BIGINN: a new beginning for business and Big Science innovation

COS-CLUSTER PROJECT N° 101037928 – BIGINN
Deliverable D2.1 Gaps and cross-sectoral/-regional collaboration opportunities in the Big Science market

Public

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Contents

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1. Introduction

1.1 Executive summary

This deliverable contains an analysis of needs for cross-sectoral and interregional collaboration in order to cover gaps in the European Big Science market and identify opportunities.

Based on the findings from Deliverable 3.4 (Future tenders and technological trends in Big Science organizations) and making use of the Business Competences Matrix (Deliverable 2.2), this task will identify opportunities for specific SMEs, as well as the gaps in the capacities of the industry to cover the current needs in the Big Science sector.

Conclusions are drawn from the matching, and potential cross-sectoral and interregional partnerships are suggested, aiming at strengthening links within companies.

1.2 Introduction and objectives

This deliverable D.2.1: “Gaps and cross-sectoral/-regional collaboration opportunities in the Big Science market” is linked with Task 2.1 “Analysis of gaps and opportunities in the Big Science-market”. It will link the identified opportunities gathered in Deliverable 3.4 (Future tenders and technological trends in Big Science organizations) together with the companies listed in the Deliverable 2.2 (Business Competences Matrix), according to their capacities. All the information has been compiled by the BIGINN project according to the information provided by the companies listed and the European BSOs.

1.3 Legal notice

Table 1. BIGINN partnership

Participant Organization Name	Short Name	Country
TEKNOLOGISK INSTITUT	DTI	Denmark
ASOCIACIÓN ESPAÑOLA DE LA INDUSTRIA DE LA CIENCIA	INEUSTAR	Spain
VIESOJI ISTAIGA FIZIKOS INSTITUTO MOKSLO IR TECHNOLOGIJU PARKAS	LITEK/FIMTP	Lithuania

2. Methodology

Mainly, the key technologies we focus on in this document are presented below in Table 2. The table also helps to identify which Big Science Organization has business opportunities in which area, according to the document D.3.4 "Future tenders and technological trends in Big Science organizations" (by Feb. 2023):

Table 2. Key technologies and corresponding facilities with business opportunity in them

	CERN	EMBL	ESA	ESO	ESRF	ESS	E-XFEL	FAIR	F4E	ILL	SKAO
Electrical, power electronics, electromechanical and RF systems	X		X			X		X	X		
Diagnostics and detectors, sensors, optics and instruments	X		X	X		X	X		X		X
Information and communication technologies	X	X	X	X	X	X	X			X	
Basic material technologies and advanced manufacturing techniques	X						X		X		
Complex building construction and its safety related systems	X				X	X			X	X	
High precision and large mechanical components	X		X	X	X	X		X	X	X	
Instrumentation, control and CODAC	X		X	X			X		X		
Cryogenics, vacuum and leak detection technologies	X		X	X		X	X	X	X		
Superconductivity and superconducting magnets	X							X			
Remote handling systems	X			X			X	X	X		

On the other hand, the matrix that contains the information of the capacities of the companies can be found at https://biginn.eu/about/ or https://litek.lt/competence-matrix/

In Table 3 the structure of such matrix is shown, marking in green the technologies where opportunities have been identified:

Table 3. Structure of the capacities matrix

Technology
(A) Electrical, power electronics, electromechanical and RF systems
Electrical and power electronics
Mechatronics
RF systems
(B) Diagnostics and detectors, sensors, optics and instruments
Diagnostics and detectors, sensors
Optics & lasers
Instrumentation
(C) Information and communication technologies

Data management and processing
Communication
IT Hardware
(D) Basic material technologies and advanced manufacturing techniques
Materials
Advanced manufacturing
Surface Treatment
Advanced welding
Additive Manufacturing
High precission/large components
Others
(E) Complex building construction and its safety related systems
Complex building construction
Safety systems
(F) High precision and large mechanical components
High Precision manufacturing
Large Mechanical components
(G) Automation, Control and Remote handling systems
(H) Cryogenics, vacuum and leak detection technologies
Cryogenics
Vacuum
Leak detection technologies
(I) Electromagnetism, magnets and superconductivity
Electromagnetism
Magnets and Superconductivity
(J) Engineering Services
(K) Training
(L) Utilities & Installations
HVAC and Plumming
Electrical Installations
Lab Equipment
Gasses and Chemicals
Office Supply and Furniture
Utilities
(M) Radioactive materials and handling
Radioactive Handling
Radioactive Materials

The methodology followed in this document is based in the identification of the opportunities for each technology[1], then a matching with the companies that have such capacities has been made based on the capacities matrix.

Finally, two examples of cross-regional collaborations are outlined in the Conclusions Section in the end of this document.

3. Key technologies

Mainly, the key technologies we focus on in this document are presented below in Table 2. The table also helps to identify which Big Science Organization has business opportunities in which area, according to the document D.3.4 "Future tenders and technological trends in Big Science organizations" (by Feb. 2023):

3.1 Electrical, power electronics, electromechanical and RF systems

The list of companies with capacities in electrical, power electronics, electromechanical and RF systems is shown in Table 4.

Table 4. Companies with capacities in electrical, power electronics, electromechanical and RF systems

	Electrical and power electronics	Mechatronics	RF systems
EKSPLA (LT)	☒	☐	☐
Esemda (LT)	☒	☐	☐
Arginta Engineering (LT)	☒	☐	☐
Danfysik (DK)	☒	☒	☐
Frecon (DK)	☐	☒	☐
Mark & Wedell (DK)	☐	☒	☐
BB Electronics(DK)	☒	☐	☐
CB Svendsen (DK)	☒	☐	☐
Kirkholm (DK)	☐	☒	☐
ABENGOA (ES)	☒	☐	☐
AERNNOVA AEROSPACE (ES)	☐	☒	☒
AIRBUS DEFENCE AND SPACE (ES)	☒	☐	☒

[1] Note that, in the matrix, there is no differentiation between companies with capacities in *instrumentation, control and CODAC* and capacities in *remote handling systems*, which are two separate items in the Big Science opportunities document. Therefore, only one section will be made for both items.

	Electrical and power electronics	Mechatronics	RF systems
AIRTIFICIAL (ES)	☒	☐	☐
ALTER TECHNOLOGY TUV NORD (ES)	☒	☐	☒
ANTEC MAGNETS (ES)	☐	☒	☐
APPLUS+ LABORATORIES (LGAI Technological Center) (ES)	☒	☒	☒
ARQUIMEA (ES)	☐	☒	☒
ASE OPTICS EUROPE (ES)	☐	☒	☐
ASTURFEITO (ES)	☐	☒	☒
AVANCEM (ES)	☐	☒	☐
AVS - ADDED VALUE INDUSTRIAL ENGINEERING SOLUTIONS (ES)	☒	☒	☒
AWGE TECHNOLOGIES (ES)	☐	☒	☒
BTC IBÉRICA (ES)	☒	☐	☐
BTESA - BROAS TELECOM (ES)	☒	☐	☒
BURDINBERRI (ES)	☐	☒	☒
CADINOX (ES)	☐	☒	☒
CAP GEMINI ENGINEERING (ES)	☐	☐	☒
CEN SOLUTIONS (ES)	☒	☐	☐
CITD ENGINEERING & TECHNOLOGIES (ES)	☒	☒	☒
CRISA (ES)	☒	☐	☐
CT ENGINEERING (ES)	☒	☒	☒
DAS PHOTONICS (ES)	☐	☐	☒
DEIMOS SPACE (ES)	☐	☐	☒
EGILE MECHANICS (ES)	☐	☐	☒
ELDU (ES)	☒	☐	☐
ELYTT ENERGY (ES)	☒	☐	☒
EMPRESARIOS AGRUPADOS INTERNACIONAL (ES)	☒	☐	☒
ENSA - EQUIPOS NUCLEARES (ES)	☐	☐	☒
EOSOL GROUP (ES)	☒	☐	☒
ESTEYCO (ES)	☐	☐	☒
FERROVIAL (ES)	☒	☐	☒
GTD SISTEMAS DE INFORMACIÓN (ES)	☐	☐	☒
IBERDROLA GENERACIÓN (ES)	☒	☐	☐
IDOM (ES)	☒	☒	☒
INDRA (ES)	☒	☐	☒
INSYTE ELECTRONICS (ES)	☐	☒	☐
INTERGRASYS (ES)	☐	☐	☒
JEMA (ES)	☒	☐	☒
LEADING (ES)	☒	☒	☒
LIDAX (ES)	☐	☒	☐
MAMMOET IBÉRICA (ES)	☒	☐	☐

	Electrical and power electronics	Mechatronics	RF systems
MECANITZATS PRIVAT (ES)	☐	☒	☐
MONCOBRA (ES)	☒	☐	☐
NORTEMECÁNICA (ES)	☐	☐	☒
OBEKI (ES)	☒	☐	☐
OBUU TECH (ES)	☒	☒	☒
OROLIA SPAIN (ES)	☒	☐	☒
PROACTIVE (ES)	☐	☒	☒
PROCON SYSTEMS (ES)	☒	☐	☐
RDT (ES)	☐	☒	☐
ROMPAL (ES)	☒	☐	☒
RYMSA (ES)	☒	☐	☒
SCHWARTZ HAUTMONT (ES)	☒	☐	☐
SCIENTIFICA (ES)	☐	☒	☐
SENER AEROESPACIAL (ES)	☒	☒	☒
SENER RYMSA (ES)	☒	☐	☒
SGENIA (ES)	☐	☐	☒
SOGECLAIR AEROSPACE (ES)	☒	☒	☒
SUPRASYS (ES)	☒	☐	☒
THALES ALENIA (ES)	☒	☐	☒
TVP - THERMAL VACUUM PROJECTS (ES)	☐	☐	☒
TSK (ES)	☒	☐	☐
TTI NORTE (ES)	☒	☐	☒
VALTRIA (ES)	☒	☐	☐

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in electrical, power electronics, electromechanical and RF systems are CERN, ESA, ESS, FAIR and F4E. The specific opportunities and challenges are summarized in the following sections:

3.1.1 CERN

The reported future tenders at CERN regarding electrical, power electronics, electromechanical and RF systems are the following:

- Rad-hard stepper motors (TID 2 MGy) need for FRAS, ~200 full steps per revolution. Market Survey for Q3 2023. Technical responsible Mario Di Castro
- PXIe Carrier (400 units), Market Survey for Q1 2024. Technical responsible Javier Serrano
- COMe CPU (400 units), Market Survey for Q4 2023. Technical responsible Javier Serrano
- PXIe-COMe adapter (400 units), Market Survey for Q1 2024. Technical responsible Javier Serrano
- FMC cards for Motion control (400 units), Market Survey for Q1 2024. Technical responsible Javier Serrano

- Stepping Motor Drivers (1200 units), Market Survey for Q2 2024. Technical responsible Javier Serrano
- Site gate monitoring system (30 units). Market Survey for Q3 2023. Technical responsible Hamza Boukabache
- BGA repair station. Technical responsible Raphael Berberat
- Reflow oven. Market Survey for Q1 2024. Technical responsible Raphael Berberat
- ROV with robotic arm. Market Survey for Q3 2023. Technical responsible Mario Di Castro
- ROV base only. Market Survey for Q1 2023. Technical responsible Mario Di Castro
- Versatile legged and wheeled solution. Technical responsible Mario Di Castro
- Motion capture system. Technical responsible Mario Di Castro
- (blanket contract) 24 kV compact switchgear. Market Survey for 2023.
- (purchase order) 2 emergency gensets rated 1.5 and 2.5 MVA.
- (blanket contract) UPS units from 20 to 200 (100 units).
- (purchase order) UPS installations from 300 to 2000 kVA (4 installations). Market Survey for Q3 2024
- (purchase order) Lead acid batteries for UPS (2300 monoblocs). Market Survey for 2023

