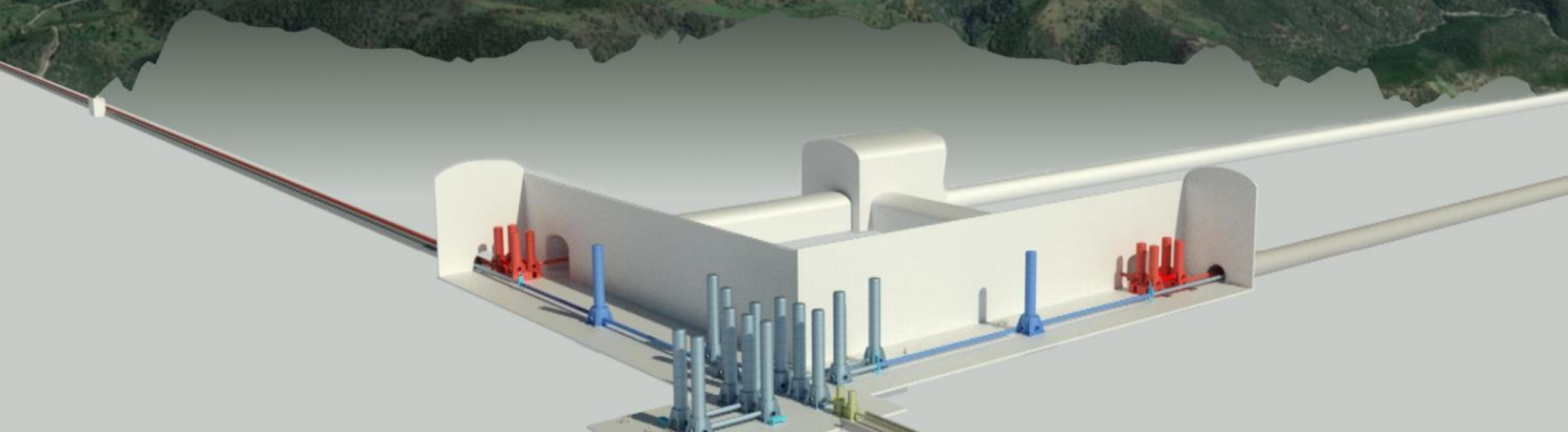
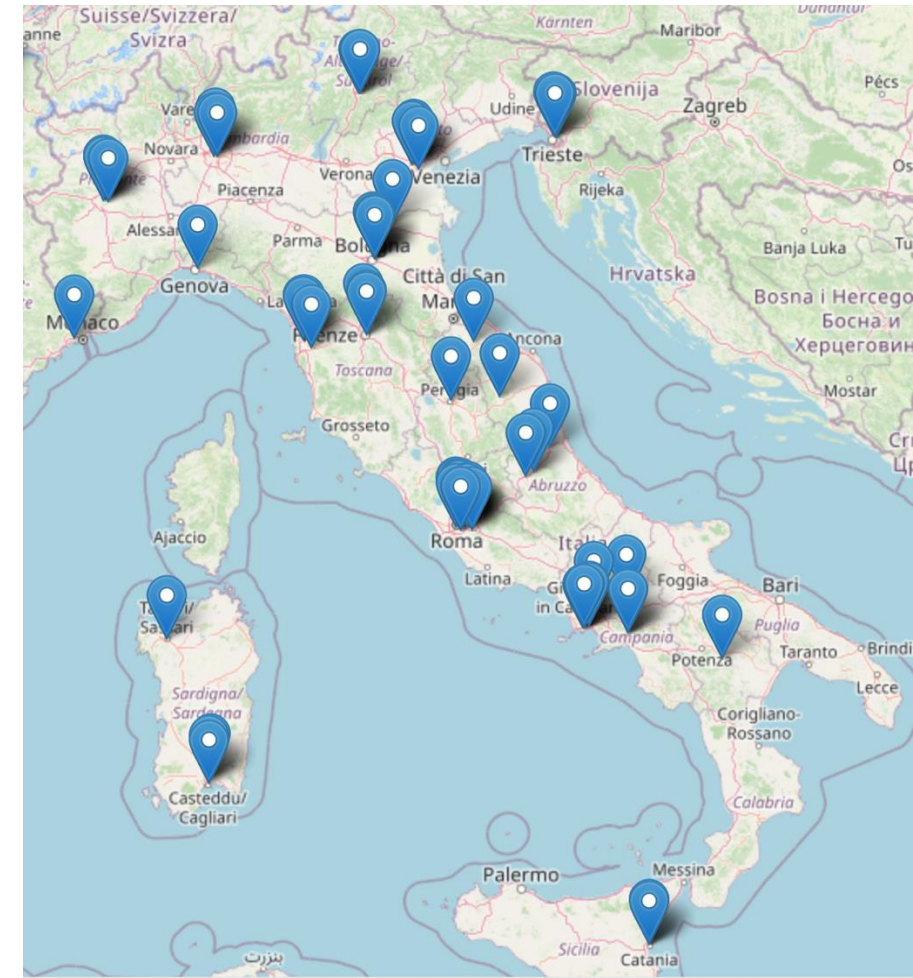


# R&D ET Italia



- ~600 members of 81 institutions for 27 RU
  - ❑ Preventivi INFN Ricercatori: 218 (68.8 FTE) - Tecnologi: 54 (13.84 FTE) - Tecnici: 6
- Site Characterization
- R&D enabling technologies



- National funds for R&D
- Common funds are current limited to vacuum and civil engineering studies (@CERN)
- R&D scenario and roadmap on going
  - DB of enable covered technologies
  - avoid duplication of efforts
  - R&D that can be offered to new RU
  - international R&D plan

# ET Enabling Technologies

Challenging engineering

New technology in cryo-cooling

New technology in optics

New laser technology

High precision mechanics and low noise controls

High quality opto-electronics and new controls

➤ The multi-interferometer approach asks for two parallel technology developments:

• **ET-LF:**

- Underground
- Cryogenics
- Silicon (Sapphire) test masses
- Large test masses
- New coatings
- New laser wavelength
- Seismic suspensions
- Frequency dependent squeezing

Parameter	ET-HF	ET-LF
Arm length	10 km	10 km
Input power (after IMC)	500 W	3 W
Arm power	3 MW	18 kW
Temperature	290 K	10-20 K
Mirror material	fused silica	silicon
Mirror diameter / thickness	62 cm / 30 cm	45 cm/ 57 cm
Mirror masses	200 kg	211 kg
Laser wavelength	1064 nm	1550 nm
SR-phase (rad)	tuned (0.0)	detuned (0.6)
SR transmittance	10 %	20 %
Quantum noise suppression	freq. dep. squeez.	freq. dep. squeez.
Filter cavities	1×300 m	2×1.0 km
Squeezing level	10 dB (effective)	10 dB (effective)
Beam shape	TEM <sub>00</sub>	TEM <sub>00</sub>
Beam radius	12.0 cm	9 cm
Scatter loss per surface	37 ppm	37 ppm
Seismic isolation	SA, 8 m tall	mod SA, 17 m tall
Seismic (for $f > 1$ Hz)	$5 \cdot 10^{-10} \text{ m}/f^2$	$5 \cdot 10^{-10} \text{ m}/f^2$
Gravity gradient subtraction	none	factor of a few

• **ET-HF:**

- High power laser
- Large test masses
- New coatings
- Thermal compensation
- Frequency dependent squeezing

Evolved laser technology

Evolved technology in optics

Highly innovative adaptive optics

High quality opto-electronics and new controls

# Major R&D Facilities in ET (incomplete)



From the XIII ET symposium, an incomplete selection of the presented large facilities

Credits to M. Punturo

### Etpathfinder in Maastricht

interreg

Main target: provide a testbed for ET tech concepts and qualify them in lo environment.

- 2 FPMI interferometers:
  - 1) 1550nm @ 18K
  - 2) 2090nm @ 123K

### OmniSense at Nikhef

VU Amsterdam

- Interferometric sensing (HoO), compact and proven
- Fused-silica suspension
- Closed-loop control
- Careful shielding for thermal fluctuations, acoustics, and E-M
- Mechanical simplicity, no cables or magnets.

