BIGINN: a new beginning for business and Big Science innovation

COS-CLUSTER PROJECT N° 101037928 – BIGINN
Deliverable D3.4 Future tenders and technological trends in Big Science Organizations

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1. Introduction

1.1 Executive summary

This deliverable contains a list of business opportunities and main future technological challenges in the different organizations in Big Science sector in Europe. This list has been compiled in collaboration with the main European Research Organizations and their ILOs (industrial Liaison Officers – PERIIA network).

The document is focused on compiling the current main business opportunities and future technological challenges in the facilities. It also includes a brief description of each of the main Big Science facilities in Europe, together with an overview of their procurement procedures.

The knowledge on future tenders and technological challenges contained in this document has mainly been extracted, summarized and analysed from all the information presented by the main European Big Science Organizations during the event BSBF (Big Science Business Forum) held in Granada, October 2022 (presentations are only available for registered participants). It has been contrasted and updated with the information available in the procurement websites of each Big Science Organization. Also, the summary on procurement processes is based on the Procurement Handbook also released for such event. Moreover, the general knowledge of the authors of the document (INEUSTAR, DTI and LITEK) has made possible to expand and reformulate some of the raw information collected from such sources.

Conclusions are drawn from the gathered intelligence with a view to inform companies on the short and mid-term market opportunities. This will encourage more companies to participate in the next set of BIGINN Xchanges planned for 2023, that include more insights on the Big Science market and its opportunities.

1.2 Introduction and objectives

This deliverable D.3.4: “Future tenders and technological trends in Big Science Organizations” is linked with Task 3.2 “Business opportunities and technological challenges identification”. It will list the current and upcoming business opportunities in the European Big Science sector, compiled by the BIGINN project according to the public information provided by 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. European Big Science facilities and their procurement processes

This section includes information from the main Big Science facilities in Europe and the procurement procedure in each of them. The information from the facilities is mainly extracted from their own websites. The procurement procedures are derived from a merge between the Procurement Handbook published for BSBF congress (https://www.bsbf2020.org/Procurement_handbook) and each facility's tendering information at their own website.

2.1 CERN (European Organization for Nuclear Research)

The *Conseil Européen pour la Recherche Nucléaire* (CERN) was established in 1954 and has become a prime example of international collaboration. This facility is often referred to as The European Laboratory for Particle Physics (its main area of research is Particle Physics).

The work carried out at CERN helps to uncover what the universe is made of and how it works. This is done by providing a unique range of particle accelerator facilities to researchers, to advance the boundaries of human knowledge.

Some of the key technologies at CERN include radiofrequency cavities; magnets and superconductivity; vacuum and ultra-high vacuum; and cryogenics.

CERN's website for procurement is http://procurement.web.cern.ch/

As an intergovernmental organisation, CERN has established its own procurement rules which comply with the principles of transparency and impartiality while aiming to achieve a balanced industrial return for all its Member States. CERN works with a network of Industrial Liaison Officers (ILOs), who are appointed by CERN's Member States to facilitate the flow of communication between CERN and its suppliers. ILOs can provide advice on the opportunities available for doing business with CERN and the support available to firms in their local regions.

Firms are encouraged to register on CERN's supplier database which CERN uses as a key source of information for preparing lists of firms to invite to its price enquiries and market surveys. Registering on the supplier database allows CERN to match companies with relevant opportunities.

At CERN, contracts are awarded following price enquiries or invitations to tender.

- Price enquiries are made for contracts with an anticipated value below 200 000 CHF and are only open to a limited number of selected firms.
- For contracts above 200 000 CHF, invitations to tender are issued to firms qualified and selected based on a preceding open market survey. Such forthcoming tendering procedures can be found at https://forthcoming-ms.app.cern.ch/#!/, and any firm with interest can register to receive the market survey documents upon their publication.

Contracts for supplies are awarded to the firm whose bid complies with the country of origin requirements, the stated technical, financial and delivery requirements, and which offers the lowest price. However, for requirements exceeding 100 000 CHF, an alignment rule may apply which provides an advantage to a bidder if at least 60% of its supplies originate from poorly balanced Member States.

Contracts for services are usually adjudicated on a Best-Value-for-Money basis taking into account the technical quality of the bid as well as the price. Criteria used to evaluate a bid's technical quality are stated in the invitation to tender, and typically include the profiles of key personnel performing services, the bidder's experience and proposed quality assurance plan, and the bidder's score in field tests held at the CERN site.

2.2 EMBL (European Molecular Biology Laboratory)

The *European Molecular Biology Laboratory* (EMBL) was founded in 1974 with the mission of promoting molecular biology research in Europe, training young scientists, and developing new technologies. Nowadays, EMBL is Europe's flagship laboratory for the life sciences – an intergovernmental organisation with more than 80 independent research groups covering the spectrum of molecular biology operating from 5 cities across Europe (Spain, France, Germany, UK and Italy).

The aim of EMBL's research is to achieve a fundamental understanding of biological processes. EMBL has developed an integrative, interdisciplinary structure that is ideally suited to tackling this challenge.

EMBL provides hundreds of users each year with access to world-leading sources of X-ray and neutron radiation. It also provides access to advanced technologies in light microscopy, electron microscopy, chemical biology, flow cytometry, genomics, metabolomics, protein expression and purification, and proteomics. In Rome, EMBL hosts additional facilities in flow cytometry, gene editing and embryology, genetic and viral engineering, and microscopy. The Mesoscopic Imaging Facility at EMBL Barcelona enables 3D imaging of samples over time, allowing scientists to study biological systems at the scale of tissues and organs.

EMBL does not use a dedicated supplier portal and procurement opportunities are not currently announced online. Companies do not have to register in a database prior to entering a partnership with EMBL. The first point of contact for a company would usually be the Purchasing Department or, on some occasions, even the scientific unit directly. Suppliers are vetted for commercial and operational robustness prior to engaging in a contractual relationship.

EMBL member states do not appoint ILOs to facilitate the flow of communication and the interaction between EMBL and the industry. Nevertheless, EMBL is regularly contacted by its member states and provides statistics on its procurement activities.

As an intergovernmental organisation, EMBL has established its own procurement rules:

- The procurement procedures are selective, price enquiries and call for tenders do not take the form of an open invitation.
- All purchases including a single item costing over 12 500 EUR shall be demonstrably competitive unless the purchase request justifies in writing non-competitive acquisition.
- Invitations to tender shall normally be limited to manufacturers and contractors located within the territories of member states, contracts shall be awarded to the firm whose tender is the lowest which satisfactorily complies with the technical and delivery requirements.

- In issuing invitations to tender and entering contracts the Director General shall ensure that satisfactory conditions exist in relation to applicable law, performance and specification, delivery, price, guarantees, insurance, contractor's obligations, intellectual property and patent rights, arbitration and penalties for non-performance.
- Selective Criteria Based Procurement (CBP) potentially also combined with a final negotiation with the remaining successful bidders is the methodology used for purchasing goods or services exceeding 12 500 EUR where evaluation is not based on cost element alone and when the value and complexity of the purchase is important enough to warrant the additional procurement resource effort. The final negotiation has proven to be very efficient and very attractive for both EMBL and its partners, in particular for SMEs. It gives a very good insight of the EMBL environment and EMBL expectations to the bidder. In a face-to-face meeting, EMBL also gets a better overview of the suppliers' competencies and capacities for executing the specific work/providing the specific ser-vices required in the tender exercise.
- For all other less complex acquisitions over 12 500 EUR, the market will be, whenever feasible, sounded by requisitioning three quotations. Single source/sole supplier and/or unique technical feature/compatibility require the submission of a detailed written scientific justification. This justification shall be approved by the Purchase Department as stipulated in the EMBL financial regulations.

Eligibility criteria are the following:
- Location: According to EMBL rules and regulations, EMBL should preferably enter business with manufacturers, companies and contractors located within the territories of member states.
- Financial aspects: Financial stability, economic performance and reliability are considered.
- Resources & competency: The company should have the required manpower resources for engaging in a project with EMBL. The company should bring evidence of the team competences.
- Capacity: The company should be in a position of executing a project within the deadlines (re-sources availability).
- Past performances/References: Supplier's customer base and business references shall be provided and will be counterchecked.

Industrial and geo-return are not an essential part of EMBL's operational model.

2.3 ESA (European Space Agency)

The *European Space Agency* (ESA) was established in 1975 and currently counts with 22 Member States. ESA is Europe's comprehensive space agency, active across every area of the space sector and bringing its benefits to society.

ESA uses Earth observation satellites to monitor the Earth and develops new communications systems. Also, working with the European Commission, ESA has built Galileo – an independent global satellite navigation system for Europe. It provides warnings about hazards such as space debris, asteroids and extreme space weather. In addition to that, ESA has been deeply involved with space exploration for more than 40 years, helping to expand the frontiers of knowledge with robotic and crewed missions. In order to achieve all of this, technological innovations and state-of-the-art equipment is continuously developed.

ESA's website for procurement is https://doing-business.sso.esa.int/

ESA procurements are, as a rule, subject to open competitive tendering. In some justified exceptions, restricted competition or direct negotiations with economic operators from ESA Member States, Associated States and Cooperating States. ESA uses also permanent calls for proposals, open to initiative of companies willing to develop new technologies or space derived application services in partnership with ESA.

Entities wishing to do business with ESA must register in ESA's System for Tendering and Registration (esa-star). Companies wishing to do business with ESA can carry out their registration in two steps. A "Light" registration will grant access to all esa-star services up to and including proposal submission. The award of ESA contracts requires "Full" registration.
SMEs are encouraged to claim their SME status during the registration process in order to benefit from the Agency's SME support measures.

esa-star Publication is a module of ESA's electronic tendering system, used for publishing a list of upcoming Invitations to Tender, News, ESA Interacts, Invitations to Tender / Requests for Quotation open for bidding, as well as general information about ESA's procurement process.

To source ideas from economic operators ESA rolled out the Open Space Innovation Platform (OSIP), a website that enables the submission of novel ideas for space technology and applications. It is not a procurement tool but a website that provides Discovery and other ESA programmes with a platform to find the best research and ideas to support. Selected ideas might lead to a business partnership which would then go through the regular ESA procurement process.

All economic operators are eligible to submit a tender to ESA provided they; 1) belong to an ESA Member State, Associate State or Cooperating State and 2) do not fall under any of the exclusion conditions laid down in Article 18 of the Procurement Regulations and 3) have registered as potential bidders in the esa-star registration tool Concerning geographical return considerations and SME policies.

Tenders are evaluated against evaluation criteria that are published in the respective ITT and are weighted against pre-defined weighting factors also published in the ITT. The evaluation criteria are nominally five and include aspects such a background and experience, understanding of requirements, proposed programme of work, management, costing and planning and compliance to the draft contract. The tender evaluation board recommends contract award based on the resulting average weighted marks, considering also the overall price and any industrial policy aspects applicable to the procurement.

2.4 ESO (European Southern Observatory)

The *European Southern Observatory* (ESO) was established in 1962 as an intergovernmental organisation supported by 16 Member States. ESO brings together over 750 staff from more than 30 countries, and countless more collaborators worldwide, all driven by the passion to build the best telescopes, serve the community and benefit society.

ESO's telescopes are currently located in the Chilean Atacama Desert, a location with unique conditions to observe the sky. In addition, ESO is building "the world's biggest eye on the sky"—ESO's Extremely Large Telescope. ESO's Headquarters are located in Garching, close to Munich in Germany, where cutting-edge telescope technologies are developed together with industrial partners.

The ESO enables scientists worldwide to discover the secrets of the Universe for the benefit of all. They design, build and operate world-class observatories on the ground.

ESO's website for procurement is https://www.eso.org/public/industry/cp.html

Since 7 November 2022, ESO is running its new procurements through an electronic tendering tool. Any company that wants to participate in ESO procurements will have to register on this tool. On top of that, the ILOs play a key role in the identification of potential ESO suppliers. For every procurement in the ESO Member States over 50 000 EUR the ILOs are requested to suggest up to 5 potential suppliers in their Member State.

All procurements above 50 000 EUR and below 150 000 EUR are published in advance on the ESO forthcoming price inquiries page. Procurements over 150 000 EUR are published in advance on the ESO forthcoming calls page. All procurements at ESO above 1 000 EUR are handled by the Contracts and Procurement Department. There are two different procurement procedures:

- The price inquiry procedure that is applied for all procurements below 150 000 EUR and/or of a less complex nature. This procedure is characterised by the relatively short duration of the process (4-6 weeks) and the standardised contract based on the General conditions for Purchase Orders.
- The Call for Tender procedure (CFT) that is applied for all procurements above 150 000 EUR and/or of a more complex nature. This procedure consists normally of two steps. The first step is the Pre-liminary Inquiry (PI) during which interested companies can qualify themselves for the forthcoming CFT. The qualification is based on compliance with requirements regarding financial strength and experience in the field of the procurement. The second step is the CFT during which the companies qualified through the PI are invited to submit an offer to provide the requested works or services.

In preparation of any procurement, it can be decided to first follow a request for Information (RFI) process. The aim of this process, that is form free, is to obtain as much market information as necessary in order for ESO to be able to define the best procurement strategy. During this phase there is also the opportunity for interested bidders to gather more information regarding the upcoming procurement that can be used to their own benefit. Next to the competitive procurements and the RFI, ESO has the possibility to do single source procurements in justified cases where a competition is not possible or not desirable.

Besides some exceptional situations, like unavailability of certain goods and services in the ESO member States, only companies established in one of the ESO Member States are eligible to be invited to ESO procurements. Once a company is invited to a procurement the country of residence doesn't play a role anymore in the rest of the procurement process.

As evaluation criteria, ESO uses a so called "two envelope system" where the bidders are requested to submit two separate proposals, one containing the technical and managerial aspects and one containing the commercial/contractual aspects. Both proposals are evaluated separately against pre-defined evaluation criteria with a pre-defined scoring model. All offers that are evaluated technically/managerially and commercially compliant are eligible for contract award. Adjudication takes place based on the lowest priced compliant bid principle or the best value for money principle. Which principle is applicable is also pre-defined before release of the procurement. The evaluation criteria as well as the adjudication principle that will be used for the evaluation of the offers are part of the documentation that is sent to the participants.

