

Presented at the FIG Working Week 2016,
May 2-6, 2016 in Christchurch, New Zealand

Advances in the use of Ground Based Radar for Disaster Recovery Risk Management

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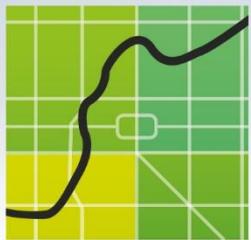


FIG Working Week 2016

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Recovery

from disaster

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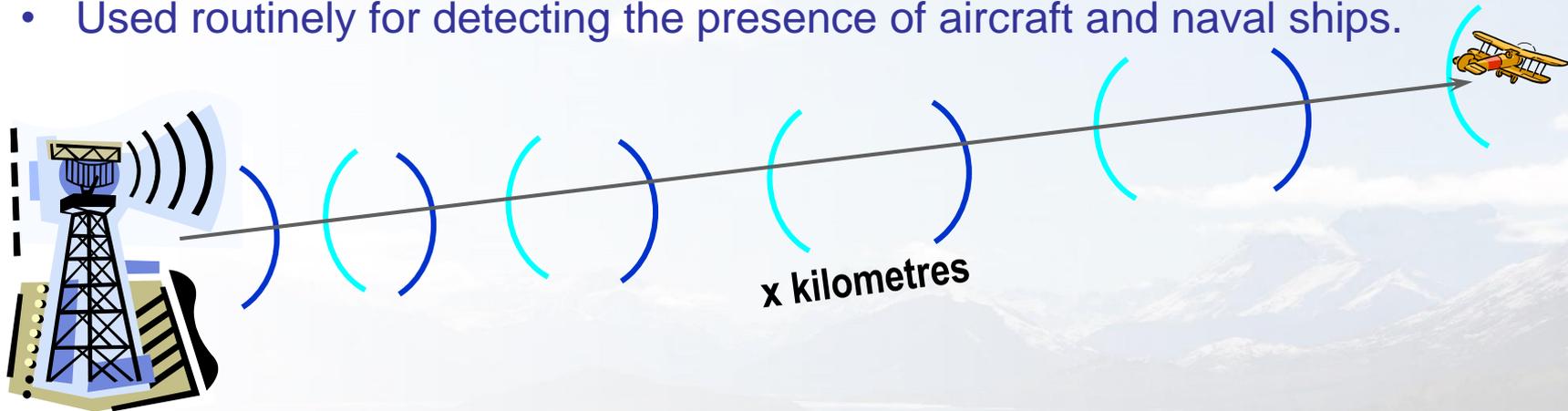
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Recovery

from disaster

- RADAR – Radio Detection And Ranging
- Used routinely for detecting the presence of aircraft and naval ships.



- More recent uses of ground based radar:
- Ground-penetrating radar (GPR) for geological / civil infrastructure investigations
- Interferometry and Synthetic Aperture Radar (SAR) for remote monitoring of the movement of structures and landscapes.
- The use of ground based radar lends itself to many applications in disaster risk management.



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Recovery

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IBIS

Image **B**y Interferometry **S**urvey



Stepped Frequency - Continuous Wave (SF-CW)
Frequency Modulated – Continuous Wave (FM-CW)



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Recovery

from disaster

PRODUCTS

IBIS F range

APPLICATIONS



IBIS - FL



LANDSLIDE & DAM MONITORING



IBIS - FM



SLOPE STABILITY IN MINING



IBIS - FS



STRUCTURAL MONITORING



IBIS-FS application overview

- IBIS-FS radar technology is used for vibration and displacement measurement
- The main advantages of the use of IBIS-FS is the high accuracy (0,01 mm) and the remote sensing nature of the system (up to 1 km range).





FIG Working Week 2016

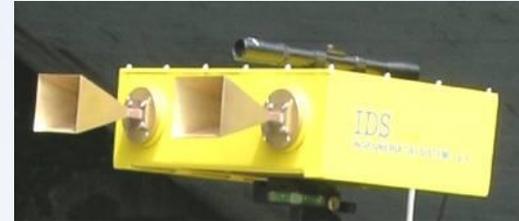
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Recovery

from disaster

Sensor unit:

- Signal Transmitter and Receiver
- 200Hz sampling



Tripod and 3-D rotating head:

- Aluminium tripod:
 - lightweight: 4.3Kg;
- 3-D rotating head:

Processing unit:

- PC with management SW



Power supply unit:

- 2 batteries 12VDC 12Ah



Techniques behind the IBIS FS system from disaster

The IBIS FS product is based on two radar techniques:

1. **Stepped Frequency - Continuous Wave (SF-CW)** is technique used to obtain a 1-Dimensional Range Profile with Range Resolution.

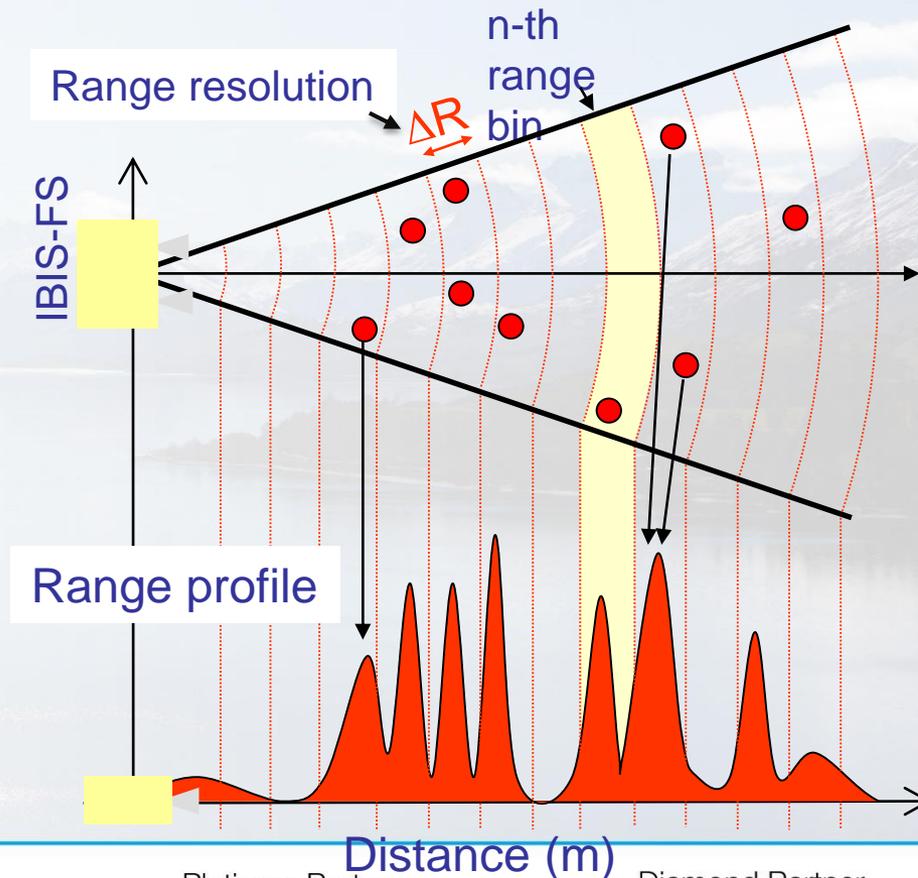


2. **Interferometry technique**, computes the displacement of each pixel by comparing the phase information of the radar signal collected between 2 acquisitions.



IBIS-FS Acquisition Mode

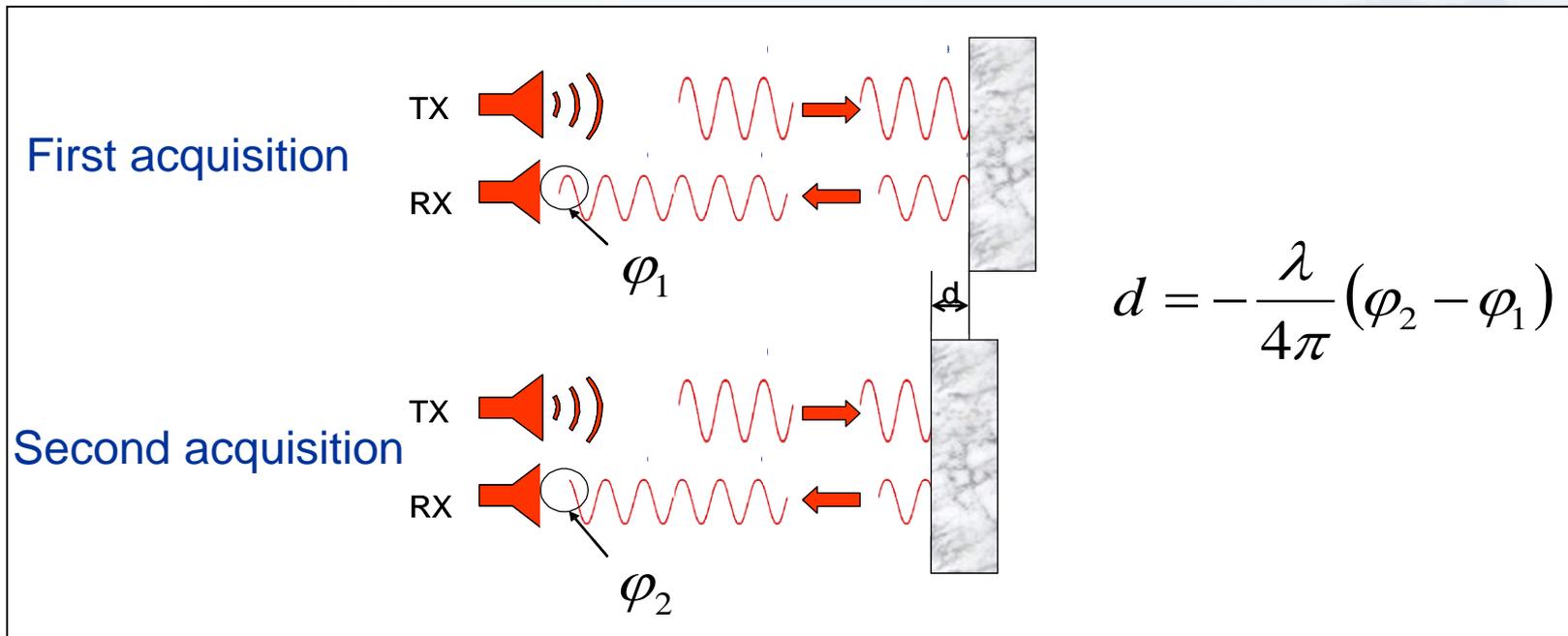
- Beamwidth variable between 20 and 100 degrees
- The measured scenario is divided into range bins, whose number depends on the **range resolution** (0.5 m minimum, constant with distance).
- User's defined **maximum range** (up to 1 Km)





Interferometric capability

The **interferometric analysis** provides displacement information by comparing phase information of reflected waves between two separate acquisitions. Allows accuracy of less than 0.01mm to be achievable.