### VATIGrav and Compact Laser Interferometry

GRAVITATIONAL WAVE DETECTION CLUSTER OF EXCELLENCE QUANTUM UNIVERSE

Main goals:

- test DFMI-based compact displacement sensors on suspensions to reduce control noise
- test inertial sensors with highly sensitive interferometric displacement sensors
- study new suspension control and seismic isolation schemes

DFMI metrology      Optical head (COBR)

Readout system and electronics      System-level testing

### The AEI 10 m Prototype Facility

Main goal: Sub- $\mu$ m interferometry

Studies of vibration isolation / control

Fused-silica welding

See Monday talk by David Wu

### DZA On solid ground

The German Centre for Astrophysics (DZA)

DZA concept - the challenges of astrophysics today

### E-TEST : Einstein Telescope EMR Site and Technology

Vibration isolation

Radiative cooling

E-TEST objectives

- Large mirror (100 kg)
- Cryogenic temperature (10-20 K)
- Isolated at low frequency (0.1-10 Hz)
- Compact suspension (4-5 meters)

### Test facility for experimental investigations of the He-II based ET-LF payload cooling concept

Suspension and cooling concept studied for ET-LF

See Monday talk by Xhesika Koroveshi

### CoMET - Coating Materials for Einstein Telescope

Goals:

- Capability to deposit virtually all the (amorphous) materials of interest for the GW community with the needed level of control
- Ability to explore different process ranges (energies, growth kinetics etc.)
- Study of the physical processes occurring during deposition

Coating deposition (samples)

- Ion beam
- Magnetron

Characterization facilities

### LMA - Laboratoire des Matériaux Avancés

Also investing into substrate growth and polishing

New large optics coater facility

Aim: produce ET cryo-compatible substrates in sapphire

Existing LMA building

Extension

### CAOS: Centro per Applicazioni sulle Onde gravitazionali e la Sismologia

New facility at the University of Perugia

Development of specific technology for the third-generation GW detectors

### GEMINI at LNGS

Goals

- Test the limits of active seismic isolation in an underground environment
- Inter-platform motion control
- Underground environmental monitoring
- Test new approaches to controls optimization
- Test new inertial sensors

Vibration target

### SAR-GRAV Laboratory

SAR-GRAV hosts ET activities as well as Geophysics and Fundamental Physics activities

Cavern that should host the Archimedes experiment

It is planned to test at least partially a preliminary version of the double-suspended inverted pendulum in a quiet underground environment.

See Monday talk by Enrico Calloni

### Amaldi Research Center at Roma La Sapienza

Facility dedicated to cryogenics development for ET.

Build prototype payload

See Monday talk by Ettore Majorana

### PLANET

Development and test of the ET environmental monitoring and the new suspension system for the ET test mass

Image Color Noise Lowry



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e della Ricerca

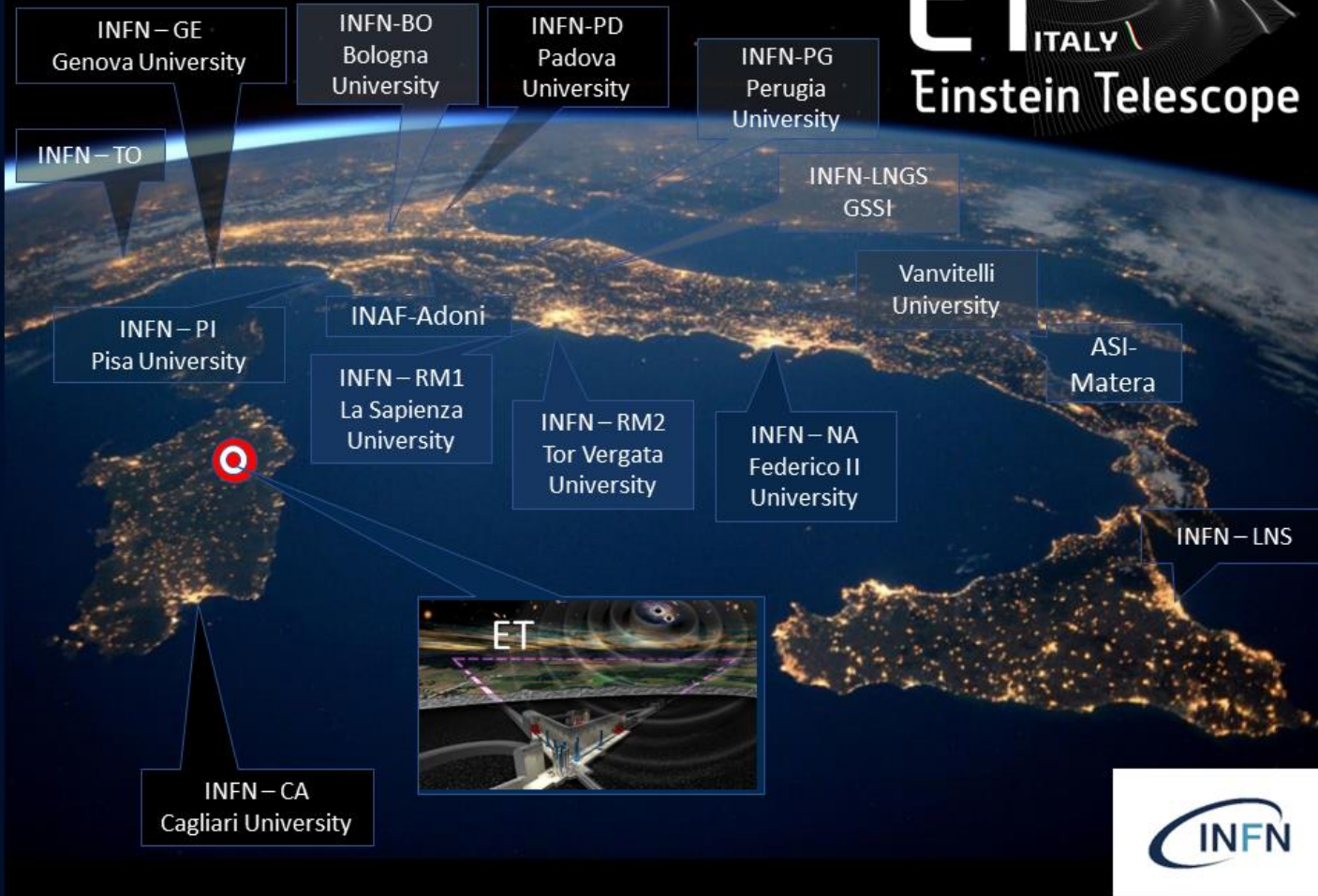


Italiadomani  
PIANO NAZIONALE  
DI RIPRESA E RESILIENZA



ETIC  
Einstein Telescope Infrastructure Consortium

### Credits to M. Punturo



- Project: PNRR –IR0000004
- Grant: 50M€ (2023-2025)
- INFN coordinator
  - Coordinating Operating Unit:
    - **INFN - Perugia**
- 11 universities, INAF and ASI
- 16M€ devoted to the candidature of the Sardinian site
  - 12M€+ contract with a consortium of Italian enterprises
- 34M€ addressed to the development of the technologies:
  - Realization of a network of Italian labs for ET
  - Recruitment of about 50 young researchers, engineers and technicians
  - Contracts with external companies



