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The DTT device: Costs, site and management aspects

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HIGHLIGHTS

- The management of all human and financial resources is a critical aspect of DTT project.
- The DTT design includes a careful comparative analysis of the breakdown of the expenses and their time evolution as well as the expected financial revenues.
- The capability of ENEA Frascati to host the DTT device is assessed in terms of both technical and socio-economic aspects.

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ABSTRACT

The DTT proposal not only considers the fundamental technical and scientific aspects, but also includes a careful financial and managerial analysis. It is organized taking into account that only a careful management of all human and financial resources can guarantee the success of the initiative.

Regarding the financial aspects, the project analyzes the costs of both engineering design and construction phases, reporting a breakdown of the expenses and their time evolution. The study also considers the expected financial revenues in terms of consistency, funding channels, and time evolution.

The organization and government layout (organs, functions, relationships) has been designed pursuing the best balance between autonomy and accountability, transparency and cooperation.

The paper also discusses the capability of the ENEA Frascati site to host the device and, in addition, examines the socio-economic impact expected by the long, expansive presence of a high number of scientists and technicians in the area.

1. Introduction

DTT [1] is one of main investment in the frame of the European strategy for the scientific and technologic research during the next decades and is one of the most important steps of the European Road Map for the achievement of Fusion. The project is framed in the well assessed cooperation between Italian and European scientific institutions and, in particular, with partners involved in Fusion research.

DTT is designed to investigate a number of challenging issue, including: (i) demonstrate the technical and technological feasibility of a system able to effectively treat the large heat exhaust in DEMO; (ii) assess alternative technologies, e.g., liquid metals, or complementary measures, e.g., advanced magnetic divertor configurations, to be integrated in DEMO to face with the heat exhaust problem; (iii) deepen the investigation of the heat exhaust mechanism in the experimental regions of interest of DEMO not reachable by the present devices.

The design of DTT, bounded by an overall 500 M€ investment costs, is characterized by the following main parameters:

- a major and minor radius of 2.15 and 0.70 m, respectively;
- an elongation of 1.6–1.8;
- a toroidal magnetic field of 6 T;
- a flat top duration of the order of 100 s.

The design has been carried out according to the following specifications: (i) resemblance to DEMO in terms of edge conditions; (ii) compatibility with DEMO in terms of bulk plasma performance; (iii) flexibility, to be able to test several divertor concepts and technologies.

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This paper is one of the contributions to the Special Issue of Fusion Engineering and Design on the DTT proposal. This Special Issue includes a number of specific contributions that describe in detail the philosophy of the project (role, objectives, relationships with ITER and DEMO, criteria for the choice of parameters), the operation programme, the safety assessment and the technological and technical details of each component of the device, namely the magnets, the divertor, the control and data acquisition system, the additional heating system, the containment system (first wall, vacuum vessel, cryostat), the technological systems including the power supply. Every detail can be found there.

This paper describes the critical aspects of cost and financial funding in both the constructional and operative phases (Section 2), the DTT project organization and management (Section 3) and the technical and economic aspects of the site choice (Section 4). Then (Section 5) the social impact of the DTT realization in the local community is discussed and, finally, (Section 6) conclusions are drawn.

2. Costs

In this section the costs estimated for both the DTT construction and operation phases, are discussed [2]. Two alternative investment scenarios presently under discussion (full public and public-private) are presented in the following.

The budget here reported includes only the quantitative direct costs and incoming. Though the socio-economic fallout is relevant for the decision of building the DTT facility, however no direct quantification of such benefits is included in the financial balance.

The DTT project [1] is founded on a virtuous equilibrium between (a) the needs to guarantee performance able to pursue the challenging scientific goal, with a suitable robustness margin, and (b) to take advantage from any possible synergy with other projects and the with availability of other facilities/infrastructures to take the final cost within reasonable limits. In order to clarify such attitude, two main examples are here reported.

