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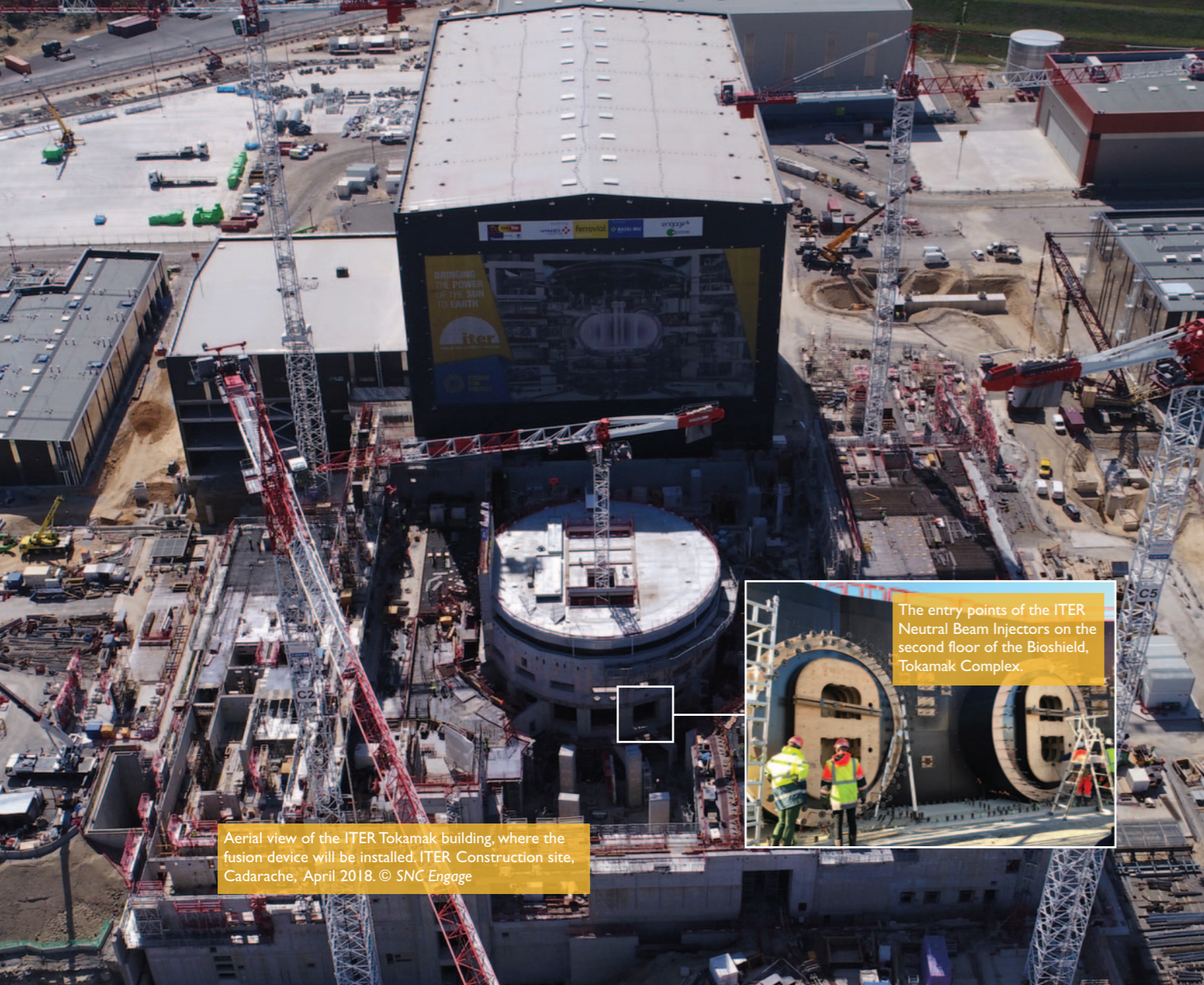
CREATING A SMALL SUN ON EARTH

