FORESEE project

Stakeholders Reference Group

1st SRG Workshop

Date: September 17th, 2019, from 13:00 till 18:00 (BST).

Venue: Leonardo HQ, 8-10 Great Georges St, London SW1P 3AE

Attendees:

Organisation		Name	Country
1.	Aiscat	Federico Di Gennaro	Italy
2.	Arup	Savina Carluccio	UK
3.	Arup	Áine Ní Bhreasail	UK
4.	Atkins	Matt Peck	UK
5.	Austostrade	Livia Pardi	Italy
6.	Balfour Beatty	Nick Boyle	UK
7.	Cemosa	Noemí Jiménez	Spain
8.	Cemosa	F. Javier Morales	Spain
9.	CSIC	Sakthy Selvakumaran	UK
10.	Eiffage Kier JV	Adrian St John	UK
11.	ERF	José Díez	----
12.	ETH	Claudio Martani	Switzerland
13.	ETS (Basque Railways)	Josu Rodríguez	Spain
14.	ETS (Basque Railways)	Cristina López	Spain
15.	FAC	Sheryl Lynch	Ireland
16.	FAC	William Hynes	Ireland
17.	Ferrovial	Javier Royo	Spain
18.	Ferrovial	David Delgado	Spain
19.	FORESEE SRG chairman	Jesús Rodríguez	Spain
20.	Geocisa UK	Diego del Saz	UK
21.	Highways England	James Codd	UK
22.	Highways England	Stuart McRobbie	UK
23.	IFSTTAR	André Dominique Orcesi	France
24.	Infraestrutura de Portugal	Rodrigo Dourado	Portugal
25.	Network Rail	Stephen Brooks	UK

26.	NIC	Eleanor Voss	UK
27.	PIARC	Miguel Caso	----
28.	Rijkswaterstaat	Sander Borghuis	The Netherlands
29.	Rina	Marcello Cademartori	Italy
30.	Rina	Daniele Pastorelli	Italy
31.	Road Directorate	Jerónimo Vicente Dueñas	Spain
32.	RWS Spain	Victor Centeno	Spain
33.	Tecnalia	Jesús Isoird	Spain
34.	Tecnalia	Iñaki Beltran	Spain
35.	Telespazio	Michael Lawrence	UK
36.	Telespazio	Maria de Farago	UK
37.	Telespazio	Erlinda Biescas	UK
38.	Telespazio	Michael Williams	UK
39.	Transport for London	Mehdi Alhaddad	UK
40.	Transport Infrastructure Ireland	Billy O'Keeffe	Ireland
41.	University of Cantabria	Daniel Castro	Spain
42.	University of Cantabria	Alejandro Roldan	Spain
43.	University of Edinburgh	Boris Gailleton	UK

**Light blue indicates FORESEE consortium members, comprising 54% of the open discussion groups.*
**Dark blue indicates SRG contact persons, comprising 46% of the open discussion groups.*

Apologies were received from:

Organisation		Name	Country
1	Aecom	Paul Clarke	UK
2	Affinity Water	Ben Hayward	UK
3	Mott MacDonald	Liz Baldwin	UK
4	Mott MacDonald	Chris Dulake	UK

Agenda

Time schedule	Topic	Responsible
13:00 am (BST)	1. Opening of the Workshop	Michael Lawrence, CCO Telespazio Vega UK; Jesús Rodríguez, FORESEE SRG Chairman
13:15	2. FORESEE project: Current status and preliminary result	Iñaqui Beltrán FORESEE coordinator Tecnalia
13:30	3. Satellite SAR monitoring: Presentation on satellite change detection and InSAR digital data in civil engineering: brief technology description, advantages, use cases, limitations and examples	Maria de Farago, Telespazio Vega UK.
14:15	4. Open discussion on satellite monitoring	Chair: Erlinda Biescas, Telespazio Vega UK
15:00	**Coffee Break**	
15:30	5. From satellite monitoring datasets to "in house" satellite monitoring system. FORESEE project. ➢ Regional hotspot survey mapping. ➢ Satellite monitoring for landslide prediction. ➢ S-SHMTM: state of art and developments in FORESEE. ➢ SUMMIT Satellite Ultra-Precise Motion Monitoring Integrated Technology.	 Alejandro Roldan, University of Cantabria Boris Gailleton, University of Edinburgh; Maria de Farago, TelespazioVega UK; Victor Centeno, RWS Spain; Maria de Farago, TelespazioVega UK.
16.15	6. Open discussion on satellite monitoring system and FORESEE	Chair: Maria de Farago, TelespazioVega UK

