Computing for the Future of the Planet

Andy Hopper

Computing is a crucial weapon in our armoury for ensuring the future of the planet.

Computing will play a key part in optimising use of physical resources and ultimately their substitution by the digital world.

Computing will be a tool for enabling developing societies to improve their standard of living without undue impact on the environment.

The Royal Society, London, 17 March 2008

Computer Laboratory
University of Cambridge

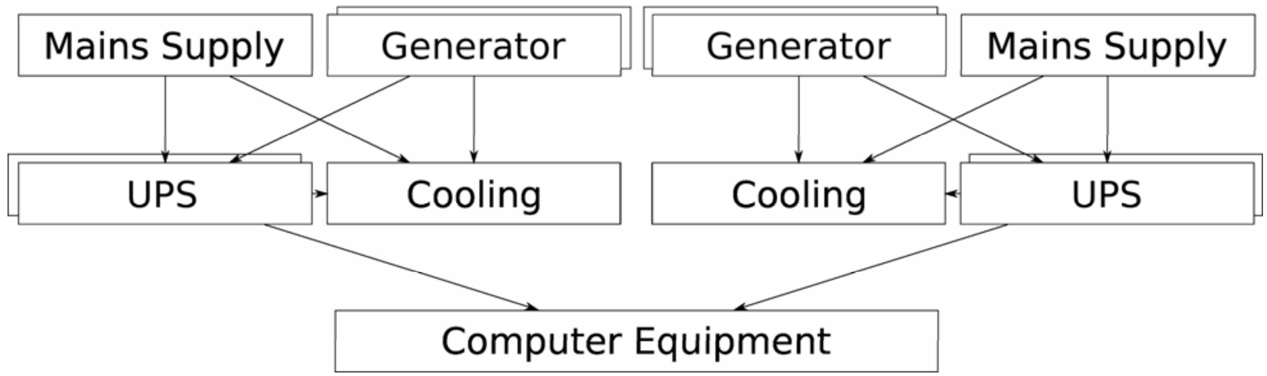
Computing for the Future of the Planet

1. Optimal Digital Infrastructure
2. Sense and Optimise
3. Predict and React
4. Digital Alternatives to Physical Activities

1 - Optimal Digital Infrastructure

- Provisioning appropriate availability
- Energy efficient computing
- The overall goal

Provisioning Appropriate Availability



- Redundancy doubles (energy) cost of datacenter
- Reduce redundancy by using new tools which monitor interdependency of components
- Decrease restart times of services (from ~4 hrs)

Energy Efficient Computing

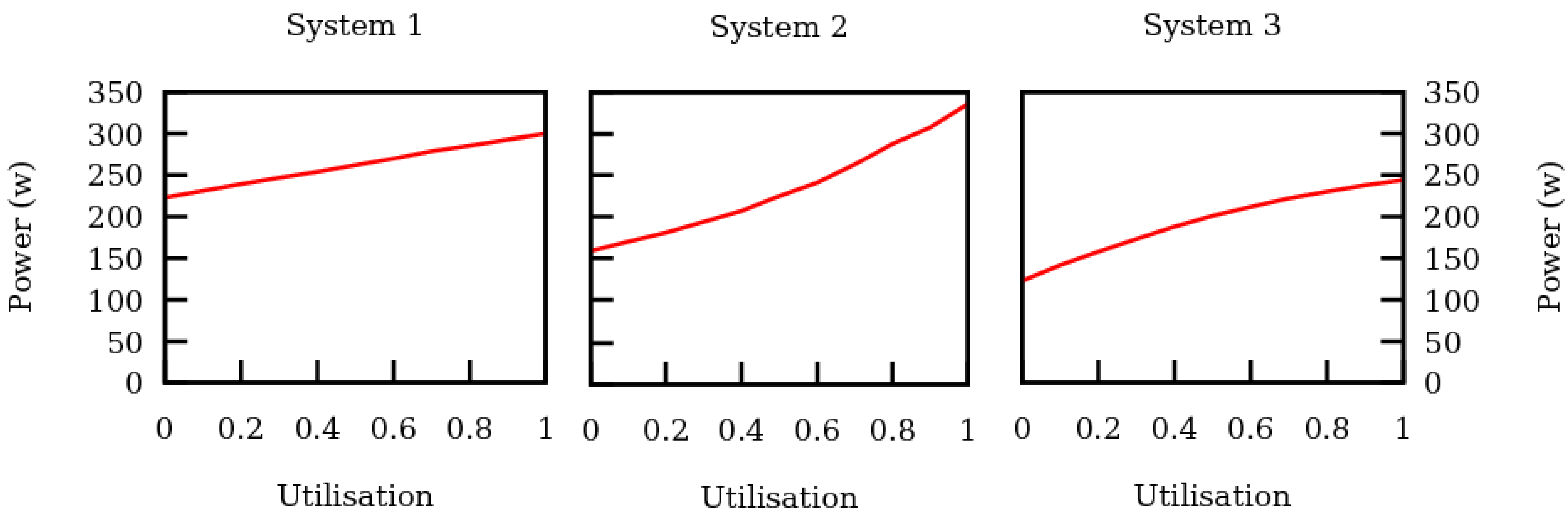
A. Rice

- Adaptive datacentres
  - Improve fault recovery by automatically back tracking through computational blocks
  - Use machine readable descriptions of service agreements
  - Include energy optimisation not just fault tolerance as part of adaptation strategy
  - Run “closer to the wire”

