EINSTEIN TELESCOPE

R&D coordination in the ET collaboration

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Scuola Normale Superiore & INFN

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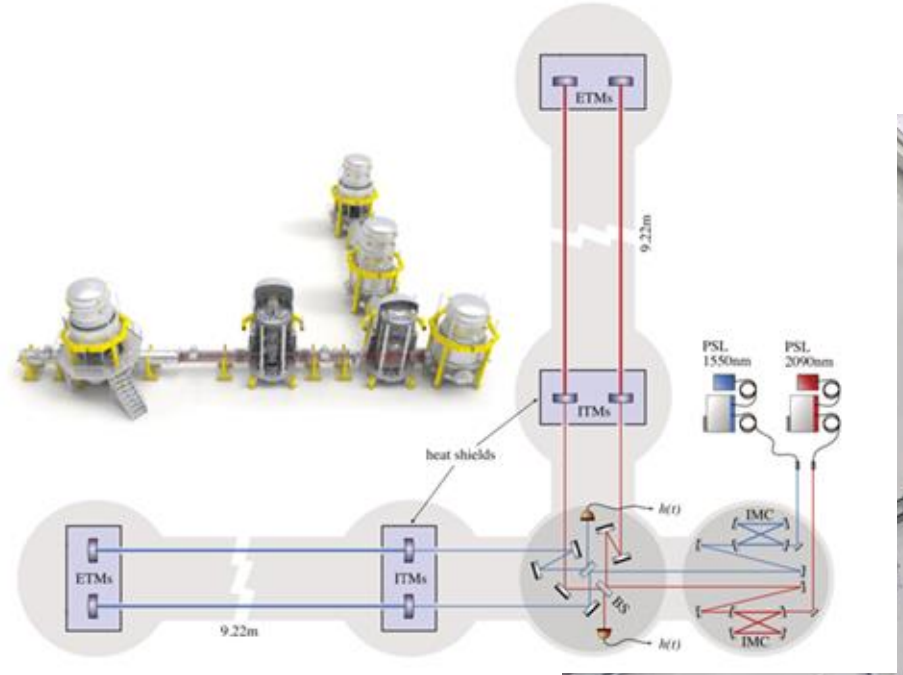
The ET R&D landscape

- More than €100 million invested in ET R&D facilities and projects across Europe
  - Comparable in scale to the combined capital investment in Virgo and Advanced Virgo
- National and regional initiatives have built a diverse R&D ecosystem
  - A common ET-wide framework for planning and coordination is still developing
- Can these activities deliver the technologies required for ET's first implementation?
  - The first task is to link ET technology needs to ongoing R&D and the facilities required for validation

