



Advanced vibroacoustic technology for monitoring transportation pipelines

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Outline

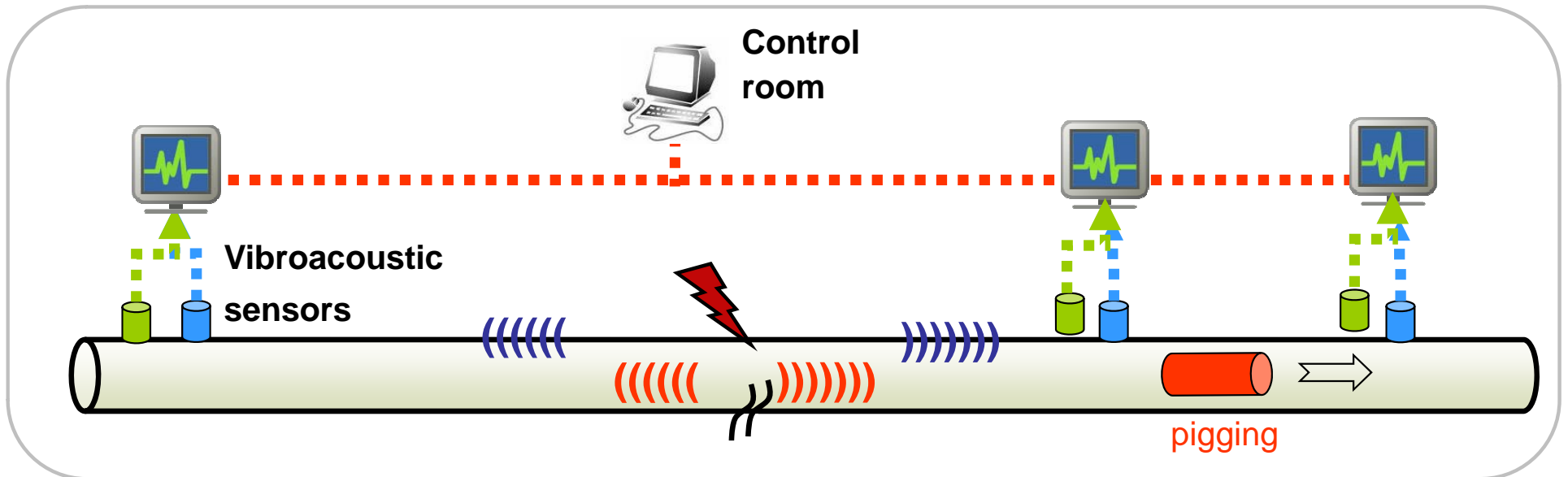
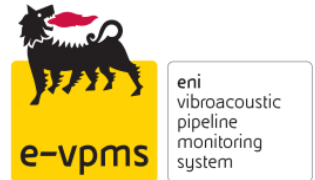
- Introduction
- Remote & Continuous Vibroacoustic Pipeline Monitoring
- Field test campaigns in controlled scenarios
- Operational installation for monitoring theft-related spillages
- Conclusions



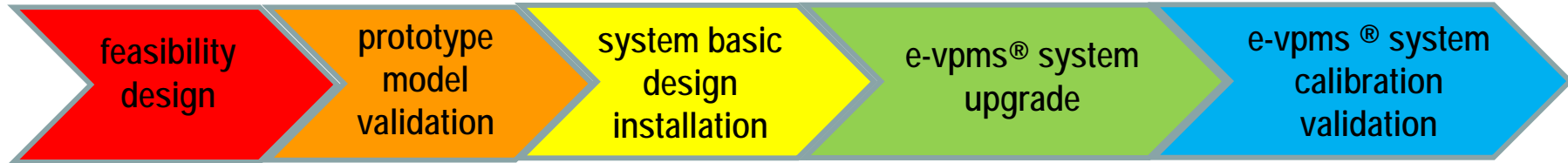
Vibroacoustic pipeline monitoring

A network of passive *multi-channel vibroacoustic stations* mounted on gas/oil transportation pipelines detect guided waves for real time detection, localization and classification of:

- spilling and leaks
- threats, impacts
- pipe deformations, obstacles
- fluid properties variations
- localization and monitoring of pigging operations



Dionisio – R&D project and technology maturity level



Years	Pipeline	Fluid	Maturity
2009 - 2010	TMPC (G&P)	Natural gas	
2010 - 2011	Chivasso-Aosta (R&M)	Crude oil	
2010 - 2011	Milano-Lecco (G&P)	Air/Nitrogen	
2011	Centro Sviluppo Materiali	Natural gas	
2011 - 2012	e-vpms® system, Patent		
2012 – ongoing	Chivasso-Aosta (R&M)	Crude oil	
2012 – ongoing	Gaeta-Pomezia (R&M)	Products	
2012 – ongoing	Messina channel (SNAM)	Natural gas	
2013 – ongoing	Akri-Kwale (E&P, NAOC)	Water/oil	
2013 – ongoing	Costa Molina 2 (E&P)	Injection water	