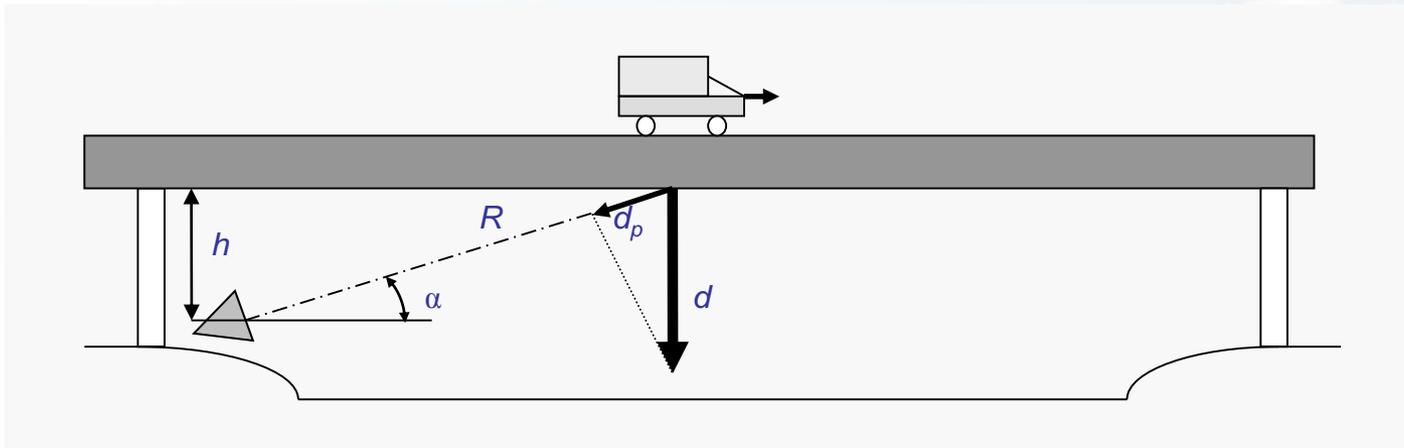




1-D Interferometric capability

The displacement is measured in the direction of the **line of sight** of the system.

To calculate the real displacement is needed to know the acquisition geometry



$$d = \frac{d_p}{\sin(\alpha)}$$



$$\sin(\alpha) = \frac{h}{R}$$



$$d = d_p \cdot \frac{R}{h}$$

*The distance R
is measured
by IBIS-S*



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Recovery

from disaster

Dynamic Monitoring: Kuranda Scenic Railway



Kuranda train (Cairns, Australia)



Measurement set-up



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Recovery

Dynamic Monitoring: Kuranda Scenic Railway from disaster

Time history displacement of a selected points (first train passage)





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Recovery

Cadore Bridge (Belluno)

length: 128m

IBIS FS Structural Monitoring System

Radar position



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Recovery

from disaster

Early warning with IBIS RADAR (University of Florence and IDS)



Stomboli,
Italy

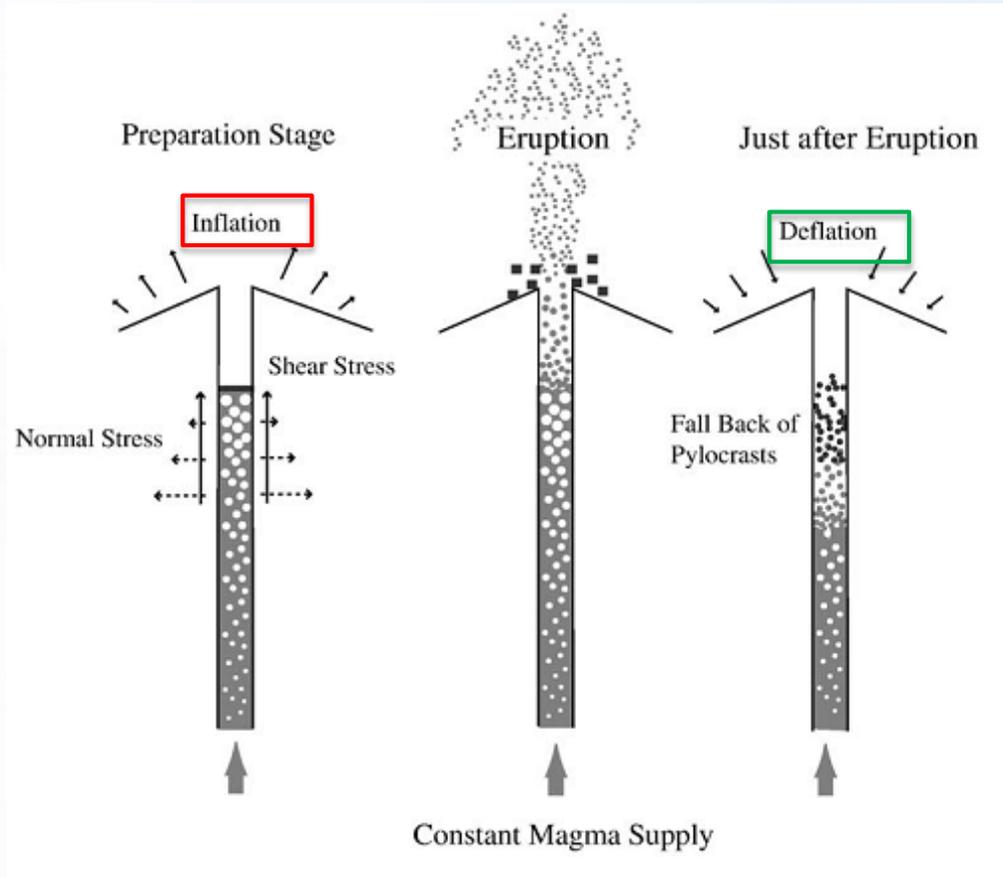


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Ground deformation induced by magma rising in the conduit



Ref. Nishimura, T., (2009), *J. Volcanol. Geotherm. Res.* 187, 178-192



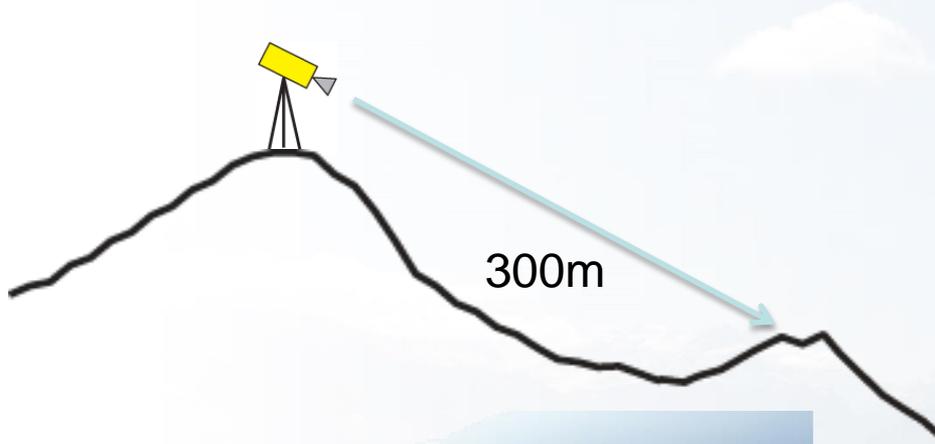
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RADAR & Volcanoes: test case Stromboli Volcano, Italy