Facility	Primary verification capability	HF , LF or both?	STATUS	LOCATION	PI	LEAD INSTITU	WEB SITE
ADONI (INAF)	Optical aberrations control	HF		Arcetri Astrophysical Observato		INAF	
AEI 10 m Prototype - Hannover	Interferometry, quantum optics and controls, sensing/actuation	HF		Hannover (Germany)		Max Planck Institute for Gravitational Physics (AEI)	
AT_LAB (UniCA_ing)	Territorial and landscape studies + SUNLAB project	HF, LF		Cagliari		UNICA	
Ai-LOVE ET Roma ToV	Wavefront sensing and control; mitigation of thermal aberrations; coating mater	HF	In operation	Roma (Italy)		INFN Roma Tor Vergata + Università di Roma Tor Vergata	
ARC/ETcryo Rome	Cryogenic payloads, cooling chains and thermal verification	LF	Cryostat commissioning	Roma (Italy)		INFN Roma 1 + Sapienza Università di Roma	
BETIF (INFN-BO)	Computing, electronics and DAQ for data synchronization and processing.	HF, LF		Bologna		INFN Bologna	
CALATIA (INAF, INFN-NA e UniVanvitel	Vacuum-material and surface-contamination characterization; Kelvin-probe me	HF, LF		Napoli (Italy)		INAF, INFN Napoli, UniVanvitelli	
CALVA Orsay	Squeezing source	HF/LF		Orsay (France)		IJCLab	
CAOS Perugia	Full-scale suspension, seismic isolation and interferometric control; two 15 m U	LF	Infrastructure ready	Perugia (Italy)		INFN Perugia + Università di Perugia	
CERN ET Beam Tube Pilot Sector	Full-scale 36 m beam-tube sector: manufacturing, welding, installation, cleanlin	HF/LF	Under construction and t	Geneva (Switzerland)		CERN	
COMET - Rovigo	Coating	HF		Rovigo (Italy)		INFN Padova + Università di Padova	
CTLab4ET (INFN-TO)	hardware/software architectures, AI, data analysis, simulation and technology t	HF, LF	In operation	Torino		INFN Torino	
DIFAET (UNIBO)	Advanced computing for algorithms and AI, Coatings	HF, LF		Bologna		UNIBO	
ET_3G LAB (UniRM1_DICEA, ASI e Uni	Geomatics, geotechnical and hydrogeological studies	HF, LF		Distributed (Italy)		Università La Sapienza + ASI + Università di Pisa	
E-TEST Liège	Full-scale cryogenic mirror and payload verification; vibration isolation, cryogen	LF	now follow-up project "ET	Liège (Belgium)		non verificato	
ETICO2 (INFN-CA e UniCA_Fis)	Optoelectronics; photonic/electronic devices; thin-film fabrication and coating ch	HF, LF		CAgliari		INFN Cagliari, UNICA	
ET-LFC (planned)	Subsystem qualification, integration and construction readiness	LF					
ETpathfinder Maastricht	Integrated cryogenic interferometer technologies: silicon optics, 1550/2090 nm	HF/LF	Subsystem commissionin	Maastricht (Netherlands)		Maastricht University	
ET-OPT Louvain	Optical components, metrology and optical integration. Parametric instabilities	HF		Louvain (Belgium)		UCLouvain	
GEMINI Gran Sasso	Vibration control, sensing, environmental monitoring	LF		L'Aquila (Italy)		LNGS + GSSI	
GALILEO Genova	Quantum optics and magnetic noise mitigation	HF, LF	In operation	Genova (Italy)		INFN Genova + Università di Genova	
Glasgow Cryogenic Interferometer Fa	Cryogenic interferometry; suspended silicon optics; coating thermal noise; 155	LF		Glasgow		University Glasgow-GCIF	
GRAVITHELIUM – KIT	Full-scale cryogenic suspension tests; Q-factor measurements; superfluid-heliu	LF		Karlsruhe (Germany)		Karlsruhe Institute of Technology (KIT)	
ILM - Sapphire growth furnaces	Large sapphire substrate (with diameter up to 45cm)	LF	In operation	Lyon (France)		Institut Lumière Matière (ILM)	
LAPP optical platform - Annecy				Annecy (France)		LAPP	
LMA Lyon	Coating, optical simulations	HF, LF	In operation	Lyon (France)		Laboratoire des Matériaux Avancés (LMA)	
MANET (UniGE) EGO	Magnetic noise mitigation	LF		Cascina (Italy)		Università di Genova	
OMNISENS Amsterdam	Seismic isolation, inertial sensing and control, control design	LF		Amsterdam (Netherlands)		University of Amsterdam (UvA)	
PisaET-IR@CISUP (UniPI)	Coatings	HF, LF		Pisa (Italy)		Università di Pisa	
PLANET Napoli	Seismic isolation, tiltmeters, squeezing	LF		Napoli (Italy)		INFN Napoli + Università di Napoli Federico II	
SAMANET (INFN-PI)	Superattenuator components, control electronics for seismic-noise attenuation	HF, LF		Pisa (Italy)		INFN Pisa	
Swiss.ET (PSI, CSEM, Swiss industrial	Vacuum, laser and optical systems, and control/readout electronics	HF, LF		Villigen (Switzerland)		PSI + CSEM + Swiss ET industrial partners	
UTwente cryogenic lab	Cryogenic engineering, detector cooling and thermal systems	LF		Twente (Netherlands)		University of Twente	
UHV.NRW lab Aachen	Ultra-high-vacuum technologies: materials, coatings, welding, pumping systems	LF	under development	Aachen (Germany)		RWTH Aachen (da verificare formalmente)	
VATIGRAV Hamburg	Vacuum test facility for inertial sensors, suspensions, active seismic isolation ar	HF, LF		Hamburg (Germany)		non verificato	
WAVE Hamburg	Distributed acoustic sensing over fibre networks; seismic and geo-acoustic mor	HF, LF		Hamburg (Germany)		non verificato	
Virgo?	Operational detector	HF, LF		Cascina (Italy)		EGO (European Gravitational Observatory)	