17:00	7. Resilience Shift initiative ➢ Resilience Shift activities with regard to transport infrastructures ➢ Open discussion on FORESEE & Resilience Shift synergies/collaborations	Áine Ní Bhreasail, Arup
18.00	8. Closing of the workshop	Jesús Rodríguez, FORESEE SRG Chairman
18.30	Networking & cocktail	Institution of Civil Engineering 1 Great George St., London

Minutes

(prepared by FAC and TVUK).

*Presentations made during the workshop are available at FORESEE Members Area, "SRG/1st workshop/Presentations" folder (*https://foreseeproject.eu/wp-login.php?loggedout=true*).*

1. Opening

Michael Lawrence opened the workshop on behalf of Telespazio and he showed the interest of the company in innovation and in projects like FORESEE.

Jesús Rodríguez chaired the workshop and he thanked Michael for the support of Telespazio hosting this workshop and contributing to its preparation and development. He introduced the consortium members and outlined the rationale for the Stakeholders Reference Group (SRG). He thanked all for their time and contribution of their expertise.

He also went through the composition of the preliminary membership and highlighted the relevance of the role of SRG for the FORESEE project. He announced the theme of the workshop: "Integration of terrestrial and satellite sensing systems for the monitoring of key infrastructures" and he also commented the invited 3rd session on Resilience Shift to explore synergies between FORESEE and other initiatives.

2. FORESEE project

Iñaki Beltrán, the FORESEE Coordinator, welcomed all and briefly introduced the project, the objectives, the toolkit to be developed, the six case studies in Germany (1), Italy (2), Spain (2) and Portugal (1), and the consortium of this project.

3. Satellite SAR monitoring

Maria de Farago, from Telespazio Vega UK lead the presentation on satellite change detection and InSAR digital data in civil engineering: brief technology description, advantages, use cases, limitations and examples. The items covered were:

- SAR basic principles;
- INSAR technique and output description;
- Use cases for Civil Engineering;
- Infrastructure lifecycle and InSAR; and next steps

SAR basic principles: Synthetic Aperture Radar (SAR) satellites are active sensors that emit radiation in the radar part of the electromagnetic spectrum and measure the reflected radiation (known as backscatter) and the phase of the radar wave. The phase is the particular point in time in the cycle of the radar wave. SAR satellites are side looking, meaning that the SAR sensor is pointing at a right angle to the flight direction and angled towards the ground. Figure 1 shows the side looking aspect of the SAR sensor. As a SAR sensor travels along its flight path, it takes repeat readings, creating a RADAR image of the earth.