- Scale energy use with useful work done at all levels

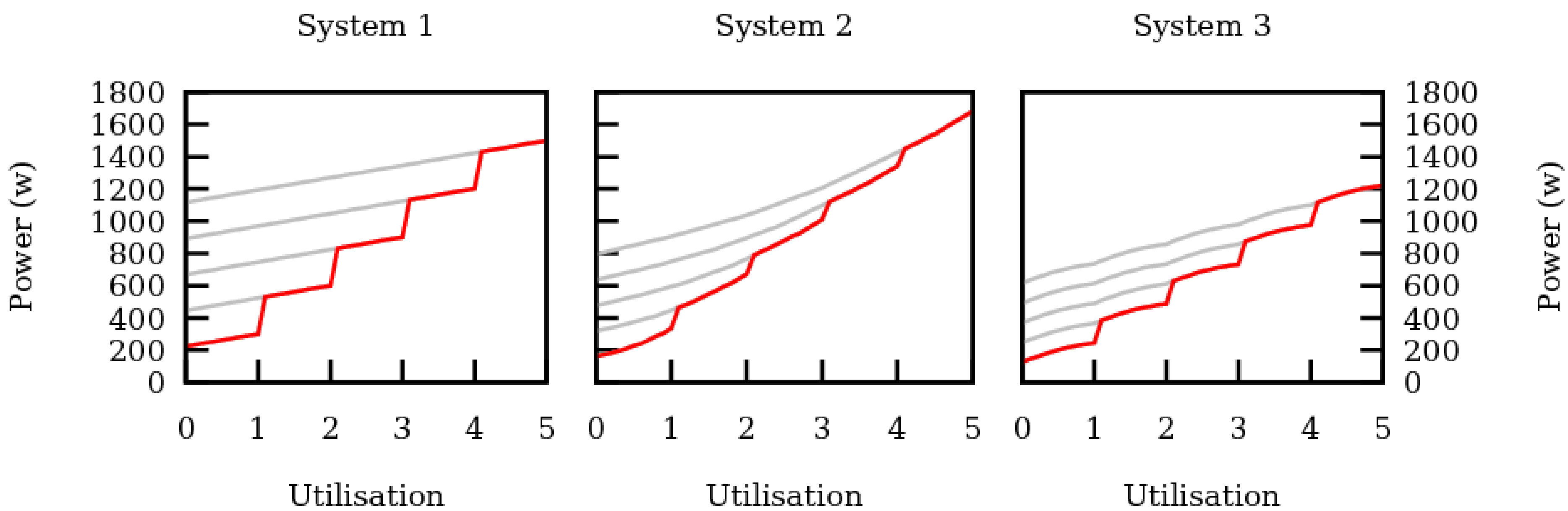
- Develop principles
  - Switch off if not in use
  - Don’t send data if not wanted
  - Know where traffic is coming from
  - Use technologies which scale energy linearly (or better)

Power and Load – Single Server



- Server consumes ~50% power when idle (power SPEC marks 2008)
- Energy efficiency is worse as server can be idle much of the time

Power and Load – Multiple Servers



- Machines not in use are switched off
- Tasks are moved between machines
- Some tasks can be delayed
- Shape of power scaling curve less important for larger clusters

Power and Load – Multiple Servers

- Load concentration gives 30-80% improvement but has specific application requirements

- XEN virtualisation comes close to energy proportional computing in the SAN context
  - Tasks move between two servers in 250msec down time and 60/10 sec (1Gb/10Gb Ethernet) elapsed time

- Non-interactive jobs are delay tolerant
  - Data indexing, batch simulation, climate models

- Power capping can remove peaks (a form of delay)

“Virtual Battery”

