complexity their geometric structure and complexity of their effect on attenuation of solar radiation permitted through the vegetation canopy. Recent developments in small-footprint laser scanning technology provide new approaches how to map and how to represent the 3-D structure of contemporary cities including the urban greenery in a high detail. However, the unprecedented resolution is also the drawback of this technology as it increases demands on computing power which makes it relatively expensive and time consuming to be efficiently applied in larger areas.

Moreover, the urban greenery in moderate climate zones contains many deciduous plant species with leaf-on and leaf-off periods that substantially change the cooling effects of greenery in the city which is combined with the more pronounced effect of the solar incidence angle in mid-latitudes. While modelling the solar radiation on the surface of relatively simple 3-D structures such as buildings is possible with the v.sun model, modelling the same phenomenon under the vegetation canopy and facades shadowed by the vegetation requires different approach. Either complex 3-D models of vegetation for particular phenological stages are needed or proxy data derivable more easily from multispectral satellite imagery can be used, such as normalized vegetation index, leaf area index, or chlorophyll content.

Sentinel-2 is a new generation of ESA's missions particularly targeted to monitoring the land cover changes within the Copernicus Earth observation programme. Sentinel-2A and 2B with their MSI sensor are on orbit for over 3 years delivering multispectral imagery every 5 days at a high spatial resolution (up to 10 m) in 13 spectral bands in visible near infrared and shortwave infrared spectrum. The mission is particularly attractive for monitoring urban greenery. While the greenery (such as trees) is usually mapped by conventional methods in a much higher spatial resolution, the seasonal changes related to phenology remain uncaptured due to the low temporal resolution of airborne photogrammetric or ground surveys. Therefore, the remote sensing parameters of the Sentinel-2 mission make it attractive for monitoring urban vegetation especially in moderate climate zones, such as in Slovakia. The acquired imagery is planned to be used for derivation of various vegetation indices based on diverse reflectance in visible and infrared spectral bands. These characteristics are particularly important for assessing cooling effects of urban greenery and heat island mitigation in many cities.

The main technical objective of the proposed project is to develop a software capable of computing the land surface temperature of 3D urban surfaces with known thermal properties and represented by the 3D city model. The software will be implemented in the open-source environment of GRASS GIS using the Python programming language.

This project will be focused on the following technical objectives (TO):

1. Description of thermal properties of urban surfaces;
2. Developing a software module for raster based LST calculation in GIS, r.lst;
3. Developing a software module for 3D vector based LST calculation in GIS, v.lst;
4. Documentation of the software (r.lst and v.lst)

1.2 REQUIREMENTS:

Achieving the technical objectives outlined in Part 1.1 requires the following:

- TO1 requires data on urban surfaces such as roofs, facades, roads, pathways, etc. to properly parameterize the LST model developed for 2D raster (r.lst) and 3D vector approach (v.lst). The

thermal properties will be ascertained with our technical equipment in the field.

- TO2, TO3 require software coding, testing and verification. The parameterization of the software will make use of the outcomes of the TO1. The LST values calculated by the software tools will be validated against in-situ thermal measurements and airborne thermal data.
- TO2, TO3 require complete documentation of the software (TO4) in the form of manual as well as tables to parameterize the model using standard information on urban surfaces.
- TO4 requires verification of the functionality of the designed software which will be possible after achieving TO2,TO3.

1.3 TECHNOLOGY READINESS LEVEL:

The current TRL can be classified as TRL3 based on the completed feasibility study SURGE: Simulating the cooling effect of urban greenery based on solar radiation modelling and a new generation of ESA sensors (ESA contract No. 4000117034/16/NL/NDe). This means the project team builds on the results and findings of this feasibility study and develops it further into a final product, thus reaching TRL 6.

1.4 ENGINEERING APPROACH

1.4.1 State of the Art

The increasing availability of high-resolution geospatial data for urban areas and adequate modeling techniques provide an alternative approach in high-resolution estimation of LST in comparison to low-resolution thermal remote sensing. Several studies showed the potential of 3D city models for estimation of solar radiation in urban areas (Hofierka and Kaňuk, 2009; Biljecki et al. 2014; Hofierka and Zlocha, 2012). Moreover, the concept of geographic information systems provides a very suitable framework for implementation of physically-based models requiring a complex set of spatially distributed data. For example, Nakata-Osaki et al. (2018) developed an ArcGIS GIS tool for calculating the maximum intensity of urban heat island based on 3-D urban geometry data adopting the empirical model of Oke (1981). However, the suite of available GIS algorithms to date lacks calculation of LST in which the potential of fine scale 3-D urban structure could be exploited. Furthermore, these kinds of tools make use of 3-D buildings but are not prepared for implementing geometries that are more complex such as trees (Tooke et al., 2012). The geometry of trees is a dynamic property especially in mid-latitudes with significant phenologic changes of deciduous tree species. Tooke et al. (2012) estimate solar irradiance in urban areas taking into account radiation transmission through urban vegetation using airborne Light Detection and Ranging (LiDAR) point clouds. The use of LiDAR in estimating canopy cover of trees is also supported by various studies based on a comparison of lidar-based canopy cover data to the metrics measured in the field (Morsdorf et al., 2006; Smith et al., 2009; Richardson et al., 2009). Recently, various physically based approaches for LST calculation were developed providing very realistic results for daytime LST. These approaches use a very complex radiative transfer modeling at the city microscale level such as SOLENE (Idczak et al. 2010), Dart (Gastellu-Etchegorry et al., 2015), FLUENT (Nazarian and Keissl, 2015). For example, Roupioz et al. (2018) presented LASER/F, a very suitable approach of 3-D simulation of kinematic LST for a single building and its surrounding based on a much more complex approach than defined in our study. They compared the results with high resolution thermal imagery achieving linear correlation of 0.96. Their approach being very efficient and robust requires accurate definition of the properties of the materials in the 3-D scene which were empirically defined. The algorithm proposed in our feasibility study SURGE, in contrast, provides simple yet realistic estimation of LST capable of considering the dynamics of the components contributing to the surface heat budget such as solar irradiance (virtually any time moment of the day time) and surface material. Albedo and thermal emissivity are estimated from freely available Sentinel 2 data, potentially every 5 days. However, such use of Sentinel 2 data requires validation against reference thermal datasets (e.g. airborne, in-situ) for the purpose of LST calculation. Vanino et al. (2018) demonstrated the use of Sentinel 2 for broad-band albedo estimation.

1.4.2 Technical Steps

1. Catalogue of urban surfaces

Thermal properties of urban surfaces such as roofs, facades, roads, etc. play an important role in affecting LST and subsequently UHI. To apply the developed software correctly and with fair results, we must provide the user with a set of parameters of the model that describe thermal properties of urban surfaces. Emissivity and albedo (reflectance) is already measured for some construction materials (e.g. database of Cool Roof Rating Council Standard (CRRC-1: coolroofs.org), but a lot of construction materials commonly used in Europe are not measured or are measured in laboratory conditions. The user usually does not have time and resources to measure these parameters in field, so we must provide a database-catalogue of materials commonly used in Slovakia with a set of input parameters for our model. Measurements will be made in the field taking into account pollution and another environmental factors influencing material surface. Measurements will be made with the following devices: portable emissometer, solar reflectometer (according to ISO 13 378:2013,ASTM E903, ASTM E408, ASTM C1371-04) and portable conductomer (using modified hot wire method) and moisturemeter. Larger non-homogeneous surfaces will be measured by pyranometer (according ISO/TR 9901:1990). These commonly used materials can be attributed to increasingly available 3-D city models. In our case, we will use 3-D city model already available for the Košice City, Eastern Slovakia which was developed during our feasibility study SURGE. The data will be used in testing, verification and documentation of the software. Therefore this step is important for achieving TO1.

2. Module structure and design

This task analyses the structure of the toolbox in accordance with current programing environment of GRASS GIS and recommends final design issues (e.g., the use of Python and shell script, modification of existing v.sun module, solving the problems with I/O operations, etc.). The key components of the proposed toolbox consists of solar radiation modules (r.sun, v.sun), map algebra and reclassification operations. The software toolbox, r.lst (2D raster data) and v.lst (3D city data), will be in the form of Python script that will call the required GRASS GIS modules in a coherent way using specified input data prepared outside of the toolbox. GRASS GIS includes the GRASS Python Scripting Library that makes development of new Python modules much easier (Zambelli et al., 2013). GRASS GIS 7.2.0+ comes with a "Simple Python Editor" which enables users to author Python scripts directly in GRASS GIS GUI. User can also run the script easily in GRASS GIS environment with all the dependencies loaded. This Python editor comes with several examples, templates, and links to documentation. Thus the goal of this task is to present the final algorithmic structure and design of the software. This step is important for achieving TO2 and TO3.

3. Coding

The existing v.sun solar radiation model implemented in open-source GRASS GIS will be modified to include the parameters characterizing the effects of vegetation canopy on incoming solar radiation. The semi-transparent canopy attenuates solar radiation incoming to the ground and lowering the ambient temperature. Moreover, the trees cast shadows on adjacent urban structures such as buildings, streets and pathways further impacting the spatial distribution of solar radiation and consequently reduce production of heat. The canopy transparency will be approximated using the simplified 3-D vegetation models with the downscaled vegetation transmittance parameters from the SURGE feasibility study using Sentinel 2 data. The performance of the model will be tested to identify critical functions and characteristics of the proposed approach for simulating the cooling effect of urban greenery. The r.lst module was recommended by our successful feasibility study. The prototype of the module was prepared using the shell script with only basic functionality. A modern approach in a development of open-source modules for GRASS GIS suggest the use of Python programming language via pygrass - an object oriented Python API (Zambelli et al., 2013). This approach will be used also in this project. Moreover, the v.lst module will work in a full 3D mode and therefore requiring GRASS 3D modules such as v.sun and r3.mapcalc. The coding of the module will be delivered in 3 phases: alpha version that is a working version with almost a full functionality that, however, probably still has lots of bugs that needs to be worked out. Beta version is near completion.

All of the features are working and the software can be open up to external testers for testing. Code bugs that will be discovered and had not shown up in the alpha testing will be fixed. Final version is the last stage of the code development with software supposed to be complete and finished. The tests will be performed using sample data prepared in a previous step with a wide range of input parameters to test the stability and sensitivity of outputs. The obvious software bugs will be documented, suspicious software behaviour described to perform further analysis by programmers. data simulated in the software will be verified using real world data, including field measurements. We expect an extensive use of thermal sensors within the study area, calibration of the model and verification of results. This step is important for achieving TO2 and TO3.

