Embedded, Real-Time and Operating Systems (ERTOS) Program

National ICT Australia

August 2003

National ICT Australia (NICTA)

- National research flagship for IT and Communications
- Established by Australian Government October 2002
- 4 core partners:
  - ➜ 2 universities: UNSW, ANU
  - ➜ 2 state governments: NSW, ACT
- Funding for first 4 years: A$200M (A$120M federal gov't)
- Steady-state federal funding: A$48M/a (indicative)
- Steady-state budget: A$100M/a (estimate)

NICTA: Four Pillars

- Research
  - ➜ Commitment to world class research across a wide range of ICT
  - ➜ Target: 300 PhD-qualified researchers
- Education
  - ➜ Training of top-class PhD graduates
  - ➜ Target: 100 PhD graduates per year
- Commercialisation
  - ➜ attractive IP/commercialisation policies
  - ➜ create a commercialisation culture
- Linkages
  - ➜ International: top research institutions, MNCs
  - ➜ Domestic: SMEs

NICTA Overview: Research "Themes"

1. Infrastructure Technologies (InfT)
   - ➜ 6 Programs, 2 planned
2. Software Engineering (SE)
   - ➜ 2 Programs, 2 planned
3. Intelligent Systems (IntS)
   - ➜ 4 Programs, 1 planned
4. Human-Machine Interaction and Usability (HMIU)
   - ➜ 1 Programs, 1 planned
5. Foundations (Found)
   - ➜ 2 Programs, 2 planned

NICTA Overview: 3 Nodes

- Sydney Research Lab — 2 locations:
  - ➜ UNSW Campus (4 Programs)
  - ➜ Australian Technology Park (3 Programs)
- Canberra Research Lab: ANU Campus (5 Programs)
- NICTA Fellows
  - ➜ Located at other Australian Universities
  - ➜ Part of NICTA's commitment to the national interest

NICTA Overview: Present Research Programs

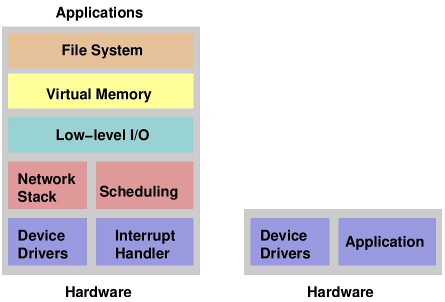
- Sydney Research Lab, UNSW Site:
  - ➜ Embedded, Real-Time and Operating Systems (Heiser, InfT)
  - ➜ Formal Methods (van der Meyden, SE)
  - ➜ Symbolic Machine Learning & Knowledge Acquisition (Sharma, IntS)
  - ➜ Knowledge Representation & Reasoning (Foo, IntS)
- Sydney Research Lab, ATP Site:
  - ➜ Networks and Pervasive Computing (Seneviratne, InfT)
  - ➜ Empirical Software Engineering (Jeffery, SE)
  - ➜ Humans Understanding Machines (Eades, HMIU)
- Split, Sydney and Canberra Research Labs:
  - ➜ Systems Engineering and Complex Systems (Anderson, Found)

- Canberra Research Lab:
  - ➜ Wireless Signal Processing (Kennedy, InfT)
  - ➜ Statistical Machine Learning & Sensor Signal Processing (Williamson, IntS)
  - ➜ Autonomous Systems & Sensing Technology (Hartley, IntS)
  - ➜ Logic & Computation (Lloyd, Found)

Embedded System

Computer system that is part of a larger system

General-Purpose vs. Embedded



- Traditional model of embedded systems
  - ➜ No longer true for complex and networked embedded systems!

Critical Issues for Embedded Systems

- Development cost
- Unit cost
- Time to market
- Size
- Performance
- Reliability
- Security

ERTOS Vision

To develop methodologies, tools, components and systems that will deliver reliable, inexpensive system *software* meeting its requirements.

ERTOS research will be driven by applications

- to identify common challenges
- to provide generic systems software

Grand Challenge: Trustworthy Systems

- Reliability of (embedded) systems is a major concern
- Can only really trust a system once mathematically proven correct
- Proofs for high-level parts of a system are of limited use
  - ➜ Need to *assume* that remaining parts are correct
- Essential to deal with hardware-software interface
- Difficult because:
  - ➜ Side effects of hardware
  - ➜ Complexity of operating system code

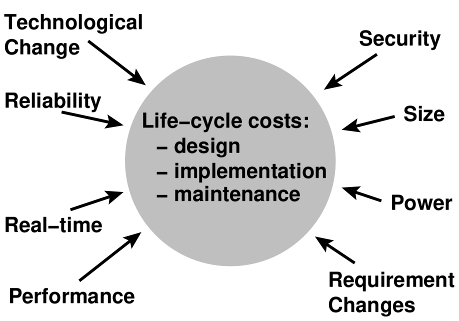
Trustworthy System

- Must prove safety properties for *whole* system
  - ➜ Break system into small components of manageable size
  - ➜ Develop formal models of each component
  - ➜ Prove that each component satisfies requirements
  - ➜ Prove that whole system satisfies requirements
- Must ensure that components interact via defined interfaces only
- Key issues:
  - ➜ components
  - ➜ encapsulation