On the other hand, the technological challenges reported can be summarized as:

- Mechatronics and electronics:
    - PXIe front-ends
    - PXIe carrier card equipped with a large FPGA for data processing and RT control; can host one FPGA Mezzanine Cards (FMC) to ensure the interface with the field instrumentation, sensors and actuators
    - Set of FPGA Mezzanine Cards (FMC) to cope with the various field control and instrumentation applications (LVDT, resolvers, IOs, strain gauges, interferometer reading, motor drivers)
    - Expansion chassis ensures modularity. It is equipped with a system controller linked and synchronized to the PXIe carriers via White Rabbit

- Site gate monitors
    - False detection rate less than 0.001% (>2.4M cars/year)
    - Detection performances
    - Live control on vehicles flow without traffic disruption
    - integration into CERN SCADA systems and CERN Access system

- Electrical network and power electronics
    - Converters with efficient energy management including magnet energy recovery
    - High precision and fast pulsed power converters (ms range)
    - Advanced regulation & real time control
    - Availability
    - Capital and operational cost
    - Radiation effects on electronics

3.12 ESA

At ESA, the reported challenges are mainly on RF payloads and for the new HERTZ 2.0:

- RF payloads:

  - Antenna/Repeater technology for Q/V-band traditional telecom payloads
  - W-band technologies for ground and space segments
  - V-band technologies for Intersatellite links
  - Antennas / RF building blocks for 5G and secure telecom systems
  - Advanced manufacturing technologies, In-flight assembly of large apertures
  - Advanced RF integration technologies for highly dense active antennas
  - RF building blocks for Q-band active antennas

- HERTZ 2.0 (hybrid facility for near field scanning and compact range):
  - Galileo1G payload testing is based on separate conducted and radiated testing
  - Considering the increased complexity and interdependencies, end-to-end radiated testing of the integrated payload/antenna is becoming mandatory for TS and Galileo2G development and constellation operational support

3.1.3 ESS

At ESS, the following items correspond to tenders that will be published:
- 3 MW Klystrons @352 MHz
- 1.5 MW klystrons @ 704 MHz
- New klystron prototype development: 500 kW, 352 MHz (Potential need for 26 systems plus spares)
- Calibration service for T&M incl. Spectrum Analysers, Vector Network Analysers, Oscilloscopes, RF power measurement, RF leakage monitoring
- T&M replacement and repair
- Electronic components, RF components and assembly material
- Klystron gun tank high voltage insulation oil
- Consumables such as filters and desiccators.
- Spares, repair and replacement
- Upcoming spares procurement includes waveguide components

3.1.4 FAIR

The reported future tenders at FAIR are listed below:
- 3 kW solid-state amplifiers (CW LINAC Components)
  - 216 MHz
  - both, CW & pulsed operation
  - about 10 pieces required for series
- CW LINAC RF system control (digital) and infrastructure (CW LINAC Components)
- Klystron auxiliary power supplies (DC only, for klystron solenoids) for 7 klystrons (p LINAC Components)
  - 2 pieces 1 kW (about 15 A) per klystron
  - 1 piece 3 kW (about 15 A) per klystron
- Circulators for 7 klystrons (p LINAC Components)
  - 325 MHz
  - 3 MW pulse, pulsed <5 Hz, 0.1 % duty cycle (p LINAC Components)
- Rectangular waveguides WR 2300 full height (about 100 m in total) (p LINAC Components)
- Auxiliary components, e.g. low-power measurement transitions from WR 2300 to coaxial type N Prof. (p LINAC Components)

On the other hand, the reported challenges are:
- Reliability (6000 operating hours per year, 24/7)

- Maintenance (must be simple in order to reduce presence in radiation-controlled area and to reduce repair time, must be possible by GSI/FAIR staff)
- In most cases customer-specific development required
- Long-term availability of spare parts (at least 8 years, 30 years of operation not unusual) –commercial product life cycles are often too short for us.
- EMC
- Radiation hardness
- More automation (measurement technology, data acquisition –also post-mortem, calibration, etc.)
- Control system integration (FESA, PLC, etc.)

3.1.5 F4E

At F4E, the following future tenders have been reported, with expected market surveys for 2024:

- High vacuum - non safety relevant - approx. 5t each
- Stainless Steel Support
- Deep Drilled Panels in CuCrZr
- Heterogenous joints
- Ceramic insulators
- High vacuum - non safety relevant - approx. 15 ton
- High precision mechanics ion huge components
- Cu electrodeposited grids
- Mo coating: thin (PVD) and thick (explosion bonding)
- Heterogenous joints (Cu-SS)
- Ceramic insulators and hydraulic breaks
- Gamma protection
- Panels of Lead and steel structure
- Duct liner
- SF6 handling plant

On the other hand, the ITER Organization needs to procure four systems for ITER

- Stage 2 Main Coil Power Converters
- VS3 In Vessel Coil Power Converter
- ELM In Vessel Coil Power Converters
- Stage 2 Reactive Power Compensation System, most likely based on STATCOM technology

Finally, the planned procurement contracts for full turnkey procurements are shown in

Table 5.

Table 5. Full turnkey procurements at ITER by ITER Organization, reported at BSBF 2023

Scope	Tender process		to be commissioned by
	launched in	duration	
Stage 2 Main Coil Power Converters, including a) DC busbar connections; b) Cooling Water System connections to manifolds; c) Update and commission (hardware and software) of the Master Control System (MCS), currently delivered by KO DA for the Stage 1, or, design, manufacture, install and commission a completely new MCS	March 2024	17 months	April 2030
VS3 In Vessel Coil Power Converter	July 2024	14 months	End of 2030
27 ELM In Vessel Coil Power Converters	August 2025	13 months	End of 2033
3 units, Stage 2 Reactive Power Compensation System (STATCOM technology)	February 2028	11 months	September 2032
66 kV and 22 kV switchgear and power cables	March 2024	16 months	November 2029
Civil works for components to be installed outdoors (mainly foundations and platforms)	February 2028	11 months	October 2031

3.2 Diagnostics and detectors, sensors, optics and instruments

The list of companies with capacities in diagnostics and detectors, sensors, optics and instruments is shown in Table 6.

Table 6. Companies with capacities in diagnostics and detectors, sensors, optics and instruments

	Diagnostics and detectors, sensors	Optics & lasers	Instrumentation
EKSMA Optics (LT)	☐	☒	☐
EKSPLA (LT)	☐	☒	☐
Litilit (LT)	☐	☒	☐
Akoneer (LT)	☐	☒	☐
Optonas (LT)	☐	☒	☐
QS lasers (LT)	☐	☒	☐
Altechna Coatings (LT)	☐	☒	☐
Progrssive Bussines Solutions (LT)	☒	☐	☐
Luvitera (LT)	☒	☐	☐
Femta (LT)	☐	☒	☐
Light Density (LT)	☐	☒	☐
Laser Trio (LT)	☐	☒	☐
Beagle Optics (LT)	☐	☒	☐
Gardis Instruments (LT)	☒	☐	☐
Magsensas (LT)	☒	☐	☐
Teravil (LT)	☒	☒	☐
BBT Fiberoptic (DK)	☐	☒	☐
Danfysik (DK)	☒	☐	☐
Polyteknik (DK)	☐	☐	☒
CHEXS (DK)	☒	☐	☐
JJ X-rays (DK)	☒	☐	☒
NKT Photonics (DK)	☐	☒	☐
ABENGOA (ES)	☒	☒	☒
AERNNOVA AEROSPACE (ES)	☐	☐	☒
AIRBUS DEFENCE AND SPACE (ES)	☐	☐	☒
ALIBAVA SYSTEMS (ES)	☒	☒	☐
ALTER TECHNOLOGY TUV NORD (ES)	☒	☒	☒
ASE OPTICS EUROPE (ES)	☐	☒	☐
AVS - ADDED VALUE INDUSTRIAL ENGINEERING SOLUTIONS (ES)	☒	☒	☒
AWGE TECHNOLOGIES (ES)	☒	☒	☐
CADINOX (ES)	☐	☒	☐
CAP GEMINI ENGINEERING (ES)	☐	☒	☐
CITD ENGINEERING & TECHNOLOGIES (ES)	☐	☒	☐
D+T MICROELECTRÓNICA (ES)	☒	☐	☐
DAS PHOTONICS (ES)	☐	☒	☐
DEIMOS SPACE (ES)	☒	☒	☒
EGILE MECHANICS (ES)	☐	☒	☐
EIIT (ES)	☒	☐	☒
EMPRESARIOS AGRUPADOS INTERNACIONAL (ES)	☒	☒	☒

EMXYS - EMBEDDED INSTRUMENTS AND SYSTEMS (ES)	☒	☐	☒
FAGOR AUTOMATION (ES)	☒	☐	☐
FERROVIAL (ES)	☒	☐	☒
FRACTAL (ES)	☐	☒	☐
FUS_ALIANZ SCIENCE, ENGINEERING AND CONSULTING (ES)	☒	☐	☐
FYLA (ES)	☐	☒	☐
GMV (ES)	☒	☒	☒
GREENLIGHT SOLUTIONS (ES)	☐	☒	☐
GTD SISTEMAS DE INFORMACIÓN (ES)	☒	☒	☒
GUTMAR (ES)	☐	☐	☒
IBERDROLA GENERACIÓN (ES)	☒	☐	☒
IDOM (ES)	☒	☒	☐
INDRA (ES)	☒	☐	☐
INSYTE ELECTRONICS (ES)	☒	☒	☒
INTERGRASYS (ES)	☐	☐	☒
LIDAX (ES)	☐	☒	☐
MONCOBRA (ES)	☐	☐	☒
NADETECH (ES)	☐	☒	☐
OROLIA SPAIN (ES)	☒	☐	☒
PROACTIVE (ES)	☒	☒	☐
RDT (ES)	☒	☒	☐
ROMPAL (ES)	☒	☐	☒
SCIENTIFICA (ES)	☒	☒	☒
SENER AEROESPACIAL (ES)	☒	☒	☒
SGENIA (ES)	☒	☐	☐
TECNOBIT (ES)	☐	☐	☒
THALES ALENIA (ES)	☒	☐	☒
TVP - THERMAL VACUUM PROJECTS (ES)	☐	☒	☐
VACTRON (ES)	☒	☐	☐

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in diagnostics and detectors, sensors, optics and instruments are CERN, ESA, ESO, ESS, E-XFEL, F4E and SKAO. The specific opportunities and challenges are summarized in the following sections:

3.2.1 CERN

At CERN, the reported future tenders are:

- Blanked contract on 1500 km of radiation resistant single mode optical fibres.
- 150+ new in vacuum instruments to design and manufacture in next 5 years for HL LHC and NA CONS, plus major beam loss monitor project.

