Fix Your mistakes

Common mistakes –

① The Abstract.

The Abstract is one paragraph which is supposed to summarize the content of the paper. It is NOT an introduction to the subject.

② The Figure Caption.

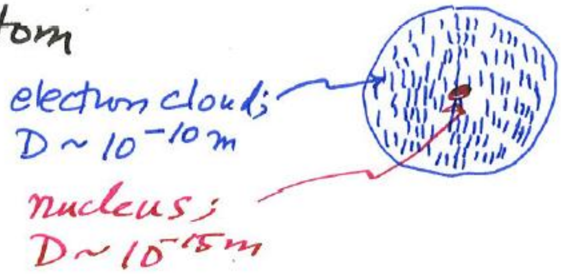
Each Figure must have a Figure Caption. The figure caption should explain the figure. It must answer the question "What does this figure show?"

③ Run on sentences

Points will be deducted for run-on sentences. If you don't know what a run-on sentence is, look it up on Wikipedia.

Applications of Nuclear Physics

- The Atom



- Isotopes : $^{A}_{Z}X$

  - Z = number of protons
  - $A = Z + N$ = number of nucleons
  - X = element symbol

- The nucleus is bound together by the strong field (an effect of quantum chromodynamics)

- Nuclear reactions, and nuclear decays, can release large quantities of mass energy

  $E = mc^2$

  Consider reaction $A + B \rightarrow C + D + \ldots$

  Mass Energy released $= (M_A + M_B - M_C - M_D - \ldots)c^2$

  $\Delta E = M_{initial}\, c^2 - M_{final}\, c^2$

  → goes into kinetic energy of the products

Fission and Fusion

- An example of **fission**

$$n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow A + B + n\text{'s}$$

This is neutron induced fission of ^{235}U.
A specific case

$$n + {}^{235}_{92}U \longrightarrow {}^{142}_{56}Ba + {}^{92}_{36}Kr + n + n$$

Exercise Calculate the mass energy released in this reaction.

$$E_{released} = M_{initial}\,c^2 - M_{final}\,c^2$$

U-236	236.045 568	u
Ba-142	141.902 501	u
Kr-92	91.904 374	u
2 n's	2.017 330	u

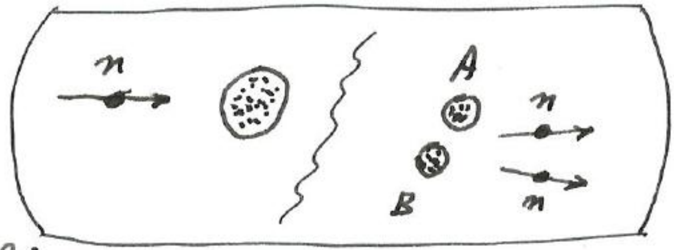
$M_i - M_f =$ 0.221 363 u

$E_{released} = 0.221\,u \times 931.5\ \frac{MeV}{uc^2} = 205.9\ MeV$

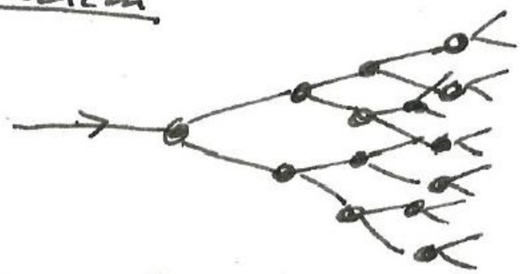
The atomic mass unit

$$1\ u = 1.660\ 539 \times 10^{-27}\ kg$$

$$1\ u = 931.494\ MeV/c^2$$



- Note that a chain reaction is possible.



- Each fission releases ≈ 200 MeV of mass energy.

