A partial history of particle and nuclear physics at Harwell and RAL

Stewart Martin-Haugh

RAL particle physics seminar
25 February 2026

Rutherford Appleton Laboratory

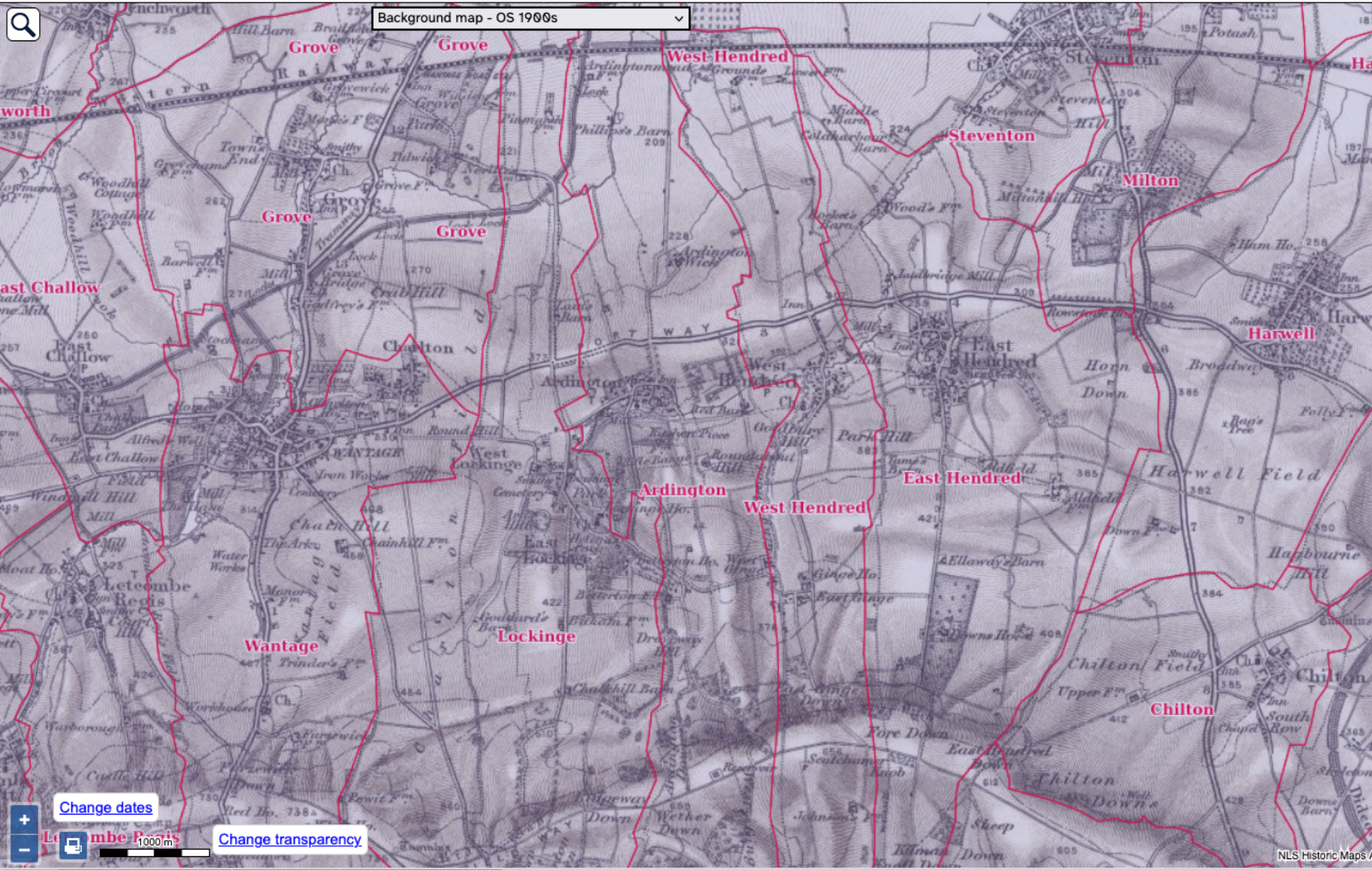
Disclaimers

- I am not a historian
- I have selected things I currently find interesting
- There are probably mistakes
- Sources
  - Harwell: the Enigma Revealed by Nick Hance
  - Independence and Deterrence: Britain and Atomic Energy, 1945 - 52 by Margaret Gowing
  - Various FRS biographies, particularly John Adams, Gerry Pickavance and Godfrey Stafford[1]
  - Science Policy under Thatcher

[1] Written by Norman McCubbin

RAF Harwell

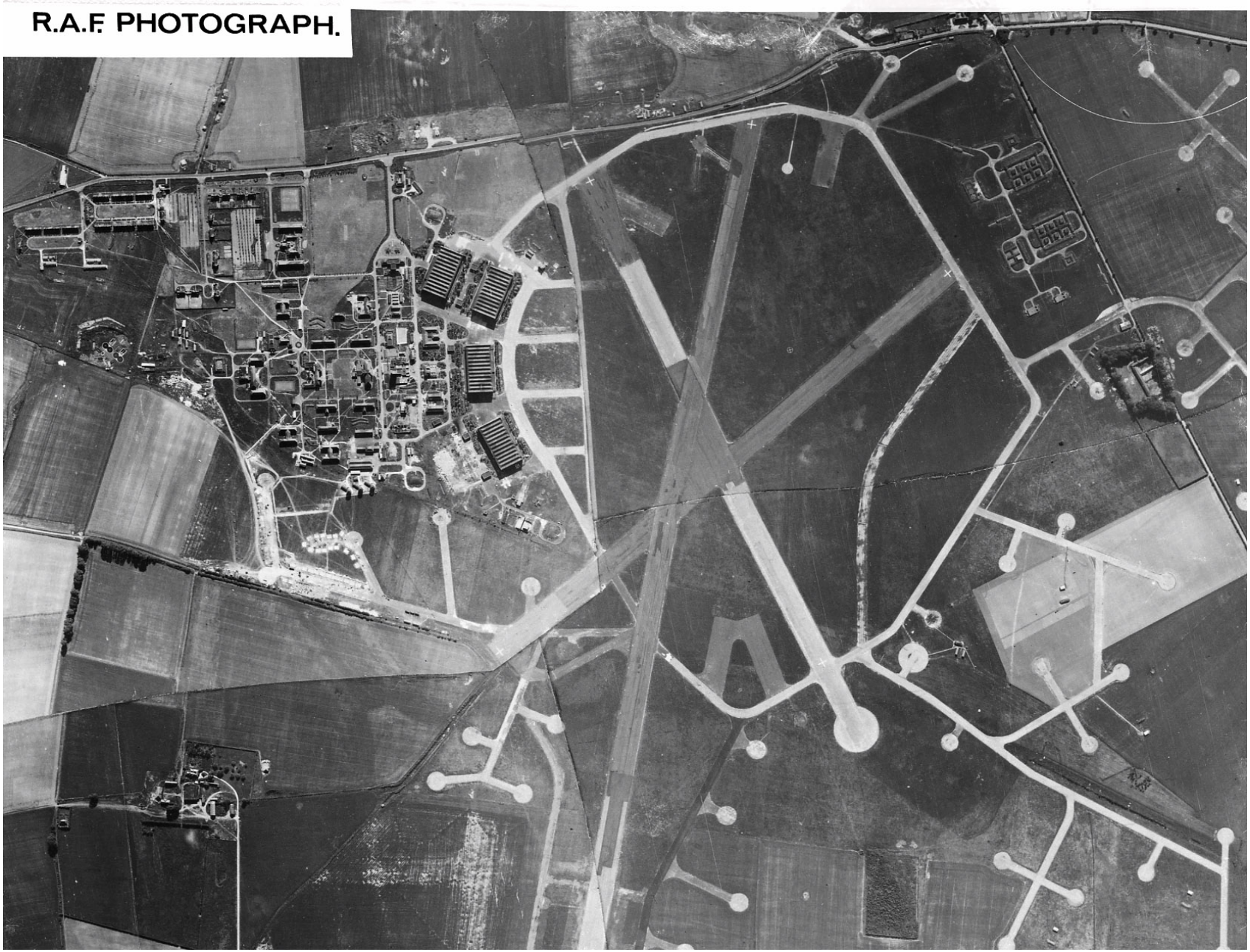
- Built in 1935 during British rearmament, operational 1937
- Split between Chilton, East Hendred and Harwell parishes
- Commanding officer decided on RAF Harwell, after the location of his house



TIP: Hold [Shift] key, and select (drag cursor) to zoom to a specific area.

