PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

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Advancement through Innovation

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GEOVIS

The 99% Data Return Recipe
Case Study of the Italian National Accelerometric Network

Kinemetrics: Mathias Franke, Stefan Radman
Dipartimento della Protezione Civile: Luisa Filippi, Elisa Zambonelli
Geovis: Alfredo Ammirati, Sebastiano, Danastasio

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AGENDA

01 **Introduction**
What is the meaning of 99%?

02 **Ingredients**
Hardware, Software, Engineering, and Human Resources

03 **RAN Examples**
The Team, System, Data Return

04 **Summary**
Takeaway

WHAT IS THE MEANING OF 99%?

CAP Theorem

The **CAP theorem** (or Brewer's theorem after Eric Brewer) states that any *distributed data store* can provide two of the following three guarantees:

- **C**onsistency: Every read receives the most recent write or an error
- **A**vailability: Every request receives a response without the guarantee that it contains the most recent write
- **P**artition Tolerance: The system continues to operate despite an arbitrary number of messages being dropped by the network between nodes

No distributed system is safe from network failures. Therefore, when a network partition failure happens, it must be decided whether to do one of the following:

- Cancel the operation and thus decrease the availability but ensure consistency
- Proceed with the operation and thus provide the availability but risk inconsistency

WHAT IS THE MEANING OF 99%?

Examples of the CAP Theorem for Real-Time Seismic Networks

A jittery clock:

- Proceed with the operation and thus provide the availability but creates inconsistency, e.g., micro gaps
- Cancel the operation and thus decrease the availability but ensure consistency

Missing data packet:

- Cancel the read operation and thus decrease the availability but ensure processing consistency, e.g., continue processing and reducing data latency
- Proceed with the read operation and thus provide the availability but creates inconsistency, e.g., increasing the data latency

Out-of-order data packets:

- Cancel the read operation (dropping packet) and thus decrease the availability but ensure processing consistency
- Proceed with the operation and thus provide the availability but creates processing inconsistency

WHAT IS THE MEANING OF 99%?

Impact of Missing Real-Time Data

Time equivalent of missing data:

- 99% (“two nines”) the data gap is 3.65 days per year
- 95% (“one and a half nines”) the data gap is 18.25 days per year
- 90% (“one nine”) the data gap is 36.5 days per year
- 85% (“a half nine”) the data gap is 57.75 days per year

Impact on processing of missing data:

- *Seismology is an **observational** science => We **cannot repeat** an earthquake!*
- Missing earthquake recordings => missing knowledge
- Reduced quality of processing results in terms of location and magnitude
- Increase of blind zone in EEWS

Impact on the operation of missing data:

- Uncertainty of station status
- Increased maintenance effort
- *Increased total-cost-of-operation (price per byte)*

INGREDIENTS

Hardware – Mean Time Between Failure (MTBF)

- Mean Time Between Failure estimated from repair & warranty records
- Cumulative Operational Hours / Repairs

Instrument	MTBF	In Production
Etna2	186 years	since 2016
Obsidian/Basalt	44 years	since 2010
EpiSensor	56 years	since 1999
Q330 Family	80 years	since 2002
Q8	275 years	since 2020
MBB-2 Sensor	127 years	since 2017

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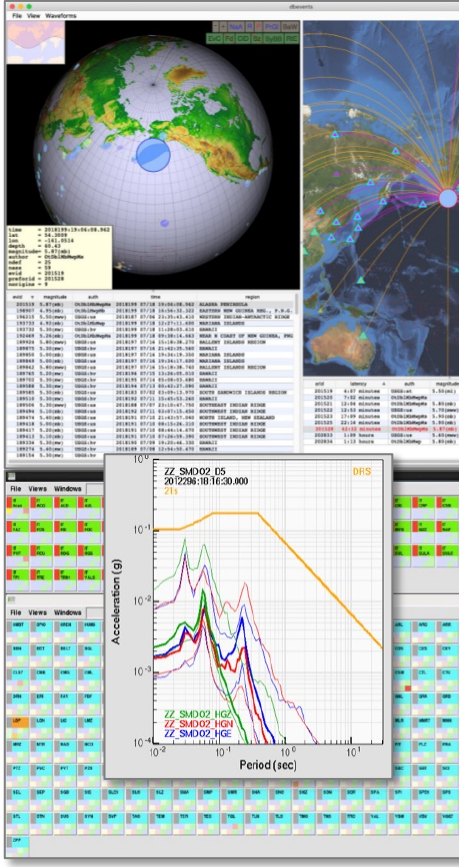
INGREDIENTS

Software – Antelope for the Aspen Enterprise-Class Data Center

Highly Configurable	• Meets any mission-critical monitoring requirement • Integrate numerous custom programs
Command & Control	• State-of-health monitoring • Remote calibration, configuration, etc.
Scalability	• Supports hundreds of simultaneous sensors • Support multiple sensor types
Minimum Latency	• Data driven • Real-time calculations
Automated Data Processing	• Highest data return >99% (in 2022) • Real-time alerts in RAN Website
Interoperability	• Data exchange with other systems (FDNS webservice) • Integrate new tools over time



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INGREDIENTS

Engineering

How Do You Monitor One Of The World's Largest Strong-Motion Networks?

Four Key ingredients are required to meet the challenge of addressing real-time monitoring needs and availability.

