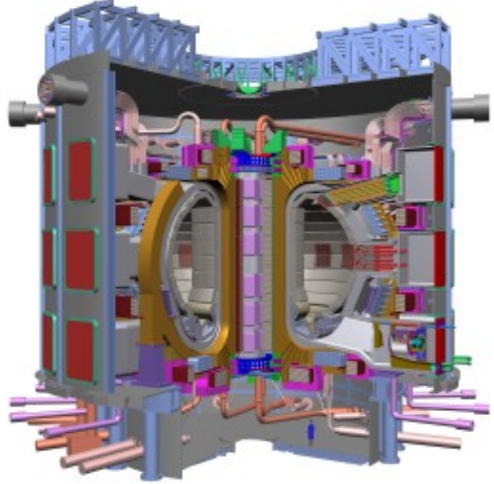
ZETA (UK), 1940 - 1950
Zero Energy Toroidal Assembly

JET (EU), 1980 -
Joint European Torus



ITER (Earth), 2015 –
International Thermonuclear Experimental Reactor

Strategic planning for Fusion Science - through ITER and beyond

Dr Matthew Hole

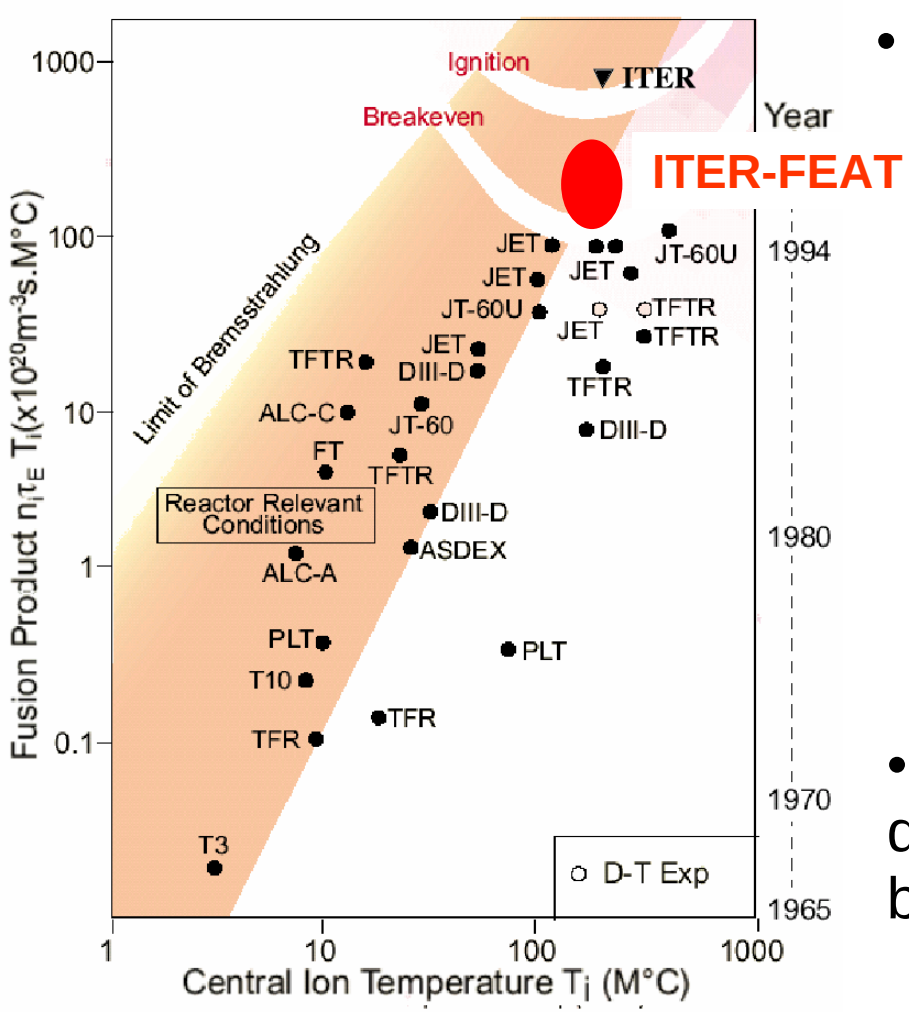
Chair, Australian ITER Forum

GEM – 4th February 2008

Contents

- **ITER and fusion - the energy driver**
- Past – what have we done?
- Present – what opportunities are available?
- Future – where is this going?