3.2.2 ESA

In Artificial Intelligence, the future tenders reported by ESA are:

- Few GSTPs covering the remaining use cases in groups

- Activities for enablers of AI: generation of synthetic data, qualification of ML algorithms, etc
- ESA Community License
- Agile approach

3.2.3 ESO

Currently, at ESO the following required technologies have been reported:

- CMOS and new IR detectors for AO or IR imaging applications
- Curved visible and IR detectors to compact/simplify instrument designs
- Free form optics
- High accuracy calibration sources: Laser Frequency Comb-ultra stable Fabry Perot
- High stability deformable mirrors with 10-20k actuators at high speed
- Laser sources and new LGS AO concept improving sky coverage
- Robust & high-efficiency fibres for K-band (2.0 < λ < 2.4)
- Secure transmission grating availability
- Promising technology: astrophotonics, e.g., integrated spectrograph, tip-tilt sensing, heterodyne interferometry

On the other hand, several challenges are in place, related to large CMOS detectors

- Motivation: guarantee long-term access to scientific-quality detectors in the visible wavelengths for astronomy
- CCDs are state-of-the-art visible detectors used in all ESO visible instruments.
    - CCD production is decreasing in favour of CMOS. Only 1.5 suppliers worldwide are still producing large-format CCDs, and cost continuously increases.
    - Availability not guaranteed beyond ~1 decade, and TBC in next 5 years (ELT).
- Alternative: CMOS detectors:
    - New readout schemes / operation modes, lower prod. Cost / pixel.
    - Some established design houses and larger variety of manufacturers.
    - Commercial CMOS specifications do not (yet) reach our requirements
- Investment and development required. MEU development requiring partnership

And also for Curved detectors and large IR detectors

- Curved detectors rated as enabling technology
    - Larger detectors behind faster cameras are needed e.g. for future survey telescopes or future massively multiplexed spectrographs (ELT 2nd generation instruments).
    - Curved detectors open a new way to design compact, high-performance optical systems (better image quality and throughput with less optical surfaces)
    - Synergy with space application (e.g. large field of view earth observation missions): high cost savings impact through simplification of the optical design
    - Project started with ESA &Teledyne for a 4k x 4k CCD231-84: 500 mm spherical concave radius
- Large IR Detectors
    - foster availability of a European NIR/SWIR large format arrays for space and ground based astronomy applications (low photons flux)
- MEU development requiring partnership

3.2.4 ESS

The following tenders have been reported by ESS:

- Construction budget scale
  - About 25MEUR for Beam Diagnostics
  - About 250MEUR for Neutron Instruments (15 instruments)
  - Majority of equipment procured via in-kind partners
  - Construction budget mostly committed
- Maintenance and operations (NB: Operations budget not yet approved)
  - Maintenance hardware budget for beam diagnostics approx. 1.4 MEUR/year in full operation
  - Maintenance hardware budget for instruments approx. 20 MEUR/year in full operation
  - May be partly procured via in-kind partners
- Upgrades and new projects (not yet budgeted or approved)
  - Additional beam diagnostics (scale of few MEUR)
  - Additional neutron instruments (e.g. 7 more in original plan, about 20MEUR each)
  - May be procured via in-kind partners

3.2.5 E-XFEL

At E-XFEL, the following upgrades during operation (e.g., gated cameras for the imagers) have been reported:

- Mid-term (~ 2030): fill the empty tunnels (SASE4+5).
  - Investment ~2/3 of original photon systems budget (e.g. ~ 5 M€ for diagnostics)
- Long-term (beyond 2030): European XFEL II
  - "cw" operation (continuous beam rate)
  - "Second fan" of tunnels

3.2.6 F4E

At F4E, the following challenges have been reported for generic manufacturing:

ITER environment	Challenge
High radiation High thermal loads High magnetic field	Limited material options, often special materials Long lead times
Ultra-high vacuum	Clean Work conditions Extensive factory testing
Limited (or no) access Tritium confinement Regulatory control	Extensive factory testing Strict qualification & control of processes Strict Quality Control Extensive QA documentation

Table 7. Generic manufacturing challenges for ITER

3.2.7 SKAO

At SKAO, the reported future tenders on LOW telescope are:

- PASD (Including Laser Diode) ASAP
  - Laser diodes for RF over Fibre, power supply, conditioning monitoring
  - The **challenging** requirement is environment and Radio Frequency Interference (RFI)
  - ~8000 units to be acquired
- SPS Almost ready to go out with ITT

  - o SPS-ADC + Fast digital electronic circuitry (FPGA)
  - o ~600 units to be acquired
- 14Meuro/y between 2023 and 2024

On the other hand, beyond 2026 the following steps can be summarized as follows:
- Complete the full Array
- Launch the Observatory Development plan (In steady state it will fund studies and projects for 20 M/y)
- Fully operational, from 2029, which means regular maintenance.
- Thinking about SKA2....

3.3 Information and communication technologies

The list of companies with capacities in information and communication technologies is shown in Table 8.

Table 8. Companies with capacities in information and communication technologies

	Data management and processing	Communication	IT Hardware
Progressive Bussines Solutions (LT)	☐	☐	☒
BBT Fiberoptic (DK)	☐	☐	☒
ATEA (DK)	☐	☒	☒
AERNNOVA AEROSPACE (ES)	☒	☐	☐
AIRBUS DEFENCE AND SPACE (ES)	☒	☐	☐
ALIBAVA SYSTEMS (ES)	☐	☒	☐
ALTER TECHNOLOGY TUV NORD (ES)	☒	☒	☒
ATS GLOBAL (ES)	☒	☐	☐
AVS - ADDED VALUE INDUSTRIAL ENGINEERING SOLUTIONS (ES)	☒	☐	☐
CRISA (ES)	☒	☐	☐
DEIMOS SPACE (ES)	☒	☒	☒
EMPRESARIOS AGRUPADOS INTERNACIONAL (ES)	☒	☒	☒
EOSOL GROUP (ES)	☒	☐	☐
FERROVIAL (ES)	☒	☒	☒
FRACTAL (ES)	☒	☐	☐
GMV (ES)	☒	☒	☒
GTD SISTEMAS DE INFORMACIÓN (ES)	☒	☒	☐
IBERDROLA GENERACIÓN (ES)	☒	☒	☒
IDOM (ES)	☒	☐	☐
INDRA (ES)	☒	☐	☐
INGECIBER (ES)	☒	☐	☐
INSYTE ELECTRONICS (ES)	☐	☒	☐
INTERGRASYS (ES)	☐	☒	☐

	Data management and processing	Communication	IT Hardware
ISDEFE (ES)	☒	☒	☐
NATEC (ES)	☒	☐	☐
OBUU TECH (ES)	☒	☐	☐
OROLIA SPAIN (ES)	☒	☒	☒
PROCON SYSTEMS (ES)	☒	☐	☐
QUASAR (ES)	☒	☒	☐
RDT (ES)	☒	☐	☐
SENER AEROESPACIAL (ES)	☒	☐	☐
SGENIA (ES)	☒	☐	☐
SOGECLAIR AEROSPACE (ES)	☒	☐	☐
TEKNO SERVICE (ES)	☒	☐	☒
TTI NORTE (ES)	☒	☐	☐

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in information and communication technologies are CERN, EMBL, ESA, ESO, ESRF, ESS, E-XFEL and ILL. The specific opportunities and challenges are summarized in the following sections:

3.3.1 CERN

At CERN, the presented opportunities for servers and storage procurement are:

- Server procurement achieved in HEPSPEC06 to
  - Maximize the HS06/CHF and HS06/Watt ratios
  - Minimize the overall cost and power consumption
  - Optimize infrastructure utilization
  - A typical server solution in 2022:
    - 64 processor cores
    - 256GB of memory
    - 4TB of raw flash storage
    - 10GbE networking and dedicated management
- Storage procurement achieved in Petabytes to:
  - Maximize the PB/CHF and PB/Watt ratios
  - Minimize the overall cost and power consumption
  - Optimize infrastructure utilization
  - A typical storage solution in 2022:
    - 24 enterprise grade hard drives
    - 18TB of raw capacity per hard drive
    - SAS connection to the server front-end
    - No hardware RAID

3.3.2 EMBL

The reported future needs in EMBL are expected to be the following for 2023 and 2024:

- Large scale object storage (40PB+)
- Tape library hardware and tape media (30PB+)
- S3 API compliant tape management software and tooling (100PB+)

For 2025, a replacement HPC cluster environment is expected.

3.3.3 ESA

The tendering opportunities at ESA can be summarised as follows:

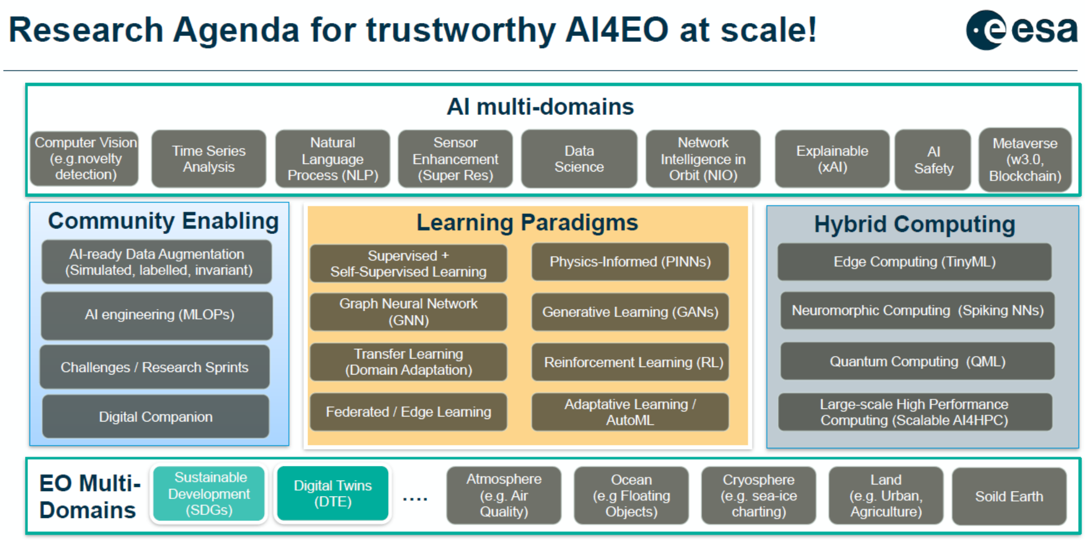

Figure 1. BSBF 2022. Pierre-Philippe Mathieu, Head of Phi-Lab Explore Office

3.3.4 ESO

At ESO, many tendering opportunities have been reported, such as:

- IT Service provision (Contract period: 3 + 2 years; estimated volume 8 – 12 M€ for tenders in 2024)
    - IT Service Desk
    - Network and Communication
    - Server: Linux, Microsoft
    - Client: Linux, Apple, Microsoft
    - Cloud services
    - Database and Big Data
    - IT / Cyber Security
    - Web and Web content management

- IT communications and network (estimated volume 10 M€ for tenders in 2026)
    - Communications 2020+: Chile: Observatories to Antofagasta and Santiago - Contract period: ~10 years
    - IT network infrastructure: Contract period: 3 + 2 years

- Software licenses (Contract period: 3 – 5 years; estimated volume 3 M€ for tenders in 2024/2025)
    - IT software licenses and subscriptions
    - Software License Management: Microsoft, Oracle, Autodesk, IBM, VMWare, SAP, Adobe, etc.