Modular Station Design

One station design integrating power system and accelerograph with flexible communication

Proven Data Processing

Low-latency, real-time processing with very high data return

Data Center Design

Scalable virtualized computing architecture, Robust telemetry, Support multiple stakeholders

Detailed SOH Monitoring

Visualize every SOH aspect of the system: Station, Communication, Hardware

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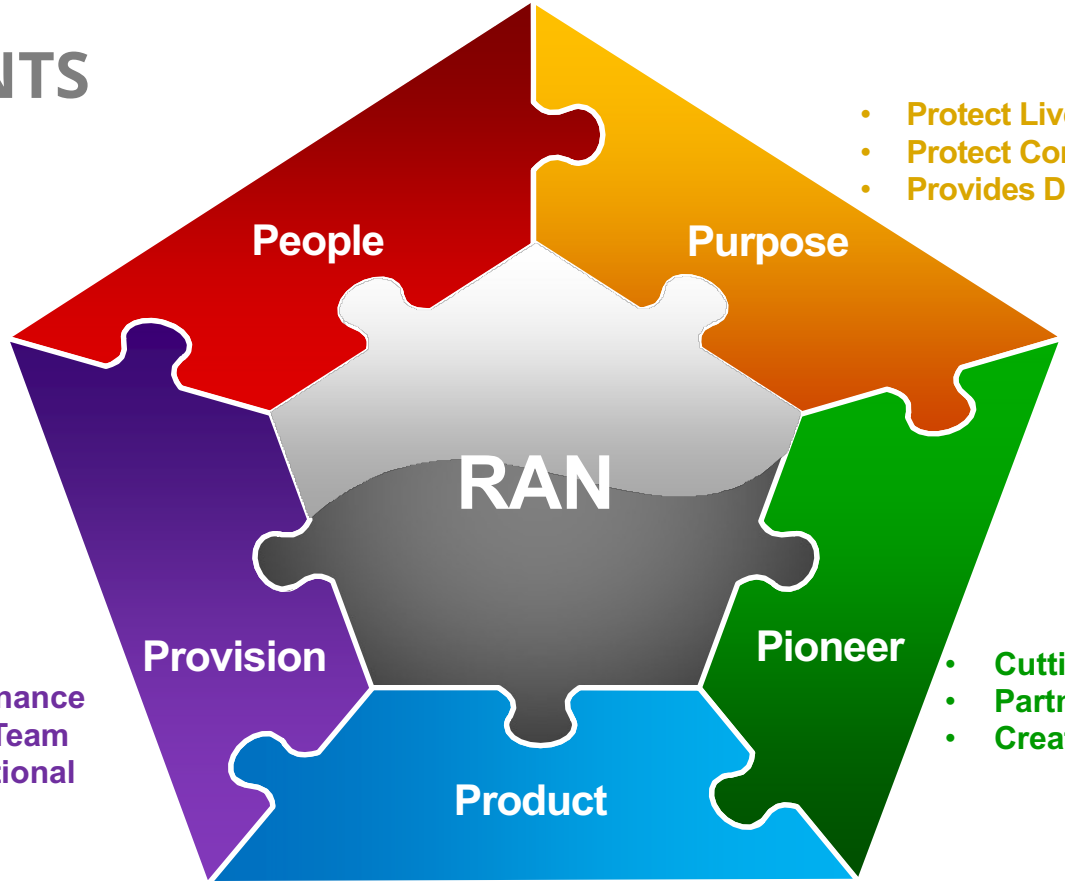
INGREDIENTS

Human Resources

- **Most Important Asset**
- **Experienced**
- **Collaborate**



- **Protect Lives**
- **Protect Communities**
- **Provides Data to Research**

- **Continuous Maintenance**
- **Dedicated Service Team**
- **Availability of Additional Resources**

- **Cutting-Edge Technologies**
- **Partner with Academia**
- **Creating Added Value**

- **Finest Instruments**
- **Best System Design**
- **Reliable System**

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The Team

- Geovis onsite team is made up of:
  - 1 Onsite Project Manager
  - 2 Office support
  - 2 Network Operators
  - 1 Field Supervisor
  - 5 Field Technicians
  - 1 Legal Advisor
- OSS remote and temporary onsite team consists of:
  - 1 Project Manager
  - 1 Sr. ICT Engineer
- DPC project team are:
  - 1 Head of Department
  - 1 Project Managers
  - 1 Contract Executive
- University of Trieste
  - 1 Consultant