- Exercise How much energy would be released if 1 kg of U-235 were to undergo fission?

$$E_{released} = 200 \frac{MeV}{particle} \times N \quad \leftarrow \frac{M}{m}$$

$$= 200\ MeV \times \frac{1\ kg}{235 \times 1.66 \times 10^{-27}\ kg}$$

$$= 5.13 \times 10^{26}\ MeV$$

$$= 8.21 \times 10^{13}\ J$$

$$= 19.6\ kt$$

$1\ eV = 1.602 \times 10^{-19}\ J$

$1\ kt = 4.184 \times 10^{12}\ J$
kiloton of TNT

Applications of Nuclear Physics

The Atom Bomb

Hiroshima and Nagasaki (1945)

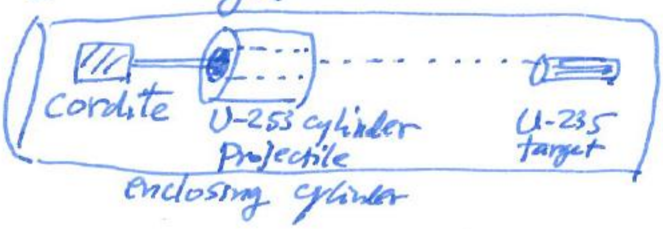
The Hiroshima bomb:

total mass = 4400 kg

mass of U-235 = 64 kg ⟨ 38kg projectile, 26kg target

energy yield = 16 kt = 67 TJ

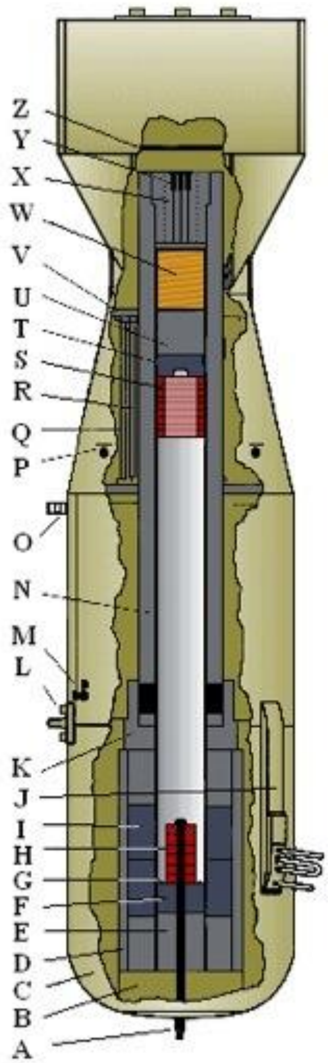
Gun design



The critical mass of U-235 for this design is ~30kg.

However, only ~1kg of the U-235 underwent fission; yield ~16kt.

An atom bomb uses a fissionable material (U-235 or Pu-239). If M is large enough (M > critical mass ⊛) then a fast chain reaction will occur; the bomb will explode.



Cross-section drawing of Y-1852 Little Boy showing major mechanical component placement. Drawing is shown to scale. Numbers in ( ) indicate quantity of identical components. Not shown are the APS-13 radar units, clock box with pullout wires, baro switches and tubing, batteries, and electrical wiring. (John Coster-Mullen)