The first is the localization proposed in the ENEA Frascati site. As a matter of fact the presence of the FTU facility in the Frascati Centre would make much easier the authorization and licensing procedures; in addition, the FTU buildings can be re-used to host various DTT systems with minor modifications, including the FTU hall well suited to serve as preassembling site, then guaranteeing a significant economic saving. The second example is the manpower that will take benefit from the availability of a wide number of professionals and scientists involved in fusion research (about 500 people only in Italy) and well established cooperation with universities and industries.

2.1. Construction phase

The cost analysis and control of DTT project are inspired by the precautionary principle. The main criteria for the cost analysis related to the construction phase are briefly listed and discussed in the following.

2.1.1. Basis for the cost estimate

The cost of the facility is estimated taking benefit and comparing direct experiences gained during the construction of several similar devices/systems.

2.2. Engineering design

The engineering design of most components is expected to be a limited part of the total effort; then, for compactness of presentation, its cost is generally included within the total investment amount.

Table 1
DTT cost breakdown.

Items	costs (M€)
Investments, including hardware and infrastructures	444
Contingency	25
Personnel	30
TOTAL	499

2.2.1. Contingency

Taking benefit from the large European experience in designing and constructing Tokamak facilities, the contingency can be limited within 5% of the total investment costs.

2.2.2. Procurements

The procurements are to be launched according to the Italian law that complies with the European directives. The wide international competition is able to guarantee both large cost saving and high quality standards. The industry can be involved in defining some technical specific aspects of the most complex system.

2.2.3. Licensing

The site selected is the ENEA Frascati Centre where several licenses of the same type have been obtained in the past; then the cost of the new licensing can be assumed as negligible.

2.2.4. Impact of the site

The selection of the site where DTT would be located has a strong impact on the cost of a number of acquisition or realization as, for example civil works, the connection to the HV grid and assembly of the site substation. The choice of the Frascati site for DTT would allow, among others advantages, to save money. In the following, when related to the site, the costs are estimated according to this choice.

2.2.5. Construction cost

2.2.5.1. Classification of the construction costs. The total cost of construction is summarized in Table 1.

It should be noticed that the personnel cost corresponds to 300 ppy when assuming an average yearly cost of 100 K€ per person; an additional support of personnel in the order of 150–250 ppy is expected to be provided by research institutions and industries, directly involved in the DTT project, in the frame of collaboration agreements.

The investment costs amount to 444 M€. The distribution among the main expenditure categories (Fig. 1) shows that the main costs (about 80%) are concentrated in the Load Assembly, the Heating Systems and the Power Supply.

The contingency fund of 25 M€ might appear rather limited (only 5% of the investment cost). This choice is made not only on the basis of an accurate estimation on the costs, but also according to the positive experience on Italian and international devices. For instance, the magnets and power supplies for JT-60SA have been realized on time and with the allocated budget evaluated in 46 million € (2006 value). Exactly this amount was spent 10 years later. Also the PRIMA buildings and the JT-60SA quench protection system have been built on time and within the expected budget.

2.2.5.2. Timing profile of the construction costs. The construction period is planned in seven years according with the schedule reported in Fig. 2, with the commitment profile sketched in Fig. 3 and, for the cumulative data, in Fig. 4. The commitment schedule also provides the bounds of the time funding profile.

2.2.6. Funding for the DTT construction

The main financial sources channels are

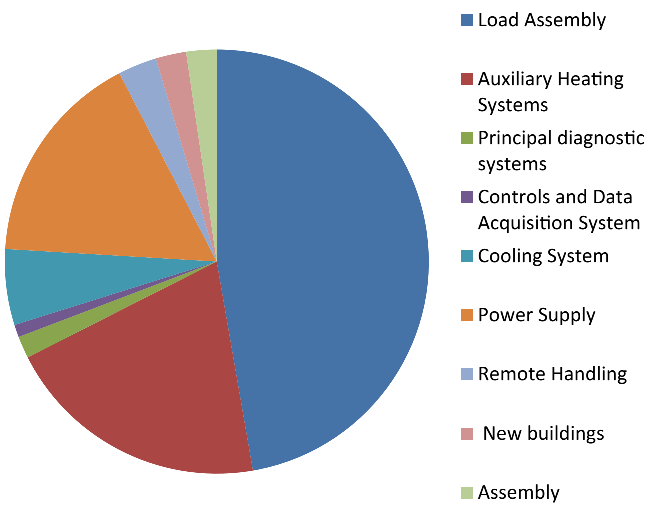

Fig. 1. Distribution of the investment costs.