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System

- Etna2
- Station
- Sierra Wireless Cellular Gateway
  - TIM APN

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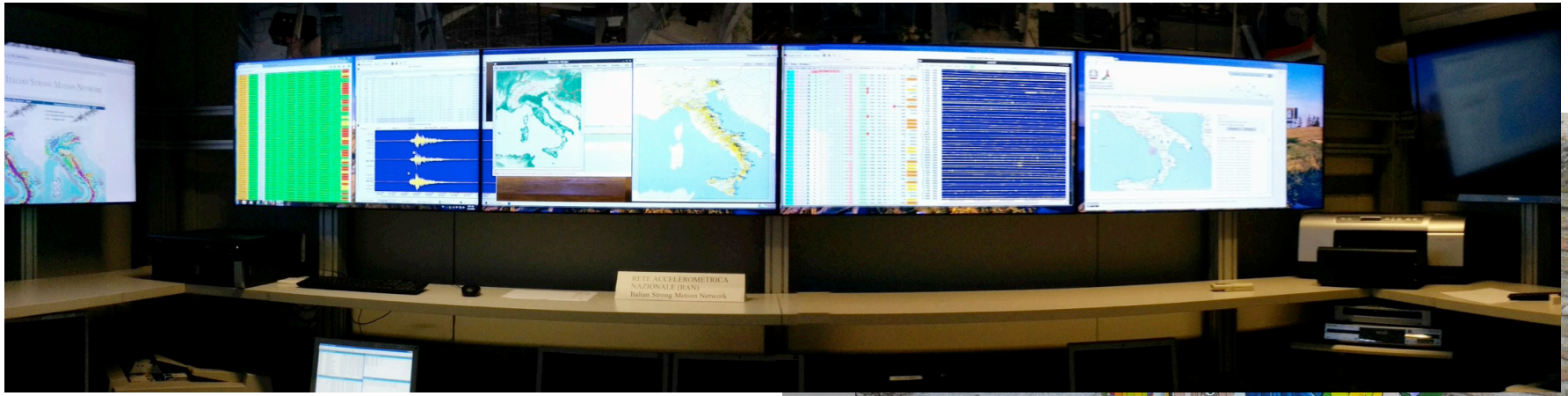
Rete Accelerometrica Nazionale - RAN



- Hardware
  - (3) HP Blades 256GB, 2x2.4GHz
  - Dell-EMC Unity nnTB
  - 10Gb Fiber Channel
  - (4) Dual-headed Dell workstations as user terminals
  - Dell workstation as video wall server with (6) Samsung Commercial Grade LED displays

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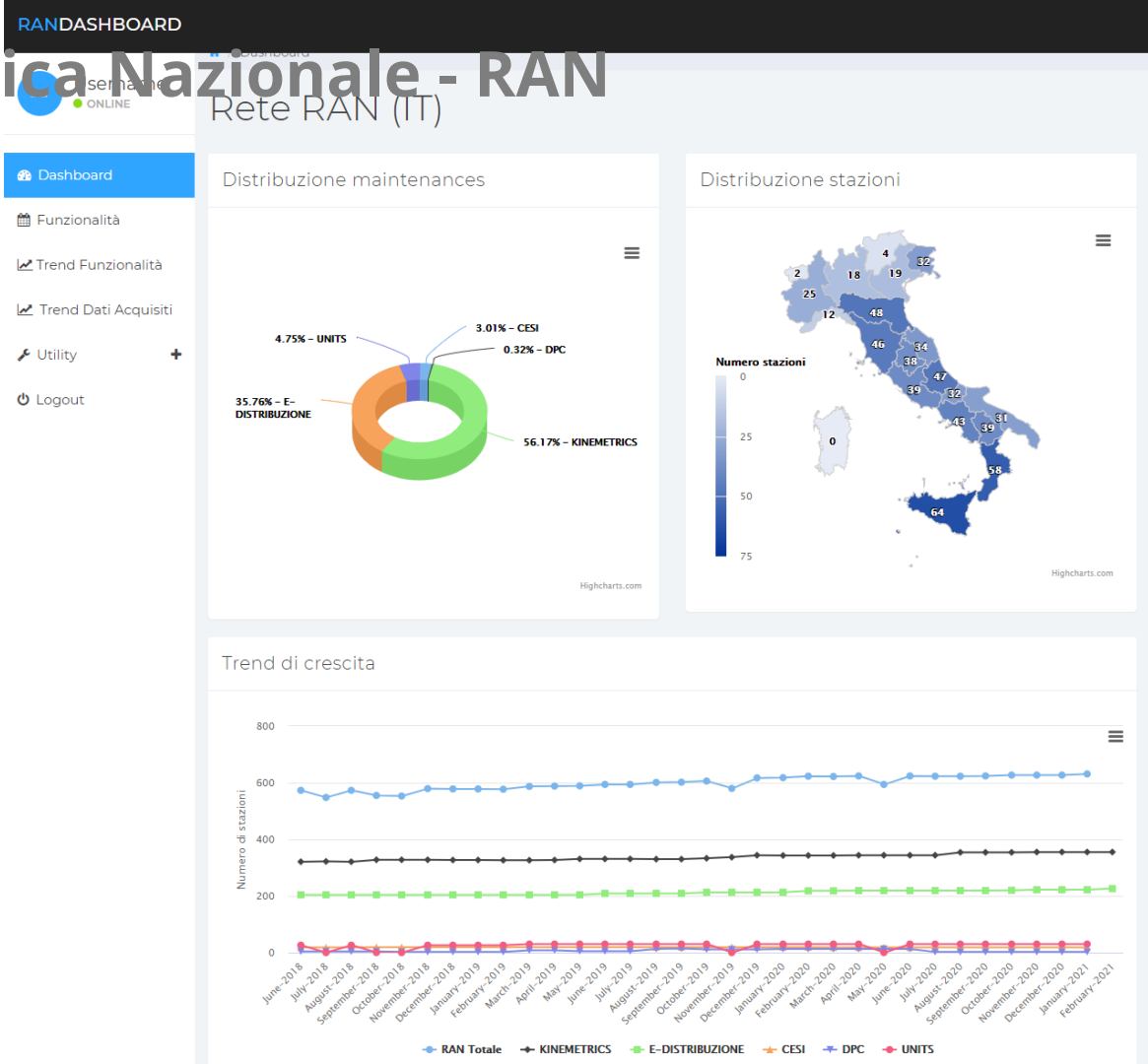
Rete Accelerometrica Nazionale - RAN