R&D ecosystem

Large facilities: ET Pathfinder





R&D ecosystem

Large facilities: CAOS





R&D ecosystem

- ET R&D spans major facilities and many smaller laboratories, with limited coordination across projects
- ET needs complete development paths from laboratory results to validation
- R&D coordination might help identifying missing steps and resources needed to complete these paths

R&D coordination in ETC

- Coordinator appointed in September
- Initial team: S Steinlechner (Maastricht Uni), F Travasso (Uni Camerino and INFN)
- **Main Tasks:**
  - Map technology needs and ongoing R&D, assess readiness and identify critical gaps
  - Prepare technical input for ET decisions and coordinate exchanges with stakeholders, Virgo and CE
- Decisions on the technical baseline, technology selection and resource allocation remain with the competent bodies
- Mandate: ET-0529A-26

R&D coordination in ETC

- R&D Coordinator deliverables

  - **Month 6:** maps of technologies for the first implementation and for infrastructure-impacting upgrades (D1.1 and D1.2)
  - **Month 12:** map of technologies for longer-term upgrades (D1.3)
  - **Month 18:** Advanced Virgo action plan (D3.1)
  - **Month 24:** catalogs of research and integration facilities and Cosmic Explorer action plan (D2.1, D2.2, and D3.2)

R&D COVERAGE AND CRITICAL GAPS

- **Immediate priority:** identify critical capabilities that current R&D activities do not cover or that lack a credible path to maturity
- **Proposed method**
  - Agree on a working list of the enabling technologies needed for ET
  - For each technology, identify who is developing it, what they have demonstrated so far and which tests are still needed
  - Identify missing development work, testing capabilities or resources that could delay readiness for ET
  - Where several projects address the same technology, assess whether they contribute different capabilities or develop alternative solutions
- A complete baseline is not yet available
  - Inputs from: pre-TDR, core program, PBS, ISB WGs, ETO task force…

FACILITY CATALOG

- Inventory (1st version) recording facility capabilities, HF/LF relevance and current status
  - Next step: facility PIs and WG leaders to check and complete the entries
- The inventory must evolve to assess each technology's current Technology Readiness Level (TRL) and its estimated evolution over time
- A dedicated digital tool is being developed by G. Hemming (EGO)
  - Integration with ETMD will link facilities to participating persons

FACILITY	PRIMARY VERIFICATION CAPABILITY	HF , LF or both	STATUS	LOCATION	LEAD I
Optics, Electronics and Photonics					
ADONI (INAF)	Optical aberrations control	HF		Distributed (I)	
AEI 10 m Prototype - Hannover	Interferometry, quantum optics and controls, sensing/actuation	HF		Hannover (D)	
AiLoV-ET (INFN-RM2 e UniRM2)	Wavefront sensing and control; mitigation of thermal aberrations; co	HF	In operation	Roma (I)	
CALVA (IJCLab)	Squeezing source	HF/LF		Orsay (F)	
CoMET (INFN-PD e UniPD)	Coatings	HF	In operation	Rovigo (I)	
ET-OPT	Optical components, metrology and optical integration. Parametric i	HF		Louvain (B)	