- Science Archive, Data Centre, etc. (Contract period: 3 + 2 years; total estimated volume 1 M€ for tenders in 2024)
    - Science Archive Infrastructure - Germany: Linux servers including storage
    - Multi-functional units (rented) - Chile (3 sites) and Germany
    - Data Centre infrastructure and maintenance - Vitacura Office/Santiago de Chile

- Service contracts (estimated volume 7 M€ in the period 2023 – 2027)
    - Sprint, review, implementation, integration, acceptance, payment for each sprint, or according to a payment model
    - Defined Statements of Work with the support of consultants
    - Project roles and Sprint process are described in the Statement of Work, as well as technical skills.
    - Agile outsourcing contracts are planned for dataflow development and maintenance, and software testing, both for VLT/ELT and ALMA dataflows

3.3.5 ESRF

At ESRF, the published future tenders are related to major sets of Equipment – technology, such as:

- Data storage (2023)
    - 20 PB available - 3GB/s
    - GPFS file system
    - Need to address performance needs in the order 5-10 GB/s (2023)

- Computing (frame contract)
    - CPU (5.5K Cores), GPU (100)
    - Intel, AMD, Nvidia

- Network (frame contract)
    - Optical fibers 30 000 km, 36 000 end connections
    - Switches 400Gb/100Gb/40Gb/25Gb, 500 u./35000 ports.
    - Cisco, Extreme Network
    - Ethernet
    - High availability

- New data center (2026-2029)

3.3.6 ESS

The published information on future tenders at ESS can be summarized in the following table:

	Procurement	Time (expected)	€ (expected)	Type
2023	HPC nodes	Q2 2023	150KEUR	Tender
	InfiniBand equipment	Q2 2023	150KEUR	Tender
	High-speed Ethernet switches	2023	260KEUR	Tender
	Virtualization	Q3 2023	215KEUR	Tender
	Datacenter buildout	2023	650KEUR	Tender
	Workstations	2023	50 - 100KEUR	Tender & framework agreement
	Licenses	2023	70KEUR	A series of RFQs
	Misc.	2023	95KEUR	A series of RFQs

2024	Data acquisition build up and HPC	Q2 2024	580KEUR	Tender &framework agreement
	High-speed Ethernet switches	2024	165KEUR	Tender
	Virtualization	Q2 2024	200KEUR	Tender
	Workstations	2024	50 - 100KEUR	Tender & framework agreement
	Licenses	2024	70KEUR	A series of RFQs
	Misc.	2024	98KEUR	A series of RFQs
2025	HPC nodes	Q2 2025	150KEUR	Tender
	High-speed Ethernet switches	2025	265KEUR	Tender
	Licenses	2025	70KEUR	A series of RFQs
	Misc.	2025	105KEUR	A series of RFQs
2026	Data acquisition build up and HPC	2026	690KEUR	Open Tender & framework agreement
	Storage systems	2026	700KEUR	Tender
	High-speed Ethernet switches	2026	110KEUR	Tender
	Virtualization	2026	200KEUR	Tender
	Licenses	2026	70KEUR	A series of RFQs
	Misc.	2026	125KEUR	A series of RFQs
2027	Data acquisition build up and HPC	2027	610KEUR	Open Tender & framework agreement
	Storage systems	2027	617KEUR	Tender
	High-speed Ethernet switches	2027	150KEUR	Tender
	Licenses	2027	70KEUR	A series of RFQs
	Misc.	2027	130KEUR	A series of RFQs

Table 9. ESS investment plan in Information and Communication technologies for 2023-2027

3.3.7 E-XFEL

The reported Investment Plan at E-XFEL includes 1.5 MEUR for Storage and 1 MEUR for Compute per year, and is typically separated as follows:

- IBM GPFS (IBM Spectrum Scale) Online Filesystem 5 PB
- IBM GPFS (IBM Spectrum Scale) Online Filesystem 45 PB
- dCache Offline storage 110 PB
- 200 PB Tape Based Archive (LTO8, LTO9, Jagger)
- Online Compute: 60 nodes, ~ 50/50 split between CPU and GPU
- Offline Compute: 350 nodes, ~15000 cores Intel + AMD, theoretical Rpeak 1Peta Flop, 20 GPU nodes (2022: 100 node extension delayed)
- InfiniBand fabrics long-range backbone HDR (200Gb/s) 1 Tbit/s to connect GPFS clusters between two sites
- 5 year system lifetime including support and warranty purchased for both compute and storage systems

3.3.8 ILL

The future projects at ILL have been reported as follows:

- Hardware
  - Increase remote data analysis capacity Openstack compute nodes) every year
  - Scientific storage Part 1 (2023 - Call for tenders is closed)
  - Scientific storage Part 2 (2025 4PB)

  - Detectors: CMOS cameras, Pixel detectors, Si-PM
  - Digital electronics for charge-division detectors
  - Digital CFD for picosecond timing
  - ZYNQ based board for data acquisition
  - Low noise, low consumption, fast response analog preamplifier
  - Robot for sample positioning and handling
  - Framework for continuous scan
  - Adaptive neutron optics
- Network
  - Redeploy wired copper cables globally on site 2023 2025
  - Refresh/replace Wi Fi solution (currently CISCO) 2023-2024
- Software solutions
  - Switch to a Kubernetes / microservices (k8s infrastructure + training) 2023
  - On-line data reduction
    - Generate consistent data sets
    - Automate decisions during experiment
    - Reduce data size
    - Speed-up analysis
  - Remote instrument control
    - More connected devices
    - Remote clients
    - Distributed environment
  - Autonomous measurements with machine learning
  - Full experiment simulation including instrument digital twin

3.4 Basic material technologies and advanced manufacturing techniques

The list of companies with capacities in basic material technologies and advanced manufacturing techniques is shown in Table 10.

Table 10. Companies with capacities in basic material technologies and advanced manufacturing techniques

	Materials	Advanced manufacturing	Surface Treatment	Advanced welding	Additive Manufacturing	High precisión / large components	Others
Ekstremalė (LT)	☐	☐	☐	☐	☐	☒	☐
Akoneer (LT)	☐	☐	☒	☐	☐	☒	☐
3DPrototipai (LT)	☐	☐	☐	☐	☒	☐	☐
Diodela (LT)	☐	☐	☐	☒	☐	☐	☐
Sargasas (LT)	☐	☐	☐	☐	☐	☒	☐
Advanced Alloys&Manufacturing (LT)	☒	☐	☐	☐	☒	☐	☐

	Materials	Advanced manufacturing	Surface Treatment	Advanced welding	Additive Manufacturing	High precisión / large components	Others
Femta (LT)	☐	☐	☒	☐	☐	☐	☐
Light Density (LT)	☐	☐	☒	☐	☐	☒	☐
Laser Trio (LT)	☐	☐	☐	☐	☐	☒	☐
Laser Fabrication Technologies (LT)	☐	☐	☒	☐	☐	☒	☐
AM Tooling (DK)	☐	☐	☒	☒	☐	☒	☐
Hammel Plast (DK)	☒	☐	☐	☐	☐	☐	☐
MC Uldall (DK)	☐	☐	☒	☒	☐	☒	☐
Polyteknik (DK)	☐	☐	☒	☐	☐	☐	☐
AF Pipe Solutions (DK)	☐	☐	☐	☒	☐	☐	☒
CHEXS (DK)	☐	☐	☒	☐	☐	☐	☒
Mark & Wedell (DK)	☐	☐	☐	☐	☐	☒	☐
Teccluster (DK)	☐	☐	☒	☐	☒	☒	☐
Alumeco (DK)	☒	☐	☐	☐	☐	☐	☐
Blunico (DK)	☐	☐	☐	☒	☐	☐	☐
JJ X-rays (DK)	☐	☐	☒	☐	☐	☒	☐
SubC (DK)	☐	☐	☒	☒	☐	☒	☐
AERNNOVA AEROSPACE (ES)	☐	☐	☒	☐	☐	☒	☒
AIMEN TECHNOLOGY CENTRE (ES)	☐	☐	☐	☒	☐	☒	☒
AIRBUS DEFENCE AND SPACE (ES)	☒	☐	☒	☐	☐	☒	☒
ALTER TECHNOLOGY TUV NORD (ES)	☒	☐	☐	☒	☐	☐	☐
ANTEC MAGNETS (ES)	☐	☐	☐	☐	☐	☒	☐
APPLUS+ LABORATORIES (LGAI Technological Center) (ES)	☐	☐	☐	☐	☐	☒	☒
ARQUIMEA (ES)	☐	☐	☐	☒	☐	☒	☒
ASTURFEITO (ES)	☒	☐	☒	☒	☐	☒	☒
AVANCEM (ES)	☒	☐	☒	☒	☐	☒	☒
AVS - ADDED VALUE INDUSTRIAL ENGINEERING SOLUTIONS (ES)	☒	☐	☐	☒	☐	☒	☒
AWGE TECHNOLOGIES (ES)	☒	☐	☐	☒	☐	☒	☒
BURDINBERRI (ES)	☐	☐	☐	☐	☐	☒	☒
CADINOX (ES)	☐	☐	☐	☐	☐	☒	☒
CAP GEMINI ENGINEERING (ES)	☐	☐	☐	☒	☐	☐	☐
CITD ENGINEERING & TECHNOLOGIES (ES)	☐	☐	☐	☐	☐	☒	☒
COMET INGENIERÍA (ES)	☐	☐	☐	☐	☐	☒	☐
CT ENGINEERING (ES)	☐	☐	☐	☒	☐	☒	☐
DEM - DISSENY, ESTUDI, I MECANITZACIÓ (ES)	☒	☐	☒	☒	☐	☒	☒
EGILE MECHANICS (ES)	☐	☐	☐	☐	☐	☒	☒
EMPRESARIOS AGRUPADOS INTERNACIONAL (ES)	☒	☐	☐	☒	☐	☐	☐
EMXYS - EMBEDDED INSTRUMENTS AND SYSTEMS (ES)	☐	☐	☐	☐	☐	☒	☐

	Materials	Advanced manufacturing	Surface Treatment	Advanced welding	Additive Manufacturing	High precisión / large components	Others
ENSA - EQUIPOS NUCLEARES (ES)	☐	☐	☐	☒	☐	☒	☒
ESTEYCO (ES)	☐	☐	☐	☐	☐	☒	☐
FAGOR AUTOMATION (ES)	☐	☐	☐	☐	☐	☒	☐
FERROVIAL (ES)	☒	☐	☐	☒	☐	☐	☒
FUS_ALIANZ SCIENCE, ENGINEERING AND CONSULTING (ES)	☒	☐	☐	☐	☐	☐	☐
GUTMAR (ES)	☒	☐	☐	☐	☐	☒	☒
HILFA (ES)	☐	☐	☒	☒	☐	☒	☒
IBERDROLA GENERACIÓN (ES)	☐	☐	☐	☐	☐	☒	☒
IDESA (ES)	☐	☐	☒	☒	☐	☐	☒
IDOM (ES)	☐	☐	☐	☐	☐	☒	☒
INGECIBER (ES)	☐	☐	☐	☐	☐	☒	☐
LEADING (ES)	☐	☐	☐	☐	☐	☒	☒
LIDAX (ES)	☐	☐	☐	☐	☐	☒	☐
MECÁNICAS BOLEA (ES)	☐	☐	☐	☐	☐	☒	☒
MECANITZATS PRIVAT (ES)	☐	☐	☐	☐	☐	☒	☒
METROMECÁNICA (ES)	☐	☐	☐	☐	☐	☒	☐
MONCOBRA (ES)	☒	☐	☐	☒	☐	☐	☒
NADETECH (ES)	☐	☐	☒	☐	☐	☐	☒
NANOKER (ES)	☒	☐	☐	☐	☐	☐	☒
NORTEMECÁNICA (ES)	☐	☐	☐	☐	☐	☒	☒
OBUU TECH (ES)	☐	☐	☐	☐	☐	☒	☒
PROACTIVE (ES)	☐	☐	☐	☐	☐	☒	☒
SCHWARTZ HAUTMONT (ES)	☒	☐	☒	☐	☐	☒	☒
SEA (ES)	☐	☐	☐	☐	☐	☐	☒
SENER AEROESPACIAL (ES)	☐	☐	☐	☐	☐	☒	☒
SGENIA (ES)	☐	☐	☐	☐	☐	☒	☒
SOGECLAIR AEROSPACE (ES)	☒	☐	☒	☐	☐	☒	☒
TECNATOM (ES)	☐	☐	☐	☐	☐	☐	☒
TVP - THERMAL VACUUM PROJECTS (ES)	☒	☐	☐	☒	☐	☐	☒
THUNE EUREKA (ES)	☐	☐	☐	☐	☐	☒	☒

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in basic material technologies and advanced manufacturing techniques are CERN, E-XFEL and F4E. The specific opportunities and challenges are summarized in the following sections:

3.4.1 CERN

The reported future tenders at CERN for basic material technologies and advanced manufacturing techniques are:

- Rolled and forged Stainless steel round bars (grade 316LN EN 1.4429)
- 3D forged Stainless steel blanks, rings (grade 316LN EN 1.4429)
- Sheets and plates in Stainless steel (grade EN 1.4307 / 1.4404 – for pressure purposes)
- Round bars in Stainless steel (grade 316L EN 1.4435)
- Tungsten heavy alloy - Absorbing material for tertiary collimators blocks and for masks. Market Survey for Q 1 2023
- CuCr1Zr - Material for tapering for the tertiary collimator's jaws. Market Survey for Q 1 2023
- Graphitic material (isostatic Graphite and Sigraflex) for the HL-LHC TDE Dump Cores. Market Survey for Q2 2023
- Al 6061 T 6 for DQW Thermal Shield. To be purchased in 2023
- ODS copper collimators backstiffeners. Market Survey for Q 2 2023
- Stainless steel 1.4441/1.4435/1.4404 Strips for series production of 400 HL LHC bellows. Market Survey for Q 1 2023
- Stainless steel 1.4404/1.4435/1.4306/1.4307 bars for flanges for series production of ~400 HL LHC bellows. Market Survey for Q 1 2023

3.4.2 E-XFEL

The challenges reported b E-XFEL are mainly on gas dynamic virtual nozzles (GDVN) (development of more complex jetting systems & mass production standard systems) and on reproducibility and accuracy on plasma target production for user experiments.