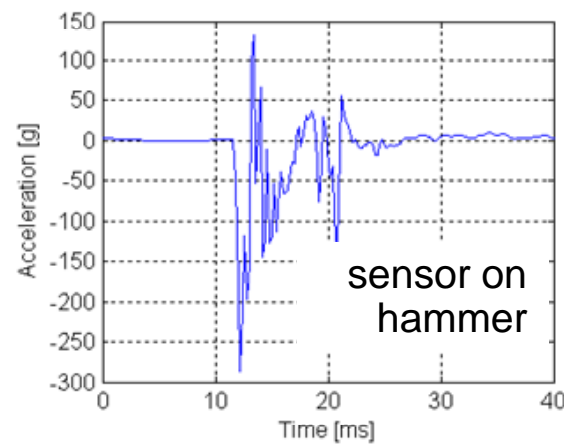
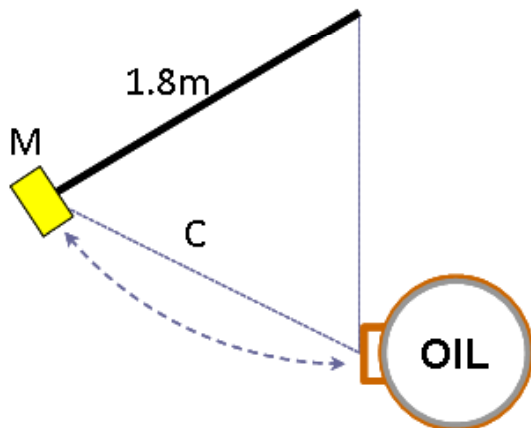


Acoustic-Elastic wave propagation in fluid filled pipeline



Impact simulations on oil pipeline

Test n.	C [m]	M [kg]	Theoretical hit energy [J]
1	0.10	80	2.2
2	0.30	80	19.6
3	0.70	80	106.7
4	0.90	80	176.4
5	1.10	80	263.5
6	1.50	80	490.0

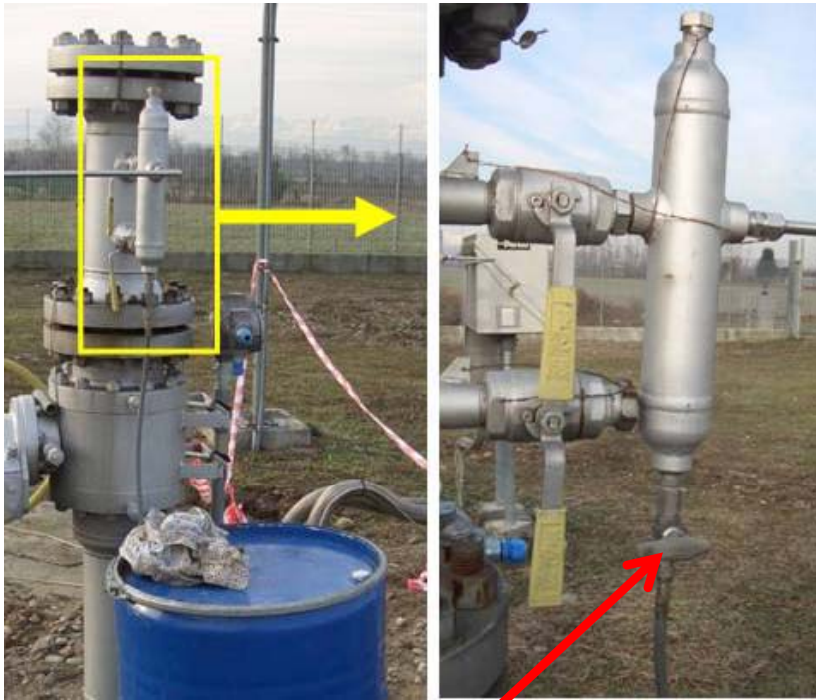


Measured impact energy around 2/3 of theoretical one



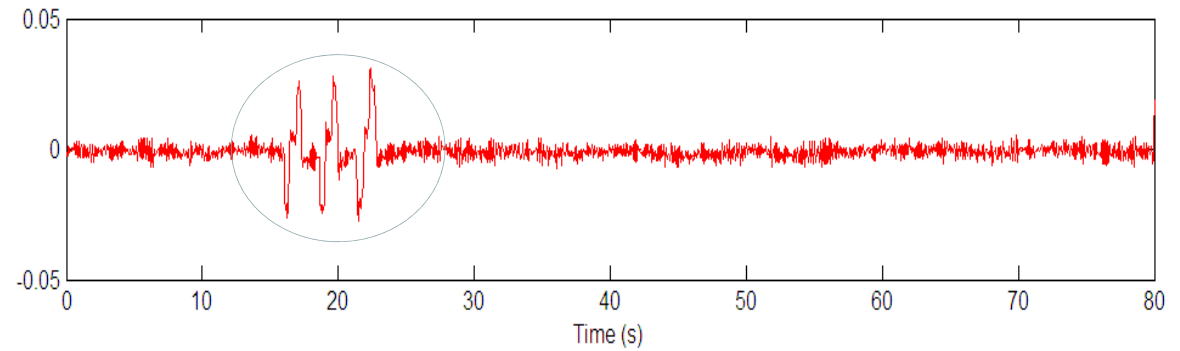
Acoustic-Elastic wave propagation in fluid filled pipeline

