7th Framework Programme

FP7-ICT-2013-10 N.611145

Dissemination Plan

Deliverable n.	D8.5	Dissemination of the Results	
Workpackage	WP8	Dissemination Activities and Exploitation of Results	
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Status	Final		
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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
COSUF	Committee on Operational Safety of Underground Facilities
CV	Computer Vision
IAARC	International Association for Automation and Robotics in Construction
ITA	International Tunnelling and underground Association
TRIP	Transport Research and Innovation Portal

EXECUTIVE SUMMARY

This deliverable includes a comprehensive report on public awareness and dissemination activities performed within the ROBO-SPECT project.

Public awareness activities were oriented on spreading the information about the project to the broad community to set the ground for exploitation of results or possible technology transfer. Major awareness/communication activities included:

- Project public website
- Sixth-monthly newsletters
- Social networks to communicate with larger audiences (twitter and LinkedIn)
- Videos showing the ROBO-SPECT system at work at YouTube
- Press releases
- ROBO-SPECT leaflet and brochure
- Presentation of the results to the public at large

The dissemination activities were performed to share the technical results of the project with the relevant business and scientific communities and promote the industrial exploitation of the results. Major dissemination activities included:

- Project workshops and special sessions
- Presentations/publications
- Presentation of the Project Results to Robotics/Construction/Tunnel Audiences
- Formation of a group of external experts to assure the project's technical solutions are properly addressing the requirements from the tunnel inspection and assessment sector and to increase the deployability and acceptance of the ROBO-SPECT solutions.
- Communication with the European National Tunnelling Associations
- Communication with seven National Technical Platforms in Construction
- ROBO-SPECT presentation to Spanish robotic networks, associations, webs, and platforms
- Theses, Teaching, Seminars
- News releaqses to the International Association for Automation and Robotics in Construction (IAARC) and the Transportation Research Portal (TRIP).

INTRODUCTION

The dissemination of activities performed and results achieved represents one of the most important phases in a research project. The main objective being to raise awareness towards any potentially interested parties and to ensure that the final outcomes of the project are properly communicated and exploited.

To this end a number of dissemination activities have been undertaken and tools produced during the ROBO-SPECT lifetime that are described in the following sections.

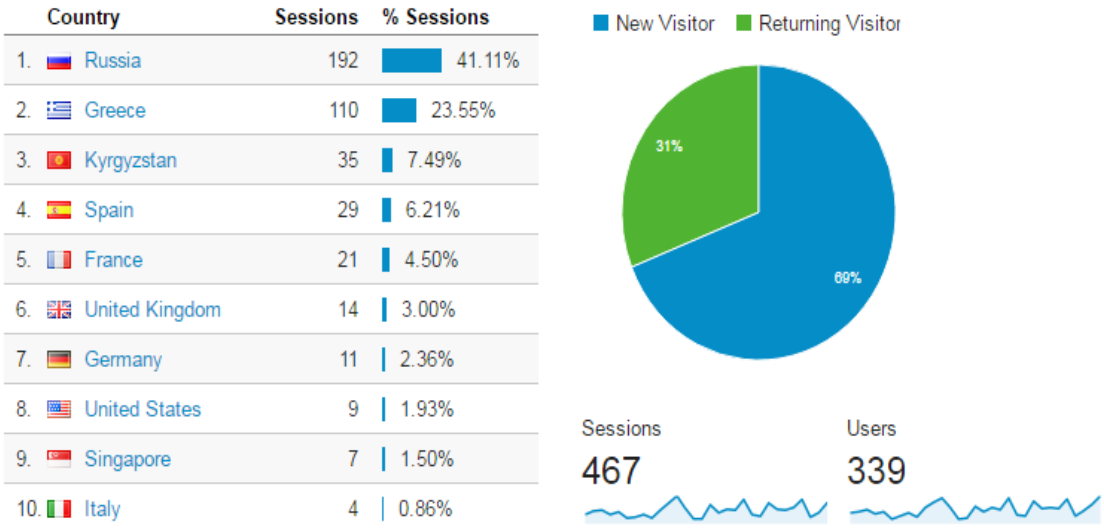
This report includes a summary of all the dissemination and communication activities performed throughout the whole ROBO-SPECT project duration. All activities have been included into separate chapters in the sections that follow.

PROJECT WEB SITE

A project website (www.robo-spect.eu, ANNEX I) has been developed in view of disseminating project outcomes; it includes project objectives and background, significant achievements, technology news, consortium contacts, scientific publications and presentations, etc. The website has been maintained and updated on a regular basis during the project's lifetime. In addition, after the completion of the project and at least for five years, the website will be sustained in order to provide all interested stakeholders with information on achievements and results, as well as contact details.

Figure 1 ROBO-SPECT Website

On average there are close to 500 unique visitors per month at the ROBO-SPECT web site providing a significant demographic coverage as can be seen in the figure below.



	Country	Sessions	% Sessions
1.	Russia	192	41.11%
2.	Greece	110	23.55%
3.	Kyrgyzstan	35	7.49%
4.	Spain	29	6.21%
5.	France	21	4.50%
6.	United Kingdom	14	3.00%
7.	Germany	11	2.36%
8.	United States	9	1.93%
9.	Singapore	7	1.50%
10.	Italy	4	0.86%

Figure 2 ROBO-SPECT website demographics

PROJECT NEWSLETTERS

Six sixth-monthly newsletters have been produded that depict the project's main outcomes together with dissemination activities and ucoming events related to the project itself. They can be found online on the project website.

Some indicative snapshots of the ROBO-SPECT newsletters have been added below:


ROBO-SPECT NEWS

ROBOtic System with Intelligent Vision and Control for Tunnel Structural INSPECTion and Evaluation

ROBO-SPECT

Issue 5 June 2016

Editorial

Welcome to this ROBO-SPECT's fifth newsletter.

ROBO-SPECT is a European 7th Framework project funded under the ICT programme on Robotics Use Cases (contract No. 611145), implemented by 10 partners from 6 European countries.

The main objective of the project consortium is to provide an automated, speedy and reliable tunnel inspection and assessment solution that can combine in one pass both inspection and detailed structural assessment and that only minimally interfere with tunnel traffic. The proposed robotic system has been evaluated at the research infrastructure of VSH in Switzerland and at a tunnel of Egnatia Motorway in Greece, while its final version will also be field evaluated and benchmarked at an Egnatia Motorway tunnel in Greece.

The project officially launched its activities in October 2013. During the first years of the project the partners identified an extended group of end-users, derived user requirements and specifications and based on these, designed the first prototypes of all components and the integrated robotic system.

Inside this issue you will find the results of the field evaluation of the ROBO-SPECT robotic system at the Egnatia Motorway tunnel and information on the consortium's participation in conferences and other events related to the project's research field.

Angelos Amditis

Project Coordinator

PROJECT FACTS

Duration: 1 October 2013 – 30 September 2016

Total Cost: 4.592.196,00€

EU contribution: 3.306.599,00€

www.robo-spect.eu

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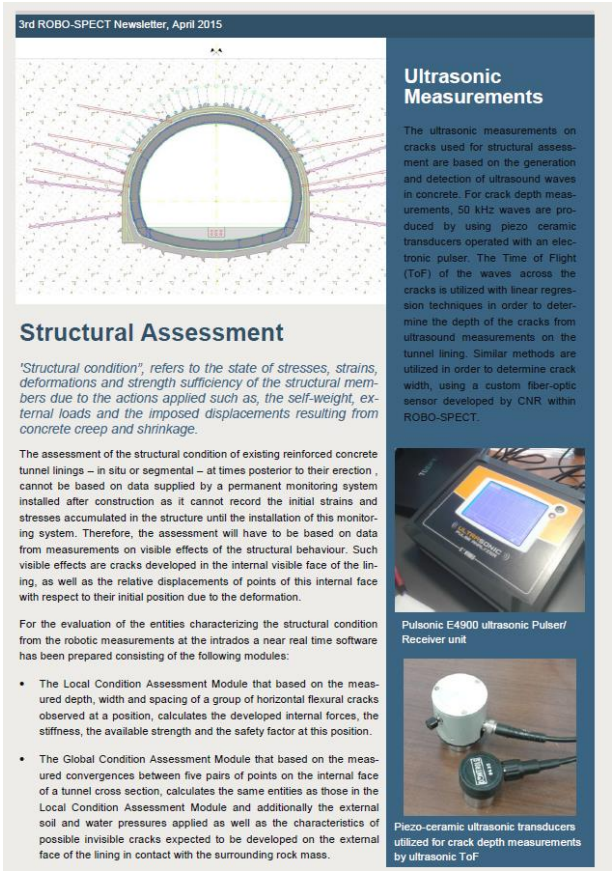
ROBO-SPECT


3rd ROBO-SPECT Newsletter, April 2015

Structural Assessment

"Structural condition", refers to the state of stresses, strains, deformations and strength sufficiency of the structural members due to the actions applied such as, the self-weight, external loads and the imposed displacements resulting from concrete creep and shrinkage.

The assessment of the structural condition of existing reinforced concrete tunnel linings – in situ or segmental – at times posterior to their erection , cannot be based on data supplied by a permanent monitoring system installed after construction as it cannot record the initial strains and stresses accumulated in the structure until the installation of this monitoring system. Therefore, the assessment will have to be based on data from measurements on visible effects of the structural behaviour. Such visible effects are cracks developed in the internal visible face of the lining, as well as the relative displacements of points of this internal face with respect to their initial position due to the deformation.