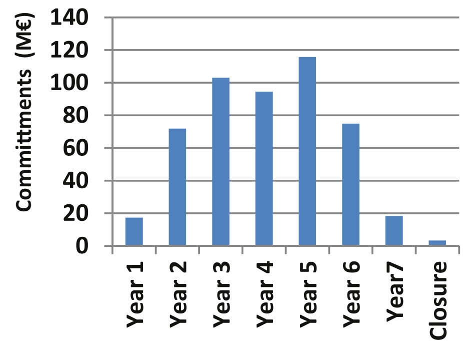

Fig. 3. Construction Cost Time Profile.

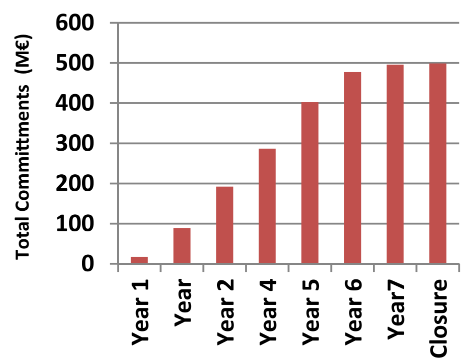

Fig. 4. Construction Cumulative Cost Time Profile.

- European Investment Bank (EIB) loan, granted through the European Fund for Strategic Investment, (EIB loan);
- European Regional Development Funds, National Operational Plan, (NOP);
- European Regional Development Funds, Regional Operational Plan, (ROP);
- International Partners (in Kind), (InP);
- EUROfusion;
- Industries (Ind).

Two alternatives financing schemes are currently being considered (Table 2), the first fully public and the second with a limited contribution of the industries. Both schemes are characterized by a schedule coherent with the expenditure time profile.

2.3. Operation phase

2.3.1. Costs during operation phase

The operating life of DTT is expected in 25 years. The average annual costs are estimated on the basis of the following assumption:

- a staff of about 200 units with an average cost of 100 K€ per year and personnel unit;
- the maintenance and refurbishment costs to allow the effectiveness of the apparatus and the optimal operation of the device, are estimated in 2 M€ per year;
- a depreciation of 4% per year of the investments cost (444 M€);
- a number of 120 professionals for exploitation activity with an average cost of 100 K€ per year and unit, and summarized in Table 3.

An additional cost, not included in Table 3, is the loan repayments of the EIB loan. Assuming a repayment period of 25 years (starting from the operation start up, scheduled for 2024) with

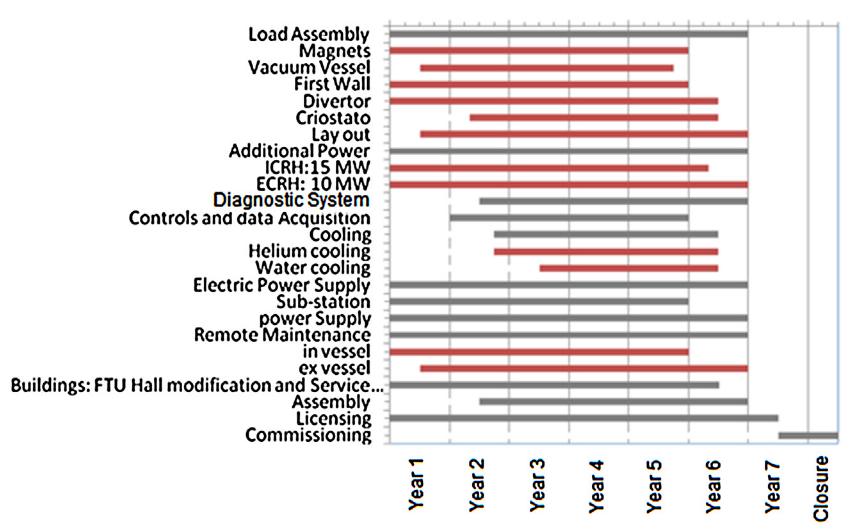

Fig. 2. Main construction phases.