oil spill simulation in 16" oil pipeline

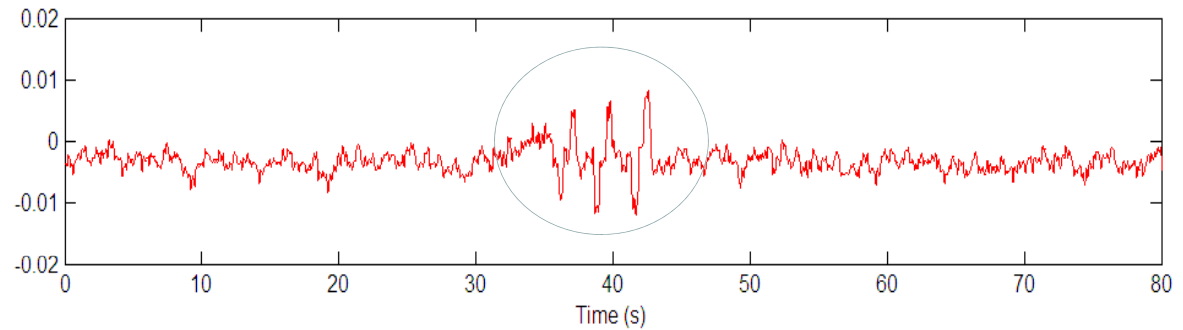


Valve and spill point:
 $\Phi=1/10''$; $P\sim 60$ bar;
Spill flow rate=0.3 l/sec

Hydrophone signal at test site



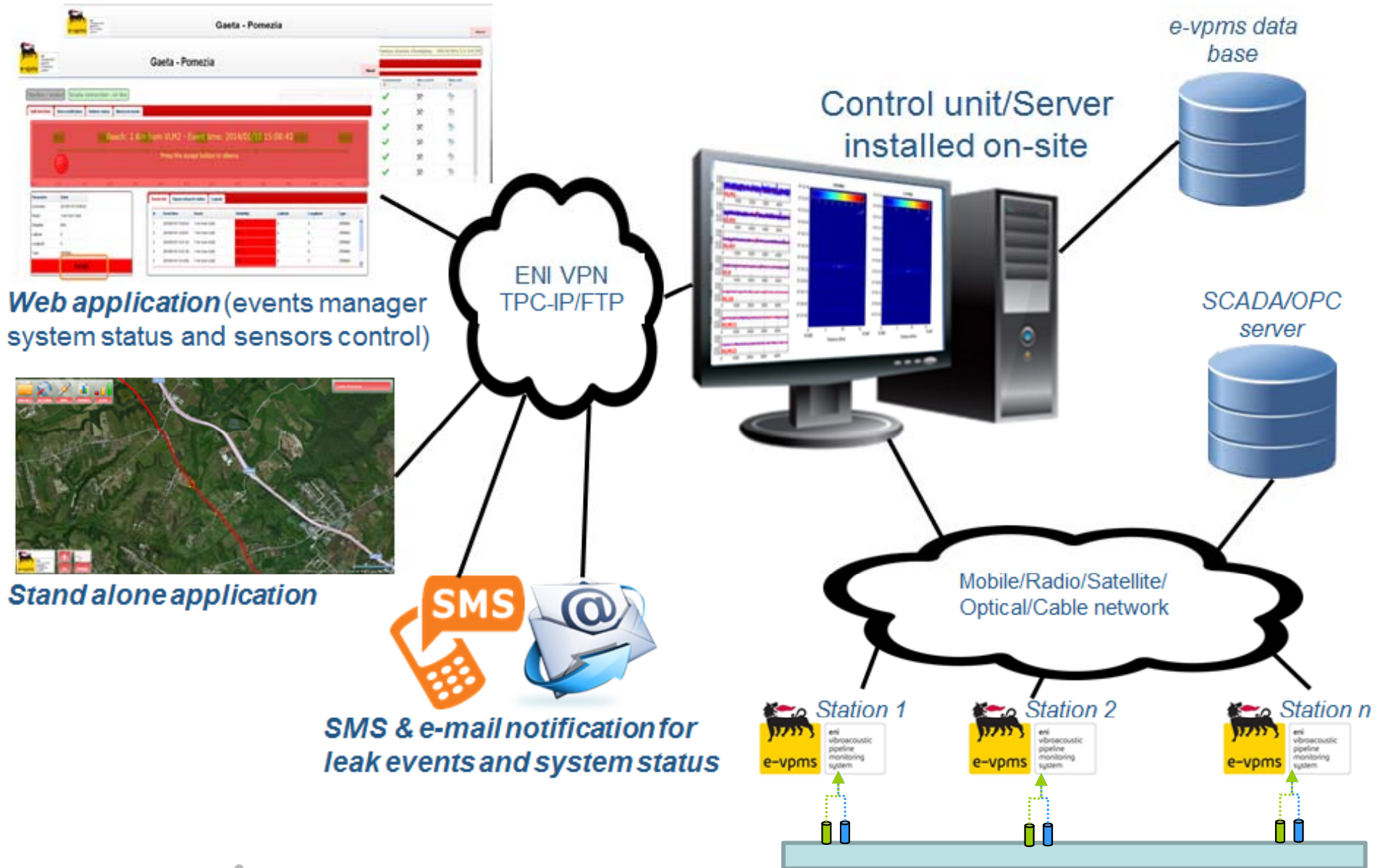
Hydrophone signal in station VM28 at about 25 km far from test site



OIL - field test summary

Test types - OIL Interferences Spilling	Observed detection distance	Estimated Detection distance	Measured pressure at source	Signal bandwidth at source	Pump noise removal
Medium energy impact by hammer (E < 500J)	2 km	5-10 km	200mbar	50-1000Hz	+/-
Moving excavator (24 tons, 160HP)	2 km	2 km	5mbar	50-1000Hz	+/-
Excavator digging (24 tons, 160 HP)	2 km	4 km	5mbar	50-500Hz	+/-
Spilling transient (flow rate=0.3 l/s at 60 bar; $\Phi=0.1''$)	25 km	50 km	20mbar	0-20Hz	++
Spilling transient (flow rate=1.4 l/s at 60 bar; $\Phi=0.2''$)	50 km	100 km	100mbar	0-20Hz	++