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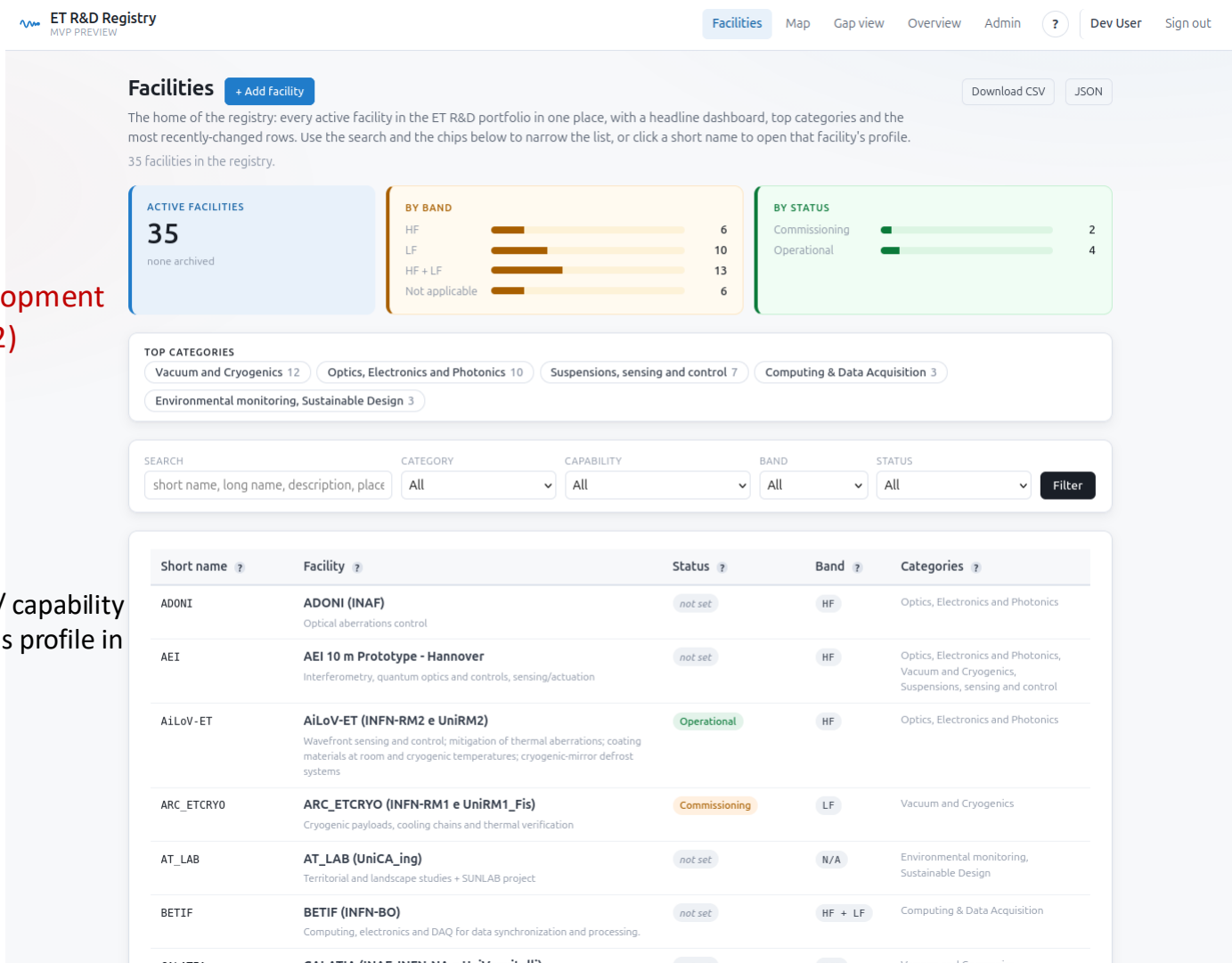
ET R&D Registry - under development

(G. Hemming – EGO - EIB Div 2)

Main page: search, filter by category / capability / band / status, and open any facility's profile in the registry



