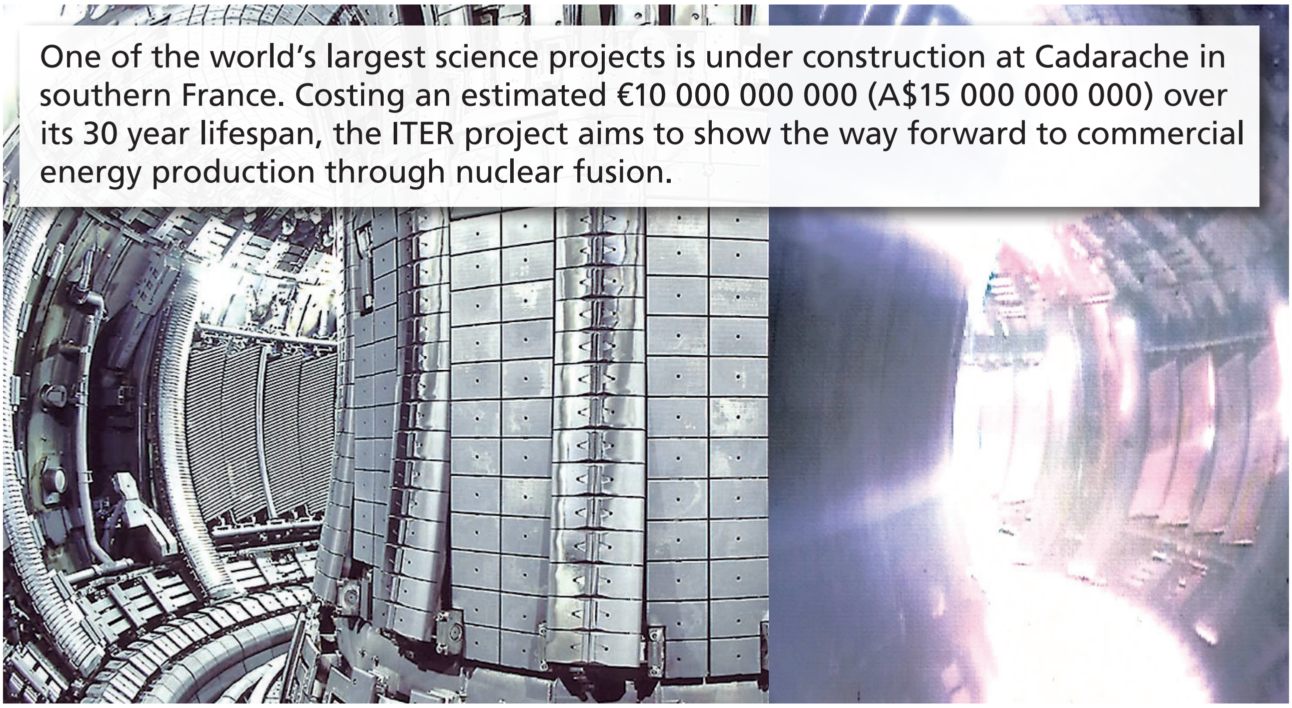
fact sheet

Nuclear reactions 5:

The ITER project

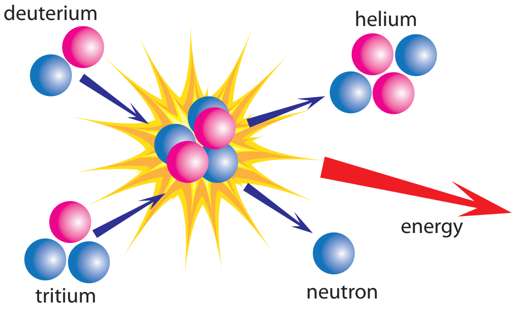
One of the world's largest science projects is under construction at Cadarache in southern France. Costing an estimated €10 000 000 000 (A$15 000 000 000) over its 30 year lifespan, the ITER project aims to show the way forward to commercial energy production through nuclear fusion.



a split photograph of the inside of JET's torus, with and without a plasma, from 1999

Energy from the sea

The ITER reactor will use deuterium and tritium as fuel. These are isotopes of hydrogen, with one and two neutrons in the nucleus respectively. In a fusion reaction they are combined to make helium and a neutron.