Ref. Nishimura, T., (2009), *J. Volcanol. Geotherm. Res.* 187, 178-192



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Recovery

from disaster

Signals correlation between radar, seismic and tiltmeter sensors

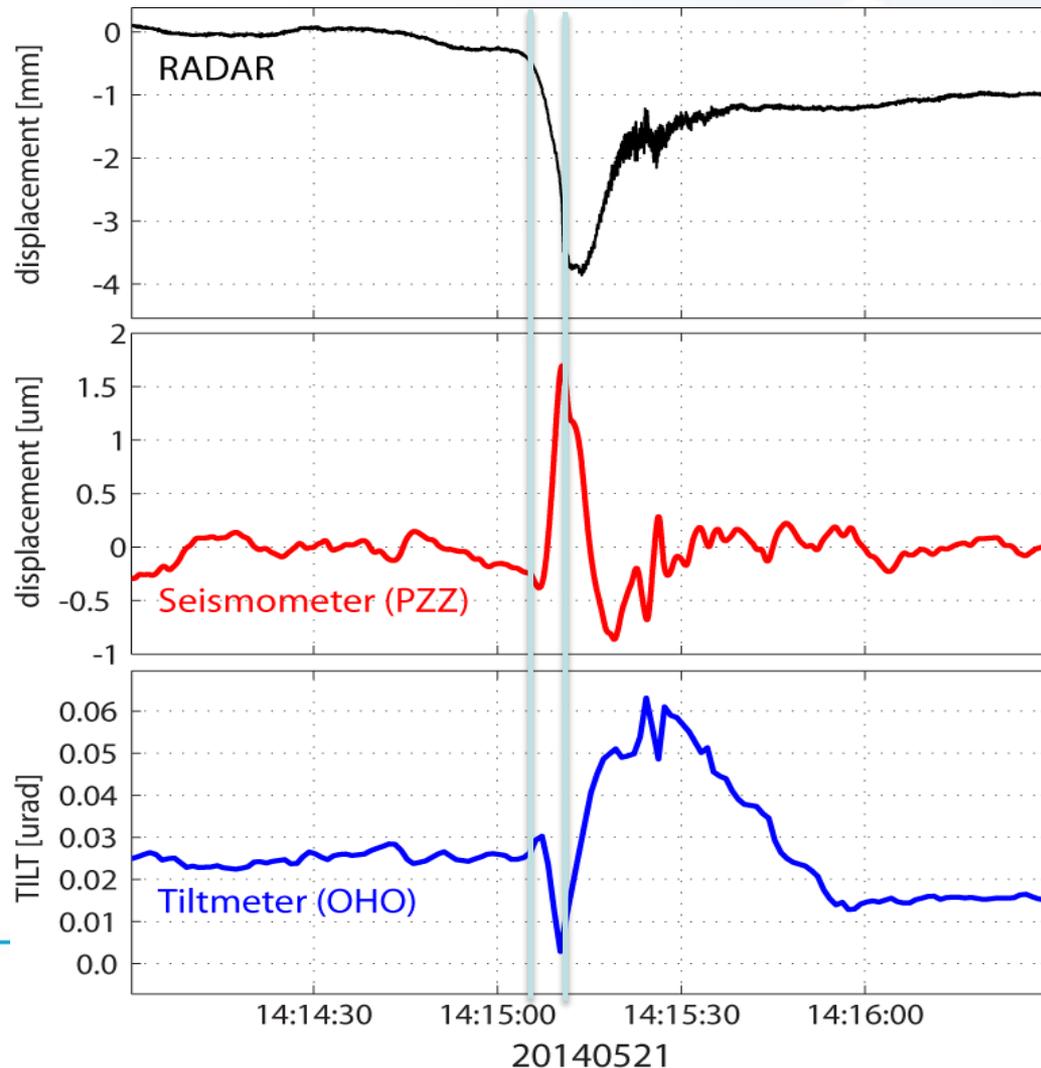




FIG Working Week 2016

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Recovery

from disaster

IBIS F range

PRODUCTS



IBIS - FL



IBIS - FM



IBIS - FS



APPLICATIONS



LANDSLIDE & DAM MONITORING



SLOPE STABILITY IN MINING



STRUCTURE MOVEMENTS

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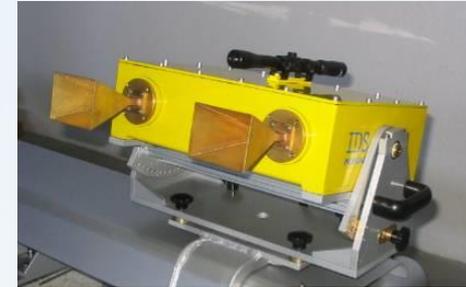
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Recovery

from disaster

Sensor unit:

- Signal Transmitter and Receiver



Linear Scanner :

- 2 m track
- Step-by-step motor



Processing unit:

- PC with management SW



Power supply unit:

- 2 batteries 12VDC 130



Techniques behind the IBIS-FL system from disaster

IBIS is based on 3 well-known radar techniques:

1. **Stepped Frequency - Continuous Wave (SF-CW)** is technique used to obtain a 1-Dimensional Range Profile with Range Resolution.
2. **Interferometry technique**, computes the displacement of each pixels by comparing the phase information of the radar signal collected between 2 acquisitions.
3. **Synthetic Aperture Radar (SAR)**



3. IBIS-FL: Synthetic Aperture Radar (SAR)

SAR technique enables the system to provide high cross range resolution exploiting the movement of the physical antenna along a linear scanner



Using 2 m rail
IBIS-L system obtains
4.38mrad (=0.25deg)
angle resolution

The SAR process allows the IBIS-FL and FM systems to synthesize a 2m antenna.

System range is 4km.



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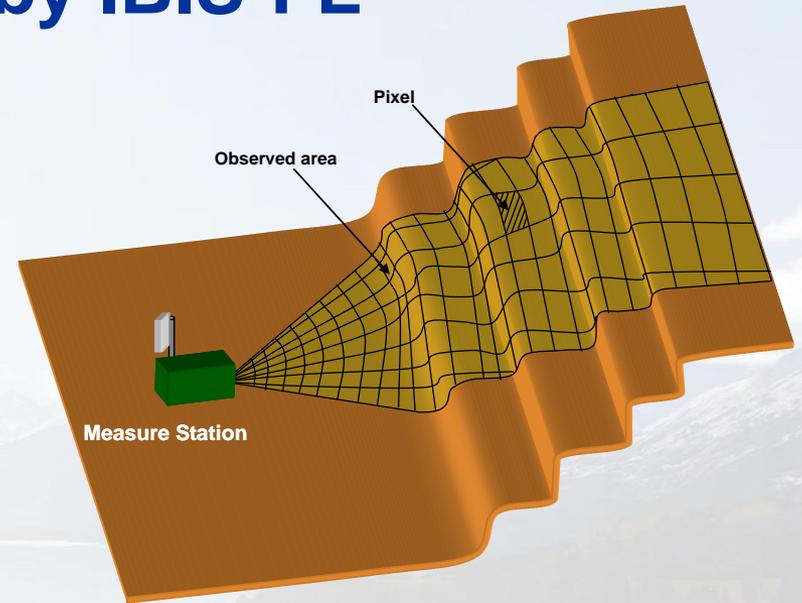
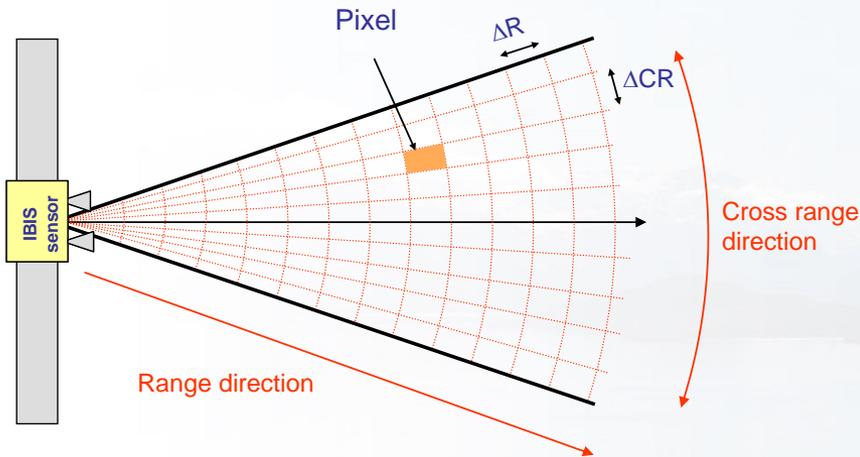
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Recovery

from disaster

Area covered by IBIS-FL

Spatial resolution



Spatial resolution:

- Pixel size varies with distance
- (1km = 0.5m x 4.3m)



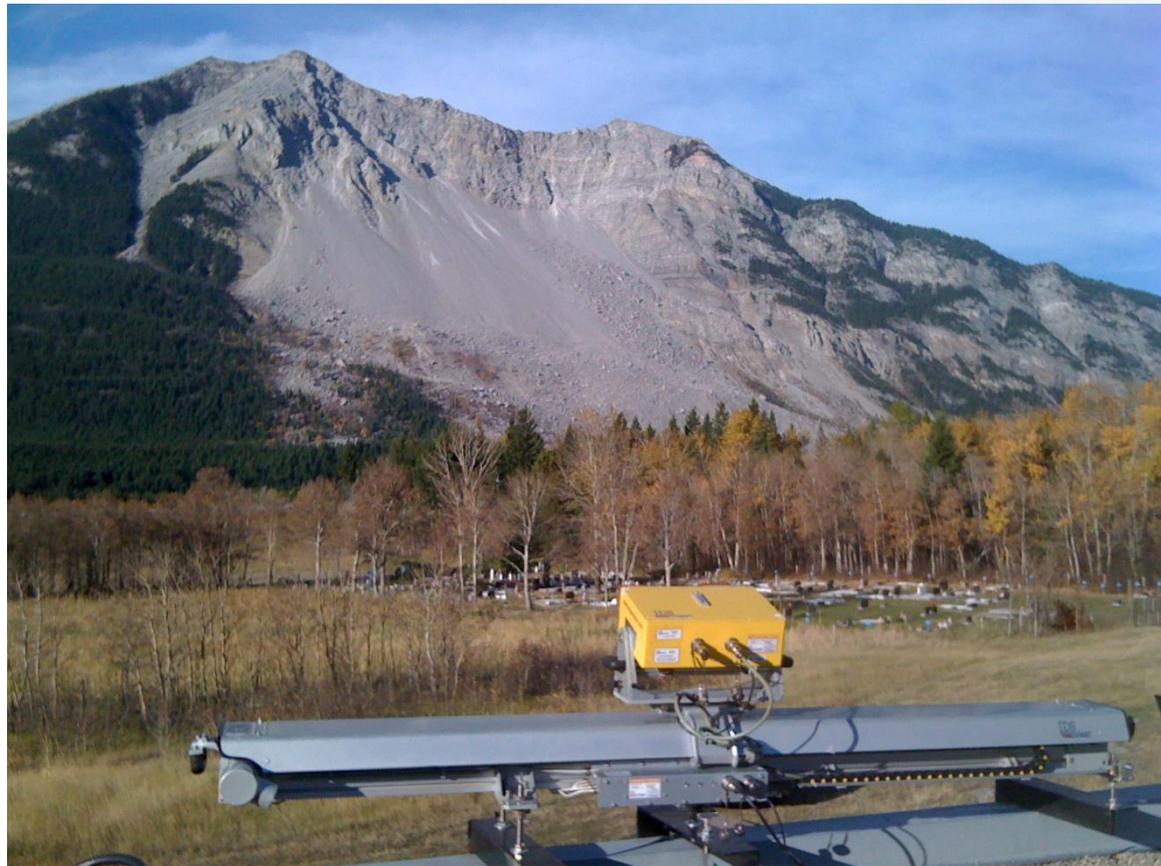
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Recovery

from disaster

IBIS-FL instalation site at Frank Slide, Canada



IBIS –FL is used for monitoring the famous Frank Slide on Turtle Mountain that in 1903 killed 90 peoples. The landslide is still active.