System Operation

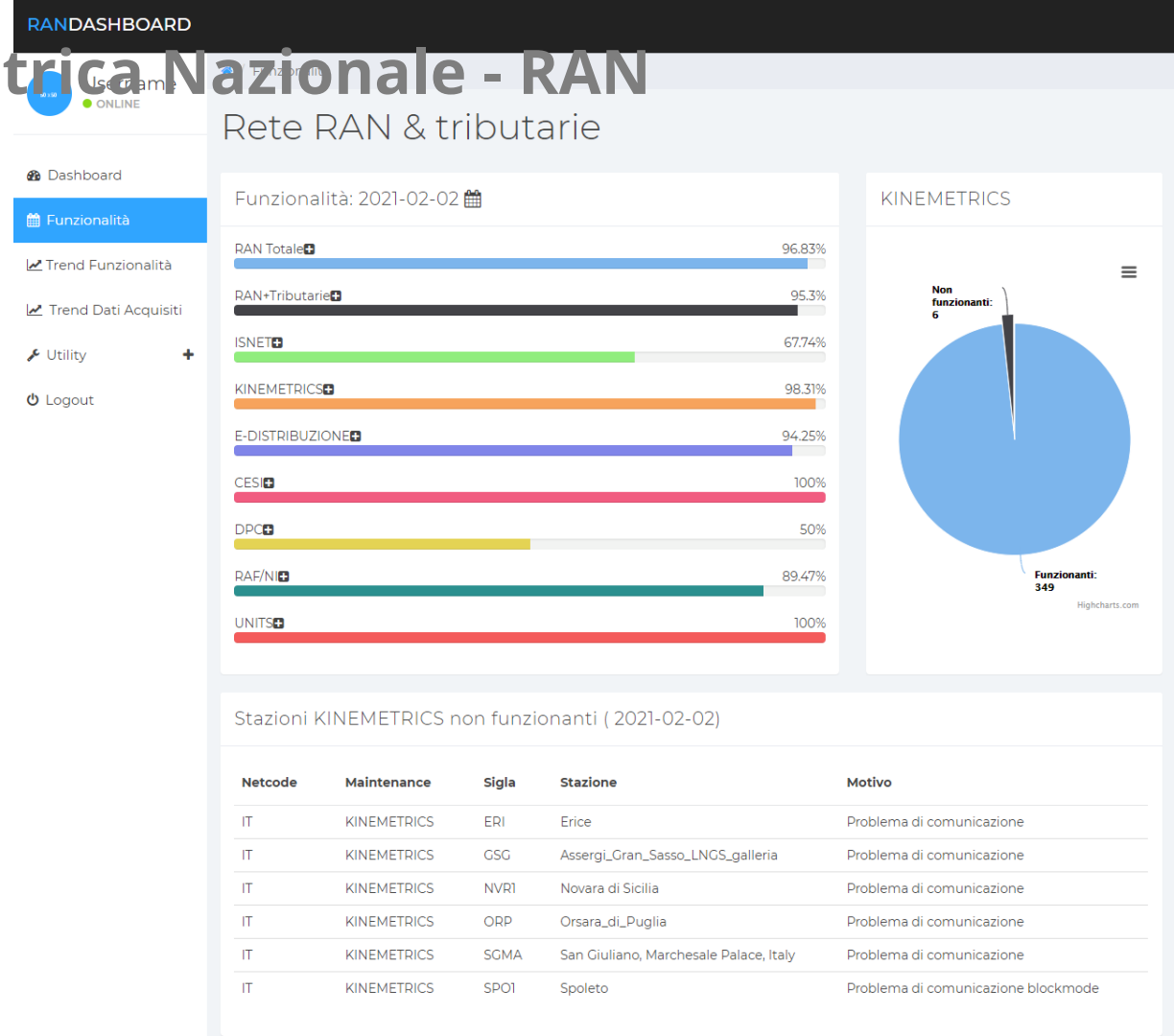
- RANDashboard
  - Web Interface to monitor station availability