Vibroacoustic Pipeline Monitoring System (e-vpms®)

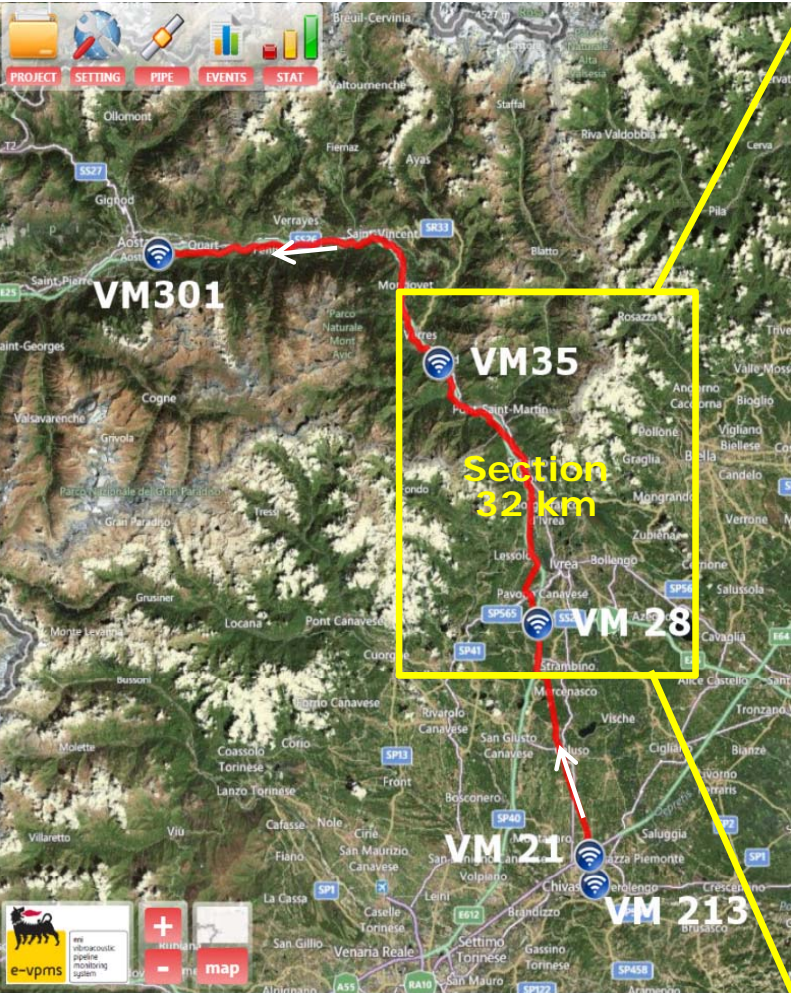


e-vpms®: R&M Chivasso-Aosta crude oil pipeline

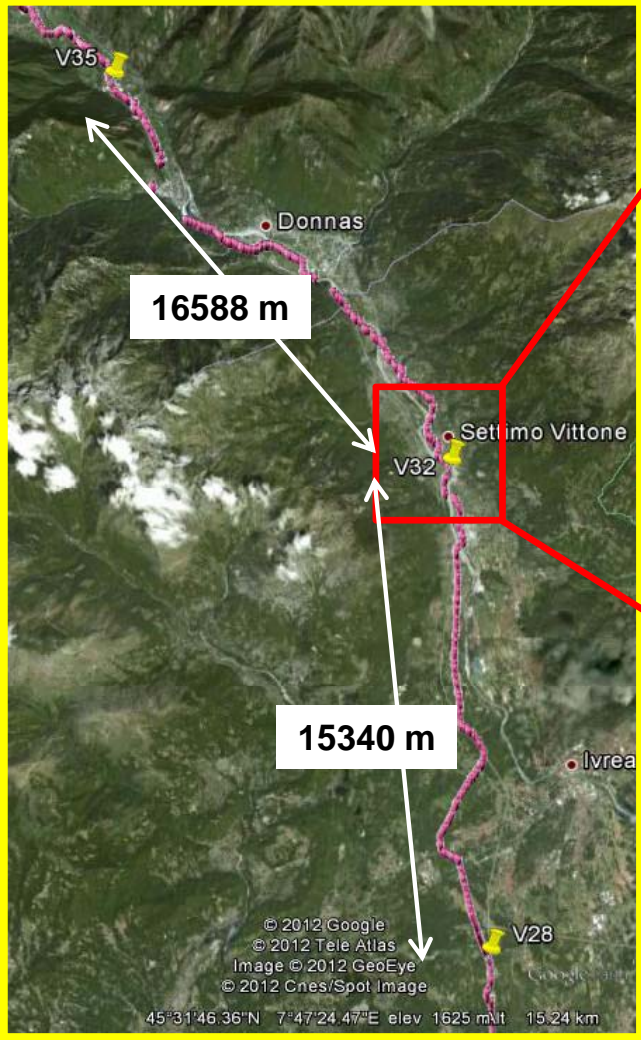
- Chivasso-Aosta 16" crude oil pipeline (100 km long), Italy
- 5 e-vpms® stations
- calibration and tuning of **third party interference** detection procedures
- **long term monitoring** campaign (2010-ongoing)