Finanziato dall'Unione europea  
NextGenerationEU



Ministero dell'Università e della Ricerca



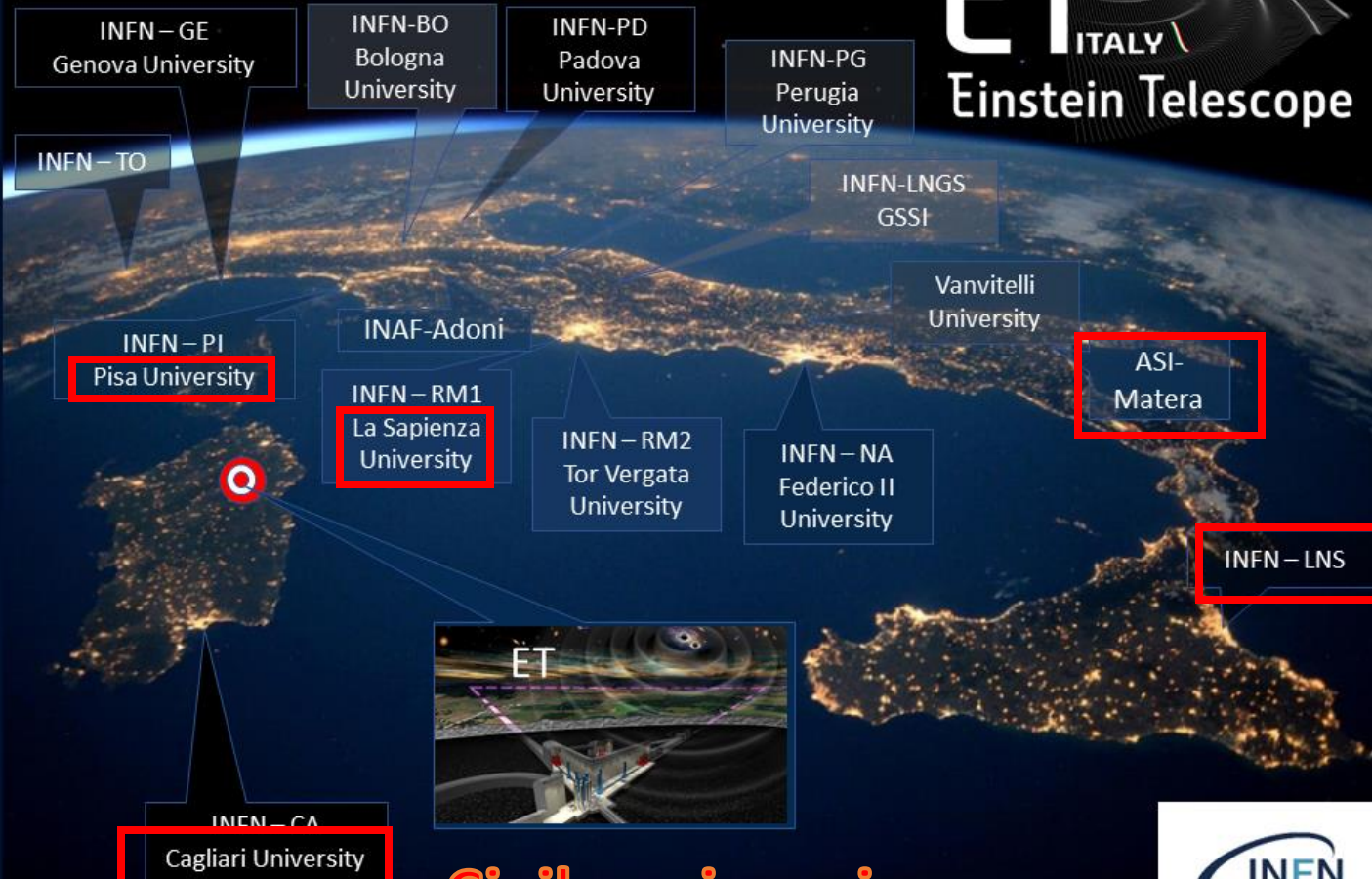
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Civil engineering,  
Site characterization





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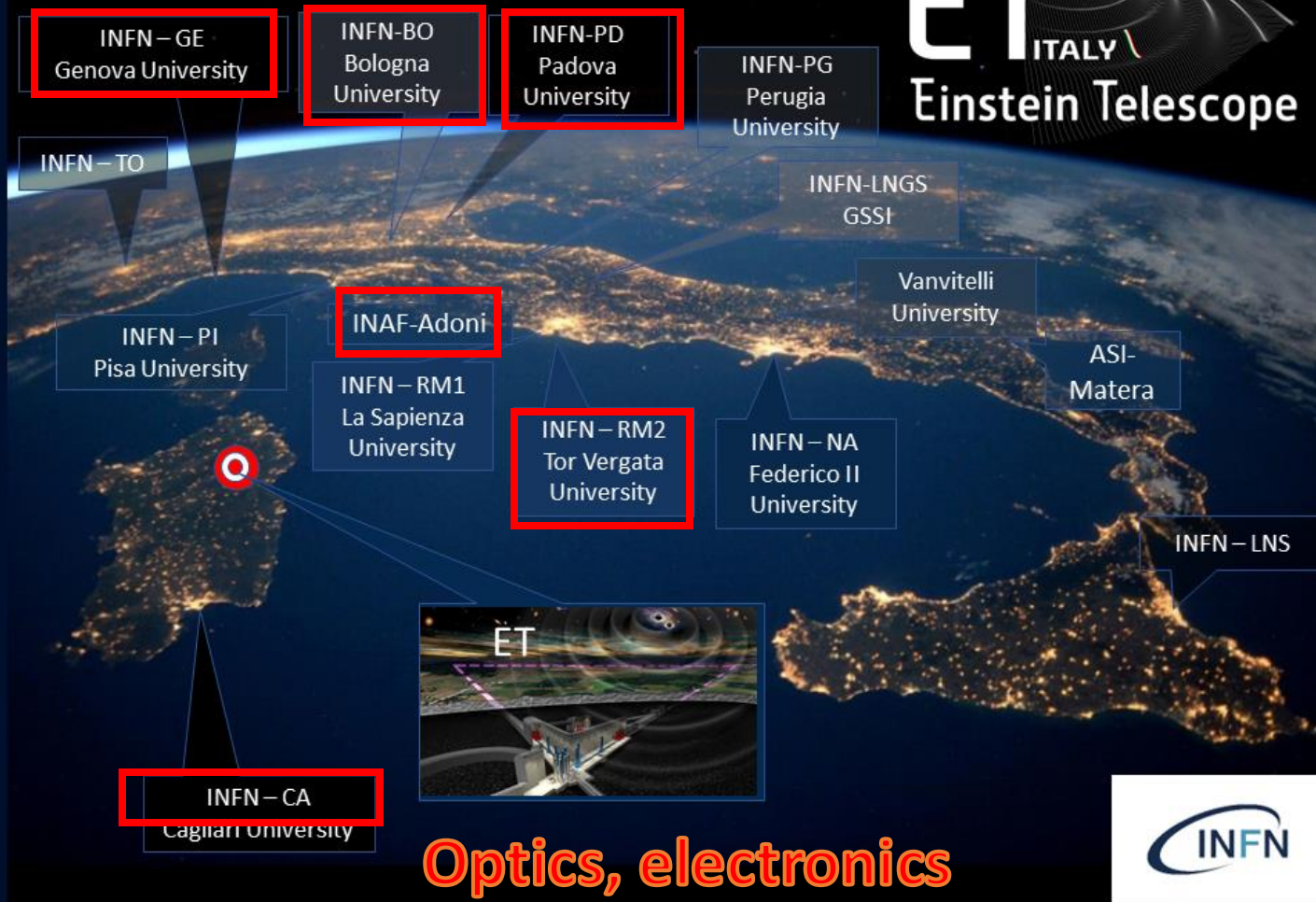