TIP: Hold [Shift] key, and select (drag cursor) to zoom to a specific area.

RAF Harwell



World War II

- Prototype catapult launch system for aircraft
- Various operations including wooden Horsa gliders for D-Day landings

Atomic energy

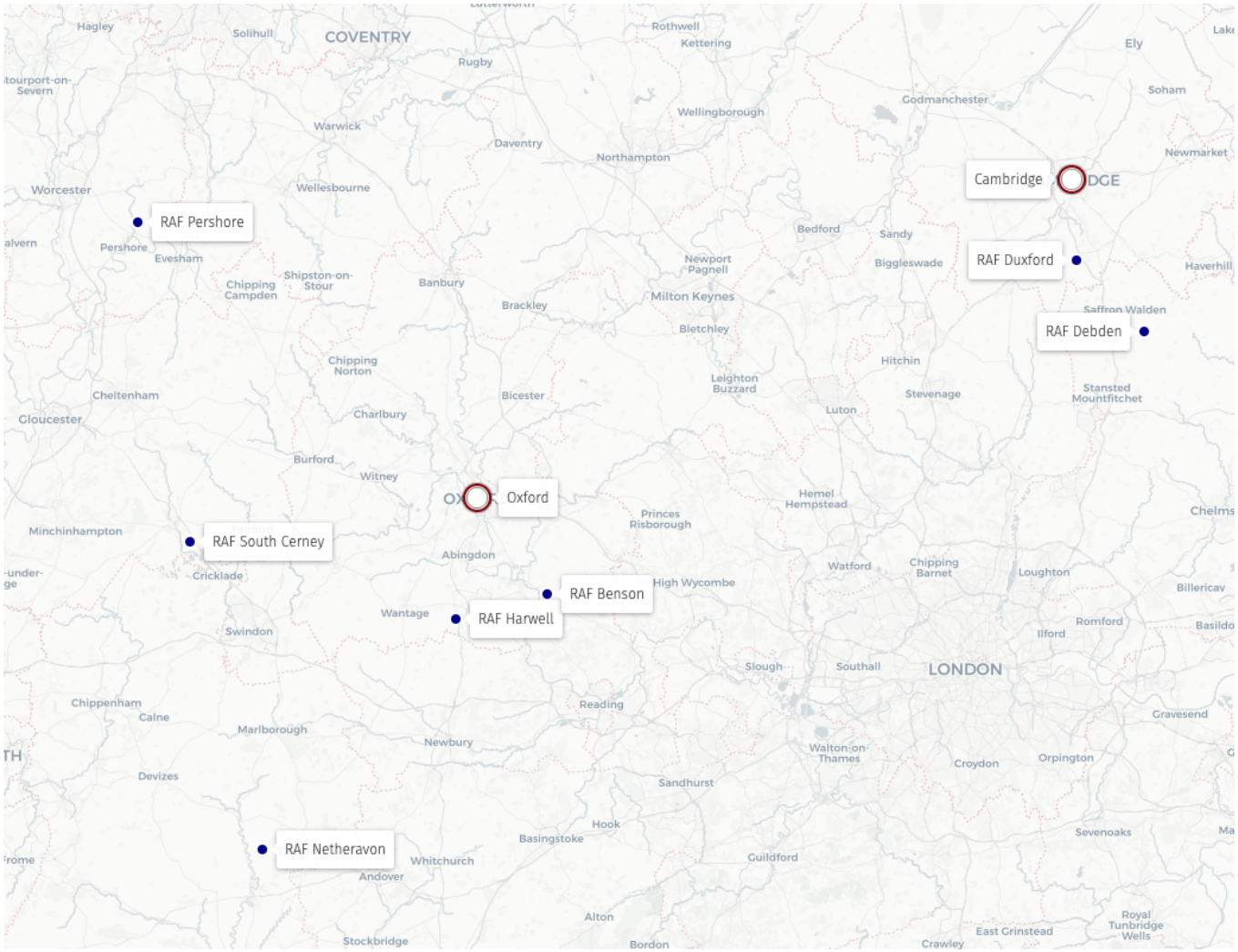
- James Chadwick, Mark Oliphant, John Cockcroft, Rudolf Peierls, Harrie Massey and Skinner meeting in Washington, November 1944
- Near Oxford or Cambridge internationally important nuclear physics laboratories:
  - Cockcroft preference for Cambridge
  - Not sure why only Oxbridge, given nuclear physics groups at other universities
  - Proximity to London also likely important
- To be run as part of Ministry of Supply: government department for supplying equipment to armed forces (broadly defined)

Choice of location

- Former RAF station ideal: construct piles in hangars, utilities and services already present
- Air Ministry offered Duxford and Debden (although wanted to keep East Anglian airfields for cold war)
  - Duxford: not enough water supply
  - Debden: water table too high, unsuitable for burying waste

Choice of location

- Choice between Harwell and Benson settled over a meal of bread, cheese, beer and pickled onions[2] at a pub in Chilton village



[2] Note that the ploughman's lunch was only popularised as a term by the Cheese Bureau in 1956

Foundations

- Prime Minister Clement Attlee announced foundation of Atomic Energy Research Establishment Harwell on 29th October 1945
- Decision as to whether to actually build an atomic bomb was not taken until over a year later (January 1947)

Hansard

Mr. W. S. Morrison Share

asked the Prime Minister what stops are being taken to develop research on the use of atomic energy in this country.

The Prime Minister Share

:In accordance with a recommendation which has been received from the Advisory Committee on Atomic Energy of which the right hon. Gentleman the Member for the Scottish Universities (Sir J. Anderson) is the Chairman, the Government have decided to set up a research and experimental establishment covering all aspects of the use of atomic energy. Accommodation is being provided for the establishment at Harwell airfield near Didcot. I am advised that the danger to surrounding areas from the experimental station is negligible. It has further been decided that in view of the importance of this work to the Service Departments, responsibility for research on this subject which has hitherto rested with the Department of Scientific and Industrial Research should be transferred to the Ministry of Supply. The Tube Alloys Directorate (which is the name by which the technical organisation dealing with these matters has hitherto been known) will accordingly become a part of that Ministry. The Department of Scientific and Industrial Research will, however, be represented both on the Advisory Committee and on some of its technical sub-committees.

Hansard

Mr. Morrison Share

:Can the right hon. Gentleman say what financial assistance it is proposed to give to this research?

The Prime Minister Share

The cost will have to fall upon the Government.

Mr. Blackburn Share

Is the right hon. Gentleman aware that research in relation to atomic energy is inseparable from production and that really effective research would involve production on a scale involving an expenditure of at least £30,000,000 or £40,000,000?

The Prime Minister Share

I am very fully advised on these matters by the Advisory Committee.

Hansard

Mr. Maxton Share

:Does this change of control to a Department more closely associated with the Services indicate that the Government are more concerned about the weapon value of atomic energy than about its production value?

The Prime Minister Share

No, not at all. It can hardly have escaped the hon. Gentleman's notice that the Ministry of Supply is also engaged on civilian production. It is a mistake to suggest that it is entirely concerned with weapons.

Mr. Boothby Share

Will the right hon. Gentleman consider making the report of the Advisory Committee available to Members of this House?

The Prime Minister Share

No, Sir. I could not accept that.

Bank of England inflation calculator

Understanding your results

This means that between 1945 and January 2026, prices have increased by 3666.3% overall.

In other words, you would need £1,506,533,355.81 in January 2026 to have the same purchasing power as £40,000,000.00 in 1945.

What could this buy back then?

What £40000000 could buy in 1945

In 1945, £40,000,000 was an colossal sum, especially as Britain emerged from wartime rationing and austerity. Here's what that fortune could have realistically acquired (these are estimates only):

- Around 50,000 new homes: With average house prices roughly £800-£1,000, this could have funded the construction of entire new towns to address post-war housing shortages. 🏠
- Over 100,000 new cars: A small family car, like a Morris Eight, might have cost around £300-£400. This would have represented a massive boost to private transport in an era of scarcity. 🚗
- Several major warships for the Royal Navy: A cutting-edge battleship of the era cost around £11-£12 million, meaning you could have commissioned over three such formidable vessels, or many thousands of fighter planes. 🚢✈️

These are estimates based on historical data.