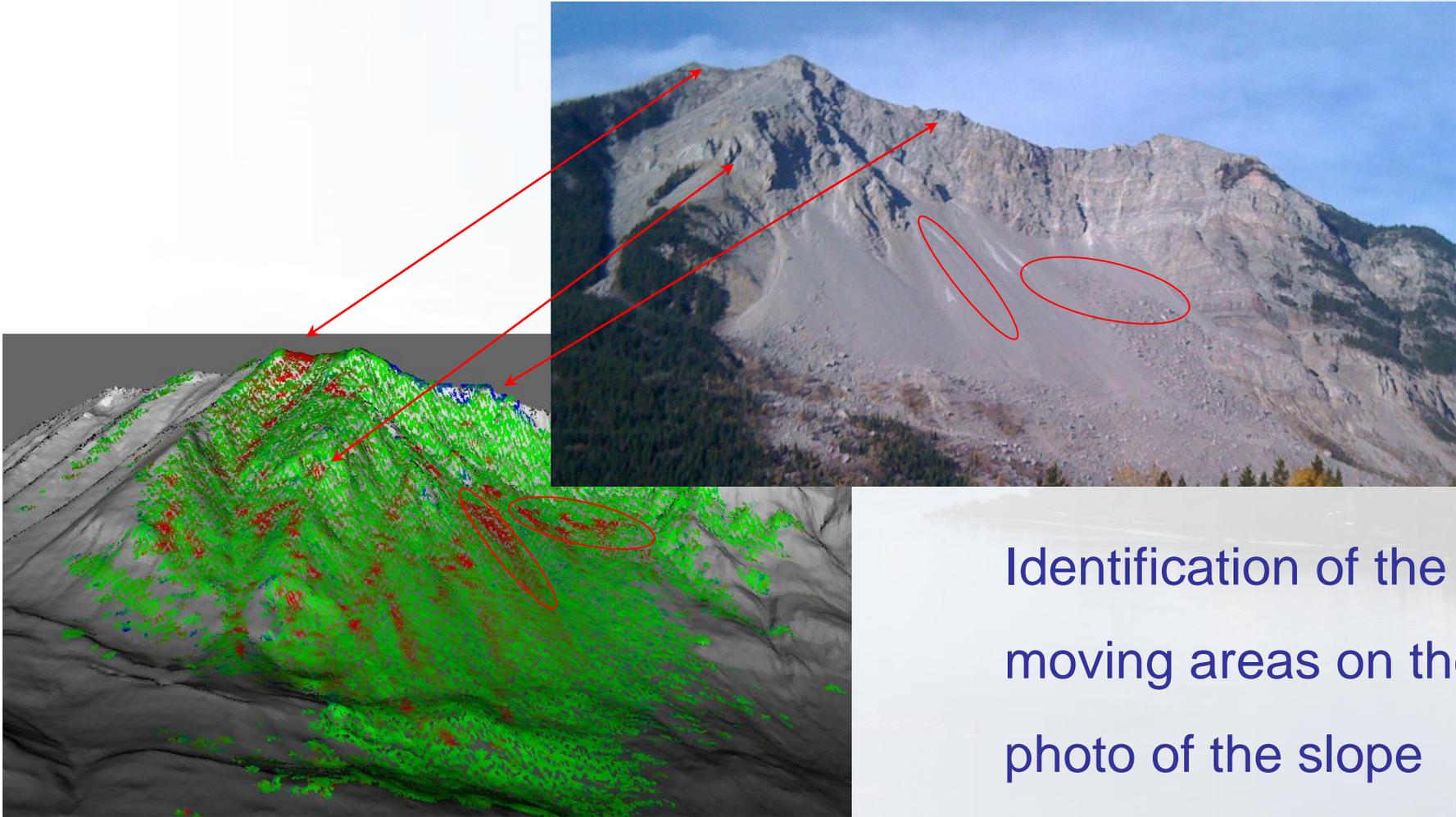


FIG Working Week 2016

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Recovery

from disaster



Identification of the moving areas on the photo of the slope



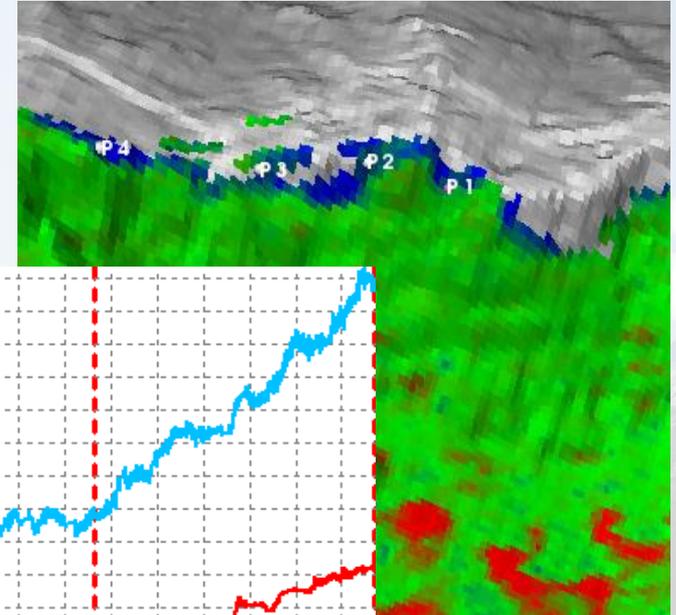
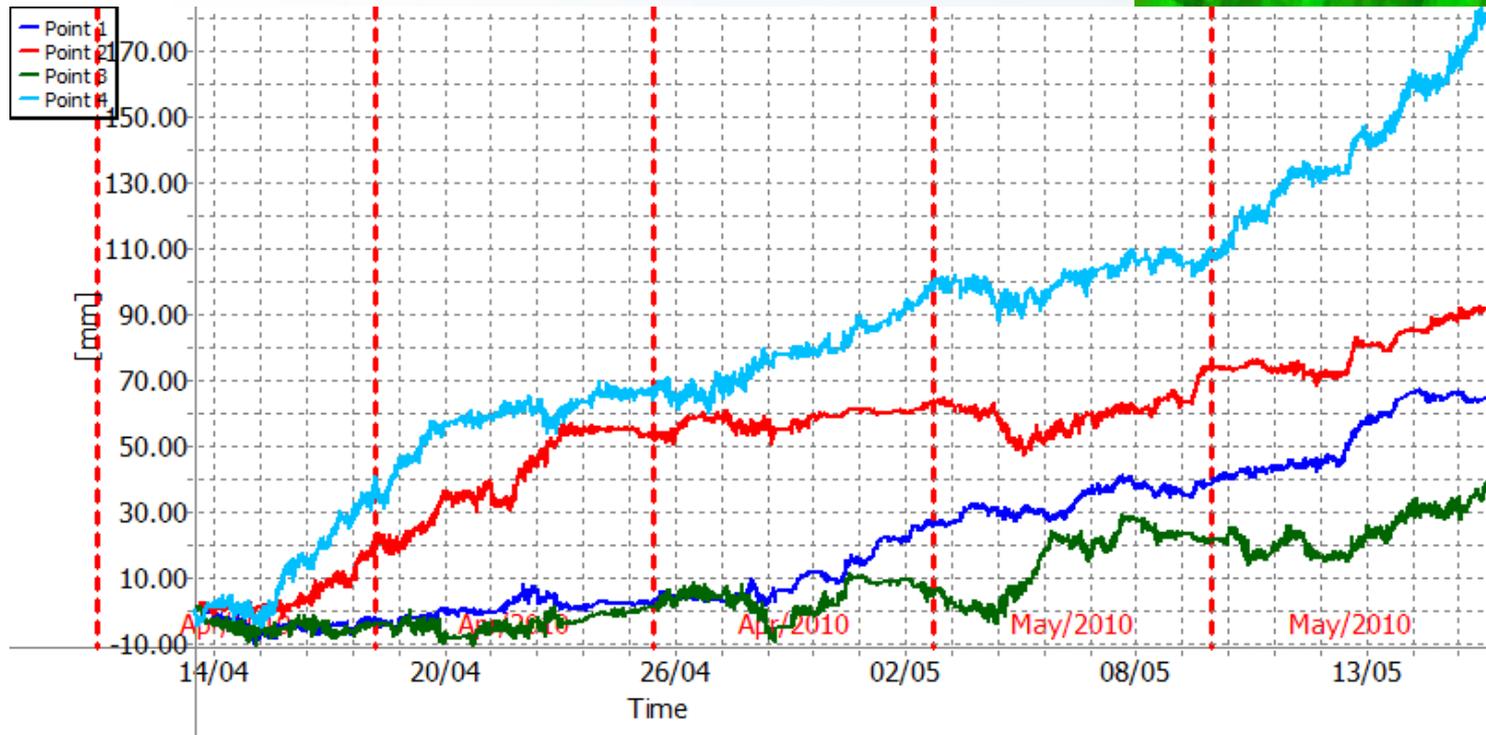
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Recovery