2.5 ESRF (European Synchrotron Radiation Facility)

The *European Synchrotron Radiation Facility* (ESRF) was conceived as a true European collaboration for the advancement of X-ray science in 1988. From 11 partner countries to 22 nowadays, the ESRF is currently a centre of excellence for fundamental research, also committed to applied and industrial research. It is the world's brightest synchrotron, providing the international scientific community with unprecedented tools to study materials and living matter.

Thanks to the brilliance and quality of its X-rays, the ESRF functions like a "super-microscope" which "films" the position and motion of atoms in condensed and living matter and reveals the structure of matter in all its beauty and complexity. It provides unrivalled opportunities for scientists in the exploration of materials and living matter in many fields: chemistry, material physics, archaeology and cultural heritage, structural biology and medical applications, environmental sciences, information science and nanotechnologies.

The ESRF calls for tender are not published on the ESRF website but only through its Industrial Liaison Officers, who can direct the call to relevant potential suppliers, who are then invited to bid. The invitation to participate to Calls for tender is done using an on-line tool that enables the ESRF and the suppliers to exchange documents.

The ESRF is not subject to the rules foreseen for the public sector concerning the announcement of tendering processes. The ESRF applies the rules approved by its Council of Administration (ESRF Financial Rules).

At ESRF, procurement above 50 000 EUR are subject to Call for Tenders. For purchases exceeding 300 000 EUR, a double envelope process applies, one for technical aspects and a second for commercial aspects. Usually, the evaluation includes at minima the criteria for technical competencies, quality aspects, experience, delivery schedule, financial health, the price and the approval of ESRF contractual conditions.

The assessment of a company to be eligible for a procurement at ESRF is based on its technical ability and experience to fulfil ESRF requirements. A formal pre-qualification exercise can be done for large procurements that require stringent and sensitive technical capabilities. In such case an in-depth analysis of technical and financial aspects is performed prior to the launch of the call for tender.

At the ESRF, Contracts are awarded on a best-value-for-money principle. Industrial return to ESRF partner countries is monitored on a quarterly basis.

2.6 ESS (European Spallation Source)

The *European Spallation Source* (ESS) is a European Research Infrastructure Consortium (ERIC), a multi-disciplinary research facility based on the world's most powerful neutron source. The construction of the facility began in the summer of 2014, and the planning for the ESS user programme is ongoing.

The ESS is one of the largest science and technology infrastructure projects being built today. The facility design and construction include the most powerful linear proton accelerator ever built, a five-tonne, helium-cooled tungsten target wheel, 22 state-of-the-art neutron instruments, a suite of laboratories, and a supercomputing data management and software development centre. In the context of its history and future as a scientific organisation, however, it is more than the sum of its parts. It is a brand new Big Science organisation, built from the ground up.

ESS's web for procurement is https://europeanspallationsource.se/procurement/listings. There is also an e-tendering tool available: https://www.kommersannons.se/ess/Default.aspx

The ESS ILOs work as a link between ESS and their national industry. ESS and the ILOs collaborate to promote business opportunities at ESS and provide information regarding the ESS procurement process. For procurements in the range 50-200 KEUR, ESS uses a special type of Request For Quotation for which the ESS ILOs suggest companies to be invited in addition to the invitees selected by the ESS technical experts.

In general, all procedures above a certain value (currently 200 000 EUR) are open and published and conducted in one of the following three forms: open procedure, restricted procedure, competitive procedure with negotiation. Under some circumstances, the organisation may negotiate directly and obtain offers from one or more suppliers. Also in those cases, the aim is to ensure competition, if possible. Procurements below the publishing threshold are conducted as Requests For Quotation (RFQ) whereby suppliers are invited directly to submit quotations. In the range 50-200 KEUR, the ILOs are invited to suggest companies to be invited to the RFQs.

All interested companies are encouraged to register in the supplier database and to configure their profile to get notified about relevant tender opportunities. The e-tendering tool and website also contain a list of planned procurements for the coming 1-12 months, called Specific Advance Notices (SAN) and interested suppliers can also register interest in those procedures.

ESS does not have a geo-return model or any return policy in their governance. The ESS-ERIC procurement rules have to follow the basic EU principles of transparency, non-discrimination and competition and the main objective is best-value-for-money. Based on that, there is no restriction as to which countries tenderers can come from. Requirements regarding managerial, technical and financial capacity are defined in each procurement procedure on a case-by-case basis.

The award criteria in ESS tender procedures is generally following the best-value-for-money principle and considers elements such as technical quality, lead time and price. The scores and weighting are determined for each procedure individually.

2.7 E-XFEL (European X-Ray Free Electron Laser)

The *European X-Ray Free Electron Laser* (European XFEL or E-XFEL) is the world's largest X-ray laser. Its construction started in early 2009 and user operation began in September 2017. To construct and operate the European XFEL, international partners agreed on the foundation of an independent research organization – the European XFEL GmbH, a non-profit limited liability company under German law. At present, 12 countries are participating.

The European XFEL generates X-ray radiation with properties similar to those of laser light. To generate the X-ray flashes, bunches of electrons are first accelerated to high energies and then directed through special arrangements of magnets (undulators). In the process, the particles emit radiation that is increasingly amplified until an extremely short and intense X-ray flash is finally created.

https://www.xfel.eu/organization/procurement/calls_for_tender/index_eng.html is E-XFEL's website for procurement. The facility counts with an Industrial Liaison Office that assists the procurement office and the scientist, to create an interest in the Big Science market industry, to become possible suppliers of cutting-edge components.

The European XFEL is subjected to the European and National Public Procurement laws. European XFEL is therefore prohibited by these laws, to fulfil the policy of fair return to the shareholder countries in the procurement field. A larger pool of potential suppliers leads to a higher participation and competition in calls for tender, which often results in better quality and best value for money.

All national tenders for goods & services (with a value from 25 000 EUR to 215 000 EUR) will be announced on the XFEL homepage as well as the Bundsanzeiger, a government platform to announce National tender. All tenders for goods and services exceeding the value of 215 000 EUR, must be published via the Tenders Electronic Daily (T.E.D.) platform. The same procedure, only with different thresholds, applies to all tenders for constructions, social services and concessions. European XFEL has fully integrated e-tendering in their processes.

The evaluation criteria depend strongly on the type of commodity to be purchased. In general, XFEL uses best value for money, which in many cases is also supported by additional criteria's like expertise, references, excellence, environmental impacts, technical implementation, compatibility, managerial competencies, technical team, delivery time, added maintenance and more.

2.8 FAIR (Facility for Antiproton and Ion Research)

The *Facility for Antiproton and Ion Research* (FAIR) is one of the largest research projects worldwide. It is being built in Darmstadt, Germany, being realised in an international collaboration. The FAIR accelerator facility will have the unique ability to provide particle beams of all the chemical elements (or their ions), as well as antiprotons.

The FAIR facility consists of a superconducting ring accelerator with a circumference of 1 100 meters, storage rings and experiment sites with several kilometres of beam line in total. The existing accelerator facility of the GSI Helmholtzzentrum für Schwerionenforschung will serve as the injector for the new FAIR facility.

FAIR's website for procurement is https://www.gsi.de/en/start/business_industry

FAIR ILOs disseminate information about FAIR's needs, identify key businesses in their area, engage industry to become involved in FAIR, assist communication between industry and FAIR, disseminate information about the scientific possibilities of collaboration with FAIR, identify the potential for spin-off, spin-out and licensing in their area and promote the industry of their area in the scientific world, among others.

Because FAIR is a German limited liability company (GmbH) all tenders are published according to German procurement and state-aid law. All calls for tender above 30 000 EUR total purchasing value by FAIR and GSI are published in the Call for Tenders section. National German calls for tender above 30 000 EUR are additionally published on the Deutsches Vergabeportal. European calls for tender (over 214 000 EUR total purchasing value) are additionally published in the Supplement to the Official Journal of the European Union TED (Tenders Electronic Daily).

Where FAIR shareholders contribute in kind, they often launch their own call for tender, according to their national procurement laws. Each country has its own modalities and call websites:

Country	Shareholder	Where to check for calls
Finland (in consortium with Sweden)	Vetenskapsrådet (Swedish Research Council)	www.vr.se/english.html
France	CEA and CNRS	www.marches-publics.gouv.fr
Germany	GSI GmbH	https://www.dtvp.de/
India	Bose Institute	www.thetenders.com/All-India-Tenders/Agency/Ten-ders-Of-Bose-Institute/
Poland	Jagiellonian University	https://opentender.eu/pl/search/tender
Romania	Ministry of Research and Innovation	http://anap.gov.ro/web/
~~Russian Federation~~	~~Rosatom~~	~~http://zakupki.rosatom.ru/en/~~
Slovenia	Ministry of Education, Science and Sport	https://opentender.eu/si/search/tender

Table 1. Websites for FAIR procurement

The majority of tenders for complex components are performed as "negotiation tenders," allowing preselection of capable bidders as well as technical reviews as well as intense negotiations during the purchasing process. If the subject of the procurement activity is fully described and no technical or commercial reviews are needed, the "open tendering procedure" is used. In this case, the award is based on capability and the submitted offers.

Depending on the procurement volume and the risk associated with the procurement package, FAIR and GSI may demand certain eligibility criteria such as minimum annual turnover, "European single procurement document (ESPD)" self-declaration form, proof of experience in the relevant market field by self-declaration, proof of availability of dedicated manufacturing equipment by self-declaration; or proof of certificates, either related to quality, personnel or equipment by self-declaration.

On the other hand, typical performance criteria might include technical concept (e.g., technical solution, highlight of critical features incl. suggestions to solve, resource availability, qualification design & development), manufacturing (e.g., availability of capacity, process flow, description of equipment and measurement devices...), lead-time, quality assurance or serviceability.

2.9 F4E (Fusion for Energy)

Fusion for Energy (F4E) was established in 2007 for a period of 35 years. It is the European Union organisation managing Europe's contribution to ITER - the biggest scientific experiment on the path to fusion energy.. Europe is responsible for nearly half of the project, while the other six parties contribute equally to the rest. This translates into a wide range of business opportunities for companies and R&D organisations. Europe's involvement in ITER offers them the possibility to extend their new know-how and gain access into a new energy market.

The mission of F4E is to bring fusion, the energy of the Sun and the stars, to Earth. To do so, they work closely with industry and research organisations to provide the infrastructure and the components of the biggest fusion device. In parallel, F4E is involved in three major fusion

R&D projects, stemming from the Broader Approach Agreement signed between Europe and Japan. Ultimately, F4E will contribute to the development of demonstration fusion reactors by offering technical know-how and expertise.

The website for F4E procurement is https://industryportal.f4e.europa.eu. F4E relies on a network of Industrial Liaison Officers (ILOs) from different European countries working to raise awareness regarding its opportunities and ways to get involved in the fusion projects. ILOs are directly nominated by F4E Member States.

This Industry Portal offers information about business opportunities, procurement modalities and key reference documents; it also hosts the partner's database and the e-procurement platform. The information therein is not limited to the announcement of calls (which are as a rule also published in TED) but includes also key reference documents such as the contract notice, specifications and technical annexes.

Procurement in Fusion for Energy follows the rules laid out by the European Commission in its General Financial Regulation with specific derogations, specified in F4E's Financial Regulation. The legal basis ensures that the following principles are respected through all steps in a procurement procedure: transparency, equal treatment, widest competition, proportionality and sound financial management.

Based on the scope of the purchase (research, support services, manufacturing of prototypes, series production, etc.), the value, the complexity of the scope or whenever specific indications are identified through market analysis, F4E will use the most suitable tender procedure to select the most economically advantageous tender. F4E can use 5 different types of procurement procedure: Open procedure, restricted procedure, negotiated procedure, competitive procedure with negotiation, competitive dialogue procedure.

The offers submitted shall in general address the way in which the company will implement the tasks described by F4E in the Technical Specifications. The Tender Specifications include all the additional specific requests and conditions which must be covered by an offer to be considered for award. Depending on the strategy, contracts will be awarded either to the cheapest offer (in simple cases) or to the offer presenting the best value for money (a combination between the quality of the proposal and the price offered, where necessary complemented by negotiations).

Participation to F4E's calls for tenders is open as a rule to economic operators from F4E Member States (EU27 + CH). In special justified cases the participation can be opened worldwide (e.g., when insufficient competition is existing in the Member States). Subcontracting is not directly limited to F4E Member States, although specific requirements can introduce additional constraints in this respect. The minimum capacity required from tenderers (in terms of technical expertise, facilities or financial stability) are defined for each call and are proportional to the scope and requirements of the contract. Procurement strategies are established to allow for maximum possible competition and to promote where possible participation of SMEs. In compliance with F4E's Industrial Policy objectives, procurement strategies pro-mote the development of critical fusion technologies within companies registered in F4E Member States.

The purpose of evaluation of tenders in F4E is to assess technical and financial offers to choose the most economically advantageous one. When award occurs to the offer with the best ratio quality vs price (the award method which is most used by F4E) the weighting between the price and the quality elements depends on the scope of the contract. As a rule, F4E also sets minimum levels of quality below which offers are excluded. In most cases F4E gives significant importance to the merit of the quality plan and the reliability of the proposed schedule, the methodology proposed for the manufacturing, identification of risks and their mitigation actions, the internal organisation of the bidding team (consortium and/or subcontractors).

2.10 ILL (Institut Laue-Langevin)

The *Institut Laue-Langevin* (ILL), established in 2007, is an international research centre at the leading edge of neutron science and technology. As the world's flagship centre for neutron science, the ILL operates the most intense neutron source in the world, a 58.3 MW nuclear reactor designed for high neutron flux, feeding some 40 state-of-the-art instruments, which are constantly being developed and upgraded. As a service institute the ILL makes its facilities and expertise available to visiting scientists. Every year, about 1 400 researchers from over 40 countries visit the ILL and 640 experiments selected by a scientific review committee are performed.