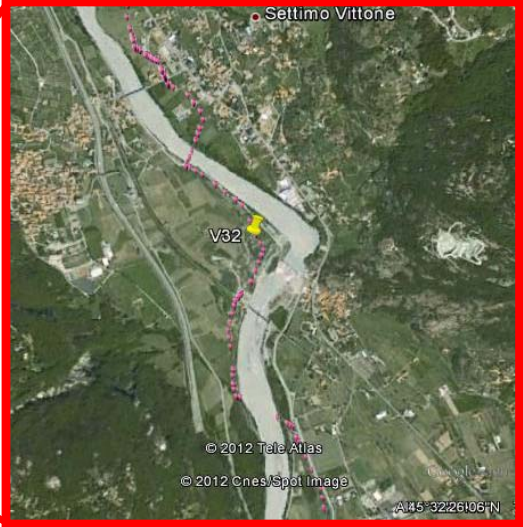
e-vpms®: R&M Chivasso-Aosta crude oil pipeline



Station B: pressure ~ 35bar



Spill test location



Station A: pressure ~ 58bar



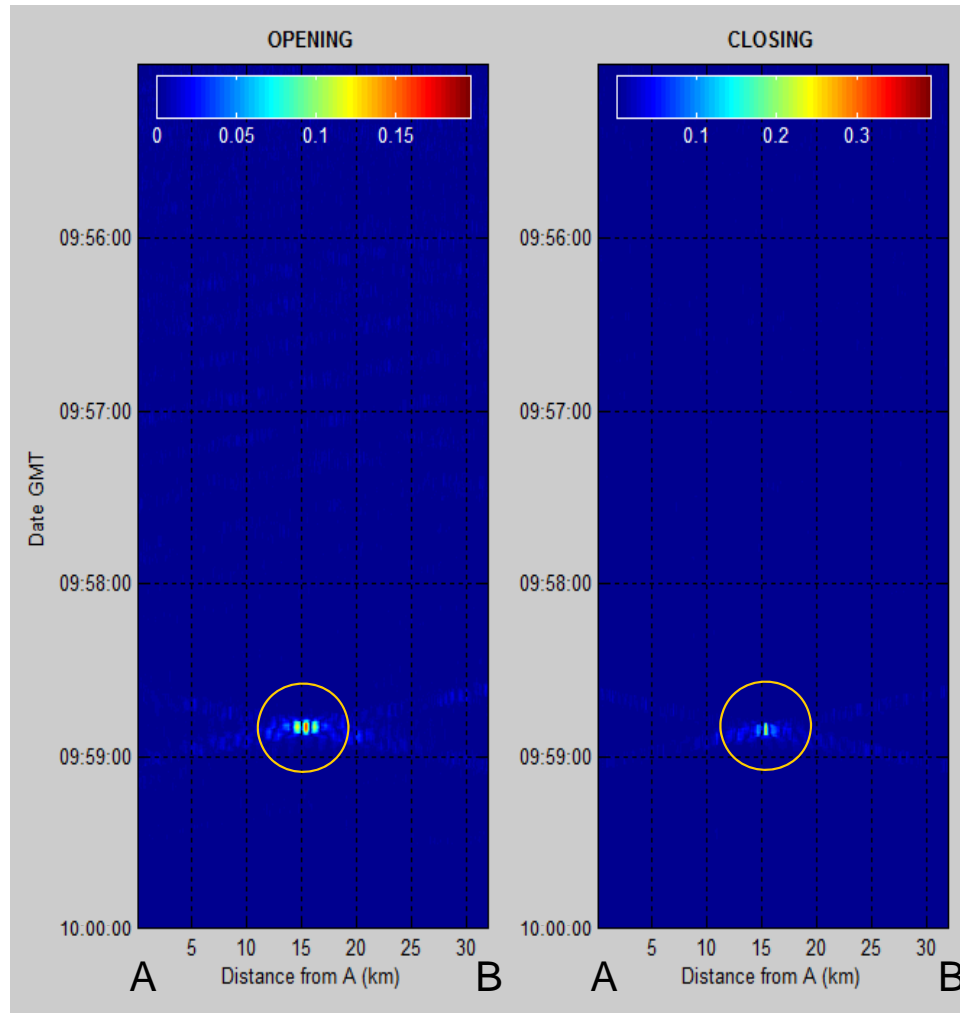
e-vpms®: R&M Chivasso-Aosta crude oil pipeline

Oil spill simulation

Real time data processing window for spilling localization

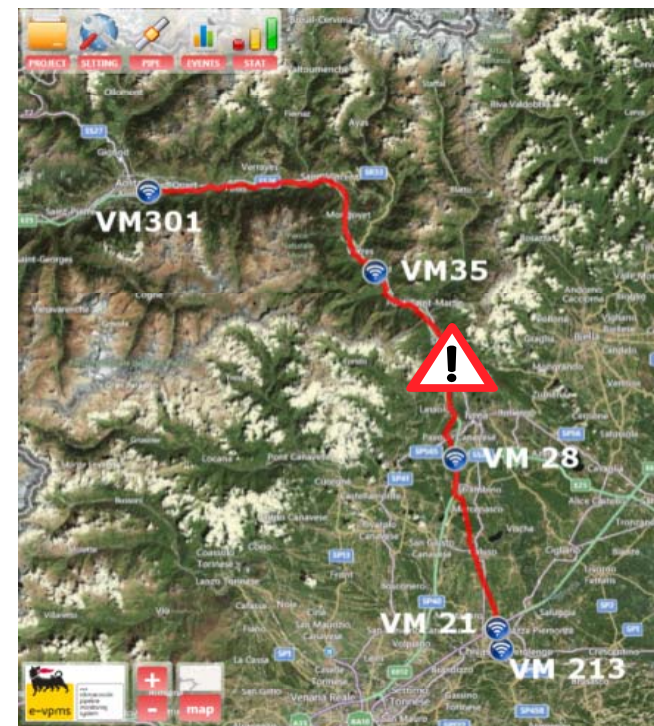
GMT time	Test description	Spill size
09:58:50	1x fast spill	0,25"