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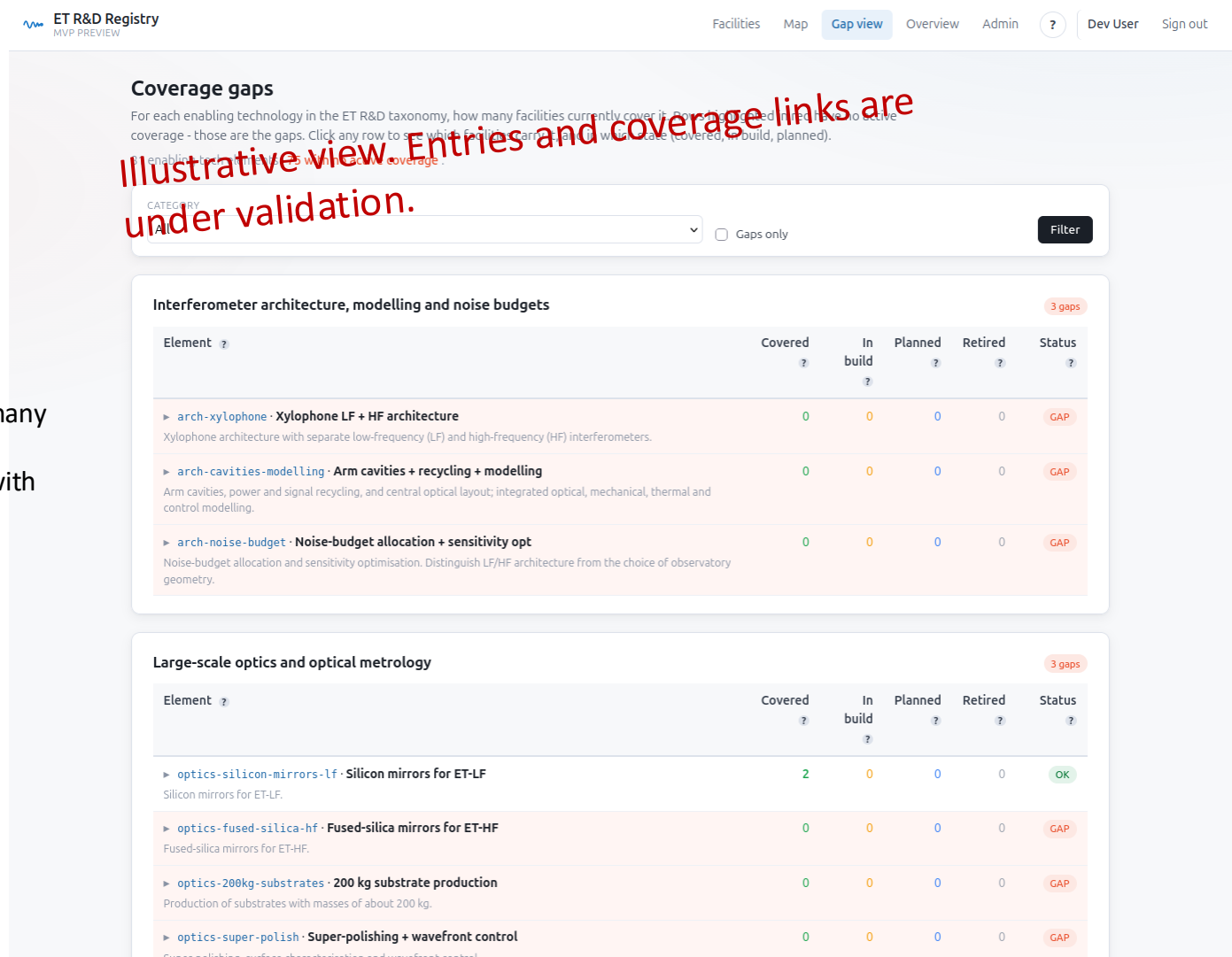
For each enabling technology, how many facilities cover it and in what state (covered / in build / planned); gaps with no active coverage are highlighted



Synergies with Virgo

- Virgo offers unique opportunities to test selected ET technologies in a full-scale detector and train future detector experts.
- Next step: identify ET technologies and test windows that fit Virgo's scientific programme and upgrade plans
  - e.g.: new sensing-control-actuation methods and technologies to reduce LF noise
- Discussions have started to explore possible pathways.