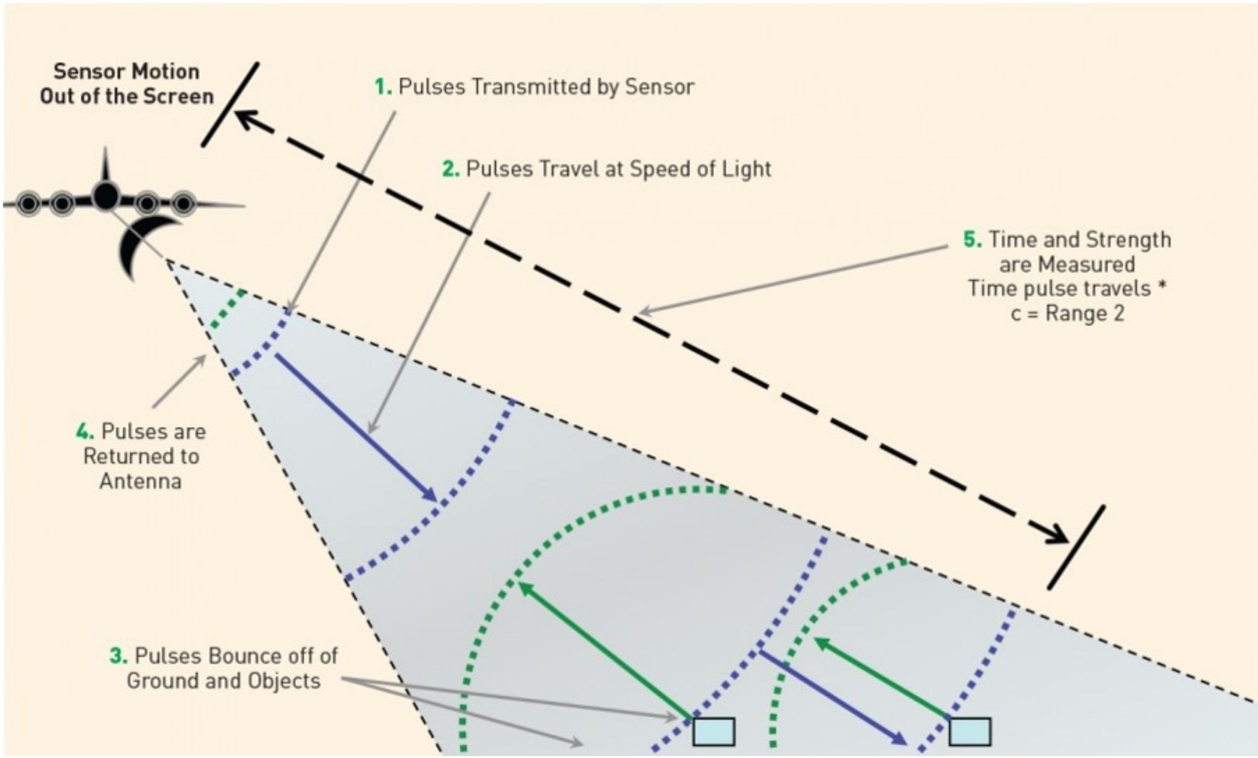

Figure 1. *Diagram of a side looking SAR sensor mounted on an airplane. The sensors flight direction is out of the paper, towards the reader.*

InSAR: Interferometric Synthetic Aperture Radar (InSAR) utilises the phase measurements of repeat satellite passes. If the ground/structure has subsided and lost elevation, then the radar wave will take slightly longer to return to the satellite because the distance the wave travels has increased. The longer time period means that the phase of the wave will have increased, which is measured by the satellite. The change in the phase is equal to the movement of the ground. Therefore, it is possible to detect millimetre changes of the ground surface movement. If the ground has been uplifted, then the time period is shorter due to the reduced distance. This results in the measured phase being reduced, which is equal to the ground uplift. This process that occurs for each pixel in a SAR scene. There are caveats to this extracting relevant information, for example extracting measurement points over vegetated areas cannot be done using the processing methodology that TVUK use.

InSAR is ideal for long term monitoring of important assets such as dams, bridges and quarries. The ability to monitor structural and ground movement across large areas is very useful for wide area monitoring. InSAR measurements are essentially "rulers" from space that can accurately measure millimetre scale changes. They measure the component of movement that is in the direction of the satellite. If the ground moves up exactly 3mm upwards, the InSAR measurement will detect the portion of that movement that has moved towards the satellite.

Use cases: Telespazio have completed numerous InSAR studies, however the results are not available to the public without the consent of the end user. Telespazio utilised InSAR with COMOS-SkyMed images across London, where the subsidence caused by the construction of a cross rail station was identified. Telespazio have also detected dangerous movement in a DAM wall, leading to a restoration project of the dam wall. Subsequently, Maria discussed the process of surveying asset infrastructures and asked our stakeholders their opinion on this and whether InSAR was an attractive option for them.

Infrastructure lifecycle and InSAR: The infrastructure cycle has three components, the planning and design phase, the construction phase and the operation and maintenance phase. InSAR can be a very useful tool during all three phases. During the planning and design phase, historical analysis will allow planners to identify areas of prior movement. This can be used to clarify liabilities in case of construction-induced movement. The Engineers and architects can use the historical ground stability to inform design choices. During the Construction phase, InSAR can be used to measure beyond the reach of in-situ instrumentation. It provides complementary and independent measurements of construction sites, in addition to regional monitoring around the construction area. For example, during tunnel excavation, the movement of structures above and around the construction area for several kilometres can be monitored. During the operations and maintenance phase, InSAR provides long term monitoring of the asset during and after the in-situ instrumentation has been removed. Furthermore, InSAR monitoring allows the planning of in-situ surveying campaigns with an understanding of the ground movement and asset deformation.