4. Test data preparation

The necessary test data required for comprehensive software testing will be prepared. This will include a wide range of data values and situations. The existing data for 3D city model of Kosice will be supplemented with thermal properties of urban surfaces as identified in the feasibility study and Task 1, namely albedo, heat transfer coefficients of materials and various building configurations. The data will be attributed to building surfaces such as roofs, facades and other intraurban surfaces. The thermal effects of urban greenery will be assessed by a separate model leading to a more accurate estimates of cooling effects manifested via the LST. This step is important for achieving TO2 and TO3.

5. Code testing and output verification

The tests will be performed using sample data with a wide range of input parameters to test the stability and sensitivity of outputs. The obvious software bugs will be documented, suspicious software behaviour described to perform further analysis by programmers. The data simulated in the software will be verified using real world data, including field measurements using terrestrial and airborne thermal data. We expect an extensive use of thermal sensors within the study area, calibration of the model and verification of results. This step is important for achieving TO2 and TO3.

6. Software documentation

The documentation will be elaborated in two parts: a standard manual page for the r.lst/v.lst modules (usually a few pages describing the aim of the module, input, output and operation behaviour of the module and a few references for further reading) and a comprehensive pdf documentation describing scientific background of the simulation supplemented by scientific papers when published. This step is important for achieving TO4.

7. GRASS GIS module submission

The finalised module will be submitted to the add-on repository of GRASS GIS. The submission will be done in two steps: Release candidate version 1, which is expected to be bug-free. If any problem or suggestion from a wider user community arises during the use of the software, these will be fixed or implemented until Release Candidate version 2. Soon after a relatively short period of time (3-4 months), a final product will be released for public use. This step is important for achieving TO4.

1.4.3 Implementation aspects

This project proposes a future GRASS GIS module that will simulate land surface temperature using the methodology already analysed in the feasibility study SURGE. The r.lst and v.lst modules will use the GRASS Python Scripting Library and a set of other GRASS GIS modules Further, algorithmic concepts will be based on the implementation of the Stefan Boltzmann land surface temperature model as described in the feasibility study and in the manuscript submitted to the Urban Climate journal. The proposed toolbox will be tested and validated using test data verified using field data taken from a set of thermal sensors on ground or by thermal airborne remote sensing. The r.lst/v.lst modules will be submitted to GRASS GIS in several stages. The open-source concept of GRASS

GIS will stimulate further development of the module and stimulate a wider use of the module including the data form ESA sensors such as Sentinel 2.

1.5 TECHNICAL FEASIBILITY, PROBLEM AREAS AND DEVELOPMENT RISK :

This project is based on the successful feasibility study that confirmed the suggested concept. Beyond the results presented in the feasibility study, we will extend the solution to a full 3D implementation. The potential risk may include delays in data preparation and technical difficulties in implementation of 3D city model in GRASS GIS which may require specific processing of standard 3D city model in a multipatch vector format, or conversion and cleaning of already available data which again may result in some delays. We will aim to synchronize the acquisition of airborne thermal sensing data with Sentinel 2 overpass which could be complicated by the abilities of the external service provider to fly on the particular day. Nevertheless, the condition of synchronized airborne and spaceborne data collection is not a showstopper, rather an ideal circumstance.

1.6 APPLICATION OF TECHNOLOGY DEVELOPMENT

Mitigation of UHIs is among top priorities for many cities, decision makers and planners at local or even global level. Mitigation strategies should include appropriate modelling tools to assess various situations or control measures. The proposed software toolbox can be an invaluable tool for such analysis. Our goal is to provide this tool to as many as potential users as possible. The free/open-source software concept fits this goal excellently. The tool can be used by private (mostly consulting) companies, governmental or non-for-profit agencies. So far we have an active cooperation with several potential users of the toolbox: Slovak Green Building Council (http://skgbc.eu/portal/), City Office of Kosice, City Office of Bratislava and several consulting companies.

The aim of the proposal is also relevant especially to ESA EO missions, Sentinel 2 and Sentinel 3 in particular. The planned software model makes use of the Sentinel 2 data for estimation of land surface albedo and surface emissivity unless other source of such data are available in higher resolution or higher accuracy. With regard to LST modelling, the benefit of Sentinel 2 mission is in providing relatively high-resolution albedo with a theoretical frequency of 5 days under persistent clear sky conditions. Sentinel 3 thermal data could be validated with the proposed software tool on lower spatial resolution.

The benefit of the proposed project to both Prime and Subcontractor are several folded. The first is the mutual and interdisciplinary collaboration of geospatial scientists and urban architects and engineers. We aim for several valuable publications to be derived from the project activity which in connection with the developed software will have a multiplicative positive effect on our research background and education, last but not least on promotion of the ESA's long-term research mission.

1.7 TECHNICAL IMPLEMENTATION / PROGRAMME OF WORK

1.7.1 Proposed Work Logic

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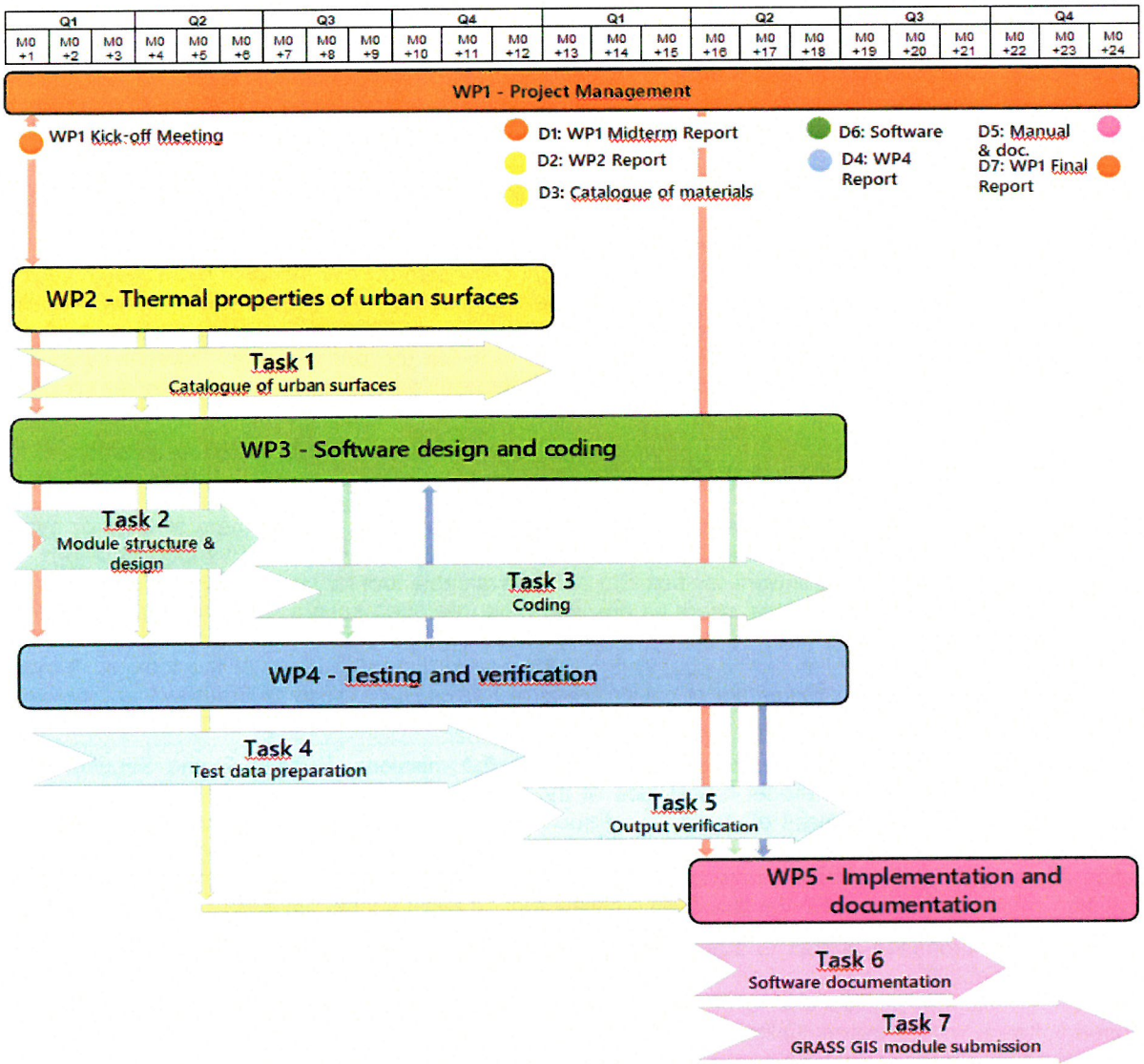
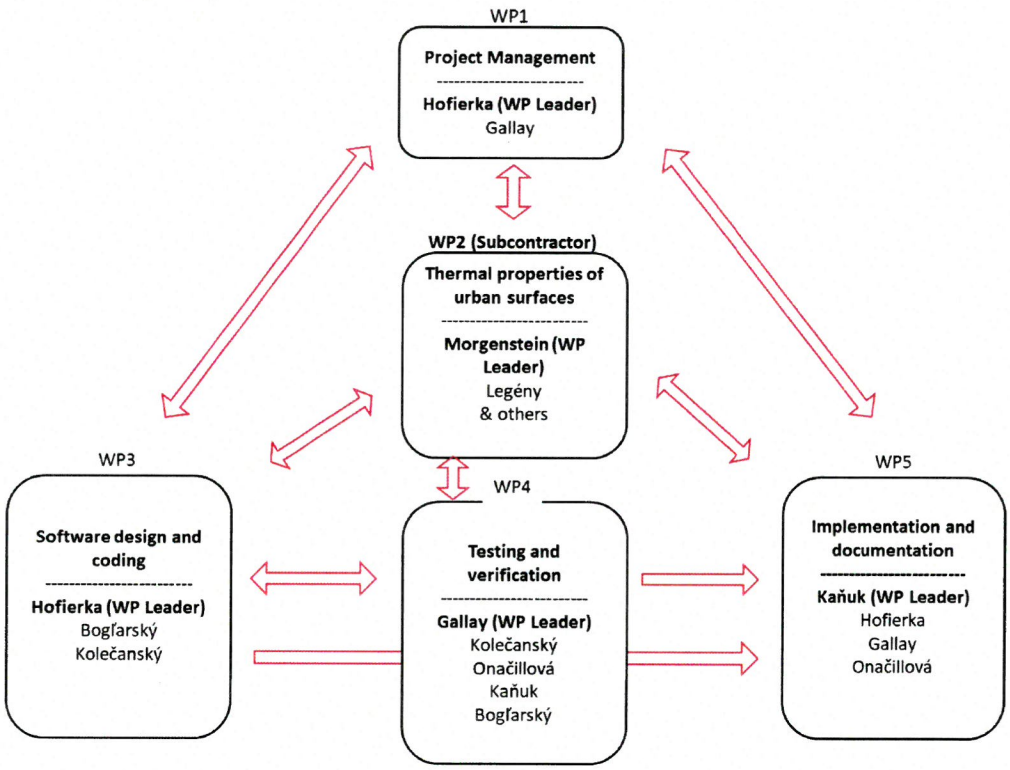


1.7.2 Contents of the proposed work

1.7.2.1 Work Breakdown Structure (WBS)

Position of the team members with respect to the structure of the work packages and their lines of communication and reporting.