Cooperation with CE

- Build on the ongoing ET–CE exchanges through the XGCD meetings
- Identify specific opportunities for joint R&D
- ETC is working to formalise a joint ET–CE working group
- A CE delegation will attend the ET Annual Meeting in Prague
  - Joint meeting planned

Decision processes and interfaces

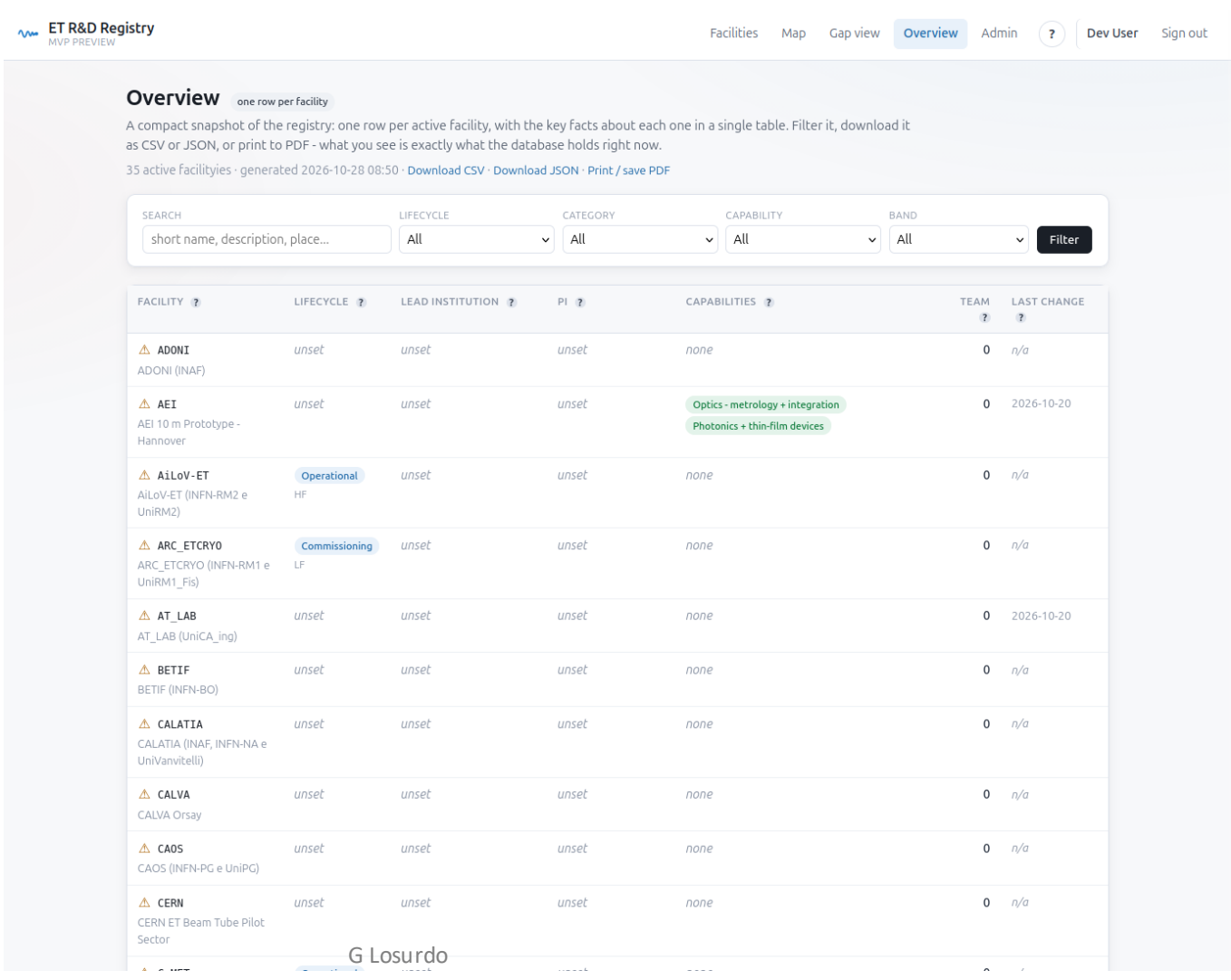
- **Technology selection**
  Who sets the criteria, organises the reviews and takes the decisions?
- **Funding coordination**
  How will funding agencies coordinate their programmes to support ET's R&D priorities and timelines?
- Funding agencies are working to establish a task force to develop an integrated ET R&D roadmap
- Its interfaces with ETO, ETC, R&D coordination and the responsibilities for technology selection are to be defined

