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Engineering Doctorates in Australia

"What does industry think of doctoral graduates and what are we doing about it ?"

Robin W King
Australian Council of Engineering Deans

Chair: *Engineers Australia* Accreditation Board
Chair: Sydney Accord
Emeritus Professor, University of South Australia

email: robin.king@uts.edu.au

overview of presentation

- **higher education context for Australian doctorates**
  - learning outcomes and the qualifications framework
  - regulatory context: metrics and institutional value
- **pathways to engineering PhDs**
  - numbers: commencers, graduations, trends by discipline
  - concentration of research training environments
  - management of research training
- **career paths for Australian engineering PhDs**
  - graduate destinations and cases
- **quality improvements in engineering doctorates**
  - Issues, professional doctorates and generic skill development
- **government reviews and recent initiatives**
- **conclusions**

Australia: population ~ 23M

- GDP/head ~ US$41,000 (2010)
- rated 2nd (to France) 2010 Quality of Life index (*International Living* magazine)
- economic growth from resource extraction
- bad global per-cap carbon footprint
- very constrained by water availability

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Exports

Resources - iron ore, copper, gold, uranium, bauxite, coal, LNG and LPG

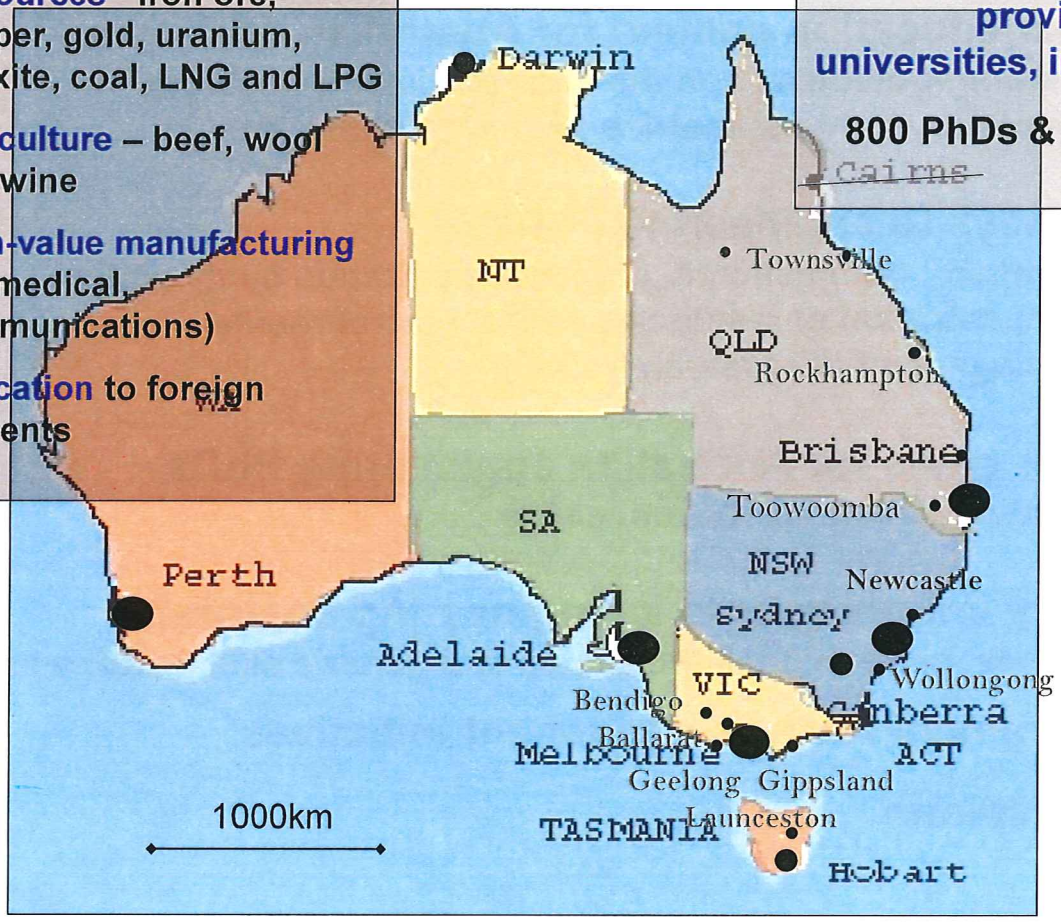
Agriculture – beef, wool and wine

High-value manufacturing (biomedical, communications)