For the evaluation of the entities characterizing the structural condition from the robotic measurements at the intrados a near real time software has been prepared consisting of the following modules:

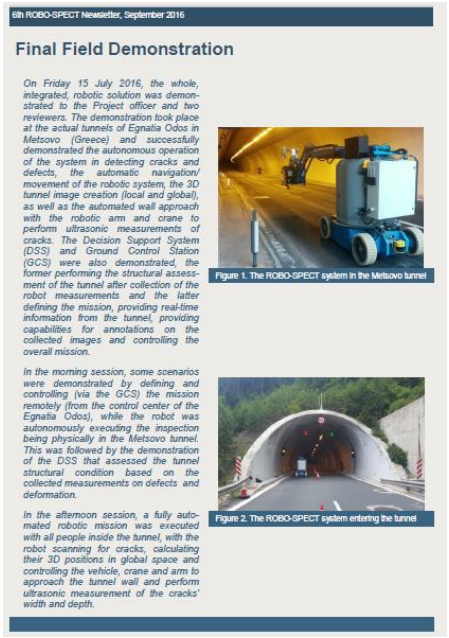
- The Local Condition Assessment Module that based on the measured depth, width and spacing of a group of horizontal flexural cracks observed at a position, calculates the developed internal forces, the stiffness, the available strength and the safety factor at this position.
- The Global Condition Assessment Module that based on the measured convergences between five pairs of points on the internal face of a tunnel cross section, calculates the same entities as those in the Local Condition Assessment Module and additionally the external soil and water pressures applied as well as the characteristics of possible invisible cracks expected to be developed on the external face of the lining in contact with the surrounding rock mass.

Ultrasonic Measurements

The ultrasonic measurements on cracks used for structural assessment are based on the generation and detection of ultrasound waves in concrete. For crack depth measurements, 50 kHz waves are produced by using piezo ceramic transducers operated with an electronic pulser. The Time of Flight (ToF) of the waves across the cracks is utilized with linear regression techniques in order to determine the depth of the cracks from ultrasound measurements on the tunnel lining. Similar methods are utilized in order to determine crack width, using a custom fiber-optic sensor developed by CNR within ROBO-SPECT.

Pulsonic E4900 ultrasonic Pulser/ Receiver unit

Piezo-ceramic ultrasonic transducers utilized for crack depth measurements by ultrasonic ToF


6th ROBO-SPECT Newsletter, September 2016

Final Field Demonstration

On Friday 15 July 2016, the whole, integrated, robotic solution was demonstrated to the Project officer and two reviewers. The demonstration took place at the actual tunnels of Egnatia Odos in Metsovo (Greece) and successfully demonstrated the autonomous operation of the system in detecting cracks and defects, the automatic navigation/ movement of the robotic system, the 3D tunnel image creation (local and global), as well as the automated wall approach with the robotic arm and crane to perform ultrasonic measurements of cracks. The Decision Support System (DSS) and Ground Control Station (GCS) were also demonstrated, the former performing the structural assessment of the tunnel after collection of the robot measurements and the latter defining the mission, providing real-time information from the tunnel, providing capabilities for annotations on the collected images and controlling the overall mission.

Figure 1. The ROBO-SPECT system in the Metsovo tunnel

In the morning session, some scenarios were demonstrated by defining and controlling (via the GCS) the mission remotely (from the control center of the Egnatia Odos), while the robot was autonomously executing the inspection being physically in the Metsovo tunnel. This was followed by the demonstration of the DSS that assessed the tunnel structural condition based on the collected measurements on defects and deformation.

Figure 2. The ROBO-SPECT system entering the tunnel

In the afternoon session, a fully automated robotic mission was executed with all people inside the tunnel, with the robot scanning for cracks, calculating their 3D positions in global space and controlling the vehicle, crane and arm to approach the tunnel wall and perform ultrasonic measurement of the cracks' width and depth.

Figure 3 ROBO-SPECT Newsletters

SOCIAL NETWORKS

The Twitter account is https://twitter.com/robo-spect while the LinkedIn group that has been established is named ROBO-SPECT and can be found under the link http://www.linkedin.com/groups?gid=7445986. The links to the social media are available in all website pages.

The Tweeter account of the ROBO-SPECT has a good presence in the Social Media generating more than 100 Tweets.The followers are important companies and media such as the TBM Magazine, Kemerli Metal, Hisparob, etc.

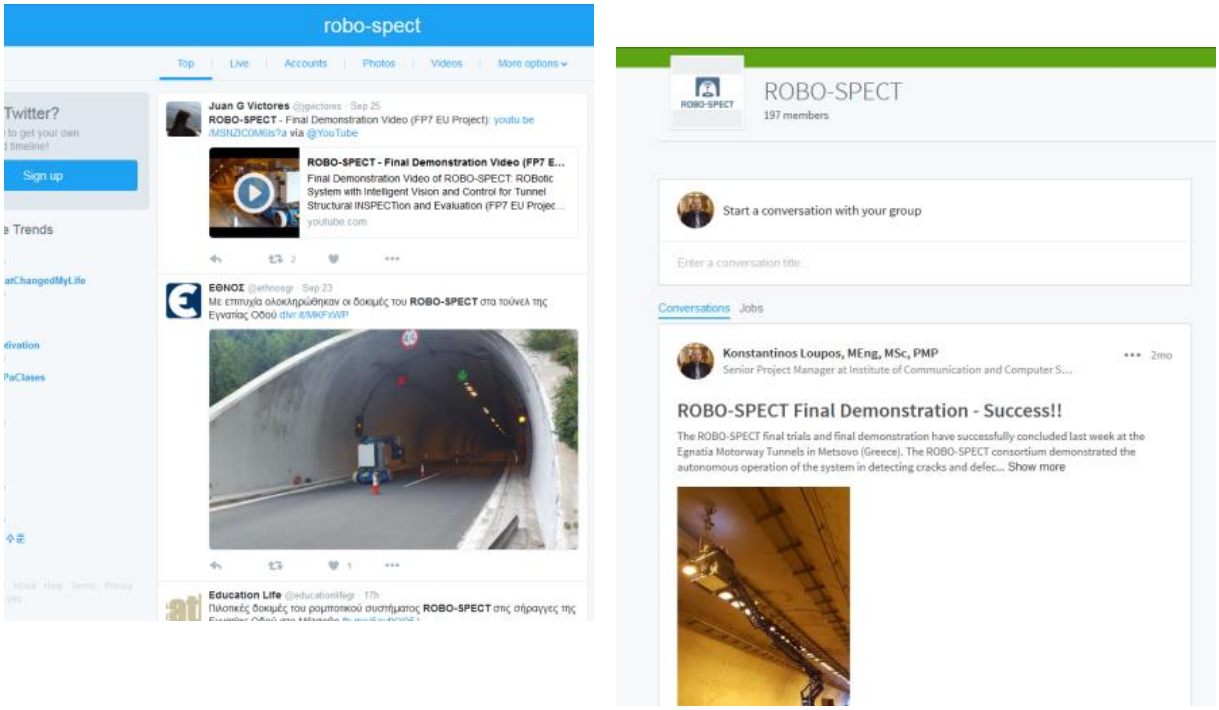


Figure 4 ROBO-SPECT Twitter (left) and Linkedin (right)

DEMONSTRATION VIDEO OF THE ROBO-SPECT SYSTEM

A video has been produsedof the ROBO-SPECT system at work and can be seen at the following address: https://www.youtube.com/watch?v=ro3fQVFCIhI
More on the ROBO-SPECT video can be found on the **D8.4.**

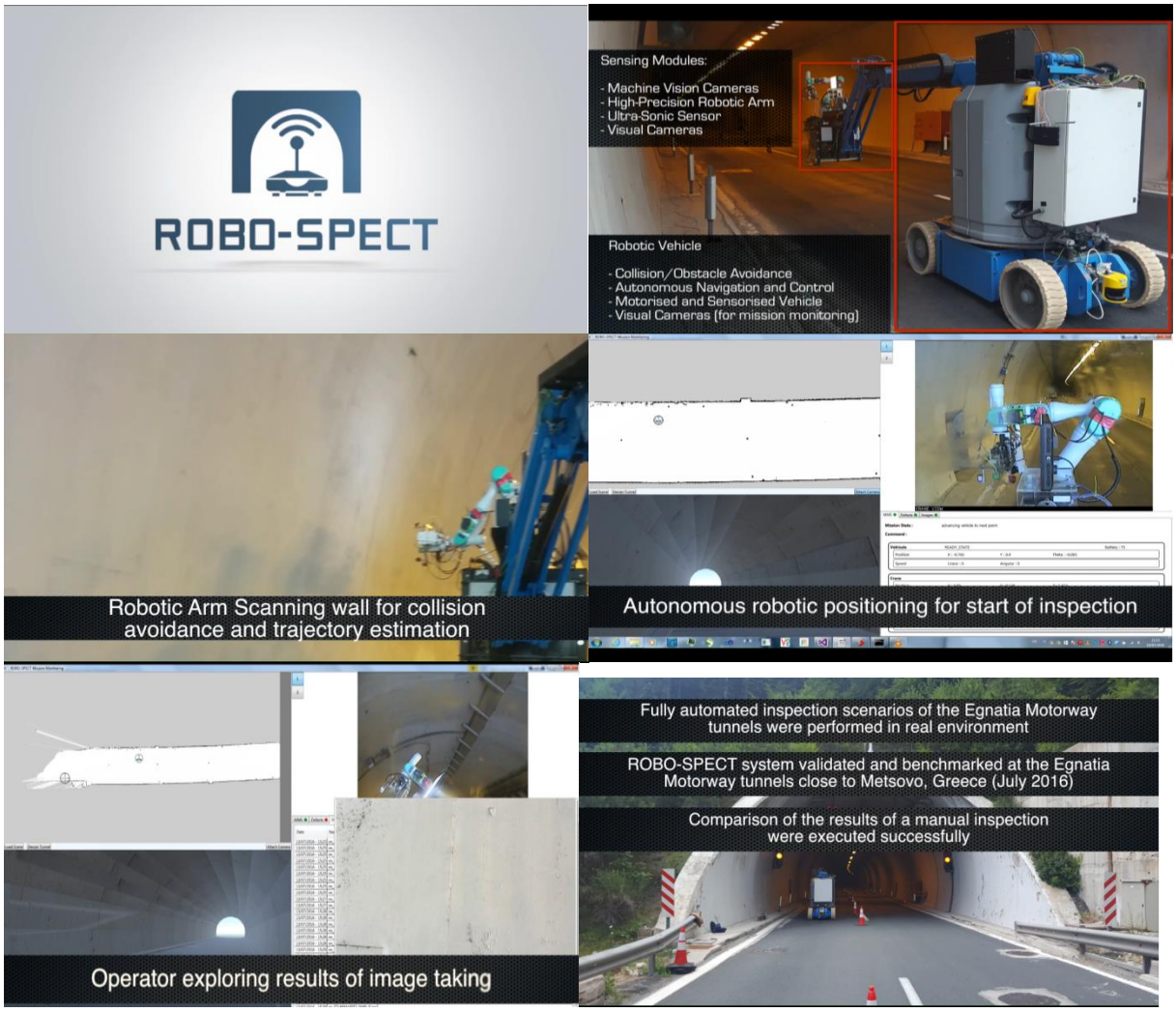


Figure 5 ROBO-SPECT Video – indicative snapshots

A first video has also been produced on the ROBO-SPET evaluation at the VSH tunnel research infrastructure and can be seen at youtube. https://www.youtube.com/watch?v=72wtRp5KV_M