SPIDER

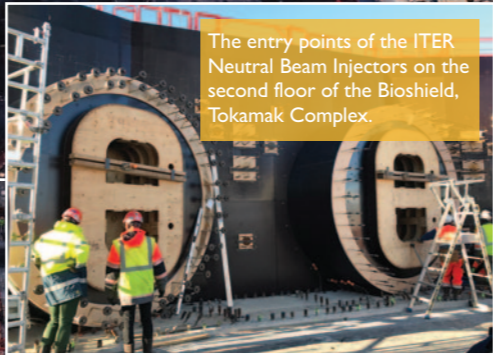
THE MOST POWERFUL NEGATIVE ION BEAM SOURCE IN THE WORLD

SPIDER





Aerial view of the ITER Tokamak building, where the fusion device will be installed. ITER Construction site, Cadarache, April 2018. © SNC Engage



The entry points of the ITER Neutral Beam Injectors on the second floor of the Bioshield Tokamak Complex.

SPIDER

a test facility for ITER

Energy is essential for our economic growth and social well-being. It helps us reduce inequalities and avoid conflict when we have enough supply. As we increase in numbers we need more of it but we must make sure it is clean. Lowering our dependency on fossil fuels to fight climate change is one of the biggest challenges facing mankind. For this reason, now more than ever, we need a sustainable energy mix where fusion can play a role in the future.

ITER is the biggest experiment to test the potential of fusion energy. China, Europe, India, Japan, Korea, Russia and the USA, are working together to deliver the most advanced fusion reactor in history. Thousands of scientists, engineers, companies and laboratories around the world are involved in this one-of-a kind project, which is under construction in Cadarache, south of France.

The SPIDER facility is the result of a unique international collaboration between Italy and Consorzio RFX (ENEA, CNR, INFN, University of Padua, Acciaierie Venete SpA); Fusion for Energy (F4E) and ITER India managing respectively Europe's and India's contribution to ITER, and ITER Organization, leading the design and oversight, and ultimately operating the ITER device, where the innovation produced in Padua will see its fullest expression.

SPIDER (Source for the Production of Ions of Deuterium Extracted from a Radio frequency plasma) is the most powerful negative ion beam source in the world. It will operate in the ITER Neutral Beam Test Facility, hosted by Consorzio RFX in Padua.

The expertise that we will acquire through SPIDER is essential for the realisation of fusion energy. SPIDER will help us create a small sun on Earth.

The goal of SPIDER is to achieve the high performance levels of the ion source that will be used in ITER. Its contribution is essential towards the development of the powerful heating systems needed to reach approximately 150 million °C allowing the fusion reaction to occur.



Aerial view of ITER Neutral Beam Test Facility, Consorzio RFX, Area of CNR, Padua, Italy.

How SPIDER

will pave the way to fusion energy

The materials that are used in the fusion reaction are deuterium, which can be extracted from seawater, guaranteeing a supply for thousands of years, and tritium which is not available readily but can be created from lithium, which is abundant in the crust of the earth. Deuterium and tritium are heated at extremely high temperatures in order to fuse and release virtually unlimited energy. The power-horses of the ITER heating systems are two neutral beam injectors, with a third one as an optional upgrade during operation.

The SPIDER beam source will help scientists to develop the ion source, one of the critical elements needed for the operation of the ITER Neutral Beam Injectors.

A few metres away from SPIDER, another experiment known as MITICA (Megavolt ITER Injector and Concept Advancement) will develop and test a prototype of the Neutral Beam Injector.

Although neutral beam injection is routinely used for heating the gas in fusion devices, the size of ITER poses a set of challenges: particle beams have to be more powerful and individual particles have to travel faster to penetrate far into the core of the ITER plasma. For this reason, negative ion based injectors are developed. The negative ions, when created, will be accelerated at 1 MV, a speed that no other neutral beam system has achieved. Once accelerated, they will be neutralised before they are injected into the ITER machine to heat the plasma.

This is the first full-scale ITER ion source, capable of running pulses of up to 3 600 seconds at maximum power with hydrogen or deuterium. The 6 MW beam generated for one hour by 1280 powerful beamlets is equivalent to the energy required by roughly 1 000 medium apartments in one day.