Location of spill at 15.350 m accuracy ± 25 m



e-vpms stations

e-vpms stations



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e-vpms®: installation on refined products pipeline

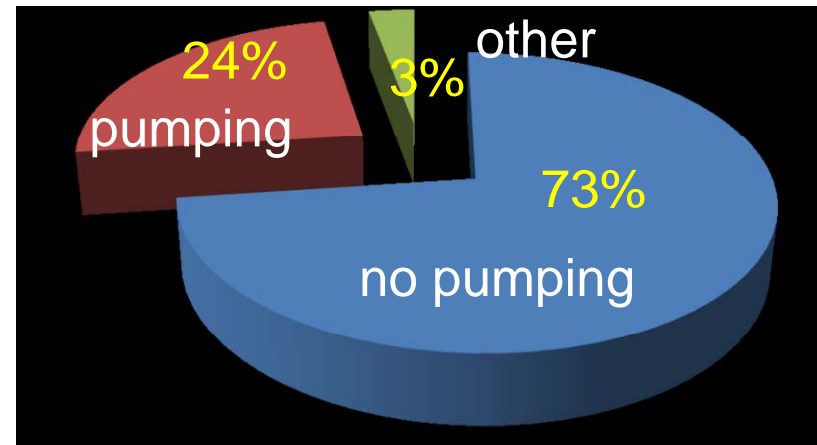
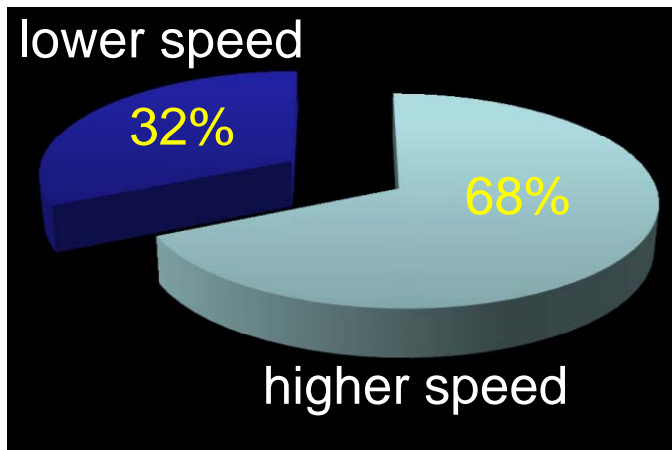


R&M Gaeta-Pomezia, 16" products pipeline (112 km long), Italy



e-vpms®: refined products pipeline installation

- e-vpms® stations with double side sensors have been installed
- calibration test and fine tuning for real-time **TPI interference** and **spill** detection procedures
- Long term monitoring of vibroacoustic parameters (sound speed and attenuation) of each section for statistical analysis of service conditions of pipeline.



e-vpms®: refined products pipeline installation

r&m Gaeta-Pomezia: thelf-spills detected and localized

Event ID	Date	Start	End	Duration	Static Pressure [bar]	Pressure drop [bar]	Location
EVT_1	24/08/2013	20:50	21:50	01:00	21	10,5	Due case (Aprilia – LT)
EVT_2	26/08/2013	21:40	22:42	01:02	18	11,8	Due case (Aprilia – LT)
EVT_3	05/09/2013	21:16	21:58	00:42	39	12	Due case (Aprilia – LT)
EVT_5	10/09/2013	15:53	15:54	00:01	20	0	Due case (Aprilia – LT)
EVT_4	08/09/2013	00:30	01:28	00:58	38,5	8,6	Borgopiave (LT)
EVT_6	20/10/2013	22:33	00:19	01:46	40	8	Borgopiave (LT)
EVT_7	02/12/2013	20:20	23:23	03:03	8,5	0,6	Machiarella (Terracina – LT)
EVT_8	03/12/2013	19:40	23:17	03:37	7,8	0,7	Machiarella (Terracina – LT)
EVT_9	19/12/2013	23:21	00:56	01:35	20	1	Campoverde (Aprilia – LT)
EVT_10	21/12/2013	23:49	00:51	01:02	30,3	5	Campoverde (Aprilia – LT)
EVT_11	22/12/2013	19:17	22:48	03:31	24,8	1	Campoverde (Aprilia – LT)
EVT_12	23/12/2013	20:16	00:31	04:15	24	1	Campoverde (Aprilia – LT)
EVT_13	07/01/2014	19:44	22:41	02:57	36,5	6,9	Campoverde (Aprilia – LT)