DEMONSTRATION CDROM

The ROBO-SPECT Demonstration CD-ROM was produced during the final stages of the project including the: Demonstration video, Final brochure, Newsletters, Poster. More information on this can be found in the accompanying report of D8.4.

Figure 6 Demonstration CD-ROM Cover Sticker

PRESS RELEASES

(a) the following nine (9) sources in Spain have published the press release in ANNEX VI on ROBO-SPECT:

- **Un nuevo robot europeo para la inspección de túneles (SINC, PRESSPEOPLE):**
  http://www.agenciasinc.es/Noticias/Un-nuevo-robot-europeo-para-la-inspeccion-de-tuneles
  http://www.presspeople.com/nota/nuevo-robot-europeo-inspeccion-tuneles
  http://portalvasco.com/blog/?p=8792

- Investigadores españoles participan en el desarrollo de un robot para la inspección automatizada de túneles **(TECNO-CARRETERAS)**
  http://www.tecnocarreteras.es/web/items/1/978/investigadores-espanoles-participan-en-el-desarrollo-de-un-robot-para-la-inspeccion-automatizada-de-tuneles

- **Robinspect: el robot español para revisar los túneles (ONE magazine, MUNDO Digital, RDIPRESS)**
  http://www.ateneadigital.es/revistaatenea/revista/articulos/GestionNoticias_15680_ESP.asp
  http://www.mundodigital.net/robinspect-un-robot-que-inspecciona-tuneles/
  http://www.rdipress.com/tag/robinspect/

- **Científicos españoles diseñan un sistema robótico para la inspección de túneles (UC3M Portal)**
  http://portal.uc3m.es/portal/page/portal/actualidad_cientifica/noticias/Robinspect

- **Diseñan un robot para la inspección de túneles (Universia Epsana)**
  http://noticias.universia.es/ciencia-nn-tt/noticia/2013/11/19/1064011/disenan-robot-inspeccion-tuneles.html

(b) the following eight (8) sources in Greece have published the press release in ANNEX VI on ROBO-SPECT

- **Ρομπότ επιθεώρησης σηράγγων από ινστιτούτο του ΕΜΠ (Michanikos Online)**
  http://www.michanikos-online.gr/news.php?aID=11746

- **ROBINSPECT project developing a tunnel-inspecting robot (NEW ATLAS)**
  http://www.gizmag.com/robinspect-tunnel-inspecting-robot/29825/

- **ROBINSPECT Υπο το Συντονισμό του ΕΜΠ (E-DISEIS, BLOG.GR, DOY)**
  http://www.e-diseis.gr/articles/128691/To-ROBINSPECT-upo-ton-suntonismo-tou-EMP.html
  http://www.blog.gr/articles/249142/To-ROBINSPECT-upo-ton-suntonismo-tou-EMP.html
  http://www.dou.gr/article.php?a=7985879

- **ROBINSPECT Πρόγραμμα για τη Δημιουργία Ρομπότ Επιθεώρησης Συράγγων (NEWSPILE, TIPOS, SARC)**

http://www.newspile.gr/61938/2014-02/robinspect-programma-gia-ti-dimiourgia-rompot-epithewrisis-siraggwn.html
http://tipos.gr/arthro/1030500-robinspect-%CF%80%CF%81%CE%BF%CE%B3%CF%81%CE%B1%CE%BC%CE%BC%CE%B1-%CE%B3%CE%B9%CE%B1-%CF%84%CE%B7-%CE%B4%CE%B7%CE%BC%CE%B9%CE%BF%CF%85%CF%81%CE%B3%CE%B9%CE%B1-%CF%81%CE%BF%CE%BC%CF%80%CE%BF%CF%84-%CE%B5%CF%80%CE%B9%CE%B8%CE%B5%CF%89%CF%81%CE%B7%CF%83%CE%B7%CF%82-%CF%83%CE%B7%CF%81%CE%B1%CE%B3%CE%B3%CF%89%CE%BD
http://www.sarc.gr/readmore.php?id=2040011&grp=923730

(c) the following four (4) sources in Spain have published press releases on the progress in ROBO-SPECT

http://portal.uc3m.es/portal/page/portal/actualidad_cientifica/noticias/Robinspect (in Spanish)
http://portal.uc3m.es/portal/page/portal/actualidad_cientifica/noticias/tunnels (in English)
http://upm.es/sfs/Monteguancedo/Noticias/noticias%20espa%C3%B1ol/docs%20noticias/mundo050214_IDR_Transferencia%20tecnol%C3%B3gica.pdf (in Spanish)
http://www.pcdemano.com/modules.php/Virtual%20Pool/modules.php?name=News&file=print&sid=21518 (in Spanish)

(d) after the project successful demonstration in July 2016, a special article has been published by ICCS to the following twelve (14) electronic magazines:

- **Πιλοτικές δοκιμές του ρομποτικού συστήματος στις σύραγγες της Εγνατίας οδού στο Μέτσοβο (AMNA)**
  http://www.amna.gr/article/125109/Pilotikes-dokimes-tou-rompotikou-sustimatos-ROBO-SPECT-stis-siragges-tis-Egnatias-Odou-sto-Metsobo
  http://www.hri.org/news/greek/apegr/2016/16-09-26_1.apegr.html

- **Επιτυχείς οι πιλοτικές δοκιμές του ρομποτικού συστήματος ROBO-SPECT στις σήραγγες της Εγνατίας Οδού (IEFIMERIDA)**
  http://www.iefimerida.gr/news/290329/epityheis-oi-pilotikes-dokimes-toy-rompotikoy-systimatos-robo-spect-stis-siragges-tis

- **Ρομπότ έλεγξε τη στατικότητα σήραγγας της Εγνατίας Οδού στο Μέτσοβο (video) (TYPOS-I)**
  https://typos-i.gr/article/rompot-eleg3e-th-statikothta-shraggas-ths-egnatias-odoy-sto-metsobo-video

- **Με επιτυχία ολοκληρώθηκαν οι δοκιμές του ROBO-SPECT στα τούνελ της Εγνατίας Οδού**
  http://www.ethnos.gr/koinonia/arthro/me_epityxia_oloklirothikan_oi_dokimes_tou_robo_spect_sta_tounel_tis_egnatias_odou-64527037/
- **Ευρωπαϊκό ερευνητικό έργο (ETHNOS ONLINE)**
  https://www.facebook.com/ethnosonline/posts/993392487453573

- Πιλοτικές δοκιμές του ρομποτικού συστήματος ROBO-SPECT στις σήραγγες της Εγνατίας Οδού στο Μέτσοβο
  http://www.spark24hnews.gr/tag/robo-spect/

- **Επιτυχείς οι πιλοτικές δοκιμές του ρομποτικού συστήματος ROBO-SPECT στις σήραγγες της Εγνατίας Οδού στο Μέτσοβο (PROPAGANDA, TANEA, PALO, IMERISIA, MICHANIKOS-ONLINE)**
  http://popaganda.gr/pop-news/epitichis-i-pilotikes-dokimes-tou-rompotikou-sistimatos-robo-spect-stis-siranges-tis-egnatias-odou-sto-metsovo/
  http://tanea24.gr/epitixeis-oi-pilotikes-dokimes-tou-rompotikou-sistimatos-robo-spect-stis-siragges-tis-egnatias-sto-metsovo.ad5765349581a71bbe4167ca8db452dc.htm
  http://www.palo.gr/psychagogia/me-epityxia-oloklirwthikan-oi-dokimes-toy-robo-spect-sta-toynel-tis-egnatias-odoy/15002982/
  http://www.imerisia.gr/article.asp?catid=26514&subid=2&pubid=114156527
  http://www.michanikos-online.gr/news.php?aID=18927

- **Ευρωπαϊκό ερευνητικό έργο ROBO-SPECT: Πιλοτικές δοκιμές στις σήραγγες της Εγνατίας Οδού στο Μέτσοβο**
  https://www.scienceandtechnology.gr/press/europaiko-ereunitko-ergo-robo-spect/

- **Το… ρομπότ μπήκε στις σήραγγες της Εγνατίας Οδού**
  http://www.epiruspost.gr/reportaz/koinonia/40347-to-rompot-mpike-stis-siragges-tis-egnatias-odou.html

ROBO-SPECT LEAFLET AND FINAL BROCHURE

In the framework of ROBO-SPECT, a project leaflet was desinged as a dissemination means at the first months of the project, whereas a final brochure was developed in the final project stages. The two pieces included the project concept, technologies and integration steps but also the final project results in terms of technological outcomes, research achievements in robotics and the overall system validation and trials. These two can be both seen in ANNEX III and IV

PRESENTATION OF THE RESULTS AT EUROPEAN RESEARCHERS' NIGHTS

ICCS participated in the Marie Curie Researchers' night held on 26/9/2014, 25/92015 and 30/9/2016 through-out Europe demonstrating Videos and distributing leaflets about the project. Techncial experts from the ICCS group were present and had several discussions about the research objectives, outcomes and challenges of the ROBO-SPECT developments.