Table 2
Financing hypotheses scheme.

Funding source	Financing hypotheses [M€]	
	100% public	Mixed public-private
EIB loan	250	250
NOP	129	99
ROP	30	25
InP	30	30
EUROfusion	60	60
Ind	0	30
Total	**499**	**499**

Table 3
Yearly costs during the operation phase.

Items	Yearly [M€]
Staff cost	20
External expenditures including maintenance	10
Services	5
Sub-total Operation cost	35
Professional cost for exploitation	12
Total running cost	47
Depreciation	17

an interest of 1%, the year installment with constant rate is about 11.85 M€/year. These costs are planned to be charged to the Italian authorities participating in the programme.

2.3.2. Income for the operation phase

The DTT operation costs are covered by national, European and international funds. The income during the operation phase is estimated on the basis of the following assumption:

- A staff of about 200 person are expected to be involved during DTT operation phase with a total yearly cost of 20 M€/year (assuming a total specific cost in the order of 100 k€/year/person). All the costs are supposed to be covered by the stakeholders and the institutions taking part to the enterprise.
- Extrapolating to the future of the current European financial availabilities and projecting to DTT, a cost of about 45.5 M€/year and 2.25 M€/year for the operation and exploitation activities area respectively, are expected. These costs will be covered by the stakeholders and the European and International Institutions taking part to the enterprise.
- Royalties revenues from technology innovations and inventions, are expected in about 1.25 M€/year in average.
- Additional contributions from the international partners are expected amounting to about 30 M€ for the full operation time.

3. Project management

The DTT aims to play the ambitious role of one of the most crucial step in the road map to commercial fusion and more in general of a very significant tool for the scientific progress [1].

Regardless of its location, DTT is to be a European facility, at the service of the entire international scientific community. Its organizational structure, including the governing and advisory functions will reflect its international nature.

3.1. Property and financial control

A new specific company has to be established to carry out the DTT project. The company will be a legal entity including a number of partners characterized by strong economic solidity and scientific expertise internationally established as, within the Italian frame, ENEA, CNR, INFN, Universities or their consortia.

3.2. Organization scheme

The DTT structure organization specifically designed for the Construction Phase is reported, in a schematic form, in Fig. 5; appropriate adjustments are to be planned for the Operation Phase. The layout, inspired by similar complex high-tech multidisciplinary enterprises, is mainly based on values of a clear and effective chain of roles, autonomies and responsibilities.

The main competences, the roles and responsibilities in the organization chart are summarized in the following. Although detailed and defined, the present organizational structure is a strongly inspired by principle of flexibility: a careful and constant monitoring will be implemented to prevent lack of efficiency, to solve unforeseen pathologies and to improve the overall performance of the system.

A new company will be established to superintend the realization of the entire DTT project including the construction and the operation. The stakeholders (public or public-private) of the new entity should have a well assessed scientific know-how and solid financial resources.

The shareholders heads (or their delegates) form the Board of Directors (DB), responsible for the strategic addressing of the project.

The Project Board (PB), appointed by the DB, advises and supports the Project Leader (PL) in monitoring the progress and schedule of the project.

The PL is the responsible of the entire project. Its office is provided with the operational tools requested for the better implementation of the project, including the appointment of experts or delegates for specific tasks, the signing up for approval of the main procurements orders; the chairing of the selection boards for recruitment of personnel; the coordination of the Project Areas; the preparation of the activity reports and planning.

A Scientific Advisory Board, made by senior experts covering the whole range of required competences but without operative tasks, is scheduled to advice the scientific activities of both PL and PB.