1.7.2.2 Work Package Description (WPD)

WP1 - Project management

Responsible company : Pavol Jozef Safarik University in Kosice
Beginning and end date of each work package: M1 – M24
Person responsible for the work package: Jaroslav Hofierka

Description of the activities in the work package: This WP is devoted to the assessment of the progress of the work towards the achievement of the objectives by performing a continuous evaluation during the project duration. This will be done by analysing the progress of the project against the project time table defined in the proposal. Monitoring will be done by regular communication of the study manager with the WP leaders and based on criteria like timeliness, diligence, quality, consistency and innovation when appropriate for achieving the results.

Inputs to the work package: The continuous communication with all WP leaders.
Outputs of the work package: D1-Midterm report, FR-Final report, ESR, CCD, FP

WP2 - Thermal properties of urban surfaces

Responsible company : Slovak University of Technology in Bratislava
Beginning and end date of each work package: M1 – M12
Person responsible for the work package: Peter Morgenstein

Description of the activities in the work package: This WP will be focused on development of a database of thermal properties of urban surfaces such as albedo, emissivity and heat transfer coefficients for common building materials used for roofs and facades. These values will be collected on data published by the

producers of the materials as well as by measurements by terrestrial and airborne thermal sensing. The database will be delivered in the form of a digital catalogue of typical materials for urban surfaces.

Inputs to the work package: WP3, WP4, WP5
Outputs of the work package: D2 - W2 report, D3 - Catalogue of materials

WP3 - Software design and coding

Responsible company: Pavol Jozef Safarik University in Kosice
Beginning and end date of each work package: M1 – M18
Person responsible for the work package: Jaroslav Hofierka
Description of the activities in the work package: This WP analyses the results of the feasibility study and allocates manpower capacity to perform all the tasks. We will analyse current programing environment of GRASS GIS and recommend final design issues (e.g., the use of Python vs. shell script, modification of existing r.sun/v.sun modules, solving the problems with I/O operations, etc.). Actual coding of the module with 3 software versions delivered: alpha version that is a working version with almost a full functionality that, however, probably still contains code bugs that need to be fixed. Beta version is near the software completion. All of the features are working and the software can be open up to external testers for testing. Code bugs that will be discovered and had not shown up in the alpha testing will be fixed. Final version is the last stage of the code development with software supposed to be complete and finished.
Inputs to the work package: WP4, WP5.
Outputs of the work package: D6 - Software - final product

WP4 - Testing and verification

Responsible company : Pavol Jozef Safarik University in Kosice
Beginning and end date of each work package: M1 – M18
Person responsible for the work package: Michal Gallay

Description of the activities in the work package: Test data preparation - based on the data prepared in WP2, the necessary data in a GRASS GIS format required for comprehensive software testing will be prepared. This will include a wide range of data values and situations. The code tests will be performed using sample data with a wide range of input parameters to test the stability and sensitivity of outputs. The obvious software bugs will be documented, suspicious software behaviour described to perform further analysis by programmers. Output verification - data simulated in the software will be verified using real world data, including field measurements and thermal sensing data. We expect an extensive use of thermal sensors within the study area, calibration of the model and verification of results.

Inputs to the work package: WP3, WP5
Outputs of the work package: D4 - WP4 Report

WP5 - Implementation and documentation

Responsible company : Pavol Jozef Safarik University in Kosice
Beginning and end date of each work package: M16 – M24
Person responsible for the work package: Ján Kaňuk

Description of the activities in the work package: This WP will be focused on submission of the software to GRASS GIS and software documentation. GRASS GIS module submission - the finalised module will be submitted to the add-on repository of GRASS GIS. The submission will be done in two steps: Release candidate version 1, which is expected to be bug-free. If any problem or suggestion from a wider user community arises during the use of the software, these will be fixed or implemented until Release Candidate version 2. Soon after a relatively short period of time (3-4 months), a final product will be released for public use. The documentation will be done in two parts: a standard manual page for the r.lst/v.lst modules (usually a few pages describing the aim of the module, input, output and operation behaviour of the module and a few references for further reading) and a comprehensive pdf documentation describing scientific background of the simulation supplemented by scientific papers when published. We expect 1-2 scientific papers to be published over the next year or two with main findings of this project.

Outputs of the work package: D5 - Manual and documentation

1.8 BACKGROUND OF THE COMPANY(IES)

Contractor: The Pavol Jozef Safarik University in Košice (www.upjs.sk) has a well-established position within the Slovak universities. Its modern history dates back to 1959. The annual turnaround in 2014 was 52 mil .EUR of which 2 mil. EUR was contributed by research grants. We will focus our background description on the Faculty of Science where the project team is based. The Faculty contributes to the research quality of the University and its financial income from research by the largest amount (almost 70%). The Faculty of Science was established in 1963, since that time it gained a strong position among the Slovak faculties of natural sciences. From the research and education point of view it was ranked the first or the second the best faculty in the last few years in Slovakia. The longest tradition is in the physical research focusing on nuclear physics, experimental physics, low-temperature physics, theoretical physics, astrophysics, and biophysics. The Faculty has a well-functioning unit to support administration of projects funded by the EU and national agencies. The Centre for Project Support has financially and administratively managed 15 R&D projects (30 mil. EUR in total) and 5 educational projects (7.5 mil EUR in total) funded by the EU structural funds since 2009.The Faculty has been granted a FP7 grant for coordination and support to build an interdisciplinary team and facilities for multiscale cell bioimaging (CELIM) worth 2.7 mil EUR to be invested in the period of 2013-2016, which is the biggest ongoing FP7 project in Slovakia.

The research team is based at the Institute of Geography, Faculty of Science (uge.science.upjs.sk). It is the smallest Institute employing 14 members of academic staff who are organized in 3 research units. The annual total budget of the institute was 282,470 EUR in 2018, and the amount of research grants funds received in 2018 was 103,830 EUR. The Institute runs research projects funded by the European Union (Horizon 2020, INTERREG, COST) as well as ESA, national grant schemes focusing on 3-D modelling of urban and natural landscape in a GIS software environment primarily based on the open-source platform (GRASS GIS, LAStools, Meshlab, R). The GIS research is closely linked to the long-term research results in speleology and karst geomorphology of the Physical Geography Research Group. Human geography Research Group focuses on various aspect of urban and rural landscape and its transformation after 1989 in the Košice City and its wider region. Our recent projects related to this topic are listed in the following table:

Duration	Project title	Principal investigator	Total budget
2018-21	APVV/SK-CN-RD-18-0015: Key Technologies on the Integration of Multi-GNSS, LiDAR and Oblique Photogrammetry in 3D High-Quality Reconstruction of Smart City (3DSMARTCITY). 10/2018 - 09/2021	Vladimír Sedlák	101,161 EUR
2016-18	Simulating the cooling effect of urban greenery based on solar radiation modelling and a new generation of ESA sensors (SURGE), contract No. 4000117034/16/NL/NDe, 06/2016 - 05/2018,	Jaroslav Hofierka	49 941 EUR
2013-17	Research of new methods for spatial modeling using laser scanning and 3D-GIS (APVV-0176-12) http://spatial3d.science.upjs.sk	Jaroslav Hofierka	150,000 EUR
2014-16	Dynamic 3D modelling of urban landscape with a multiscale approach (VEGA 1/0473/14)	Ján Kaňuk	39,000 EUR

The list of publications in international peer-reviewed impacted journals provides the best picture of our background and experience:

- **HOFIERKA, J., GALLAY, M., ONAČILLOVÁ, K.**, HOFIERKA, J., JR. (2019): Physically-based land surface temperature modeling in urban areas using 3D city models and multispectral satellite data. Urban Climate. Submitted.
- **ONAČILLOVÁ, K., GALLAY, M.** (2018).Spatio-temporal analysis of surface urban heat island based on LANDSAT ETM+ and OLI/TIRS imagery in the city of Košice, Slovakia. Carpathian Journal of Earth and Environmental Sciences, 13(2), 395 - 408.
- **HOFIERKA, J., GALLAY, M., KAŇUK, J., ŠUPINSKÝ, J., ŠAŠAK, J.** (2017). High-resolution urban greenery mapping for micro-climate modelling based on 3D city models. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (ISPRS Archives), XLII-4/W7, 7-12.
- **HOFIERKA, J.**, LACKO, M., ZUBAL, S. (2017). Parallelization of interpolation, solar radiation and water flow simulation modules in GRASS GIS using OpenMP. Computers & Geosciences, 107, 20-27.

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- **KAŇUK**, J., **GALLAY**, M., **HOFIERKA**, J. (2015): Generating time series of virtual 3-D city models using a retrospective approach. Landscape and Urban Planning, 139, 40-53.
- **GALLAY**, M., **KAŇUK**, J., **HOFIERKA**, J. (2015). Capacity of photovoltaic power plants in the Czech Republic. Journal of Maps, 11(3), pp. 480-486.
- **HOFIERKA**, J., **KAŇUK**, J., **GALLAY**, M. (2014). Spatial distribution of photovoltaic power plants in relation to a solar resource potential: a case study of the Czech Republic and Slovakia. Moravian Geographical Reports, 22(2), pp. 26-33.
- **HOFIERKA**, J.; ZLOCHA, M (2012). A New 3-D Solar Radiation Model for 3-D City Models. Transactions in GIS. 16(5), 681-690.
- **HOFIERKA**, J.; **KAŇUK**, J. (2009). Assessment of photovoltaic potential in urban areas using open-source solar radiation tools. Renewable Energy, 34(10), 2206-2214.
- ŠÚRI, M.; **HOFIERKA**, J. (2004). A New GIS-based Solar Radiation Model and Its Application to Photovoltaic Assessments. Transactions in GIS, 8: 175–190.