Figure 7 ROBO-SPECT @ Researchers' Night 2015, Athens, Greece

PROJECT WORKSHOPS AND SPECIAL SESSIONS

1. A special session was organised in the frame of the World Tunnel Congress (WTC) 2015 in Croatia and took place on May 26, 2015 from 9:00 a.m. to 13:00 p.m. The title of the conference was ' **Aging Tunnels - Safety in Operation and During Refurbishment.**' The ROBO-SPECT logo was on the official programme of the Congress, as can be seen in the picture below, while ROBO-SPECT partners made 9 presentations.

Figure 8 ROBO-SPECT Workshop @ ITA WTC 2015

2. A workshop on **"Ageing Tunnels: Inspection and Assessment"** has been organised by the partners in London on November 1, 2015.

The aim of this workshop was to:

- share information on the current needs and issues in tunnel structural inspection from several end users and technology providers
- present the first ROBO-SPECT results
- discuss some of the challenges the tunnel structural inspection is facing and receive feedback on the ROBO-SPECT research.

Fourteen representatives of end users attended the meeting. They represented the following organizations:

- London Underground,
- Crossrail,

- CH2M,
- SITAF,
- Attico Metro,
- Egnatia Odos,
- VSH,
- Aegean Motorways

In the first part of the workshop the partners presented their results in the ROBO-SPECT project. Following this, the partners learned about current needs and issues in tunnel inspection from end users and received feedback about the ROBO-SPECT research.

3. A special session was arranged by ICCS and launched in conjunction with the **International Symposium on Visual Computing with the name "ST5: Spectral Imaging Processing and Analysis for Environmental, Engineering and Industrial Applications,'** on December 12-14, 2016, in Las Vegas, Nevada, USA.

4. A special session was organized by ICCS in conjunction with the **VISAPP 2016, that is part of the 11th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications** , on February 27-29, in Rome, under the title "RBG and Spectral Imaging for Civil/Survey Engineering, Cultural, Environmental, Industrial Applications".

5. A ROBO-SECT Special Session took place at **EU Robotics 2016 (Ljubljana, Slovenia, 22 March 2016).** The aim of this workshop was to present the recent developments and future challenges of the autonomous robotic inspection systems.

6. On September 8, 2016, the **final ROBO-SPECT workshop** took place in Athens (Greece). Participants had the chance to learn more about the project results and discover the latest innovations in the fields of computer vision, ultra-sonic sensing and applied robotics, integrated in a user- friendly system. Specifically, the Workshop was structured in four complementary sessions, during which the following topics were addressed and discussed by known experts in the area:

- The state of the art in the field of applied robotics;
- The ROBO-SPECT outcomes and trial findings;
- The progress being made in various other European projects towards the robotic inspection of industrial plants and critical infrastructures, based on aerial and terrestrial robots;
- End-user round table discussion on transportation tunnel structural inspection and assessment.

The event was attended by 50 participants and was an invaluable opportunity for fruitful exchanges between research, industry, respective suppliers and solution providers, as well as end-users, in order to identify the next axes of development and the most effective solutions for industrialization.

At the first session of the workshop (“Robotics and Automation in Transportation Tunnels Inspection and Assessment”), two keynote speeches were presented, focusing on the “Maintenance of EU civil infrastructures: Towards fully autonomous intelligent robotic systems” (Carlos Balaguer, Board of Directors, EU Robotics, Spain) and “State of Art and Future Robotic Construction and Maintenance of Infrastructures” (Thomas Bock, Professor, Technical University of Munich, Germany). This actually paved the way to the rest of the sessions that focused on the ROBO-SPECT EC Project Activities, Research Initiatives and Relevant Projects and closed with the End Users Needs and Future Challenges towards Wide Implementation.

Figure 9 ROBO-SPECT Final Conference

ROBO-SPECT PUBLICATIONS

A large list of publications has been produced by the ROBO-SPECT consortium in the fields of robotics, computer vision, 3D imaging and processing as well as structural monitoring. This way various fields in the areas of research and industry have been approached with significant feedback that has seriosuly enhanced the ROBO-SPECT concept design and applicabily to industrial environments such as those of the tunneling industry. The list of publications has been included below:

1. Carlos Balaguer, key note speech with special reference to ROBINSPECT, ' Towards Fully Automated Tunnel Inspection: A Survey and Future Trends,' ISARC 2014, International Symposium on Automation and Robotics in Construction, Sydney, Australia, July 9-11, 2014.

2. K. Loupos, A. Amditis, C. Stentoumis, P. Chrobocinski, J. Victores, M. Wietek, P. Panetsos, A. Roncaglia, S. Camarinopoulos, V. Kallidromitis, D. Bairaktaris, N. Komodakis, R. Lopez - ROBOTIC INTELLIGENT VISION AND CONTROL FOR TUNNEL INSPECTION AND EVALUATION - THE ROBINSPECT EC PROJECT, 2014 IEEE International Symposium on Robotic and Sensors Environments - IEEE International Symposium on Robotic and Sensors Environments, 16-18 October, 2014. Timisoara, Romania.

3. Makantasis, K., Protopapadakis, E., Doulamis, A.D., Doulamis, N.D., Loupos, C., "DEEP CONVOLUTIONAL NEURAL NETWORKS FOR EFFICIENT VISION BASED TUNNEL INSPECTION," IEEE International Conference on Intellignence, Communication, and Processing, 3-5 September, Cluj-Napoca, Romania (2015)

4. Eftychios Protopapadakis and Nikolaos Doulamis - IMAGE BASED APPROACHES FOR TUNNELS' DEFECTS RECOGNITION VIA ROBOTIC INSPECTORS," International Symposium on Visual Computing, Las Vegas, USA, December 2015.

5. Loupos, K. et al. 'Integrated Robotic System for Tunnel Assessment - The ROBO-SPECT EC Project,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

6. Stentoumis C. et al. 'A Computer Vision System for Tunnel Inspection,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

7. Wright, P. 'Case Studies of Tunnel Inspection and Assessment,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

8. Chrobocinkski, P. 'Robotic Systems for Autonomous Tunnel Inspection,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

9. Panetsos, P. 'Greek Road Tunnel Case Studies,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

10. Bairaktaris, D. 'Structural Assessment of the Lining Based on Measurements from the Intrados,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

11. Loupos, K. 'Tunnel Inspection and Evaluation: The ROBO-SPECXT Project,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

12. Lopez, R. 'Mobile Robot for Tunnel Inspection,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

13. Stentoumis, C. 'Computer Vision for Structural Damage in Tunnel Intrados,' World Tunnel Congress 2015, May 26, Dubrovnik, Croatia.

14. K. Loupos, A. Amditis, C. Stentoumis, P. Chrobocinski, J. Victores, A. Roncaglia, S.Camarinopoulos, N. Komodakis, R. Lopez - ROBOTIC SYSTEM WITH INTELLIGENT VISION FOR TUNNEL STRUCTURAL ASSESSMENT - SYSTEM ARCHITECTURE - THE ROBO-SPECT-EC PROJECT – Third Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures, SMAR 2015, 7-9 September 2015, Antalya, Turkey, ISBN: 978-3-905594-65-2.

15. K. Makantasis, E. Protopapadakis, N. Doulamis, A. Doulamis, K. Loupos - DEEP CONVOLUTIONAL NEURAL NETWORKS FOR EFFICIENT VISION BASED TUNNEL INSPECTION, 11th International Conference on Intelligent Computer Communication and Processing, IEEE ICCP 2015, 2-5 September 2015, Cluj-Napoca.

16. C. Stentoumis, A. Amditis, G. Karras - CENSUS-BASED COST ON GRADIENTS FOR MATCHING UNDER ILLUMINATION DIFFERENCES, International Conference on 3D Vision (3DV 2015), Lion, October 2015.

17. C Stentoumis, E. Karkalou, G. Karras - A review of penalty functions in semi-global matching Evaluation under radiometric differences - 11th International Conference on Intelligent Computer Communication and Processing, IEEE ICCP 2015, 2-5 September 2015, Cluj-Napoca.

18. K. Makantasis, A. Doulamis, K. Loupos - VARIATIONAL INFERENCE FOR BACKGROUND SUBTRACTION IN INFRARED IMAGERY, 11th International Symposium on Visual Computing (ISVC 2015), 14-16 December 2015, Las Vegas, Nevada, USA.

19. Loupos, C. et al. 'Robotic System with Intelligent Vision for Tunnel Assessment - System Architecture - The ROBO-SPECT EC Project,' Third Conference on Smart Monitoring, Assessment and Rehabilitation of Structures, 7-9 Sept. 2015, Andalusia, Spain.

20. N. Doulamis, A, Doulamis, K. Makantasis, K. Karantzalos, K. Loupos. 'Thermal Imaging for Active Evacuation Routes' 8th ACOM International Conference on Pervasive Technologies Related to Assistive Environments, 1-3 July 2015, Corfu, Greece.

21. K. Loupos et al. 'Robotic System with Intelligent Vision for Tunnel SHM - ROBO-SPECT EC Project,' Structural Health Monitoring of Intelligent Infrastructure (SHMII), July 1-3, 2015, Torino, Italy.