Long-term vs. Intermediate Goals

- Work on the Grand Challenge is
  - ➜ medium- to long-term
  - ➜ high-risk
  - ➜ potentially disruptive
- Will also perform research that is
  - ➜ short- to medium-term
  - ➜ medium-risk
  - ➜ incremental
  - ➜ addresses present challenges
- Outcomes:
  - ➜ insights, design principles, methodologies
  - ➜ software: kernels, compilers, frameworks, tools
  - ➜ closing in on the Grand Challenge

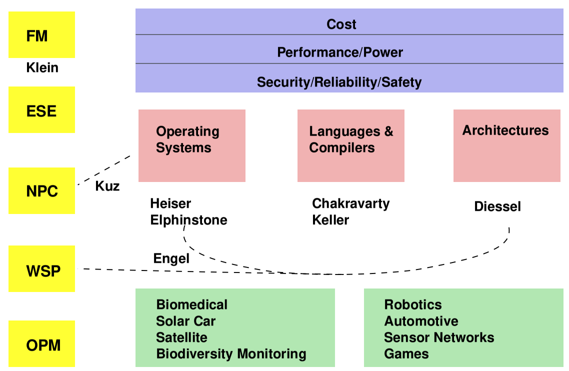
Embedded Systems Constraints



Strategies for Meeting the Challenges

- Generic frameworks which can be specialised
  - ➜ application driven
  - ➜ based on microkernel approach
- All-of-systems approach
  - ➜ address challenges at all levels of system
- Open Source
  - ➜ share infrastructure cost
  - ➜ ease uptake

ERTOS Overview



Indicative Projects

- Formal modeling of low-level system code
  - ➜ with Formal Methods Program
  - ➜ first step towards meeting Grand Challenge
- Light-weight high-performance distributed robot OS
  - ➜ with ARC Centre of Excellence for Autonomous Systems
  - ➜ with Symbolic Machine Learning Program
  - ➜ with Autonomous Systems & Sensor Technologies Program
- Sensor networks software infrastructure
  - ➜ with Networks & Pervasive Computing Program
  - ➜ also, personal area network demonstrator
  - ➜ industrial client desirable

Indicative Projects...

- Embedded systems on a chip
  - ➜ with Wireless Signal Processing Program
  - ➜ with potential Circuits & Systems Program
- High-performance switching systems
  - ➜ with Optical Processing & Monitoring Program
- Real-time systems design
  - ➜ with Formal Methods Program
  - ➜ possible applications: robotics, automotive
- Embedded systems product line
  - ➜ with Empirical Software Engineering Program
  - ➜ possibly with Fraunhofer Software Engineering Institute

Education

- Global shortage of graduates/PhDs with good “systems” skills
- UNSW is only place left in Australia where students get to:
  - ➜ get real experience with low-level systems code
  - ➜ build sizable systems from the ground up
  - ➜ get trained with real-live systems (Linux)
- Undergraduate student achievements:
  - ➜ 3 × winners CISRA Project Prize
  - ➜ 2 × NSW winners Siemens Prize for Innovation
  - ➜ 4 × winners Aurema Operating Systems Prize
  - ➜ winner AUUG Open Source Prize
  - ➜ 2 × winners AUUG John Lions Award
  - ➜ 3 placed as interns at IBM Watson (6–12 months each)
    - ➜ latest round of applications just closed (3 applied)

Education

- Advanced-Level Courses, coverage unique in Australia:
  - ➜ Advanced Operating Systems
  - ➜ Advanced Compilers
  - ➜ Advanced Functional Languages
- PhD students
  - ➜ presently 20 students
  - ➜ 7 commenced in 2003
- Summer Scholarships for Undergraduates:
  - ➜ 18 students in 2002–3
  - ➜ similar number expected next summer

Strategic Linkages

- IBM T J Watson Research Center and OzLabs (HPCS)
- HP Labs
- Microsoft Cambridge Lab
- Xilinx, Intel
- CMU, UIUC, Waterloo, Karlsruhe and Dresden U, Barcelona
- Partner in EU FP6 Project
  - ➜ ST Microelectronics, Dresden, Prague

Commercialisation

- Presently all work is in open-source domain
  - ➜ will continue to open-source generic infrastructure
  - ➜ client-specific code subject to standard commercialisation arrangements
- Reasons:
  - ➜ little profit in basic software infrastructure
  - ➜ impact is more important to NICTA than cash
  - ➜ unrestricted accessibility (BSD License) encourages uptake
- Goal: Create the BSD of Embedded Systems!

Summary

ERTOS will:

- Make conceptual contributions to software frameworks and methodologies for the development of embedded systems
  - ➜ A concrete outcome will be kernels, systems and tools which will be widely available and used, and will enhance the NICTA brand
- Produce concrete applications of these systems in specific domains which will lead to commercialisable outcomes
- Build capabilities to overcome a lack of systems expertise — a critical resource for the future of Australia