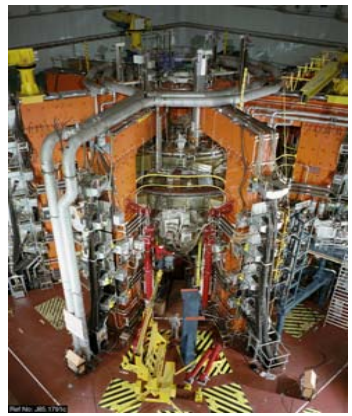
Progress in magnetically confined fusion



- "Breakeven" regime :

$Q = P_{out} / P_{in} \sim 1$

Eg. Joint European Tokamak : 1983 -



1997 : Q=0.7, 16.1MW fusion
1997- : steady-state, adv. confinement geometries

- "Burning" regime : plasma dominantly self-heated by fusion born alpha's

- "Ignition" regime, fully self-sustained : **Power Plant.**

Next step experiment…

Aims

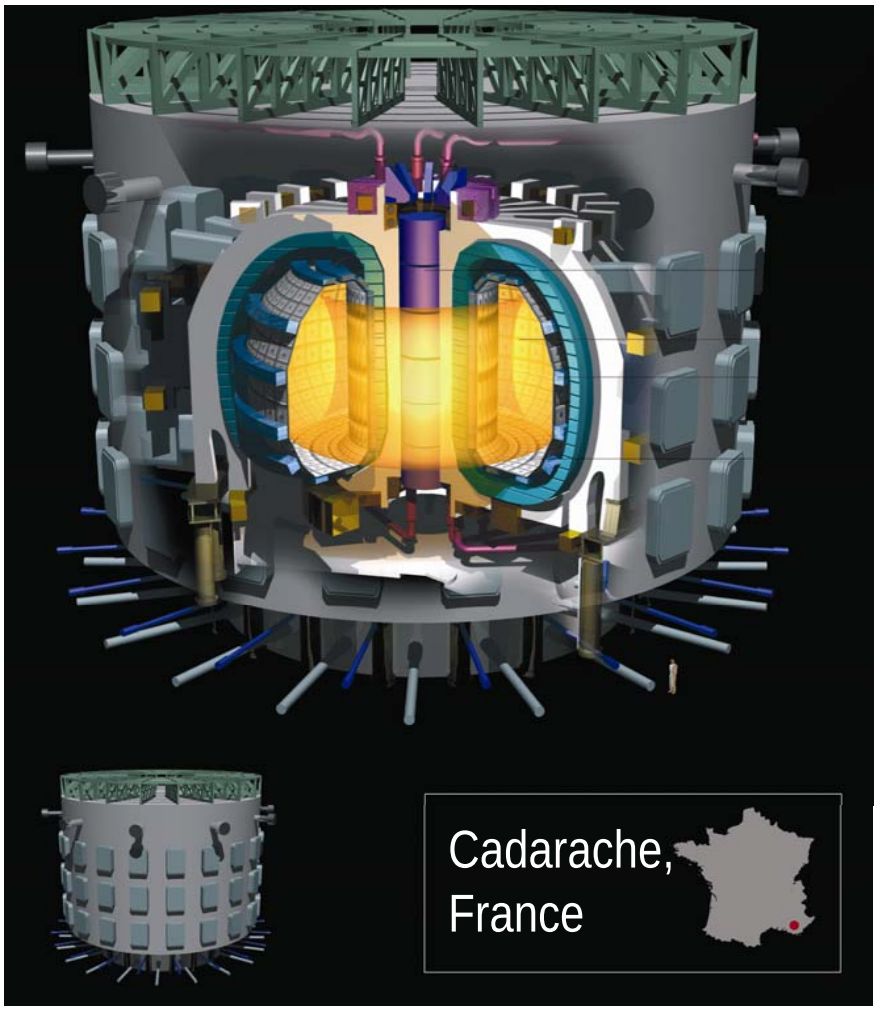
- Produce and study inductively-driven, burning plasma at $Q = P_{out}/P_{in} \geq 10$ (400-500 MW) for an "extended" time, ~ 400 s
- Produce and study burning plasma with non-inductive drive $Q \geq 5$
- Integrate essential fusion reactor technologies: superconducting magnets, high heat flux components, remote handling
- Test reactor components: eg tritium breeding module concepts (neutron power load > 0.5 MW m^{-2}, fluence > 0.3 MW year m^{-2}).