Immediate priority and next steps

- **Goal:** establish whether current R&D can deliver the technologies needed for ET's first implementation
- **Short term:** map enabling technologies to ongoing projects and validation facilities; identify critical gaps
- **Mid term:** Work with ET groups, facility teams and relevant bodies to assess readiness; define the R&D and resources needed to close the gaps

BACKUP

one row per facility with lifecycle, lead institution, PI, capabilities and team. Exportable as CSV, JSON or PDF



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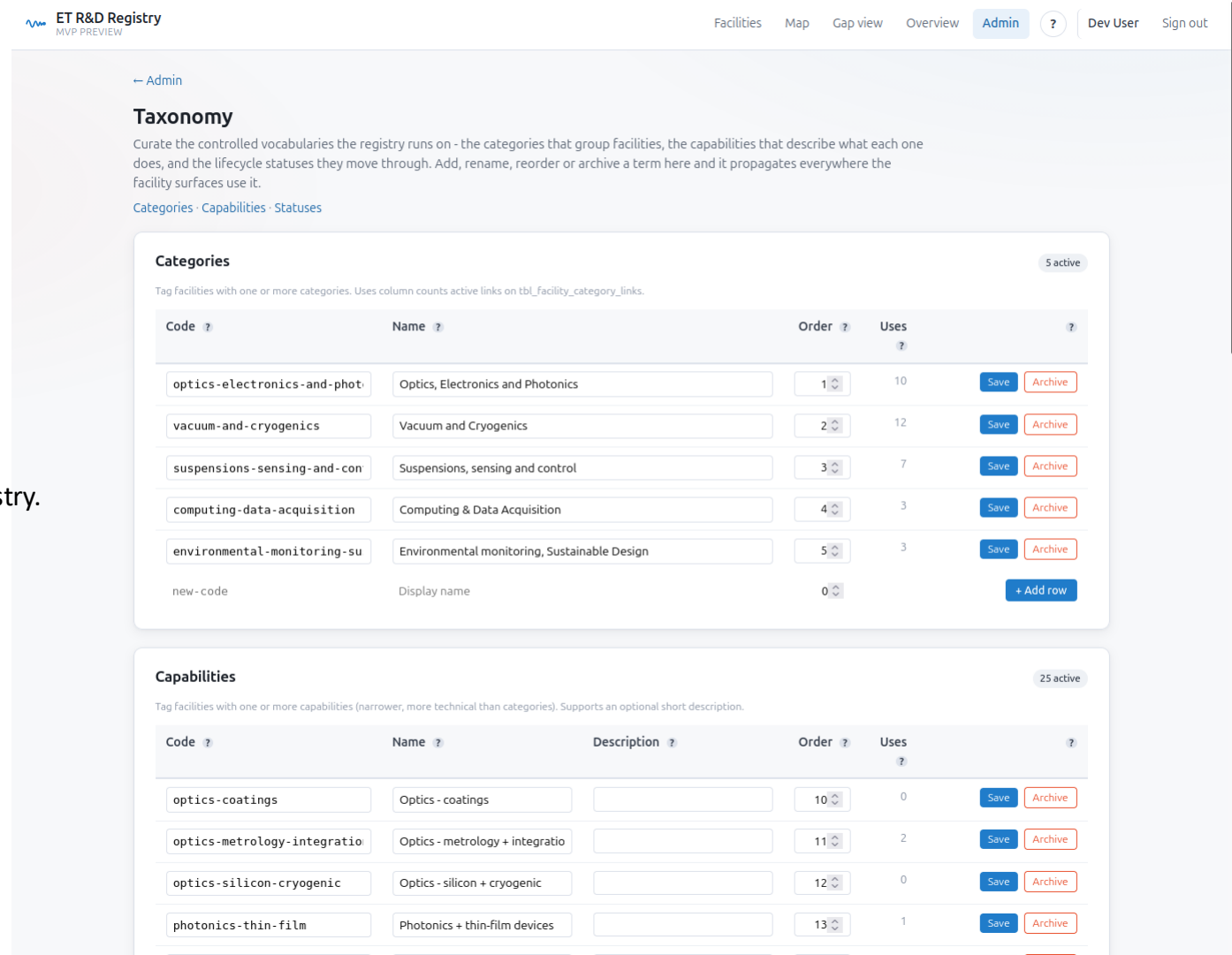
categories, capabilities and statuses managed centrally; every change propagates to every page in the registry.