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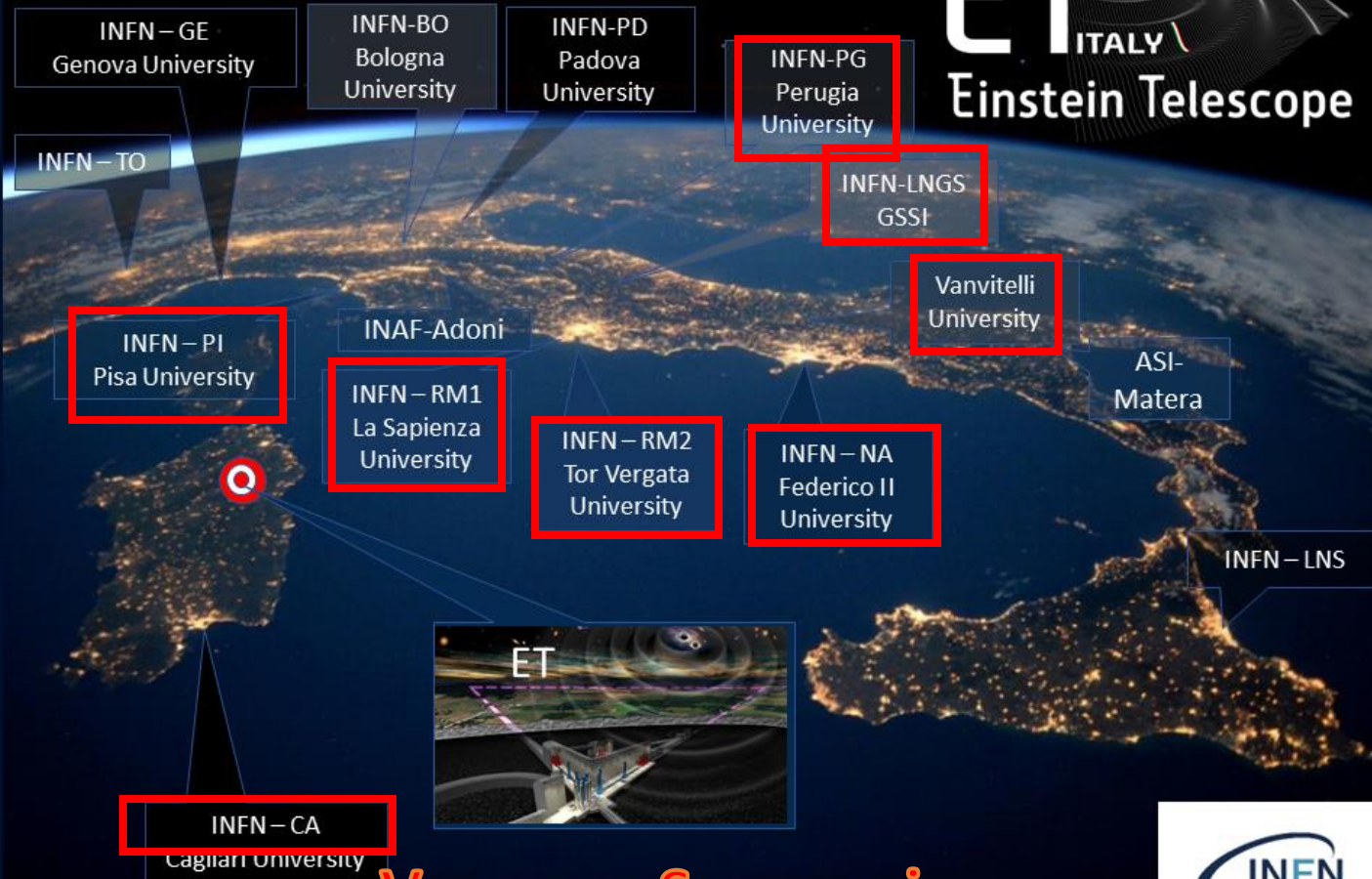


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Vacuum, Suspensions,  
Large test facilities





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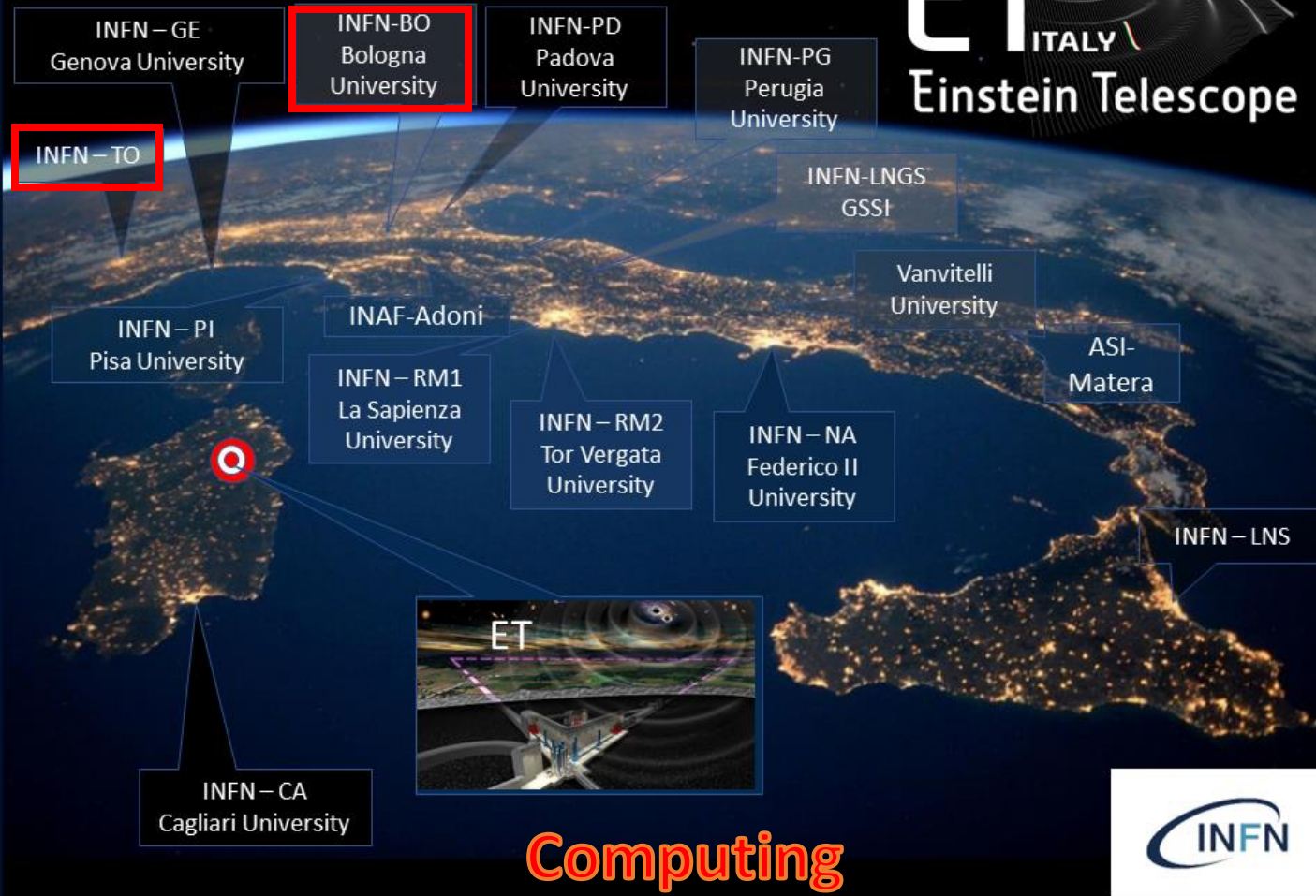