from disaster

14/04/2010-17/05/2010 dataset



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Recovery

from disaster



FM-CW SIRIO OBSTACLE DETECTION SYSTEM

Innovative technology for high risk zones



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Recovery

from disaster

PROBLEM: COLLISION BETWEEN TRAIN AND AN OBSTACLE ON TRACK

2012 Italy
Level Crossing Accident



2012 England
Level Crossing Accident



2010 China
landslide



2010 Italy
landslide



FIG Working Week 2016

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Recovery

from disaster

SYSTEM COMPOSITION



2. Video Sensor

- ❑ Triggered by radar alarm



3. NCU-Node Control Unit

- ❑ Power supply
- ❑ Interface with Signalling System



4. Remote Control Unit

- ❑ GUI Interface for operator

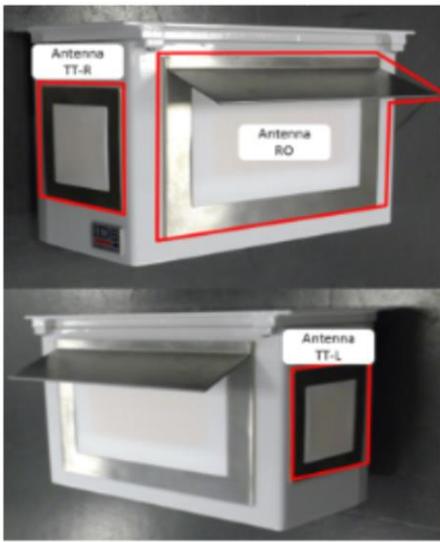




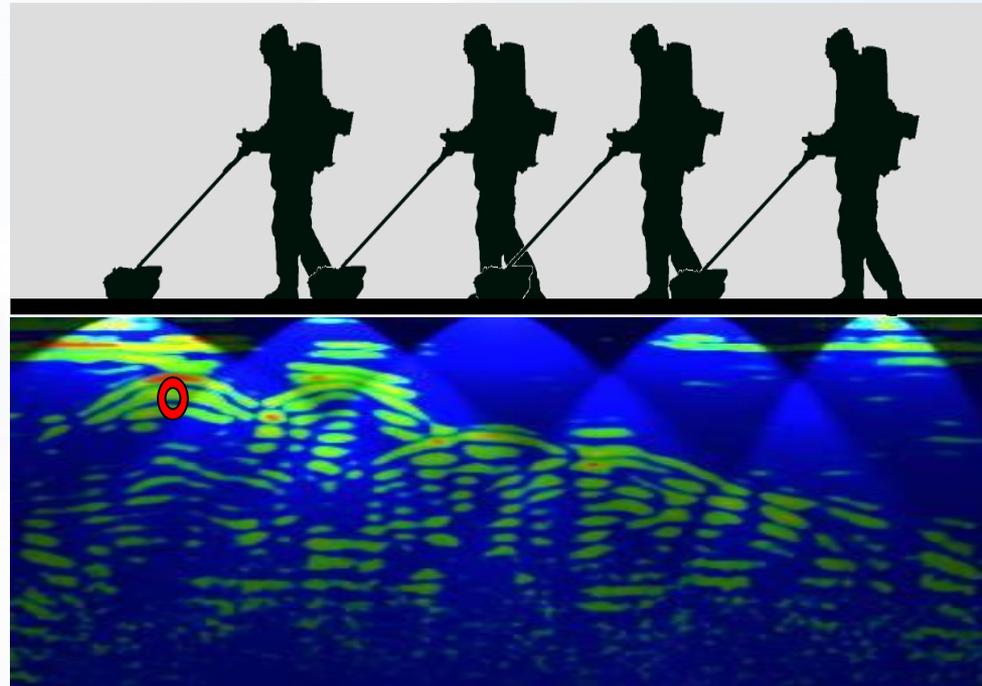
FIG Working Week 2016

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Recovery

from disaster

GPR



Contrasting EM properties show as features and these can be mapped



WHY GPR technology?

- Varying depth and resolution possible, highest resolution geophysical technique
- **GPR** can **detect all material types** and is a **MUST** method in urban environments
- **GPR optimizes** excavations - reduces cost and risk.

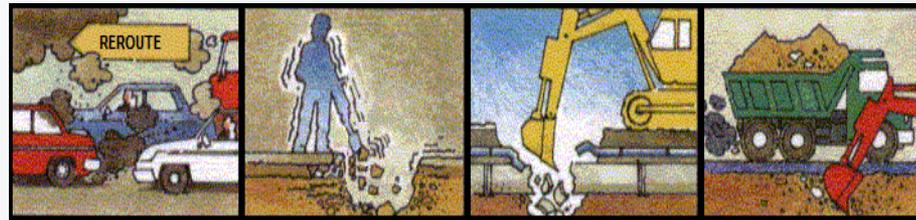




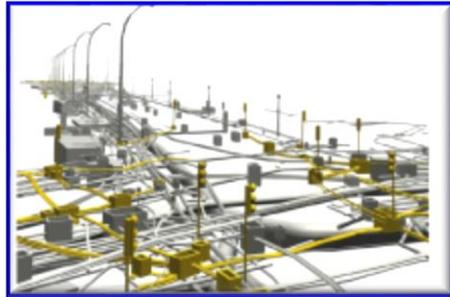
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Recovery

from disaster

SPECIALIZED SOLUTIONS FOR UTILITIES



UTILITY DETECTION AND MAPPING



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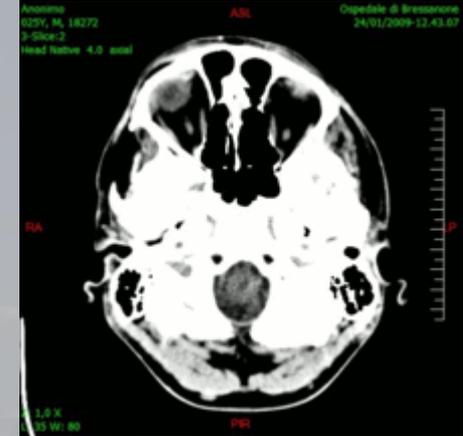
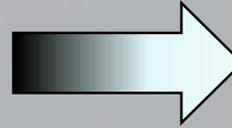
CHRISTCHURCH, NEW ZEALAND 2-6 MAY 2016

Recovery

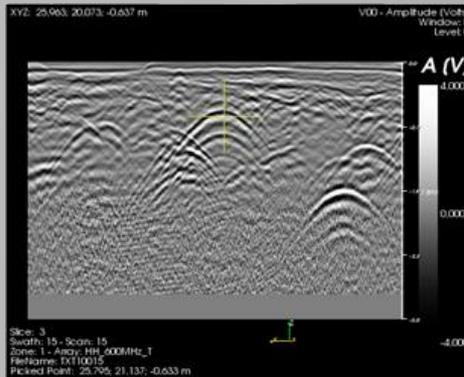
from disaster



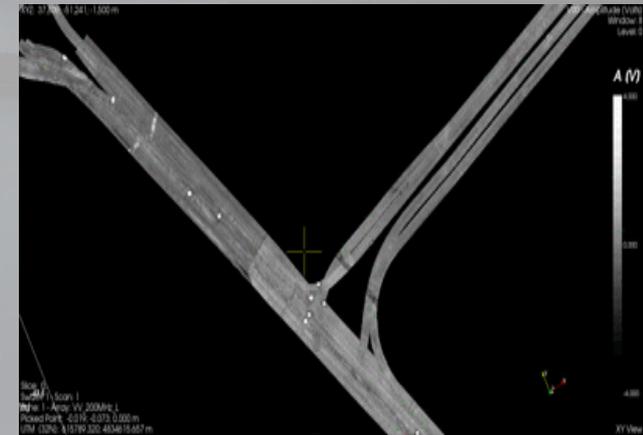
Radiography



CAT (Tomography)



B-Scan



C-Scan (Tomography)



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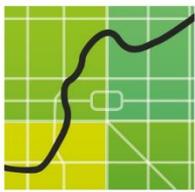


FIG Working Week 2016

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Recovery

One Vision - Real time tomography (1of7)

from disaster





FIG Working Week 2016

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Recovery

One Vision - Real time tomography (2of7)

from disaster

Survey_2014.12.12_003 - OneVision

Array 200 VV Swath 1

C-Scan

B-Scan1 - Ch. 9

B-Scan2 - Ch. 38

Depth (m)

395.01m

365.04 380 390

1 2 3 4.00m

395.04m

363.60 380 390

1 2 3 4.00m

6.9 km/h

18

C-Scan B-Scan1 B-Scan2 T-Scan



FIG Working Week 2016

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Recovery

One Vision - Real time tomography (3of7)

from disaster

The screenshot displays the OneVision software interface for real-time tomography. The main window is titled "Survey_2014.12.12_003 - OneVision". At the top, there is a toolbar with icons for navigation and settings, and a dropdown menu set to "Array 200 VV" and "Swath 1".

The interface is divided into several sections:

- C-Scan:** A large map view on the left showing a yellow highlighted path over a grayscale terrain. A compass rose is visible in the top right of this section.
- B-Scan1:** A tomography plot on the top right showing depth (m) on the y-axis (0 to 4.00m) and distance on the x-axis (377.76 to 400). It displays seismic waveforms.
- B-Scan2:** A second tomography plot on the bottom right, similar to B-Scan1 but for channel "Ch. 38", with a depth of 407.79m.
- Controls:** A vertical panel on the right side containing several large circular icons for navigation and data management.
- Status Bar:** At the bottom, it shows a speed indicator of "7.1 km/h", a speed limit sign of "18", and buttons for "C-Scan", "B-Scan1", "B-Scan2", and "T-Scan".