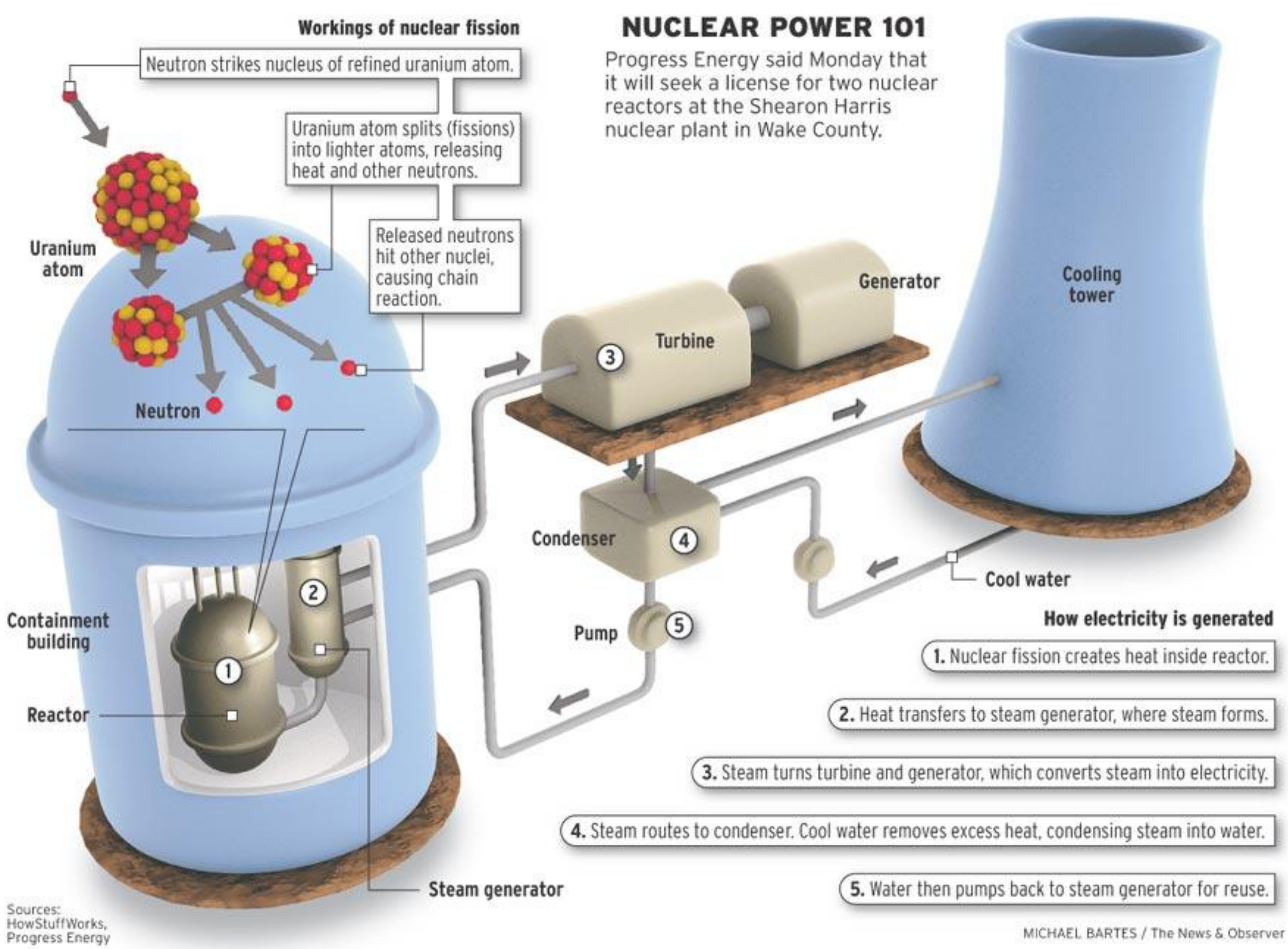
Z) Armor Plate
Y) Mark XV electric gun primers (3)
X) Gun breech with removable inner plug
W) Cordite powder bags (4)
V) Gun tube reinforcing sleeve
U) Projectile steel back
T) Projectile Tungsten-Carbide disk
S) U-235 projectile rings (9)
R) Alignment rod (3)
Q) Armored tube containing primer wiring (3)
P) Baro ports (8)
O) Electrical plugs (3)
N) 6.5" bore gun tube
M) Safing/arming plugs (3)
L) Lift lug
K) Target case gun tube adapter
J) Yagi antenna assembly (4)
I) Four-section 13" diameter Tungsten-Carbide tamper cylinder sleeve
H) U-235 target rings (6)
G) Polonium-Beryllium initiators (4)
F) Tungsten-Carbide tamper plug
E) Impact absorbing anvil
D) K-46 steel target liner sleeve
C) Target case forging
B) 15" diameter steel nose plug forging
A) Front nose locknut attached to 1" diameter main steel rod holding target components

"Atom Bombs: The Top Secret Inside Story of Little Boy and Fat Man," 2003, p 112.
John Coster-Mullen drawing used with permission

The Peaceful Atom

Nuclear Power Reactors

In a nuclear reactor, a controlled chain reaction releases mass energy by nuclear fission. The heat is used to power electric generators.