Research on ILL focuses primarily on fundamental science in a variety of fields: condensed matter physics, magnetism, chemistry, biology and health, nuclear and particle physics and materials science, etc. The neutron techniques available in the facility are neutron diffraction, small-Angle Neutron Scattering, neutron reflectometry, neutron spectroscopy, neutron imaging. The technology also includes detectors, optics and isotopes production for medicine.

The ILL website for procurement is https://www.ill.eu/neutrons-for-society/doing-business-with-the-ill. In 2023, an e-procurement platform is expected. Industrial Liaison Officers are appointed by ILL's Member States to facilitate the flow of information and opportunities between ILL and its suppliers. ILO's can provide advice on doing business with ILL and they have access to all the available call to tenders. They are currently the main entry point for doing business with the ILL.

The ILL purchases equipment and services in compliance with its procurement rules. ILL's procurement procedures are selective and its invitations to tender and price enquiry documents are designed to guarantee fair competition. Contracts and orders are awarded to the firm whose bid meets the technical, financial and delivery requirements and represents the best value for money. It is the Purchasing Service's main mission to manage the ILL's business with its suppliers, ensuring that its contracts and purchasing procedures guarantee both quality and overall compliance.

2.11 SKAO (Square Kilometre Array Observatory)

The *Square Kilometre Array Observatory* (SKAO) is an intergovernmental organisation, established in 2021. It began its construction on December 5th, 2022. The SKAO, formally known as the SKA Observatory, is an intergovernmental organisation composed of Member States from five continents and headquartered in the UK. Its mission is to build and operate cutting-edge radio telescopes to transform our understanding of the Universe and deliver benefits to society through global collaboration and innovation.

The SKAO is a next-generation radio astronomy Big Data Facility. Its two telescopes, each composed of hundreds of dishes and thousands of antennas, will be constructed in South Africa and Australia and be the two most advanced radio telescopes on Earth. A later expansion is envisioned in both countries and other African partner countries.

Together with other state-of-the-art research facilities, the SKAO's telescopes will explore the unknown frontiers of science and deepen our understanding of key processes, including the formation and evolution of galaxies and fundamental physics in extreme environments. It will also investigate the dark energy that is proposed to accelerate the expansion of the Universe; and test Einstein's theory of general relativity by investigating gravity around black holes, and timing pulsars and the origins of life.

SKAO's procurement database is https://www.kommersannons.se/skaobservatory/. After pre-informing the SKAO ILO network, all significant contract opportunities are advertised. Any specific tendering restrictions are highlighted alongside every highlighted procurement opportunity. A significant number of competitive tender opportunities are restricted to potential suppliers from pre-defined SKAO member countries.

The SKAO always pre-qualifies potential tenderers before they are invited to take part in the subsequent tendering exercise. All potential tenderers will be invited to complete and submit a pre-qualification questionnaire and provide additional supporting documentation as requested. The SKAO maintains a database of all qualified suppliers and encourages all interested suppliers to register on the SKAO Supplier Portal.

The SKAO is an international organisation established by convention and external regulations, such as the European public sector procurement rules, do not apply. The SKAO procurement process is typical of other similar organisations insofar as restricted competitive tendering is their preferred route to market.

Subject to overriding fair work return considerations, the SKAO always awards to the supplier submitting the 'most economically advantageous tender', i.e., best overall value for money to the SKAO. Best value for money is evaluated against various pre-defined criteria such as quality, price, total cost of ownership, lowest environmental impact etc. Evaluation criteria and weightings are always highlighted within SKAO's tender documentation.

3. Main business opportunities and future technological challenges

This section includes a summary of the information presented by each Facility at the BSBF congress held in Granada (Spain) in October 2022 and been updated with the information published at each facility's tendering information, at their own website. The presentations from BSBF congress are only available to the participants in the event.

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:

	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		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		

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

3.1 CERN

CERN's website for procurement is http://procurement.web.cern.ch/

For the 2022–2026 period, CERN plans to spend 2.5 billion Swiss francs on procurement (2 509 MEUR). The main ongoing procurement projects are:

- 'High Luminosity LHC' (HL LHC), a major upgrade to both the LHC machine, with also major upgrades to the LHC experiments
- A long term Consolidation project (CONS) to update and replace many of the older machine systems, in particular fixed target beam experimental areas (NA CONS, EA CONS)

3.1.1 Electrical, power electronics, electromechanical and RF systems

In mechatronics and electronics

➔ Full Remote Alignment System (FRAS) project.
  - Alignment sensors, motorized adapters, their acquisition and control/command systems, associated software.

- All components from Q1 to Q5 (i.e., quadrupoles and dipoles magnets, collimators) in the LHC interaction points.
- Installation and commissioning deadline: LS3 (end 2028)
- **Future tender** 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

➔ Sensors Acquisition & Motion Control (SAMbuCa)

- **Future tender** PXIe Carrier (400 units), Market Survey for Q1 2024. Technical responsible Javier Serrano
- **Future tender** COMe CPU (400 units), Market Survey for Q4 2023. Technical responsible Javier Serrano
- **Future tender** PXIe-COMe adapter (400 units), Market Survey for Q1 2024. Technical responsible Javier Serrano
- **Future tender** FMC cards for Motion control (400 units), Market Survey for Q1 2024. Technical responsible Javier Serrano
- **Future tender** Stepping Motor Drivers (1200 units), Market Survey for Q2 2024. Technical responsible Javier Serrano
- **Technological challenges:**
    - 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

- Detection and interception of radioactive objects at CERNs site exits
- The procurement strategy is not yet decided. Two possible alternatives: (a) Full externalization → engineering and manufacturing (open to collaboration) (b) Partial externalization → Only manufacturing and assembly (engineering in house)
- Complete renewal of CERN car gates RP monitoring systems by LS3 (i.e. 2028)
- **Future tender** Site gate monitoring system (30 units). Market Survey for Q3 2023. Technical responsible Hamza Boukabache
- **Technological challenges:**
    - 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

➔ Electronics Workshop machines renewal

- BGA repair station: Infra-red based process, embedded mini-stencil station, live process control (temp+camera), max PCB dimension to be determined, semi-automated at least.
- Reflow oven: Vapor phase process, real time temperature control, PCB dimension up to 650x650mm, batch equipment.
- **Future tender** BGA repair station. Market Survey for Q1 2023. Technical responsible Raphael Berberat
- **Future tender** Reflow oven. Market Survey for Q1 2024. Technical responsible Raphael Berberat

➔ Robotics
- ROV with robotic arm (Minimum 6DoF, ~ 100 kg payload, Minimum speed 2km/h, Battery autonomy > 4hours)
- ROV base only (Minimum speed 2km/h, Battery autonomy > 4hours)
- Versatile legged and wheeled solutions to reach complicated zoned with robotic arm (~ 5 kg payload, Minimum speed 2km/h, Battery autonomy > 2 hours)
- Motion capture system (Area to cover ~ 5 x 5 meters, Sub mm precision, Up to 20 objects to track, > 200 Hz of acquisition rate)
- **Future tender** ROV with robotic arm. Market Survey for Q3 2023. Technical responsible Mario Di Castro
- **Future tender** ROV base only. Market Survey for Q1 2023. Technical responsible Mario Di Castro
- **Future tender** Versatile legged and wheeled solution. Market Survey for Q2 2023. Technical responsible Mario Di Castro
- **Future tender** Motion capture system. Market Survey for Q1 2023. Technical responsible Mario Di Castro

In electrical network and power electronics

➔ Supply
- **Future tender (blanket contract)** 24 kV compact switchgear. Market Survey for 2023.
- **Future tender (purchase order)** 2 emergency gensets rated 1.5 and 2.5 MVA. Market Survey for Q2 2023.
- **Future tender (blanket contract)** UPS units from 20 to 200 (100 units). Market Survey for Q1 2023
- **Future tender (purchase order)** UPS installations from 300 to 2000 kVA (4 installations). Market Survey for Q3 2024
- **Future tender (purchase order)** Lead acid batteries for UPS (2300 monoblocs). Market Survey for 2023

➔ Electrical power converters
- Solid state modulators for RF klystrons
- High voltage power converters for RF amplifiers and particle sources
- Power converters from 100W to 100MW for DC, cycling or pulsed magnets
- Static VAR compensators and harmonic filters
- **Technological challenges:**
    - 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

3.1.2 Diagnostics and detectors, sensors, optics and instruments

➔ Optical fibres
- **Future tender (blanket contract)** 1500 km of radiation resistant single mode optical fibres. Market Survey for 2023. Technical responsible Daniel Ricci

➔ Beam instrumentation
- 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. Technical responsible Ray Veness

3.1.3 Information and communication technologies

Tender opportunities for servers and storage procurement will take place in 2023.

- ➔ Server procurement achieved in HEPSPEC06
  - Aim:
    - 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
  - Aim:
    - 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

3.1.4 Basic material technologies and advanced manufacturing techniques

Technical contact Ignacio Aviles

- ➔ Stainless steel, special grades and shapes
  - Strips of 316 L grade 1 4441 1 4435 or 1 4404 for bellows' convolutions
    - ESR remelted
    - Very low impurities (P&S)
    - Composition guarantees: Ferrite free, no martensitic transformation after cold work
  - Very tight requirement on inclusion content to avoid leaks
  - **Supply challenge:**
    - Limited consumption and scarce availability in small quantities
  - **Future tender** Rolled and forged round bars (grade 316LN EN 1.4429)
  - **Future tender** 3D forged blanks, rings (grade 316LN EN 1.4429)
  - **Future tender** Sheets and plates (grade EN 1.4307 / 1.4404 – for pressure purposes)
  - **Future tender** Round bars (grade 316L EN 1.4435)

- ➔ Titanium and titanium alloys
  - Fluctuation of the demand of plates for the crab cavities' He tanks (grade 2).
  - Relatively steady demand of bars for the fabrication of flanges (Grade 5 and grade 23)
  - **Supply challenge:**
    - Purchasing of small quantities but with very demanding quality requirements

- ➔ Needs of others for HL-LHC

- **Future tender** Tungsten heavy alloy - Absorbing material for tertiary collimators blocks and for masks. Market Survey for Q 1 2023
- **Future tender** CuCr1Zr - Material for tapering for the tertiary collimator's jaws. Market Survey for Q 1 2023
- **Future tender** Graphite - Absorbing material for secondary collimators blocks and taperings. Procurement Q 1 2023
- **Future tender** Graphitic material (isostatic Graphite and Sigraflex) for the HL-LHC TDE Dump Cores. Market Survey for Q2 2023
- **Future tender** Al 6061 T 6 for DQW Thermal Shield. To be purchased in 2023
- **Future tender** ODS copper collimators backstiffeners. Market Survey for Q 2 2023
- **Future tender** Stainless steel 1.4441/1.4435/1.4404 Strips for series production of 400 HL LHC bellows. Market Survey for Q 1 2023
- **Future tender** Stainless steel 1.4404/1.4435/1.4306/1.4307 bars for flanges for for series production of ~400 HL LHC bellows. Market Survey for Q 1 2023

➔ Steel for vacuum chambers: the Einstein telescope
- **Technological challenge:** Is it possible to build UHV chambers with a cost-effective solution (mild steel, ultra-low carbon steel…)?

3.1.5 Complex building construction and its safety related systems

Technical contact Pierre Ninin

In complex buildings

➔ Prevessin Office Center
- 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
- **Future tender** Prevessin Office Center. Market Survey in 2023

➔ B140 (Meyrin)
- Office building, training center, light laboratories, cafeteria & parking
- 18000 m^2
- Emphasis on sustainable design & construction
- Built in two phases
- **Future tender** B140 Tendering process to target delivery of the 1st Phase in 2027 and 2nd Phase in 2030

➔ Point 5 (Cessy)
- Civil engineering for electrical installations and harmonic filters
- **Future tender** Point 5. IT Q4 2022 (phase 1), 2023 (phase 2). Works 2023 and 2024

➔ Vertical core excavation HL-LHC
- 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
- **Future tender** Vertical cores. Market Survey for Q1 2023. Works 2024-2025

➔ Retention basins
- 3 Projects under discussion. Ad hoc tendering for studies and construction.
- **Future tender** France in 22-23, Switzerland 23-24

➔ Sustainable Heating Plants
- Main power via renewable energy sources to cover the major part of the current heating needs in Meyrin & Prevessin sites.
- **Future tender** projects under discussion. 2023

In safety systems

➔ LHC & Experiments Automatic Gas and ODH detection systems renewal
- 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.
- **Future tender** System renewal, expected end 2023

➔ Sniffer system renewal for LHC Experiments (ATLAS, LHCb , ALICE)
- Development: detection (smoke, flammable & toxic gas), electronic acquisition card.
- Cabinets renewal. Depends on the experiment
- On hold

➔ LHC Evacuation Renewal
- Renewal of LHC Audible Emergency Evacuation system composed of:
  - Système de Mise en Sécurité incendie" (SMSI) interfacing with PPS and containing safety action matrices
  - "Système de Sonorisation de Sécurité" (SSS) triggering Beam Imminent Warning and Evacuation sounds (control Indicating Equipment (CIE), Loudspeakers, Micros and MMI, power supplies, etc.)
- On hold

➔ Fire Detection & Protection Prospection
- Market investigation for competencies and new technology in Fire Detection and competencies in Fire protection (extinguishing means) for future contracts
- On hold

3.1.6 High precision and large mechanical components

➔ LHC collimators
- 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 stabilised at ?1?C.
- **Future tender** production, assembly and Quality Assurance of 36 collimators. Market Survey ongoing

3.1.7 Instrumentation, control and CODAC

➔ Sensors Acquisition & Motion Control (SAMbuCa) (see 3.1.1)