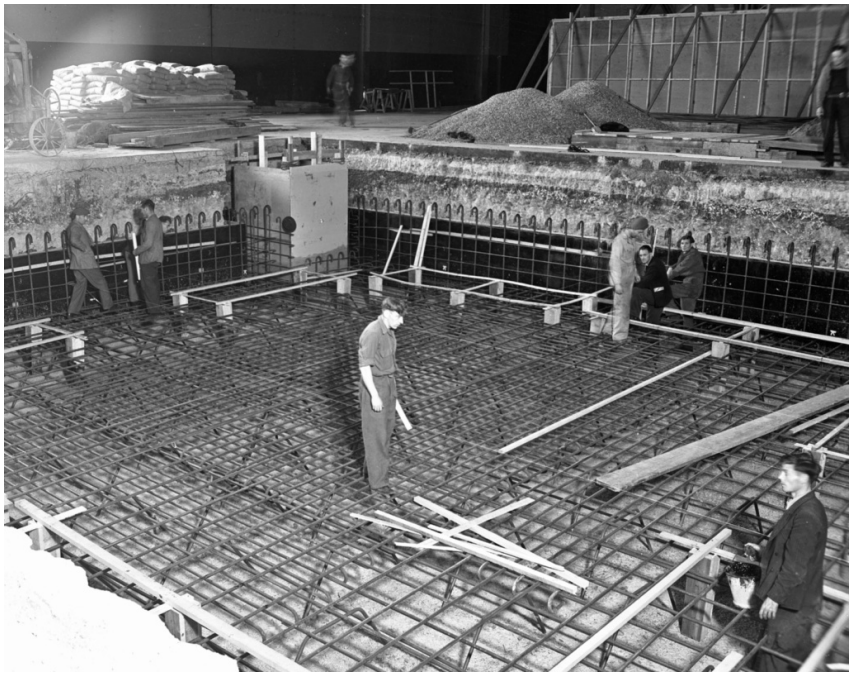
Harwell from the prefab, 1947, Mary Flowers

Organisational structure

- Ministry of Supply Department of Atomic Energy (DAtEn)
- Controller, Lord Portal
  - Christopher Hinton: Production (Risley, Warrington)
  - John Cockcroft: Research
  - William Penney: Weapon making (Fort Halstead, moved to RAF Aldermaston)

Graphite Low Energy Experimental Pile (GLEEP)

- First Harwell reactor, first in Western Europe
- Top priority: steel intended for Parliament repair diverted to Harwell
- Went critical 15 August 1947 (100W)
- Design power, 100 kW
- Operated largely at 3 kW until 1990
- Cost: £2.5 M (or £85.3M today)



Other reactors

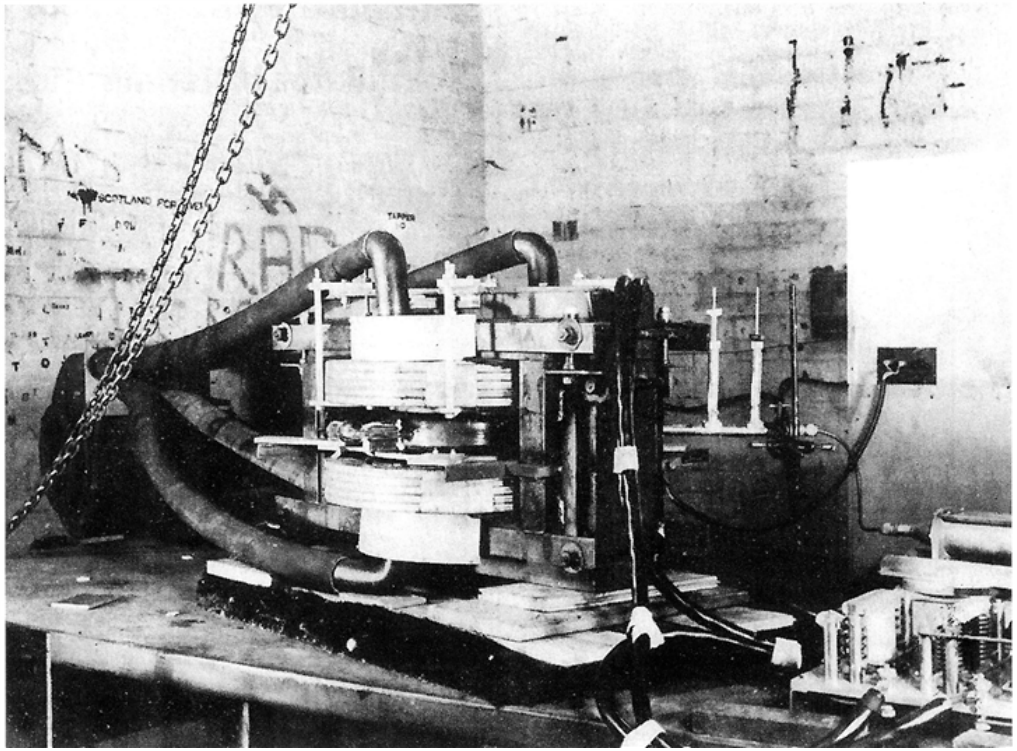
Reactor	Power	Lifetime
GLEEP	3 kW	1947 - 1990
BEPO	6 MW	1948 - 1968
DIMPLE	100 W	1954 - 1960
ZEPHYR	10 W	1954 - 1958
ZETR	negligible	1955 - 1957
ZEUS	100 W	1955 - 1957
LIDO	340 kW	1956 - 1974
DIDO	26 MW	1956 - 1974
PLUTO	26 MW	1956 - 1974
NEPTUNE	100 W	1957 - 1959
NERO	100 W	1957 - 1959
HAZEL	1 W	1958 - 1958
DAPHNE	100 W	1958 - 1958

BEPO

- NEPTUNE moved to Rolls-Royce Derby in 1963, still operational
- DAPHNE: DIDO and PLUTO's Handmaiden for Nuclear Experiments

The world's first synchrotron

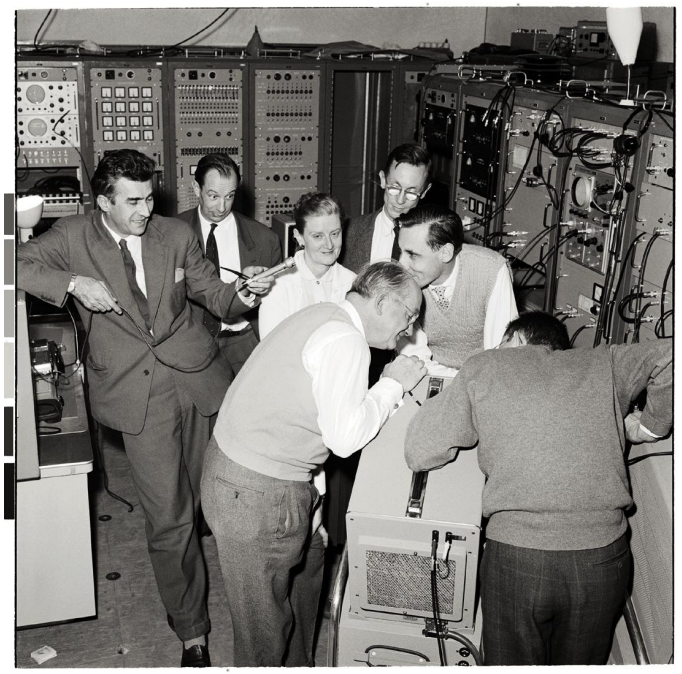
- Betatron sent from the US to Royal Arsenal at Woolwich for bomb disposal tasks (never used)
- Converted to a synchrotron, achieved 8 MeV in August 1946 (2 months before General Electric synchrotron)
- Later shipped to Malvern