Education to foreign students

engineering education and research is provided by 33 universities, in 19 cities

800 PhDs & 200 MRes per year



Higher Education Context for Engineering PhDs

- all 38 public universities offer PhD and Masters by Research
- universities must have defined research capability
- doctorates are at Level 10 of the Australian Qualifications Framework (AQF) with deliver learning outcomes as in Table
  - PhDs are assessed by thesis
  - professional doctorates (mostly DBA and EdD) coursework and research thesis on professional practice

knowledge	substantial; forefront of field; original; research principles and methods
skills	cognitive – critical, systematic expert – technical and creative; design, implement analyse, theorise and communicate communication – explain and present to peers and community
application	independence; initiative and creativity, responsibility, accountability ; execution of original research; ongoing capacity to generate new knowledge

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- government provides funds for HDR Research Training places and scholarships (HDR = "higher degrees by research")
- universities may have additional outcome specifications
  - the University of South Australia has 7 "research degree graduate qualities" – include all the AQF 10 and specifically reference: collaborative research, ethical & social issues, and international perspectives
- university performance metrics related to HDR research training
  - HDR graduations, research publications and research income are used in government formulae to allocate funded future HDR places, scholarships and research infrastructure
  - universities usually use the same metrics for allocation between disciplines - engineering does relatively well
- measurement of research quality and excellence is a continuing "hot-topic" >> funding concentration
- the new Tertiary Education Qualification Standards Agency (TEQSA) will establish "research standards" during 2012

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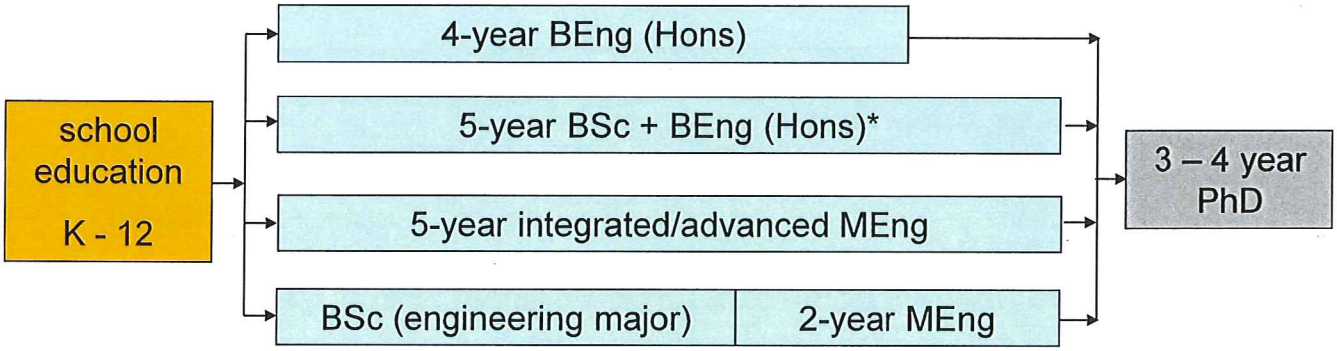
- **HDR funded places account for ~ 70% of domestic enrolments**
  - **6,000 commencing enrolments in 2010 for 3,500 funded places**
  - **engineering wins about 12% of the HDR allocation**

for engineering

- **most engineering schools will fund HDR places from other sources, including from industry collaborations**
- **entry pathways (for engineering):**



- **the qualifying degree must be at a high level of merit (at least second class honours or equivalent)**