➔ OASIS high-speed digitizers
- A distributed oscilloscope application for operators and equipment experts
- 1500 signals acquired by 350 multiplexed digitisers. Using 370 trigger events
- Another 2200 signals from FGCs and 850 signals from other data sources
- Current systems based on Compact PCI and PCI
- Complete consolidation required by LS3 (2028) because of EoL of the installed digitizers
- **Future tender** 8 bits. 1 GSPS sampling rate. 500 installed channel count. Existing form 50% cPCI, 50% PCI. New Form PXIe (4+ channels per slot). Market Survey for Q1 2025. Technical responsible Dimitris Lampridis
- **Future tender** 10 bits. 2 GSPS sampling rate. 45 installed channel count. Existing form cPCI. New Form PXIe (2+ channels per slot). Market Survey for Q4 2023. Technical responsible Dimitris Lampridis
- **Future tender** 10 bits. 4 GSPS sampling rate. 20 installed channel count. Existing form cPCI. New Form PXIe/PCIe (2+ channels per slot). Market Survey for Q4 2023. Technical responsible Dimitris Lampridis

➔ DI/OT project
- Distributed I/O Tier: where electronics modules installed close to a particle accelerator in radiation-exposed or radiation-free areas controlled by the master in the Front-end tier over the fieldbus
- These are usually FPGA-based boards sampling digital and analog inputs, driving outputs and performing various safety critical operations.
- **Future tender** 200 DI/OT crate. Market Survey for Q2 2023. Technical responsible Greg Daniluk

➔ White Rabbit
- White Rabbit provides sub-nanosecond accuracy and picoseconds precision of synchronization for large distributed systems (IEEE1588-2008)
- It allows precision time-tag measured data using the same network to transmit data
- It is foreseen to consolidate by 2028 all the CERN accelerator timing (i.e. Rs485 copper based) with WR
- **Future tender** 150 WR switches v.3. Market Survey for Q1 2023. Technical responsible Evangelia Gousiou
- **Future tender** 100 WR switches v.4. Market Survey for Q1 2023. Technical responsible Evangelia Gousiou

➔ VME System Boards CPU

- More than 1000 VME crates are currently in operation in the CERN accelerator complex as front-ends for controls and acquisition
- Around 900 VME crates are equipped by a system board that will be obsolete by 2028:
    - Increase MTTF
    - Memory not enough for new applications
    - Intel Core 2 Duo not supported by new Linux distribution
- A smooth consolidation campaign will be launched in the next couple of years
- **Future tender** 1200 VME System Board. Market Survey for Q1 2023. Technical responsible Erik Van Der Bij

3.1.8 Cryogenics, vacuum and leak detection technologies

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

3.1.9 Superconductivity and superconducting magnets

High Field Magnet Programme Hosted at CERN
HFM programme aims to look forward to a future of accelerator magnet technologies and builds, in particular on the past conceptual designs of FCC-hh magnets
Fostering and profiting from collaborations with EU partners will be an essential part of the HFM programme as well as linking to ongoing worldwide efforts

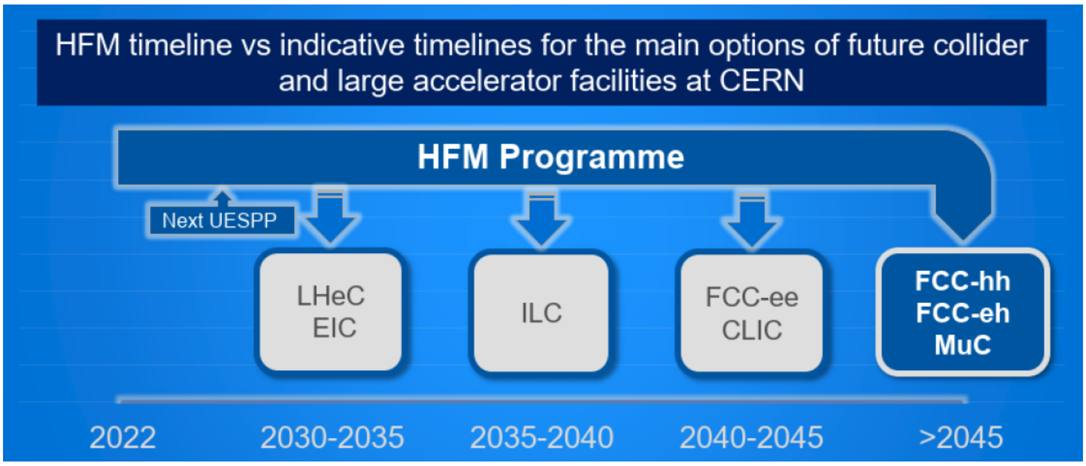

Figure 1. BSBF 2022. A. Siemko - Shaping a new generation of high field magnets for future accelerators at CERN

The Accelerator R&D Roadmap at CERN identifies two main objectives for the HFM programme:

1) To demonstrate Nb_3Sn magnet technology for large scale deployment. This will involve:
    a. moving towards production scale through robust design, industrial manufacturing processes and cost reduction, taking as a reference the HL LHC magnets, i.e., 12 T)
    b. pushing the Nb_3Sn magnet technology to its practical limits in terms of ultimate performance (towards the 16 T target required by FCC_{h-h})
2) To demonstrate the suitability of high temperature superconductors (HTS) for accelerator magnet applications, providing a proof of principle of HTS magnet technology beyond the range of Nb_3Sn, with a target in excess of 20 T

R&D Strategy and Focus Areas (2022-2027):

➔ Topic 1 Nb3Sn Conductors
  - Present limitations linked to stress/strain sensitivity and degradation, to be overcome by
    - improved mechanical robustness
    - higher Jc (thus, increased margins)
  - Development and industrialization of improved Nb_3Sn superconductors will require industrial partners
  - Otherwise, magnet structures must be adapted to deal with performance limitations in more realistic ways than FCC-hh CDR (see topic 3)

➔ Topic 2: 12 T Robust Nb_3Sn Magnets
  - Implement all lessons learned from LARP + HL-LHC programs
  - Demonstrate maturity of Nb_3Sn technologies
  - Improve manufacturability and protection of coils against overstresses
  - Collaboration of CERN as well as INFN with the industry is an integral part of this project
  - Reaching 14+T with this robust technology will be aided by improved mechanical robustness of conductor (see Topic 1)

➔ Topic 3: 14+T Feasibility Studies
  - Multiple, exploratory magnet development by EU laboratories.
  - Approaches range from evolutionary, based on LARP/HL-LHC technology to departures from state of the art.
  - From evolutionary to revolutionary: cos theta (see Topic 2) block coil (reduced high field coil stress) common coil (simplification of coil manufacturing) stress managed

version of either coil variant (drastically reduced coil stresses, at cost of lower efficiency)
- 1st priority: performance and (sufficient) robustness.
- 2nd priority: maximum robustness and reduced cost.

➔ Topic 4: HTS Conductor and Magnet Technology
- Improve ReBCO conductor in view of accelerator requirements.
- Development of alternative HTS superconductors.
- Stand-alone demonstrator magnets.
- Subscale tests in background field and hybrid HFMs.

In particular, the following technological challenges are introduced

➔ 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

➔ Others
- **Technological challenges**:
    - "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).

3.1.10 Remote handling systems

➔ TAN crane
- Project in proposal phase
- Stainlees steel structure
- Camera system
- Remote control desk and cubicles
- **Future tender** for 2026-2027

➔ Hot cell
- Project in preliminary analysis
- Repair of activated equipment
- Post-mortem analysis
- Waste treatment: sorting of parts according to their activation to optimize the volume of waste
- Building equipped with:
    - Overhead crane

  - Manipulators
  - Tooling

➔ Tooling
- Specific or general-purpose handling accessories

3.2 EMBL

EMBL does not use a dedicated supplier portal and procurement opportunities are not currently announced online.

Based on an extrapolation of the average procurement budget of the past years, the total estimated procurement budget for the period 2022-2026 amounts to 237 million EUR.

During the next five years, EMBL will invest in its campus and IT-infrastructure (compute, storage, connectivity, data security) and procure a diverse range of scientific equipment, among others: state-of-the-art high and ultra-high-resolution light and electron microscopy. It will also continue investing in beamline detectors and instrumentation.

3.2.1 Information and communication technologies

Per year, **future needs** in EMBL are expected to be the following:

➔ 2023:
- Large scale object storage (40PB+)
- Tape library hardware and tape media (30PB+)
- S3 API compliant tape management software and tooling (100PB+)

➔ 2024: Similar to 2023

➔ 2025: A replacement HPC cluster environment

Challenges:
Many storage, data management and analytics products tailored to life sciences data offer attractive features, however:
- Most advanced features do not scale well beyond 20PB and several billion files
- Storage and tools at this scale often need to be simple to be sustainable

3.3 ESA

ESA's website for procurement is https://doing-business.sso.esa.int/

ESA's procurement budget is in the range of 5.5 billion EUR per year in the period 2022-2026, foreseeing to place more than 1000 contracts per year. This involves procurements in all areas where ESA is active.

3.3.1 Electrical, power electronics, electromechanical and RF systems

➔ **Challenges** for RF payloads:
- Antenna/Repeater technolonogyfor 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

➔ **Challenges** for new 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

3.3.2 Diagnostics and detectors, sensors, optics and instruments

Technical contact Evridiki Vasileia Ntagiou

In Artificial Intelligence:
- **Future tender** Few GSTPs covering the remaining use cases in groups
- **Future tender** Activities for enablers of AI: generation of synthetic data, qualification of ML algorithms, etc
- **Future tender** ESA Community License
- **Future tender** Agile approach

3.3.3 Information and communication technologies

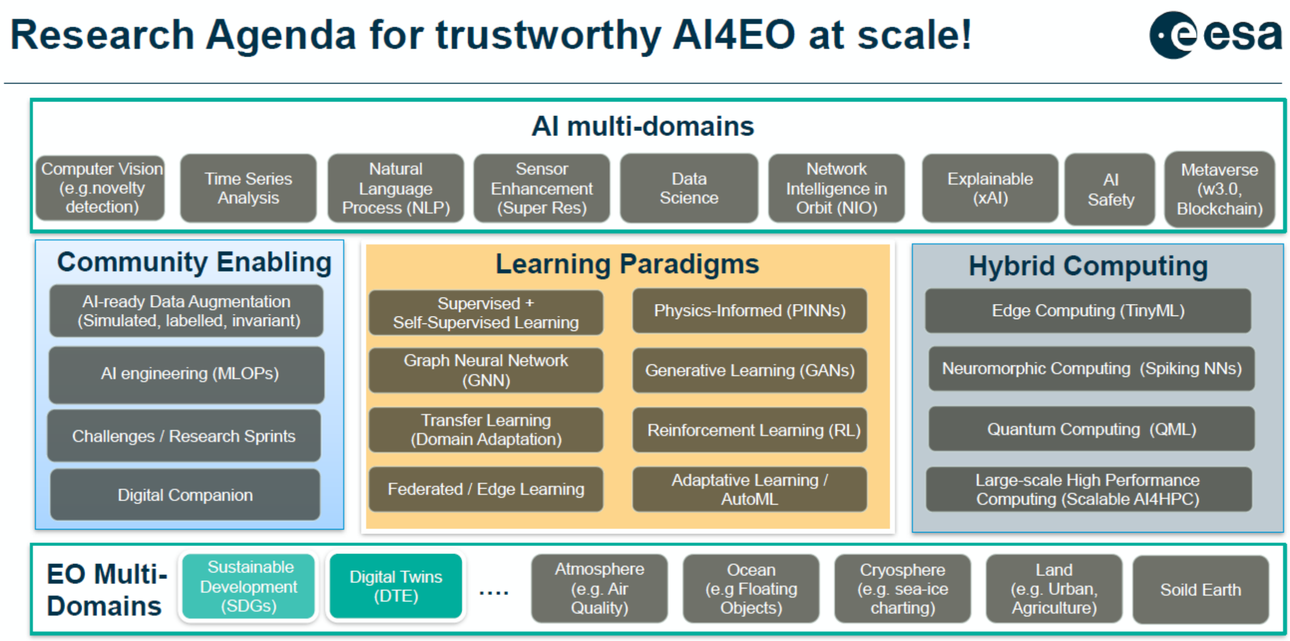

Figure 2. BSBF 2022. Pierre-Philippe Mathieu, Head of Phi-Lab Explore Office

3.3.4 Basic material technologies and advanced manufacturing techniques

Areas of interest in Advanced manufacturing:

- Verification Methods/NDI/Metrology
- Virtual Manufacturing/Factory
- Process Modelling/Simulations
- Standardization
- Personnel Training
- Materials Processing
- Surface Engineering
- Additive manufacturing/
- Shaping
- Joining/Bonding
- Assembly
- Metals
- Polymers
- Ceramics
- Hybrid Functional
- Electronic Materials

3.3.5 High precision and large mechanical components

➔ 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

➔ Manufacturing for Space
- Current approach:
  - Design and manufacturing of spacecrafts for launch on ground
    - Launcher fairing size limitation → Spacecraft structure (e.g. solar array, antennae) size limitation → performance limitation
    - Design to resist launch loads → i.e. added mass, long qualification
    - Long time to market
  - Alternative: Deployable structures → Complexity, long lead time
    - Infrastructure and supplies for human exploration missions are provided from Earth, as redundancy payload or through regular cargo missions:
    - Significant amount of supplies not used (in addition to packaging, etc…)
    - Launch costs associated to cargo missions
    - Not practical for future missions to remote destinations (e.g. Mars)
- **Challenges.** New paradigm: on-orbit manufacturing

  - 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

3.3.6 Instrumentation, control and CODAC

ESA periodically (every 2-3 yrs) releases a "technology harmonization dossier" that summarises state-of-the-art, trends, market analysis, project needs and roadmaps including recently closed, running and proposed new activities (in next 5 years).
Last "OBCDHSM dossier" release: 29 Nov 2021 "TECHNOLOGY HARMONISATION DOSSIER - ON-BOARD COMPUTERS, DATA HANDLING SYSTEMS AND MICROELECTRONICS-" ESA/IPC/THAG(2021)5 includes 130 new proposed activities -> 104M€ (average 800K€ per activity)
All European space sector stakeholders can request access to the Harmonisation Document Management System (HDMS/DCCM: https://tec-polaris.esa.int/eclipse) by sending an e-mail to harmo@esa.int providing business affiliation and position in the company.