Design a function of physics and engineering constraints:

A. Power Balance (ignition criteria, collision cross section)
B. Energy confinement time (increases with major radius)
C. Density limit (density)
D. Edge magnetic winding factor (stability $\Rightarrow$ coil + heating design)
E. Engineering Choices (aspect ratio)
F. Materials Limits (limits B, divertor design)

A through F + Q>5 $\Rightarrow$ ITER-FEAT design

The ITER project



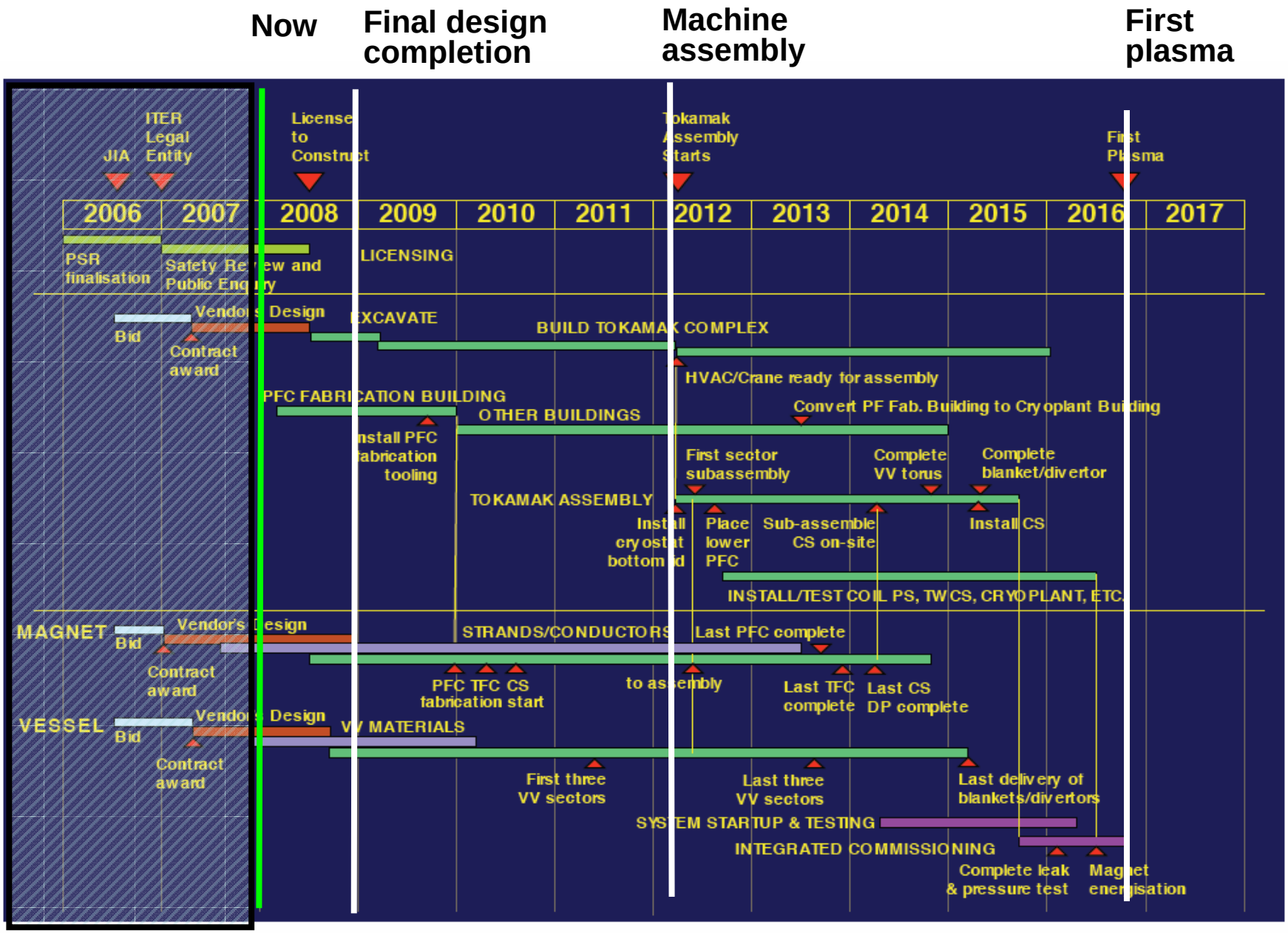
- Fusion power = 500MW
- Power Gain > 10
- Temperature ~ 80 million °C