Fall under the PL coordination also the Administration (with competences in financial and legal activities and in the management of the human resources), the Central Integration Office (responsible also for safety and information management) and Communication Office.

The Project Team, established at local and European level will evolve along time, according to the need time profile; its average size is in the order of 125 professionals and 50 technicians and administrative persons.

4. Site layout

The choice of the site has been done taking into account the role of DTT as "European facility". In this view, the accessibility of the site and its attractiveness for the interested people from many European and worldwide countries (researchers, scientists, engineers) that will contribute to the project/construction and operational activity, providing an important beneficial impact also on the scientific and technical performance, has to be primarily considered. Among others, the choice of one of Italian sites, justified by a number of funding reasons, cold be considered attractive.

Another important factor to be taken in account is the "cultural background" of the site. As a matter of fact, an environment with a solid and multicultural background can strongly stimulate the creativity of the involved team. Actually this aspect has been already, in the past, one of the main factors in selecting one or the other site; for instance when realizing the European Tokamak JET in England, the site was chosen (among others) by the European Commission thanks to its closeness to Oxford.

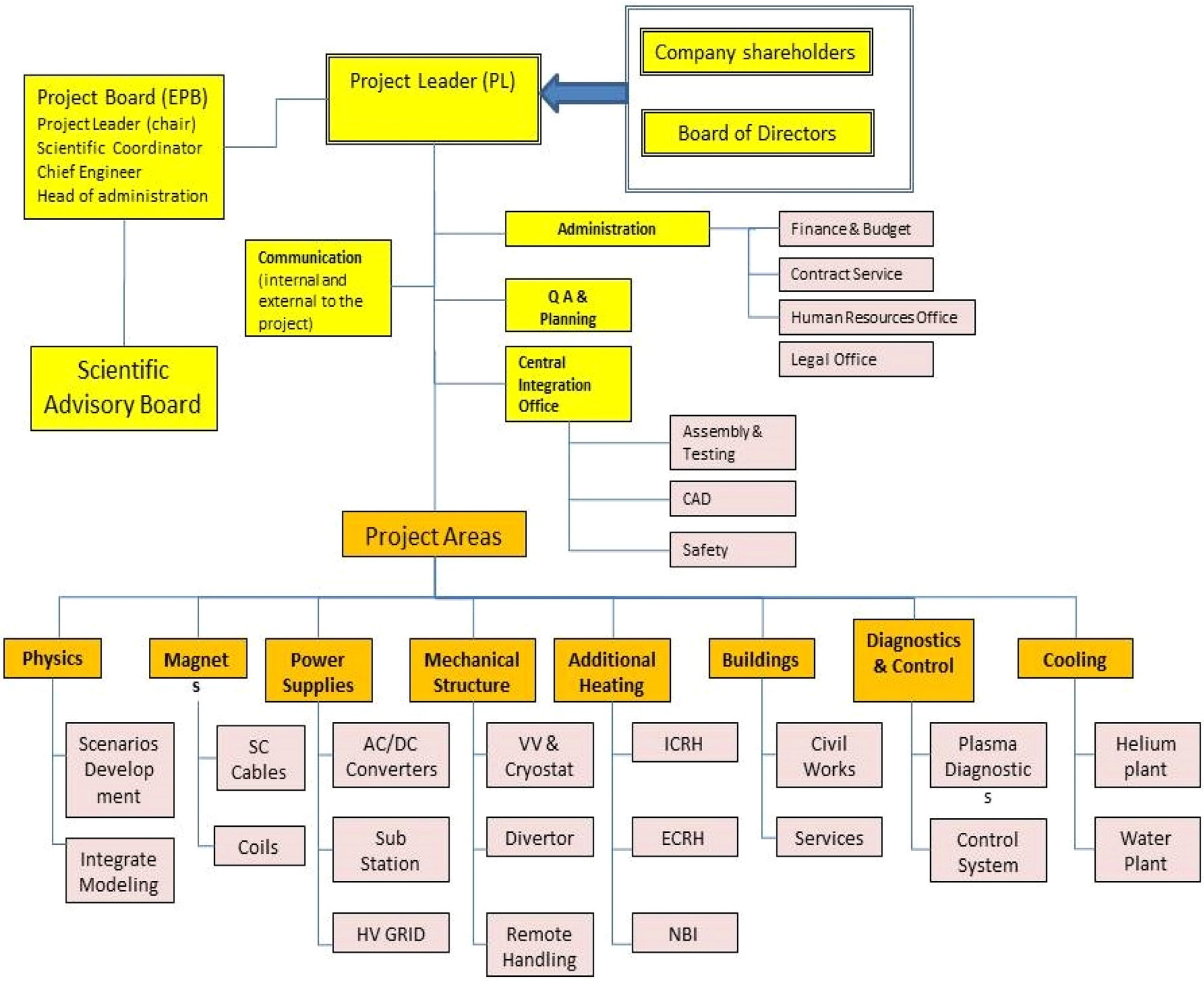

Fig. 5. The DTT structure organization (Construction Phase).

Last but not least, the realization of the facility within an existing laboratory would allow to save money, by using all the already existing facilities and infrastructures. Although there are several sites in Italy able to host DTT, the choice of Frascati research area as DTT site is – from this standpoint – one of the most suitable for guarantying the success of this prestigious enterprise. In the Frascati research area, since the 50′s, ENEA, INFN, CNR and, more recently, the University of Rome Tor Vergata originated a number of scientific and technology initiatives, making this area one of the most prestigious worldwide.

In particular the ENEA Research Centre has been analyzed in detail in order to assess the possibility to realize the DTT facility, given its capability to meet the various technical requirements, including the actual possibility to start the construction phase as soon as possible.'

Within the ENEA Frascati site it is already operating the FTU Tokamak. The presence of such a facility would make much easier the authorization and licensing procedures of the new machine. Moreover, the FTU buildings can host DTT with some modifications, already discussed with local authorities. Almost all the additional building volume required to adapt the FTU hall to DTT hall are already available since the construction of FTU.