The new THD dossier OBCDHSM contains detailed State-of-the-Art, Trends and activity Roadmaps
Technology overview and trends organized in 3 technology families:

- Technology Family 1: CDHS Architecture, units, modules and communication systems
  - Platform and Payload CDHS Architectures Background
  - CDHS Units, Modules and functions (Platform and Payload)
  - CDHS communication links, buses and networks
- Technology Family 2: Microelectronic devices and enabling technology
  - FPGA (Field Programmable Gate Array)
  - Microprocessors, microcontrollers, DSP
  - ASSP (Application Specific Standard Products) (digital, analogue and mixed-signal)
  - ASIC (Application Specific Integrated Circuit) platforms (rad hard cell libraries, IP, Design Kits, packaging, supply chain space quality)
  - IP (Intellectual Property) Cores
- Technology Family 3: CDHS EGSEs & Microelectronics Development methods and tools
  - EGSE and tools for CDHS used at satellite level or instrument level
  - EGSE for CDHS Units
  - EGSE that are used to verify the proper functionality of a module to be then integrated in a CDHS unit.
  - Microelectronics development methods and tools

Key Future Activities

- Advanced Data Handling Architecture. Incremental building approach with:
  - Architecture consolidation and documentation preparation (2022)
  - First EM unit (2023) and then EQM unit (2025)
- OBCDHS architectures study for high reliability (2FT) missions types.
- Study of OBCDHS architectures based on microcontrollers (decentralized DHS Architectures)
- SpaceWire: Deterministic communication (new routing switch), network management, network simulators
- SpaceFibre: Interface chip, routing switch chip, physical layer testing, reference designs

- Ethernet: TTEthernet test bed, end point, and switch; Time Sensitive Network characterization and development
- CAN: Integrated design environment for CAN-based networks
- HW Processing Modules based on rad-hard Microelectronics (under development by primes, with European processors and FPGAs)
- HW Processing Modules based on COTS
- Cubesat Modules
- ADHA Modules (EM)
- COTS activities: selection, characterization, design mitigation techniques, robustness and performance evaluation.
- Component benchmark activities (OBPMark completion, FPGA / GPU / Accelerators).
- Machine Learning investigations: evaluation & assessment of specific techniques on different HW platforms (NN, Neural Morphic, ...)
- Algorithms and relevant datasets (image/video/data compression, data reduction, cloud detection, etc.)
- EGSE to test buses, network and communication technologies (SpaceWire, SpaceFibre, Ethernet, TSN, CAN): network simulators, physical layer testing, test bed, bus tester.
- ADHA module crates or racks
- ADHA unit EGSE (incremental approach following the ADHA modularity)
- 6 nm FinFET (TSMC) - test chip & IP eval + simulations
- Further development and consolidation of Design Kits and rad hard IP for the various platforms, for high speed digital processing and data communication, detector back-ends, power conversion and control
- Evaluation and demos of embedded FPGA IPs and tools
- More evaluations of non-European reprogrammable FPGAs (e.g. Microchip PolarFire, Xilinx KU060)
- RISC-V instruction extensions, SW tool ecosystem
- RISC-V Fifth Generation Space Microprocessor (VGSM) EM and FM
- Next generation ARM MCU (55nm) and MPU (28nm)
- Space Microcontroller with open instruction set architecture
- New developments on applications, evaluations (also of COTS), qualifications
    - Latch-up protection
    - ADC, DAC
    - electro-optical transceivers
    - power conversion, conditioning and control
    - LVDS drivers/receivers
    - evaluation of non volatile memories
    - frequency synthesizers
    - high speed communication interfaces and switches (e.g. SpaceFiber chips)
    - Telecommand and Telemetry encoder/decoder chips
- AI with FPGAs (IPs and tools)
- New IP Cores (AMBA to AXI bridge, supervisors for COTS devices, RISC-V extensions, high speed communications, DSP accelerators, ADHA functions/interfaces, TSN, TTEthernet, etc.)
- Validation tests functional coverage methods and tools
- Radiation effects mitigation techniques for COTS and rad tolerant (non rad hard) FPGAs

Challenges:

- 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

Future tenders in 2022-2027 (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)

3.3.7 Cryogenics, vacuum and leak detection technologies

Future trends:
- 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)

Challenges:
- Vibration Reduction.
- Remote Cooling.
- Long Lifetime.
- Cryogenic Fluids Handling.

3 different domains:
- Spacecraft Cryogenics for innovative, sophisticated and relatively compact coolers or integration solutions (approximate budget: ~ 1.2MEUR/year)
- Space Transportation for fluid management and larger volumes (approximate budget: ~ 5MEUR/year)
- On-ground Testing for more classical lab-based solutions (approximate budget: ~ 2.5MEUR/year incl. investments and running costs)

3.4 ESO

ESO's website for procurement is https://www.eso.org/public/industry/cp.html

The estimated procurement budget for ESO in the period 2022-2025 is 840 MEUR.

This volume is built of some remaining procurements for the ELT construction, and operational cost to run the existing sites (La Silla Paranal Observatory, ALMA observatory and APEX). The latter will be the vast majority of this volume, and the vast majority of this amount is already committed.

3.4.1 Diagnostics and detectors, sensors, optics and instruments

➔ ELT's first set of Instruments & Technologies is in Final Design Phase:
- METIS: Mid infrared imager and (IFU) spectrograph
  - R=100 000
  - Geosnap 3-13mm IR detector (Teledyne)
  - 400-500 mm free form cryogenic optics (40-70K)
- HARMONI: Near IR AO assisted 3D (IFU) spectrograph
  - R=3500-20 000
  - Low noise fast readout wavefront sensors
  - IR and visible gratings
- MICADO: Near IR Adaptive Optics assisted instrument:
  - Diffraction limited imager and spectrograph
  - R=8000
  - High accuracy free form cryogenic optics 500 mm
  - IR/Visible 500 mm dichroic
- MORFEO: Multi-Conjugate AO system for MICADO
  - 1 m class deformable mirrors
  - Wavefront sensing with 3 natural and 6 laser guide stars
  - 600-800 mm class dichroic (600nm cutoff)
  - Low noise fast readout wavefront sensors

➔ 2nd generation ELT instruments and technologies are in phase A study level
- HIRES: HIgh REsolution Spectrograph. Technologies to be developed
  - High-efficiency gratings for high resolution spectroscopy R > 100,000
  - Robust & high-efficiency fibres for K-band (2.0 < λ < 2.4 mm)
  - Coating with high performance from 0.35 to ~2 mm
  - Ultra stable calibration source: Laser Frequency Comb
- MOSAIC: Multi Object AO assisted spectrograph. Technologies to be developed
  - Large format VPHs (~300mm) for medium resolution spectroscopy (5,000-20,000) in optical and near-IR
  - Curved detectors (CCD) 4Kx4K
  - Coating with high performance from 0.35 to ~2microns

➔ **Required technologies**
- 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 ($2.0 < \lambda < 2.4$)
- Secure transmission grating availability
- Promising technology: astrophotonics, e.g., integrated spectrograph, tip-tilt sensing, heterodyne interferometry...

➔ **Challenges** for 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 favor 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

➔ **Challenges** 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

3.4.2 Information and communication technologies

➔ IT Service provision
- **Future tenders**
  - 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

  - Contract period: 3 + 2 years
  - Estimated volume 8 – 12 M€ for tenders in 2024

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

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

➔ Science Archive, Data Centre, etc.
- **Future tenders**
  - 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
  - Contract period: 3 + 2 years
  - Total estimated volume 1 M€ for tenders in 2024

➔ Service contracts
- **Future tenders**
  - 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
  - Estimated volume 7 M€ in the period 2023 – 2027

➔ **Challenges:**
- Global Support is a must
  - Vendors have to deal with global support at remote sites
  - Standardisation of infrastructure and processes
  - Logistic restrictions
- Long lifecycles
  - Solutions are in operation typically for over 10 years
  - Select Hardware and Software vendors carefully
- Requirements are diverse due to scientific needs

3.4.3 High precision and large mechanical components

➔ **Future tenders** 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

3.4.4 Instrumentation, control and CODAC

➔ ELT control system
  - Subsystem LCS's in development by suppliers
  - M1LCS: first version available and under test
  - Central Control System and Local Supervisors in development at ESO
  - **Future tender:** Support for ESO internal development by outsourcing contract
    - Call for tender planned for Q4/2022
    - Up to 4 FTE/year for up to 5 years
    - Contribution to CCS, LSVs and related activities

➔ VLT (Very Large Telescope)
  - In operation since >20 years
  - 4 unit telescopes (UTs) with 8.2m primary mirror
  - 3 instruments per UT
  - 4 additional auxiliary telescopes (ATs) with 1.8m
  - Interferometer (VLTI) with additional instruments
  - The control SW for VLT/VLTI consists of >2 million NLOC
  - New release every year
    - ~200 bug fixes
    - ~50-100 changes due to new features and improvements
  - New features mainly from requirements of new instruments and infrastructure
  - **Future tender:** maintenance supported by outsourcing contract
    - 4 FTE per year over 2+1+1+1 years

3.4.5 Cryogenics, vacuum and leak detection technologies

Technical contacts for cryogenics: Gerd Jakob and Matteo Accardo

➔ **Challenges** for 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

➔ Cryo-vacuum at ESO

- **Future tender** ELT LIN distribution system infrastructure: design, construction, on-site installation
    - industrial contract
    - for companies specialized in large LIN infrastructures
    - PI released recently
    - Start 2023 / end 2026
- **Future tender** ESO HQ LIN distribution system infrastructure: design, construction, on-site installation
    - industrial contract
    - for companies specialized in large LIN infrastructures
    - Start 2023 / end 2025
- **Future tender** LIN delivery service LaSilla-Paranal-Observatory (La-Silla & VLT), Chile; 30000 L/month
    - frame contract, recurring every 3-5 years
    - for LIN suppliers
    - Start 2025 / end 2028
- **Future tender** LIN delivery service on-site Armazones, Chile; for ELT FL instruments; 30000 L/month
    - frame contract, recurring every 3-5 years
    - for LIN suppliers
    - Start 2026 / end 2030
- **Future tender** LIN delivery service on-site Armazones, Chile; for ELT 1st and 2nd gen. instr.; 60000 L/month
    - frame contract, recurring every 3-5 years
    - for LIN suppliers
    - Start 2030 / end 2035
- **Future tender** LIN delivery service on-site ESO HQ, Germany; 4000 L/month
    - frame contract, recurring every 3-5 years
    - for LIN suppliers
    - Start 2024 / end open
- **Future tender** customized LIN transfer lines
    - hardware procurement
    - for LIN transfer line suppliers
    - Start 2023 / end open
- **Future tender** ELT cryo-cooler infrastructure: compressors, He piping, thermal enclosures, anti-vibration mount
    - hardware procurements and industrial contracts
    - for suppliers for cryo-coolers, instr. protection, welding
    - Start 2023 /end 2030

3.4.6 Remote handling systems

Remote handling systems for ELT

- ETF internal transporter
    - Max mass of the unloaded transporter 14000kg.
    - Max mass to be lifted and then transported 35000kg.
    - The transporter shall be designed and constructed to withstand accelerations resulting from earthquakes

  - The driving speed of the transporter shall be continuously adjustable from 0 to 0.2m/s in, as a minimum, in the X and Y directions.
  - The transporter is intended to transport the following items of the ELT:
    - M2 Unit Transport Container, with or without the M2 Unit
    - M3 Unit Transport Container, with or without M3 Unit
    - M4 Unit support structure with or without M4 Unit
    - M5 Unit Transport Container with or without the M5 unit.
    - Modules of Nasmyth instruments (Volume 7x7x6m "L x W x H").
- **Future tender** ELT internal transporter (for M2/M3/M4/M5 and instruments) (2023)
- **Future tender** ELT-ETP internal transporter (for M2/M3/M4/M5 and instruments)
- **Future tender** Automatic connection for refilling of LN2
- **Future tender** Integrated operations programme

3.5 ESRF

The ESRF calls for tender are not published on the ESRF website but only through its Industrial Liaison Officers.

Over the period 2022-2026, the ESRF will invest 66 MEUR for the construction of new beamlines complemented by some refurbishments and for IT infrastructure and a detector programme.

In particular, the procurement opportunities in the period 2022-2026 are estimated as follows:

	2022	2023	2024	2025	2026	Total
Optics	1.7	1.3	1	1	0.5	5.5
Precision Mechanics	3.6	4	3	2.5	2.5	15.6
IT Infrastructure	4	5	5	5	5	24
Buildings	0.2	2	3	2	1	8.2
Infrastructure	4	5	5	0.5	1	7.5
Detectors	1.7	1.5	0.4	1	1	5.6

Table 3. ESRF Procurement 2022-2026 in MEUR

3.5.1 Information and communication technologies

➔ Major sets of Equipment - technology

- Data acquisition
  - In the range of 10 MB/s to 2.5 GB/s per Beam Line (44 BL) from sub second to several hours
  - On line data analyses and Data compression
  - HDF5 file format
- **Future tender** Data storage (2023)
  - 20 PB available - 3GB/s
  - GPFS file system
  - Need to address performance needs in the order 5-10 GB/s (2023)
- **Future tender** Computing (frame contract)
  - CPU (5.5K Cores), GPU (100)
  - Intel, AMD, Nvidia
- **Future tender** 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
- **Future tender** New data center (2026-2029)

3.5.2 Complex building construction and its safety related systems

➔ ESRF 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 High precision and large mechanical components

Head of group MARION Philippe
Head of Procurement Unit: DALLE Didier

➔ Main projects - Experimental programme overview 2022-2029
- 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

➔ Machining of individual parts
- Unitary part only
- Very few series of pieces
- Conventional machining
- Electro-erosion
- Mechanical welded
- UHV manufacturing
- Welding
- Brazing
- Inspection report

- Additive manufacturing
- Machining of individual parts has a **budget of** ~400k€ / year

➔ Manufacturing of comprehensive instruments
- Machining of all parts
- Possibility of pre assembly
- In vacuum undulators
- from ESRF drawings and technical specifications
- **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

- **Future tenders**
    - BM18 Slits - CFT to be launched soon for 4 units.
    - BM18 Attenuators - CFT to be launched soon for 15 axis and vacuum chambers.
    - Scope of supply:
        - Fabrication
        - Assembly
        - Tests
    - Capabilities required:
        - Precision machining
        - Stainless steel welding
        - Vacuum brasing
        - Cleaning
        - Assembly
        - Vacuum testing
        - High precision motion tests

3.6 ESS

ESS's web for procurement is https://europeanspallationsource.se/procurement/listings.