22. R. Montero, J.G. Victores, S. Martinez, A. Jardon, C. Balaguer 'Past, Present and Future of Robotic Tunnel Inspection' Automation in Construction, vol.59, 2015, pp.99-112.

23. S. Zagoryuko and N. Komodakis, 'Learning to Compare Image Patches via Convolutional Neural Networks,' CVPR 2015, June 8-10, Boston, USA

24. W. Zou and N. Komodakis, 'HARF: Hierarchy-Associated Rich Features for Salient Object Detection,' ICCV 2015, Dec. 13-16, Santiago, Chile.

25. L. Belsito, L. Masini, M. Sanmartin, A. Roncaglia - Ultrasonic Sensor System for Automatic Depth Measurement of Surface Opening Cracks in Concrete by Means of a Robotic Arm – International

Conference on Smart Infrastructure and Construction (ICSIC), ICSIC 2016, 27 - 29 June 2016, Cambridge, UK.

26. K. Loupos, A. Amditis, C. Stentoumis, P. Chrobocinski, J. Victores, A. Roncaglia, S.Camarinopoulos, N. Komodakis, R. Lopez - Integrated ROBOTIC Solution for Tunnel Structural Evaluation and Characterization – ROBO-SPECT EC Project – International Conference on Smart Infrastructure and Construction (ICSIC), ICSIC 2016, 27 - 29 June 2016, Cambridge, UK.

27. E. Protopapadakis, C. Stentoumis, N. Doulamis, A. Doulamis, K. Makantasis, K. Loupos, G. Kopsiaftis, A. Amditis, - AUTONOMOUS ROBOTIC INSPECTION IN TUNNELS, XXIII International Society for Photogrammetry and Remote Sensing (ISPRS) Congress, Prague, July 2016.

28. K. Loupos, A. Amditis, P. Chrobocinski, R. Montero, L. Belsito, R. Lopez, N. Doulamis - AUTONOMOUS ROBOT FOR TUNNEL INSPECTION AND ASSESSMENT - 6th International Symposium on Tunnels and Underground Structures in SEE 2016 Urban, Underground Structures in Karst, March 16-18, 2016, Radisson Blu Resort, Split, Croatia

29. K. Loupos, A. Amditis, A. Doulamis, P. Chrobocinski, J. Victores, M. Wietek, P. Panetsos, A. Roncaglia, S. Camarinopoulos, V. Kallidromitis, D. Bairaktaris, N. Komodakis, R. Lopez - INTEGRATED ROBOTIC SOLUTION FOR TUNNEL STRUCTURAL EVALUATION AND CHARACTERIZATION – ROBO-SPECT EC PROJECT. International Conference on Smart Infrastructure and Construction (ICSIC), 27 - 29 June 2016, Robinson College, Cambridge

30. C. Balaguer - STATE-OF-THE-ART ON ROBOTIC TUNNELS' INSPECTION - eu Robotics Forum 2016, March 22, 2016, Ljubliana, Slovenia.

31. K. Loupos - COMPUTER VISION METHODOLOGIES AND ALGORITHMS FOR TUNNEL STRUCTURAL ASSESSMENT - eu Robotics Forum 2016, March 22, 2016, Ljubliana, Slovenia.

32. L. Belsito - ULTRASONIC TECHNOLOGIES FOR MEASURING CRACK WIDTH AND DEPTH IN HIGH ACCURACY - eu Robotics Forum 2016, March 22, 2016, Ljubliana, Slovenia.

33. P. Wright -END-USERS POINT OF VIEW: TUNNELS' INSPECTION AND ASSESSMENT - eu Robotics Forum 2016, March 22, 2016, Ljubliana, Slovenia.

PRESENTATION OF THE RESULTS TO ROBOTICS/CONSTRUCTION/TUNNEL AUDIENCES

ROBO-SPECT has been presented at the following strategic conferences/fairs, widely disseminating and demonstrating project results but at the same time initiate large brainstorming sessions between research and industry.

1. at **IROS 2015** in Hamburg from Sept 28 to Oct. 2

Figure 10 ROBO-SPECT @ IROS 2015

The partners attended the IROS 2015 conference and supported the ROBO-SPECT dissemination activities through a booth at the conference exhibition.

ROBO-SPECT was disseminated through many discussions with attendees and booth followers through leaflets, posters and newsletters.

2. at a highly successful special session that was organized in the **European Robotics Forum (ERF) 2016 in Ljubljana**, Slovenia, 22 March 2016. The aim of this workshop was to present the recent developments and future challenges of the autonomous robotic inspection systems. The focus was on structural assessment of civil infrastructures, such as highway and train tunnels, metro stations and underground storages. The main robotics and sensors analysis technologies were presented and discussed. The view of end-users of the tunnelling sector was also presented. The special session was attended by about 70 persons from the civil, robotics and inspection industries and academia.

3. at the **Spanish Technological Platform in Construction** (PTEC) forum 2016 in Barcelona (6 April 2016), where a poster has been presented to an audience of large Spanish construction companies, such as ACS-Dragados, FCC, OHL, etc.

4. the **ITA Croatia, 6th International Symposium on Tunnels and Underground Structures in South-East Europe**, on March 16-18, 2016, with the title "Urban underground structures in karst" organized with the support of International Tunneling Association ITA-AITES.

During most of the above workshops, feedback was collected from the end-users in the form of brainstorming sessions and the aid of questionnaires as presented in Annex II

GROUP OF OUTSIDE EXPERTS

The following group of outside experts has been established in order to discuss with project participants the validity of results, challenges, promotion of the work to potential users, standardisation, benchmarking, economic and legal issues.

Name	Institution	Country	Field of Expertise	Email
De Fabio Bonsignorio	Heron Robotics, Chairman of the TG on Benchmarking in the eurobotics, Prof. Scuola Superiore de Santa Ana, Italy	Spain, Italy	Robotics	Fabio.bonsignorio@sssup.it
Prof. Angel del Pobil	University Jaume I	Spain	Robotics (manipulation and task planning)	pobil@icc.uji.es
Evaggelos Pergantis	Attico Metro	Greece	Tunnel Operator/Structural Assessment	vpergantis@ametreo.gr
Caterina Ritta	SITAF	Italy	Tunnel Operator	Caterina.ritta@sitaf.it
Chryssi Potsiou	President, International Federation of Surveyors	Greece	Surveyor/Structural Assessment	chryssyp@survey.ntus.gr
Dr Ashwin Seshia	University of Cambridge	UK	Sensors, Nanoscience, Smart Infrastructure	Aas41@cam.ac.uk
Prof. Kenichi Soga	University of Cambridge	UK	Monitoring and Assessment of Underground Structures	Ks207@cam.ac.uk
Guy Fremont or Journe Alexia	SANEF	France	Tunnel Operator/Structural Assessment	Guy.Fremomt@sanef.com
Cecile Boulogne	CETU	France	Technical Service of the Ministry of Ecology, Energy, Sustainable Development and the Sea, responsible for technical aspects	Cecile.boulogne@developement-durable.gouv.fr

			of tunnels	
Hung (Jim) La	Dept. of Computer Science and Engineering, Univ. of Nevada	US	Computer Vision	hla@une.edu
George Bebis	Dept. of Computer Science and Engineering, Univ. of Nevada	US	Computer Vision	bebis@cse.unr.edu

COMMUNICATION WITH THE EUROPEAN NATIONAL TUNNEL ASSOCIATIONS

The partners have been in contact with several Tunneling Associations in Europe. The following text has been used as the basis for the project presentation:

ROBO-SPECT (ROBOtic System with Intelligent Vision and Control for Tunnel Structural INSPECTion and Evaluation)

A large number of underground transportation tunnels have been in operation for more than half a century and are in dire need for inspection, assessment and maintenance. Things are bad to the point that there have been a number of failures resulting in collapses in tunnels in recent years which highlighted the need for better ways to inspect and assess the tunnel stability of in-service tunnels.
ROBO-SPECT adapts and integrates recent research results in robotics, computer vision and non-destructive sensing in a innovative, integrated, robotic system that automatically scans the intrados for potential defects on the surface and detects and measures radial deformation in the cross-section, distance between parallel cracks, cracks and open joints that impact tunnel stability, with mm accuracies. This permits in one pass, both the inspection and structural assessment of tunnels.
The ROBO-SPECT system has been evaluated at the VSH research infrastructure of tunnels in Switzerland, while next year it will be field evaluated and benchmarked at actual tunnels in UK and Greece. The following picture is from the VSH trials. Please note that the system will be autonomous. There will be no driver in the vehicle, while the picture in the monitor is what will be seen at the Ground Control Station.

Figure 11 ROBO-SPECT First tests at VSH Haggerbach

The Robotic Arm System during the VSH tests. In the monitor one can see also the scanned surface and the state of the robot
The above system is expected to:

- Reduce tunnel closures or partial closures because of tunnel inspection.
- Eliminate the need for emergency repairs.
- Decrease the life-cycle maintenance costs.
- Improve the working conditions of tunnel inspectors.

The project is supported by the European Commission under the 7th Framework Programme.
More information can be found under: www.robo-spect.eu

COMMUNICATION WITH SEVEN NATIONAL TECHNICAL PLATFORMS IN CONSTRUCTION

The partners have been in contact with several national technical platforms in construction from various countries such as:

- Austria,
- Greece,
- Hungary,
- Italy,
- Poland,
- Portugal and
- Slovenia.

This collaboration has aided not only the wider project dissemination but also getting closer to the end-user and structural requirements as expected by the actual industrial sectors.