Rete Accelerometrica Nazionale - RAN

System Operation

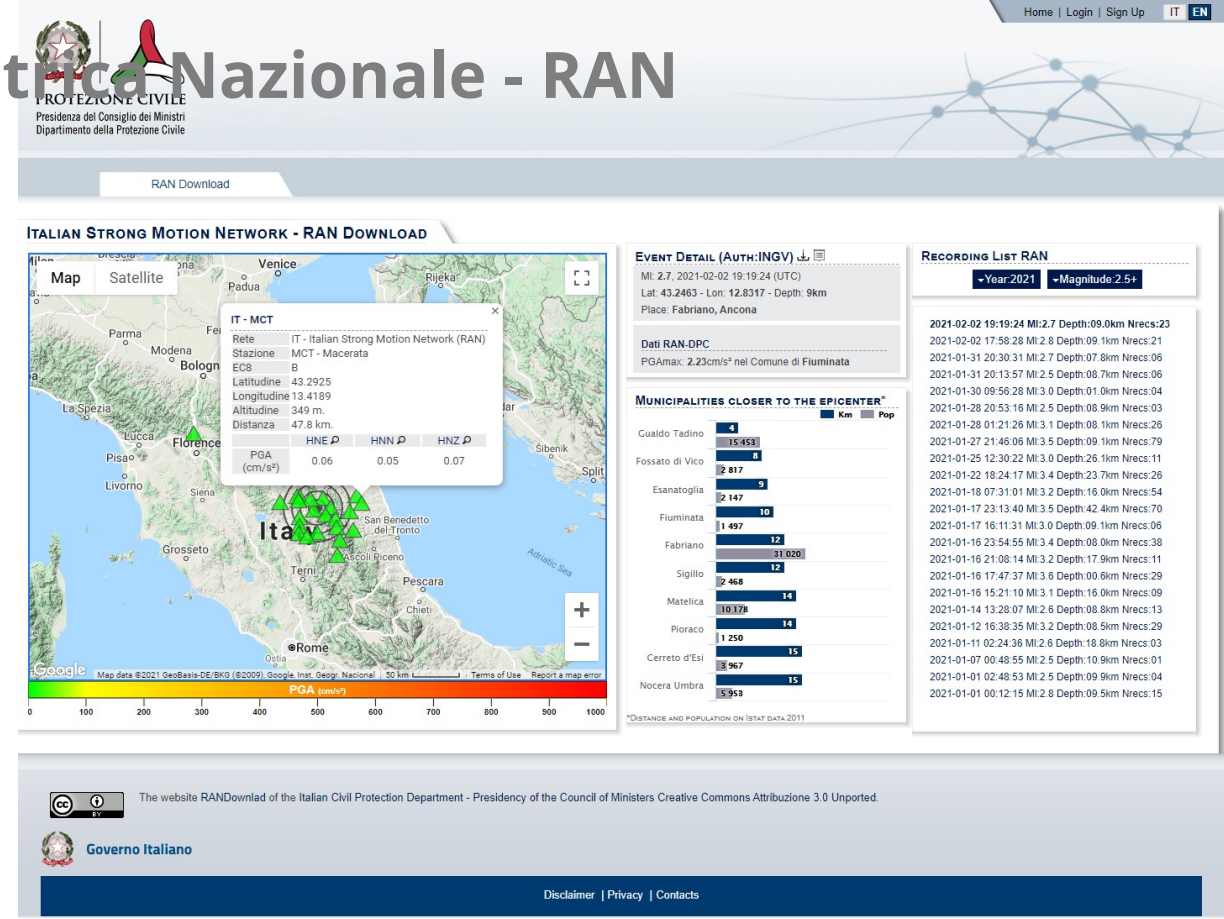
- RANDashboard
  - Web Interface to monitor station availability
  - Information by subnetwork



Rete Accelerometrica Nazionale - RAN

System Operation

- RANDashboard
  - Web Interface to monitor station availability
  - Information by subnetwork
- RANLive
  - Web Interface for emergency officers



Rete Accelerometrica Nazionale - RAN

System Operation

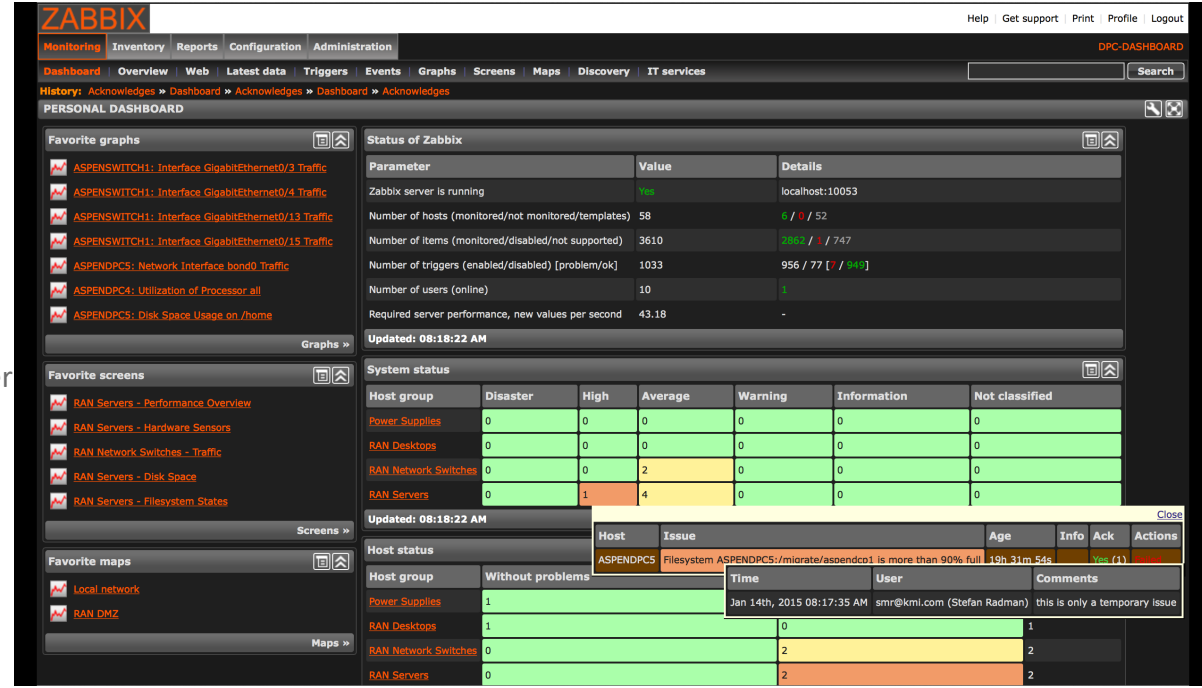
- RANDashboard
  - Web Interface to monitor station availability
  - Information by subnetwork
- RANLive
  - Web Interface for emergency officers
  - Detailed acceleration derivatives