The ESS procurement budget is estimated to be 175 MEUR, covering all new procurements from the ESS cash budget in the period 2022-2026. This includes the procurements of all values i.e., from low-value procurement to high-value tenders published on the organisation's website.

The largest accelerator and target work packages are already covered under In-Kind agreements and contracts awarded by ESS. It is expected that the procurement during 2022-2026 will shift towards the science / instrument area, installation and integration work as well as the areas related to ESS taking over the building site and the new Campus buildings (permanent offices, lab/workshop building, entrance/guard building).

3.6.1 Electrical, power electronics, electromechanical and RF systems

➔ Competence and capability needs from industry
  - RF and Electronic Design
  - PCB production and assembly
  - Design and Build-to-Print
  - High and low power amplifier components
- Test and Measurement
  - Equipment
  - Test and calibration services
  - EMC compliance testing
- Electronic Component and System Assembly
- Waveguide and Coax component manufacture
- Component and system supply
  - Spares
  - Consumables
  - Obsolescence management
- Machining, welding and cooling systems
- Cable assembly manufacture

➔ **Future tenders:**
- 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
- Cabling and Connectors

3.6.2 Diagnostics and detectors, sensors, optics and instruments

Future tenders:
- 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

3.6.3 Information and communication technologies

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

3.6.4 Complex building construction and its safety related systems

Challenges

- ➔ 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

3.6.5 High precision and large mechanical components

- ➔ Some **future needs** in the Target System:
  - Target Wheel: design upgrade and replacement
    - o Don´t interfere with the protons and neutrons (Minimum distance, Minimum material)
    - o Heat load 3 Mw (5MW proton beam) - 3 kg/s helium mass flow (11 bar)
    - o Radiation and vacuum (cold welding, instrument failure, leakage)
    - o 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 Cryogenics, vacuum and leak detection technologies

- ➔ Technologies of interest to ESS
  - 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

- ➔ **Upgrade Proposed**: Cryomodule Maintenance Facility
  - 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

- ➔ **Current estimated procurements**:

- 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. Estimate: 100 kEuros total from 2023 - 2027
- Vacuum - 0.5MEuros in 2023, 0.75MEuros annually for 2024 - 2027

3.7 E-XFEL

https://www.xfel.eu/organization/procurement/calls_for_tender/index_eng.html is E-XFEL's website for procurement.

The procurement budget for period 2022– 2026 is estimated to be 418 million EUR. The campus is still growing and further developed, with additional user infrastructures such as an additional office building and a visitor's center on the way. There are also two more tunnels (SASE 4 & 5) waiting to be equipped for future use.

The Mid-term development at European XFEL (2022-2026)
- Develop and build a superconducting afterburner for SASE2
- Build a 3rd scientific instrument at SASE2
- Provide sub-femtosecond pulse duration capability (ASPECT)
- Initiate the design and construction of a 2nd generation of pixel detectors (DET, R&D)
- Prepare and build SASE4 and SASE5 FELs and the instruments at them

3.7.1 Diagnostics and detectors, sensors, optics and instruments

➔ **Upgrades / future constructions**
- Smaller upgrades during operation (e.g., gated cameras for the imagers)
    - 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

3.7.2 Information and communication technologies

➔ Current Resources and Investment Plan
- 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

➔ Annual Budget for Hardware Invest 2.5 Million EUR. Typicall split:

- 1.5 MEUR for Storage
- 1 MEUR for Compute

3 year framework contracts resulting from tenders managed by DESY (Host CC)

➔ **Challenge**

- Data reduction and compression

3.7.3 Basic material technologies and advanced manufacturing techniques

➔ **Challenges**

- Gas dynamic virtual nozzles (GDVN).
  - Develop more complex jetting systems
  - Mass produce standard systems
- Plasma target production for user experiments
  - Reproducible
  - Accurate

3.7.4 Instrumentation, control and CODAC

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

Table 5. Estimates for procurement related to beamline control systems in ESS for 2022-2027

3.7.5 Cryogenics, vacuum and leak detection technologies

Needs

- Securing operation
- Maintenance & substitution/upgrades
- Internal R&D projects

3.7.6 Remote handling systems

➔ **Challenges**

- 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

3.8 FAIR

FAIR's website for procurement is https://www.gsi.de/en/start/business_industry

FAIR's procurement has three pillars:
1. Site and buildings, with a total value of more than 1 billion EUR (price point 2020).
2. Accelerator, with a total value of over 300 million EUR (price point 2020),
3. Experiment, of which most will be supplied via collaborations and not by FAIR.

Counting GSI together with FAIR direct tender, over 300 MEUR worth of accelerator technology is being tendered on the open market between 2020 and 2024. The table below gives the estimated German expenditure, by technology branch:

Technology	Estimated expenditure (MEUR)
Cryogenics, vacuum and leak detection technologies	55
Diagnostics, detectors, sensors, optics and instruments	35

Electrical, power electronics, electromechanical and RF systems	43
High precision and large mechanical components	10
Instrumentation, control and CODAC	34
Superconductivity and superconducting magnets	25
Normal conducting magnets	30
Remote handling	7

Table 6. German FAIR procurement 2022-2026 in MEUR

3.8.1 Electrical, power electronics, electromechanical and RF systems

➔ Next systems to be realized
- Upgrade of amplifiers for Alvarez structures (call for tenders running for 150kW driver amplifiers)
- SIS100 Barrier Bucket system, SIS100 Longitudinal Feedback system (4 identical cavities)

➔ **Future tender** CW LINAC Components
- 3 kW solid-state amplifiers
  - 216 MHz
  - both, CW & pulsed operation
  - about 10 pieces required for series
- CW LINAC RF system control (digital) and infrastructure

➔ **Future tender** pLINACComponents
- Klystron auxiliary power supplies (DC only, for klystron solenoids) for 7 klystrons
  - 2 pieces 1 kW (about 15 A) per klystron
  - 1 piece 3 kW (about 15 A) per klystron
- Circulators for 7 klystrons
  - 325 MHz
  - 3 MW pulse, pulsed <5 Hz, 0.1 % duty cycle
- Rectangular waveguides WR 2300 full height (about 100 m in total)
- Auxiliary components, e.g. low-power measurement transitions from WR 2300 to coaxial type N Prof.

➔ **Challenges**
- 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.)

3.8.2 High precision and large mechanical components

➔ **Future needs**:

- 2 radiation hard dipoles for Super-FRS

3.8.3 Cryogenics, vacuum and leak detection technologies

➔ **Needs** Vacuum Chambers SFRS

- 17 Focal Plane Chambers
  - 17 variants
  - Rectangular shape
  - size max 460x100x100 cm^3
  - High requirements on overall flatness of the top plate (0.1 mm)
- 18 Pumping Chambers
  - 18 variants
  - Round DN400 shape
  - Size length 20 - 50cm
  - Incl. hydroformed bellow, flanges 2x DN400CF, 2xDN160CF, 2x DN40CF plus support frame for each chamber
- 30 Beam pipes, round shape
- 32 Bellows, round DN400& racetrack shape
- Material: stainless steel of any type (without specified magnetic permeability) such as 1.4301, 1.4306, 1.4307, 1.4404, 1.4435 or 1.4429. (must follow DIN EN 10088)
- Vacuum Requirements: outgassing rate 1x10-9mbar l/s cm2, leak rate 1x10-9mbar l/s, special RGA acceptance criteria

➔ **Needs** Magnet Vacuum Chambers SFRS

- 3 NC dipole chambers
  - 2 variants
  - rectangular/ trapezoidal shape
  - length max 365cm, aperture entrance: 50x14cm^2, aperture exit: 120x14cm^2
  - Material Ti6Al4V, complex structure, high power deposition from beam, water cooling required, Helicoflex type sealing, support frame for each chamber required
- 3+15 Dipole chambers bended for SC magnets
  - 1 + 4 variants
  - rectangular/racetrack bending shape
  - angle type 1:11° / bending angle type 2: 9,75° / length= 3-3.2m / aperture: 38x14cm^2 / wall thickness: 6 - 11mm
  - Material stainless steel 316LN or other non magnetic alloy
  - Support frame for each chamber
  - Type 9.75° has included bellow and pumping chamber
- 3+3 Dipole chamber branching for SC magnets
  - 2 + 2 variants
  - Y shaped & V shaped size
  - length 2.8m / aperture: 38x14 (resp 68x14)cm^2 / wall thickness max 11mm
  - Material stainless steel 316LN or other non magnetic alloy
  - Support frame for each chamber
  - Type 9.75° has included bellow and pumping chamber
- Vacuum Requirements:
  - outgassing rate $1x10^{-9}$ mbar l/s cm^2
  - leak rate $1x10^{-9}$ mbar l/s,
  - special RGA acceptance criteria
  - Required relative magnetic permeability: ≤1.01

➔ **Needs** Magnet Vacuum Chambers HEBT

- 11 (24) Dipole chambers
  - 6 (9) variants
  - Rectangular / trapezoid size
  - length: 2.5 - 3.8m / aperture: 110x67mm², 120x60mm², 120-200x60mm² / wall thickness: ~4-6mm
  - Incl. holders
- 120 (200) Quadrupole / Steerer Chambers
  - 32 (57) variants
  - Round shape
  - Length 0.5-2m / aperture 100mm, 120mm, 150mm / wall thickness 2-3mm
  - Some chambers will have one or two bellows included
  - Flanges DN160CF
- 26 (47) Quadrupole Chambers elliptical
  - 5 (9) variants
  - Elliptical shape
  - length 1.4-2.1m / aperture: 138x68mm² / wall thickness 2-5mm
  - Some with one or two bellows included
  - Flanges DN160CF & DN400CF (4 chambers)

- Material:
  - Chamber/bellow/flanges: material according to EN 10088: 1.4301, 1.4306, 1.4429 or 1.4435
  - Flange material: material according to EN 10088: 1.4306 or 1.4307 or higher quality
  - Magnetic permeability m r ≤ 1.01 (or m r ≤ 1.05 for components outside of yoke)
- Vacuum requirements:
  - Integral leak rate ≤ 1x10 10 mbar l/s
  - Outgassing rate ≤ 5x10 10 mbar l/(s cm 2
  - Residual gas composition as acceptance criteria
  - UHV suitable cleaning
  - Non bakeable

➔ **Needs** Vacuum chambers HEBT

- 84 (251) Straight beam pipe
  - ~30 (~90) variants
  - Round shape
  - length: 0.5-6m / aperture: 154mm / wall thickness: ~2-3mm
  - Flanges DN160CF
- ~25 (65) Pumping Chambers
  - 3 variants
  - Round shape
  - length ~400-800mm / diameter ~160mm / height ~650mm
  - Flanges: 5x DN160CF, 1x DN40CF
  - Material for flanges 1.4429ESR
  - support structure welded to chamber
- 1 (6) Special Chambers
  - 3 variants
  - Branching x-cross shape
  - ~2100 x ~500x ~500mm² / ~2545 x ~600 x ~450mm²
  - Flanges: 2x DN160CF, 1x DN400CF
  - Flanges: 6x DN160CF
  - Both chambers have a support structure

- 216 (567) Bellows
  - ~10 variants
  - Round shape
  - length: ~186mm / aperture: 154mm
  - Flanges DN160CF (one fixed/one rotatable)
  - Material bellows: 1.4404, 1.4406, 1.4435, 1.4541, 1.4571
- Material:
  - Chamber material according DIN EN 10088: 1.4304, 1.4306, 1.4307, 1.4429 or 1.4435
  - Flanges according ISO 3669, material according DIN EN10088: 1.4306 or 1.4307 or higher quality
  - magnetic permeability chamber m r ≤ 1.3 flanges m r ≤ 1.05
  - Surface quality Rz =25
- Vacuum requirements:
  - Integral leak rate ≤ $1x10^{-10}$ mbar l/s
  - Outgassing rate ≤ $5x10^{-10}$ mbar l/(s cm^2)
  - Residual gas composition as acceptance criteria
  - UHV suitable cleaning
  - Non-bakeable

➔ **Needs** Vacuum Chambers SIS100

- 11 Straight beam pipe
  - 2 variants
  - Round shape
  - Length: ~1.3 & ~3m / Aperture: DN160 / Wall thickness: ~2-3mm
  - Bake out jackets and chamber support stands part of delivery
- 6 Chamber for resonance sextupole
  - Round with bellow shape
  - length 730 mm / diameter ~160mm / height ~650mm
  - With integrated corrugated (hydroformed) bellow
  - Magnetic permeability m r ≤ 1.01
  - Bake out jackets and chamber support part of delivery
- 2 Chamber rad. res. Quadrupole
  - Star-shaped
  - Length: ~2m / Aperture: 135 x135 mm^2
  - Flanges DN160CF & DN300CF
  - Magnetic permeability: m r ≤ 1.01
  - Thin bake out jackets (8 10 mm) part of delivery
  - NEG coating required
- Materials:
  - Chamber material according to EN 10088: 1.4306, 1.4307, 1.4404, 1.4429 or 1.4435
  - Flanges DN160CF, material according to EN 10088: 1.4429 ESR
  - Surface quality Rz =10
  - Vacuum firing (950°) required
- Vacuum requirements:
  - Integral leak rate ≤ $1x 10^{-10}$ mbar l/s
  - Outgassing rate (after bake out) ≤ 1x 10 12 mbar l/(s cm^2)
  - UHV suitable cleaning
  - Bakeable up to 300 C
  - Bake out cycle for acceptance test required