ROBO-SPECT PRESENTATION TO SPANISH ROBOTIC NETWORKS, ASSOCIATIONS, WEBS AND PLATFORMS

1) **RoboCity2030 – Madrid cluster for robotics:**
http://es.slideshare.net/RoboCity2030/robocity2030-sept-2013 (in Spanish)
http://roboticslab.uc3m.es/robocity13/?q=programa (in Spanish) – workshop
http://www.robocity2030.org/robocity2030/eng/public-en/menu/noticias/indexexitnoticia.php?not=334 (in Spanish)

2) **Jornadas de Automatica de CEA-GTRob – Spanish Robotic network:**
http://www.ceautomatica.es/sites/default/files/upload/10/files/CEA_GTRob_boletin22.pdf (in Spanish)

3) **PTEC - Spanish Technological Platform for Construction:**
http://www.plataformaptec.com/ver-noticia.php?id=1273& (in Spanish)

4) **RoboticLab UC3M web:**
http://roboticslab.uc3m.es/roboticslab/news/tunnel-inspecting-robot-robo-spect

THESIS, TEACHING, SEMINARS

Diploma Thesis:

- One Diploma thesis at the Dept. of Rural and Survey Engineering (firmly linked with ICCS team activities) was assigned to test the efficiency of 3D laser scanners in cylinder surfaces like the ones encountered in ROBO-SPECT.

Teaching and seminars:

- UC3M: 7th Robotics Lab Spring 2015 Workshop (at UC3M Ph.D. program on Robotics and Automation) – 13/6/2015

- UC3M: euRobotics – European PPP in Robotics

- ICCS has demonstrated the first integration meeting in VSH (Switzerland) in the first lecture of the course of Multimedia Technologies teaching under the master program of Techno-economic systems co-funding by the National Technical University of Athens and University of Piraeus.

NEWS RELEASES TO IAARC AND TRIP

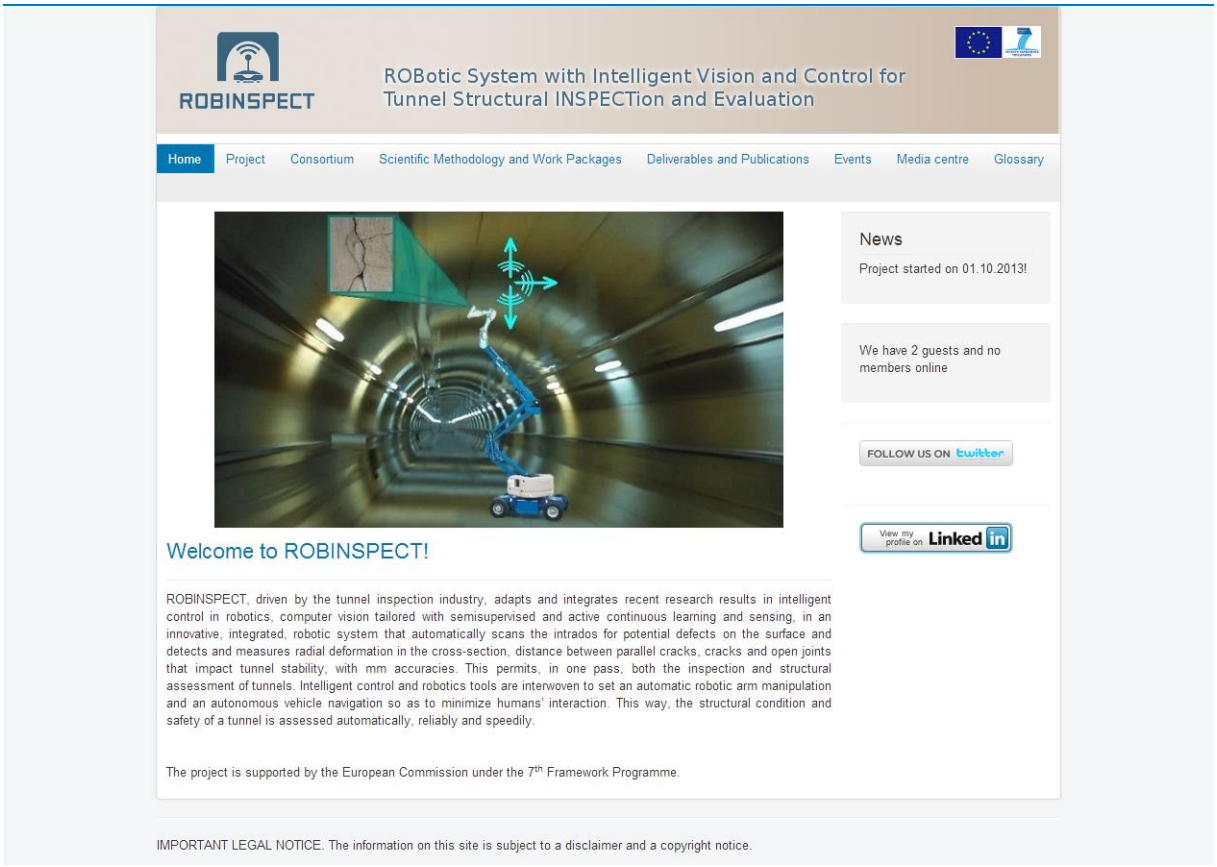
The partners also advertised the project through press releases to the:

- IAARC (International Association for Automation and Robotics in Construction) and

- TRIP (Transport Research and Innovation Portal)

ANNEXES

ANNEX I: ROBO-SPECT Web site



Following the best practice guidelines for EU project websites, the structure of the website which is presented as a main horizontal menu that is visible in all website pages, is:

- Homepage
- Project Overview
- Consortium and Management Structure
- Scientific Methodology and Work Packages
- Deliverables and Publications
- Events
- Media centre
- Glossary

ANNEX II End-user Feedback Questionnaire

7th Framework Programme

FP7-ICT-2013-10 N.611145

END USER WORKSHOP – 2 November 2015

QUESTIONNAIRE

PERSONAL DETAILS:

Name and Surname: _____

Expertise: _____

Institution/company _____

Functional REQUIREMENTS

Please complete the table below with **H (high), M (medium), L (low)** depending on the priority of each requirement for your application/experience.

Requirement	Requirement Details	Requirement Ref	Requirement Details		Interest
1.Tunnel geometries that should be covered	Horseshoe	FS#1.01	With Invert		
		FS#1.02	Without Invert		
	Circular	FS#1.03	With Invert		
	Oval	FS#1.04	With Invert		
2.Clearance	FS#2.01	1-11m			
3.Length	FS#3.01	From less than 500m to more than 2500m			
5.Speed of inspection	FS#5.01	As speedy as possible			
6.Material deterioration	Corrosion of the reinforcement	cracking	FS#6.09	Orientation (i.e., along the main reinforcement, diagonal, etc.)	
			FS#6.10	Type (i.e., single, multiple, linear, irregular, interconnected, distorted)	
			FS#6.11	Length (i.e., distance from beginning to end)	
			FS#6.12	Width (i.e., the widest opening on the surface, variation along its length)	
			FS#6.13	Depth (where possible)	
			FS#6.14	Associated features (i.e., spalling, water ingress, corrosion stains, surface deposits, swelling)	
		staining	FS#6.15	Colour	
			FS#6.16	Size (i.e., largest diameter, width vertical to the latter diameter)	
			FS#6.17	Associated features (i.e., cracks, swelling, spalling, exposed steel reinforcement, wet patches)	
		spalling	FS#6.22	Largest diameter and its orientation	
			FS#6.23	Width vertical to the above diameter	
			FS#6.24	Associated features (i.e., wet patches, exposed steel reinforcement)	
			FS#6.25	Colour (i.e., discoloured suggests water percolation through a crack, white suggests deposits)	

	Calcium leaching and efflorescence	White deposits	FS#6.30	Location and size (Length, width of the area)	
			FS#6.31	Colour (shades of white)	
	Joints water leakage	FS#6.32	Location		
	Cracks water leakage	FS#6.33	Location		
7.Structural Damage	Structural cracks on the surface	FS#7.01	Width with 0.1 mm accuracy		
		FS#7.02	Depth with 2-3 mm accuracy		
		FS#7.03	Location		
		FS#7.04	Distance between parallel cracks with 5 mm accuracy		
	Openings of the joints in segmental linings	FS#7.05	Width with 0.1 mm accuracy		
		FS#7.06	Depth with 2-3 mm accuracy		
	Spalling, mainly at connections between precast elements	FS#7.09	Length, width		
	Deformed shape of the internal face of the permanent lining as a function of time	FS#7.11	Radial deformation with an accuracy of 1 mm		
		FS#7.12	Changes of structural form as a function of time		
8.Structural assessment	Structural assessment of specific	FS#8.01	Safety factor		
		FS#8.02	Probability of failure		

	sections of the lining ring			
	Structural assessment of the whole lining ring	FS#8.03	Safety factor	
		FS#8.04	Probability of failure	
9.Map of defects of a specific segment of the tunnel	FS#9.01			
10.Evolution of the defects as a function of time (voids, width of cracks, etc)	FS#10.01			
11.Ultrasonic sensors	FS#11.01	Should be enough to ensure stabilisation of the robotic system		
	FS#11.02	Should allow the process of approaching the tunnel wall in a way that will take into account the uncertainties of the manipulator and the operating distance to the wall.		
	FS#11.03	Measure the width of cracks with an accuracy of 0.1mm		
	FS#11.04	Measure depth of cracks with accuracy of 2-3 mm		
	FS#11.07	Measure opening of the joints between segments with 0.1 mm accuracy		
	FS#11.08	Measure depth of the opening of the joint between segments with 2-3 mm accuracy		
12.Control modalities	FS#12.01	Autonomous with human interaction possible		
13.Mobile vehicle	FS#13.01	Should be capable to move on road or rail		
	FS#13.02	Should be able to move forward on its own.		
	FS#13.03	Should be able to avoid obstacles to reach the inspection zones (thus, it should be able to go forward, backwards and turn left and right)		
	FS#13.04	Should be able to ‘see’ obstacles (needs a series of sensors with laser technology or similar)		
	FS#13.05	Should be able to control the vehicle position (e.g., encoders to measure position and velocities as well as an IMU to measure accelerations could be installed)		
	FS#13.06	Should be able to minimize vibrations (use a stabilization system, for example outriggers)		