Net	Sta	Chan	Loc	Lat (°)	Lon (°)	Nome Stazione	Filtro (Hz)	dist (km)	PGA (cm/s²)	EPA (cm/s²)	PGV (cm/s)	PGD (cm)	PSA03 (cm/s²)	PSA10 (cm/s²)	PSA30 (cm/s²)	Td (s)	Arias (cm/s)	Housner (cm)	EC8
IT	GLT	HGE	--	43.2331	12.7890	Gualdo_Tadino	0.5 - 49.9	3.76	1.17	0.76	0.03	< 0.01	---	0.20	0.01	3.11	< 0.01	---	C
IT	GLT	HGN	--	43.2331	12.7890	Gualdo_Tadino	0.5 - 49.9	3.76	1.58	0.73	0.03	< 0.01	---	0.07	0.01	2.57	< 0.01	---	C
IT	GLT	HGZ	--	43.2331	12.7890	Gualdo_Tadino	0.5 - 49.9	3.76	1.30	0.85	0.04	< 0.01	---	0.08	0.01	2.21	< 0.01	---	C
IT	FMNT	HNE	--	43.1836	12.9381	Fiuminata	0.5 - 49.8	11.08	2.05	1.18	0.05	< 0.01	---	0.28	0.01	3.61	< 0.01	---	-
IT	FMNT	HNN	--	43.1836	12.9381	Fiuminata	0.5 - 49.8	11.08	2.23	0.99	0.05	< 0.01	---	0.13	0.01	3.20	< 0.01	---	-
IT	FMNT	HNZ	--	43.1836	12.9381	Fiuminata	0.5 - 49.8	11.08	1.26	0.66	0.03	< 0.01	---	0.07	0.01	4.45	< 0.01	---	-
IT	SIG	HNE	--	43.3308	12.7408	Sigillo	0.7 - 49.8	11.93	0.37	0.19	0.01	< 0.01	---	0.02	< 0.01	8.17	< 0.01	---	C
IT	SIG	HNN	--	43.3308	12.7408	Sigillo	0.7 - 49.8	11.93	0.49	0.21	0.01	< 0.01	---	0.02	< 0.01	8.43	< 0.01	---	C
IT	SIG	HNZ	--	43.3308	12.7408	Sigillo	0.7 - 49.8	11.93	0.22	0.11	<0.01	< 0.01	---	0.02	< 0.01	9.85	< 0.01	---	C
IT	FBR	HGE	--	43.3436	12.9119	Fabriano	0.5 - 47.0	12.61	0.86	0.35	0.01	< 0.01	---	0.04	< 0.01	6.50	< 0.01	---	C
IT	FBR	HGN	--	43.3436	12.9119	Fabriano	0.5 - 47.0	12.61	0.65	0.29	0.02	< 0.01	---	0.03	0.01	6.73	< 0.01	---	C
IT	FBR	HGZ	--	43.3436	12.9119	Fabriano	0.5 - 47.0	12.61	0.36	0.21	0.01	< 0.01	---	0.07	< 0.01	8.18	< 0.01	---	C
IT	MTL	HGE	--	43.2494	13.0083	Matelica	0.4 - 49.4	14.30	0.71	0.39	0.02	< 0.01	---	0.05	0.01	6.23	< 0.01	---	B
IT	MTL	HGN	--	43.2494	13.0083	Matelica	0.4 - 49.4	14.30	0.69	0.41	0.02	< 0.01	---	0.05	0.01	6.91	< 0.01	---	B
IT	MTL	HGZ	--	43.2494	13.0083	Matelica	0.4 - 49.4	14.30	0.34	0.17	0.01	< 0.01	---	0.04	< 0.01	9.30	< 0.01	---	B
IT	GBP	HGE	--	43.3138	12.5894	Gubbio_Piana	0.4 - 48.1	20.99	0.17	0.15	0.01	< 0.01	---	0.08	0.01	15.29	< 0.01	---	C
IT	GBP	HGN	--	43.3138	12.5894	Gubbio_Piana	0.4 - 48.1	20.99	0.27	0.23	0.01	< 0.01	---	0.11	0.01	12.75	< 0.01	---	C
IT	GBP	HGZ	--	43.3138	12.5894	Gubbio_Piana	0.4 - 48.1	20.99	0.12	0.10	0.01	< 0.01	---	0.05	< 0.01	17.71	< 0.01	---	C
IT	VLFB	HNE	--	43.1594	12.5964	Valfabbrica	0.5 - 45.9	21.37	0.20	0.09	<0.01	< 0.01	---	0.03	< 0.01	12.24	< 0.01	---	-
IT	VLFB	HNN	--	43.1594	12.5964	Valfabbrica	0.5 - 45.9	21.37	0.26	0.10	<0.01	< 0.01	---	0.03	< 0.01	13.68	< 0.01	---	-
IT	VLFB	HNZ	--	43.1594	12.5964	Valfabbrica	0.5 - 45.9	21.37	0.12	0.05	<0.01	< 0.01	---	0.03	< 0.01	41.89	< 0.01	---	-
IT	GBB	HGE	--	43.3569	12.5972	Gubbio	0.8 - 47.5	22.60	0.12	0.11	<0.01	< 0.01	---	0.02	< 0.01	11.93	< 0.01	---	B
IT	GBB	HGN	--	43.3569	12.5972	Gubbio	0.8 - 47.5	22.60	0.17	0.11	<0.01	< 0.01	---	0.03	< 0.01	11.85	< 0.01	---	B
IT	GBB	HGZ	--	43.3569	12.5972	Gubbio	0.8 - 47.5	22.60	0.10	0.07	<0.01	< 0.01	---	0.02	< 0.01	14.57	< 0.01	---	B
IT	CMRN	HNE	--	43.1392	13.0718	Camerino	1.0 - 43.8	22.81	0.32	0.20	0.01	< 0.01	---	---	< 0.01	9.81	< 0.01	---	-
IT	CMRN	HNN	--	43.1392	13.0718	Camerino	1.0 - 43.8	22.81	0.26	0.17	0.01	< 0.01	---	---	< 0.01	11.37	< 0.01	---	-
IT	CMRN	HNZ	--	43.1392	13.0718	Camerino	1.0 - 43.8	22.81	0.14	0.09	<0.01	< 0.01	---	---	< 0.01	11.59	< 0.01	---	-
IT	GBSL	HNE	--	43.3558	12.5717	Gubbio Parcheggio Santa Lucia	0.5 - 49.4	24.30	0.08	0.07	<0.01	< 0.01	---	0.01	< 0.01	35.88	< 0.01	---	-
IT	GBSL	HNN	--	43.3558	12.5717	Gubbio Parcheggio Santa Lucia	0.5 - 49.4	24.30	0.07	0.06	<0.01	< 0.01	---	0.02	< 0.01	37.88	< 0.01	---	-
IT	GBSL	HNZ	--	43.3558	12.5717	Gubbio Parcheggio Santa Lucia	0.5 - 49.4	24.30	0.06	0.03	<0.01	< 0.01	---	0.02	< 0.01	33.83	< 0.01	---	-
IT	FOS	HNE	--	43.0146	12.8351	Foligno Seggio	0.7 - 46.3	25.76	0.19	0.12	0.01	< 0.01	---	0.03	< 0.01	8.66	< 0.01	---	B
IT	FOS	HNN	--	43.0146	12.8351	Foligno Seggio	0.7 - 46.3	25.76	0.29	0.17	0.01	< 0.01	---	0.03	< 0.01	10.01	< 0.01	---	B
IT	FOS	HNZ	--	43.0146	12.8351	Foligno Seggio	0.7 - 46.3	25.76	0.14	0.07	<0.01	< 0.01	---	0.02	< 0.01	9.79	< 0.01	---	B