Operation Plowshare

“and they shall beat their swords into plowshares, …and study war no more”

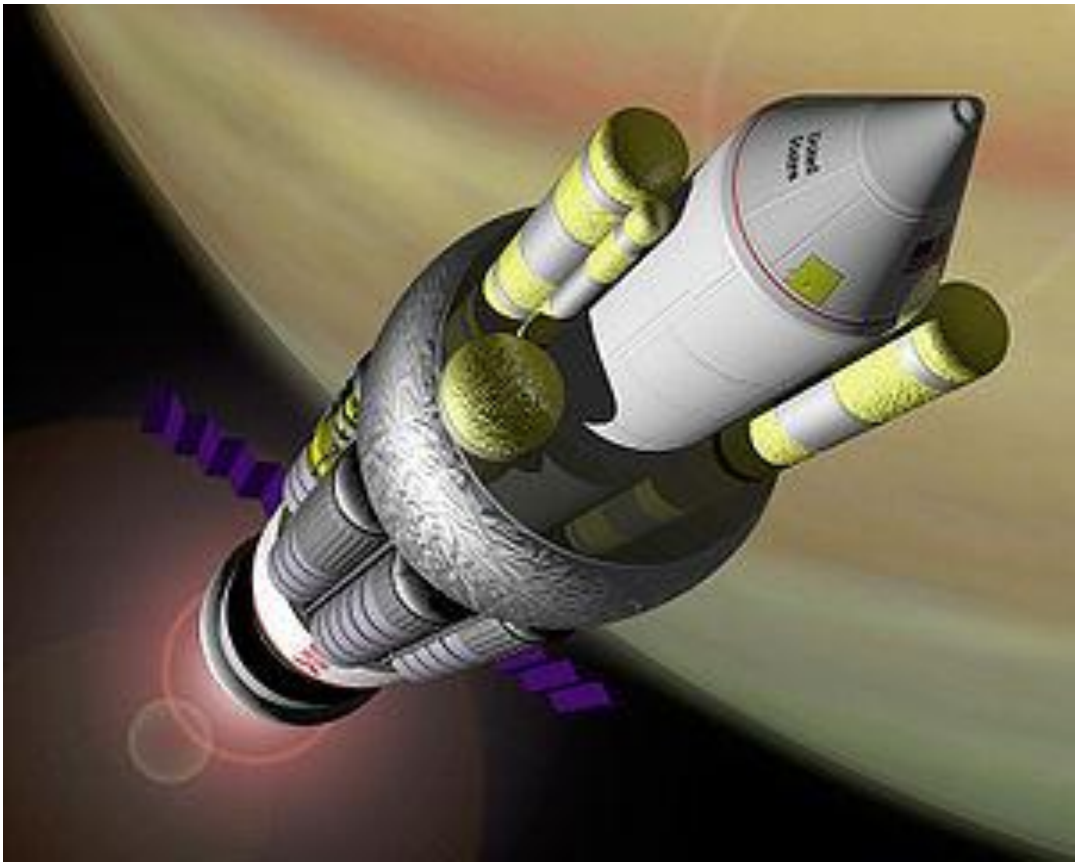
Isaiah (2:3)

The 1962 "Sedan" plowshares shot displaced 12 million tons of earth and created a crater 320 feet (100 m) deep and 1,280 feet (390 m) wide