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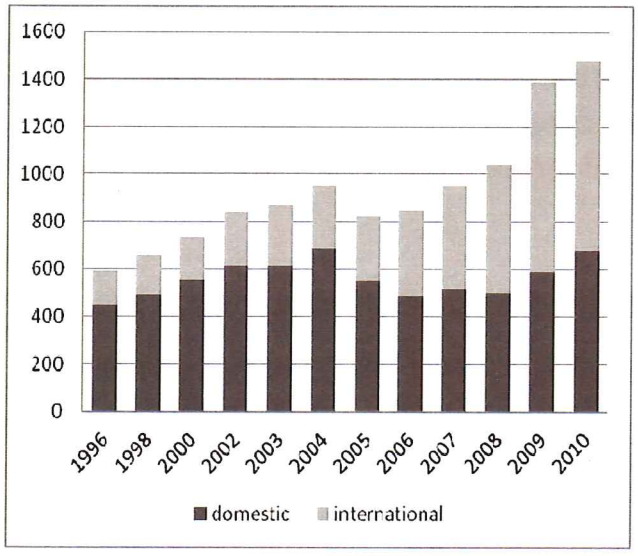
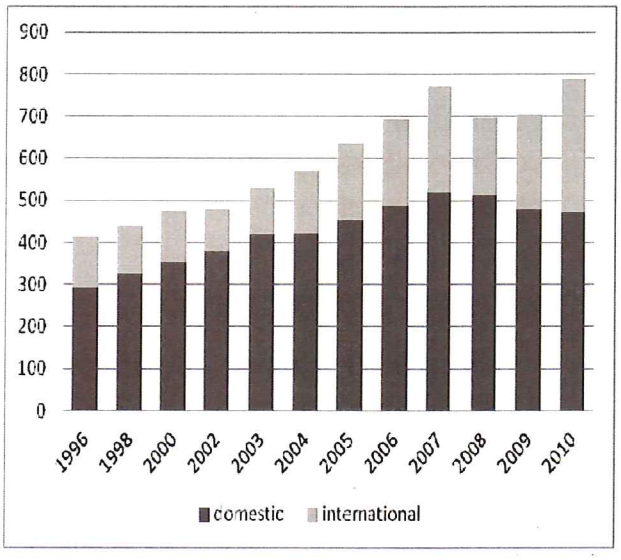
commencing enrolments and graduations in engineering PhDs





- **international growth ~ 50% of enrolments & graduations**
- **high overall completion rate**
  - **800 commencers in 2004 >> 730 graduates over 2006-8 (estimate)**
- **about 20 – 25% of enrolments are women (contrasts with 15% for bachelor degrees)**

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- **distribution of PhDs between engineering branches is similar between domestic and international students**

Engineering branch	%
Electrical & Electronics (including Computer Engineering)	32
Process and Resources	30
Civil	18
Mechanical, Manufacturing and Industrial	11
Other: geomatic, aerospace, maritime, biomedical, etc.	9

- **Are we producing sufficient PhD graduates for national needs, including for replacing retiring academic staff ?**
  - **domestic enrolments are not increasing and most international graduates are likely to return home (eventually)**

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an international comparison

	Australia		USA	
population, 2010	**22,421,000**		**309,975,000**	
engineering qualifications	**graduate numbers**	**domestic graduates per million population**	**graduate numbers**	**domestic graduates per million population**
bachelors (domestic %)	9,149 (68.2%)	278	78,347 (93.8%)	237
masters (domestic %)	4,635 (28.9%)	60	43,023 (53.9%)	75
doctorates (domestic %)	789 (59.8%)	21	8,995 (45.8%)	13

- **Australian produces more engineering PhD's per population than USA; with similar international trends**
- **Is there similar data for other countries?**

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the changing environment of university engineering research and research training

- concentration of research into university types:
  - 62.5% of all engineering PhD graduates from 10 "research" uni's
  - 25.6% from 6 former Institutes of Technology
- erosion of the "supervisor – apprentice" model of training, to more corporately regulated and accountable forms
- growth of research concentration in "centres" and "institutes" and growth of post-doctoral positions
  - bigger questions need bigger teams and more $
  - governments can identify and fund "centres of excellence" , as in
  - Special Research Centres (funded by the Australian Research Council) for basic research
  - Cooperative Research Centres for industry-linked "pre-competitive applied multidisciplinary research"
- alongside very competitive research grant (ARC) schemes
- HDR places are allocated preferentially to the funded national programs (covering about a third of the students)

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a cooperative research centre: CIEAM

- the Centre Integrated Engineering Asset Management
  - 7 universtiy research partners and 2 government agencies
  - 11 industries (mining, water and energy utilities, transport, defence)
  - focus is on maintenance technologies, maintenance management practice and life-time extension of engineering plant and assets
  - 50 PhD graduates since 2006 in engineering, information systems and management
  - graduates participate in national and international forums

research in engineering education

- growth of research in engineering education with PhD enrolments has led to networked discussions about a nationally networked centre – as well as developing a "new generation" of engineering academics

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management of research training

- each provider has explicit regulations for supervision, facilities provision, student progress and thesis submission
- students are supported by workshops on research methods, planning and research writing
  - these should focus on the culture of engineering research, *noting*
  - engineering is a "design" discipline, so research questions may be on the science of hypothetical future design, rather than "knowledge discovery"

- PhD candidates in engineering are usually encouraged to publish during candidature
- thesis requirements are usually ~100,000 words + appendices
- examination is independent of supervision, and usually includes one or more international examiner; *consequently ...*
- verbal defence (*viva*) is NOT normally part of the process
- Can managed PhD candidature be treated more effectively as a professional development process?