4. Open discussion on satellite monitoring.

Chair: Erlinda Biescas, Telespazio Vega UK

Figure 2: Wordcloud of transcript from first open discussion via https://www.jasondavies.com/wordcloud/ (accessed September 2019)

The key themes of this discussion can be summarised by the three Cs: cost, capacity, and coverage.

Cost:

Participants wanted to know how much it would cost to get an InSAR analysis, image processing and report.

There are two types of satellite data, open source and commercial.

- Open source satellite data such as the Sentinel missions and Landsat make all their data free to access.
- Commercial satellites such as the digital globe constellation and COSMO-SkyMed require payment to acquire these images. Commercial data is more accurate than the free data by an order of magnitude. For example, Sentinel-1 the highest resolution open

source SAR data set has a spatial resolution of 20m, where are COSMO-SkyMed SAR has a spatial resolution of up to 1m.

The price of InSAR analysis is twofold, the processing costs of the satellite data and the acquisition of commercial data. InSAR using free data such as Sentinel-1 is cheaper because the cost is just the processing time. A combination of free and commercial data can be very useful and cost efficient. Telespazio VEGA UK have completed a number of projects using Sentinel-1 data for wide area analysis, to generate hot spots, which are then analysed using the higher resolution COMSO-SkyMed data.

A very rough estimate of the total cost of one InSAR study using COSMO-SkyMed could be £60,000, however that can vary significantly depending on the extent of the area to be monitored, the time period, the satellite, how often clients require updates, how many images you require etc. The cost would be much cheaper if the study was done using free to use satellite data instead of the COSMO-SkyMed data. It is important that the client makes a decision early on in the monitoring design aspect of project management which instrumentation to use, understand what is on offer, and what's the best solution for the project you are running. A desire for a breakdown of costs i.e. an itemised service offering and a comparative cost effect analysis including comparison of different satellites, instrumentation and techniques is desired and information on public procurement procedures (which differ across Europe) is also wanted. Case studies outlining the cost savings by using this technology earlier in the project would also be welcome.

Capacity:

The capability of the technology was of great interest, with questions ranging from whether the satellite could predict the stability of road and bridge assets built on blanket bog (peat) terrain to the capacity of the data to affect project decisions. For example, one participant asked "from the information that has been available by the collection by the sensors, do you know if any engineering companies have taken action based on your results?" to which he was replied "there is quite a distance between the data providers and the data analysts – need to work together more closely. We supply the results, whether the company acts on the information is not up to us". Thus, the capacity of the technology is optimum when teams on-board and communicate correctly. The key to optimising this innovation is using it preventatively and not only when you realise you have a problem: preventative utilisation rather than reactionary is recommended. Confidence in height was also mentioned in terms of the capacity of this technology, one participant queried "What is the accuracy in terms of height for the Sentinel 1 data, what is confidence I can have in the altitude point, the PS. I want to know if I am seeing some reflection on the bridge, is it the bridge or something underlying motorway that passes under the bridge" to which he was replied: "InSAR results come in the form of a point cloud, points with x, y and z coordinates. As part of the FORESEE project, we are projecting the InSAR points onto a 3D model of the structure. It will be easy to determine if the points are above or below the bridge. Higher resolution is better for this process as more points will be captured on and around the bridge using COSMO-SkyMed, than Seninel-1".

Coverage (Geographic and temporal):

From 1992 to today, there is an archive of medium resolution data, that InSAR processing can be applied to. This data comes from a range of satellites such as ERS -1, ERS-2, ENVISAT, RADARSAT and Sentinel-1. Sentinel-1 was launched in 2014, the benefit of this satellite is that it acquires data continuously over Europe, therefore, the entirety of Europe is imaged every 6 days with 20m spatial resolution. Maybe this resolution is good enough for one client but not for another.

High-resolution data starts in 2007, however the coverage is sporadic, as the satellites do not acquire data continuously, images are acquired from paid requests from end users/operator. The COSMO-SkyMed constellation and the (TerraSAR –X/TanDEM-X) constellation were both launched in 2007. There is a good archive over Europe for high-resolution SAR imagery, especially over capital cities. There are areas that are continuously imaged but even these areas can face disruptions in the archive due to being tasked by Military/NATO decisions and have to image different areas than the planned area. An example of this is disaster mapping (e.g. flooding, earthquakes) and military images which can be acquired at any time.