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### Credits to M. Punturo

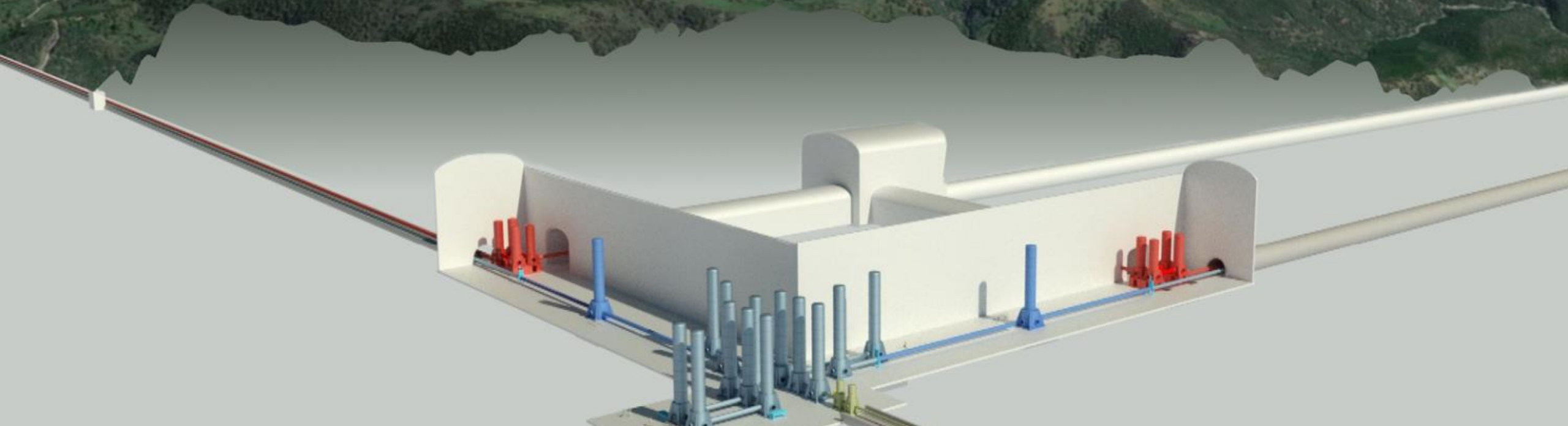


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- 3G Vacuum Systems and Cryogenics (VAC)
- Cryogenic payload (CPAY-LF)
- Suspensions and Seismic Isolation Systems (SUS)
- Active Noise Mitigation (ANM)
- Core Optics and Coatings (CRD)
- Wave front sensing and control (WSC)
- Quantum Noise Reduction (QNR)
- Stray light mitigation (SLM)
- Computing
- DAQ

- Env. Noise Measurement (measurements and effect estimation)
- R&D
- Manpower
- Virgo/EGO the GYM for ET community
- Virgo post-O5 pathway towards ET

# Presentazione Richieste Finanziarie



# Esempio:

# Suspensions and Seismic Isolation Systems (SUS)



## DESCRIZIONE

The seismic isolation system foreseen for ET is based on the Superattenuator, that is successfully operating in the VIRGO interferometer and is now 25 years old.

The goal of ET-LF is to isolate the test masses from seismic noise at frequencies above 2 Hz, with a significant improvement with respect to the current structure.

To address this requirement, a R&D plan is running along three main lines: i) Cryogenic payload, ii) Mirror suspension, and iii) **Seismic Isolation and Control** which is the subject of this section

## Readiness

Il livello di readiness è diverso a seconda delle varie parti

- Nuove antimolle magnetiche: TRL 4 (Technology validated in lab)
- Per il resto: TRL2-3 ma con l'idea di arrivare a TRL3 a breve

## DOCUMENTI DI RIFERIMENTO

Descrizione progetto: [https://pandora.infn.it/ws-preventivi-2025-1/3-Preventivi e report attività di gruppo/PI/ReportAttivitaET\\_Pisa.pdf](https://pandora.infn.it/ws-preventivi-2025-1/3-Preventivi%20e%20report%20attivit%C3%A0%20di%20gruppo/PI/ReportAttivitaET_Pisa.pdf)

Presentazione ai referee: <https://pandora.infn.it/ws-preventivi-2025-1/2-Slides/3-ET-SUS.pptx>

- 1. PRE: Pre-Isolator
- 2. NIP: Nested Inverted Pendulum
- 3. MAS: Magnetic Anti-Spring
- 4. SSA: Superattenuator Sensors and Actuators
- 5. SCS: Superattenuator Control System
- 6. MLC: Machine Learning for Controls
- 7. IPT: Sensing and Control for NIP test
- 8. NTE: Non-Equilibrium Thermal Noise

## RISULTATI

Grazie all'esperienza maturate in Virgo e ai progetti PNRR, i risultati ottenuti finora sono molteplici. Di seguito sono riportati solo i principali.

WP1: si sta realizzando il test di un nuovo tipo di pre-isolator a Pisa per poi essere testato a CAOS

WP2: un nuovo laboratorio PNRR è in fase di realizzazione a Napoli

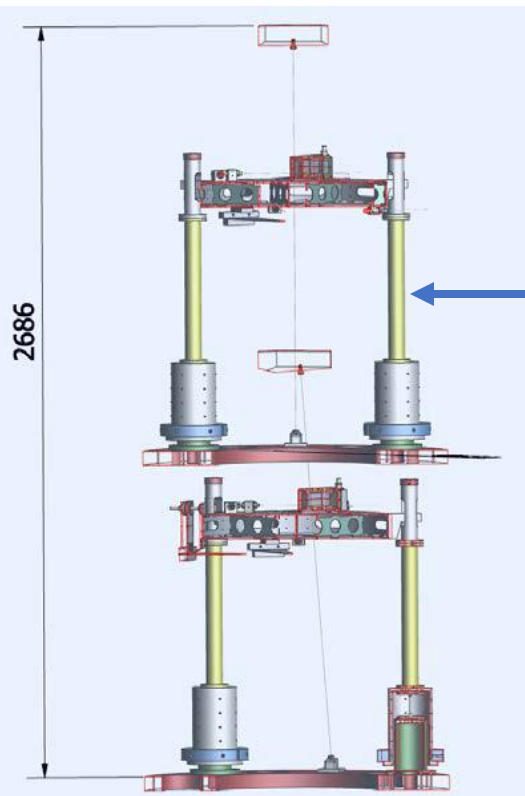
WP3: nuovi materiali e un nuovo design per le MAS sono in fase di studio per la realizzazione dei test tra il laboratorio di Pisa e CAOS

WP5: una nuova elettronica è in fase di design tra i laboratori di Pisa e Bologna

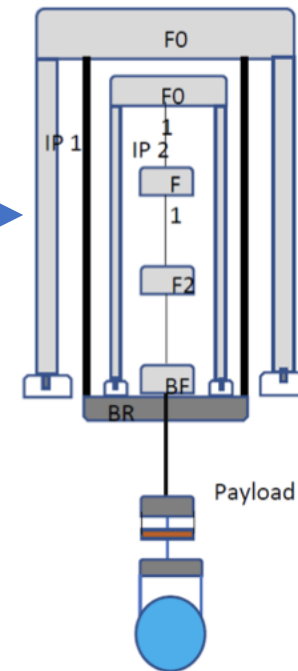
WP8: sistema di misura già realizzato e testato dove andranno effettuate le misure finali entro il 2025.

# SUS: Activities

➤ Several activities are today running following the R&D plan updated in 2021 and successive integrations



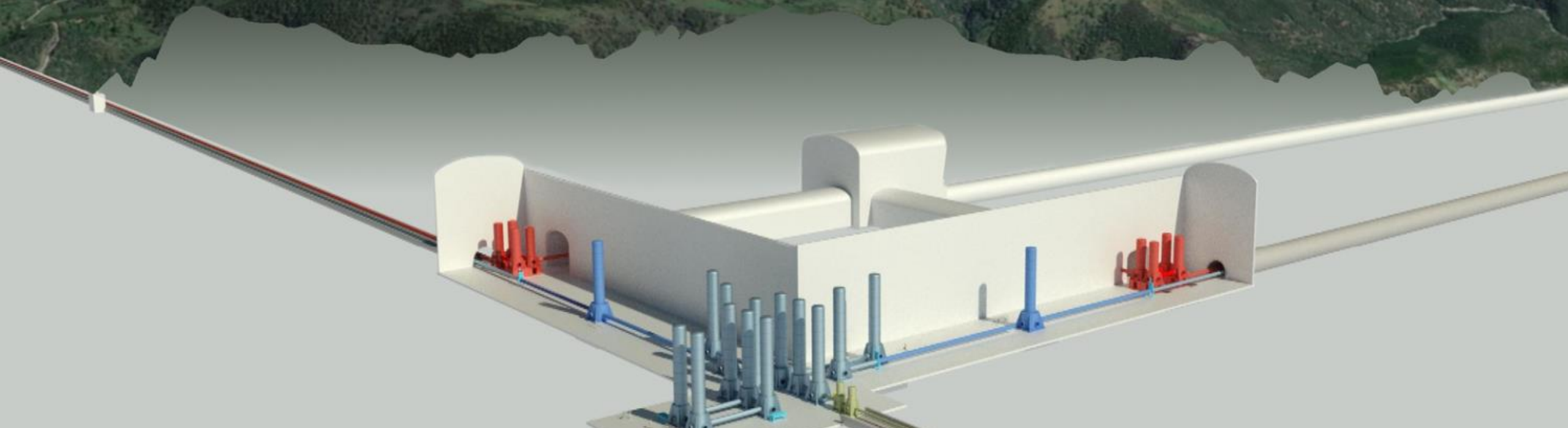
	2023	2024	2025	2026	2026
<b>SUS.PRE.1</b>	Vertical preisolator				
<b>SUS.PRE.2</b>			Horizontal preisolator		
<b>SUS.NIP</b>	NGSA				
<b>SUS.MAG.1</b>					
<b>SUS.MAG.2</b>		New cross-bar for seismic filters			
<b>SUS.PIP</b>	Pendulum Inverted Pendulum - BHETSA				
<b>SUS.SSA.1</b>	Displacement Sensor				
<b>SUS.SSA.2</b>	Inertial Sensor				
<b>SUS.SSA.3</b>			Actuators		
<b>SUS.SCS.1</b>					
<b>SUS.SCS.2</b>	RCS Zangle (GPU-based control system)				
<b>SUS.MLC.1</b>		GPU Server Setup			
<b>SUS.MLC.2</b>			ML-based control		
<b>SUS.IPT</b>			NGSA Control		
<b>SUS.CAOS</b>	Suspensions CAOS ET-LF				
<b>SUS.NTE</b>		NTE Interferometer			