Subcontractor1: The cooperating organization of the project is the Faculty of architecture, Slovak University of Technology in Bratislava (FA STU). Mainly involved institutes in the submitted project will be the Institute of Ecological and Experimental Architecture with the support of Institute of Urban Design and Planning. Topics of sustainable architecture and town planning, resilience of cities to the changing climate, architectural and urban integration of sustainable energy sources (mainly solar energy), reduction of heat islands, solar urbanism, urban economy, Smart City concepts belong to the main long-term focus areas of the department and its individual scientific staff members. Team of the FA STU participated on multiple national and international research projects (APVV, VEGA, KEGA, INTERREG, TEMPUS/PHARE, CEEPUS, Vysegrad Funds) thematically aimed on sustainable architecture and urban planning, solar urbanism and virtual reality. Members of the team have been publishing their research findings on national and international forums, and are members of editorial boards of technical and scientific journals, and of international consortia. Two team members were engaged into a number of European projects at the Bratislava Chief City Architect's Office devoted to application of measures for increasing of city's resilience and sustainability in the course of climate change.

Ing. arch. Peter Morgenstein, PhD. works as a researcher at the Institute of Ecological and Experimental Architecture of FA STU and at Danube University in Krems, Austria. In long-term he has been occupied with the research in the field of ecological architecture and urbanism, energy cooperation of urban structures, Smart City and Smart Grid concept. He is the co-author of the scientific monograph Solar strategy of a sustainable city. He has 27 records in the publication database, out of which 3 in WoS, 6 in Scopus, altogether 20 citations, out of which 4 in WoS and/or Scopus databases. He also gained experience at the Bratislava Chief City Architects Office.

Within the project, he will be the coordinator of the FA STU team. He will be responsible for selection of urban surfaces to be examined, which will form the basis of the materials catalogue. He will cooperate with the team members on obtainment and processing of data (emissivity, conductivity and reflectivity) of selected surfaces by researching actual databases and by direct communication with material producers as well as by measurements on site. He will be responsible for communication with municipalities and strategic partners of the project.

Ing. arch. Ján Legény, PhD. works as a researcher at the Institute of Ecological and Experimental architecture of FA STU. In a long term he has been occupied with problematics of ecological architecture, urban planning and generating of urban structures based on the sun movement. He is a co-author of the scientific monograph Solar strategy of a sustainable city. He has 39 records in the publication database, out of which 3 in WoS, 7 in Scopus, altogether 25 citations, out of which 7 in Scopus database. He participated in three national projects (VEGA, APVV) and one international project (Interreg Danube Transnational Programme). He was awarded twice a post-doc position at the STU with his research topic "Intensification of solar energy use in the urban space". He also gained experience at the Bratislava Chief City Architects Office. In the project, he will be a deputy of P. Morgenstein in the matters of coordination of the FA STU team. He will mainly be responsible for urban surfaces monitoring (emissivity, conductivity and reflectivity), especially of roofs.

In the project implementation, 5 researchers (Morgenstein, Legény, Pifko, Krajcsovics, Varga) and several Ph.D. candidates will be directly involved. It is planned to involve students of architecture and urbanism into the process, mainly in the field of data gathering and preliminary processing and testing of the software. Involvement will be done via agreements.

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1.9 FACILITIES

The following facilities and infrastructure will be used to reach the outlined technical objectives of the study. All of it is managed by the project team or can be freely accessed. The framework of study concerns acquisition, processing and interpretation of geographic data. For these purposes, we will make use of our Laboratory of GIS which is managed by Ján Kaňuk. The lab comprises all equipment and technical infrastructure related to acquisition or location of spatial data via the field survey or remote sensing methods. Further, it encompasses the software needed for extraction and digital analysis of acquired spatial data. The laboratory manages also spatial datasets generated or purchased by the Institute of Geography of the Prime contractor.

The equipment in the GIS lab is in the ownership of the tenderer and the most relevant items comprise:

- FARO Focus 150 terrestrial laser scanner for ultra resolution 3D mapping up to 150 meters, including embedded HD camera for photo overlay up to 165 megapixel colour, with dedicated FARO Scene software.
- Long range terrestrial laser scanner VZ-1000 by RIEGL LMS GmbH. with an integrated and calibrated camera NIKON D-700 capable of online waveform processing of the recorded laser pulse reflections.
- Unmanned aerial system PHANTOM 4 by DJI with an inbuilt digital optical camera, data link and FPV, the system is capable of an autonomous flight with a ground control and Parrot Sequia multispectral camera (VIS+NIR spectral bands)
- Unmanned aerial system Scout B1-100 by Aeroscout with the wePilot3000 control system, GPS/IMU unit with a dual OXTS RT3003 antennas, with an integrated laser scanning payload (Riegl VUX-1 scanner) and a hyperspectral payload (AisaKESTREL 10 by Specim) for remote sensing and mapping; the system is capable of an autonomous flight with a ground control.
- Tangible Landscape - this system comprises PC with LINUX Ubuntu and GRASS GIS, xBox One Kinect, dataprojector, table with stand and kinetic sand;
- Digital photogrammetric workstation (PGW) equipped with the PHOTOMOD v5.2 software by RACURS the PGW is dedicated for processing digital aerial and satellite imagery, generation of 3D landscape models and orthoimagery;
- Two GNSS receivers for precise positioning in real time or after post-processing by TOPCON (EPP Set – Hiper II: Digital UHF 410-440 MHz s GSM/GPRS). The GNSS receivers will be used in combination with terrestrial scanner to precisely locate the acquired point clouds and control points for validating satellite data
- Other technical infrastructure comprises: handheld GPS receivers Trimble Juno SB, Garmin eTrex with the firmware; Total positioning station Leica TC 605; Laser distance meters Leica Disto D3; Universal theodolite MOM-Te-D4; Large format plotter HP DesignJet Z2100 Photo
- Software licences:
    - RiScanPro, RiAcquire, RiProcess for processing laser scanning data by RIEGL scanners;
    - ENVI by Harris Geospatial for processing hyperspectral and other remote sensing data;
    - 30 licences ArcGIS 10.6 by ESRI (including Spatial Analyst, 3D Analyst a Geostatistical Analyst); Installations of an open-source software GRASS GIS 7; R; MapServer; LAStools,
- Data: various collections of vector and raster data covering Slovakia including custom airborne and terrestrial lidar datasets

The Faculty of Sciences of the Pavol Jozef Šafárik University, which integrates the Institute of Geography, also provides complementary infrastructure for conducting activities related to the aims of the proposed project. High performance computing can be performed with the equipment of the Laboratory of Intelligent Data Analyses (LIDA). Distributed data storage is an integral part of the LIDA and it allows for sharing the data and computations. It comprises a distributed infrastructure: central server and data storage located at the P. J. Šafárik University in Košice, two satellite servers located in Banská Bystrica (Matej Bell University) and Žilina (University of Žilina). Each node of this network comprises a particularly dimensioned multiprocessor server, a disc array, and a back-up unit, mounted in a holder with a stabilized and back-up power source. The storage components within the nodes are based on the Fibre Channel technology. The nodes are interconnected by the academic network SANET of 1Gb/s data flow capacity The infrastructure is dedicated for data collection, development and testing of algorithms for searching, classification, representation, and interpretation of knowledge.

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Slovak University of Technology in Bratislava (Subcontractor):

Equipment of the University Science Park of the Faculty of Architecture SUT relevant for the project:

1. Laboratory with computer equipment specialized for work with simulation software and GIS technologies
2. Multilicence Autodesk Suite EDU 2014
3. Laptops
4. 3D scanner - digital laser scanner, with accessories
5. Geodetic GNSS kit - Leica Zeno
6. System for video conference - Polycom 700 (device for communication among project partners during the project, communication with foreign institutions and experts)
7. Ploter Imageprograph 4000 – printing of large formats, possibilities for scanning of large formats – digitalization of documents for research of buildings and urban structures
8. Wacom Tablets – enabling the use of advanced graphic work techniques with interactive interface and direct graphical input of the architect/urban planner

PART 2 MANAGEMENT PART

2.1 TEAM ORGANISATION AND PERSONNEL

2.1.1 Proposed team

2.1.1.1 Overall team composition, key personnel

The project team consists of 11 researchers. All members of the Prime contractor are members of a single institute (Inst. of Geography) which is a unit within the Faculty of Sciences, P.J.Šafárik University in Košice. The subcontractor's team is based in the Institute of Ecological and Experimental Architecture of the Faculty of Architecture, Slovak University of Technology in Bratislava. Both teams collaborated in the last two years on preparation of common projects focused on solar cadastre and solar irradiation modelling for urban environment. The project manager will organise regular project meetings (3-month period) to monitor the progress of the individual work packages, identify problems, delays and discuss possible solutions. The work package leaders will organise the work package meetings in similar time periods to discuss the progress in respective work packages. The roles of the team members with respect to the proposed work packages and communication lines between them are shown in the scheme displayed in PART C Section 4a, 4b.

c) Key personnel

prof. Jaroslav Hofierka (project manager and WP1, WP3 leader) - In this project, he will be a principal investigator (a project manager) responsible for most research activities as well as a key WP3 - software design and coding. The average percentage of the total working time 25%, man-hours assigned to Work Packages: 1100

Dr. Michal Gallay (WP4 leader) - within the project, he will be responsible for WP4 - test data preparation, output verification including field measurements and thermal sensing data. His average percentage of the total working time 25%, man-hours assigned to Work Packages: 1000

Dr. Ján Kaňuk (WP5 leader) - He will be responsible for WP5 - software submission to GRASS GIS under official GRASS GIS rules as well as a complete software documentation. Average percentage of the total working time 15%, man-hours assigned to Work Packages: 600

Ing. arch. Peter Morgenstein, PhD. (WP2 leader) - He will lead the WP2 which will be focused on development of a database of thermal properties of urban surfaces such as albedo, emissivity and heat transfer coefficients for common building materials used for roofs and facades. These values will be collected on data published by the producers of the materials as well as by measurements by terrestrial and airborne thermal sensing. The average percentage of the total working time 25%, man-hours assigned to Work Packages: 1000

Ing. arch. Ján Legény, PhD. - In the project, he will hold a position of deputy of the main STU coordinator and will be responsible for urban surfaces monitoring (emissivity, conductivity and reflectivity), especially of roofs. The average percentage of the total working time 10%, man-hours assigned to Work Packages: 400

Doc. Ing. arch. Henrich Pifko, PhD. He will mainly be responsible for for urban surfaces monitoring (heat conductivity, albedo and emissivity) measurements especially for hard landscape materials. The average percentage of the total working time 10%, man-hours assigned to Work Packages: 400

Ing. arch. Lorant Krajcsovics, PhD. He will mainly be responsible for for urban surfaces monitoring (heat conductivity, albedo and emissivity) measurements especially for hard landscape materials. The average percentage of the total working time 10%, man-hours assigned to Work Packages: 200

Ing. arch. Tibor Varga, PhD. He will mainly be responsible for for urban surfaces monitoring (heat conductivity, albedo and emissivity) measurements especially for building used materials, facades and roofs. The average percentage of the total working time 10%, man-hours assigned to Work Packages: 400