$$^{2}_{1}D + ^{3}_{1}T \longrightarrow ^{4}_{2}He + ^{1}_{0}n$$

Deuterium is readily extracted from seawater at a cost of around $1 per gram. Tritium, which is radioactive, is much more expensive – a gram costs up to $100 000. To get around this, the ITER reactor will make its own tritium. Neutrons from the fusion reaction are captured in a blanket of lithium that surrounds the reactor. Fission of lithium nuclei creates tritium by two reactions:

$$^{1}_{0}n + ^{7}_{3}Li + \text{energy} \longrightarrow ^{3}_{1}T + ^{4}_{2}He + ^{1}_{0}n$$

$$^{1}_{0}n + ^{7}_{3}Li + \text{energy} \longrightarrow ^{3}_{1}T + ^{4}_{2}He + ^{1}_{0}n$$

Fission of ^{7}Li releases a neutron that can sustain a chain reaction. Natural sources of lithium contain 7.5% ^{6}Li and 92.5% ^{7}Li.

Progress to fusion

Despite 50 years of research, a self-sustaining fusion reactor has yet to be built. One measure of progress to this goal is the fusion 'triple product'. This is calculated by multiplying together fuel density, fuel temperature and confinement time. For sustained fusion of deuterium/tritium, the triple product has to be at least 10^{21} keV s m^{-3}. Experimental reactors have individually achieved high fuel densities, temperatures and confinement times – but not all at the same time.

The first experimental reactors, developed in USSR through the 1960s, achieved a triple product of about 5×10^{14} keV s m^{-3}. Today's reactors, such as ITER's predecessor, JET (pictured above), have increased this to 10^{20} keV s m^{-3}. ITER is aiming for a value of 3×10^{20}, which is close to that required for sustained fusion.

To do this, fuel has to be heated to an incredible 150 000 000 °C, more than ten times the temperature at the core of the Sun. At this temperature the reactants occur in a plasma state. Strong magnetic fields are used to contain the electrically-charged plasma at the required density.