- Most of activities have one-to-one overlapping with VIRGO. Here few examples.
  - ❑ SUS-PRE. Vertical preisolator is derived from the VIRGO base ring vertical control. Extension to horizontal degrees of freedom will be applicable in VIRGO to improve seismic isolation.
  - ❑ SUS-MAG. New magnetic anti-springs will allow reducing the size of seismic filters and therefore the size of vacuum chambers (the “slim” Superattenuator today under study for VIRGO stable recycling cavities)
  - ❑ SUS-SCS. New control system under development was already inserted into VIRGO base line for next observation run. Future extension allowing introduction A.I. support will be fully applicable in VIRGO.
  - ❑ SUS-SSA. New inertial sensors will constitute a valid replacement for sensors that are now in operation since more than 20 years.
- Personnel arrived thanks to PNRR ETIC contracts is today contributing to the preparation of VIRGO upgrades for next observation run and beyond.
  - ❑ New seismic isolation systems for additional optics
  - ❑ New control electronics and software

# Richieste Finanziarie



# Richieste 2025

Struttura	altri_cons		apparati		consumo		missioni		inventario		licenze-SW		speservizi		trasporti		Total	
	Ric	SJ	Ric	SJ	Ric	SJ	Ric	SJ	Ric	SJ	Ric	SJ	Ric	SJ	Ric	SJ	Ric	SJ
BO	2	10	0	0	0	0	21	0	40.5	151	2.5	0	0	0	0	0	66	161
CA	0	0	0	0	30	0	111	0	6.5	0	0	0	35	0	0	0	182.5	0
FE	0	0	0	0	9	14	17.5	0	27	0	0	0	0	0	0	0	53.5	14
FI	0	0	0	0	0.5	8	14	0	33.5	0	0	0	0	0	0	0	48	8
GE	0	0	19	0	56	0	12	0	0	0	0	0	0	0	0	0	87	0
LNF	0	0	0	0	15	0	18	0	0	0	0	0	0	0	0	0	33	0
LNGS	0	0	0	10	5	70	12	0	0	0	0	0	0	0	0	0	17	80
LNS	20	300	0	0	0	0	30	10	50	100	7	0	20	0	0	0	127	410
MIB	0	0	0	0	3	0	13.5	0	30	0	0	0	0	0	0	0	46.5	0
NA	0	0	30	0	61	0	56	0	46.5	0	2	0	0	5	0	0	195.5	5
PD	7	0	0	0	19.5	16	17.5	0	49.5	4	0	0	0	0	0	0	93.5	20
PG	0	0	64.5	10	46.5	9.464	142.5	5	5.5	209.03	2.5	0	0	0	0	0	261.5	233.494
PI	0	0	0	0	100	5	74.5	0	0	0	0	0	0	0	0	0	174.5	5
RM1	0	0	0	0	74.5	0	100	0	44.5	0	0	0	67.5	0	0	0	286.5	0
RM2	0	0	72.5	219.5	9	0	23.5	0	24	0	0	0	0	0	0	0	129	219.5
SA	0	0	0	0	18	0	16	4	26	26	0	0	0	0	0	0	60	30
TIFP	0	0	0	0	14	0	16	0	28.5	0	6	0	0	0	0	0	64.5	0
TO	0	0	0	0	0	0	46.5	0	0	0	0	0	0	0	0	0	46.5	0
TS	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	12	0
<b>TOTAL</b>	<b>29</b>	<b>310</b>	<b>186</b>	<b>239.5</b>	<b>461</b>	<b>122.464</b>	<b>753.5</b>	<b>19</b>	<b>412</b>	<b>490.03</b>	<b>20</b>	<b>0</b>	<b>122.5</b>	<b>5</b>	<b>0</b>	<b>0</b>	<b>1984</b>	<b>1185.994</b>

➤ Richieste 2025: dati nel DB (2073k + 615k SJ) da aggiornare alla luce dei recenti sviluppi delle attività 1984k + 1186k SJ

- Possibilità scavo BH su vertice 1: 400k SJ
- Costo DSS aggiornato a 170k, da considerarsi SJ

Categories	RIC	SJ	Δ RIC (2024)	Δ SJ (2024)
ANM		20	80	20
CPAY-LF		168	23	78
CRD		229	56	-12
DAQ		47.5	0	26
ETIC		75	580.994	-206.5
MIS	534.5	0	215.5	-4
QNR	123	10	43	10
SITE	430	410	277.5	410
SLM	0	6	0	6
SUS	175	10	43	0
VAC	100	0	45.5	0
WSC	67	0	-41	0
OTHERS	15	10	15	10
<b>TOTAL</b>	<b>1984</b>	<b>1185.994</b>	<b>504</b>	<b>989.994</b>

### Maggiori Differenze:

#### - Missioni:

- richieste legate alle attività (**200k**)
- richieste legate agli FTE

dei singoli gruppi: FTE aumentati di 10 unità

- richieste legate ai vari ruoli ricoperti in ETC/ETO: aumento ruoli di responsabilità (da 45 a 63)
- richieste conferenze (~**200k**, algoritmo CSN2)
- aumento costo viaggi

#### - SITE:

- Realizzazione Nuove aree di misura in corrispondenza dei nuovi vertici
- Nuovo BH al vertice P1
- Missioni sul sito

#### - Spese ETIC

Capitoli spesa	RIC	SJ
altri_cons		29
apparati		186
consumo		461
missioni	753.5	19
inventario		412
licenze-SW		20
speservizi		122.5
trasporti		0
<b>TOTAL</b>	<b>1984</b>	<b>1185.994</b>

Δ RIC (2024)	NOTE	Δ SJ (2024)	NOTE
19		310	
49		214.5	
-10.5		122.464	Attrezzature ETIC
198		-9	
79.5		357.03	Pozzo V1
-16.5		0	
122.5	Geologia+Rinnc	-5	
-1		0	
<b>440</b>		<b>989.994</b>	