- International Atomic Energy Agency project
- Consortium of 7 nations

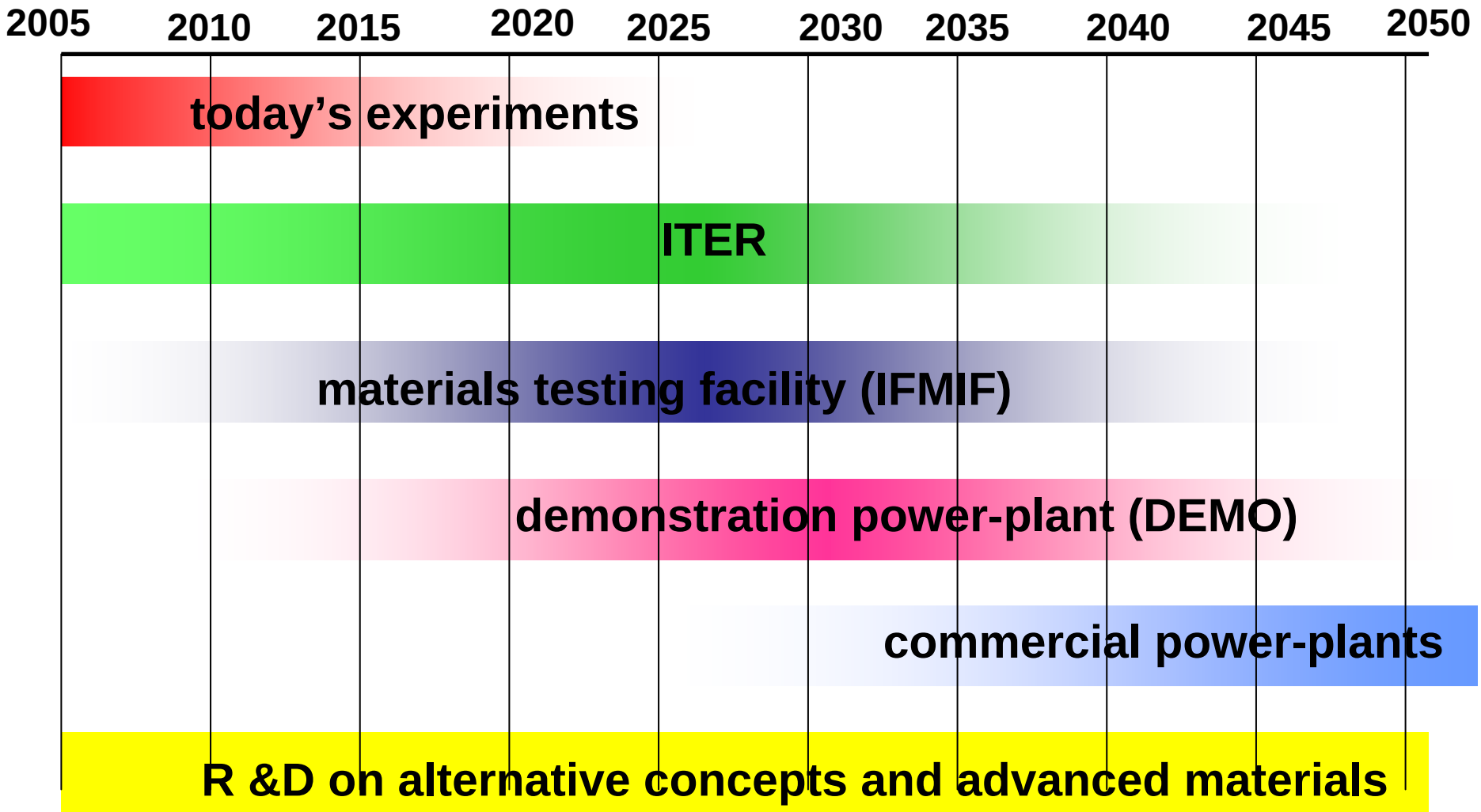
Construction cost $10 billion, 10 year operation $6 billion