1954 – 1977; cancelled because of public opposition

Plowshare test blasts

Test name	Date	Location	Yield	Test series
Gnome	10 December 1961	Carlsbad, New Mexico	3 kilotons	Nougat
Sedan	6 July 1962	Nevada Test Site	104 kilotons	Storax
Anacostia	27 November 1962	Nevada Test Site	5.2 kilotons	Dominic I and II
Kaweah	21 February 1963	Nevada Test Site	3 kilotons	Dominic I and II
Tornillo	11 October 1963	Nevada Test Site	0.38 kilotons	Niblick
Klickitat	20 February 1964	Nevada Test Site	70 kilotons	Niblick
Ace	11 June 1964	Nevada Test Site	3 kilotons	Niblick
Dub	30 June 1964	Nevada Test Site	11.7 kilotons	Niblick
Par	9 October 1964	Nevada Test Site	38 kilotons	Whetstone
Handcar	5 November 1964	Nevada Test Site	12 kilotons	Whetstone
Sulky	5 November 1964	Nevada Test Site	0.9 kilotons	Whetstone
Palanquin	14 April 1965	Nevada Test Site	4.3 kilotons	Whetstone
Templar	24 March 1966	Nevada Test Site	0.37 kilotons	Flintlock
Vulcan	25 June 1966	Nevada Test Site	25 kilotons	Flintlock
Saxon	11 July 1966	Nevada Test Site	1.2 kilotons	Latchkey
Simms	6 November 1966	Nevada Test Site	2.3 kilotons	Latchkey
Switch	22 June 1967	Nevada Test Site	3.1 kilotons	Latchkey
Marvel	21 September 1967	Nevada Test Site	2.2 kilotons	Crosstie
Gasbuggy	10 December 1967	Farmington, New Mexico	29 kilotons	Crosstie
Cabriolet	26 January 1968	Nevada Test Site	2.3 kilotons	Crosstie
Buggy	12 March 1968	Nevada Test Site	5 at 1.1 kilotons each	Crosstie
Stoddard	17 September 1968	Nevada Test Site	31 kilotons	Bowline
Schooner	8 December 1968	Nevada Test Site	30 kilotons	Bowline
Rulison	10 September 1969	Grand Valley, Colorado	43 kilotons	Mandrel
Flask	26 May 1970	Nevada Test Site	105 kilotons	Mandrel
Miniata	8 July 1971	Nevada Test Site	83 kilotons	Grommet
Rio Blanco	17 May 1973	Rifle, Colorado	3 at 33 kilotons each	Toggle