FIG Working Week 2016

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Recovery

One Vision - Real time tomography (4of7)

from disaster

The screenshot displays the OneVision software interface for real-time tomography. The main window is titled "Survey_2014.12.12_003 - OneVision". At the top, there is a toolbar with icons for array selection, swath selection, and various tool functions. Below the toolbar, the interface is divided into several sections:

- C-Scan:** A large map view on the left showing a yellow highlighted path over a grayscale terrain image. A compass rose is visible in the top right of this section.
- B-Scan1:** A tomography plot on the right showing depth profiles for channel 9. The plot has a vertical axis labeled "Depth" and a horizontal axis with values 337.24, 400, and 410. The depth scale on the right ranges from 1 to 4.00m, with a specific value of 417.24m marked.
- B-Scan2:** A second tomography plot for channel 38, showing similar depth profiles with a marked value of 417.30m.
- Controls:** A vertical panel on the right side containing several large circular icons for navigation and control, including a home button, a refresh button, and a zoom button.
- Status Bar:** At the bottom, there is a speed indicator showing "7.6 km/h", a red circular warning icon with the number "18", and a row of buttons for "C-Scan", "B-Scan1", "B-Scan2", and "T-Scan".





FIG Working Week 2016

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Recovery

One Vision - Real time tomography (5of7)

from disaster

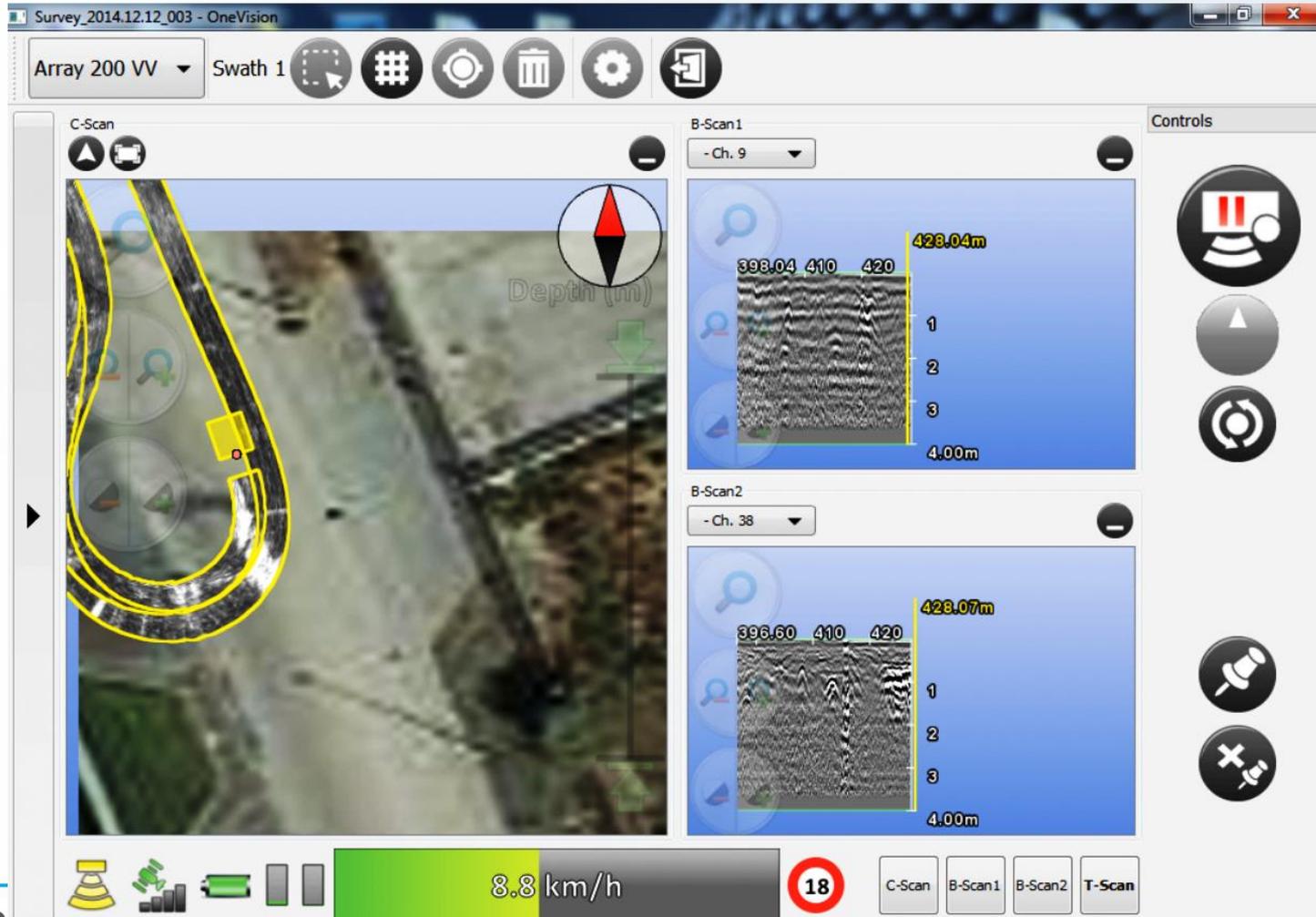




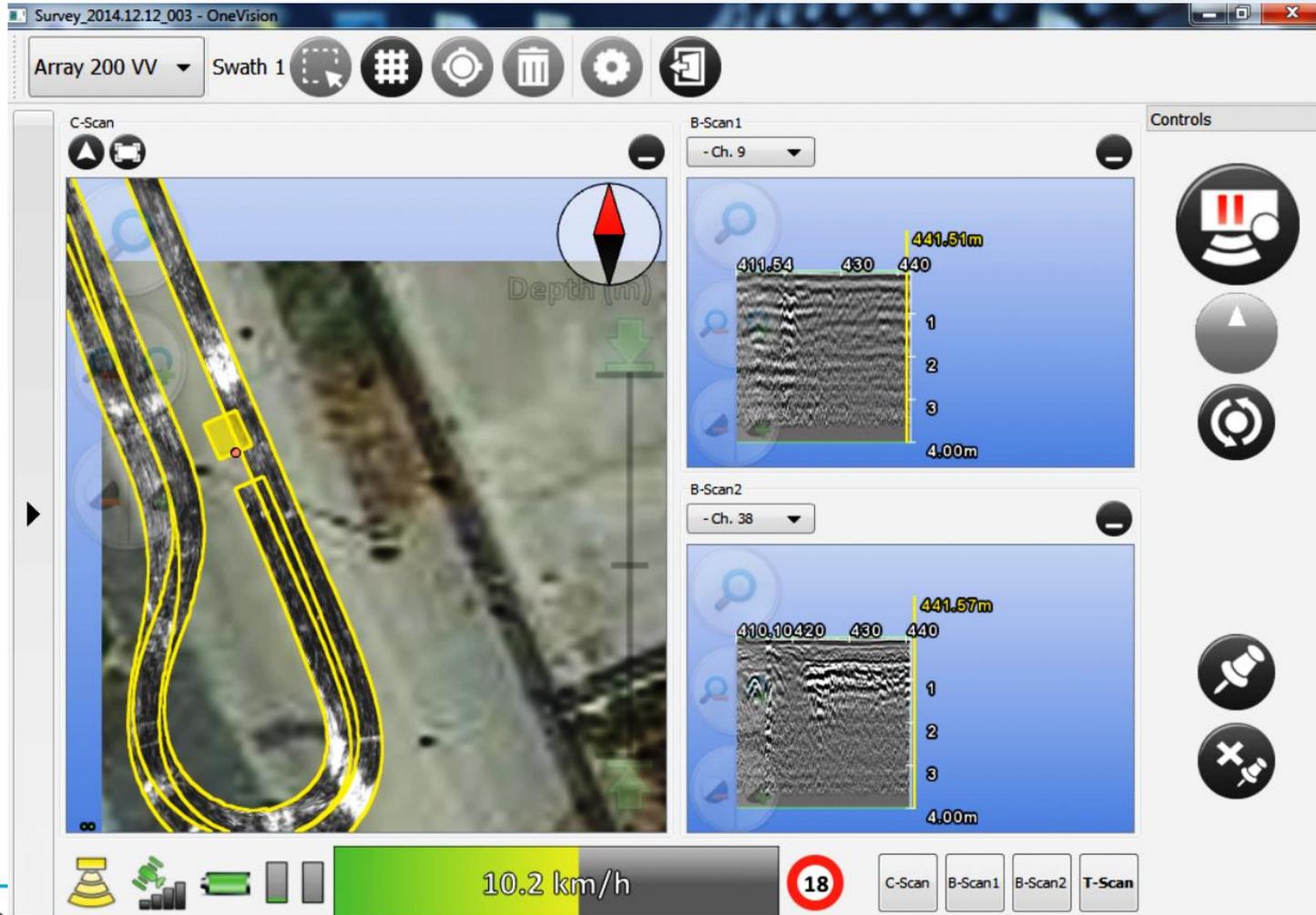
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Recovery