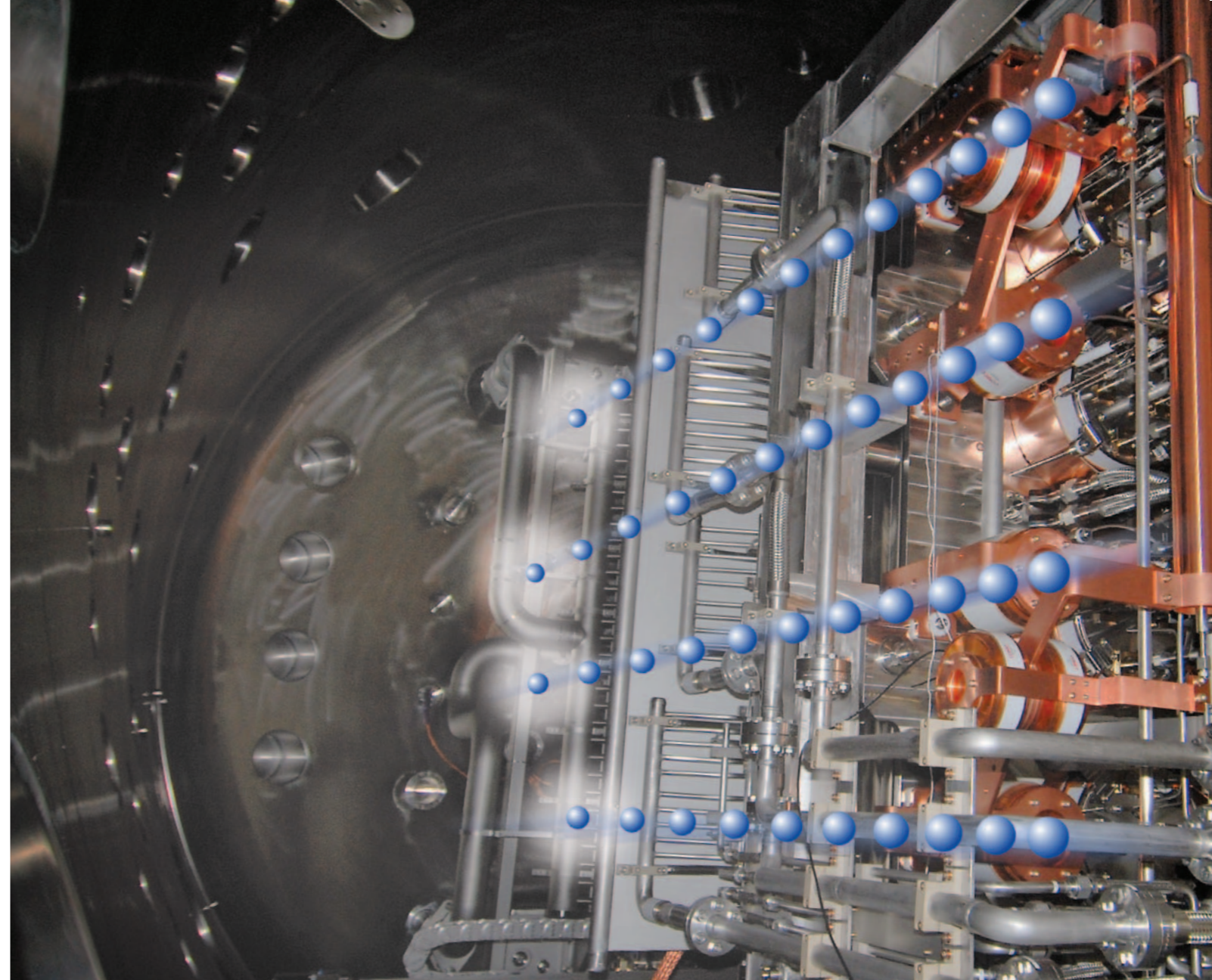
The realisation and exploitation of the ITER Neutral Beam Test Facility is recognised as a necessary step to make the operation of the ITER heating neutral beam injectors efficient and reliable. The knowledge acquired will help us to deliver the plasma temperatures needed in ITER and potentially in DEMO, the demonstration fusion power plant that will follow.



SPIDER High Voltage Deck.



Installation of SPIDER Vacuum Vessel.