The synchrotron at Malvern, from JD Lawson's history

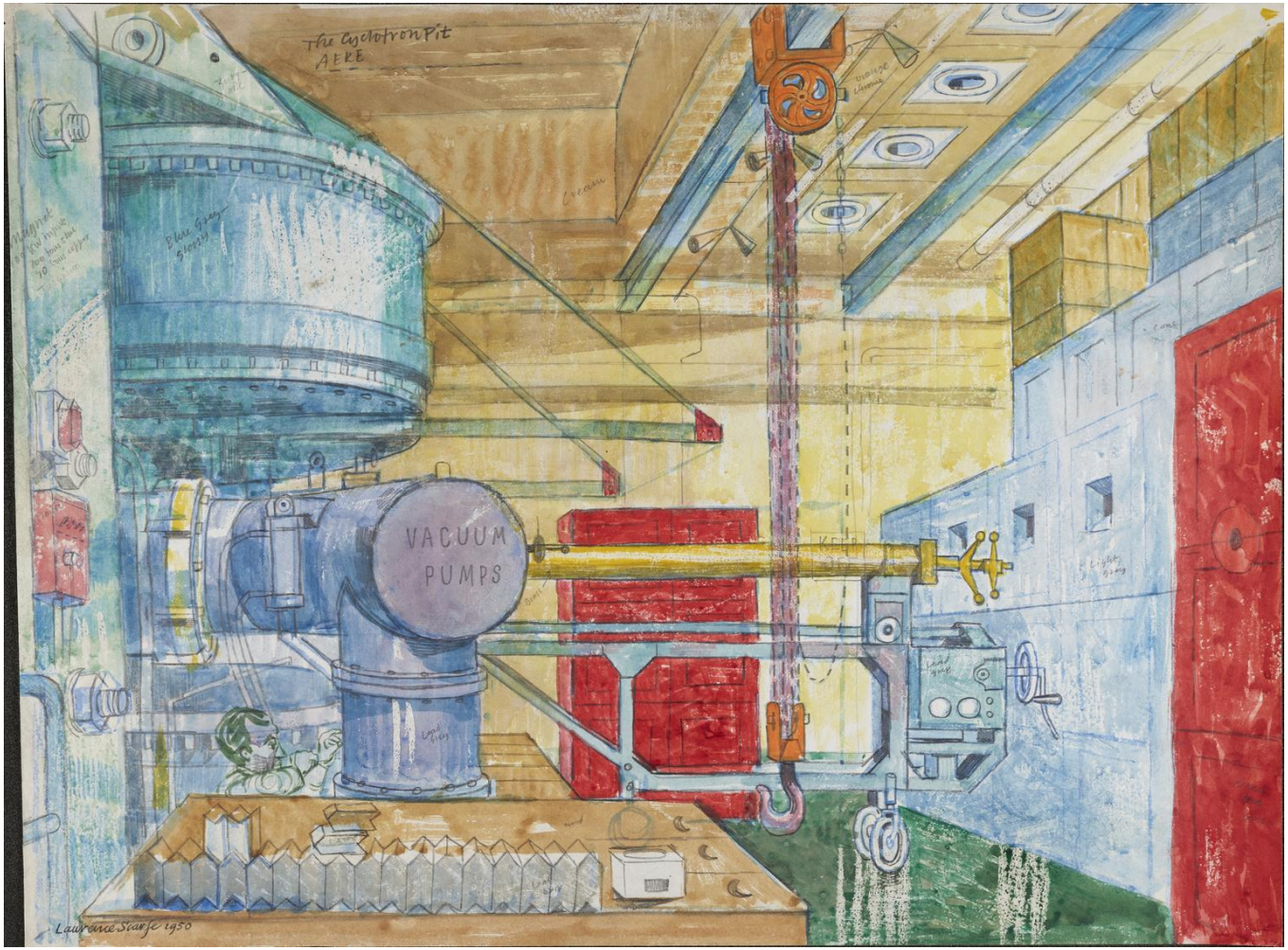
John Adams

- Born 1920
- Early career in radar at Swanage and Malvern, involved in Malvern synchrotron project
- Moved to AERE Harwell to work on accelerators in 1945
- Moved to CERN in 1953 to lead Proton Synchrotron project
- First Culham director, 1960 to 1966
- CERN Director General 1971 to 1980



John Adams and other CERN Proton Synchrotron staff (including Hildred Blewett) in 1959 (source)

Harwell synchrocyclotron



Harwell synchrocylotron, 1950 drawing by Laurence Scarfe for Atomic Energy mural (Festival of Britain)

Tandem Van de Graaff

- Used for material testing and nuclear physics, 1959 - 2002
- Demolished 2005
- Still generating papers as of 2021

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 1013, 11 October 2021, 165636

Technical notes

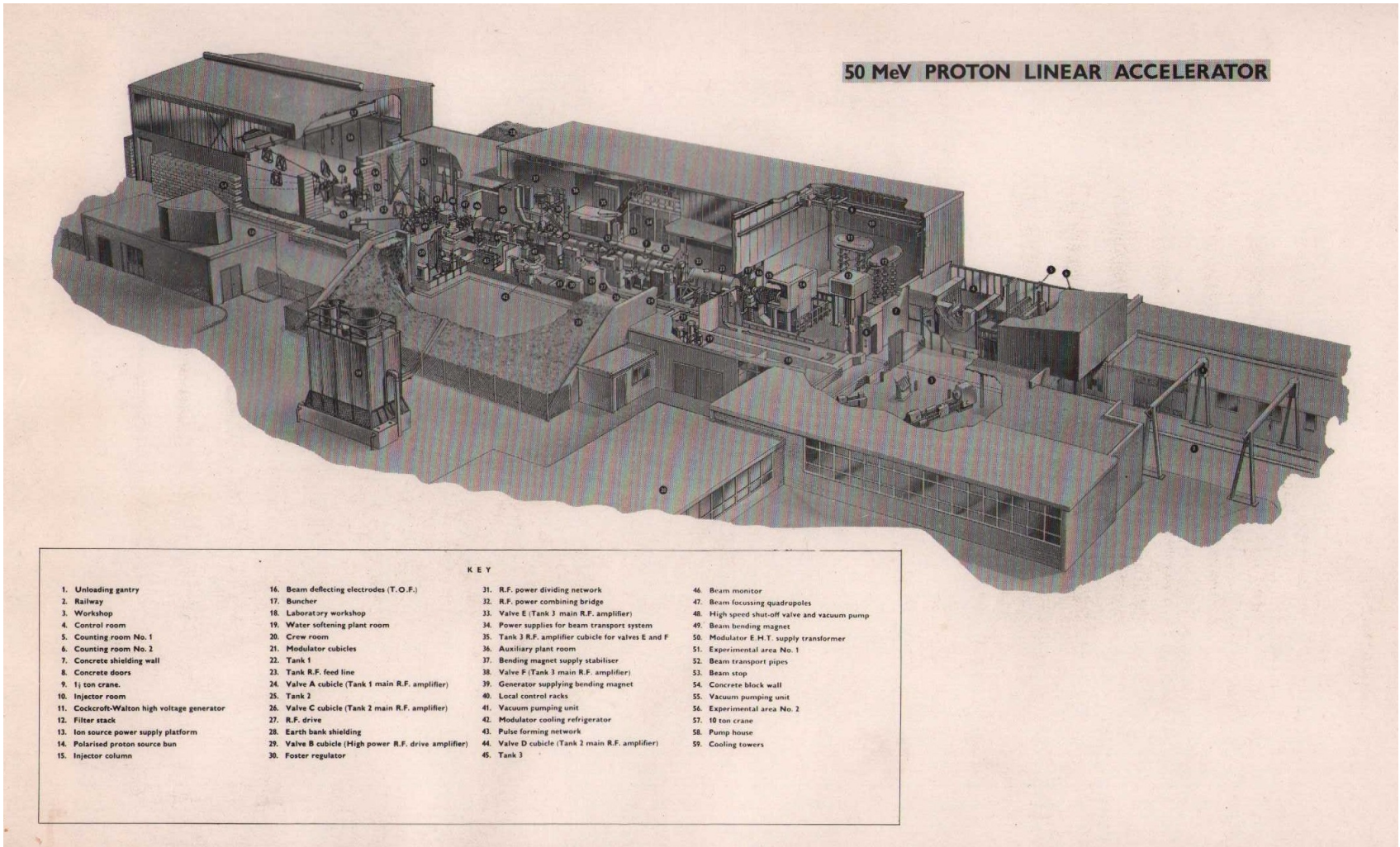
α-particle induced yield of 6.13 MeV γ-rays in carbon

Stephen Croft [a], A. Favalli [b], R.D. McElroy Jr. [c]

[a] Lancaster University, Bailrigg, Lancaster, UK
[b] Los Alamos National Laboratory, Los Alamos, NM, USA
[c] Oak Ridge National Laboratory, Oak Ridge, TN, USA

Proton Linear Accelerator (PLA)

- Started in 1954, planned 600 MeV energy
- Overtaken by synchrotrons: decided to build first stage only (50 MeV)
- Moved to RAL (R12) in 1960