One Vision - Real time tomography (6of7)

from disaster



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Recovery

One Vision - Real time tomography (7of7)

from disaster



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Recovery

from disaster

SafeRailSystem – High Speed GPR

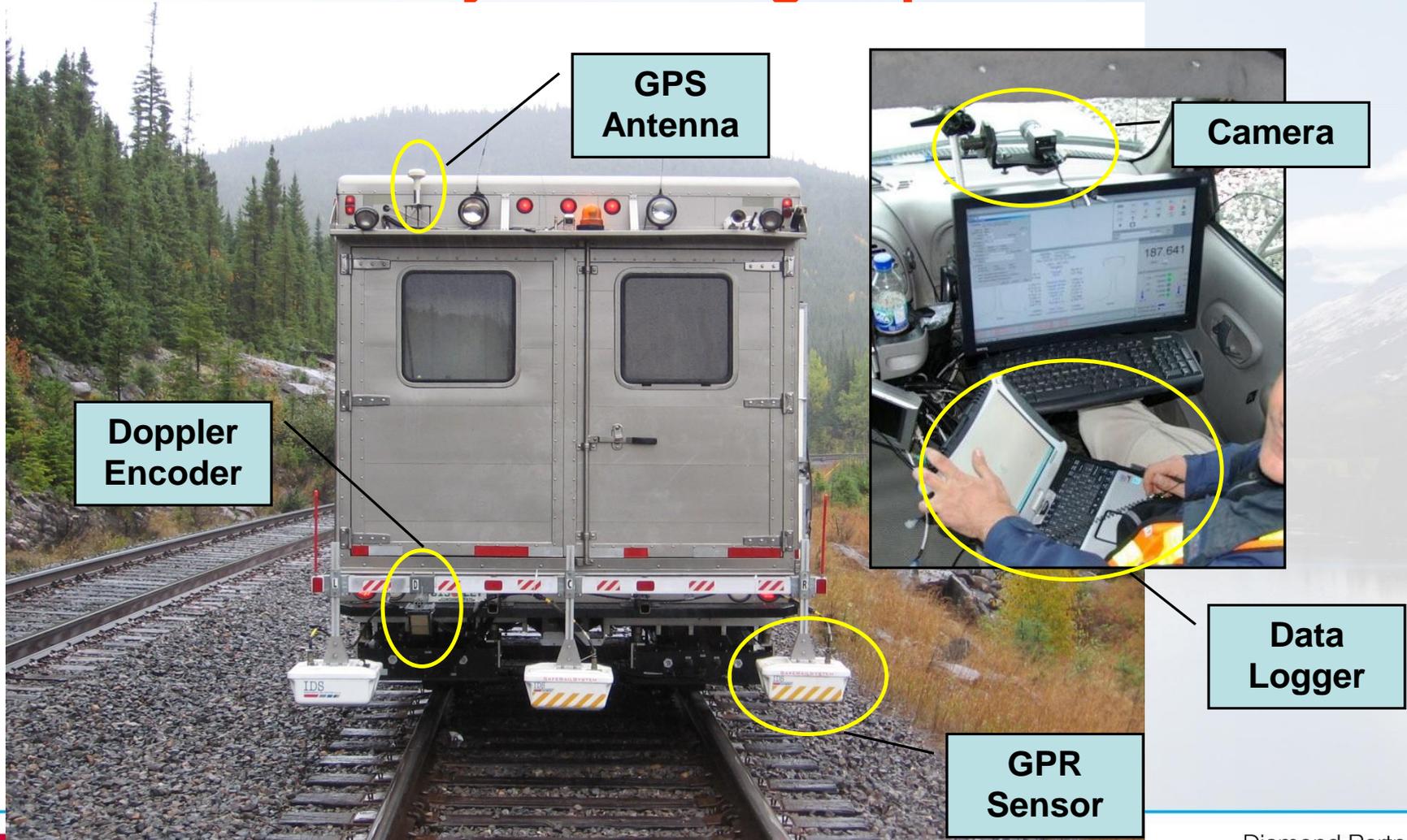




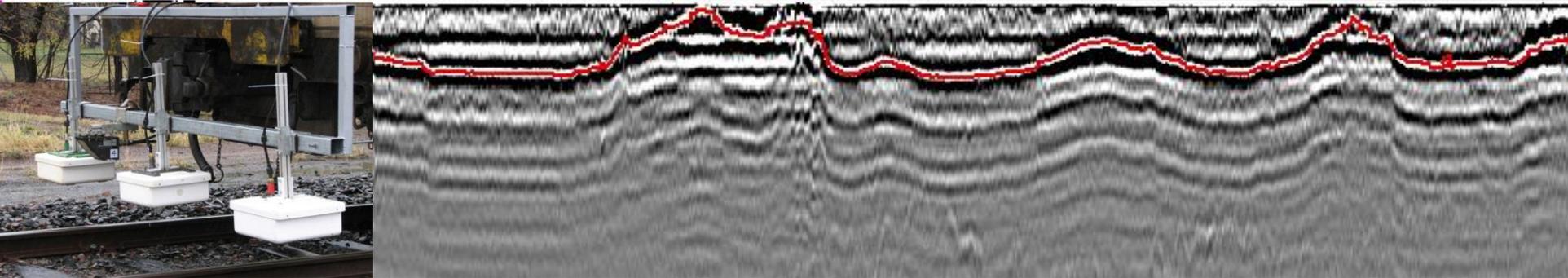
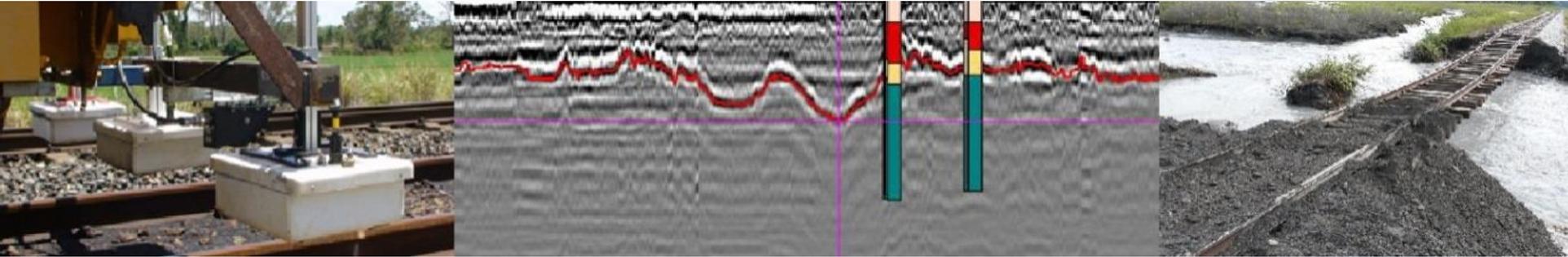
FIG Working Week 2016

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Recovery

SafeRailSystem – High Speed GPR

from disaster



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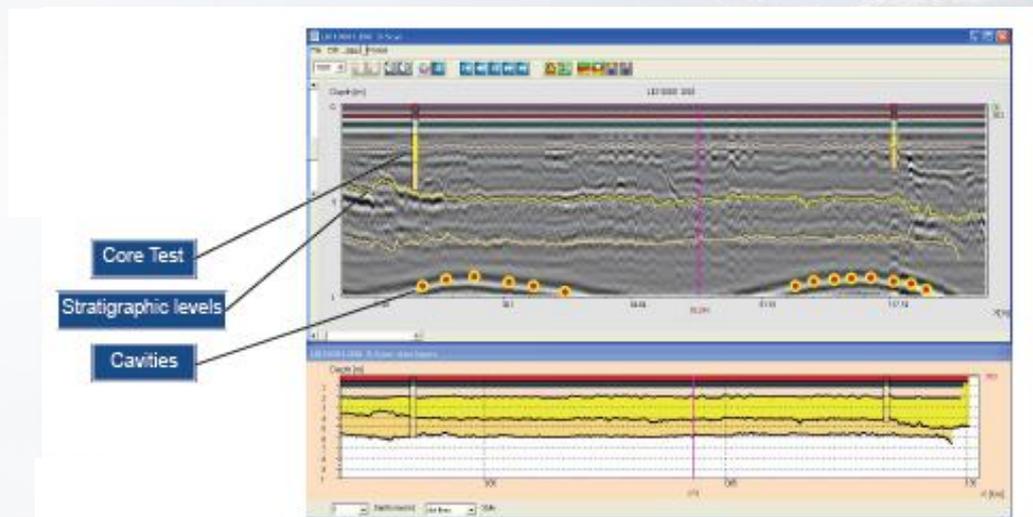
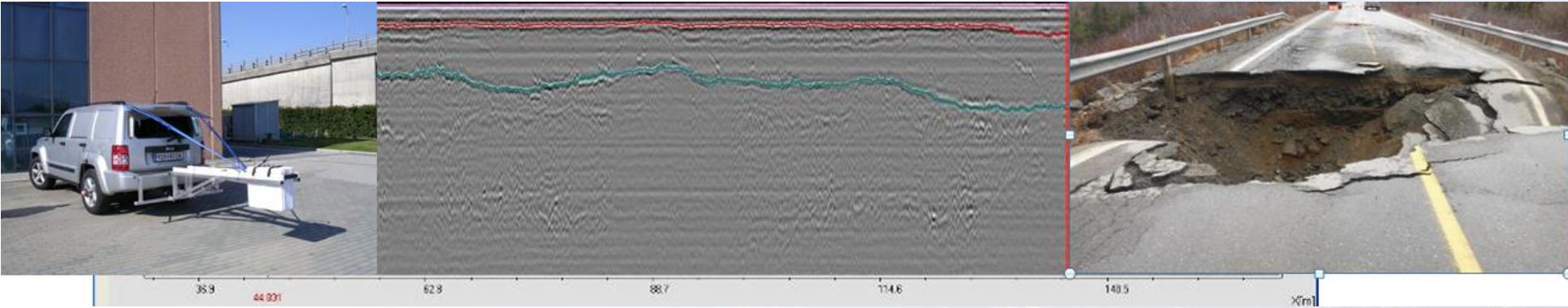
FIG Working Week 2016

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Recovery

from disaster

Hi-Pave – High Speed GPR



Imaging of:

- Debonding
- Cavities
- Moisture ingress



FIG Working Week 2016

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Recovery

from disaster



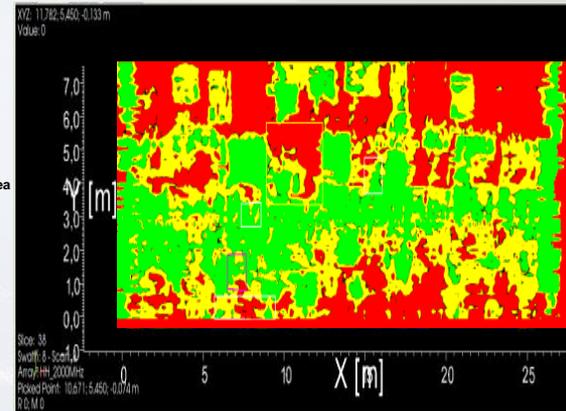
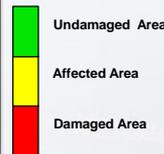
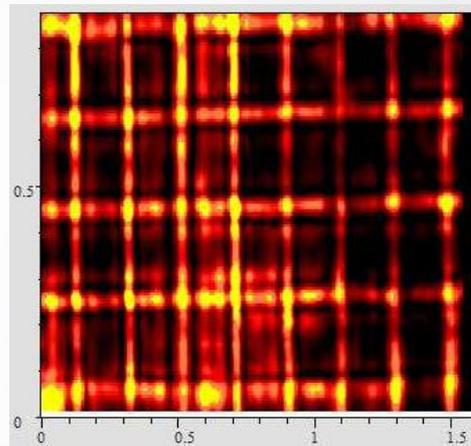
Civil and Structure Engineering