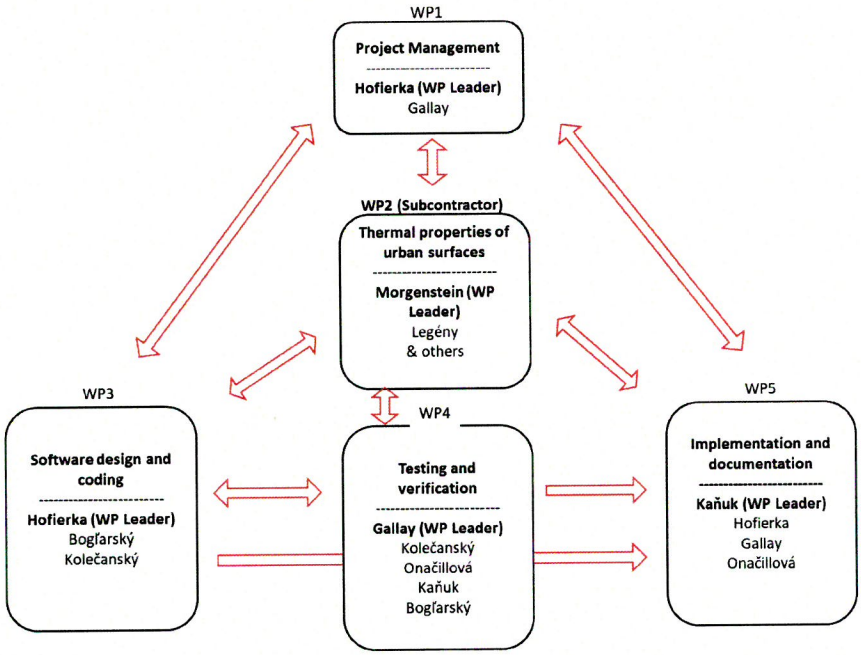
Ms. Katarína Onačillová - a Ph.D. candidate in geoinformatics and remote sensing. She will participate in the test data collection, software verification and documentation. Average percentage of the total working time 20%, man-hours assigned to Work Packages: 800.

Mr. Štefan Kolečanský – a Ph.D. candidate in geoinformatics and remote sensing. He will participate in a test

data collection, input data preparation, software coding, verification and visualization of results. Average percentage of the total working time 30%, man-hours assigned to Work Packages: 1200

Mr. Jozef Bogľarský – a Ph.D. candidate, in geoinformatics and remote sensing. He will participate in software coding and testing, test data collection, software verification. Average percentage of the total working time 50%, man-hours assigned to Work Packages: 1500

2.1.1.2 Reporting lines within the team



2.1.1.3 Time dedication of key personnel

Key Personnel	Total Hours dedicated to the Project	Total Working Hours during Project Timeframe	% of Total Working Hours dedicated to the Project
project manager Jaroslav Hofierka	1100	4000	27.5%
WP manager Michal Gallay	1000	4000	25%
WP manager Ján Kaňuk	600	4000	15%
WP manager Peter Morgenstein	1000	4000	25%
Researcher Ján Legény	400	4000	10%
Researcher Katarína Onačillová	800	4000	20%
Researcher Štefan Kolečanský	1200	4000	30%
Researcher Jozef Bogľarský	1500	4000	37.5%
Senior researcher Henrich Pifko	400	4000	10%
Researcher Lorant Krajcsovics	200	2000	10%
Researcher Tibor Varga	400	4000	10%
TOTAL	8600	42000	20.5%

2.2 CURRICULA VITAE

prof. Jaroslav Hofierka (project manager, WP leader) - Director of Institute, a professor in Geoinformatics. He is a co-author of the r.sun and v.sun solar radiation models implemented in open-source GRASS GIS. He has published a numerous papers on geospatial modelling, solar radiation modelling using GIS and 3-D city applications. He has been a member of the GRASS development team for more than 20 years. During this period he has been participating on the development of more than 10 GRASS GIS modules related to spatial interpolation and simulation of landscape processes such as solar radiation, surface hydrology and 3-D modelling. He was a principal investigator in several research projects funded by Slovak grant agencies (in total exceeding 300 000 EUR). He also participated in several international projects such as the 6th Framework Programme EU, INCO-COPERNICUS Programme, COST-ESF, and National Science Foundation (USA). In this project, he will be a principal investigator (a project manager) responsible for most research activities. The average percentage of the total working time 25%, man-hours assigned to Work Packages: 1000

Dr. Michal Gallay (WP leader) - Deputy Director and associate professor. He was awarded his Ph.D. in Geography. His research activities are focused on application of remote sensing techniques, such as laser scanning, IfSAR, and photogrammetry in digital terrain modelling. He was awarded his doctoral degree at the Queen's University Belfast in 2010 for the thesis on assessing digital elevation data acquired by alternative methods. He published 21 research papers on laser scanning data validation, spatial analysis of massive datasets, and vegetation spatio-temporal dynamics. He has been a co-investigator of 6 national research projects. Within the project, he will be responsible for processing and analysing the satellite imagery to derive suitable vegetation metrics and to downscale the metrics to 3-D urban greenery models. He will also participate on terrestrial laser scanning of urban greenery. His average percentage of the total working time 25%, man-hours assigned to Work Packages: 1000

Dr. Ján Kaňuk (WP leader) - Head of the Geoinformatics Research Group the Institute of Geography and associate professor. He was awarded his Ph.D. in Regional Geography at the Prešov University specialized in 3-D city modelling and assessment of landscape potential for photovoltaic applications. He is an assistant professor in Geography at the Institute. He is a principal investigator of a national research project focusing on dynamic 3-D modelling of urban landscape with a multiscale approach and a co-investigator of 1 international COST-ESF research project. He was a co-investigator in 8 national research projects in the past. He published over 20 scientific papers concerning solar radiation modelling in urban areas, photovoltaic energy potential in cities, and 3-D city modelling. Within the project, he will participate on terrestrial laser scanning of urban greenery, GNSS measurements as well as other measurements of the selected landscape components. He will be responsible for generating 3-D city models including 3-D urban greenery models, visualizations, processing multispectral satellite data, testing and validating the modelled solar radiation. Average percentage of the total working time 25%, man-hours assigned to Work Packages: 1000

Ing. arch. Peter Morgenstein, PhD. works as a researcher at the Institute of Ecological and Experimental Architecture of FA STU and at Danube University in Krems, Austria. In long-term he has been occupied with the research in the field of ecological architecture and urbanism, energy cooperation of urban structures, Smart City and Smart Grid concept. He is the co-author of the scientific monograph Solar strategy of a sustainable city. He has 27 records in the publication database, out of which 3 in WoS, 6 in Scopus, altogether 20 citations, out of which 4 in WoS and/or Scopus databases. He also gained experience at the Bratislava Chief City Architects Office.

Within the project, he will be the coordinator of the FA STU team. He will be responsible for selection of urban surfaces to be examined, which will form the basis of the materials catalogue. He will cooperate with the team members on obtainment and processing of data (emissivity, conductivity and reflectivity) of selected surfaces by researching actual databases and by direct communication with material producers as well as by measurements on site. He will be responsible for communication with municipalities and strategic partners of the project.

Ing. arch. Ján Legény, PhD. works as a researcher at the Institute of Ecological and Experimental architecture of FA STU. In a long term he has been occupied with problematics of ecological architecture, urban planning and generating of urban structures based on the sun movement. He is a co-author of the scientific monograph Solar strategy of a sustainable city. He has 39 records in the publication database, out of which 3 in WoS, 7 in Scopus, altogether 25 citations, out of which 7 in Scopus database. He participated in three national projects (VEGA, APVV) and one international project (Interreg Danube Transnational Programme). He was awarded twice a post-doc position at the STU with his research topic "Intensification of solar energy use in the urban space". He also gained

experience at the Bratislava Chief City Architects Office.

In the project, he will be a deputy of P. Morgenstein in the matters of coordination of the FA STU team. He will mainly be responsible for urban surfaces monitoring (emissivity, conductivity and reflectivity), especially of roofs.

Assoc. prof. Ing. arch. Henrich Pifko, PhD, (senior researcher) works at the Faculty of Architecture STU, Institute of Ecological and Experimental Architecture. His main field is the energy-efficient architecture, but he deals with the building materials and technologies and with the sustainable urban development too. He participated in national and international projects, including Interreg, 5thframe programme and Erasmus LLC (most important projects being EcoCity, OikoDomos, and OikoNet). He is author of the book NEED – Designing Energy-Efficient Houses, co-author of the books Efficient Housing, CESBA and Handbook of Sustainable Architecture. He has five of his scientific publications in the Scopus database and in WoS and Scopus he has 21 citations (5 of them in Scopus).

Ing. arch. Lorant Krajcsovics, PhD. works as a researcher at the Institute of Ecological and Experimental architecture of FA STU. In a long term he has been occupied with problematics of ecological low energy architecture. He will mainly be responsible for urban surfaces monitoring heat conductivity, albedo and emissivity measurements especially for hard landscape materials. He is a successful leader of national VEGA research project and participated in 3 EU granted projects. He has 21 records in the publication database, out of which 2 in WoS, 6 in Scopus, altogether 4 citations, out of which 3 in Scopus database.

Ing. arch. Tibor Varga, PhD. works as a researcher at the Institute of Ecological and Experimental architecture of FA STU. In a long term he has been occupied with problematics of construction materials and timber structures. He will mainly be responsible for for urban surfaces monitoring (heat conductivity, albedo and emissivity) measurements especially for building used materials, facades and roofs. Ing. arch. Peter Morgenstein, PhD. (WP leader) - Vice-dean and researcher at the Institute of Ecological and Experimental Architecture of FA STU and at Danube University in Krems, Austria. In long-term he has been occupied with the research in the field of ecological architecture and urbanism, energy cooperation of urban structures, Smart City and Smart Grid concept. Within the project, he will be the coordinator of the FA STU team. He will be responsible for obtainment and processing of energy consumption data input, analysis of energy flows of observed urban areas and completion of the 3D model development areas according to the actual regulation plans. Methodically, he will be participating on the definition of energy cooperation indicators and solar potential of urban structures as well as their implementation. He is the co-author of the scientific monograph Solar strategy of a sustainable city. He has 27 records in the publication database, out of which 3 in WoS, 6 in Scopus, altogether 20 citations, out of which 4 in WoS and/or Scopus databases. He also gained experience at the Bratislava Chief City Architects Office.