The authorization process, thereby, should not take long time. Practically only the permit to build the new hall must be requested and it will be part of the licensing process. The new hall will have a low environmental impact and will be architectonical similar to the FTU buildings, of which it is just an extension.

The required upgrade of the HV grid calls for the extension of the existing 150 kV line. This is an important aspect of the project. Discussions are in progress with Terna Group Italy, the leading grid operator for electricity transmission. The bureaucratic procedure to get the connection permission is ongoing and would be finalized shortly. To be mentioned that the extension will be made in tunnel thus avoiding any possible impact on the environment. Two cables at 150KV will supply the requested 300 MVA power needed at the facility.

The realization of the cryoplant will have an impact on the general layout because it should be located as close as possible to the large tanks for liquid nitrogen and liquid/gas He and to the machine to avoid long pipelines.

All these aspects will be analyzed in depth in the environmental impact evaluation (VIA, "Valutazione di Impatto Ambientale") document.

Fig. 6 shows an aerial view of the present FTU buildings highlighting the modifications planned to install the DTT tokamak. The other buildings in the picture are now part of the FTU infrastructures and will be reused for DTT with some minor internal modifications. Fig. 7 illustrates the location of the DTT in the new hall and a preliminary general layout with the indication of the building destinations. The machine would be preassembled in a

Fig. 6. Aerial view on of the present FTU buildings, (requested upgrading highlighted in yellow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

modular way inside the present FTU hall, which, on a longer time scale, should host, when planned, the NBI injector.

5. Socio-economic impact of DTT project

5.1. Industrial involvement

The DTT Project aims at addressing key technologies required for the realization of a fusion reactor, and therefore it will contribute significantly to industry’s readiness for designing and realizing a technologically and economically viable DEMO reactor. During the last phase of, or soon after, the end of the manufacturing of ITER components by the European industry, it will also contribute to provide continuity in the "fusion market", which is necessary to attract the industry involvement in the fusion development programme. In this respect, it is worth noting that DTT is the only fusion experimental device, and a superconducting one, to be realized in Europe in the next years apart from ITER. As one of a very few new scientific facilities using superconductors, it represents a key undertaking for a strategic industrial sector.