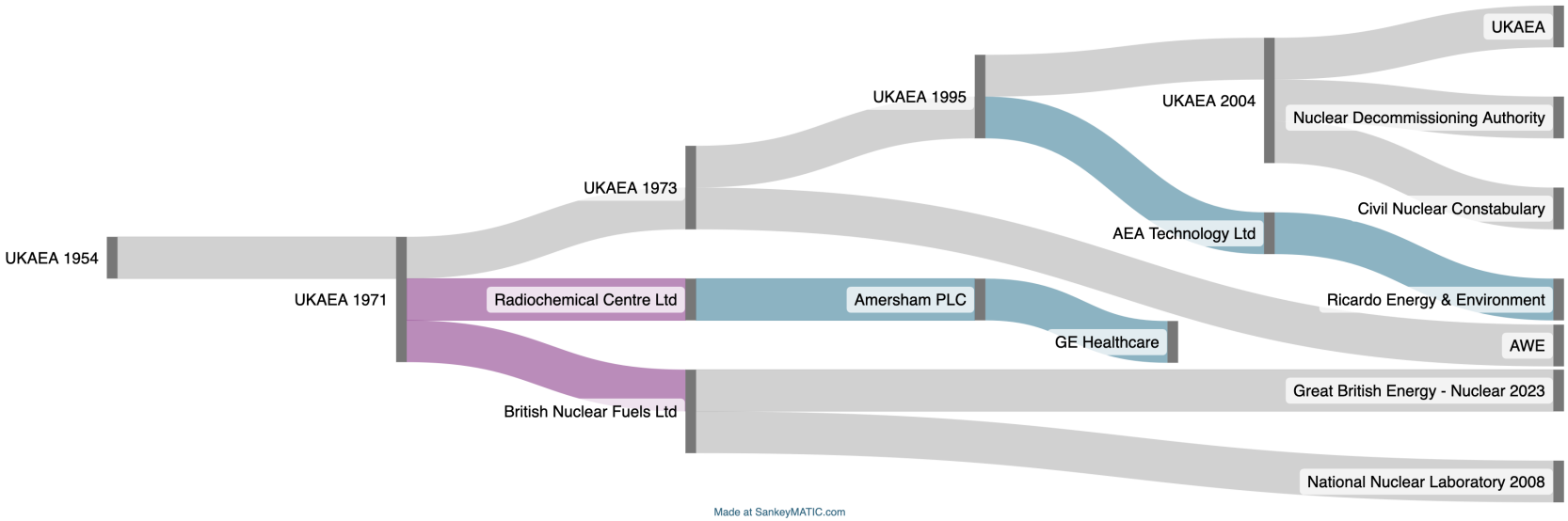
Harwell accelerators

Accelerator	Power	Lifetime
110-inch synchrocyclotron	170 MeV	1949-1970s
Electron linac	3 MeV	1949-1952
Cockcroft-Walton	500 kV	1950s-1970
Electron linac	15 MeV	1952-1959
Proton Linear Accelerator (PLA)	50 MeV	1954-1964
Van de Graaff	5 MeV	1950s-1980s
Electron linac	50 MeV	1959-1975
Tandem Van de Graaff	2-60 MeV	1959-2002
Variable Energy Cyclotron (VEC)	protons at 50 MeV (max)	1965-1980s
Electron linac (Helios)	136 MeV (max)	1979-1986
Electron linac (Helios #1 and #2)	5-20 MeV	1990s-2004
Electron linac (Helios #3)	10 MeV	1994-2004

Adapted from Chilton computing

UKAEA

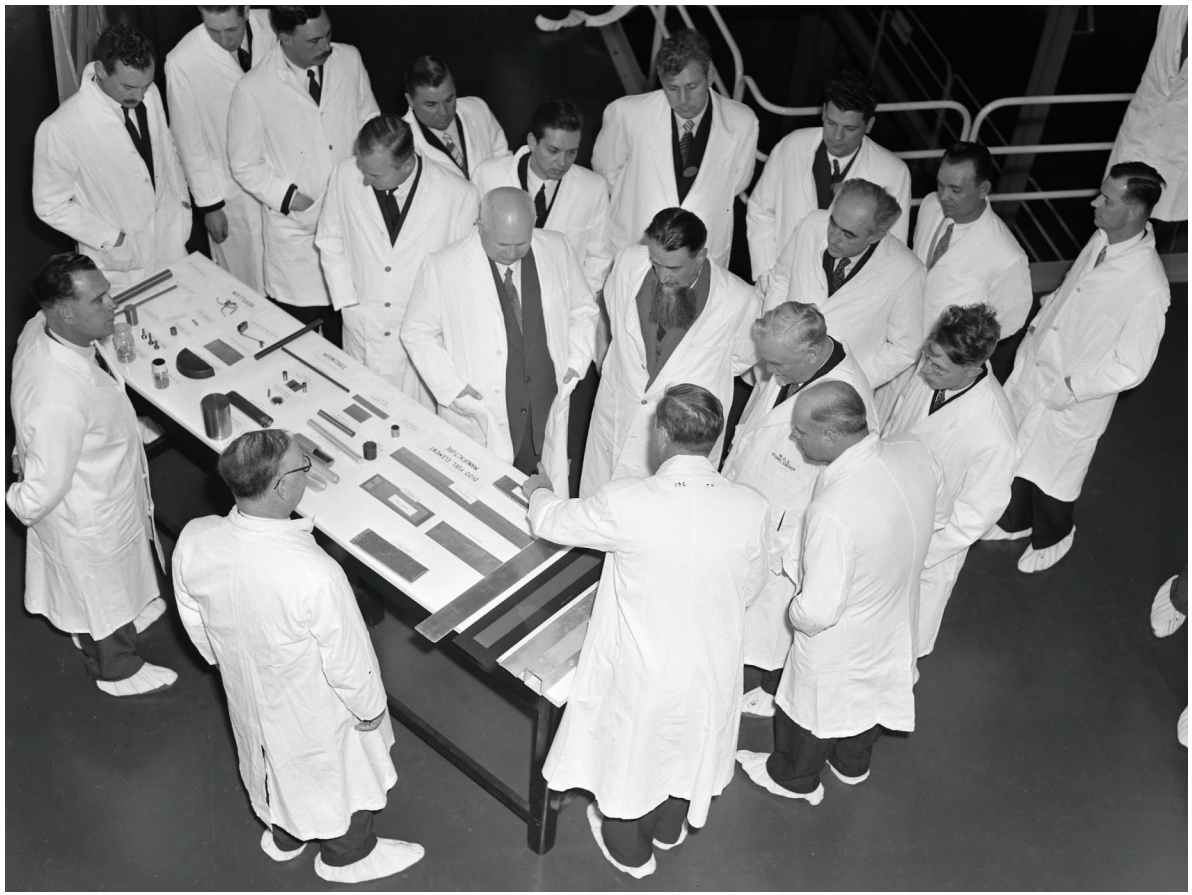
- Nuclear energy moved out of Ministry of Supply to a separate agency in 1954
- Gradual divestment of functions (weapons, fuel processing, isotopes) until only fusion programme left
- 21st century resurgence and new locations (Rotherham, planned Spherical Tokamak for Energy Production in Nottinghamshire)