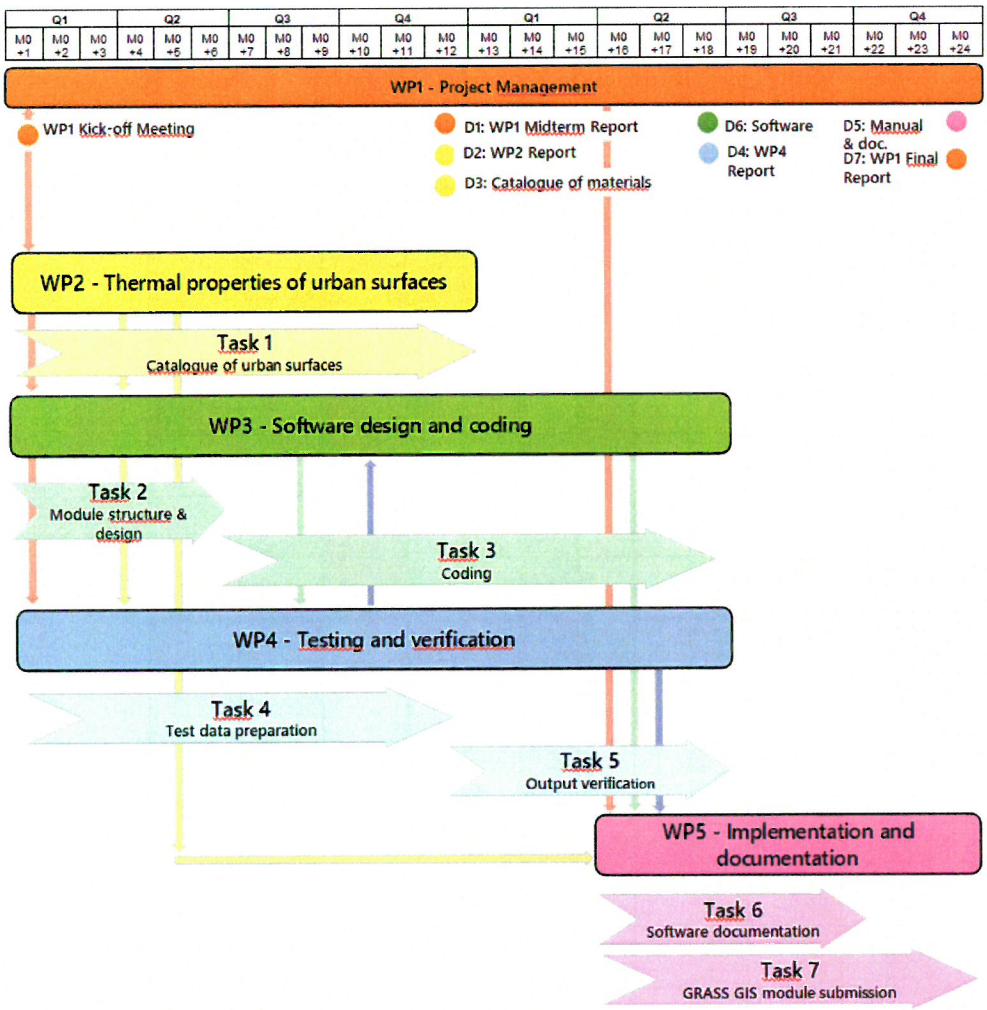
2.3 MANAGEMENT PLAN

The structure of the proposed team is well-balanced. The team is lead by well-experienced researchers including 5 senior researchers and several Ph.D. students. We also expect an involvement of Master graduate students by temporary contracts for works related to mapping and basic data processing. All researchers work in the same institution (Institute of Geography, P.J. Šafárik University in Košice), which is directed by prof. Hofierka who is also a principal investigator. The principal investigator will supervise all tasks within the project and, if needed, he will be substituted by doc. Gallay. Each partial objective will be done by at least 2 researchers. By this means, substitution in all aspects of project work is defined. Complementation of researchers results from the above description of their competences. The research team of UPJŠ will regularly meet with the cooperating research team of FA STU and we expect frequent virtual meetings using Skype and other virtual collaboration tools.

2.4 PLANNING

2.4.1. Gantt chart

2.4.2 Proposed Schedule



2.4.3 Meeting and Travel Plan

Meeting	Purpose	Companies attending	Date(s)	Location	Work Package or Milestone
Kick-off meeting	Kick-off meeting	Pavol Jozef Safarik University in Kosice	M1	teleconference	WP1
	Progress meeting	Pavol Jozef Safarik University in Kosice	M13	Kosice	MS1 (WP2)
	Final meeting	Pavol Jozef Safarik University in Kosice	M24	ESA	MS3 (WP1)

2.5 DELIVERABLE ITEMS

2.5.1 Documentation

Doc ID	Title	Milestone	Description of documents *
D1	*Midterm report*	*M12*	
D2	*WP2 report*	*M12 - end of Task 1*	Report comprising description of work performed under WP2
D3	*Catalogue of materials*	*M12 - end of Task 1*	Digital database of thermal properties of urban surface materials ascertained under WP2
D4	*WP4 report*	*M18 - end of Task 5*	Report on performance of the preliminary software code and bug reports.
D5	*Manual and documentation*	*M24 - end of Task 6*	Documentation and user manuals of software
D6	*Software - final product*	*M24*	Final software source code
TDP	Technical Data Package	Final Review	As defined in section 1.5 of Appendix 1 to the Draft Contract
ESR	Executive Summary Report	Final Review	see above
FR	Final Report	Final Review	see above
CCD	Contract Closure Documentation	Contract Closure	see above
FP	Final Presentation	Final Review	

2.5.2 Other Deliverables (Hardware, Software, Models, Data, etc.)

Item Identifier	Title	Milestone	Quantity to be delivered	Format / Description
SW1	Alpha version	M12 - see Gantt chart in 2.4.1	1	Source code/Deliver on DVD-ROM
SW2	Beta version	M15 - see Gantt chart in 2.4.1	1	Source code/Deliver on DVD-ROM
SW3	Release candidate 1	M19 - see Gantt chart in 2.4.1	1	Source code/Deliver on DVD-ROM
SW4	Release candidate 2	M22 - see Gantt chart in 2.4.1	1	Source code/Deliver on DVD-ROM
SW5	Final product	M24 - Contract Closure (M24), see Gantt chart in 2.4.1	1	Source code/Deliver on DVD-ROM

PART 3 FINANCIAL PART

3.1 PRICE QUOTATION FOR THE CONTEMPLATED CONTRACT:

The total amount quoted as a Firm Fixed Price (FFP) is 199,520 EUR.

Remarks concerning certain price elements:

a) Charging of royalties and licence fees:

Not applicable.

b) Quotations free of taxes and custom duties:

Both Prime Contractor and Subcontractor are public institutions established by law. We undertake research and development activity within our main activity, not as a commercial activity. Therefore, we will remain subject to payment of taxes and we are not eligible for VAT deduction (20%) according to national legislation of Slovakia.

3.2 DETAILED PRICE BREAKDOWN

3.2.1 PSS costing forms:

Annex to this Proposal:

- ***PSS A1** Company Cost Rates and Overheads*
- ***PSS A2** Company Price Breakdown Form*
- ***PSS A2** Exhibit A – Other Cost Element Details (if applicable)*
- ***PSS A2** Exhibit B – Travel and subsistence plan*
- ***PSS A8** Manpower & Price Summary per WP*

3.2.2 Milestone Payment Plan

Milestone (MS) Description	Schedule Date	Payments from ESA to (Prime) Contractor (in Euro)	Country (ISO code)
Progress (MS 1): Upon successful completion of WP 2 and/or successful [review] and acceptance by the Agency of all related deliverable items [Test data - D.1 ,D2, D3, D4, D5].	To +12 months	134,870	SK
Progress (MS 2): Upon successful completion of Wp3, Wp4 and/or successful review and acceptance by the Agency of all related deliverable items [D6-D13].	To + 18 months	44,698	
Final Settlement (MS 3): Upon the Agency's final acceptance of software and acceptance of all deliverable items due under the Contract and the Contractor's fulfilment of all other contractual obligations including submission of the Contract Closure Documentation	To + 24 months	*19,952* *(not less than 10% of the total contract price)*	
TOTAL		199,520	

Prime (P)	Company Name	ESA Entity Code (at contract signature)	Country (ISO code)	Advance Payment (in Euro)	Offset against	Offset by Euro	Condition for release of the Advance Payment
P	Pavol Jozef Safarik University in Kosice	1000017323	SK	*19,952*	MS 1	*19,952*	Upon signature of the Contract by both Parties

Univerzita Pavla Jozefa Šafárika
v Košiciach
Šrobárova 2, 041 80 Košice

For Information purposes only : **Amounts in Euro for Contractor and Subcontractor(s)**						
Milestone (MS) Description	**Prime Contractor**	***Insert Country (ISO code)***	**Sub-contractor name**	***Insert Country (ISO code)***	**Sub-contractor name**	***Insert Country (ISO code)***
MS1	Pavol Jozef Safarik University in Kosice (SK) 77,462 EUR		Slovak University of Technology in Bratislava (SK) 57,408 EUR			
MS2	Pavol Jozef Safarik University in Kosice (SK) 44,698 EUR					
MS3	Pavol Jozef Safarik University in Kosice (SK) 19,952 EUR					

3.3 COST TO COMPLETION

3.3.1 Further steps/ Activities needed to complete the development

This software product does not require a higher TRL for a full applicability.

3.3.2 Estimated Cost per step

Not applicable

PART 4 CONTRACT CONDITIONS PART :

4.1 INTELLECTUAL PROPERTY RIGHTS

4.1.1. Background Intellectual Property and Third Party Intellectual Property Rights

In line with Article 6.3 of the Draft Contract, no Background Intellectual Property and no Third Party Intellectual Property Rights will be used to achieve the objectives of the work.

4.1.2 Foreground Intellectual Property

The Foreground Intellectual Property Rights are expected in relation to the developed software, its source code, documentation, and associated materials which will be licensed under terms of the GNU General Public License (GPL).

4.1.3 Ownership of Foreground Intellectual Property *(Article 6.2.1 of the draft Contract)*

The developed software, its source code, documentation, and associated materials should be licensed under terms of the GNU General Public License (GPL). The Prime contractor and the Sub-contractor reached the agreement between the parties on the ownership of the Intellectual Property and the principles for its exploitation, use and benefits.
We confirm that the Agency shall have an irrevocable right to use the information used in that application, for its own requirements on the terms set out in Article 6.2.2 of the draft Contract.

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v Košiciach
Šrobárova 2, 041 80 Košice

4.2 IMPORT AND EXPORT LICENCES

4.2.1 Import and Export Licences applicable to this Activity

The Tenderer declares that no items subject to import or export control will be used in the execution of this activity.

4.2.2 Import and Export Licences applicable to a product or services arising from or resulting from this Activity

The Tenderer declares that any products or services arising from or resulting from this activity will not be subject to import or export control or make use of any import/ export controlled items.