14.Crane, manipulator	FS#14.01	The crane will move the manipulator and all the sensors attached to it to the desired zone on the wall.	
	FS#14.02	It needs to reach the dimensions of the tunnel and be capable to stand the forces and torques caused by the manipulator. Position control of the joints needs to be guaranteed.	
	FS#14.03	Industrial quality robotic manipulators should be controlled efficiently with their sensors-actuators. The vibration in the base of the manipulator needs to be compensated or reduced to improve the accuracy. Stabilization or anti-vibrating system in the robot base and/or tip is also needed.	
	FS#14.04	The ultrasonic sensors will be mounted on the tip of the manipulator to make the assessment. Additional laser sensors at the tip are necessary to perform the approximation task.	
15.Vision system	FS#15.01	Attached to the mobile vehicle, crane or manipulator, depending on the required accuracy.	
16.Control sensors for the robot	FS#16.01	Should be placed in such a way that will allow the movements of all parts of the system	
	FS#16.02	Should provide measurements with the required accuracy and speed to perform the different tasks of the process.	
17.Inspection	FS#17.01	Marks/milestones of known position need to be identified to guide auto positioning of the robotic vision system (Based on these the tunnel will be divided into sections or slices. The robotic system will move to each slice and begin the inspection process) The inspection process to be performed at three levels: 1. Coarse inspection with laser technology or similar – low precision and fast 2. Fine inspection based on artificial vision – medium precision and velocity	

		3. Structural assessment when required – high precision and slow –	
18.The robot	FS#18.01	Its principal function will be to reach the damaged area of the tunnel so that the inspection sensors are able to operate without movement problems. It should provide full mobility for the sensors. Three kinds of movements will be necessary to reach the damaged area; each of them will be performed by three different mobility agents: 1. Movement along the tunnel: the vehicle will move along the tunnel to reach the damaged region. 2. Movement around the vehicle, when it has reached the end position. It is called primary movements arm. This will be the crane attached to the vehicle. 3. Movements around the primary movements arm once it has reached it's definitely position. This arm is called secondary movements arm. This will be an industrial manipulator at the end of the crane.	
	FS#18.02	• Primary movements arm: Crane The crane must carry out those movements necessary to locate the next arm in such a point so that, with its reduced movements capability, is able to reach all and each of the to-be-inspected area points. The range of distance between starting and ending point of the motion doesn't exceed the tunnel dimension (3.8-7 m). For longer distances the crane will be placed in its folded position, and transported to the next goal by moving the whole vehicle. • Secondary movements arm: Manipulator Once the crane has carried out the primary pertinent movements, the manipulator must reach the inspected area. The range of distance between starting and ending point of the motion covers from few centimeters to one (1.0) meter approximately. For longer distances, manipulator will be folded, fasted and transported to operate in the next area	
19.Robotic Arm	FS#19.01	The manipulator is installed at the end of the crane. The support platform will be, in general, horizontal, and at its end will be mounted the robotic arm. The range of movements cover from few centimetres to one (1.0) meter approximately.	

	FS#19.02	The degrees of freedom required depends on the geometry of the fissure. To cover all the possible geometry of any fissure, the robotic arm needs six (6) degrees of freedom. An additional one will be used to provide obstacle avoidance and correct orientation capabilities.	

Operational Specifications (summary)

Please complete the table below with the interest level and your comments regarding each of the operational specifications below:

Specification	Specification Details	Interest / Comments
Robotic platform size	Max working height 12,52 m Max platform height 10,52 m Horizontal range 6,78 m	
Robotic platform speed	Drive speed stowed 6,4 km/h Drive speed raised 1,08 km/h	
Robotic platform weight	5.179 kg	
Wireless connectivity	The wireless communications shall cover the entire length of the tunnel. Where needed, relay shall be installed to warrant the permanent connectivity between the robot and the GCS. The wireless communications should be WIFI (compatible with the existing data link).	
Ground control Station	The Ground Control Station shall be transportable to the tunnel location. The GCS shall be able to operate in an interval of temperatures of 0°C to 30°C. The GCS should be equipped with its own source of energy, allowing a range of 4 hours (TBC).	
Structural Assessment Tool	The internal forces and external loads applied on every point of the lining cross-section and the local and global safety factor at the time of the inspection.	
Structural Assessment Tool	Structural reliability and probability of local or global failure at the lining cross-section at the time of the	

	inspection.	
Structural Assessment Tool	The probability of local or global failure in the future (for tunnels where the external loading on the lining has reached a stable value).	
Structural Assessment Tool	The evolution of material damage assessed by algorithms corrected with inspection results	
Structural Assessment Tool	This Tool will provide warnings in case of abnormal situations and allow the end-user to examine different scenarios for hypothetical situations (e.g., rapid progress of corrosion).	

Other general comments

Please indicate particular parameters or platform operation that you would be interested in:

Please indicate particular characteristics that you would be interested in:

Please state other comments in relation to the ROBO-SPECT:

ANNEX III – ROBO-SPECT Leaflet

Expected Impact

Speedy tunnel inspection
ROBO-SPECT is expected to reduce tunnel closures or partial closures for tunnel inspections.

Increased Safety
ROBO-SPECT will also improve the working conditions for tunnel inspectors that may be currently unhealthy and unsafe as well as the safety for general public uses the infrastructures.

Decreased costs
ROBO-SPECT is expected to highly reduce labor and infrastructure costs by automating inspections and assessment.

Higher use of robotics in the emerging service robot sector
ROBO-SPECT will make the use of autonomous, integrated robots more attractive to the transportation tunnel inspection industry, which is a new market for robots with high potential.

Increased residual lifetime of existing tun-nels
This will preserve natural resources, resultin significant cost savings and increase transportation capacity.

Project Facts

Duration: 1 October 2013 – 30 September 2016,

Total Cost: 4.592.196,00€

EU contribution: 3.306.599,00€

http://www.robo-spect.eu

Consortium

Institute of communication and Computer Systems *(ICCS)*

CASSIDIAN *(CAS)*

University Carlos III, Madrid Dpto. De Ingeniera de Sistemas y Automatica Robotics Laboratory *(UC3M)*

VSH Hagerbach Test Gallery Ltd. *(VSH)*

Egnatia Motorway S.A. *(EOAE)*

Institute of Microelectronics and Microsystems, National Research Council of Italy *(CNR)*

RISA Sicherheitsanalysen GmbH *(RISA)*

Techniche e Consulenze Nell' Ingegneria Civile S.p.A - Consulting Engineers S.p.A *(TECNIC)*

D. Bairaktaris & Associates Structural Design Office Ltd. *(DBA)*

Ecole des Ponts ParisTech *(ENPC)*

ROBOTNIK *(ROB)*

Dr. Angelos Amditis
Project Coordinator
Institute of Communication and Computer systems
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HTTP://WWW.ROBO-SPECT.EU

ROBO-SPECT

ROBOtic System with Intelligent Vision and Control for Tunnel Structural inSPECTion and Evaluation

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 611145

Concept

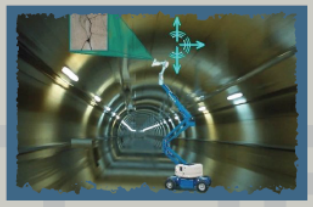
ROBO-SPECT, driven by the tunnel inspection industry, adapts and integrates recent research results in intelligent control in robotics, computer vision (semisupervised and active continuous learning and sensing), in an innovative, integrated, robotic system that automatically scans the intrados of tunnels for potential defects and detects and measures radial deformation in the cross-section, distance between parallel cracks, cracks and open joints with mm accuracies. This permits, in one pass, both the inspection and structural assessment of tunnels. Intelligent control and robotics tools are interwoven to set an automatic robotic arm manipulation and an autonomous vehicle navigation so as to minimize humans' interaction. This way, the structural condition and safety of a tunnel is assessed automatically, reliably and speedily.

Objectives

ROBO-SPECT aims towards the development and validation of the prototype of an innovative, automated intelligent robotic system for the inspection and structural assessment of transportation tunnels in one pass, speedily and reliably that has the potential to be commercialized in the short to medium term.

Scientific Objectives:

- To develop an automated and optimized robotic inspection and assessment system for tunnels that will include a computer vision system, a the sensor system and laser equipment able to measure radial deformation with an accuracy of 1 mm.
- To adopt specific methodologies and strategies for collecting visual datasets of tunnel defects.
- To develop a computer vision system for tunnel inspection and assessment of the structural condition able to detect structural defects and color changes at the inspected concrete lining intrados.
- To extend already existing 3D reconstruction tools so that they can be able to precisely detect tunnels' cracks and use these models at later stages to derive more robust knowledge on tunnels stresses.
- To promote a new evaluation framework able to extract local knowledge from types of tunnels that can be extended to other, incorporate social knowledge from civil engineering, improve control mechanisms of robots in velocity of inspection and orientation.
- To develop a sensor system installable on the robotic inspection system able to measure (a) the depth of cracks or the depth of the opening of joints of interest with an accuracy of 1 mm and (b) the width of these cracks and openings with an accuracy of 0.1 mm.
- To develop a quantitative structural assessment tool that based on input from the system inspection will automatically assess the structural condition and stability of the tunnel.
- To test, validate and benchmark the integrated system at the research infrastructure of tunnels of VSH and in real rail and road tunnel environments (London Underground rail tunnels and Egnatia Motorways).



Technologies and System Validation

Robotic Systems for Tunnel Inspection
The ROBO-SPECT robotic system will be designed and developed as a multi-degree-of-freedom (MDOF) robotic system capable of reaching extended lengths (heights) found in common among tunnels.