3.4.3 F4E

The reported re-occurring call for tender to maintain active service contract at F4E is a 4 years contract that will open on 2024 is the OFC-1082 Running contract for “Materials and manufacturing testing/qualification services” (ceiling 2.700.000 Euro). It has already been awarded to TWI UK, Tecnalia Spain and, today, is running with ISQ Portugal.

Further needs have been reported by F4E, mainly:

- Materials (316LN)
- Components /pipes, bolts, cabling, sensors, etc.)
- Free-issue items
- EB/TIG welding, diffusion bonding by HIP, etc.
- NDT (visual, X-ray, UT, etc.)

3.5 Complex building construction and its safety related systems

The list of companies with capacities in complex building construction and its safety related systems is shown in Table 11.

Table 11. Companies with capacities in complex building construction and its safety related systems

	Complex building construction	Safety systems
ABENGOA (ES)	☒	☒
AIRTIFICIAL (ES)	☒	☐
ALTER TECHNOLOGY TUV NORD (ES)	☒	☒
APPLUS+ LABORATORIES (LGAI Technological Center) (ES)	☐	☒
ARCECLIMA (ES)	☒	☒
ARQUIMEA (ES)	☐	☒
ARRAELA (ES)	☒	☐
ASTURFEITO (ES)	☒	☐
CBRE GWS (ES)	☒	☒
CT ENGINEERING (ES)	☒	☐
DEIMOS SPACE (ES)	☒	☐
DRAGADOS (ES)	☒	☐
EIIT (ES)	☒	☐
EMPRESARIOS AGRUPADOS INTERNACIONAL (ES)	☒	☒
ESTEYCO (ES)	☒	☐
FAGOR AUTOMATION (ES)	☒	☐
FERROVIAL (ES)	☒	☒
GDES (ES)	☒	☐
GMV (ES)	☐	☒
GTD SISTEMAS DE INFORMACIÓN (ES)	☒	☐
HILFA (ES)	☒	☐
IBERDROLA GENERACIÓN (ES)	☒	☐
IDESA (ES)	☒	☐
IDOM (ES)	☒	☐
INGECIBER (ES)	☒	☐
INTARCOM (ES)	☒	☐
LEADING (ES)	☒	☐
MONCOBRA (ES)	☒	☒
PROCON SYSTEMS (ES)	☒	☒
SCHWARTZ HAUTMONT (ES)	☒	☐
SENER AEROESPACIAL (ES)	☒	☒
TSK (ES)	☒	☐

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in complex building construction and its safety related systems are CERN, ESRF, ESS, F4E and ILL. The specific opportunities and challenges are summarized in the following sections:

3.5.1 CERN

The reported future tenders at CERN are divided into complex building construction and safety systems, as follows:

For complex buildings

- Prevessin Office Center (Market Survey in 2023)
  - Tertiary building (475 p.) + new restaurant (500 s.) + Parking
  - 12000 m2
  - Compliance Master Plan 2040, Compliance RE 2020 (environmental regulation)
  - Low embodied energy (mass timber structure)
  - Preservation of nearby forest
  - Integrate soft mobility
  - 2026: end of works
- B140 (Meyrin) (Tendering process to target delivery of the 1st Phase in 2027 and 2nd Phase in 2030)
  - Office building, training center, light laboratories, cafeteria & parking
  - 18000 m^2
  - Emphasis on sustainable design & construction
  - Built in two phases
- Point 5 (Cessy) (IT Q4 2022 (phase 1), 2023 (phase 2). Works 2023 and 2024)
  - Civil engineering for electrical installations and harmonic filters
- Vertical core excavation HL-LHC (Works 2024-2025)
  - Connections between HL-LHC galleries and LHC tunnel
  - 12 Ø 1m vertical cores at both Point 1 and 5 (24 cores)
  - 5 to 7 meters long
  - Design & build approach
  - Execution in two phases
  - Logistic constraints due to CERN operations
- Retention basins (France in 22-23, Switzerland 23-24)
- 3 Projects under discussion. Ad hoc tendering for studies and construction.
- Sustainable Heating Plants (projects under discussion)
- Main power via renewable energy sources to cover the major part of the current heating needs in Meyrin & Prevessin sites.

For safety systems

- LHC & Experiments Automatic Gas and ODH detection systems renewal (System renewal, expected end 2023)
  - Maintenance & projects: Oxygen deficiency detection, flammable gas and toxic gas detection in LHC.
  - Technology options to be investigated (radiation resistance, EMC).
  - Covers: LHC (renewal) & HL LHC (new) and maintenance for all CERN sites.
- Sniffer system renewal for LHC Experiments (ATLAS, LHCb , ALICE) (on hold)
  - Development: detection (smoke, flammable & toxic gas), electronic acquisition card.
  - Cabinets renewal. Depends on the experiment
- Renewal of LHC Audible Emergency Evacuation system (on hold) composed of:
  - Système de Mise en Sécurité incendie" (SMSI) interfacing with PPS and containing safety action matrices

    - o “Système de Sonorisation de Sécurité” (SSS) triggering Beam Imminent Warning and Evacuation sounds (control Indicating Equipment (CIE), Loudspeakers, Micros and MMI, power supplies, etc.)
- Fire Detection & Protection Prospection (on hold)
- Market investigation for competencies and new technology in Fire Detection and competencies in Fire protection (extinguishing means) for future contracts

3.5.2 ESRF

The reported future tenders at ESRF are focused on beamlines & radioprotection hutches:

- Personal safety system
- Roof pannel
- Wall pannels
- Electrical & fluids chicanes
- Roof chicanes
- Hvac chicanes
- Doors
- Bremsstrahlung wall & lead collars
- Vacuum pipe supports & shielding
- Radioprotection hutches & lead shielding → Turnkey contract

3.5.3 ESS

For ESS, the challenges faced can be summarized as follows:

- While constructing ESS, new security scenarios were given.
- The after-math of the Fukushima event resulted in “stress tests” concerning seismic safety
- The shielding analyses of neutron beam lines turned out to give a high dose to office staff in the office building
- The amount of potentially contaminated process water requires pipelines instead of manual transport of casks
- There is no space given for handling of activated components

3.5.4 F4E

The reported needs at F4E are mainly related to (1) Tokamak Maintenance:

- A large number of In and Out of Vessel systems need to be maintained and / or repaired.
- Due to induced activity, activated dust or chemical hazards (like beryllium); remote , confined and shielded maintenance is a necessity.

And (2) on the hot cell facility

- Large and complex nuclear facility, comparable to the Tokamak Complex. First of A Kind (FOAK) for remote activities. Maintenance of sophisticated and heavy, large sized equipment.
- Licensing challenge: The Hot Cell Facility delivery is mandatory for obtaining the hold point release from the Nuclear Regulator to operate the ITER Tokamak.
- Schedule constraints: First functionalities need for Pre Fusion Power Operation (PFPO).
- Budget Constraints:
    - o Adjust the scheduled and corrective maintenance program to the strict and real needs
    - o Avoid conservative approach to rationalize the Facility

  - Build on the basis of mature and validated design
  - Design with a constrained budget in mind
- It is fully part of the science and technology demonstration of ITER
- Safety:
  - Seismic conditions
  - Fire protection
  - Extreme climatic conditions
  - Airplane Crash
  - Drop Loads (heavy and large components)
  - Workers radiation exposure limitation
  - Confinement of Radiological materials
  - Workers Chemical risks (exposure limitation to Beryllium)

3.5.5 ILL

One future tender of 4M€ has been reported for ILL, regarding the installation of a permanently connected sprinkler system:

- Installation of the circuit and 600 Sprinkler
- Heads able to resist an earthquake
- NF EN12845 or APSADRI
- ILL project owner and project manager
- Realization: 08/2023 04/2024

3.6 High precision and large mechanical components

The list of companies with capacities in high precision and large mechanical components is shown in Table 12.

Table 12. Companies with capacities in high precision and large mechanical components

	High Precision manufacturing	Large Mechanical components
Ekstremalė (LT)	☒	
Akoneer (LT)	☒	
Sargasas (LT)	☒	
Arginta Engineering (LT)		☒
Light Density (LT)	☒	
Laser Trio (LT)		☒
Beagle Optics (LT)	☒	
AM Tooling (DK)	☒	☒
MC Uldall (DK)	☒	
Teccluster (DK)	☒	
Alumeco (DK)	☒	

	High Precision manufacturing	Large Mechanical components
Blunico (DK)	☒	
SubC (DK)	☒	☒
AERNNOVA AEROSPACE (ES)	☒	☒
AIMEN TECHNOLOGY CENTRE (ES)	☒	☒
AIRBUS DEFENCE AND SPACE (ES)	☒	☒
ANTEC MAGNETS (ES)	☒	☒
APPLUS+ LABORATORIES (LGAI Technological Center) (ES)	☒	☒
ARQUIMEA (ES)	☒	☒
ASTURFEITO (ES)	☒	☒
AVANCEM (ES)	☒	☒
AVS - ADDED VALUE INDUSTRIAL ENGINEERING SOLUTIONS (ES)	☒	☒
AWGE TECHNOLOGIES (ES)	☒	☒
BURDINBERRI (ES)	☒	☒
CADINOX (ES)	☒	☒
CITD ENGINEERING & TECHNOLOGIES (ES)	☒	☒
COMET INGENIERÍA (ES)	☒	☒
CT ENGINEERING (ES)	☒	☒
EGILE MECHANICS (ES)	☒	☒
EMXYS - EMBEDDED INSTRUMENTS AND SYSTEMS (ES)	☒	☒
ENSA - EQUIPOS NUCLEARES (ES)	☒	☒
ESTEYCO (ES)	☒	☒
FAGOR AUTOMATION (ES)	☒	☒
GUTMAR (ES)	☒	☒
HILFA (ES)	☒	☒
IBERDROLA GENERACIÓN (ES)	☒	☒
IDOM (ES)	☒	☒
INGECIBER (ES)	☒	☒
LEADING (ES)	☒	☒
LIDAX (ES)	☒	☒
MECÁNICAS BOLEA (ES)	☒	☒
MECANITZATS PRIVAT (ES)	☒	☒
METROMECÁNICA (ES)	☒	☒
NORTEMECÁNICA (ES)	☒	☒
OBUU TECH (ES)	☒	☒
PROACTIVE (ES)	☒	☒
SCHWARTZ HAUTMONT (ES)	☒	☒
SENER AEROESPACIAL (ES)	☒	☒
SGENIA (ES)	☒	☒

	High Precision manufacturing	Large Mechanical components
SOGECLAIR AEROSPACE (ES)	☒	☒
THUNE EUREKA (ES)	☒	☒

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in high precision and large mechanical components are CERN, ESA, ESO, ESRF, ESS, FAIR, F4E and ILL. The specific opportunities and challenges are summarized in the following sections:

3.6.1 CERN

In particular, the future technological challenges for CERN are mainly related to the LHC collimators, and the tender identified on high precision and large mechanical components is the production, assembly and Quality Assurance of 36 collimators.