ATTACHMENTS:

ANNEX 1: Signed PSS-A1 form
Signed PSS-A2 form
Signed PSS-A2 Exhibit A form
Signed PSS-A2 Exhibit B form
Signed PSS-A8 form

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COMPANY RATES AND OVERHEADS	FORM No. PSS A1	Page no. 1 of 1	Issue 5
		COMPANY NAME:	Pavol Jozef Safarik University in Kosice
RFQ/ITT no.:	AO/1-9588/18/NL/SC		
PROPOSAL no.:	1000024234	Name and title:	prof. RNDr. Pavol Sovák, CSc., rector
ECONOMIC CONDITIONS:	24 months		
NATIONAL CURRENCY (NC):	EUR	Signature:	
VALIDITY PERIOD :	From. 1.10.2019 To.30.9.2021		
ESA Audit agreement reference / date			

Univerzita Pavla Jozefa Šafárika v Košiciach Šrobárova 2, 041 80 Košice

	Agreed by
	Status (x when applicable)

1. LABOUR

Direct labour cost centres or categories Code and Name		Basic Hourly Rate (NC)	Direct Overhead (% or Rate in NC)	Gross Hourly Rate (NC)
1,1	Senior researcher	15,00	35,2	20,28
1,2	Researcher	10,00	35,2	13,52

2. INTERNAL SPECIAL FACILITIES

Facility Code and Name		Type of Unit	UNIT RATE (NC)

3. OTHER COST ELEMENTS

Standard ESA type		According to normal company type	OVERHEAD %
3,1	Raw materials		
3,2	Mechanical parts		
3,3	Semi-finished products		
3,4	Electric & electronic components		
3,5	Hirel parts		
	a) procured by company		
	b) procured by 3rd party		
3,6	External major products		
3,7	External services	20000	15
3,8	Transport, insurance		
3,9	Travels	1500	15
3,10	Miscellaneous		

GENERAL EXPENSES

According to ESA type	According to normal company type	Applicable on cost element no.	OVERHEAD %
5. General & Administration expenses			
6. Research & Development expenses	102076		15
7. Other (specify)			

COMPANY PRICE BREAKDOWN FORM		Form No. PSS A2		Page no. 1 of 1	Issue 5
RFQ/ITT No.:	AO/1-9588/18/NL/SC		COMPANY		
Proposal/Tender No.:	1000024234		Name:	Pavol Jozef Safarik University in Kosice	
Type of Price:	FFP	Firm Fixed Price	Country:	Slovakia	
Economic Condition:	24 months				
National Currency (NC):	EUR		Representative		
Exchange Rate (X):	1 EURO =	1,00000 EUR	Name and Title:		
Contractual Phase:			Signature:	Univerzita Pavla Jozefa Šafárika v Košiciach prof. RNDr. Pavol Sovák, CSc., rector Šrobárova 2, 041 80 Košice -26-	
Project/Work Package(s):	TEMPUS	/ WP1, 3,4,5			

							TOTAL (NC) EUR	TOTAL (EURO) NC / X
	LABOUR							
Direct Labour cost centres or categories Code / Description		*No. of FTE (calculated) U = W / V*	*Sold Hours per ManYear V*	*Manpower Effort No. of Hours W*	*Gross Hourly Rate in NC*			
1,1	senior researcher	1,4	2 000	2 700	20,28		54 756,00	54 756,00
1,2.	researcher	1,8	2 000	3 500	13,52		47 320,00	47 320,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
1	Total Direct Labour Hours and Cost	*3,1*		*6200,0*		**A**	*102 076,00*	*102 076,00*
	INTERNAL SPECIAL FACILITIES							
Code	*Description*		*Type of unit*	*No. of units*	*Unit rates in NC*			
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
2	*Total Internal Special Facilities Cost*					**B**	*0,00*	*0,00*
	OTHER DIRECT COST ELEMENTS	*Base amounts in NC*	*+ OH %*	*OH amounts in NC*				
3,1	Raw materials						0,00	0,00
3,2	Mechanical parts						0,00	0,00
3,3	Semi-finished products						0,00	0,00
3,4	Electrical & electronic components						0,00	0,00
3,5	HIREL parts							
	a) procured by company						0,00	0,00
	b) procured by third party						0,00	0,00
3,6	External Major Products						0,00	0,00
3,7	External Services	20 000	15,0%	3 000			23 000,00	23 000,00
3,8	Transport and Insurances						0,00	0,00
3,9	Travel and Subsistence	1 500	15,0%	225			1 725,00	1 725,00
3,10	Miscellaneous						0,00	0,00
3	*Total Other Direct Cost*	*21 500,00*		*3 225,00*		**C**	*24 725,00*	*24 725,00*
4	**SUB-TOTAL DIRECT COST**				**(A+B+C)**	**D**	**126 801,00**	**126 801,00**
	GENERAL EXPENSES	*Cost items to which % applies*		*Base Amount in NC*	*OH %*			
5	General & Administration Expenses					**E**	0,00	0,00
6	Research & Development Expenses			102 076	15,0%	**F**	15 311,00	15 311,00
7	Other					**G**	0,00	0,00
8	**TOTAL COMPANY COST**				**D+(E+F+G)**	**H**	**142 112,00**	**142 112,00**
		Cost items to which % applies		*Base Amount in NC*	*%*			
9	PROFIT			0,0	0,0%	**I**	0,00	0,00
10	COST WITHOUT ADDITIONAL CHARGE					**J**		0,00
11	FINANCIAL PROVISION FOR ESCALATION					**K**		0,00
12	**TOTAL COMPANY PRICE**				**(H+I+J+K)**	**L**	**142 112,00**	**142 112,00**
13	TOTAL SUB-CONTRACTOR PRICE					**M**		0,00
14	REDUCTION for COMPANY CONTRIBUTION					**N**		0,00
15	**TOTAL PRICE FOR ESA**				**(L+M-N)**		**142 112,00**	**142 112,00**

If insufficient space is available to identify all required information, please use additional sheet or insert lines

COMPANY PRICE BREAKDOWN FORM		EXHIBIT "A" TO PSS A2				Issue 5
		Page No.		No. of Pages		
RFQ/ITT No.:	AO/1-9588/18/NL/SC	COMPANY NAME:	**Pavol Jozef Safarik University in Kosice**			
Proposal/Tender No.:	TEMPUS 1000024234	Name and Title:	**prof. RNDr. Pavol Sovák, CSc., rector**			
National Currency:	EUR					
Contractual Phase		Signature	Univerzita Pavla Jozefa Šafárika v Košiciach Šrobárova 2, 041 80 Košice			
Applicable to PSS-A2 elements: 3.1-3.4 - 3.6 - 3.7 - 3.10 - 10						
Project TEMPUS / Work Packages 1, 3, 4, 5						

Cost El. No.	ITEM DESCRIPTION	Type of Price	Purchase Currency	Purchase Amount	Exchange rate 1 NC =	Amount in NC
1,1	Senior researcher	FFP	EUR	52 728,00	1,00000	54 756,00
1,2	Researcher	FFP	EUR	54 080,00	1,00000	47 320,00
3,9	Travel and Subsistence	FFP	EUR	1 725,00	1,00000	1 725,00
3,7	External Services - airborne and terrestrial thermal imaging data, country: Slovakia	FFP	EUR	23 000,00	1,00000	23 000,00
6	Research & Development Expenses	FFP	EUR	16 021,00	1,00000	15 311,00

TRAVEL PLAN AND COST DETAIL

EXHIBIT "B" TO PSS-A2

Issue 1

RFQ/ITT No.:	AO/1-9588/18/NL/SC	Representative name and title: prof. RNDr. Pavol Sovák, CSc., rector	Project:	**TEMPUS**	
Proposal/Tender No.:	1000024234	Signature:	Company:	**Pavol Jozef Safarik University in Kosice**	
Contractual Phase					
Economic Condition:					
National Currency (NC)*:	**EUR**		Type of Price:	FFP	
			Exchange (X): 1 EURO =	1 EUR	

v Košiciach

041 80 Košice

WP Reference Number	WP Title	Purpose/Event	Departure	Destination	Nr. of Trips	Avg.People per Trip	Travel Cost p.p. (NC)	B / E	Avg.Days per Trip	Subsistence Cost p.d. (NC)	A / R	Total Cost (NC)	Total Cost (EURO)
WP1	Project management	Final meeting	Kosice	ESA	1	2	390	E	3	120		1 500	1 500
												0	0
												0	0
												0	0
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												0	0
Total Cost, WBS level 1 (equal to the item 3.9 of PSS-A2)												**1 500**	**1 500**

COMPANY MANPOWER AND PRICE SUMMARY PER WP

Form no. **PSS/A8**

Issue 5

ITT/RFQ:	AO/1-9588/18/NL/SC
Proposal/Tender No.:	1000024234
Company Name:	Pavol Jozef Safarik University in Kosice
Contractual Phase:	
WBS-Level (Number and Title):	1

Representative name and title: prof. RNDr. Pavol Sovák, CSc.

Signature:

Univerzita Pavla Jozefa Šafárika v Košiciach Šrobárova 2, 041 80 Košice

Price Type:	FFP
Economic Conditions:	24 months
National Currency (NC):	EUR
Exchange Rate: 1 EUR =	

WP Title		Project management	Software design and coding	Testing and verification	Implementation and documentation									Total WBS-Level
WP Number		1	3	4	5									
Labour Hours per category	Hours													
Senior researcher	#	200	700	1 000	800									
Researcher	#		1 700	1 400	400									
...	#													
...	#													
...	#													
...	#													
...	#													
...	#													
Total Labour Hours	#	200	2 400	2 400	1 200									
1. Total Labour Cost	NC	4 056,00	37 180,00	39 208,00	21 632,00									
2. Internal Special Facilities Cost	NC													
3.1-3.4 Material Costs	NC													
3.5 High Rel Parts Costs	NC													
3.6 External Major Products Cost	NC													
3.7 External Services Cost	NC			20 000,00										
3.8 Transport/Insurance Cost	NC													
3.9 Travel and Subsistence Cost	NC	1 500,00												
3.10 Miscellaneous Cost	NC													
3. Total Other Costs (sum of above 3.x)	NC	1 500,00		20 000,00										
4. Sub-Total Direct Cost	NC	5 556,00	37 180,00	59 208,00	21 632,00									
5.- 7. General expenses	NC	833,00	5 577,00	8 881,00	3 245,00									
8. Sub-Total Company Cost	NC	6 389,00	42 757,00	68 089,00	24 877,00									
9. Profit Fee	NC													
10. Cost without additional charge	NC													
11. Financial Provision for escalation	NC													
12. Total Company Price	NC													
	EURO													
13. Total Sub-Contractors Price	NC													
	EURO													
14. Reduction for Company contribution	NC													
15. Total Price for ESA	NC	6 389,00	42 757,00	68 089,00	24 877,00									
	EURO	6 389,00	42 757,00	68 089,00	24 877,00									

If more than 12 WPs are to be reported, then duplicate the form as necessary, do not add columns.