➔ **Needs** Vacuum Chambers SIS100

- ~120 Bellow cryogenic
  - 3 variants
  - round shape
  - length: ~0.1 & ~0.3m / aperture: DN160
  - Operational temperature < 20 K
  - Corrugated (hydroformed) bellows
  - Surface Rz ≤ 6.3
- ~70 Bellow bakeable
  - ~10 variants
  - round shape
  - length: ~0.1 & ~0.3m / aperture: DN160
  - Corrugated (hydroformed) round bellows
  - Flanges DN160CF & DN200CF
  - Bake-out jackets part of delivery
- 50 Beam Vacuum Cold Warm Transitions (BV-CWTs)
  - 6 variants
  - star-shaped / elliptical inner tube
  - length: ~0.5m / aperture: 133 x 133 mm^2 & 133 x 65 mm^2
  - Operational temperature (on cold side) < 20 K
  - Surface Rz ≤ 6.3
  - Bake-out jacket part of delivery (on warm side)
  - Additional Helicoflex type seal
- Materials (according to EN 10088):
  - Flanges DN160CF, material: 1.4429 ESR
  - Chamber material: 1.4404 or 1.4571
  - Bellow material: 1.4404, 1.4406, 1.4435, 1.4541, 1.4571
  - Bellows single-walled, wall thickness ~0.3mm
- Vacuum requirements:
  - 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

➔ **Needs** standard components

- Standard components will be procured via call for tender as framework contract (including minimum and maximum number). Contract duration 4 years
- ~50-230 Gate & Angle valves all metal
  - 3-7 variants
  - Gate valves: DN63-DN400 / Angle valves DN100-DN200
  - CF flanges
- ~150-500 Gate & Angle Valves Viton/EPDM
  - 13-18 variants
  - Gate valves: DN63-DN400 / Angle valves DN100-DN200
  - CF flanges & ISO-K flanges
- ~ 50-170 Turbo molecular pumps
  - 7 variants
  - Pumping speed 300l/s-1200l/s / Flanges CF & ISO-K
  - Hybrid bearing
  - some have to be radiation hard
  - communication to controller via ProfiNet or ProfiBus
- ~50-170Roughing Pumps

    - Pumping speed 15-65m³ /h
    - Dry pumps, some have to be radiation hard
- ~40-100 Mobile pumping stations
    - 2-5 variants
    - Consisting of a TMP, roughing pump, periphery, stations shall include a PLC
- ~10 Residual Gas Analyser
    - Faraday & SEM

➔ **Needs** SFRS local cryogenics

- Transfer Lines of Branch B central link. Branch B is the central distribution Branch of the Super FRS Helium Cryogenic system: Four Transfer Lines connect the Branch Box to the neighbouring branches (incl. installation):
    - Four pieces of vacuum insulated helium cryogenic transfer lines
    - 62 m total length
    - Vacuum jacket DN 400
    - Active thermal shield
    - 4 process headers (DN80, DN50, DN40, DN40)
    - Design Pressure PS = 20 bar(a)
- Feed Boxes Branch E and R
    - 18 Feed Boxesfor Branch E and Branch R of the Super FRS Local Cryogenics, for the supply of magnet cryostats with cold / liquid helium (4K)
    - ~4 FB design subtypes
    - Design Pressure PS = 20 bar(a)
    - 6 cold control valves
    - 2 warm control valves
    - 1 warm check valve
    - two 4-header ports (DN400: TLs/EB)
    - one 5-header port (DN400: JC), incl. VB
    - one 1-header port (DN65: MPL), incl. VB
    - several warm hand valves, capillary outlets
    - electrical terminal box
    - cryogenic instruments
- Capillary Piping for remote pressure sensors. Cryogenic Valve Boxes located in the Super FRS beam tunnel are exposed to radiation Sensitive pressure sensors need to be placed remotely on racks in service rooms
    - Connections to:
        - 63 Feed Boxes, 7 End Boxes, 1 Branch Box
        - 22 remote racks, to host the pressure sensors
    - ~500 capillary pipes required
        - 6x1 mm (stainless steel or copper)
        - 20-100 m individual lengths
        - in total ~16 km of piping
        - Design Pressure PS = 20 bar(a)
        - Incl. design, production and installation
- Warm Piping System auxiliary process lines. The Warm Piping System (WPS)
    - 3 auxiliary process headers for the Super FRS Local Cryogenics system (incl. installation)
    - Multipurpose Return (MPL)
    - Cooldown Return and Quench Buffer
    - Vacuum insulated 1-header TL
    - DN200 (VJ), DN125 (header), Design Pressure PS = 20 bar(a)
    - Top = 5-300 K, Pop = 1.3 20 bar(a)
    - ~550 m (including T-pieces)

    - Valves and instruments
- Warm GHe Supply (WGS)
    - GHe Supply to 63 FBs, 7 EBs, 1 BB
    - DN80, Design Pressure PS = 20 bar(a)
    - Top = 300 K, Pop = 18 bar(a)
    - ~1100 m length (including T-pieces)
    - Valves and instruments
- Current-Leads Return (CGR)
    - GHe Return from 63 Magnet Cryostats
    - DN80, Design Pressure PS = 20 bar(a)
    - Top = 300 K, Pop = 1.2 bar(a)
    - ~1100 m length (including T-pieces)
    - Valves and instruments

➔ **Needs** 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))
    - 6 current lead boxes
    - 1 current lead box link
    - transport frames
    - incl. 2D design / documentation, production and integration
    - mild steel for warm, G10/11 for cold supports
    - stainless steel and aluminium for vacuum vessel and shield, resp.
    - vacuum vessel bellows
    - stainless steel for process pipes (small for PED; no hoses due to small diameters)
    - ceramic vacuum barrier feedthroughs (design existing, already used in BPL)
    - instrumentation ~ 20 TVOs; 18 ball valves; 8 control valves @ cold, 6 safety valves; 6 lift plates; 24 filters @ warm
    - GSI delivery
        - main current leads incl. warm valves attached to MCLs
        - voltage breakers
        - bus bar cable
- Cryogenic North-South-Link: About 200 m of cryogenic helium transfer line DN500 (vacuum insulated with 4 inner process lines: 4K supply/return, 50 K supply/return), one vacuum insulated line DN 200, three warm gas lines PN20 with DN100, DN150, and DN300 Cryogenic distribution box DB2 build as two connected valve boxes including 4K recooler
    - Design along predefined installation space according to 3D model
    - Maximum allowed pressure drop and heat load given
    - Additional Request:
        - Complete design/engineering by manufacturer
        - Vacuum and mechanical requirements to be proven by FAT from manufacturer
        - Full documentation of design/engineering and FAT tests
        - Complete installation of the system on the FAIR construction site, finalized by vacuum/welding tests as SAT

3.8.4 Superconductivity and superconducting magnets

- ➔ **Future tender** SIS100 quadrupole units & doublets
  - Design:
    - Superferric, Nuclotron type cable
    - Forced flow cooling
    - Fast ramped dimensions
  - Dimensions:
    - aperture: d = 100 mm
    - units: 1.2 t (without cryostat)
  - gradient 28 T/m
  - current 10.5 kA
  - scope: 3 prototypes
  - design status: spec in revision
  - timeline: after budget decision

- ➔ **Future tender** Super-FRS – Energy Buncher Magnets
  - design:
    - superferric, racetrack
    - thermosiphon cooling
    - self protecting
  - dimensions:
    - large aperture: 500 mm 140 mm
    - 75 t
  - field strength 1.6 T
  - current < 300 A
  - scope: three dipoles
  - design status: spec by end of 2022
  - timeline: 2025 assumed

- ➔ **Future tender** APPA: final focusing quadrupoles
  - Design:
    - cos θ, Rutherford type
    - forced-flow cooling
  - dimensions:
    - aperture: d = 198 mm
    - ~ 8 t
  - gradient 33 T/m
  - current 6 kA
  - scope: four quadrupoles
  - design status: spec available
  - timeline: after budget decision

- ➔ **Future tender** CBM: detector magnet
  - Design:
    - superferric, racetrack
    - thermosiphon cooling
    - self protecting
  - dimensions:
    - huge aperture: 1.44 m 3.0 m
    - 150 t
  - field strength 1 T
  - current 666 A

- scope: single magnet, CLs (HTS), control dewar
- design status: spec available
- timeline: after budget decision

➔ **Future tender** PANDA: detector magnet

- Design:
    - instrumented yoke, solenoid
    - thermosiphon
    - (fully) self protecting
- Dimensions:
    - huge aperture: d = 1.8 m
    - ~ 360 t
- field strength 2 T
- current 5 kA
- scope: single magnet, CLs (HTS), control dewar
- design status: spec available
- timeline: latest 2027

➔ Strategic projects (under consideration)

- HTS cables
    - Next-gen accelerator magnet
    - Power transfer
- HTS coil replacement
    - Energy saving compared to NC beam line magnets
- Collector ring
    - Re-consideration of SC design

➔ **Procurement needs**: superconducting magnets for FAIR

	time line	status		# of magnets
		model	spec	
SIS100 units	asap	Q4/22 (in revision)	Q4/22 (in revision)	3
CBM		ok	10/22	1
APPA		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		concept studies		tbd
HTS cable		concept studies		n/a

Table 7. Procurement needs at FAIR regarding superconducting magnets

3.8.5 Remote handling systems

- ➔ Future tenders
    - Turntable
        - Max load capacity: 10t
        - Rotation: 360° infinite
        - Z-axis frame (lifter) integrated
        - Redundancy for both movements
        - Footprint 1500mmx1500mm
        - Compatibility with all plugs means of adapter plates
        - Attachment of the BC extractor on the Z-axis frame
        - Mounting of tools for the dissasembly/cuting p bar parts
        - Intagrated temporary tool / bolts storage
    - Double lid shielding flask interface
        - Shielding Flask:
            - Dimensions (m): BxLxH: 2,2x4,7x5,5
            - Weight: 56t
            - Positioning accuracy: <5mm
    - Waste drum convey Detail the equipment of the HC (cameras, power supplies, tools, etc.)
    - Development and tendering of the activation measurement station of the decay cell
    - Super FRS special installation components

3.9 F4E

The website for F4E procurement is https://industryportal.f4e.europa.eu.

For the period of 2008-2020 (covering roughly 60% of the ITER construction activities), F4E had a budget of about 7 billion EUR for the European contribution to the ITER and BA projects. For the period of 2021-2027 F4E has a budget of about 6.5 billion EUR, separated as follows:

Year	Budget forecast (MEUR)
2021	710
2022	498
2023	854
2024	512
2025	496
2026	524
2027	406
TOTAL	4 000

Table 8. F4E procurement volume for 2024-2027

In particular, each of F4E programme has its own budget for the same period:

Forecast 2021/2027	MEUR
Magnets	22
Main Vessel	874
Remote Handling	264
Cryoplant & Fuel Cycle	231
Antennas and Plasma Engineering	162
Neutral Beam and EC Power Supplies and Sources	258
Diagnostics	201

Site and Buildings and Power Supplies	1 246
Technical Support Activities	144
Broader Approach	500
DONES	100
TOTAL	4 002

Table 9. F4E expenditure forecast per programme for 2024-2027

Note: These figures are indicative and subject to modification having regard in particular the political context from February 2022 and the potential impact of COVID 19 on economic activities. F4E's planning will be adjusted to take into account spending priorities based on the updated ITER Project Baseline. Actions of Vacuum Vessel, In-Vessel Blanket, In-Vessel Divertor and Test Blanket Module are presented merged in one single line due to commercial sensitive information.

3.9.1 Electrical, power electronics, electromechanical and RF systems

➔ **Future tenders** (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

➔ For ITER, the ITER Organization needs to procure four systems
- 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

Also, the planned procurement contracts for full turnkey procurements are shown in Table 10:

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

Table 10. Full turnkey procurements at ITER by ITER Organization

3.9.2 Diagnostics and detectors, sensors, optics and instruments

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 11. Generic manufacturing challenges for ITER

3.9.3 Basic material technologies and advanced manufacturing techniques

➔ **Future tender**

- 2024
- Re-occurring call for tender to maintain active service contract
- 4 years contract
- OFC-1082 Running contract for “Materials and manufacturing testing/qualification services” (ceiling 2.700.000 Euro)
  - Been awarded to TWI UK, Tecnalia Spain and today with ISQ Portugal

➔ **Needs**

- 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.)

3.9.4 Complex building construction and its safety related systems

- **Needs** 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.

- **Challenges** in 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:
    - Adjust the scheduled and corrective maintenance program to the strict and real needs
    - 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)

- **Future tender** Hot Cell Complex Engineering support for 2023

- **Future tender** Hot Cell Complex Preliminary Design contractors for 2023

3.9.5 High precision and large mechanical components

- **Future tender** Neutral Beams (NB) Remote Handling System (RHS) (see also 3.9.8)
  - 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

- **Future tender** Neutral Beams (NB) Cryopumps (see also 3.9.7)
  - 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

3.9.6 Instrumentation, control and CODAC

➔ **Future tender** I&C Integrator contract
- OFC 989
- awarded to GTD
- 7 years long - until 2026
- requires knowledge of ITER I&C technologies
- requires experience of system integration
- design of I&C Systems
- small scale manufacturing
- Expect renewal call in Q4 2023-Q1 2024.
- (Contract ceiling will be reached earlier.)