Pink = goverment company, blue = privatisation

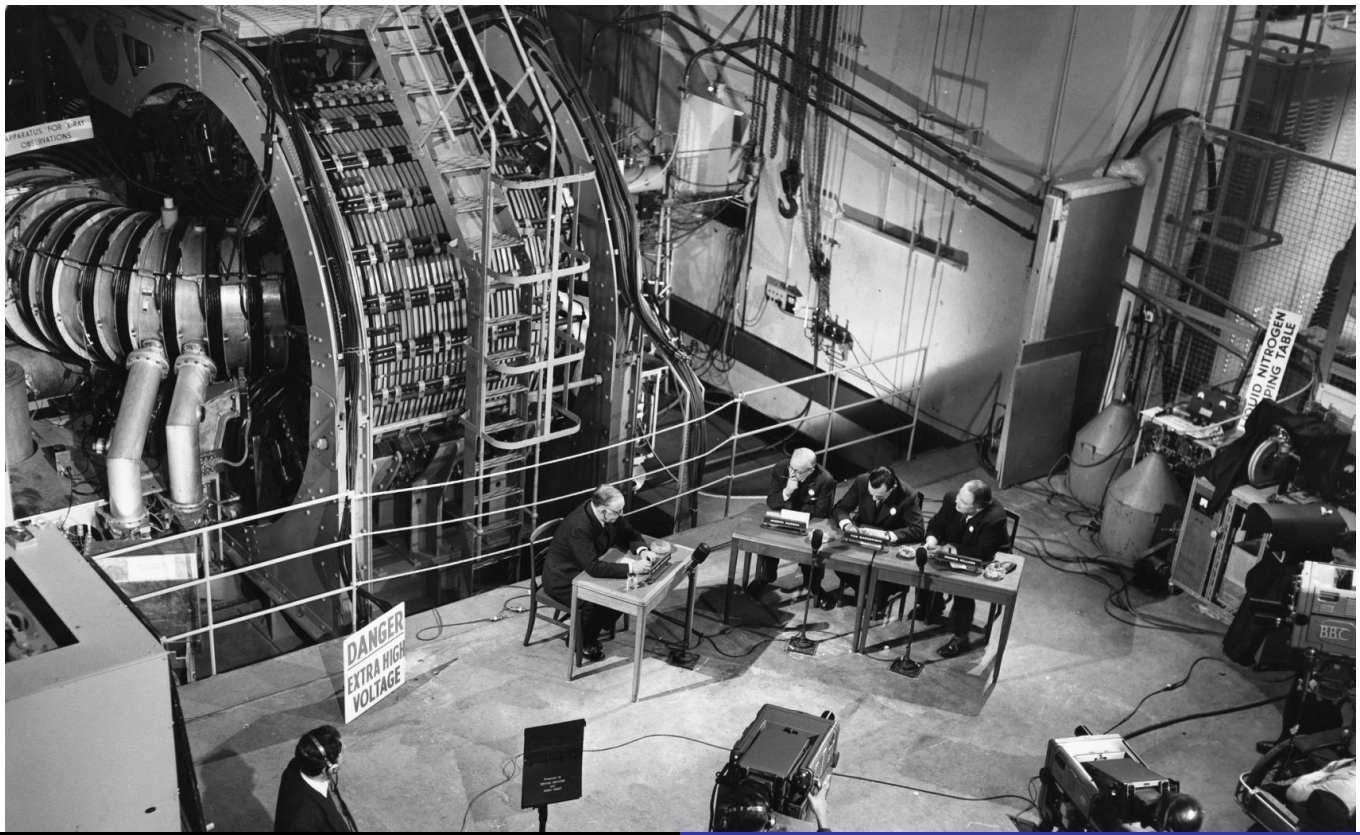
Fusion

- Soviet visit to Harwell in 1956: first visit of Soviet leaders (Bulganin, Kruschev) to the West
- Arrived in Portsmouth by cruiser (escorted by two destroyers)
- Igor Kurchatov, head of Soviet Nuclear Programme revealed nuclear fusion programme
- Shared details of Soviet fusion work: all secret at the time



ZETA: Zero Energy Thermonuclear Assembly

- In August 1957 the ZETA toroidal pinch started running with deuterium
- Huge neutron flux observed: attributed to fusion
- Leaks and rumours: press conference in January 1958
- Awkward climbdown a few months later: neutrons from plasma instabilities
- Fusion research moved to new laboratory at RNAS Culham in 1960



National Institute for Research in Nuclear Science

- Enoch Powell (better known for later work) announced the founding of a new academic lab at Harwell on 14th February 1957

26.

Mr. E. Fletcher Share

asked the Chancellor of the Exchequer whether he will now state what steps are being taken for the establishment of a national centre for nuclear physics when the Atomic Energy Authority and the universities co-operate in research in nuclear physics.

Mr. Powell Share

Yes. After consultation between the University Grants Committee, the Atomic Energy Authority, and the Departments concerned, the Government have now decided to set up a National Institute for Research in Nuclear Science.The main object of the Institute will be to provide, for common use by universities and others, facilities and equipment which are beyond the scope of individual universities and institutions carrying out research in the nuclear field. It will not replace the research now being done in individual universities with assistance from Government funds; nor will it affect the Government's participation in the international scheme for common facilities in Geneva. It will, in the Government's view, satisfactorily fill a gap which would otherwise exist in this country's power to keep in the forefront of nuclear progress.

- Run as a subsidiary of UKAEA until 1965

NIMROD

- National Institute Machine Radiating on Downs
- 7 GeV proton sychrotron at RHEL, completed in 1963

Source

Questions about NIMROD

- Why build a machine less powerful than those available in the US and at CERN?
  - 1959 letter from Denys Wilkinson to Gerry Pickavance: "...our machine is relying for its being a decade too late on its superiority in shielding and provision of experimental facilities...as it stands at the moment, there is some superiority in flux, but...there is no advantage...over the Bevatron...other than a slightly higher repetition rate. It may well transpire...that the Bevatron can make up for this on account of its much larger aperture."
- Behind the energy frontier but had a 14 year experimental programme
  - Peter Kalmus: "Nimrod should have been built as a strong focussing accelerator of higher energy. However, we were lucky. The Nimrod energy region proved to be an extraordinarily fruitful one, and much of our knowledge of hadron spectroscopy stems from this machine."

NIMROD

- 8 and 9 seemed most favourable, but 2 eventually chosen
- Final beam intensity of 1.5×10^{13} protons circulating

Table I. 6 GeV Machine Designs Described at the December 1955 Meeting

	Machine type		Magnet weight (tons)	Performance relative to the Bevatron (3×10^9 protons per second)
1	Bevatron	2×10^{10} protons per pulse, 10 pulses per minute	10,000	1
2	Bevatron Mk II	Better injector, magnet, higher repetition rate	7,500	100-500
3	Alternating gradient synchrotron			1
4	Kerst Mk I	FFAG type, very difficult to build		50
5	Kerst Mk II			
6	2 GeV synchrocyclotron + 6 GeV synchrotron	Both with spiral ridges; difficult and costly to build		1,000
7	Synchrocyclotron + synchrotron	Both with weak focussing; difficult and costly to build		50
8	Double magnet synchrotron	10^{12} protons per pulse, 30 pulses per minute	2,000	100-500
9	Spiral ridge synchrotron with saturable lips	10^{12} protons per pulse, 30 pulses per minute	2,000	100-500
10	Spiral ridge cyclotron	Difficult and very costly to build	30,000	1,000

NIMROD

NIRNS CHILTON
CERNLAB GENEVE

GENEVE TELEX 22548/272 29.8.63

DT T. G. PICKAVANCE

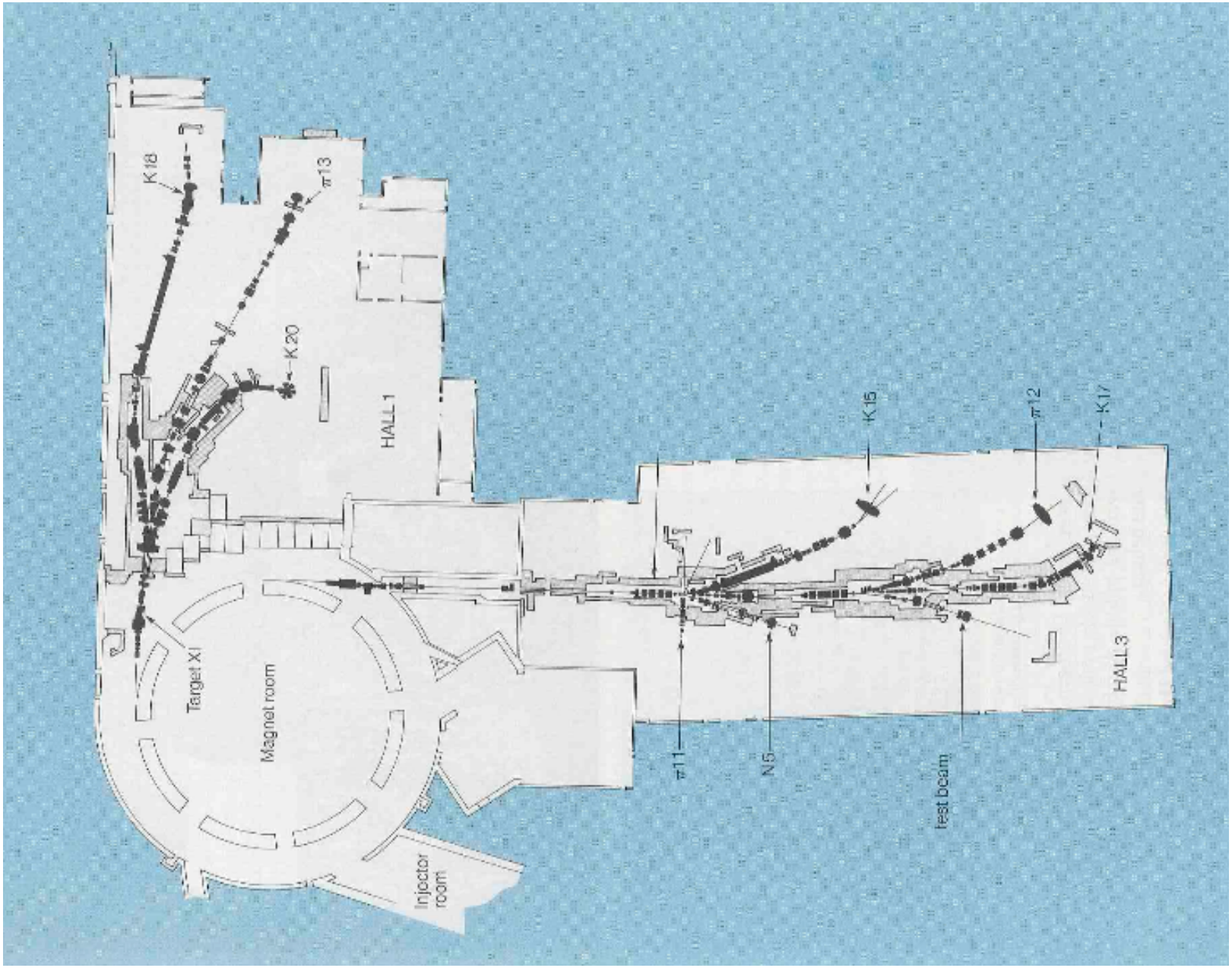
MANY CONGRATULATIONS ON SUCCESSFUL START UP OF NIMROD STOP ALL IN CERN GREATLY PLEASED TO HAVE YOU WITH US IN THE FIELD AND HOPE WE CAN HELP EACH OTHER IN BUILDING A STILL STRONGER BASE FOR EUROPEAN PHYSICS IN THE FUTURE