If Labour Categories require more lines, please add as necessary.

COMPANY RATES AND OVERHEADS	FORM No. PSS A1		Page no. 1 of 1	Issue 5
			COMPANY NAME:	Slovak University of Technology in Bratislava
RFQ/ITT no.:	AO/1-9588/18/NL/SC			
PROPOSAL no.:	1000024234		Name and title:	prof.h.c. prof. Ing. Robert Redhammer, PhD.,
ECONOMIC CONDITIONS:	24 months			
NATIONAL CURRENCY (NC):	EUR		Signature:	
VALIDITY PERIOD :	From. 1.10.2019	To.30.9.2021		
ESA Audit agreement reference / date				

Agreed by	
Status (x when applicable)	

1. LABOUR

Direct labour cost centres or categories Code and Name		Basic Hourly Rate (NC)	Direct Overhead (% or Rate in NC)	Gross Hourly Rate (NC)
1,1	Senior researcher	12,80	35,2	17,30
1,2	Researcher	8,66	35,2	11,70

2. INTERNAL SPECIAL FACILITIES

Facility Code and Name		Type of Unit	UNIT RATE (NC)

3. OTHER COST ELEMENTS

Standard ESA type		According to normal company type	OVERHEAD %
3,1	Raw materials		
3,2	Mechanical parts		
3,3	Semi-finished products		
3,4	Electric & electronic components		
3,5	Hirel parts		
	a) procured by company		
	b) procured by 3rd party		
3,6	External major products	12500	15
3,7	External services		
3,8	Transport, insurance		
3,9	Travels	1500	15
3,10	Miscellaneous		

GENERAL EXPENSES

According to ESA type	According to normal company type	Applicable on cost element no.	OVERHEAD %
5. General & Administration expenses			
6. Research & Development expenses	35920		15
7. Other (specify)			

COMPANY PRICE BREAKDOWN FORM				Form No. PSS A2	Page no. of	Issue 5
RFQ/ITT No.:	AO/1-9588/18/NL/SC			COMPANY		
Proposal/Tender No.:	1000024234			Name:	Slovak University of Technology in Bratislava	
Type of Price:	FFP	Firm Fixed Price		Country:	Slovakia	
Economic Condition:	24 months					
National Currency (NC):	EUR			Representative		
Exchange Rate (X):	1 EURO =	1,00000	EUR	Name and Title:	prof.h.c. prof. Ing. Robert Redhammer, PhD., rector	
Contractual Phase:				Signature:		
Project/Work Package(s):	TEMPUS/WP2					

							TOTAL (NC) EUR	TOTAL (EURO) NC / X
	LABOUR							
Direct Labour cost centres or categories Code / Description		*No. of FTE (calculated) U = W / V*	*Sold Hours per ManYear V*	*Manpower Effort No. of Hours W*	*Gross Hourly Rate in NC*			
1,1	senior researcher	0,7	2 000	1 400	17,30		24 220,00	24 220,00
1.2.	researcher	0,5	2 000	1 000	11,70		11 700,00	11 700,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
1	Total Direct Labour Hours and Cost	*1,2*		*2400,0*		A	*35 920,00*	*35 920,00*
	INTERNAL SPECIAL FACILITIES							
Code	*Description*		*Type of unit*	*No. of units*	*Unit rates in NC*			
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
							0,00	0,00
2	*Total Internal Special Facilities Cost*					B	*0,00*	*0,00*
	OTHER DIRECT COST ELEMENTS	*Base amounts in NC*	*+ OH %*	*OH amounts in NC*				
3,1	Raw materials						0,00	0,00
3,2	Mechanical parts						0,00	0,00
3,3	Semi-finished products						0,00	0,00
3,4	Electrical & electronic components						0,00	0,00
3,5	HIREL parts							
	a) procured by company						0,00	0,00
	b) procured by third party						0,00	0,00
3,6	External Major Products	12 500	15,0%	1 875			14 375,00	14 375,00
3,7	External Services						0,00	0,00
3,8	Transport and Insurances						0,00	0,00
3,9	Travel and Subsistence	1 500	15,0%	225			1 725,00	1 725,00
3,10	Miscellaneous						0,00	0,00
3	*Total Other Direct Cost*	*14 000,00*		*2 100,00*		C	*16 100,00*	*16 100,00*
4	**SUB-TOTAL DIRECT COST**				(A+B+C)	D	**52 020,00**	**52 020,00**
	GENERAL EXPENSES	*Cost items to which % applies*		*Base Amount in NC*	*OH %*			
5	General & Administration Expenses					E	0,00	0,00
6	Research & Development Expenses			35 920	15,0%	F	5 388,00	5 388,00
7	Other					G	0,00	0,00
8	**TOTAL COMPANY COST**				D+(E+F+G)	H	**57 408,00**	**57 408,00**
		Cost items to which % applies		*Base Amount in NC*	*%*			
9	PROFIT			0,0	0,0%	I	0,00	0,00
10	COST WITHOUT ADDITIONAL CHARGE					J		0,00
11	FINANCIAL PROVISION FOR ESCALATION					K		0,00
12	**TOTAL COMPANY PRICE**				(H+I+J+K)	L	**57 408,00**	**57 408,00**
13	TOTAL SUB-CONTRACTOR PRICE					M		0,00
14	REDUCTION for COMPANY CONTRIBUTION					N		0,00
15	**TOTAL PRICE FOR ESA**				(L+M-N)		**57 408,00**	**57 408,00**

If insufficient space is available to identify all required information, please use additional sheet or insert lines

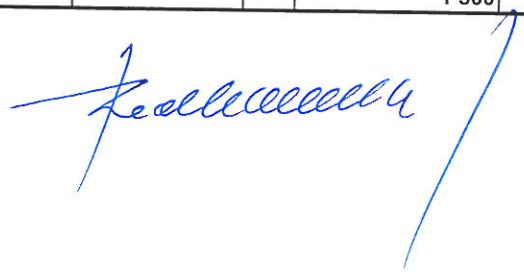
COMPANY PRICE BREAKDOWN FORM		EXHIBIT "A" TO PSS A2				Issue 5
		Page No. 1		No. of Pages 1		
RFQ/ITT No.:	AO/1-9588/18/NL/SC	COMPANY NAME:	**Slovak University of Technology in Bratislava**			
Proposal/Tender No.:	1000024234	Name and Title:	**prof.h.c. prof. Ing. Robert Redhammer, PhD. Rector**			
National Currency:	EUR					
Contractual Phase		Signature				
Applicable to PSS-A2 elements: 3.1-3.4 - 3.6 - 3.7 - 3.10 - 10						
Project / Work Packages	**TEMPUS**					

Cost El. No.	ITEM DESCRIPTION	Type of Price	Purchase Currency	Purchase Amount	Exchange rate 1 NC =	Amount in NC
1,1	Senior researcher	FFP	EUR	24 220,00	1,00000	24 220,00
1,2	Researcher	FFP	EUR	11 700,00	1,00000	11 700,00
3,9	Travel and Subsistence	FFP	EUR	1 725,00	1,00000	1 725,00
3,6	External Major Products - terrestrial emissivity, albedo and conductivity data useing measurement devices: Reflectomer, Emissomer, Conductomer and Moisture measurement device, country: Slovakia	FFP	EUR	14 375,00	1,00000	14 375,00

TRAVEL PLAN AND COST DETAIL — **EXHIBIT "B" TO PSS-A2** — Issue 1

RFQ/ITT No.:	AO/1-9588/18/NL/SC	Project:	TEMPUS	
Proposal/Tender No.:	1000024234	Company:	**Slovak University of Technology in Bratislava**	
Contractual Phase		Name and Title:	**prof.h.c. prof. Ing. Robert Redhammer, PhD.**	Rector
Economic Condition:	FFP	Type of Price:	FFP	
National Currency (NC)*:	**EUR**	Exchange (X): 1 EURO =	1 EUR	

WP Reference Number	WP Title	Purpose/Event	Departure	Destination	Nr. of Trips	Avg.People per Trip	Travel Cost p.p. (NC)	B / E	Avg.Days per Trip	Subsistence Cost p.d. (NC)	A / R	Total Cost (NC)	Total Cost (EURO)
WP2	Thermal properties of urban surfaces	Final meeting	Bratislava	ESA	1	2	390	E	3	120		1 500	1 500
Total Cost, WBS level 1 (equal to the item 3.9 of PSS-A2)												**1 500**	**1 500**



COMPANY MANPOWER AND PRICE SUMMARY PER WP Form no. **PSS A8** Page 1 of 1 Issue 5

ITT/RFQ:	AO/1-9588/18/NL/SC
Proposal/Tender No.:	1000024234
Company Name:	Slovak University of Technology in Bratislava
Contractual Phase:	
WBS-Level (Number and Title):	1

Name and Title: Rector
prof h.c. prof. Ing. Robert Redhammer, PhD.
Signature:

Price Type:	FFP
Economic	24 months
National Currency	EUR
Exchange Rate:	

WP Title		Thermal properties of urban surfaces	
WP Number		2	Total WBS-Level
Labour Hours per category	Hours		
Senior researcher	#	1 400	
Researcher	#	1 000	
...	#		
...	#		
...	#		
...	#		
...	#		
...	#		
Total Labour Hours	#	2 400	
1. Total Labour Cost	NC	35 920,00	
2. Internal Special Facilities Cost	NC		
3.1-3.4 Material Costs	NC		
3.5 High Rel Parts Costs	NC		
3.6 External Major Products Cost	NC	12 500,00	
3.7 External Services Cost	NC		
3.8 Transport/Insurance Cost	NC		
3.9 Travel and Subsistence Cost	NC	1 500,00	
3.10 Miscellaneous Cost	NC		
3. Total Other Costs (sum of above 3.x)	NC		
4. Sub-Total Direct Cost	NC	49 920,00	
5.- 7. General expenses	NC	7 488,00	
8. Sub-Total Company Cost	NC	57 408,00	
9. Profit Fee	NC		
10. Cost without additional charge	NC		
11. Financial Provision for escalation	NC		
12. Total Company Price	NC		
	EURO		
13. Total Sub-Contractors Price	NC		
	EURO		
14. Reduction for Company contribution	NC		
15. Total Price for ESA	NC	57 408,00	
	EURO	57 408,00	

If more than 12 WPs are to be reported, then duplicate the form as necessary, do not add columns

If Labour Categories require more lines, please add as necessary.