ITER Neutral Beam Test Facility –

a tour of the site

Power Supplies System containing:
High Voltage Deck
Ion Source and Extraction Power
Supply (provided by Europe),
Acceleration Grid Power Supply
(provided by India).

The cooling system of the ITER
Neutral Beam Test Facility
(provided by Europe).

SPIDER beam source installed
inside the vacuum the vessel with
its vacuum system.
The beam source is connected to
the power supply through the
transmission line
(provided by Europe).
Beam Dump in the vessel
(provided by India).

Gas storage tank for MITICA
Cryoplant (provided by Europe).

MITICA vessel containing the full
scale Neutral Beam Injector
prototype (provided by Europe).

1 MV gas insulated transmission
line (provided by Japan).

MITICA 1 MV High Voltage Deck
containing the Ion Source and
Extraction Power Supply
(provided by Europe).
On the right, the Insulating
Transformer (provided by Japan).

Five 200 KV DC generator, part
of the MITICA Accelerator
Power Supply (provided by
Europe and Japan).

◀ SPIDER ▶

◀ MITICA ▶



"SPIDER is the result of collaboration between technical teams, companies and laboratories

that worked for years to get here. It felt like putting together a mini ITER. In fact, this is the first fully integrated ITER system deploying successfully various technologies. Europe has made important technical and financial contributions to SPIDER because it will help us develop the powerful heating systems to achieve the superhot plasma of the biggest fusion device."

Tullio Bonicelli
Neutral Beam & Electron Cyclotron Power Supplies and Sources Project Manager
Fusion for Energy



"I'm very proud that a first important milestone has been reached with the SPIDER operation.

Since the beginning, we've been aware of the Neutral Beam Test Facility's strategic role and felt the responsibility to guarantee its success within the timeline requested by ITER. The international team involved in this project, placing in Padua its competences and resources, is conscious of the crucial goal and is strongly committed in reaching it."

Vanni Toigo
Neutral Beam Test Facility Project Manager
Consorzio RFX



"The exemplary framework provided through the ITER project, has ensured the realisation of

SPIDER integration. This facility will lead the research for the development of the ITER Neutral Beam Injector systems. India conveys its best wishes for the inauguration of SPIDER, and compliments Consorzio RFX, the other ITER Parties and the Neutral Beam Programme Committee, for their efforts in ensuring its successful integration and operation."

Arun K. Chakraborty
Diagnostics Neutral Beam Project Manager
ITER India



"The start of SPIDER initiates us along the path in demonstrating one of the most powerful heating

systems needed for ITER, where heating capabilities will exceed the sun core temperatures. With SPIDER we will develop the ion source that will one day power ITER. Thanks to the perseverance and creativity of the scientific and industrial teams of RFX, Europe, India and the ITER Organization, together, we are moving one step closer to generating an artificial sun on Earth to the benefit of all future generations. It is a proud occasion for all who have played a role in this important milestone".

Deirdre Boilson
Head of Heating & Current Drive Division
ITER Organization

SPIDER

an extraordinary international partnership

The most powerful negative ion beam source in the world is the result of collaboration between several Parties:



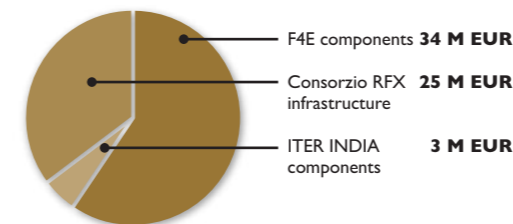
Italy and Consorzio RFX have provided the facility, the industrial base, and most of the personnel. Consorzio RFX is responsible for the scientific exploitation of the experiment.

Fusion for Energy (F4E), has procured, financed and overviewed most of the components by drawing on the expertise of European industry and research organisations.

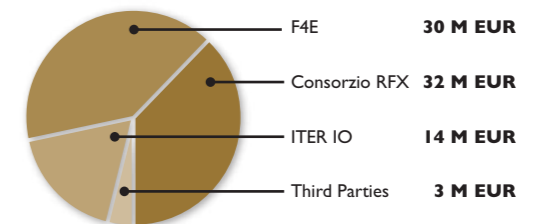
ITER India has contributed in terms of equipment.