Rete Accelerometrica Nazionale - RAN

System Operation

- RANDashboard
  - Web Interface to monitor station availability
  - Information by subnetwork
- RANLive
  - Web Interface for emergency officers
  - Detailed acceleration derivatives
- Zabbix
  - Custom Dashboard to monitor data center hardware



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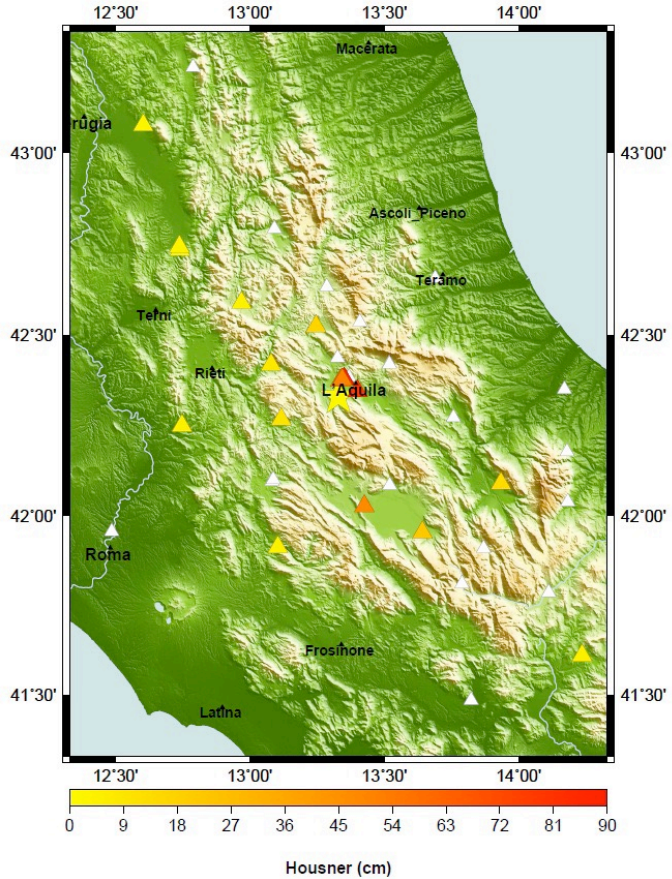
- Zabbix
  - Custom Dashboard to monitor data center hardware
  - Monitors station power & communication
- Civil Defense “fast-report”
  - Client EQ dissemination program