Computer-Vision Systems for Tunnel-Inspection
Computer vision algorithms will be developed able to detect cracks and material degradation in tunnels by visual inspection. The target is to deploy tools able to quickly identify 'objects' with a high accuracy (1mm) .

Crack, Depth And Width Measuring Devices
Fiber-Optic Ultrasound Sensor Prototypes will be included in the ROBO-SPECT sensing platform to measure (a) the depth of cracks or the depth of the opening of joints of interest with an accuracy of 1 mm and (b) the width of these cracks and openings with an accuracy of 0.1 mm.

Structural Reliability Models
ROBO-SPECT will develop a quantitative structural assessment tool with a user interface that will automatically assess the structural condition and stability of the tunnel so that tunnel operators can decide on an immediate intervention or next inspection needs.

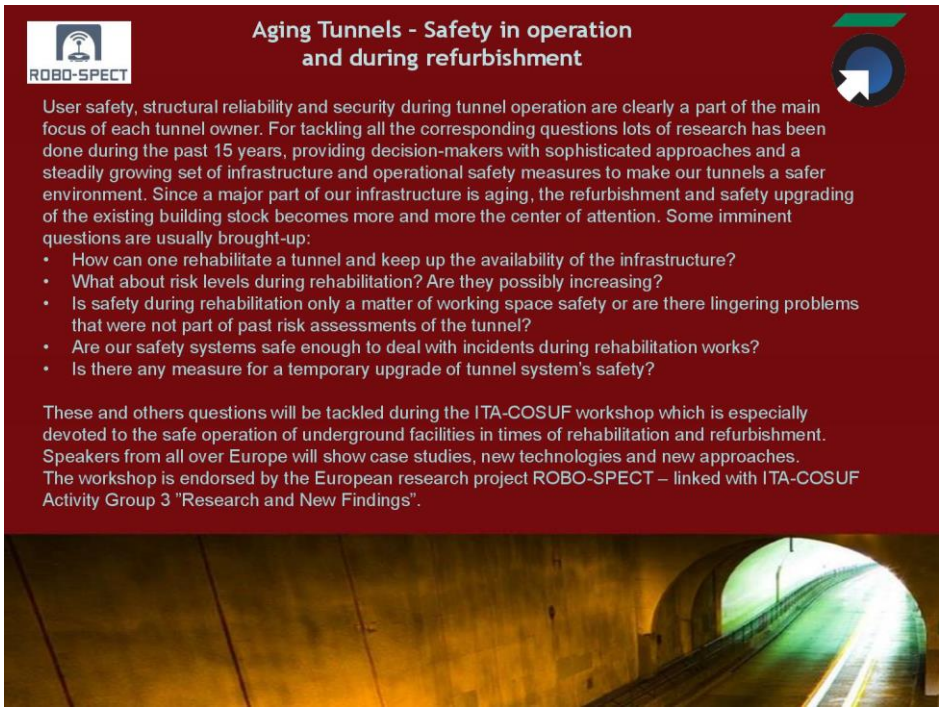
System Validation
The integrated robotic system will be evaluated and benchmarked at the research infrastructure of tunnels of VSH and will be evaluated in field trials will take place at the rail tunnels of London Underground (UK) and road tunnels of Egnatia Odos (Greece).

Figure 12 ROBO-SPECT Final Brochure

ANNEX IV – ROBO-SPECT Final Brochure

Figure 13 ROBO-SPECT Final Brochure

ANNEX V – ROBO-SPECT WTC 2015 ITA COSUF Dubrovnik 20150513



Programme

08:30 - 09:00 ITA COSUF General Assembly
Intended for ITA COSUF members but open to all

Session 1: Opening session: Case studies

09:00 - 09:10 Opening by ITA-COSUF chairman Roland Leucker (STUVA e.V.)
09:10 - 09:30 Implementation of the EU directive 2004/54, Enrico Pastori (TRT, on behalf of DG-Move)
09:30 - 09:50 The Mont Blanc tunnel, Gilles Rakoczy (Director of the Mont Blanc Tunnel)
09:50 - 10:10 Case studies of tunnel inspection and assessment, Peter Wright (CH2M)
10:10 - 10:30 Refurbishment under operation - tunnel in tunnel method, Thomas Edelmann (Herrenknecht)
10:30 - 10:40 Discussion

10:40 – 11:00 Refreshment break

Session 2: Monitoring, inspection and assessment

11:00 - 11:20 Robotic systems for autonomous tunnel inspection, Philippe Chrobocinkski (CAS)
11:20 - 11:40 Mobile Robot for Tunnel inspection, Rafael Lopez (Robotnic)
11:40 - 12:00 Greek Road Tunnel Case studies, Panos Panetsos (EGNATIA)
12:00 - 12:20 Structural lining assessment based on intrados measurements, Dimitrios Bairaktaris (DBA)
12:20 - 12:40 Discussion

Preliminary Programme

12:40 - 14:00 Lunch

Session 3: Research and new products

14:00 - 14:25 Tunnel Inspection and Evaluation: The ROBO-SPECT Project, Konstantinos Loupos (ICCS)
14:25 - 14:50 Acceptable risk levels during refurbishment work, Nils Peter Hoj (Hoj Consulting GmbH)
14:50 - 15:15 Computer Vision for Structural Damage in Tunnel, Nikos Komodakis (ENPC&ICCS)
15:15 - 15:30 Discussion

15:30 – 16:00 Refreshment break

Session 4: Risk and Refurbishment

16:00 - 16:20 Refurbishment of Railway tunnels during operation, Max Wietek (VSH, RhB)
16:20 - 16:40 Autostrada Brennero - Emergency Exercise, Carlo Costa (Autostrada)
16:40 - 17:00 Refurbishment of a listed tunnel: Maas Tunnel Rotterdam, Han Admiraal (ENPRODES)

17:00 - 17:20 ITA-COSUF Award
17:20 - 17:40 Discussion

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This ITA COSUF workshop is open to all participants of the ITA-AITES World Tunnel Congress 2015. Registration to the congress should be made through the congress website: www.wtc15.com . One-day registration is available for those who wish to attend the ITA COSUF workshop only; it gives access to all congress events which take place on 26 May 2015. After 15 March 2015 the registration fees for the full conference will increase. A second increase will follow on 15 May 2015.

ANNEX VI – ROBO-SPECT Press Release Template

(follows in next pages)

ROBINSPECT

Partner logo

Contact: <name of lead partner>
Company: <company name>
Tel.: <tel. number>
Email: <e-mail address>

<Place>, <date dd/mm/yyyy>

Press Release

ROBotic System with Intelligent Vision and Control for Tunnel Structural INSPECTion and Evaluation (ROBINSPECT)

One of the greatest challenges facing engineers today is the inspection, assessment, maintenance and safe operation of the existing civil infrastructure such as, tunnels, bridges, roads, and much more. Due to ageing, environmental factors, increased loading, change in use, damages caused by human/natural factors, inadequate or poor maintenance and deferred repairs, civil infrastructure is progressively deteriorating, urgently needing inspection, assessment and repair work. Nowhere is this need more apparent than in underground transportation tunnels, a large number of which have been in operation for more than half a century and there are widespread signs of deterioration, evidenced by an increase in the proportion of budgets spent on inspection and assessment. Things are bad to the point that there have been a number of collapses in tunnels in recent years which highlighted the need for better ways to inspect and assess tunnel stability of in service tunnels.

Presently, structural tunnel inspection is predominantly performed through tunnel-wide visual observations by inspectors. This process is slow, labour intensive, expensive, subjective and often requires lane shutdown during inspection. In this frame, the ROBINSPECT project is aiming to provide an automated robotic system that in one pass will provide speedily and reliably tunnel inspection and structural assessment.

ROBINSPECT is a project co-funded by the European Commission under FP7 that launched its activities in October 2013 with the organisation of the consortium kick-off meeting that was held in Athens, Greece and hosted by the project coordinator, the Institute of Communication and Computer Systems (http://i-sense.iccs.gr). The main objective of ROBINSPECT is to provide an automated, faster (that does not, or only minimally interfere with tunnel traffic) and reliable tunnel inspection and assessment solution that can combine in one pass both inspection and detailed structural assessment. The proposed robotic system will be evaluated at the research infrastructure of VSH in Switzerland, at London Underground and at the tunnels of Egnatia Motorway in Greece.

For immediate release or For release <time>, <Day>, <Date dd/mm/yyyy>

Partner logo

ROBINSPECT is expected to:

- increase the speed and reliability of tunnel inspections
- provide assessment in addition to inspection
- minimize use of scarce tunnel inspectors while improve the working conditions of such inspectors
- decrease inspection and assessment cost
- increase the safety of passengers
- decrease the time when tunnels are closed for inspection

Additional paragraph (no more than 5-6 sentences):
(Name of the partner) is participating in the WP(no) and its main responsibilities are……

Project Fact Sheet:

Duration: October 1, 2013 - September 30, 2016

Total cost: 4,592,196 €

EC contribution: 3.306,599 €

Coordinator: Institute of Communication and Computer Systems (ICCS)
Partners:

- Institute of Communications and Computer Systems, Greece
- CASSIDIAN, France
- University Carlos III, Madrid, Dpt. de Ingeniera de Sistemas y Automatica, Robotics Lab. Spain
- Egnatia Motorway S.A. Greece
- Consiglio Nationale delle Ricerche, Italy
- RISA GmbH
- TECNIC S.p.A.
- D. Bairaktaris and Associates Ltd. Greece
- Ecole des Ponts-Paris Tech, France
- ROBOTNIK, Spain

website: http://www.robinspect.com (to be available by the end of DEcember 2013)

More info:

Dr. Angelos Amditis
Institute of Communication and Computer Systems

Email: a.amditis@iccs.gr

For immediate release or For release <time>, <Day>, <Date