Fiscally, world's largest science experiment

ITER construction: window of opportunity



Beyond ITER…



Source: *Accelerated development of fusion power*. I. Cook et al. 2005

Why should Australia engage in ITER?

- **Climate change mitigation: co-development of a *global* long-term energy solution**
- **Global framework: R&D now driven by ITER program and ITER partners** (not individuals, groups, or even nations)
- **Capability development: equip nation with skills to assess and/or adopt fusion power during DEMO**
- **Kudos and leadership: (Direct) engagement with world's largest science project.**

- Fostering international research linkages
- Skills and training: supporting other power technologies (eg. high-temperature coal, fission, solar)
- Promotion of Australia's high-tech industry & minerals
- Increased cross-fertilization of plasma physics, materials science, complex systems, engineering etc.

Why now?

- Internal drivers
  - Sustainable capability: lack of early-mid career opportunities means field approaching a generational cliff.
  - Funding gap: Most Australian programs focus on “discovery”, not strategic R&D

- External drivers
  - ITER engagement time window closing
  - Global program. ITER partners now planning well beyond ITER. Risk of lock-out from fusion energy program.
  - >$20 billion in next generation infrastructure coming online

Next Generation Infrastructure (>$20bn)

Some key infrastructure…

Contents

- ITER and fusion- the energy driver
- **Past – what have we done?**
- Present – what opportunities are available?
- Future – where is this going?

Developing National Vision: response to ITER

- Australian ITER Forum formed in 2005
  - Started raising awareness with parliamentarians, bureacrats, wider science community and the public
  - Policy engagement: COAG, UMPNER, Emissions Trading, Rural Affairs and Transport, APEC, and bipartisan Prosser enquiry, which recommended the Australian government:

    "negotiate involvement in the ITER project on a whole-of-government basis… establish a national research centre in fusion science to consolidate and coordinate Australia's research efforts, and examine the merits of establishing fusion science as a national priority"
- International workshop held in Sydney in 2006
  - International Science Linkage grant (DEST)
  - Most ITER parties attended
  - Opened by Chief Scientist, Dr Jim Peacock

Strategic Plan Development

- Following Workshop, Australian science community undertook strategic planning exercise:
  - Issues paper released in Dec. 2006
  - Strategic plan released in Parliament on August 15.