M.G.N. HINE
DIRECTORATE MEMBER OF APPLIED PHYSICS

FOR VICTOR F. WEISSKOPF
DIRECTOR-GENERAL

(14.33)

NIRNS CHILTON
CERNLAB GENEVE



NIMROD beamlines in 1977

Daresbury Laboratory

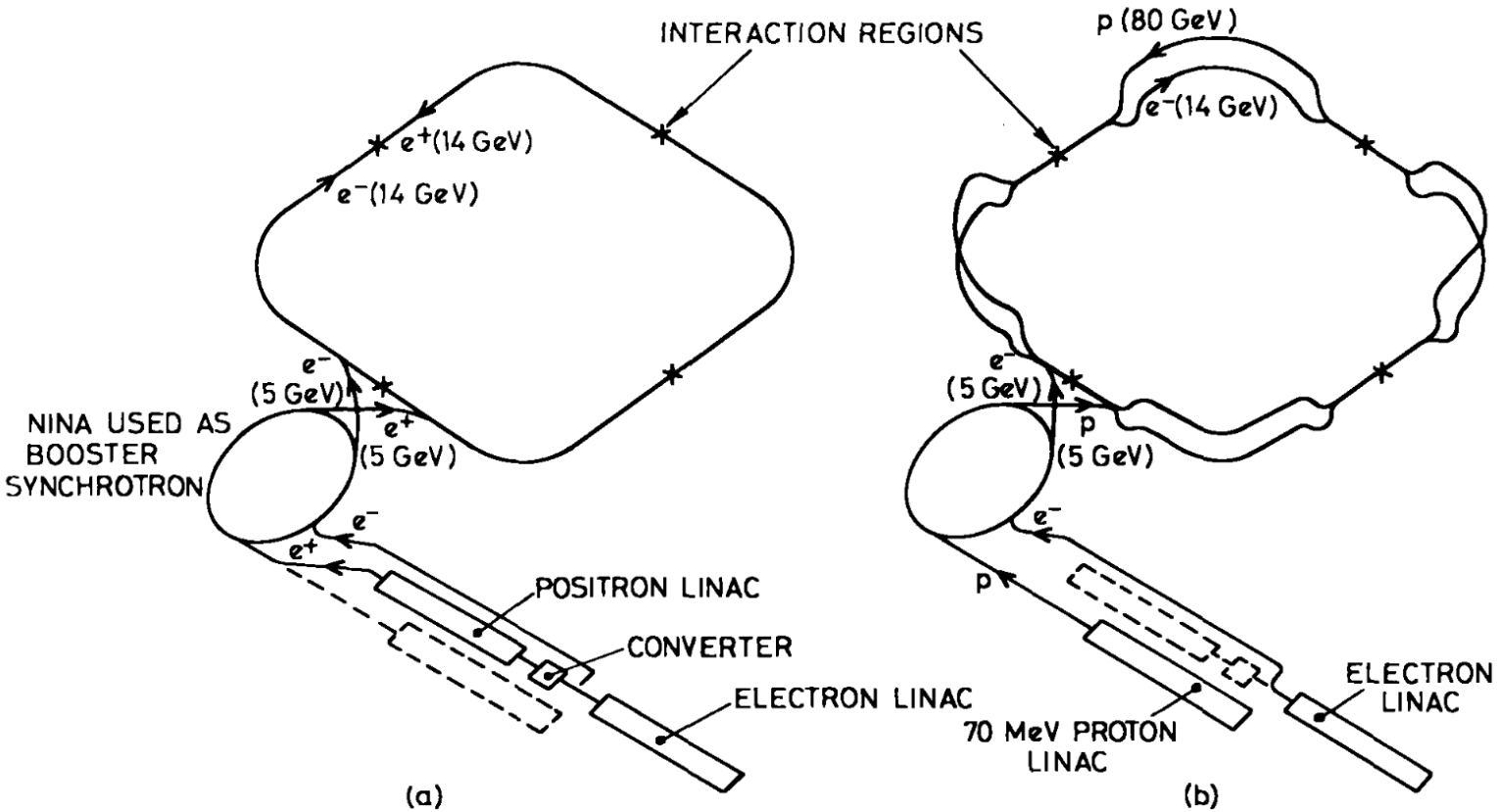
- Before NIMROD was even built, permission was given in 1962 to build an electron synchrotron at Daresbury
  - "only financially possible by limiting the rate of growth in the CERN budget" (Lord Hailsham, Minister for Science)
- 4 and then 5 GeV machine, operational from 1966
- Synchrotron radiation used from early days: first proposal in 1965
- Shut down in 1977

Joining the SPS

- The CERN 300 GeV programme was going to be very expensive, particularly if it involved a new laboratory
- Under John Adams, cost-cutting measures were coming in
- UK eventually agreed to join under the condition that the national accelerators were wound down
  - NINA in 1977: infrastructure and components largely reused for Synchrotron Radiation Source
  - Nimrod in 1978

Path not taken: EPIC

- Serious proposal for a $\sqrt{s} = 28$ GeV e^+e^- collider to be hosted at RAL
- Second stage: 200 GeV proton ring for ep collisions
- Presented to Science Research Council in November 1974: J/ψ discovery: approved!
- Killed in practice by German announcement of PETRA



Path not taken: EPIC

- Open questions from The Scientific Case for EPIC

(a) What is the nature of the recently discovered sub-structure of protons and neutrons?

(b) What are the properties of these nucleon constituents (partons)?

(c) Are the quarks which were invented to explain the properties of the multitudinous "elementary" particles, the same as partons?

(d) Does the weak interaction have a non-zero range and if so what is the mediating particle?

(e) Are the new theories that unify the weak and electromagnetic interactions on the right lines and, if so, which version provides the best description of nature?

(f) Why are there two sorts of neutrinos; why, indeed, does the muon exist at all; are there heavier leptons?

(g) Why does nature distinguish between right and left and what is the significance of the observed violation of time reversal?

ISIS

- Neutron scattering experiments with DIDO, PLUTO and HERALD[3] throughout 1960s and 1970s
- Proposal for British High Flux Beam Reactor eventually rejected (1971) in favour of joining Franco-German ILL Grenoble
  - Interest in developing a pulsed spallation source: different probe compared to continuous neutron stream
- Quick study and approval after 1975 cancellation of EPIC

[3] reactor at AWE Aldermaston

ISIS rebirth: component reuse

- Needed to keep costs down
  - NINA 1MW White-circuit choke
  - NIMROD beamline magnets
  - 1 MW motor-alternator set: second-hand motor from a Sheffield colliery, second-hand alternator from a Swedish tramway
- Came online in 1984 and the rest is history!