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career paths for Australian engineering PhDs

- employment rates for PhD and research Masters
  - 78.6% graduating in 2010 in full-time employment (sample survey)
  - mining and aeronautical all employed (small numbers)
  - electrical/electronics/computing ~ 20% seeking work
  - 80% in large organisations
  - 80% in full-time employment judged their research degree to be *at least important* for their employment (except for mining)
  - some (median) salary advantage on appointment is apparent, but would not compensate for years of study, compared with BEng contemporaries

  - more data and graduate tracking is highly desirable to answer the question *"what does Australian industry think of engineering doctorates"*
  - *and the answer will depend on who you ask*

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three examples make a case for research centres

- one of China's most successful engineers, founder of Suntech Power has a PhD in solar photovoltaics from UNSW
  - ARC Centre of Excellence in Advanced Silicon Photovoltaics and Photonics and its predecessors have been world leaders in solar cell research since 1985, has had numerous PhDs and industry outcomes

- the Institute of Photonics and Optical Sciences at the University of Sydney was featured in *Nature*, as
  - "*a premier institute ... with 40 postgraduate students*"
  - the Institute's predecessor has spawned many companies, one employing 40 PhDs in physics and engineering and making world-leading optical fibre devices in Sydney
- Cochlear Ltd. is the world's leading manufacturer of implantable hearing devices, and high ranked publically listed company
  - material, manufacturing and signal processing technologies have been developed in a sequence of CRCs going back to 1992. There are 31 enrolled PhD students in the current CRC

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quality improvements in engineering doctorates

- some engineering employers "*will not employ PhD graduates*", because of perceptions that they have
  - narrow focus (on detail and in their area of expertise)
  - poor generic skills, and lack of ability "to get the job done"

- some engineering academics do not consider that Australia operates at world best practice (except in national centres of excellence) because
  - advanced coursework is not normally included
  - 3-year minimum duration for original research is too short
  - research questions are not at the forefront of the discipline

- professional doctorates have been introduced to focus advanced work on engineering practice, eg UniSA
  - very small enrolments, and confined to the defence industry
  - includes advanced coursework (one year equivalent)
  - major thesis (two thirds of assessment) on systematic problem definition, solution formulation and coordination

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generic skills for doctoral candidates

- short courses are provided by many universities, *but most systematically by the*
- *e-Grad School* (ATN Group of universities, five former Institutes of Technology) - a virtual graduate school, linked into the CRC system
- *e-GSA* topics for doctoral candidates include
  - research methods and information literacy
    career planning and positioning; preparation for university teaching
- *e-GSA* operates "LEAP" (Learning Employment Aptitude Program) with employability-focussed modules on
  - project management; entrepreneurship; leadership and communication; research commercialisation; public policy and global sustainability
- these, together with advanced engineering subjects (eg in summer and winter schools) would strengthen the engineering doctoral experience as professional development
  - who pays for the subjects and the extra enrolment time?

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Australian government reviews and initiatives on research training

- review (2008) on Australia's "innovation system" recommended
  - building research concentrations
  - allocating doctoral stipends to institutions that demonstrate excellence on quantitative measures; increasing stipends and funded places to 4 years
  - funding overseas experience in the early careers of academic researchers
- government's research workforce strategy (for 2020) reinforced CRCs for research training, and improvements around:
  - professional needs of graduates
  - establishing and monitoring research standards and benchmarks
- government announced (December 2011) a new Industrial Transformation Research Program to
  - develop 20 research hubs and 50 research training centres, and fund up to 600 industrial PhDs (where will they come from?)

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conclusions – the way ahead

- the Australian engineering doctoral system is working reasonably well, and is broadly supported by government policy
  - the system can be improved and must look forward
  - a specific specification for engineering PhDs may be desirable
- generic skills development, advanced coursework and international experience would be highly desirable
  - funding and regulation are inadequate at present
- higher numbers of well-qualified Australian BEng graduates must be attracted into research, and be valued by employers
  - but increases are unlikely in the current economy
  - new incentives are necessary to encourage "the best"
- new models of research training that incorporate *professional career development* merit trial in selected institutions
- models for research training that include *multidisciplinary thinking* may be needed to address emerging problems

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acknowledgements

- the examples have been taken from universities in which I have worked; there are many other similar and successful cases
- Professor John Beynon, President of ACED, for comments on the paper

Questions ?

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