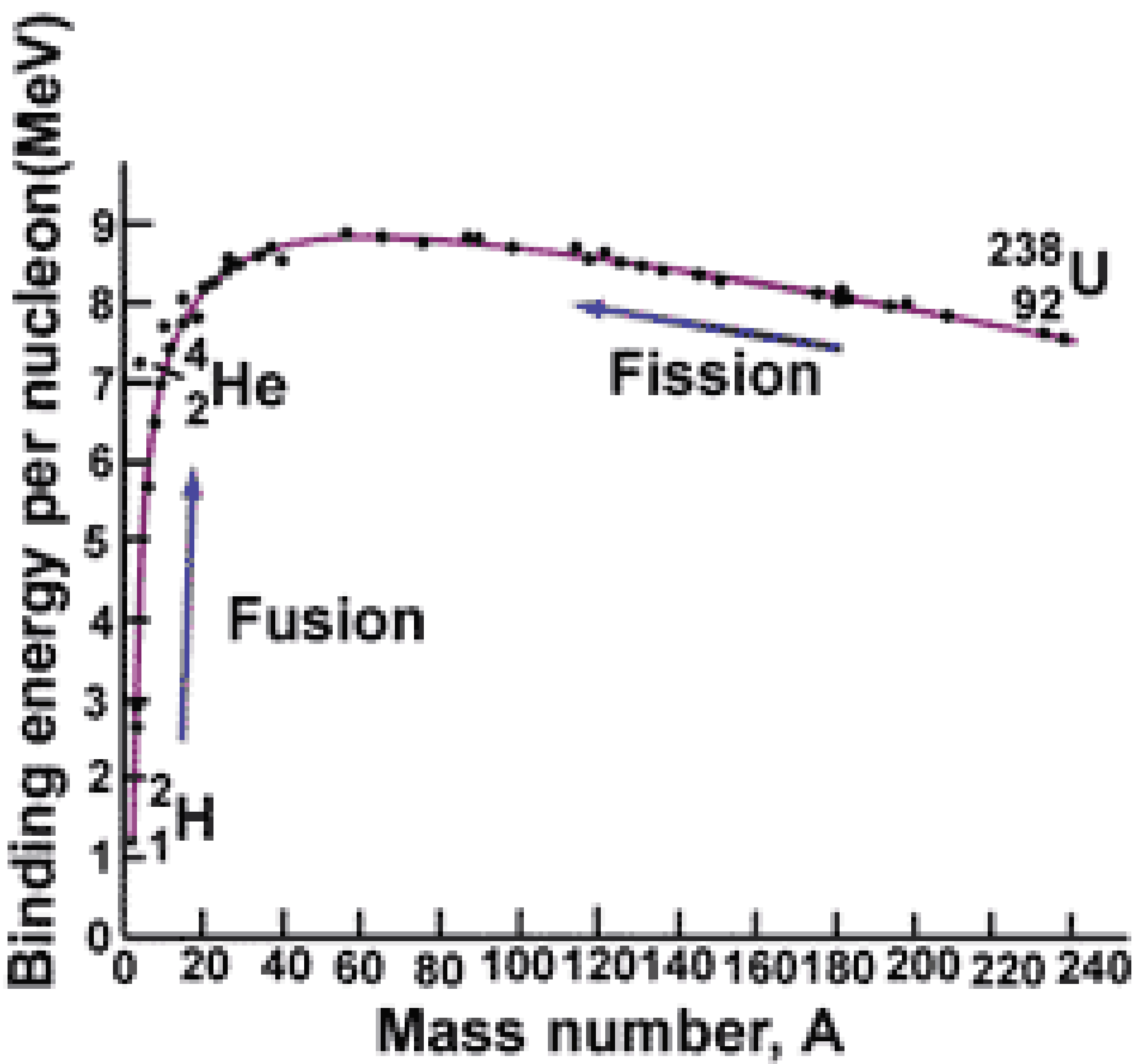
Project Orion

Nuclear Pulse Propulsion for interstellar space travel

1958-1968

Cancelled because of the Nuclear Test Ban Treaty

The curve of binding energy



Nuclear Fusion

(1)

Consider an example of nuclear fusion

$$\underset{pnn}{t} + \underset{pn}{d} \rightarrow \underset{ppnn}{{}^4He} + \underset{n}{n}$$

$$Z: \quad 1 + 1 = 2 + 0$$

$$A: \quad 3 + 2 = 4 + 1$$

Calculate the mass energy released in this reaction.

	Masses	
t	3.016 049 278	u
d	2.014 101 777	u
${}^4He$	4.002 603 254	u
n	1.008 664 916	u

$$M_{initial} = 5.030\ 151\ 055 \ u$$

$$M_{final} = 5.011\ 268\ 170 \ u$$

$$E_{released} = (M_i - M_f)c^2 = 0.018\ 883 \ u \cdot c^2$$

$$= 0.018\ 883 \times 931.5 \ MeV$$

$$= 17.6 \ MeV$$

$$(1\ u) \times c^2 = 931.494 \times 10^6 \ eV$$

The hydrogen bomb

(more precisely, tritium/deuterium bomb)

There is no chain reaction in the fusion reactions.
A high temperature is necessary.

Calculate the temperature required for fusion.

Fusion requires $d \approx 10^{-15}\,m$

The Coulomb potential energy $= \dfrac{e^2}{4\pi\epsilon_0 d}$

$$= 9\times10^9\ \frac{N\,m^2}{C^2} \times \frac{1.6\times10^{-19}\,C}{1.0\times10^{-15}\,m}\ e$$

$$= 14.4\times10^5\ \underbrace{\frac{N}{C}\,m}_{\to\ \frac{V}{m}}\ e \;=\; 1.44\times10^6\ eV$$

Thermonuclear fusion requires $k_B T \sim U_{Coulomb}$

$$T \sim \frac{1.44\times10^6\ eV}{8.62\times10^{-5}\ eV/K} = 2\times10^{10}\ K$$

$= 20$ billion degrees

Boltzmann's constant
$k_B = 1.38\times10^{-23}\ J/K = 8.62\times10^{-5}\ \frac{eV}{K}$

Use a fission explosion to produce this very high temperature.

[By the way, this calculation shows why "COLD FUSION" is impossible.]