For applying, interested firms shall have a proven experience and competence in:

- Manufacturing engineering (ability to produce 2D execution drawings and 3D models, as well as time and methods production process analysis)
- High precision machining and production of engineering components, with experience in oil free machining and stress relief heat treatments
- Electron Beam Welding and Tungsten Inert Gas welding for Ultra High Vacuum in stainless steel (mainly austenitic)
- UHV leak testing and outgassing tests
- Surface treatments, electroplating and cleaning for vacuum brazing of copper alloys and stainless steels
- Vacuum brazing on copper based materials and stainless steel
- Assembly of UHV components and all the related best practices for cleaning and handling of mechanical components for UHV applications
- Assembly of precise mechanisms with a ten micrometers tolerance
- 3D metrology with a dedicated installation

3.6.2 ESA

Reported future tenders at ESA on high precision and large mechanical components are mainly related to what they call *future mega-trends*:

- Structures:
    - Reusability / Smart Structures
    - Demisable Design for “undemisable structures” + Design Guidelines and Tools
    - Virtual Testing and Verification Methodologies
    - Margins Reduction Methodologies
    - Advanced Analysis Methodologies and Tools / End-to-End Digitalization
- Mechanisms:

  - Closed loop control / low micro-vib / Micro-vib isolation
  - Artificial Intelligence, Big data / Machine Learning (e.g. initiative on common ball bearing data base)
  - Multi-Physics / Multi-Body Analysis
  - Dust Management for on Planet (Moon/Mars) Mechanisms
  - Digital twins / Hardware in the loop / Digitalisation
  - COTS / Building Blocks / Standardisation
  - Technology Transfer (from Space to Ground application)
  - Mega constellations needs / Packing density
  - Health Monitoring
  - High Precision/High Accuracy/Long Life (for e. g. Intersatellite Links, etc.)
  - Out of earth manufacturing / In-orbit servicing
- Materials:
  - Digitalization and Materials Modelling
  - Manufacturing Data Acquisition and Manipulation / Machine Learning and Repair + NDI Strategies
  - Manufacturing Digital Twin ➔ Input for Virtual Testing (reducing lead time/time to market)
  - 4D Printing
  - Biomimicry
  - Smart Factory Manufacturing (Megaconstellations + Launchers)
  - Out of Earth Manufacturing (ISRU, Recycling, Assembly, etc.)
  - Materials Demisability Enhancement and Testing
  - Cleanliness and Contamination Control as a System Approach + Modelling and IOD
- Thermal:
  - Deployable radiators – heat rejection
  - Thermal switches
  - Mechanically Pumped 2 phase loops – heat transport
  - Leverage on new materials and manufacturing processes for increased performance
  - Cryocoolers
  - Heatshields – thermal protection
  - Digitalisation of Thermal Engineering Process
  - Thermal digital twin

On the other hand, and keeping in mind that space is a sector outside Big Science, there is a new paradigm on manufacturing for Space applications: the on-orbit manufacturing, which includes the following challenges:
- Larger structures (no fairing size limitation), e.g.:
  - Solar arrays → higher power and higher payload capacity for a given class of satellites, higher performance-to-launch-cost
  - Antennae reflectors → narrower emitted beam, higher gain, higher data throughput for telecommunications
  - Large aperture Telescope, large Interferometer → higher science return
- Spacecraft on-orbit refurbishment and upgrade enabled → life extension, cost savings compared to launching new assets
- Longer term: leasing of assets (e.g. reflectors), decoupled payload and platform → payload update on orbiting platforms; platforms leasing
- Long term: manufacturing and maintenance of very large structures (e.g. space-based solar power)
- Benefits applicable to a wide range of missions for Telecom, Earth Observation, Navigation, Science, Exploration

- On-demand manufacturing and recycling of spare parts, tools during long term human exploration missions → simplified maintenance logistics → savings in resupply missions and materials
- In-situ manufacturing and assembly e.g. of cubesats → flexibility and redundancy in mission planning
- In-situ construction of infrastructure, in-situ propellant production and in-situ manufacturing of hardware (e.g. tools) for human exploration to the lunar (and Martian) surface → enabling capabilities for sustainable surface exploration, longer term commercial activities
- Use of space conditions for production of materials with enhanced properties (i.e. without defects associated to terrestrial conditions) for commercialization on Earth

3.6.3 ESO

At ESO, the main technological challenges are for hardware:

- Laser platform for Gravity Plus (UT1, UT2 and UT3). For 2023
- 4MOST Platform/handling for 2023
- PDS (Phasing Diagnostic station) structure fabrication for 2023
- Azimuth carriage for M3/M4/M5 unit for 2025

3.6.4 ESRF

At ESRF, the Experimental programme overview 2022-2029 includes the following main projects:

- New insertion devices + small gaps
    - Large metallic welded frames
    - High rigidity
    - Motorized
    - Completely assembled
- Four new beamlines fully optimized for EBS
    - High precision mechanic systems
    - High rigidity, high stability
    - High thermal load / LN2 cooling
    - UHV
    - Nano positioning
- Refurbishment Programme (several beamlines)
    - Huge diversity of mechanical components
    - From simple to very complex systems
    - From single parts to complete assemblies

In particular, the machining of individual parts has a budget of ~400 k€/year, including:

- Unitary part only
- Very few series of pieces
- Conventional machining
- Electro-erosion
- Mechanical welded
- UHV manufacturing
- Welding
- Brazing

- Inspection report
- Additive manufacturing

For manufacturing of comprehensive instruments (with possibility of pre assembly, including in vacuum undulators, and from ESRF drawings and technical specifications), the future tenders will be split in several Call For Tenders:

- External motion systems and support frame
  - Capabilities required: welded machined “heavy” precision motion systems
- Vacuum chambers and internal parts
  - Capabilities required: Stainless steel welding, Vacuum brazing, Cleaning, Vacuum testing
- High precision machined parts

Other future tenders identified are BM18 Slits and BM18 Attenuators. The supply’s scope include fabrication, assembly and tests. The capabilities required are the following:

- Precision machining
- Stainless steel welding
- Vacuum brazing
- Cleaning
- Assembly
- Vacuum testing
- High precision motion tests

3.6.5 ESS

At ESS, for the Target System, the following future needs identified are:

- Target Wheel: design upgrade and replacement
  - Don´t interfere with the protons and neutrons (Minimum distance, Minimum material)
  - Heat load 3 Mw (5MW proton beam) - 3 kg/s helium mass flow (11 bar)
  - Radiation and vacuum (cold welding, instrument failure, leakage)
  - Design code (RCC-MRx category N3. / MQC4 & quality vs possibility to repair, impact to the availability)
- Target Instrumentation: additional system
- Maintenance of heavy components - vacuum/radiation: maintenance support

3.6.6 FAIR

The reported needs at FAIR are 2 radiation hard dipoles for Super-FRS.

3.6.7 F4E

The reported future tenders at F4E for Neutral Beams (NB) can be summarized in two categories:

Remote Handling System (RHS):

- Manufacturing of the 40 t nuclear grade crane (manufacturing design, fabrication, installation and commissioning)
- Main Technical Challenges: ~140 m crane railway with high precision manufacturing, installation and alignment
- Launch of call for tender Q 2 2024
- Delivery Q 3 2027

And cryopumps:

- Manufacturing and Assembly of the Neutral Beams (NB) Cryopumps
- Main Technical Challenges: Manufacturing of vacuum and cryogenic assemblies to tight tolerances
- Current phase final design
- Launch of call for tender 2024
- Delivery 2029

3.6.8 ILL

Finally, on high precision and large mechanical components, at ILL there will be needs for the reactor division:

- Installation of sprinkler circuit inside the reactor building (2023)
- Seismic reinforcement of the crane of the level C inside the reactor building (2025)
- Renewal of the horizontal cold source installation (ESPN SKID, ESPN Vessel) (2025)
- Seismic reinforcement of the handling devices of the fuel elements (2025)
- Manufacture of reactor parts (ESPN) (2028): vertical cold source, fuel element support...

And for the DPT division:

- Seismic reinforcement of concrete casemate
- Instrument Projects
- SHARP collimation (2023)
- SHARP collimation shielding (2023)
- D11 collimation (2023)

3.7 Automation, Control and Remote handling systems

The list of companies with capacities in automation, Control and Remote handling systems is shown in Table 13.

Table 13. Companies with capacities in automation, control and Remote handling systems

	Automation, Control and Remote handling systems
Danfysik (DK)	☒
AERNNOVA AEROSPACE (ES)	☒
AIRBUS DEFENCE AND SPACE (ES)	☒
ALIBAVA SYSTEMS (ES)	☒
ALTER TECHNOLOGY TUV NORD (ES)	☒

	Automation, Control and Remote handling systems
APPLUS+ LABORATORIES (LGAI Technological Center) (ES)	☒
ARQUIMEA (ES)	☒
ASE OPTICS EUROPE (ES)	☒
AVS - ADDED VALUE INDUSTRIAL ENGINEERING SOLUTIONS (ES)	☒
AWGE TECHNOLOGIES (ES)	☒
CITD ENGINEERING & TECHNOLOGIES (ES)	☒
DEIMOS SPACE (ES)	☒
EMPRESARIOS AGRUPADOS INTERNACIONAL (ES)	☒
FERROVIAL (ES)	☒
FRACTAL (ES)	☒
GMV (ES)	☒
GTD SISTEMAS DE INFORMACIÓN (ES)	☒
GUTMAR (ES)	☒
IDOM (ES)	☒
INSYTE ELECTRONICS (ES)	☒
INTERGRASYS (ES)	☒
ISDEFE (ES)	☒
LIDAX (ES)	☒
MAMMOET IBÉRICA (ES)	☒
METROMECÁNICA (ES)	☒
MONCOBRA (ES)	☒
OBEKI (ES)	☒
OBUU TECH (ES)	☒
OROLIA SPAIN (ES)	☒
PROCON SYSTEMS (ES)	☒
SENER AEROESPACIAL (ES)	☒
SOGECLAIR AEROSPACE (ES)	☒
TECNATOM (ES)	☒
THALES ALENIA (ES)	☒
TVP - THERMAL VACUUM PROJECTS (ES)	☒
VERSE EUROPA (ES)	☒

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in automation, Control and Remote handling systems are CERN, ESA, ESO, E-XFEL, FAIR and F4E. The specific opportunities and challenges are summarized in the following sections:

3.7.1 CERN

The reported future tender opportunities at CERN are summarized in Table 17.