- **Recommendation:** Formation of an “Australian Fusion Initiative”, that would enable enable the development of expertise and industry capabilities to meet the nation’s long-term needs. The initiative comprises:
  - A fellowships program, focused on early- and mid-career researchers to build up a researcher base with relevant expertise
  - Development of an ITER machine technology contribution – a diagnostic – which would serve as a flagship for Australia’s national effort in this area and deliver defined benefits to the nation
  - Support for research infrastructure, both to enable the development of an ITER diagnostic and to invest in new facilities and operation of facilities, established on a leveraged basis
  - Support for travel and exchanges.

“Australian Fusion Initiative”: Components

A. 40 competitive AFI fellowships ~$32M over 10 years - essential element!
B. ITER “flagship diagnostic” ~$9.3M - multi-institutional, mutli-disciplinary
C. Key infrastructure ~$1.8M – essential to mounting diagnostic, subject to international review
D. Infrastructure leverage fund ~$9.5M over 10 years - open competition for infrastructure, e.g. “physics upgrade” to H-1
E. Operating fund $2.5M over 10 years. Open competition. 2/3 funding from initiative, 1/3 from elsewhere.
F. Collaboration and exchange ~$4.7M over 10 years
G. Management ~$3M over 10 years

Total Budget ~ $27M over 5 years, $63M over 10 years

Implementation: Federal allocation, initiative governed by a committee & directo

Critical timing: sychronising with ITER

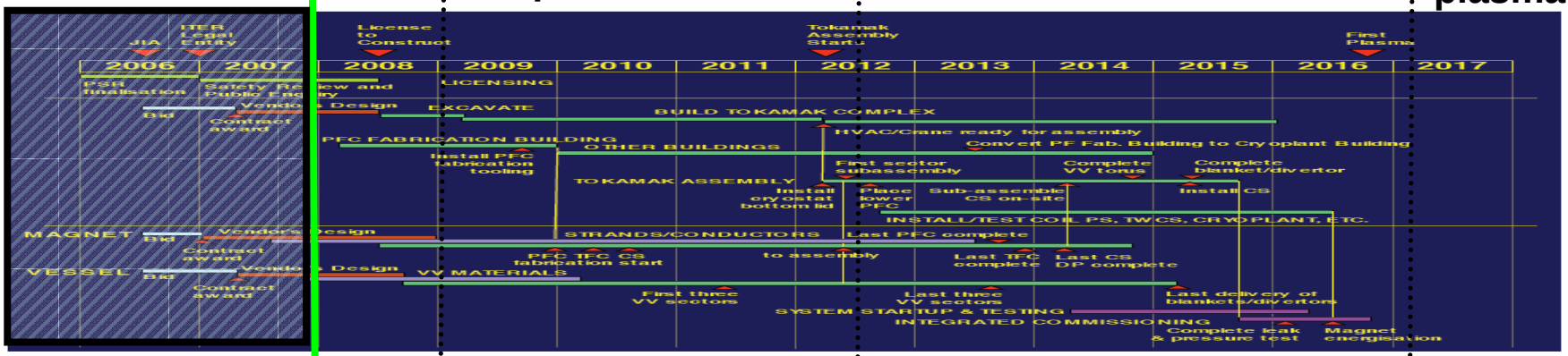
2008 2010 2012 2014 2016 2018

Now

Final design completion

Machine assembly

First plasma



Strategic Fellowships

Key infrastructure upgrade

Australian diagnostic

Gov. – ITER contract negotiation

Diagnostic evaluation

Scoping R&D

Full testing

ITER prototype

Installation /check

exploitation

Strategic Plan support

Written letters of support from:

- Australian National University,
- University of Sydney,
- University of Newcastle,
- University of Wollongong,
- Curtin University,
- Macquarie University,
- Australian Nuclear Science and Technology Organisation,
- Australian Institute of Nuclear Science and Engineering,
- H1 Major National Research Facility,
- Australian Institute of Physics
- Australian Institute of Energy,
- Australian Academy of Technological Sciences and Engineering,
- The Australia Institute,
- The ITER organization.