Like for any large research infrastructure, in the shorter term significant positive effects to industry are expected in terms of different types of technological innovation, commercial and organizational learning, which would be gained by the companies through their participation in the DTT Project. A wide range of industrial areas relevant to fusion development would be involved, including:

superconductivity (advanced cable-in-conduit technology, cable design optimization, current quench detection, coil testing, instrumentation);

materials (heterogeneous joints for innovative materials, dynamics of liquid metals in the presence of magnetic fields, chemical/mechanical compatibility of different materials, plasma spray coatings for high temperature operation such as W coatings on metals, manufacturing of high heat flux components, high precision mechanical components and assemblies

vacuum technology and HV power supply (alternative vacuum systems based on non evaporable getters, development of power lasers for neutraliser, development of multi-physics codes for particle tracing, design and manufacturing of power system for HV DC and modulation, HV holding for in vacuum components, complex multipurpose HV feedthroughs, high frequency generator and amplificatory);

robotics (manipulators, sensors, activators, metrology tools, in-vessel viewing system, rad-hard sensors and actuators) controls (real time, active feedback control system for plasma stability and plant protection, radiation hard sensors and fast actuators, fast computing, plasma diagnostic systems);

gas exhaust (efficient methods for high purity hydrogen production based on membrane technology);

design and manufacture tools and engineering (implementation of extended CATIA capabilities, high quality standards in both design and manufacture phases, high quality qualification programme for each specific process, metrology controlled manufacture based on laser tracking, advanced software for metrology and manufacture control, advanced simulation of laser welding and optimization of welding sequence for shrinking mitigation, time dependent coupling of currents, temperature and stresses).

It is worth noting that all these technologies have also a valuable applicability in many industrial sectors outside fusion (Medical imaging and diagnostics, Renewable energy industry, Space industry, Robotics, Electrical, mechanical and chemical industry).

Several tens of industries, including SMEs, will be involved in the realization of the DTT device during the seven years of design and construction period. To this purpose, it is worth noting that more than 80% of the capital invested in DTT project is devoted to the procurement of the machine load assembly (vacuum vessel, superconducting magnets, high heat components for divertors, cryostat) and of the heating and diagnostic systems, all involving advanced technologies and high quality standards. Commitments will peak about 2–3 years from the start of construction. During the operation phase, a level of expenditure of about 15 M€/y is anticipated mainly for high-tech services.

Close contacts will be established between the companies involved in the Project and the Research Laboratories and University teams who will develop the design and will provide support in the component construction, thus ensuring that industry can take benefit of state of the art equipment and expertise that exist in research centres. The involved companies will find in the DTT Project an opportunity to develop new technological competences, to improve the existing products in their business portfolio, to enhance their production techniques, and to build knowledge in the company’s personnel. In this way, the companies will gain in competitiveness, especially in the fast growing, high tech and innovation sectors, thus generating new occupation, in particular with highly skilled, highly-paid jobs. These sectors have the highest impact multiplier on society: according to a recent analysis [3], for each job in the software and technology industries, four to five new jobs are indirectly created ranging in all other economic sectors.

In addition, enhancements in managerial skills can be expected, in particular for SMEs involved, thanks to the participation in a complex project aligned to the highest scientific standards, such as: contract management of large and complex contracts, preparation of technical specifications for non-standard components, experience management tools (handling of non-conformities,

Fig. 7. General layout of the DTT facility.

change-notes ..), experience in quality management, experience in project documentation systems, experience in working with interlinked work breakdown structures (WBS) to follow the schedule of tasks within the project globally, back office (measurement of as built configuration, comparison with design geometry).

5.2. Socio-economic effect on the local/regional environment

A very important aspect is the socio-economic effect of the DTT Project on the immediate local and regional environment. By attracting many companies, including hi-tech companies, and many scientists from all over Europe, and offering new employment possibilities, the DTT Project is expected to have a significant impact on the local life. The most obvious factor is the direct economic return from spending locally on supplies and services and from employment opportunities.