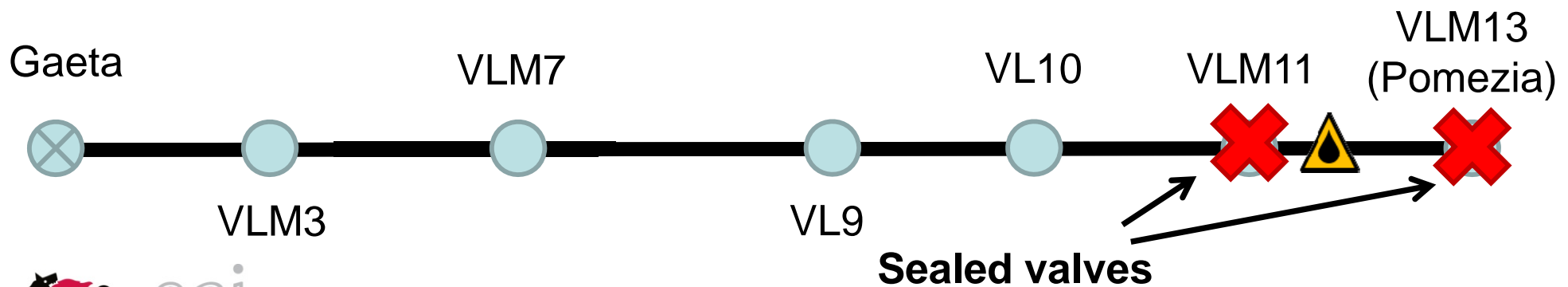
Theft/spillages detected and localized



e-vpms®: refined products pipeline installation

EVT3 (September 5th 2013, 21:16)

Detected intrusion	September 5 th , 19:16 (UTC) 21:16 (Local time)
Leakage end	September 5 th , 19:58 (UTC) 21:58 (Local time)
Pipeline status	STEADY-STATE Valves VLM11, VLM13
Localization	N 41.6046 E 12.5969
Data analysis	Spill detection confirmed and localized



e-vpms®: refined products pipeline installation

EVT3 (September, 5th 2013, 21:16 local time)

Effective real-time alert for actions

- No false alarms -

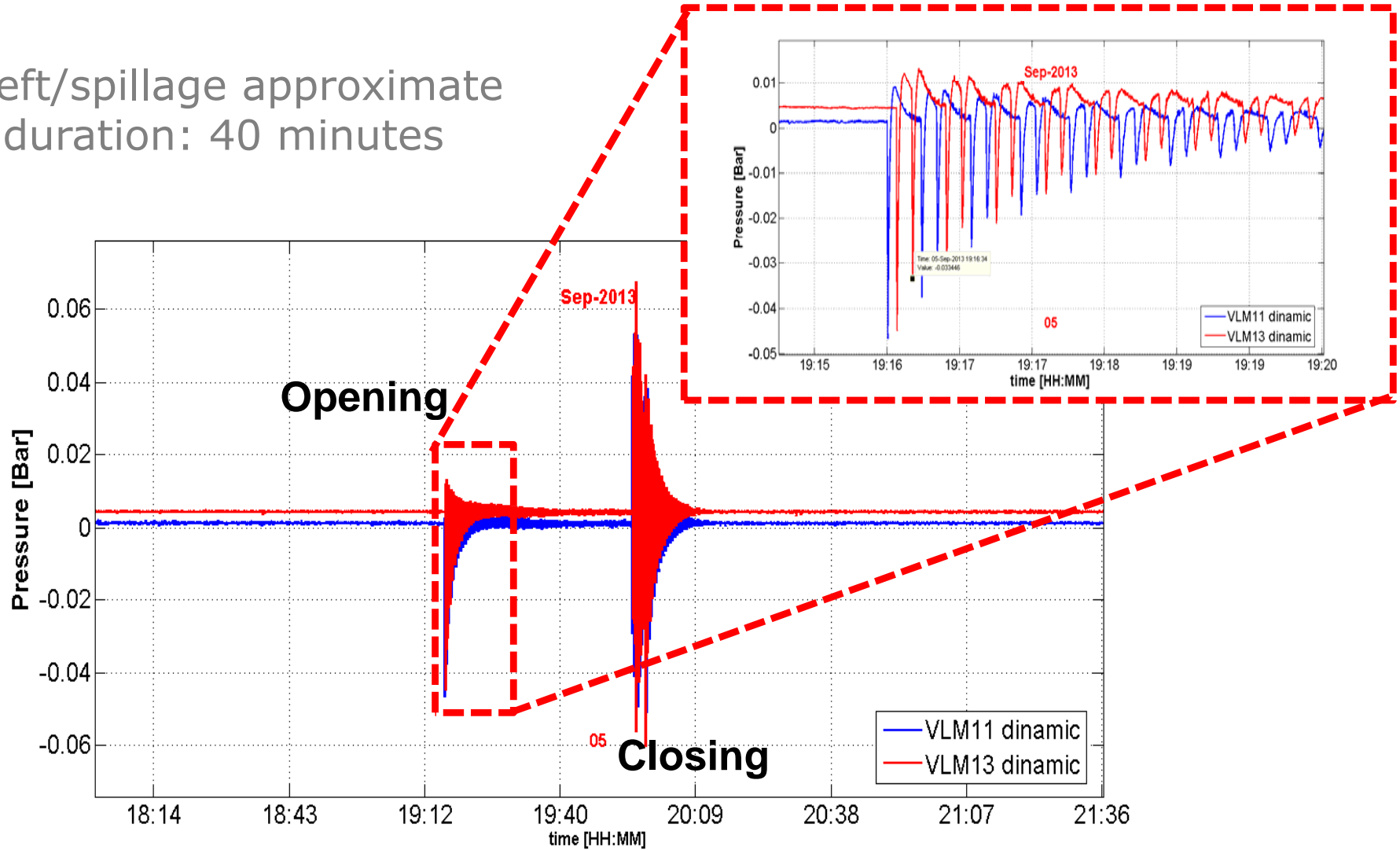


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e-vpms®: refined products pipeline installation

EVT3 (September, 5th 2013, 21:16 local time)