In process… University of Melbourne, IAEA

Contents

- ITER and fusion- the energy driver
- Past – what have we done?
- **Present – what opportunities are available?**
- Future – where is this going?

Maximising opportunities 1/2

- Strategic plan before Government: ongoing consultation
- Mid-career fellowships promised by ALP during election cycle. (Watch this space)
- Review of National Innovation System: (announced 22 Jan. 2008, Minister Carr)
  - Appointed an expert panel to review the national innovation system and the coherence and effectiveness of existing Government support.
  - Panel chaired by Dr Terry Cutler ~ 80% commercial appointees
  - Panel to "identify gaps and weaknesses in the innovation system and develop proposals to address them."
  - Panel will release of "Issues paper" in February. *Forum strongly encouraged to lodge a strong submission*
  - Panel to produce green paper by end of July 2008,
  - White Paper response from the Government (probably Sep.)

Maximising opportunities 2/2

- Australia 2020 Summit (announced 3 Feb)
  - Will be convened on 19-20 Apri, Parliament House, to help shape a long term strategy for the nation's future.
  - 10 theme areas. Science, education, skills, training, science and innovation as part of the nation's productivity agenda under "Future directions for the Australian economy". Energy addressed under "Population, sustainability, climate change, and water"
  - 1000 participants, selected by a 10 member non-government Steering Committee. Co-chaired by the Prime Minister and Professor Glyn Davis, Vice Chancellor of the University of Melbourne.
  - All Australians will be invited to make submissions on each of the 10 future challenges.

- Another recommendation of the strategic plan was better targeting of existing grant mechanisms:

Some existing opportunities

- International Science Linkages
  - Now targetted to: US,EU – Framework, UK, Germany, Japan, Brazil, Singapore
  - Strong focus on Clean Energy Technology and Climate Change
  - Principally funds people, travel
  - **Open 11 February 2008, close 5pm 11 April 2008.**
  - ***Also Australia-China Special Fund …***
- Australia-India Strategic Research Fund
  - Co-funded by Indian Government. Funds collaboration with Indian scientsits in targetted areas (includes energy)
  - Principally funds people, travel
  - **Round 3 open August 2008**. Completion date - June 2011
- Marie Curie International Research Staff Exchange Scheme
  - Supports a European scientist to work in Australia (up to 12 months) … may need some workaround of EURATOM
  - Closing date: 28 March 2008
- Academy of Science traveling fellowships,
  - Funds travel to participate in collaborate research with partners in Europe, China, Japan Korea, Taiwan, Nth America

Contents

- ITER and fusion- the energy driver
- Past – what have we done?
- Present – what opportunities are available?
- **Future – where is this going?**

The future of the Australian ITER Forum

Recommendations of the strategic plan:

- Forum has an ongoing role in outreach, policy engagement, community building (identity), conference organization
- Likely change of name reflecting increase span, breadth and scope to fusion science and engineering (not just ITER).
- Forum should become a formally defined organisation with a constitution, enabling clearer lines of membership, annual elections and a more structured decision-making process

- Possible Australian overseas fusion network

Feedback on strategic plan recommendations welcome.
Ongoing presence needs your commitment!

Summary

- ITER is a paradigm shift in undertaking global science – *the way of the future for large scale international collaborations*
- Drivers for Australia to respond to ITER challenge *now:*
  - **Australian core capability at critical level, and approaching a generational cliff. Need to broaden expertise mix for next generation.**
  - **ITER under final design & construction**
- A strategic plan for the future of Australia's fusion capability and international engagement. The plan:
  - involves researchers, industry and government
  - builds on Australian capabilities in fusion science
  - is managed by the Australian ITER Forum
  - secures nation with skills to assess and/or adopt fusion power during DEMO
- Initiative needs wider community leadership.