Another participant commented: "I can see the benefit of this technology over long periods for monitoring post construction, I don't see how you would use this technology during construction when you can have an image every 4 or 25 days, when you need to make very fast decisions". The response was: "This technology is not suited for monitoring during construction apart from monitoring areas that will not change such as the ground around the structure, in the case of a skyscraper, the ground surrounding the building can be monitored to see if the ground is subsiding dangerously. This technology cannot acquire measurement points for areas that are constantly changing like a construction site. The key to this technology is to use it where it can provide actionable data. It will not replace all monitoring techniques, it is just another tool in the tool box of monitoring technologies"

One participant asked why is this technology more accurate in the East-West direction, as opposed to the North-South. This issue is more pronounced in mountainous areas; on flat ground, the difference in accuracy is negligible. The InSAR measurements are in the line of sight of the satellite, ergo the satellites do not measure the ground/structural motion from directly above the structure, they measure the motion from the angle shown in Figure 1. Imagine a West facing slope and a South facing slope. As the satellite passes from South to North (named as an ascending orbit), looking down at the East at a 20 degree angle from vertical, the movement of the slopes are measured in the East-West direction at that angle. The South facing slope may have moved 2mm in the southerly direction but the satellite will pick up the East-West direction of movement which will be less than the 2mm. The key is that this technology is designed to alert users when there is movement where they shouldn't be. In the case of a dam, any movement past a certain threshold will be investigated. Dams face all directions, however if the dam is facing south, then the InSAR measurements will still show movement that could be deemed dangerous. The technique will not identify the exact direction of movement, however the crucial information is obtained, that the dam is moving past a pre-designated threshold.

5. From satellite monitoring datasets to "in house" satellite monitoring system. FORESEE project.

5.1 Regional hotspot survey mapping. (Alejandro Roldan, University of Cantabria)

Illustrating Regional hotspot survey mapping via geographic information systems (GIS), this presentation concludes that using GIS for risk assessment is: fast; cheap; a good first approach; and upgradeable. This capability uses InSAR and change detection from Sentinel-1 imagery. This methodology can be used to calculate the risk in other parts of the transport network quite easily and readily. If additional data sets are generated, such as a high-resolution InSAR from COSMO-SkyMed, then this data layer can be easily integrated with the GIS system.

5.2 Satellite monitoring for landslide prediction (Boris Gailleton, University of Edinburgh)

Focussing on Landslides and infrastructure, this presentation outlined a model to predict landslides involving initial pressure distribution, rainfall input and InSAR measurements in order to determine the transient pore pressure and the landslide failure time and location. The numerical landslide prediction model developed by the University of Edinburgh uses a number of input datasets to predict the failure rate of slopes. The model has over 15 different parameters such as the soil transient pore pressure, the soil type, the angle of the slope etc. The innovation is using satellite data to replace in-situ data for the model so that is can be applied to a much larger area. A digital evaluation model is used to replicate the slopes topography and InSAR monitoring provides the slopes actual movement. The model is trained by iteratively running the model with different parameter values until the parameters accurately shows the movement detected by the InSAR measurements. Once the model is trained, different rainfall scenarios are run through the model, which produces failure times and depths for slopes with particular rainfall amounts. The planned final product is a real-time landslide risk algorithm that is generated using real–time precipitation data. For example, a thunderstorm is predicted over an area of landslide risk, the model then runs with varying amounts of rainfall, predicting the risk of landslides. The output would be a risk index for each amount of predicted rainfall. This product would be bale to send road and railway asset managers information telling them the risk of landslides of particular sections of slopes near assets.

5.3 S-SHM: state of art and developments in FORESEE (Maria de Farago, Telespazio Vega UK; Victor Centeno, RWS Spain)

This presentation outlines developments in Satellite Structural Health Monitoring (S-SHM) in FORESEE, highlighting the confluence of factors and tools involved Hot Spot Risk Mapping i.e. lithology, land cover, DEM, weather, population, infrastructures and InSAR.

S-SHM is an innovate solution for structural health monitoring. Every structure has thresholds of movement that are within safe boundaries and movements that exceed this. Regular structural health monitoring methods are in-situ devices that relay information back to the asset manager. These can be expensive to place around a large asset such as quarries, dockyards etc. When In-situ devices are located around a dockyard, they are only sampling where the instrumentation are located, the areas between them have no data. Using High-resolution InSAR, asset managers can measure the movement of their asset every 1m square across their site. An added bonus of this technology is the graphic representation that is shown to the end user. They can see their asset in 3D, being able to navigate around their asset looking at the structural health in virtual reality.