➔ **Future tender** I&C Support
- OFC 1015
- awarded to LEONARDO
- Frame contract
- 7 years long
- highly skilled I&C engineering support in F4E-BCN
- System Engineering
- Electronic Engineering
- Experience in I&C System design
- Expect renewal call in 2026.

➔ **Future tender** Nuclear I&C Support
- OFC 1016
- awarded to JACOBS
- Frame contract
- 7 years long
- Nuclear I&C experience
- I&C qualifications to nuclear standards
- Skilled engineering support to F4E-Cadarache
- Design of Nuclear I&C systems
- Expect renewal call in 2026.

➔ **Future tender** Design opportunity
- OFC 1087
- awarded to ALTER
- Frame contract
- 7 years long Electronics Design
- Assembling & Manufacturing
- Prototyping
- EMC Qualification
- Expect renewal call in 2027.

Apart from the above, the ITER Organization will procure for CODAC (Control, Data Access and Communication)

➔ **Future tender** Service Contract for Software Maintenance and User Supports

- CODAC Core System User Support: help desk, training course
- Software Maintenance: bug fixes, QA, testing
- Control System Studio: bug fixes, QA, integration supports
- Contract Status: on going
- Call for new tender: Q4 2024

➔ **Future tender** Engineering Service Contracts for CODAC Operation Application
- Implementing, testing, commissioning, maintenance
    - Lot 1: Supervision & Automation System (SUP & AUTO), Pulse Schedule Preparation System (PSPS)
    - Lot 2: Real time Framework (RTF), Plasma Control System (PCS)
- Contract Status: on going (3years + 2years opt.)
- Call for new tender: Q3 2024 (or Q3 2026)

➔ **Future tender** Engineering Service Contract for Remote Participation Application
- Contract Status: on going
- Call for new tender: Q1 2025

➔ **Future tender** Engineering Service Contract for Data Handling System
- Contract Status: on going
- Call for new tender: Q2 2025

➔ **Future tender** Procurements of Equipment and Servers in CR and SR
- Servers, storage systems, operator terminals, wall display
- Supply, installation, testing and maintenance
- Status: BoM ready
- Call for tender (and/or procurement): 2024

➔ **Future tender** Procurements of SDCC (Scientific Data and Computing Center) Hardware
- Servers, storage systems, networks
- Supply, installation, testing and maintenance
- Status: BoM in preparation
- Call for tender (and/or procurement): Q3 2023
- Contract Owner: IT

The ITER Organization will procure for CIS (Central Interlock System)

➔ **Future tender** Engineering Service Contract for CIS Fast Architecture
- Design and implementation of Advance Protection System
- Call for new tender: Q1 2023

The ITER Organization will procure for ACS (Access Control and Security)

➔ **Future tender** Construction of Early Security Fence
- Early Security Fence: anti intrusion fences , detection systems, civil work, gates
- Design, procurement, installation, validation, commissioning
- Call for tender (and/or procurement): Q2 2023

The ITER Organization will procure for Integration of Instrumentation and Control

➔ **Future tender** Service Contract for Integration and Commissioning of ITER Control System
- Validation, deployment, integration, maintenance of I&Cs
- Contract status: on going
- Call for new tender: Q1 2024

➔ **Future tender** Service Contract for I&C Design and Integration Support
- Design, implementation, validation, integration of I&Cs
- Call for new tender: Q2 2023

➔ **Future tender** Service Contract for Instrumentation and Control (I&C) Cubicles Maintenance
- Maintenance of Instrumentation & Control (I&C) cubicles for conventional, investment protection, access control systems and occupational safety systems
- Contract Status: on going (3years + 2years opt.)
- Call for new tender: Q4 2024 (or Q4 2026)

3.9.7 Cryogenics, vacuum and leak detection technologies

➔ **Future tender** Neutral Beam Cryopumps
- 3 cryopumps (2 sides each)
- >100m2 pumping surface
- >500 cryopanels
- >650 thermal shield panels
- 1000s of radiography films
- >500 leak tests
- Protection Important Activities
- Tight tolerances
- Est. 1st contract: 2025
- Value: >10MEUR

➔ **Future tender** Isotope Separation System
- Cryogenic distillation of D-T
- Ongoing Sizing studies
- Cold box ≈ 7.5m high
- He refrigerator ≈ 3kW @ 16K
- He tanks ≈ 15m3 @ 16K
- Tritium containment function
- Complex qualification scope
- Contracts ongoing with ITER
- Est. 1st F4E contract: 2026
- Opportunities for:
    - Integration services
    - Final design & procurement
        - Refrigeration system
        - Cold box manufacturing
        - Pressure vessels
        - Piping and structure

➔ **Future tender** Radiological and Environmental Monitoring System (Est. next F4E contract: 2025)

➔ **Future tender** Water Detritiation System (Est. 1st F4E contract: 2026)

3.9.8 Remote handling systems

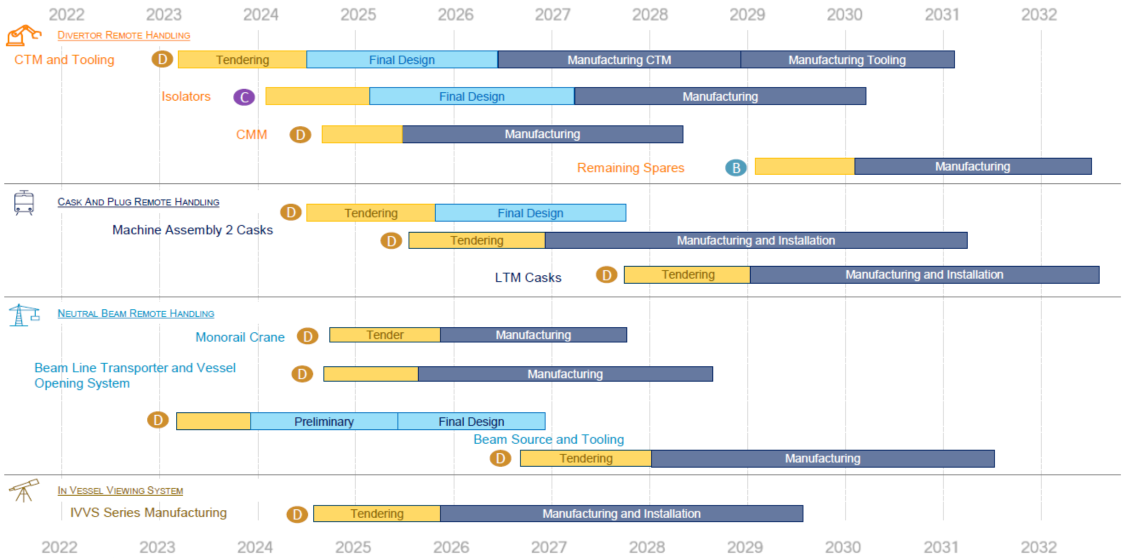

Figure 3. BSBF 2022. Carlo Damiani, Programme Manager – Remote Handling. Long-term outlook for remote handling systems in ITER by F4E. Includes tendering opportunities

➔ **Challenges** 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

The following tenders will be published by Iter Organization:

➔ **Future tender** NB Cell Upper Port RH Equipment (UPRHE)

- UPRHE Transporter
- Filter Jacking tool
- UPRHE Cabling System
- Assembly Frame
- Bioshield Plug End Effector
- Manipulator End Effector
- Manipulator Transporter
- Procurement Process:
  - Detailed design and manufacture based on preliminary design (PD completed Sept-22)
  - International Tender 2025

➔ **Future tender** VVPSS RH System

- VVPSS RH system is for removal and replacement of the rupture disk assembly (scheduled maintenance) and bleed line valve assembly (corrective maintenance)
- VVPSS RHE is composed of:
    - Flange bolting tools
    - Flange confinement tools
    - Relief line cleaning tool
    - Bellows compression tools
- Procurement Process
    - Detailed design and manufacture based on preliminary design (PD completion Q4-23)
    - International Tender 2025

➔ **Future tender** RH Test Facilities and Mock-ups
- Detailed design and manufacture based on preliminary design (PD completion Q4-23)
- International Tenders starting 2025

3.10 ILL

The ILL website for procurement is https://www.ill.eu/neutrons-for-society/doing-business-with-the-ill.

Between 2018 and 2026 a further 77 million EUR are being invested in the ILL's "Endurance" and "Key Reactor Components" programmes, guaranteeing that the Institute will maintain its world-leading position for at least another decade.

The Endurance programme launched in 2015 progresses in two phases: Phase I & II. The remaining cost assumptions for Endurance Phase II amount to almost 36 MEUR. There remain a few opportunities in:
- High Precision: manufacturing and assembly
- Cryogenic technology
- Vacuum & Leak Detection Technologies
- Diagnostics, Detectors and Instruments
- Instrumentation & Control and CODAC

The Key Reactor Components are mainly mechanical parts for the reactor, sources, safety upgrades, studies and calculations, etc. The average annual spend is 4.2 MEUR spent over the period 2020-2029. There are opportunities in:
- Large mechanical components: manufacturing and assembly
- Vacuum & Leak Detection Technologies
- Electrical, Electromechanical

A specific project for the Reinforcement of Physical Protection (RPP) is progressing and phase one (new reception building and perimeter fence) is now complete. The second phase of the project represents an estimated spend of 7 MEUR until 2023, covering:
- Complex civil construction, safety-important buildings
- Safety systems, Licensing and Protection of hazardous installations, access control, fire and gas detection

3.10.1 Information and communication technologies

IT contact: Erwan Le Gall
Instrument control contact: Paolo Mutti
Scientific Computing contact: Stephane Rols

➔ **Future projects**
- 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

3.10.2 Complex building construction and its safety related systems

➔ **Future tender** 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
- Budget: 4 M€

3.10.3 High precision and large mechanical components

➔ **Future needs** of 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…

➔ **Future needs** of the DPT division
- Seismic reinforcement of concrete casemate
- Instrument Projects
- SHARP collimation (2023)
- SHARP collimation shielding (2023)
- D11 collimation (2023)

3.11 SKAO

SKAO's procurement database is https://www.kommersannons.se/skaobservatory/.

Over the period 2021-2024, SKA plans to commit around 600 MEUR for procurement across a number of categories including significant infrastructure in the two host countries.

Initial procurements are in infrastructure, including buildings with specialist fitments such as RFI shielding and software frameworks. In the seven-year construction programme, large volume invitations to tender will be published in the areas of:
- Detectors, Sensors and Instruments.
- High Precision and Large Mechanical Components.
- Cryogenic and Vacuum technology.

Later, the necessary procurements for HPC will take place.

3.11.1 Diagnostics and detectors, sensors, optics and instruments

➔ **Future tenders** LOW telescope
- 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
  - SPS-ADC + Fast digital electronic circuitry (FPGA)
  - ~600 units to be acquired
- 14Meuro/y between 2023 and 2024

➔ **Future steps** (beyond 2026)
- Complete the full Array
- Launch the Observatory Development plan (In steady state it will fund studies and projects for 20M/y)
- Fully operational, from 2029, which means regular maintenance.
- Thinking about SKA2….

4. Conclusions

More than 35 000 M€ will be spent altogether in the Big Science facilities covered by this document in the period 2022-2026:

	MEUR	Comments
CERN	2 509	
EMBL	237	based on extrapolation
ESA	27 500	5.5 billion EUR per year in the period
ESO	840	
ESRF	66	
ESS	175	
E-XFEL	428	
FAIR	300	On accelerator technology
F4E	2 884	498 for 2022, 854 for 2023, 512 for 2024, 496 for 2025 and 524 for 2026
ILL	73	36 endurance + 4.2/year for key reactor components + 7 for RPP
SKAO	600	

Table 12. Budget for procurement at each Big Science facility in 2022-2026 in MEUR

Although some facilities have part of their budget already allocated, most of the procurement processes listed in this document are either underway or will be published in the upcoming years.

On the other hand, it must be outlined that tendering processes and rules depend on each facility:

- Each BSO has his own clauses and conditions for contracts, procurement regulations, and selections of contractors subcontractors.
- BSO may issue different types of procurements procedures depending on the complexity of the procurement and on the BSO rules, e.g.: open and competitive procedure, restricted procedure, competitive procedure with negotiation, a request for quotation or a request for information.
- All BSOs have different evaluation and eligibility criteria as prerequisite for companies, e.g.: to participate in certain invitation to tenders procedure, bidders may first have to be qualified on the basis of their replies to a market survey or a pre qualification.
- BSOs may request technical and procurement standards, e.g.: DIN norm, CE conformity, ECSS, form templates for financial data, ECOS for WBD structure and data, IPR policy, national price and salary statistics, etc.
- Evaluation criteria and their balance (experience excellence impact implementation team price others) is depending on the procurement type.
- Different contracts awarded criteria on the basis of: lowest priced compliant bid principle, best value for money principle, best evaluation result , etc. depending on the procurement type and the BSO.
- Debriefing with unsuccessful companies are possible depending on the procurement procedure and value.
- Some BSOs have e-Procurement Web and Industrial Portal in place; other haven't.

Moreover, the legal status of the facilities is totally heterogeneous:

- Some BSOs are IGO (Inter Governmental Organization): CERN, ESA, EMBL, ESO, ESRF, SKAO.
- Some are ERIC (European Research Infrastructure Consortiums): ESS.
- Some BSOs follow General Financial Regulations of European Union bodies: F4E.

- Some BSOs follow national and European public tender rules, laws, and regulations: XFEL
- Some BSOs are internationally financed scientific or research facilities: CERN, ILL, ESRF.
- Each BSO has its legal status and rules, and each one follows its own Procurement Rules.
- Some BSO are subject to the fair return principle (ESA, SKAO) and others are not (EMBL, XFEL), while some others only aim to achieve a balanced industrial return (CERN, ESO).

Added to the aforementioned, procurement information is not homogeneously distributed to the public, even some facilities don't have their own procurement website (ILOs are the main distributors of the tendering opportunities). All this complicates the access of the companies to such opportunities, as they are obliged to follow many sources and be constantly informed on completely different procedures and obligations for procurement.

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