Interlude: Thatcher era science funding

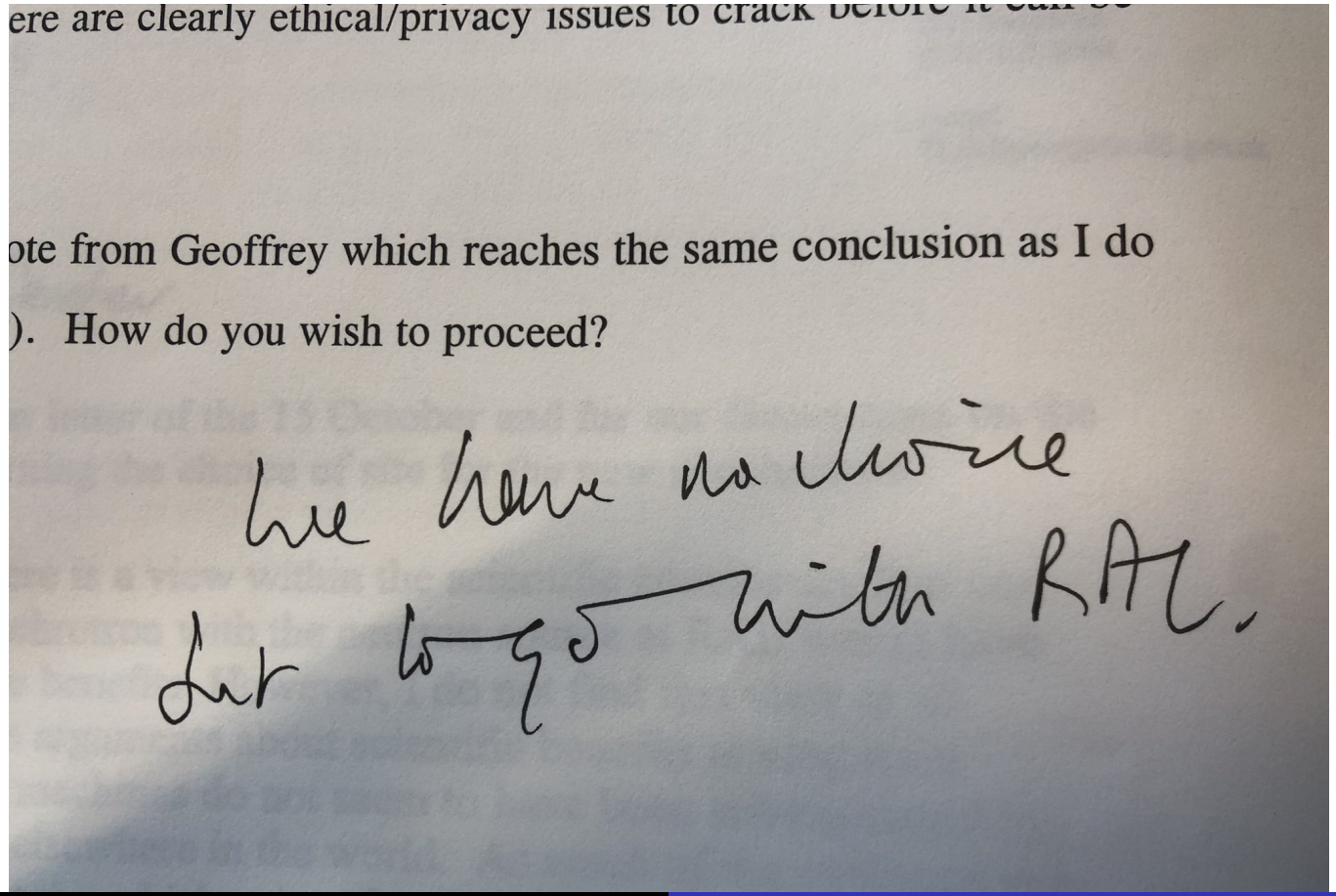
- Debate over leaving CERN bubbled under from 1983 to 1988 or so
- Robin Nicholson (Chief Scientific Advisor 1983 - 1985) was not convinced

> Withdrawal from CERN must be contemplated as one option ... I personally doubt it will come to that. More likely will be recommendations to improve the cost-effectiveness of CERN (you've seen the gold plating yourself) and, crucially, to slow down the pace and hence the rate of spend on this area of research. There is no reason why the tax-payers of Europe and the USA should have to fund a private race between two scientific cliques carried out at a pace determined largely by their own curiosity and arrogance.[131]

This discussion was occurring during the time between 1983, when CERN discovered the W boson particles, and 1984, when CERN scientists won the Nobel Prize for Physics for their discovery.

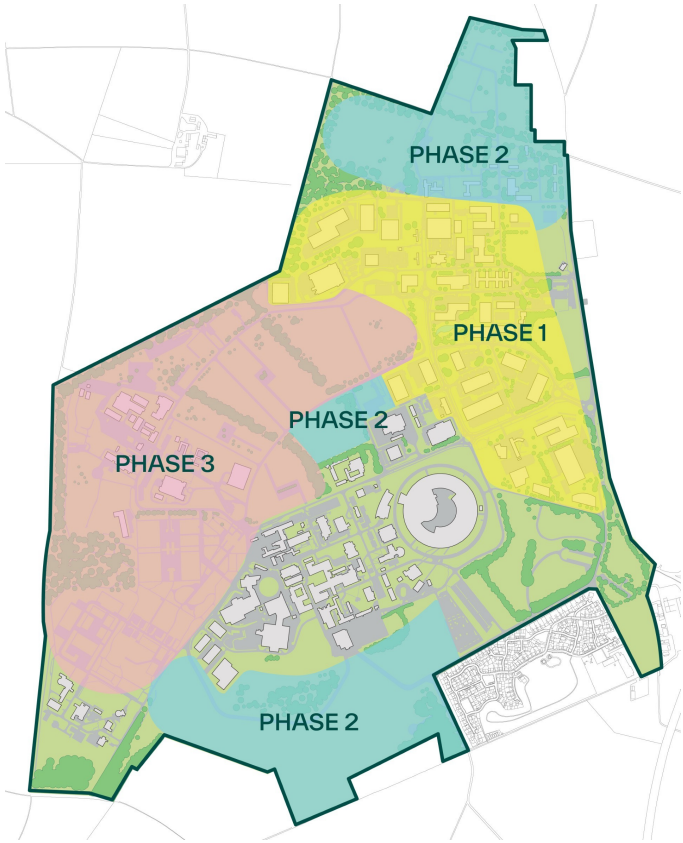
Diamond

- Desire in 1990s to build a new light source
- Funding: 50% UK, 30% France[4], 20% Wellcome Trust
- But where to build it?
  - Daresbury: supported by many, vetoed by Wellcome Trust
  - RAL: preferred by French due to better proximity to Eurostar
- Eventual decision came to Tony Blair in 2000



AERE Harwell decommissioning

- GLEEP shut down in 1990, site decommissioning began in 1992
- UKAEA headquarters moved from Harwell HQ building to Culham
- Decommissioning progress most easily tracked by Nuclear Restoration Services Site Group
- Harwell Campus: joint venture between UKRI/STFC, UKAEA and private partners manages released land



Not covered today

- MRC Harwell unit (radiobiology, mice)
- Atomic spies: Klaus Fuchs etc
- National Radiological Protection Board (now UKHSA)
- Particle detectors
- Bubble chambers
- Computing
- Lasers
- Space

Backup: The Atomic Gardening Society

The 'Atoms in the home' chapter of *Atom and Eve* included a discussion of the cold sterilization of food by gamma rays, with the news from America that 'potatoes irradiated two years ago are still fresh and not sprouting. I am trying to get some of these to taste'.[36] By 1959 Howorth had done so, appearing in the newspapers for having cooked and consumed food preserved by irradiation. It was a traditional English meal of beef, vegetables and Yorkshire pudding – except that the potatoes and onions were three years old and completely tasteless, having been kept sterile in a storeroom at Harwell thanks to the inclusion of a few grains of radioactive sodium. Howorth asserted that it was alleviating hunger, not taste, which mattered. After staging the meal she sometimes carried an irradiated potato in her handbag or pocket – a symbol, she said, 'of the way eventually we are going to use nuclear energy to help in feeding the undernourished people of the world'.[37] It is notable that although Howorth utilized the traditionally feminine loci of the kitchen, and later the garden, in her interpretations of atomic science, she refused to be confined to them. Over the course of her atomic activism she had much more to say about factories and hospitals, power plants and laboratories than about the home.

From Safeguarding the atom: the nuclear enthusiasm of Muriel Howorth by Paige Johnson

Backup: a reminiscence of 1940s Harwell

Extract from Atomic Spice by Mary Flowers
The train from Paddington to Didcot was slow and dirty...My mood was as black as the grime on the windows... The war had ended eight months previously. It was April 1946.
I was on my way to what was to be my home, on and off, for quite a long time, and the scene of countless exciting events... in both my own life and of those around me. Some were happy and many thrilling; others sad, difficult, and even shattering; but all were in some way related to the dawn of a new era, the nuclear age.
Harwell was the site of the new Atomic Energy Research Establishment...[My] first husband, Oscar Buneman, [assembled] the Theoretical Physics Division. The [leader] had already been chosen. He was Dr Klaus Fuchs...the most dangerous spy this country has ever known. The second head of that Division was Brian Flowers...my second husband. How he was to turn out I shall tell later.