5.4 SUMMIT Satellite Ultra-Precise Motion Monitoring Integrated Technology (Maria de Farago, TelespazioVega UK)

This content delineates SUMMIT's capacity as Automatic; Updates Real-Time; 3D Motion Monitoring; Millimetric precision; Early warning; Enhanced Safety; Low Maintenance.

SUMMIT is an in-situ Global Navigation Satellite System (GNSS) sensor that collects ultra-precise, continuous location data. A number of these sensors placed on a critical asset, for example a dam, allows continuous monitoring of the structure at the end users requirements, such as every 5 minutes. Thresholds can be programmed into the software so that when a threshold has been crossed an automatic alert is sent to the asset manager. The boxes are low maintenance as they consist of a GNSS receiver and the container that is attached to the asset. Each receiver is connected to the brain box, which takes in all the GNSS data, stores and transmits it over the internet. The main hardware is the brain box, which is situated in an easy to access location and easy to repair.

The negative of this technology is that the SUMMIT boxes only monitor the fixed point that they are placed. There may be deformation of the dam between the boxes, which will not be picked up immediately. The solution is to utilise InSAR in conjunction with the SUMMIT boxes. The areas between the boxes will be covered and the InSAR will have ground truths that increase the accuracy of the InSAR measurements.

6. Open discussion on satellite monitoring system and FORESEE

Chair: Maria de Farago, Telespazio Vega UK

Figure 3: Wordcloud of transcript from second open discussion via https://www.jasondavies.com/wordcloud/ (accessed September 2019)

This discussion elicited the three I's: interoperability, international standards and integrated monitoring. Cost was again a pervasive feature of the discussion, embedded into the themes below:

Interoperability: There is a challenge in integrating new data visualisation and new technology into existing platforms; they are not always interoperable. If a client has a single platform and with all the asset data from numerous layers from various providers, including maps and survey information, it would be very useful to have an InSAR map layer as a dataset. Perhaps even a point cloud and be able to click on certain areas. It would be very useful.

If a client does not have their own data management system, it's hard to determine what you want from this visual, 3D approach. Some questions included: "So, if new companies are starting from scratch, can you provide them with a solution of how to store the data? Can you give them guidance as to how to monitor their assets?". Is there a solution as to how to visualise the data and transfer the raw data from your system to theirs in a smooth way? The aim is to integrate the digital world, the physical world and its existing infrastructure and be able to marry everything together to help make decisions easier. Telespazio can say that this is where the industry is moving towards. We think it's the right approach, but we need a better perception of the gaps between just sending datasets and creating digital environments based on that knowledge.

International standards:

Local authorities/municipalities work in tight templates. It would be needed a change of standards in order to sanction investing in satellite imagery. The contractual set up is tricky in procurement processing. You need to bridge this technology with someone with vision to articulate the benefits of this technology. Governmental funding for this type of research was also advocated for so that countries invest in the technology for the betterment of asset monitoring in Europe.

Trust is an issue; confidence in the data and reports needs to be strengthened as there are some conflicting conclusions coming out from the same data from different providers in the market. There is a need to either accredit or standardise InSAR providers. An argument against standardising is that it will stifle innovation, as indicated by one participant: "There are slightly different algorithms and lots of different parameters but it's down to the scale and expertise of the analyst. I agree we should have a list of who are the good providers but, in the end, we need to pay attention to the process and client spec provided. Standardising is hard and it may very well stunt innovation and usefulness in this area. Perhaps accreditation is the way forward". Using the requirements of the end user, expert InSAR analysts are able to extract information from data sets and are able to provide information as to when and why it might or might night not be possible to acquire InSAR measurements.

Integrated monitoring:

InSAR is not a panacea, it is a tool and it can be used with other tools and analytics to monitor and analyse the environment and critical structures. Using InSAR and other satellite technology as an additional tool to physical onsite inspection of assets adds a complementary feature to asset management, bolstering monitoring rigour and reducing the number of onsite visits which are costly and time consuming and subject to human error/limitations of the human eye. The technology can be complementary and perhaps reduce the amount of time or the frequency that personnel have to go to the site i.e. onsite from every 5 years to every 10 years.