Youtube

Nuclear bomb - first H bomb test

Nuclear Fusion Reactors (3)

↳ do not exist

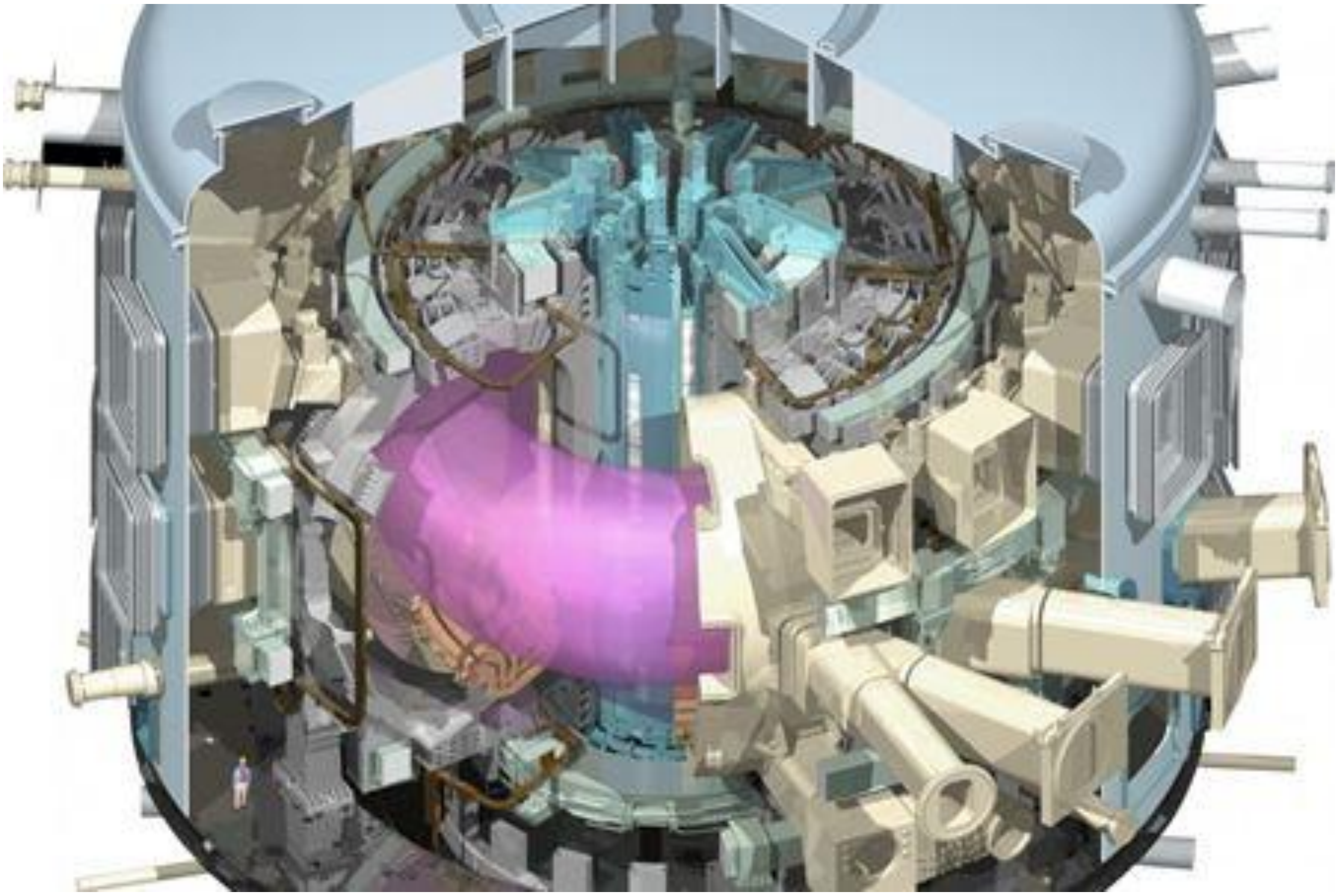
Will fusion reactors solve mankind's energy desires?

— not today
— not in the near future
— perhaps not ever

ITER

↳ the international research project to produce a controlled nuclear fusion reactor.

ITER



ITER (originally an acronym of **International Thermonuclear Experimental Reactor**) is an international nuclear fusion research and engineering project, which is currently building the world's largest and most advanced experimental tokamak nuclear fusion reactor at the Cadarache facility in the south of France.[1] The ITER project aims to make the long-awaited transition from experimental studies of plasma physics to full-scale electricity-producing fusion power plants. The project is funded and run by seven member entities — the European Union (EU), India, Japan, China, Russia, South Korea and the United States. The EU, as host party for the ITER complex, is contributing 45% of the cost, with the other six parties contributing 9% each.[2][3][4]