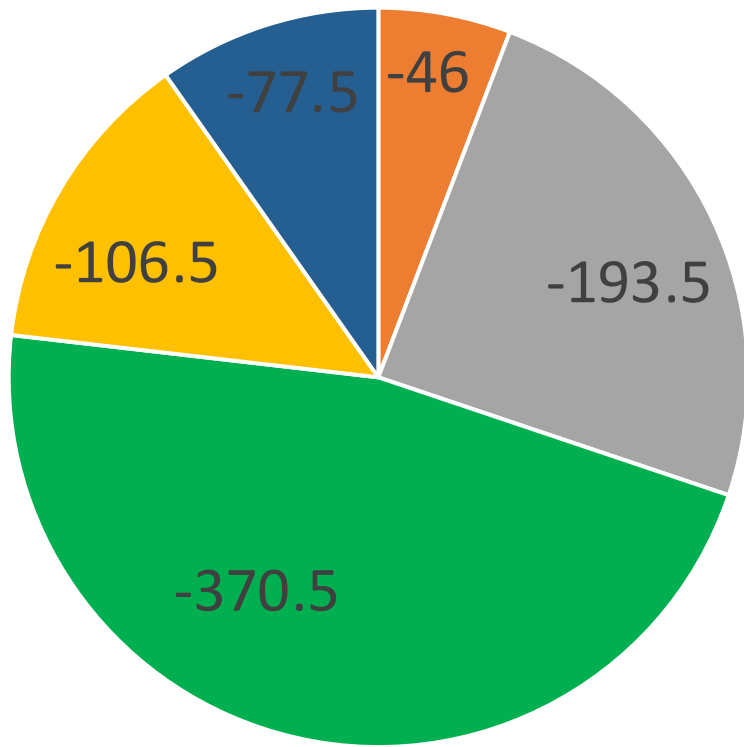
ANM	Active Noise Mitigation
CPAY-LF	Cryogenic payload
CRD	Coating R&D
ETIC	ETIC-PNRR
MIS	Missioni
OSB	Observational Science Board
QNR	Quantum Noise Reduction
SITE	Site Characterization
SLM	Stray Light Mitigation
SUS	Suspensions
VAC	Vacuum
WSC	Wavefront Sensing and Control

# Assegnazioni 2025

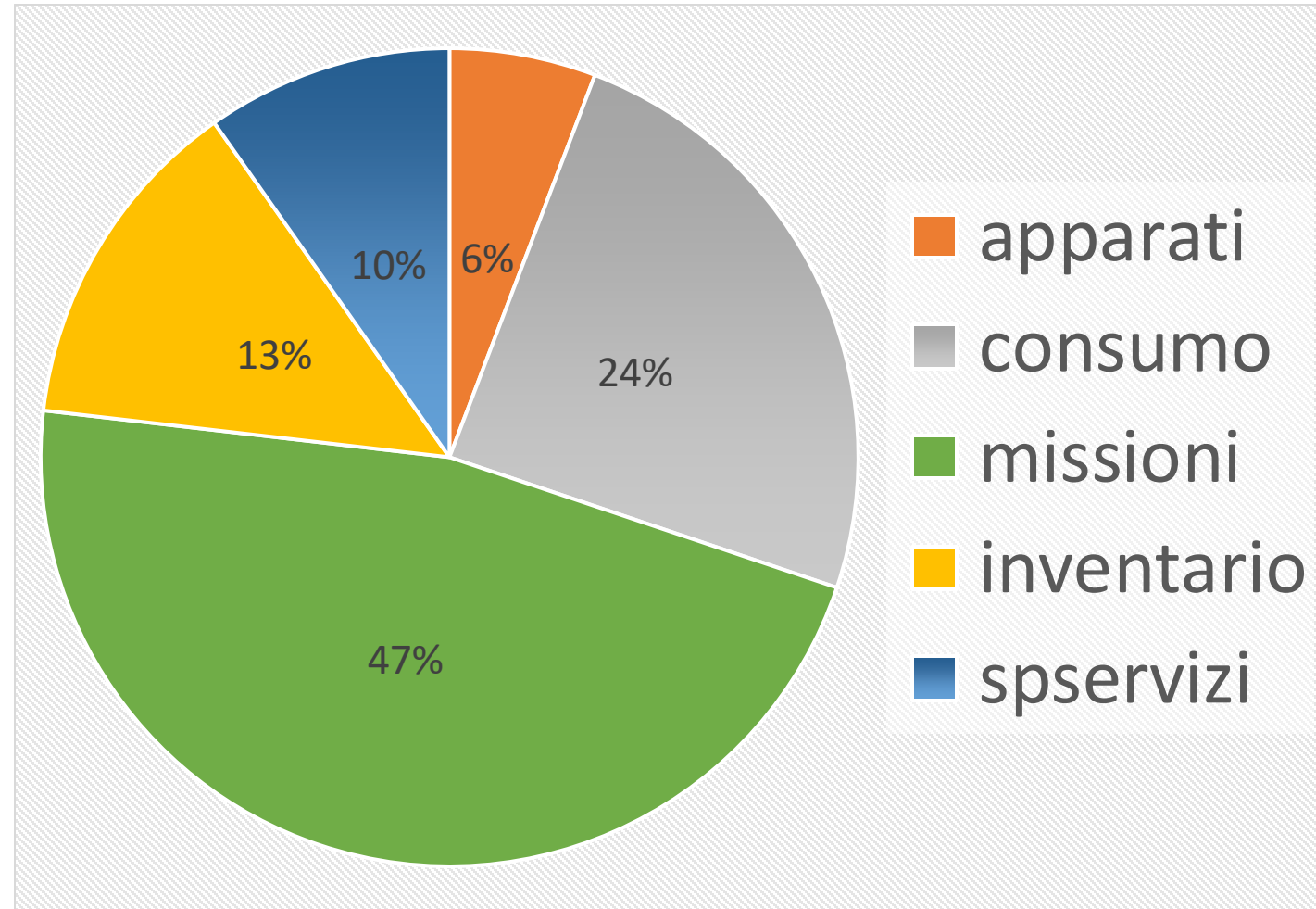
Struttura	altri_cons		apparati		consumo		missioni		inventario		licenze-SW		spse	trasporti		Total Ric	Total	
	ASS	SJ	ASS	SJ	ASS	SJ	ASS	SJ	ASS	SJ	ASS	SJ	ASS	ASS	SJ			
BO	0.5	10	0	0	0	0	6.5	4	30.5	161	2.5	0	0	0	1.5	0	41.5	1
CA	0	0	0	0	0	30	52	43	6.5	0	0	0	35	0	0	0	123.5	
FE	0	0	0	0	3	14	5	3	27	0	0	0	0	0	0	0	35	
FI	0	0	0	0	4.5	4	4	0	31	2.5	0	0	0	0	0	0	39.5	
GE	0	0	8	10	1	55	6	0	0	0	0	0	0	0	0	0	15	
LNF	0	0	0	0	10	0	9	0	0	0	0	0	0	0	0	0	19	
LNGS	0	0	0	0	1	52	6	0	0	0	0	0	0	0	0	0	7	
LNS	20	300	0	0	0	0	15	0	50	100	7	0	0	0	0	0	92	4
MIB	0	0	0	0	0	0	7	0	30	0	0	0	0	0	0	0	37	
NA	0	0	0	30	7	40	17	20	46.5	0	2	0	0	5	0	0	72.5	
PD	7	0	0	0	22	13.5	9	0	0	28.5	0	0	0	0	0	0	38	
PG	0	0	64.5	0	20	0	70	0	5.5	90	0	0	0	0	0	0	160	
PI	0	0	0	0	100	5	74.5	0	0	0	0	0	0	0	0	0	174.5	
RM1	0	0	0	0	42	8.5	50	0	33	0	0	0	10	0	0	0	135	
RM2	0	0	67.5	224.5	3	6	12	0	24	0	0	0	0	0	0	0	106.5	23
SA	0	0	0	0	14	0	8	0	9	26	0	0	0	0	0	0	31	
TIFP	0	0	0	0	10	0	8	0	12.5	0	0	0	0	0	0	0	30.5	
TO	0	0	0	0	0	0	18	10	0	0	0	0	0	0	0	0	18	
TS	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6	
<b>TOTAL</b>	<b>27.5</b>	<b>310</b>	<b>140</b>	<b>264.5</b>	<b>267.5</b>	<b>198</b>	<b>383</b>	<b>80</b>	<b>305.5</b>	<b>408</b>	<b>11.5</b>	<b>0</b>	<b>45</b>	<b>5</b>	<b>1.5</b>	<b>0</b>	<b>1181.5</b>	<b>126</b>