ET R&D Registry
MVP PREVIEW

Facilities | Map | Gap view | Overview | Admin | ? | Dev User | Sign out

← All facilities

AEI 10 m Prototype - Hannover

Edit

A single facility's profile - what it is, what it does, where it is, who's on the team, and the full history of changes made to
Edit (top right) to update any attribute.

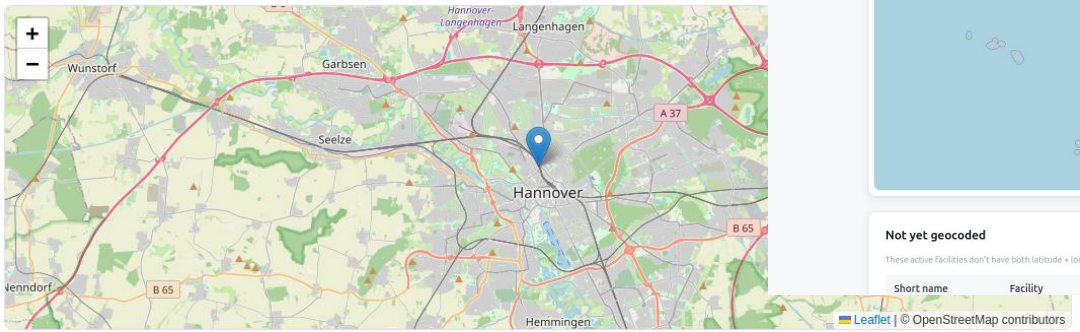
AEI · not set · HF

Overview

Interferometry, quantum optics and controls, sensing/actuation

Website	https://smoke.example
Location	Hannover, Germany (52.3850000, 9.7320000)
Lead institution	not set
Principal Investigator	not set
Categories	Optics, Electronics and Photonics · Vacuum and Cryogenics · Suspensions, sensing and control
Capabilities	Optics - metrology + integration · Photonics + thin-film devices
Team	not set

Where it is



Tiles are OpenStreetMap. Edit the location on the edit page.

Audit

ET R&D Registry
MVP PREVIEW

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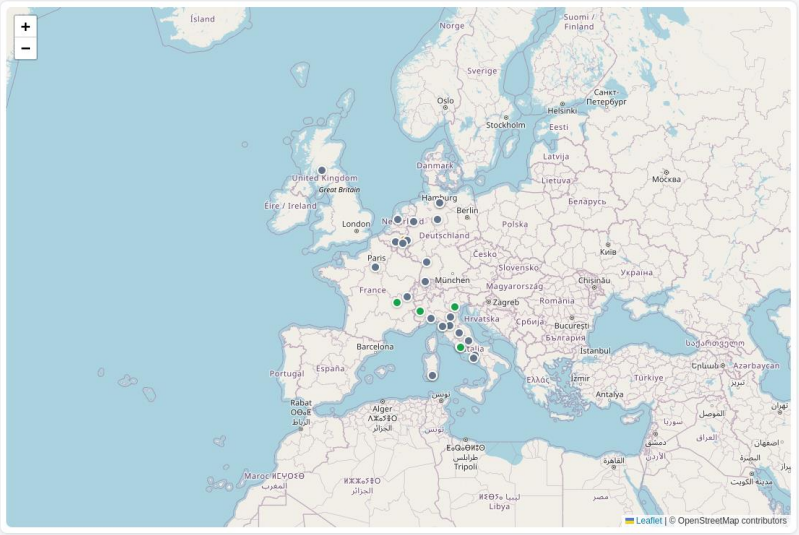
Map

Every facility with coordinates set, on one map. Click a pin to see the facility's name and open its profile. Facilities without coordinates are listed below the map so they can be found + geocoded from their Edit page.

32 of 35 active facilities on the map · 3 not yet geocoded (see list below).



Not yet geocoded

These active facilities don't have both latitude + longitude set, so they can't appear on the map. Open any one of them in the Edit page + click on the Location map to drop a pin.

Short name	Facility	Place name