Both the project and the personnel, with their families, will depend heavily on locally produced goods and services, thus supporting the local economy and employment. It can be anticipated that a few tens of companies will be involved and more than one hundred of people (scientists, designers, workers) will be present on-site during the construction. During the operation phase, more than 100 people will be involved. A large fraction of these will move to the region from elsewhere with their families.

The socio-economic impact has been analyzed in details for a fusion research facility similar to DTT, i.e. the Joint European Torus (JET), which was realized at Culham (Oxfordshire, UK) in 1978–1983 and is still in operation [4]. The cost of JET was about 200 Million European Units of Account (roughly 480 M€ in 2015 value, calculated assuming an average European inflation rate [5]). The impact of JET Project on the economy of the local districts/county (Vale of White Horse District, South Oxfordshire/Oxfordshire) was surveyed in terms of direct employment, staff and contract expenditures, housing, education etc. in the year 1993, which may be considered as a typical operation year. The expenditure profile of JET, in fact, has not significantly changed in time, and 1993 the figures may be considered as representative of the whole period. The main outcome was the following:

- about 20% of the annual JET expenditure for contracts and orders, excluding salaries, was spent locally (about 6M£/y out of about 30M£/y) during the operation phase (software and hardware, electrical engineering, scientific equipment, mechanical engineering, civil engineering, site services, travel agencies, other services). About 25–50 companies gained the bulk of this expenditure;
- About 25% of JET suppliers recruited additional staff as a result of their work for JET. A further 20% could avoid redundancies for the same reason;
- JET workforce is very highly skilled, with qualifications and average salaries much higher than the county workforce as a whole. 90% of JET staff lived in Oxfordshire, they and their family spent between 17–21M£/y in the Oxfordshire economy;
- The resulting overall expenditure in Oxfordshire amounted to about 25 M£/y (roughly 45 M€ in 2015 value). Considering the 35 years operation life of JET so far, this represents an economic return on investment of a factor 3.4 for the local economy.

The JET study showed also that the significant impact of the Project on the local life was determined by the characteristics of both the locality and the Project. In the UK context, Oxfordshire has a tradition of research and high technology based industry. The JET workforce is highly skilled and the majority of staff have gone to Oxfordshire just to work at JET. These favourable characteristics are strikingly similar to those of DTT and of the hosting area of Frascati. As in the case of South Oxfordshire, the Frascati area hosts already numerous research centres and benefits from the presence of a University campus nearby. The area has the potential to further grow and become an innovation centre for industries and attract innovative companies [5]. The DTT Project can be a major player in this process.

5.3. Education, dissemination and outreach

Finally, the impact on society also builds on education and outreach activities. It is expected that about 10 undergraduate students and 10 PhD students will work in the DTT Project each year in the construction phase, numbers that are expected to increase significantly in the operation phase. Given the scale and the multidisciplinary nature of the DTT Projects, it will certainly attract the interest of many University groups from Physics and Engineering departments, in addition the many already involved in the Italian fusion programme. Like for industry, they will also benefit from the participation in a complex project aligned to the highest scientific standards. The Project represents also an excellent opportunity for training of engineers and physicists who will be later employed in ITER.

6. Conclusions

The DTT project is a major challenge not only for the technical and technological aspects but also from the financial, administrative and organizational points of view.

Analyses show that the ambitious objectives of DDT can only be achieved through a strict control of costs and the best use of human and financial resources.

The general direction of DTT is imposed by the role assigned within the European Fusion Roadmap. However, its specific mission of facility aimed at testing and assessment imposes the maximum flexibility in the design, construction as well as operation and management.

Despite being largely financed with national funds, DTT is envisaged as a fully European resource. In this respect the choice of Frascati site, beyond to the technical requirements, ensures a good attractiveness and hosting capabilities. In the light of the experience gained in similar cases, studies show that the investment is very promising in terms of support for the advanced European industry, as well as for local socio-economic development.

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