**Residuo Missioni Dec 24: 500 k**

# Tagli Assegnazioni 2025 (totale 802 keuro)

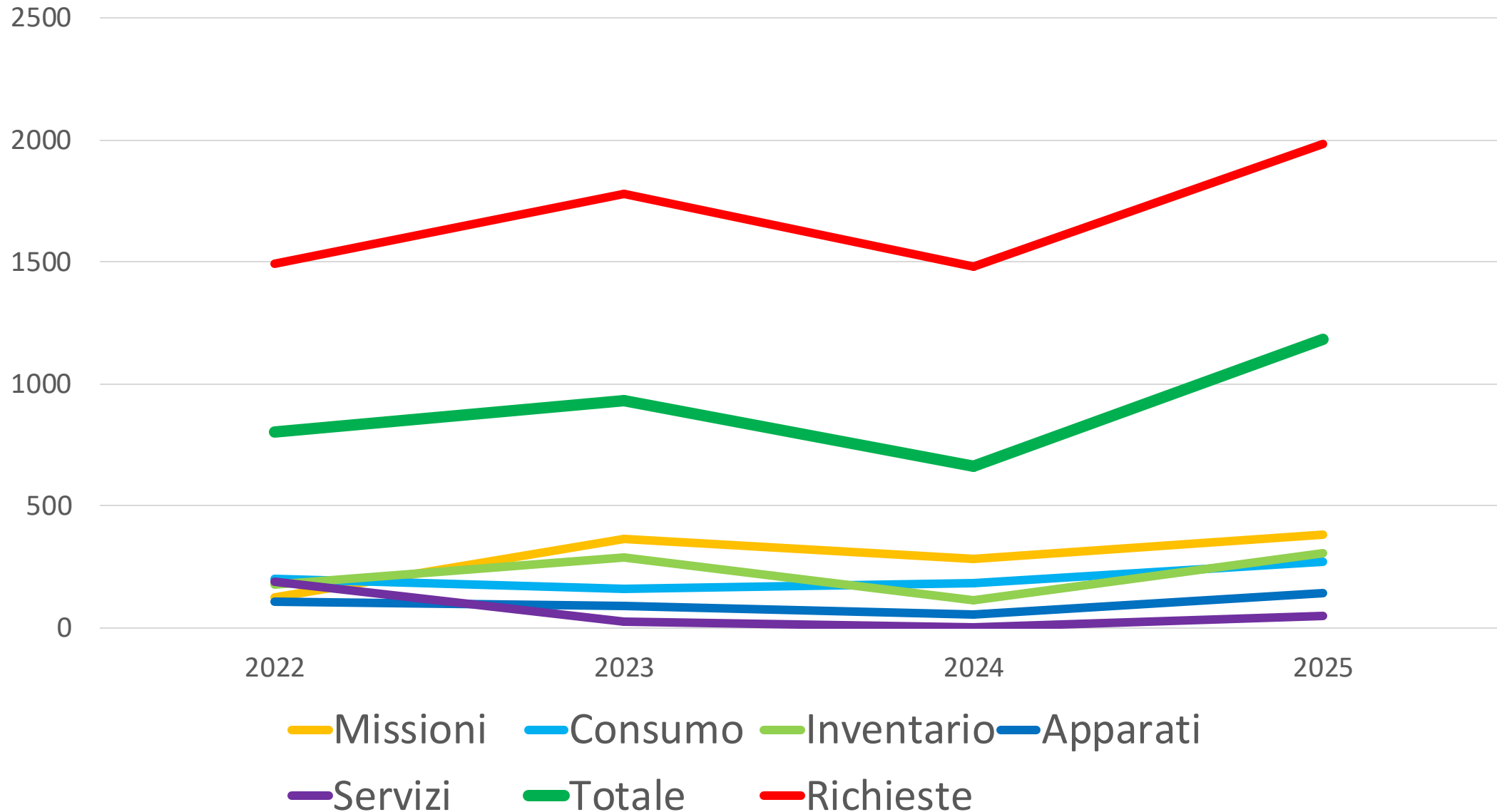


- apparati
- consumo
- missioni
- inventario
- spservizi

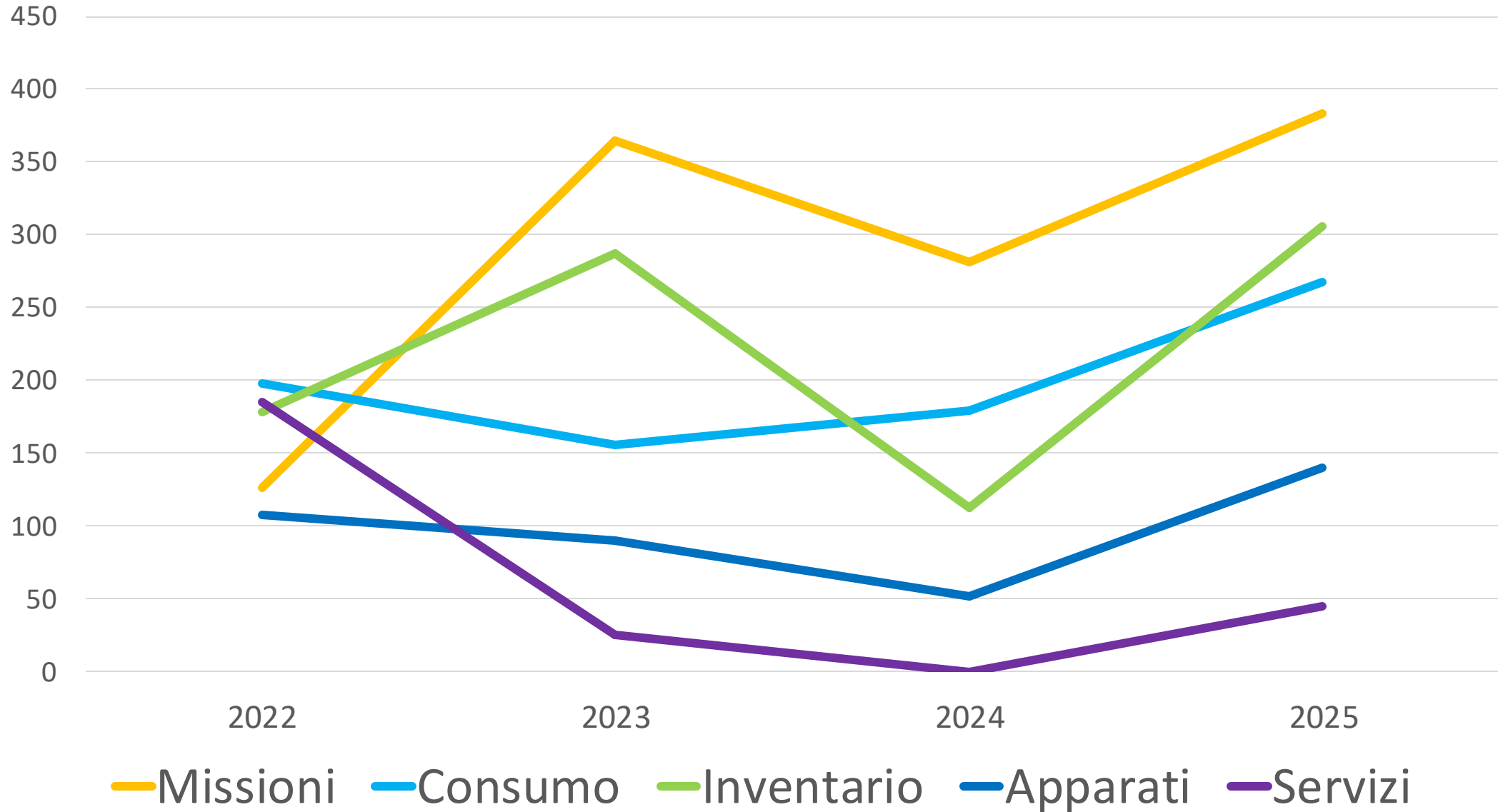


- apparati
- consumo
- missioni
- inventario
- spservizi

# Finanziamenti 2022-2025



# Finanziamenti 2022-2025





- Verifica necessità finanziarie
  - fondi trasferite disponibili
  - previsioni spese trasferite fino a luglio 2025
  - previsioni spese trasferite fino a dicembre 2025
  - Acquisto apparati/strumentazioni
- Update piano R&D (vedi presentazione Flavio)
  - verifica stato piano R&D 2022-2025
  - definizione R&D strategici
  - centralità infrastrutture ETIC