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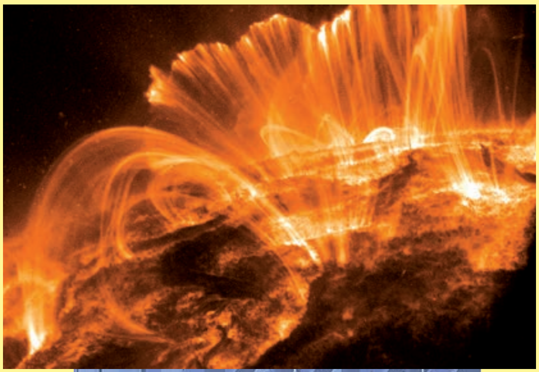
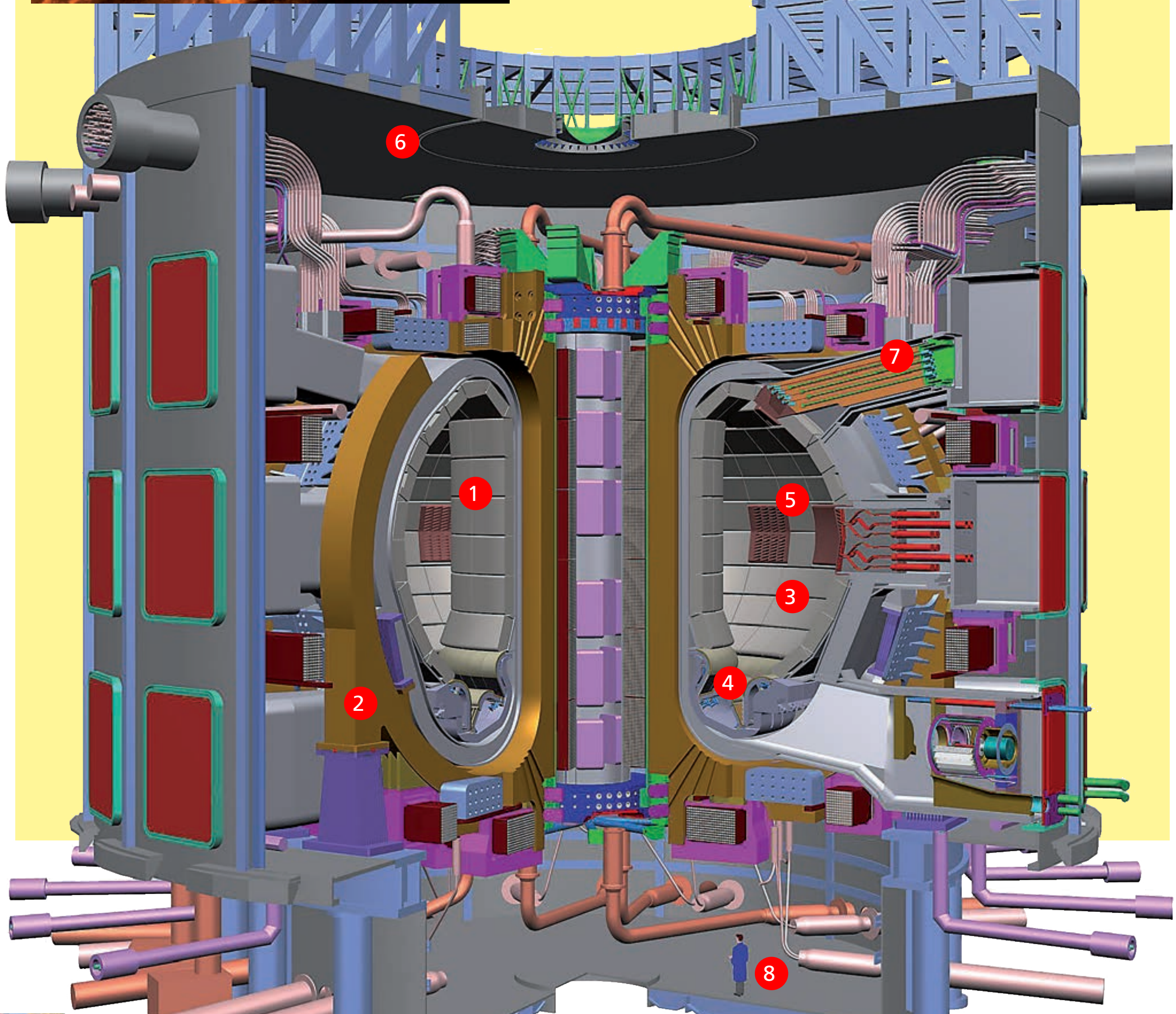


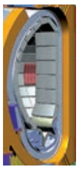
Fusion in the Sun

Fusion takes place in the Sun at a lower temperature than fusion reactors on Earth. This is because of the Sun's massive gravity, which results in plasma densities far greater than can be achieved on Earth.

	DENSITY (g cm^{-1})	TEMPERATURE (°C)
CORE OF THE SUN	150	15 000 000
ITER REACTOR	4 x 10^{-10}	150 000 000



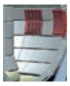
ITER reactor cutaway © ITER Organisation, www.iter.org/mach/Pages/Tokamak.aspx



1. **Vacuum vessel**: the doughnut-shaped vacuum vessel contains the hot plasma where fusion occurs.

2. **Magnets**: 10 000 tonnes of magnets generate a field to contain the plasma. They are cooled to 4 K (-269 °C) to achieve superconductivity.

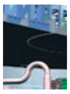
3. **Blanket**: this shields the magnets from intense radiation and heat generated by the plasma. Tritium breeding also takes place in the blanket modules.



4. **Divertor**: high energy plasma particles are directed by magnetic fields to the diverter, where their kinetic energy is converted to heat. ITER will research materials here that can withstand sustained temperatures of 3000 °C.

5. **External heating**: high energy beams and strong electromagnetic fields are used to heat the plasma initially, to the required temperature.

6. **Cryostat**: this stainless steel vessel provides a supercool vacuum environment. It is 31 m tall and 36.5 m wide.



7. **Diagnostics**: 50 different diagnostic systems monitor the state of the machine, including temperature, density and energy confinement times.

8. Note the person for scale!