Integrating the technology into monitoring non-linear structures was also raised: "FORESEE is obviously looking at linear networks and often in scenes there's a huge amount of space that's not relevant to those networks - is there any other way of packaging the data to look more at the areas of interest?" Cutting down the space around the asset could be a way to reduce costs, i.e. providing bespoke reports on smaller coverage areas for less money. The use cases here are linear because the structures themselves are linear. There is no particular required shape or size for InSAR monitoring. There are minimum sizes for example Telespazio VEGA UK practices a minimum of 2km buffer around the target to ensure accuracy. There is no maximum size limit for InSAR monitoring; there are European countrywide ground deformation datasets that can be accessed online, produced from Sentinel-1 data. To do so with COSMO-SkyMed data is prohibitively expensive.

It was said that “Many people have been turned away from InSAR because a number of InSAR providers have stated completely different results from the same data”. Different results can be produced from the same data due to the level of processing that is required to extract the measurement points and level of certainty. How do the end users know which providers are correct and are selling the correct information?

It was wanted to know how any InSAR points would there would be over the UK. This cannot be determined until the data has been acquired and processed. An average coverage number could be determined based on the land cover type. This would inform the decision-making processes if they should use InSAR monitoring.

It was stated that they see the benefit of high resolution InSAR but it is hard to access high-resolution data. They do not want to replace reactive monitoring with satellite data. Currently, the practice is to wall walk and carry out visual inspection that if a defect is found to carry out further monitoring with more intensive quantities methods. They “want to reduce the frequency of the wall walking as the satellite data won’t replace the human eye”.

It was asked “What is the precision of measurements point height?”. As in how to know if the measurement point is on the bridge or a lamp on the bridge. The points are 3D due to the InSAR recording the time difference between sending the radar pulse and response. The InSAR measurement is the change in the phase, which is the millimetre change in height. Overlaying the points onto a 3D environment will show the user if the point is on the bridge or the lamp above the bridge.

Integration of InSAR data into end user systems

It is difficult to communicate new technologies to civil engineering sector. Most systems are not prepared for InSAR data integration in raw form. Some companies require full data assimilation whereas other companies have systems that they would like to ingest InSAR measurement data. Highways England have their own monitoring system that would like to have the data to integrate with their own data. For example a GIS layer to import; this has been done for other clients.

Some attendees struggle with the cost of high resolution data, so they use sentinel-1 imagery. They are required to trust in the algorithms used to extract the data. How do they know whom to trust to accurately extract the data? There needs to be a trust in the data and the provider.

It was asked how do they trust the data and outcomes that different companies are producing using the same data? If you lower the confidence, the number of InSAR points is increased, therefore there is more coverage using the same data. This decision should be communicated to the end user, so they can make an informed choice on the data they receive.

7. Resilience Shift initiative

Resilience Shift activities with regard to transport infrastructures (Áine Ní Bhreasail, Arup)

This presentation outlined ARUP's global initiative to catalyse resilience within and between critical infrastructure sectors and summarised its work under three themes: ways and means; resilience drivers; and common understanding of resilience across sectors.

Open discussion on FORESEE & Resilience Shift synergies/collaboration

The discussion entailed reflection on societal shifts in resilience, cultural awareness of the term and what it means for individuals, organisations, decision makers, first responders and asset managers. The term 'resilience' itself was also discussed and the UNISDR definition was recommended as a baseline. SRG members and FORESEE consortium members expressed interest in working with the Resilience Shift and adding their tools to the database. The resilience cycle was addressed in terms of adapting the technology, from prevention to response to recovery. If it's overly expensive, you are not going to be investing in it until you clearly have a problem which is something FORESEE researchers and indeed EU decision makers are trying to avoid. We are trying to invest in early warning systems and pay attention to these movements *before* something catastrophic happens. So, the ideal of the FORESEE project is to have a suite of tools that will help you differentiate your needs depending on what end of the resilience cycle your asset is at. Linking back to other participants, there are ways for this to be cost effective so that you are not physically assessing assets as often, which saves money, damage and response resources in the long run.

8. Closing of the Meeting

SRG chairman thanked all and reiterated that the material (i.e. PPT and questions) will be sent to all attendees. He highly appreciates your comments and the answer to the questionnaires but please feel free to react to these question and comments today, before October 11th, 2019.

He asked for suggestions for other SRG members to broaden the present membership. He reminded all attendees of the upcoming **SRG Webinar in November 14th**. Finally, he again highlighted the relevance of the role of SRG for FORESEE project