ITER Organization, as the chief client for SPIDER, has led its design and oversight, aiming to apply the knowhow that will be generated to the ITER machine.

SPIDER Components and Construction (2012-2018)



R&D for ITER Neutral Beam Test Facility (2012-2018)



SPIDER

connecting research, business and technology



62
Million
EUR



20
Main
Contractors



100
Sub
Contractors

To push forward our knowledge boundaries in order to acquire further technical expertise in the field of fusion energy, SPIDER promoted the collaboration between the R&D and business sectors. The former was responsible for designing the equipment that it will have to operate; the latter was entrusted with the manufacturing of its components. By working together this experiment has come to life and has earned Consorzio RFX the prestigious status of an ITER facility.

SPIDER has generated a wave of economic activity by involving directly at least 20 companies, the majority being small-medium enterprises, from the areas of power supplies, electronics, vacuum technology, cryogenics, mechanical engineering and construction. The value of contracts signed in the fields of manufacturing and construction is in the

range of 62 M EUR, without taking into account the direct and indirect investment in R&D. Through their participation, companies gained insight into ITER and were given the incentive to grow and employ, re-train and retain workforces. Their association to this technologically-advanced test bed is part of their legacy.



“Thales is very proud to have delivered the SPIDER beam source and to have contributed to the heating sources that will be used to raise the temperature of the ITER plasma. The finalisation of this

component has been possible thanks to the high competency and motivation of the teams, because in such “state of the art” project, the difficulties we may face are unknown. SPIDER has been a success and Thales is very thankful to its partners Galvano-T, Cecom, Zanon and to F4E, Consorzio RFX and ITER Organization for the great spirit of collaboration in which this project has been achieved.”

Charles-Antoine Goffin
Thales DefSI and Transformation Director



“Contributing to the SPIDER facility, as part of the ITER project, has been an exciting challenge. It motivated us to offer all our technical and project management skills. It has been a very demanding job making everyone in our company proud to be part of it.”

Giuseppe Taddia
OCEM PE General Manager



“We are really proud to have contributed to such an innovative and strategic project for the development of safe, clean and almost unlimited energy. Collaborating with F4E has been very interesting as well as a great opportunity for technical growth.”

Giovanni Faoro
COELME Project Manager for SPIDER High Voltage Deck & Transmission Line



“Because of our collaboration with F4E we had the opportunity to deliver a large-scale plant and address technical challenges with a team of experienced people, in order to harness fusion – a new sustainable energy”

Giorgio Biginelli
Delta-Ti impianti CEO



“Thanks to the involvement of Angelantoni Test Technologies in the ITER project, our company was able to improve its technical and management knowhow. We have been given fresh business opportunities and the possibility to develop new partnerships.”

Mauro Margherita
Angelantoni Test Technologies General Manager



“Working with ITER-India for SPIDER leveled our strong expertise in high tech components up to the large scale of ITER.”

Christian Eckardt
PVA TePla Manager Research Devices



“The cooperation with RFX for the realisation of the SPIDER project has been a great opportunity for our technical growth. This experience confirmed once again our propensity to research and the development of new solutions.”

Luigi Berlese
Treesse General Manager



“ECIL is proud to have collaborated with ITER-India and is happy that the SPIDER, whose Acceleration Grid Power Supply was delivered by ECIL, is being inaugurated for operation at Neutron Beam Test Facility (NBTF).”

Debashis Das
Chairman and Managing Director, Electronics Corporation of India Limited



“It has been a challenging experience to deliver novel multi-secondary transformers for SP-AGPS at the SPIDER facility, we stretched our limits to satisfy the demand.”

Jitendra Mamtora
Chairman and Director, Transformers and Rectifiers (India) Limited



“This project has meant a lot for us, not only in terms of business but also in terms of passion, prestige and know-how. We’re very proud to have been part of it.”

Fabio Munaretto
Gemmo Livio & Figli srl



“Our involvement in SPIDER has been a great experience with emphasis on learning and delivering the supply of Amtech converters for the Accelerated Grid Power Supply. Our equipment was successfully integrated achieving the desirable performance”.

Piyush Patel
Managing Director, Amtech Electronics (India) Ltd