Table 14. Reported future tenders at CERN on automation, control and remote handling systems

Tender	Technical responsible	Expected date for Market Survey
PXIe Carrier (400 units)	Javier Serrano	Q1 2024
COMe CPU (400 units)	Javier Serrano	Q4 2023
PXIe-COMe adapter (400 units)	Javier Serrano	Q1 2024
FMC cards for Motion control (400 units)	Javier Serrano	Q1 2024
Stepping Motor Drivers (1200 units)	Javier Serrano	Q2 2024
OASIS high-speed digitizers. 8 bits. 1 GSPS sampling rate. 500 installed channel count. Existing form 50% cPCI, 50% PCI. New Form PXIe (4+ channels per slot)	Dimitris Lampridis	Q1 2025
OASIS high-speed digitizers. 10 bits. 2 GSPS sampling rate. 45 installed channel count. Existing form cPCI. New Form PXIe (2+ channels per slot)	Dimitris Lampridis	Q4 2023
OASIS high-speed digitizers. 10 bits. 4 GSPS sampling rate. 20 installed channel count. Existing form cPCI. New Form PXIe/PCIe (2+ channels per slot)	Dimitris Lampridis	Q4 2023
200 DI/OT crate	Greg Daniluk	Q2 2023
White Rabbit. 150 WR switches v.3	Evangelia Gousiou	Q1 2023
White Rabbit. 100 WR switches v.4	Evangelia Gousiou	Q1 2023
1200 VME System Board	Erik Van Der Bij	Q1 2023
TAN crane		2026-2027
Hot Cell		In preliminary analysis
Tooling. Specific or general-purpose handling accessories		N/S

On the other hand, the technological challenges faced by CERN are:

- PXIe front-ends
- PXIe carrier card equipped with a large FPGA for data processing and RT control; can host one FPGA Mezzanine Cards (FMC) to ensure the interface with the field instrumentation, sensors and actuators
- Set of FPGA Mezzanine Cards (FMC) to cope with the various field control and instrumentation applications (LVDT, resolvers, IOs, strain gauges, interferometer reading, motor drivers)
- Expansion chassis ensures modularity. It is equipped with a system controller linked and synchronized to the PXIe carriers via White Rabbit

3.7.2 ESA

The reported future tender opportunities at ESA until 2027 are summarized as follows (number of tenders):

- OBCDHS architectures based on modules (5)
- Buses, network and communication (14)

- OBCDHS modules (19)
- Building blocks for OBCDHS modules (33)
- EGSE for OBCDHS units/modules (3)
- ASIC Platforms, UDSM (6)
- FPGA (4)
- Microprocessors, microcontrollers (4)
- Mixed-signal ASSPs (22)
- IP Cores, design tools (17)

On the other hand, the challenges are:

- Advanced Data Handling Architecture (ADHA) based on interchangeable and interoperable standardized modules.
- Higher integration of OBC facilitated by multi-core System-on-Chip and processors.
- Reduced and standardized interfaces of I/O modules for Remote Terminal Units and Instrument Control Units.
- Instrument advanced computing & processing modules incl. AI and ML applications.
- Availability of European radiation hard microchips: ASIC tech platforms (ultra deep submicron), FPGAs, Microprocessors and Microcontrollers, Application Specific Standard Products (converters, front ends, High Speed Serial Links), Digital and Analogue IP Cores.
- Heterogeneous integration multi-die packaging solutions (custom System-in-Package, 2.5/3D, "chiplets")
- Evaluation & mitigation techniques for reliable use of high performance COTS and rad tolerant microelectronic devices
- European Non-Dependence

3.7.3 ESO

The reported future tender opportunities at ESO are summarized as follows:

- VLT (Very Large Telescope): maintenance supported by outsourcing contract (4 FTE per year over 2+1+1+1 years)
- Remote handling systems for ELT (ETF internal transporter)
- Integrated operations programme

3.7.4 E-XFEL

For instrumentation control and CODAC, the estimates for procurement reported future tender opportunities at E-XFEL are summarized in Table 15.

Table 15. Estimates for procurement related to beamline control systems in E-XFEL for 2022-2027

Control system integration from external vendors and software consultants	250 kEuro / year
PLC System assemblies	150 kEuro / year
PLC System parts	100 kEuro / year
Cabling and connectors	100 kEuro / year
MicroTCA Systems and cards	100 kEuro / year

On the other hand, the challenges are the following:

- Sample damage and debris for high-intensity experiments
  - 1 sample per mm^2
  - 100x100 mm -> 10.000 samples
  - Sample for 1000 seconds at 10 Hz (A bit more than ¼ hour)
- Automated sample changer required for high-intensity experiments
  - Load lock for vacuum operation
    - Insert sample without venting main chamber
    - Store new sample in a safe place
  - Cartridge system
    - Here for eight 50x50 mm frames
- Better fast stages and encoders
  - Movement in vacuum
  - Reliable and accurate positioning in µm scale
  - Fast acceleration and stopping within 100 ms
  - Capable of repeated small movements
  - Absolute encoders
  - Concepts for the control system software
- Hexapod systems
  - Most compact system for 6 degrees of freedom. But:
    - Limited movement range
    - Complex dependences
- Robotic arms. Issues with
  - Vacuum compatibility
  - Space restrictions
- Standardized sample frame systems
  - Cheap and easy purchase for external users (Catalogue ware)
  - Variations to user specs
  - Unique ID engraved on frame
  - Included fiducials
- EMP hard solutions
  - Sample scanning microscopes
  - Enabling users to pre-characterize samples
  - Give positions in x,y,z
    - In µm, sometimes better, precision
    - Relative to frame fiducials
    - Exportable to EuXFEL target database
- Image recognition software
- New motor concepts:
  - Accuracy in the order of µm
  - Movements 100 mm
  - 1 mm start-stop in 0.1 second

3.7.5 FAIR

In the field of remote handling systems, the future tenders reported from FAIR are:

- Turntable
- Double lid shielding flask interface
- Waste drum convey
- Development and tendering of the activation measurement station of the decay cell

- Super FRS special installation components

3.7.6 F4E

The reported future tender opportunities at F4E for automation, control and remote handling systems are summarized in Table 16.

Table 16. Reported future tenders at F4E on automation, control and remote handling systems

Tender	Expected date
I&C Integrator contract	Q4 2023-Q1 2024
I&C Support	2026
Nuclear I&C Support	2026
Design opportunity	2027
Software Maintenance and User Supports	Q4 2024
CODAC Operation Application	Q3 2024 (or Q3 2026)
Remote Participation Application	Q1 2025
Data Handling System	Q2 2025
Equipment and Servers in CR and SR	2024
SDCC (Scientific Data and Computing Center) Hardware	Q3 2023
Construction of Early Security Fence	Q2 2023
Integration and Commissioning of ITER Control System	Q1 2024
I&C Design and Integration Support	Q2 2023
Instrumentation and Control (I&C) Cubicles Maintenance	Q4 2024 (or Q4 2026)
NB Cell Upper Port RH Equipment (UPRHE)	2025
VVPSS RH System	2025
RH Test Facilities and Mock-ups	2025

On the other hand, the challenges reported refer to ITER Tokamak – maintainable elements.

- In-vessel RH
  - Large components (up to 48T)
  - Narrow gaps (<10mm)
  - High radiation (up to 500 Gy/hr)
  - Radioactive & toxic dust (Be, W)
  - Wide variety of components
- Neural Beam RH
  - Large components (up to 20T)
  - Narrow gaps (<10mm)
  - Moderate radiation (mGy/hr)
  - Radioactive & toxic dust (Be, W)
  - Wide variety of components
- Size and weight of in-vessel components combined with small clearances
- Gamma radiation in the 100s of Gy/hour range
- Presence of radioactive and toxic dust

3.8 Cryogenics, vacuum and leak detection technologies

The list of companies with capacities in cryogenics, vacuum and leak detection technologies is shown in Table 17.

Table 17. Companies with capacities in cryogenics, vacuum and leak detection technologies

	Cryogenics	Vacuum	Leak detection technologies
Gardis Instruments (LT)			☒
Danfysik (DK)	☒	☒	
Polyteknik (DK)		☒	☒
AF Pipe Solutions (DK)	☒	☒	
Mark & Wedell (DK)	☒	☒	
Blunico (DK)		☒	
JJ X-rays (DK)	☒	☒	
SubC (DK)	☒		
AERNNOVA AEROSPACE (ES)	☒	☒	
AIRBUS DEFENCE AND SPACE (ES)	☒		
ANTEC MAGNETS (ES)		☒	
APPLUS+ LABORATORIES (LGAI Technological Center) (ES)	☒	☒	
ARQUIMEA (ES)		☒	
ASTURFEITO (ES)	☒	☒	
AVANCEM (ES)	☒	☒	
AVS - ADDED VALUE INDUSTRIAL ENGINEERING SOLUTIONS (ES)	☒	☒	
AWGE TECHNOLOGIES (ES)	☒	☒	
CADINOX (ES)	☒	☒	
CAP GEMINI ENGINEERING (ES)		☒	
CITD ENGINEERING & TECHNOLOGIES (ES)	☒	☒	
CT ENGINEERING (ES)	☒	☒	
ENSA - EQUIPOS NUCLEARES (ES)		☒	
ESTEYCO (ES)		☒	
GTD SISTEMAS DE INFORMACIÓN (ES)	☒		
GUTMAR (ES)	☒	☒	
IDESA (ES)	☒	☒	
IDOM (ES)	☒	☒	
INTARCOM (ES)	☒		
LIDAX (ES)	☒	☒	
MECÁNICAS BOLEA (ES)		☒	
MONCOBRA (ES)	☒	☒	
NORTEMECÁNICA (ES)	☒	☒	

	Cryogenics	Vacuum	Leak detection technologies
PROACTIVE (ES)	☒	☒	
SENER AEROESPACIAL (ES)	☒	☒	
SGENIA (ES)		☒	
SUPRASYS (ES)	☒	☒	
TVP - THERMAL VACUUM PROJECTS (ES)	☒	☒	
THUNE EUREKA (ES)		☒	
TTI NORTE (ES)	☒	☒	
VACTRON (ES)		☒	

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in cryogenics, vacuum and leak detection technologies are CERN, ESA, ESO, ESS, E-XFEL, FAIR and F4E. The specific opportunities and challenges are summarized in the following sections:

3.8.1 CERN

The reported future tender opportunities at CERN are summarized in Table 18.

Table 18. Reported future tenders at CERN on cryogenics, vacuum and leak detection technologies

Tender	Expected date for Market Survey
Supply of High-Grade Helium	2026
Supply of Liquid Nitrogen	2023
Supply of Liquid Argon	2023
Industrial support for cryogenics M&O	2023
Dark Side 20k liquid argon proximity cryogenics; install. In Italy.	2023
Major overhauling 3.3 kV electrical motors for helium compressors	2025
Supply of electrical controls cabinets	2023
Warm interconnection piping infrastructure (2x1.5 km, DN200)	2023
Cryogenic valves (control, quench)	2023
Onsite re-work of existing cryogenic distribution multi-header line	2023
Cryogenic instrumentation (PT, LD, Actuators)	2023
Cryogenic instrumentation (Rad Tol Electronics, 1500 cards, 50 crates)	2023

3.8.2 ESA

Reported future tenders at ESA on cryogenics, vacuum and leak detection technologies can be summarized as follows:

- Explore new industrialisation concepts for cryogenic “Equipped Insulated Tanks”, incl. light-weight and high performance insulated common bulkhead technologies

- Foster the readiness level of new liquid Oxygen/Methane based "soft cryogenic" systems for towards low-cost Space Transportation applications (new rocket stages)
- Progressing towards extended cryogenic upper stage mission flexibility by advancing propellant management under micro gravity conditions (e.g. new propellant management solutions, zero-boil-off systems, versatile thermal insulations, second life as propellant depot)

On the other hand, the technological challenges that are being faced are mainly Vibration Reduction, Remote Cooling, Long Lifetime and Cryogenic Fluids Handling.

3.8.3 ESO

At ESO, the main technological challenges on cryogenics, vacuum and leak detection technologies are related to ELT cryogenic instruments:

- Two tennis-court size Nasmyth platforms A and B for instruments
    - First light instruments (2027-29): MICADO, MORPHEO, METIS, HARMONI
    - 2030+ instruments: ANDES, MOSAIC, 2nd AO, PCS
- Instruments scale with telescope size: ~10 x VLT size
- Vessel volume / weight / cold mass: 25000+ L / 25+ t / 5000 kg
- Large cryo-vacuum systems
- Proven concept of LIN cooling and local cryo-coolers adopted from VLT
- LIN on-site delivery service refilling main storage tank (e.g. 42000 L)
- Distribution to instruments via fixed piping system (lesson learned VLT)
    - Advanced LIN infrastructure required
- Selected COTS cryo-coolers standardized at ESO
    - 2-stage cryo-coolers 1W @ 4K (15W @ 20K) / 50W @ 60K, ~9 kW input power
    - Up to 36 compressors in ELT; 4 cryo-coolers per instrument
    - Long Helium flex lines required (~100 m)
    - Low vibration versions required (PTC, etc.)
    - Very demanding vibration requirements
    - Advanced vibration isolation systems required

The reported future tender opportunities at ESO are summarized in Table 19.