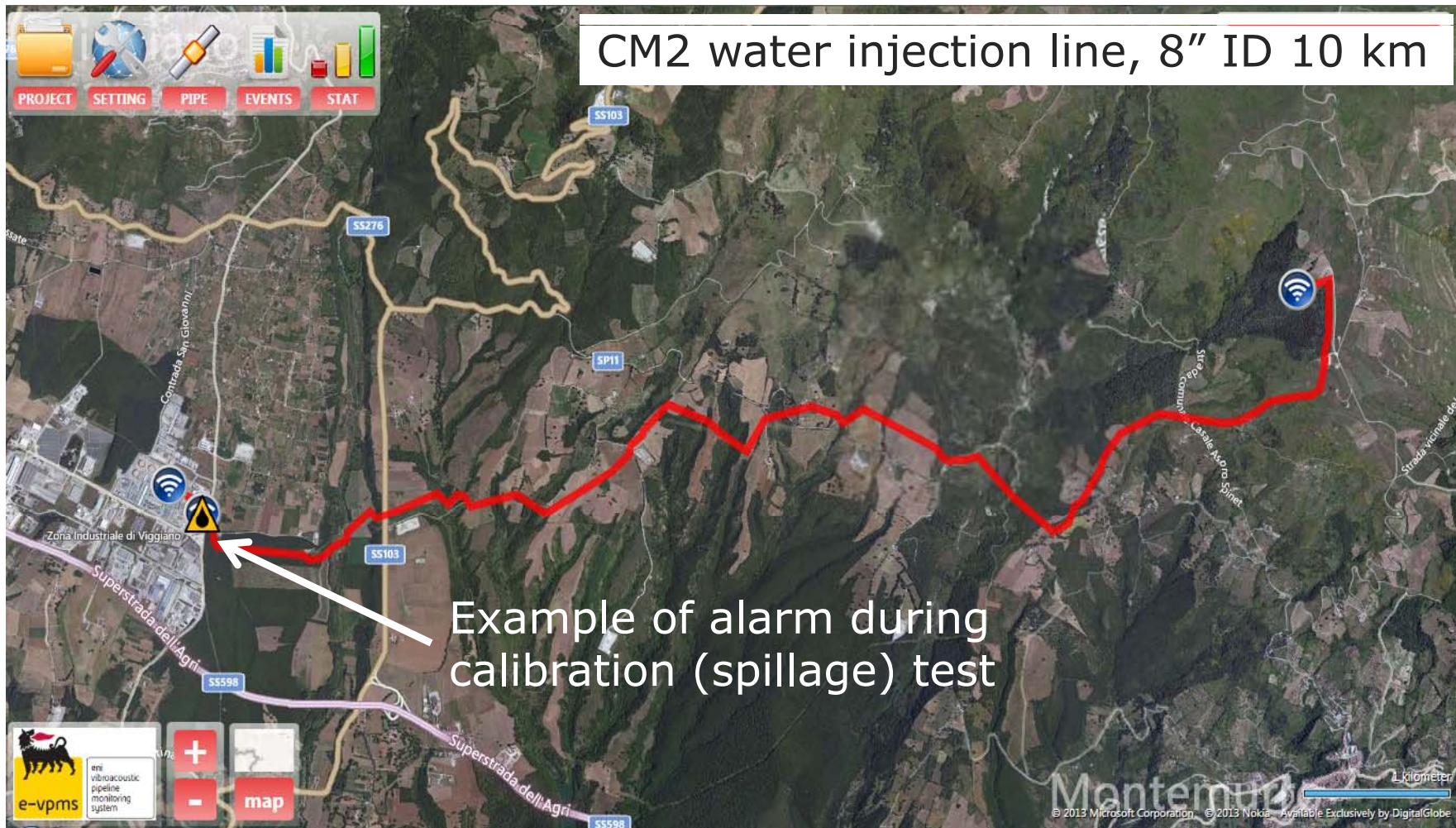
Theft/spillage approximate duration: 40 minutes



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e-vpms®: water injection line installation E&P, Val d'Agri (Italy)

- 2 e-vpms® stations (3 acquisition points)
- calibration test and fine tuning for real-time leak detection



e-vpms®: offshore gas pipeline application in SNAM, Italy



- **Messina Channel** – offshore natural gas pipelines;
- **Line 1**, 20", 15.9 km
- **Line 4**, 26", 31.3 km
- $P_{\max}=115$ bar:

- environmental noise in service condition of gas transportation pipelines
- data analysis during controlled TPI tests;
- data processing routines for real-time pig tracking;
- long term performances between liquid and gas pipelines.

Summary

- Multipoint acoustic sensing is emerging technology for monitoring oil&gas pipelines
- Interesting side products:
 - Third Party Intrusion
 - Spill and Leaks
 - Sound propagation parameters within the transported fluids
 - Long term monitoring
- Jointly identification of fluid/pipe properties for improving transport reliability and environmental sustainability.
- Applications for oil, water, products and gas pipeline scenarios



References

Scientific Papers

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- Bernasconi, G., Del Giudice, S., Giunta, G., Dionigi, F., Schiavon, R., Zanon, F., "*Advanced pipeline monitoring using Multipoint Acoustic Data*", Proceedings 11th OMC Conference, Ravenna, 2013.
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Patents

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- Giunta, G., Bernasconi, G., "*Method and system for continuous remote monitoring of the integrity of pressurized pipelines and properties of the fluids transported*", ENI S.p.A, Patent Application PCT/EP2013/077116.
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