RIS Hi-Bright:
Array for bridge deck survey

Depth: 0.10m

Image rebar and internal structures



Bridge deck maps

- Moisture
- Rebar corrosion
- Concrete cover



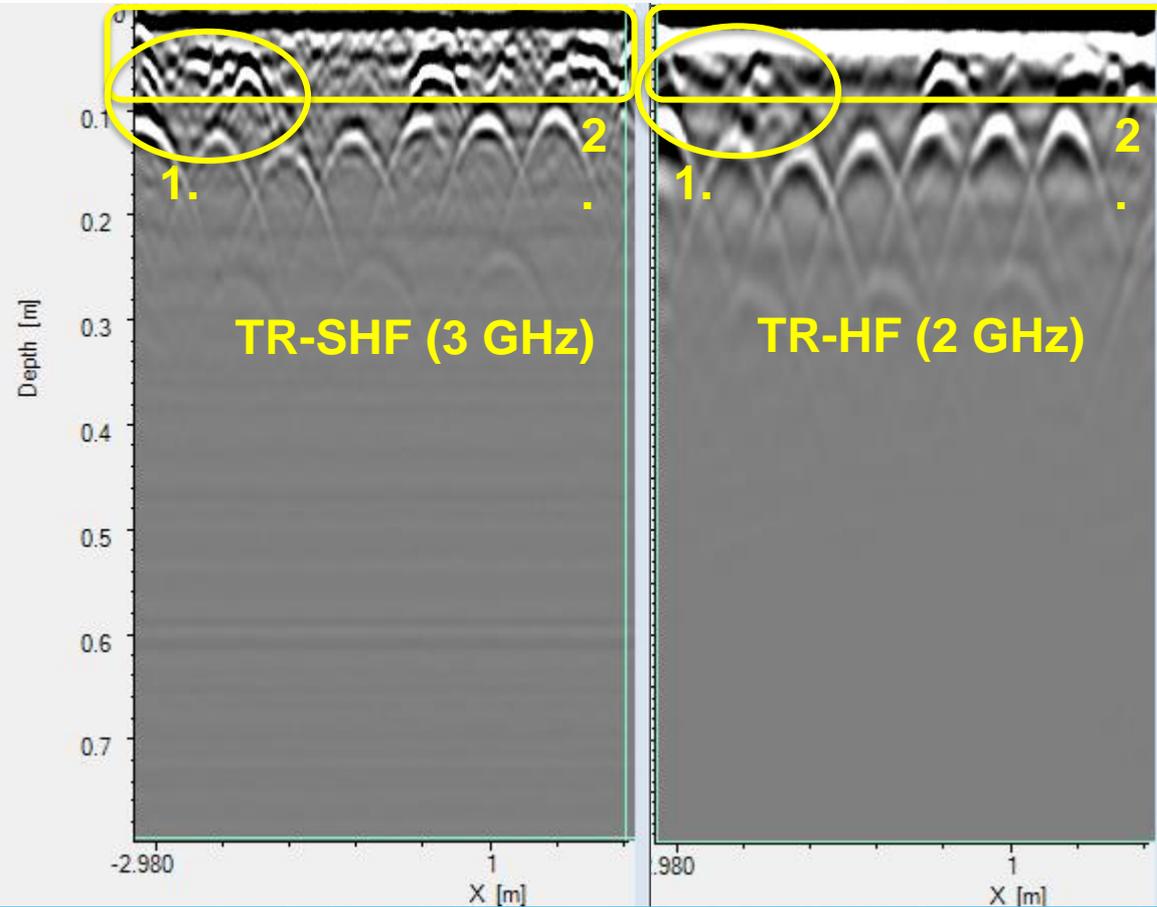
TR-SHF Super High Frequency antenna: 3 GHz



Super High-Resolution antenna for concrete inspection



Comparison TR-SHF vs. TR-HF (1of2)



Super High-Resolution permits to:

1. distinguish close rebar;
2. Resolve fine defects (Voids, cracks)



Through Wall Radar

Carbon & Glass fibre materials, total weight 4,5 Kg, dimensions 60x32x12 cm

Sensitivity
adjustment

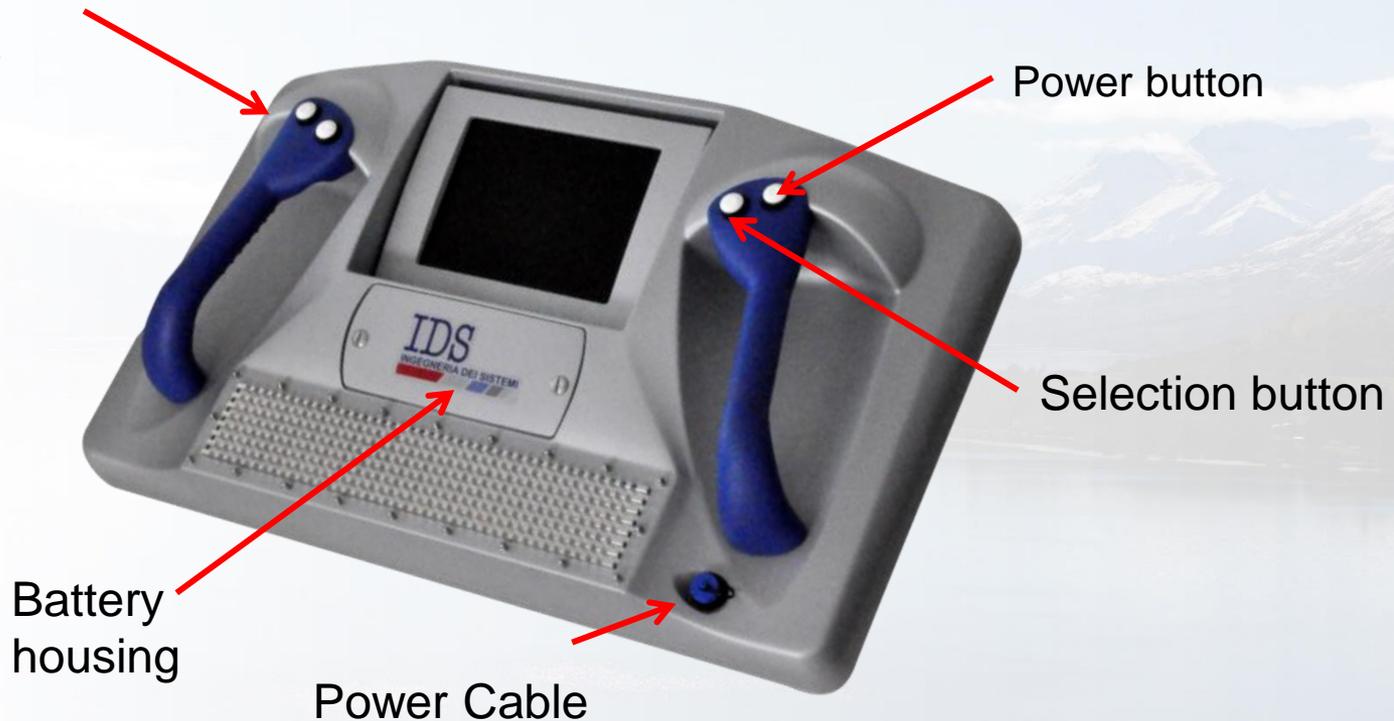




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Recovery

from disaster

Through Wall Radar



multi-target tracking and detection of stationary personnel through breathing

- Buried persons under debris
- Location of people in smoke-filled or dim environments



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Recovery

from disaster

Through Wall Radar



Observed Scene		Radar Detection
Target	Movement	Range [m]
Moving person	Walking	15
	Crawling	10
Moving still person	Chest, Head, Arms, Legs	8
Still person not moving	Speech, Breathing	0,2-4
	Heartbeat (holding breath)	0,5-2





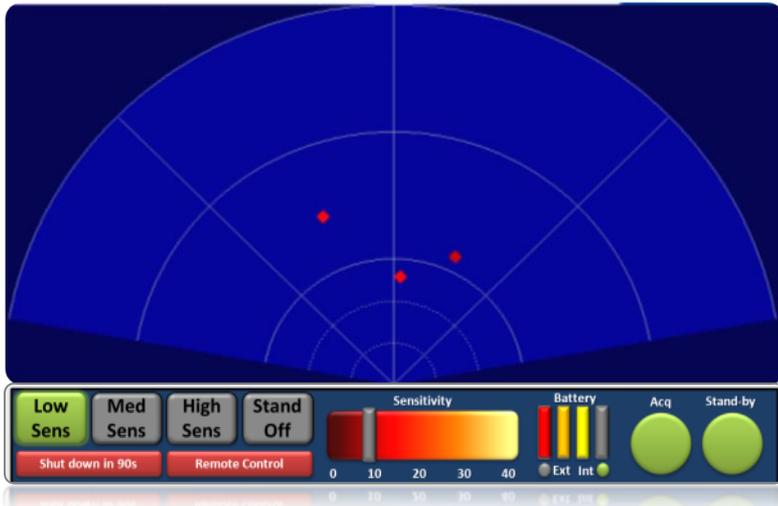
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Recovery

from disaster

Through Wall Radar



Display mode: 2D plain view, 1.5D (range with time history)

Display type: Colour, tilt-able, ultra bright



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Recovery

from disaster

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