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Data Return

+ Partial year until end of May
** includes period without contract

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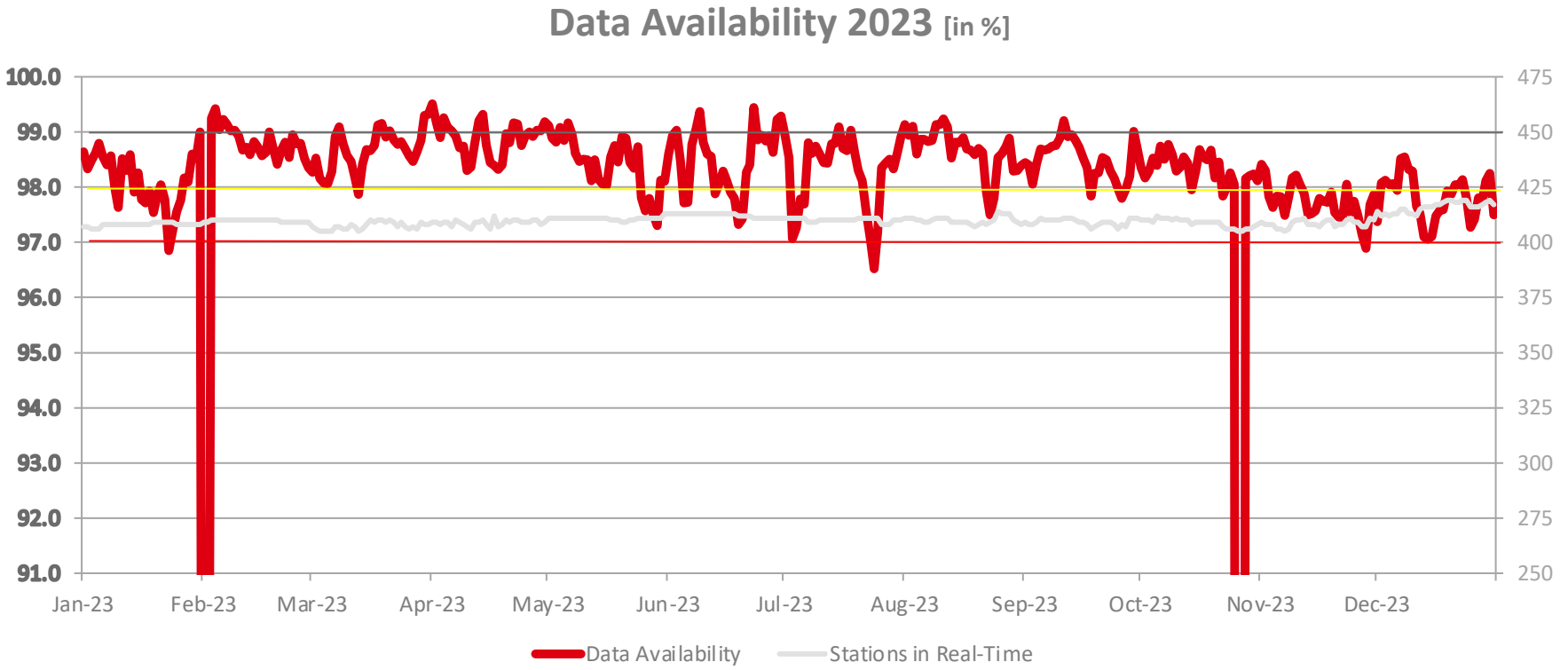
Real-Time Data Return



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Seismic Networks

Network	2023	2022	2021	Comments
Italian Strong-Motion Network, DPC	98% 417 Stations	99.2% 405 Stations	98.9% 387 Stations	Etna2 Cellular Com
Earthquake Monitoring Network, Saudi Arabia	99.96% 25 Stations	99.1% 25 Stations	99.4% 25 Stations	Q330S+ VSAT Com
Earthquake Monitoring Program of Oman	98.9% 19 Stations	n/a	n/a	Q330 family VSAT Com
GeoSphere (a.k.a. ZAMG), Austria	98.96% 16 BB Stations 21 SM Stations	~99% 16 BB Stations 20 SM Stations	~99% 16 BB Stations 20 SM Stations	Q330, Etna2
Slovenian Seismic Network	98.5% 26 Stations	99.96% 26 Stations	99.83% 26 Stations	Q330HR Government Intranet Data completeness
USArray/TA	2016-2018: 1166 dataloggers, 10,292 physical data channels at multiple sample rates, about 40,000 channels of SOH waveform data, 8760 instance-days of software running, 16 Tera samples of end-user data (not including SOH)			Q330 Cellular Com (mostly) Data completeness 99.7%

Summary

Takeaway

Why do we need 2+ nines?

- *Seismology is an observational science with non-repeatable events*
- *Seismologists need a complete data set for real-time and post-processing*
- *Reduced costs of operation and processing*
  (What is the price per byte?)

Q & A

THANK YOU

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Address

Kinemetrics
222 Vista Avenue
Pasadena, CA 91107

Contact Us

Direct Line: +1-626-795-2220
www.kinemetrics.com
sales@kmi.com

Social Media

facebook.com/osskinemetrics
twitter.com/osskinemetrics
linkedin.com/company/kinemetrics