Table 19. Reported future tenders at ESO on cryogenics and vacuum

Tender	Type	Start	End
ELT LIN distribution system infrastructure: design, construction, on-site installation	industrial contract	2023	2026
ESO HQ LIN distribution system infrastructure: design, construction, on-site installation	industrial contract	2023	2025
LIN delivery service LaSilla-Paranal-Observatory (La-Silla & VLT), Chile; 30000 L/month	frame contract, recurring every 3-5 years	2025	2028
LIN delivery service on-site Armazones, Chile; for ELT FL instruments; 30000 L/month	frame contract, recurring every 3-5 years	2026	2030
LIN delivery service on-site Armazones, Chile; for ELT 1st and 2nd gen. instr.; 60000 L/month	frame contract, recurring every 3-5 years	2030	2035
LIN delivery service on-site ESO HQ, Germany; 4000 L/month	frame contract, recurring every 3-5 years	2024	open
Customized LIN transfer lines	hardware procurement	2023	open

ELT cryo-cooler infrastructure: compressors, He piping, thermal enclosures, anti-vibration mount	hardware procurements and industrial contracts	2023	2030

3.8.4 ESS

Regarding cryogenics, vacuum and leak detection technologies, the reported areas of interest to ESS are:

- Room temperature piping
- Valves, flanges, seals
- Motors, cabling
- Warm gas storage systems
- Room temperature instrumentation and control systems
- Heat exchangers
- Welding services & rigging services
- Compressor and motor servicing, compressor oil
- Small cryocoolers & dilution refrigerators
- Cryogenic instrumentation
- Storage dewars for cryogenic liquids & cryostats

On the other hand, there is an upgrade proposed to the Cryomodule Maintenance Facility, which includes:

- Cleanroom
- High Pressure Rinsing system
- Vertical Cavity Test Stands
- Assembly space and tooling
- This facility will require significant cryogenics and vacuum capabilities
- Cost & Schedule are still TBD

Finally, on cryogenics, due to prebuying of spares and existing framework agreements, there is a limited amount of new procurements expected during the next 5 years. These are mostly limited to the needs of the neutron instruments. Estimated for vacuum - 0.5MEuros in 2023, and 0.75MEuros annually for 2024 - 2027

3.8.5 E-XFEL

The reported future trends on cryogenic, vacuum and leak detection technologies at E-XFEL include securing operation, maintenance & substitution/upgrades and internal R&D projects

3.8.6 FAIR

The future tenders at FAIR include cryogenics, vacuum and leak testing technologies, and are summarized in Table 20

Table 20. Reported future needs at FAIR on cryogenics, vacuum and leak testing technologies

Need	Details	Vacuum requirements
Vacuum Chambers SFRS	17 Focal Plane Chambers 18 Pumping Chambers 30 Beam pipes, round shape 32 Bellows, round DN400& racetrack shape	outgassing rate 1x10-9mbar l/s cm2 leak rate 1x10-9mbar l/s special RGA acceptance criteria
Magnet Vacuum Chambers SFRS	3 NC dipole chambers 3+15 Dipole chambers bended for SC magnets 3+3 Dipole chamber branching for SC magnets	outgassing rate 1x10-9 mbar l/s cm2 leak rate 1x10-9 mbar l/s, special RGA acceptance criteria Relative magnetic permeability: ≤1.01
Magnet Vacuum Chambers HEBT	11 (24) Dipole chambers 120 (200) Quadrupole / Steerer Chambers 26 (47) Quadrupole Chambers elliptical	Integral leak rate ≤ 1x10 10 mbar l/s Outgassing rate ≤ 5x10 10 mbar l/s cm2 Residual gas composition as acceptance criteria UHV suitable cleaning Non bakeable
Vacuum chambers HEBT	84 (251) Straight beam pipe ~25 (65) Pumping Chambers 1 (6) Special Chambers 216 (567) Bellows	Integral leak rate ≤ 1x10-10 mbar l/s Outgassing rate ≤ 5x10-10 mbar l/s cm2 Residual gas composition as acceptance criteria UHV suitable cleaning Non-bakeable
Vacuum Chambers SIS100	11 Straight beam pipe 6 Chamber for resonance sextupole 2 Chamber rad. res. Quadrupole	Integral leak rate ≤ 1x 10-10 mbar l/s Outgassing rate (after bake out) ≤ 1x 10 12 mbar l/(s cm2) UHV suitable cleaning Bakeable up to 300 C Bake out cycle for acceptance test required
Vacuum Chambers SIS100	~120 Bellow cryogenic ~70 Bellow bakeable 50 Beam Vacuum Cold Warm Transitions (BV-CWTs)	Integral leak rate ≤ 1x 10-10 mbar l/s Outgassing rate (after bake-out) ≤ 1x 10-12 mbar l/(s cm2) UHV suitable cleaning Bakeable up to 300°C Bake-out cycle for acceptance test required
Standard components	~50-230 Gate & Angle valves all metal ~150-500 Gate & Angle Valves Viton/EPDM ~ 50-170 Turbo molecular pumps ~50-170 Roughing Pumps ~40-100 Mobile pumping stations ~10 Residual Gas Analyser	None
SFRS local cryogenics	Transfer Lines of Branch B central link Feed Boxes Branch E and R Capillary Piping for remote pressure sensors Warm Piping System auxiliary process lines Warm GHe Supply (WGS) Current-Leads Return (CGR)	None

Need	Details	Vacuum requirements
Others	KF parts	
	Small valves for venting	
	Fast closing valve system	
	Leak detectors	
	Bake out jackets	
	SIS100 Current Lead Box	in-kind delivery by Wroclaw University of Science and Technology (Poland)
	Cryogenic North-South-Link	About 200 m of cryogenic helium transfer line DN500

3.8.7 F4E

The reported future tender opportunities at F4E are summarized in Table 21.

Table 21. Reported future tenders at F4E on cryogenics and vacuum

Tender	Details	Est. 1st contract	Value
Neutral Beam Cryopumps	3 cryopumps (2 sides each)	2025	>10MEUR
Isotope Separation System	Cryogenic distillation of D-T	2026	
Radiological and Environmental Monitoring System		2025	
Water Detritiation System		2026	

3.9 Superconductivity and superconducting magnets

The list of companies with capacities in superconductivity and superconducting magnets is shown in Table 22.

Table 22. Companies with capacities in superconductivity and superconducting magnets

	Electromagnetism	Magnets and Superconductivity
Magsensas (LT)	☒	
Danfysik (DK)	☒	☒
Mark & Wedell (DK)		☒
AIRBUS DEFENCE AND SPACE (ES)		☒
ANTEC MAGNETS (ES)		☒

CITD ENGINEERING & TECHNOLOGIES (ES)		☒
ELYTT ENERGY (ES)		☒
EMPRESARIOS AGRUPADOS INTERNACIONAL (ES)		☒
IBERDROLA GENERACIÓN (ES)		☒
NANOKER (ES)		☒
PROACTIVE (ES)		☒
SUPRASYS (ES)		☒

On the other hand, and in accordance with Table 2, the facilities with business opportunities and future technological challenges in superconductivity and superconducting magnets are CERN and FAIR. The specific opportunities and challenges are summarized in the following sections:

3.9.1 CERN

In particular, the future technological challenges for CERN are mainly related to the FCC-ee power consumption of magnets. The FCC-ee baseline at the Conceptual Design Report:

- The FCC-ee is a conventional (warm) accelerator, much like LEP (CERN, 1989-2002) containing among others 2900 quadrupole and 6336 sextupole magnets, all normal conducting
- The total power loss in all (warm) magnet systems is ~80MW at the top energy of the collider
- **Technological challenges**:
    - Change magnets to superconducting magnets. Potential power reduction for these systems: ~90%
    - “Nest” the magnets, to reduce space. More pace available for bending magnets, so performance of the accelerator also increases

Other technological challenges reported by CERN are:

- “Co-extrusion technology” of Al-stabilizer and NbTi/Cu conductor to be resumed and widely available
- “Hybrid structure technology” by using electron beam welding (EBW) or by other approaches, to maximize the performance of Al-stabilized SC (Ni or Cu/Mg doped) combined with ultimately high-strength Al-alloy structure.
- Backup solutions such as soldering technology of NbTi /Cu conductor with Cu stabilizer, Cu coated Al stabilizer, and/or conductor technology developed for fusion applications (Cable in Conduit Conductor, HTS).

3.9.2 FAIR

The reported future tenders from FAIR regarding superconducting magnets can be found in Table 23

	time line	status: model	status: spec	# of magnets
SIS100 units	asap	Q4/22 (in revision)	Q4/22 (in revision)	3
CBM	asap	ok	10/22	1
APPA	asap	ok	ok	4
Super-FRS EB dipoles	2025	Q4/22	Q4/22	3
PANDA	2027	ok	ok	1
Collector Ring	mid-term	concept studies		26 (+ 29)
Beam line upgrade	mid-term	concept studies		tbd
HTS cable	mid-term	concept studies		n/a

Table 23. Procurement needs at FAIR regarding superconducting magnets extracted from BSBF 2022 PowerPoint presentation

4. Conclusions

A global overview of the information gathered in this document shows that, although not in every country (Denmark, Lithuania, Spain) have been identified companies with capacities for each block of key technologies, there is no block of technologies with a clear lack of providers.

As stated in the methodology (see Section 2), when an opportunity is identified, the companies listed under such capacities are contacted and informed. If a company estimates they need a partner with a specific capacity, they can also check in the capacities matrix which company can they partner with.

On the other hand, the Big Science market is mainly made up by small- to medium-size companies, many with niche capacities: for example, a company under the umbrella on "cryogenics, vacuum and leak detection technology" can have capacity in vacuum but not in ultra-high vacuum (with higher requirements). It is important to mention that the break-down of specific niche technology where each company has a capacity, and where a Big Science facility has a need, is outside the scope of this document.

Despite the above, and thanks to the knowledge of the BIGINN partnership on the companies of their country, two examples of cross-regional collaboration opportunities are shown:

- In terms of superconductivity and superconducting magnets, the collaboration between companies Mark & Wedell (DE) and Elytt Energy (ES) is key to approach CERN's future technological challenges related to the FCC-ee accelerator (see Section 3.9.1). Here, Elytt Energy could manufacture the superconducting magnets necessary to reduce the high power consumption nowadays in up to a 90%; and Mark & Wedell can provide the current leads necessary for the transition between the large copper conductor at the warm terminal and the small superconductor at the cold terminal in the Particle Accelerator.
- In terms of Diagnostics and detectors, sensors, optics and instruments, the collaboration between companies ASE Optics Europe or AVS (ES) and a Lithuanian company such as Eksma Optics or Ekspla could be of interest to give answer to the reported required technologies at ESO (see Section 3.2.3). In particular, technologies such as free form optics or integrated spectrographs. The Lithuanian companies could be the providers of laser and/or optics ad-hoc technologies, and the Spanish ones could act as the integrators, covering the whole need.

More than the half of the current and future opportunities in Big Science Facilities gathered in this document are designed for more than 1 company as they imply two or more diverse technological fields. Big Science companies are usually sized from Micro SME to Medium Size, so their expertise are niche. Also, some companies are manufacturers and some others are integrators, with a huge potential for covering the whole need of the Facilities, a challenging, but very promising, market.

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