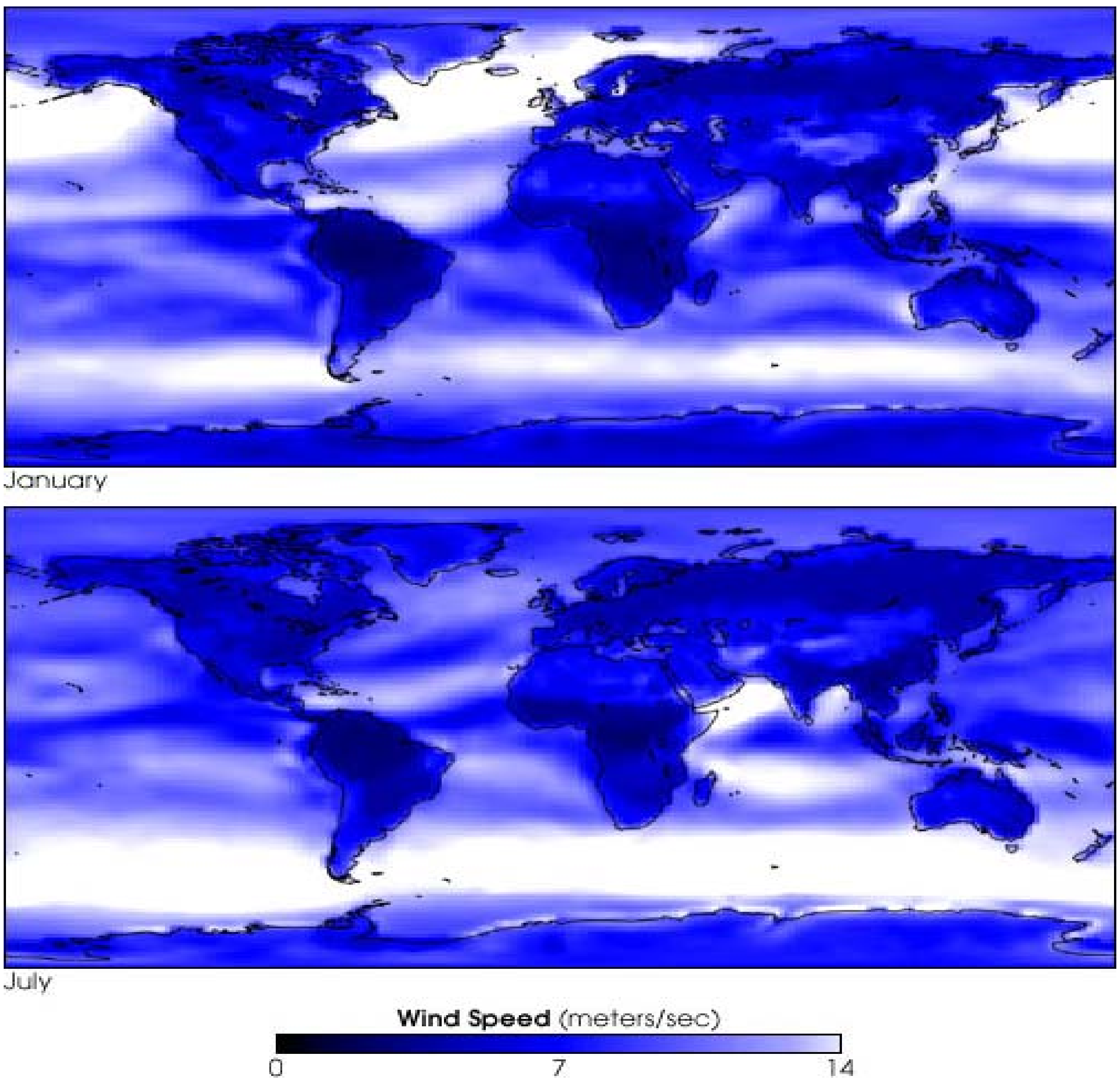
Sun

Siemens press picture

- Keep moving computing tasks to where energy is available
  - Cheaper to transmit data rather than energy
  - At what granularity should jobs be shipped?
  - Do we ship program, data, or both?
  - Would the energy be lost if not used?

Wind Power Meteorology

visibleearth.nasa.gov



- What is the equivalent latency map?
- Where do we put the server farms?

The Overall Goal

- Optimal Digital Infrastructure
  - Components switched off if not doing useful work
  - Energy proportional computing and communications at all levels
  - Where possible use energy that would otherwise be lost (virtual battery)

- Components
  - Servers / Server Farms
  - Networks
  - Workstations
  - Terminals

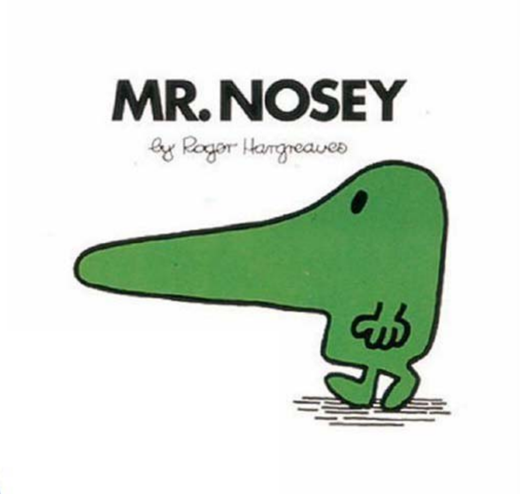
REAL VNC

2 - Sense and Optimise

- A sensor-based digital model of the planet

- "Googl<u>ing"</u> Earth!
- "Googling" Space-Time!

- How do we do it?
  - coverage
  - fidelity
  - scalability
  - performance
  - usefulness

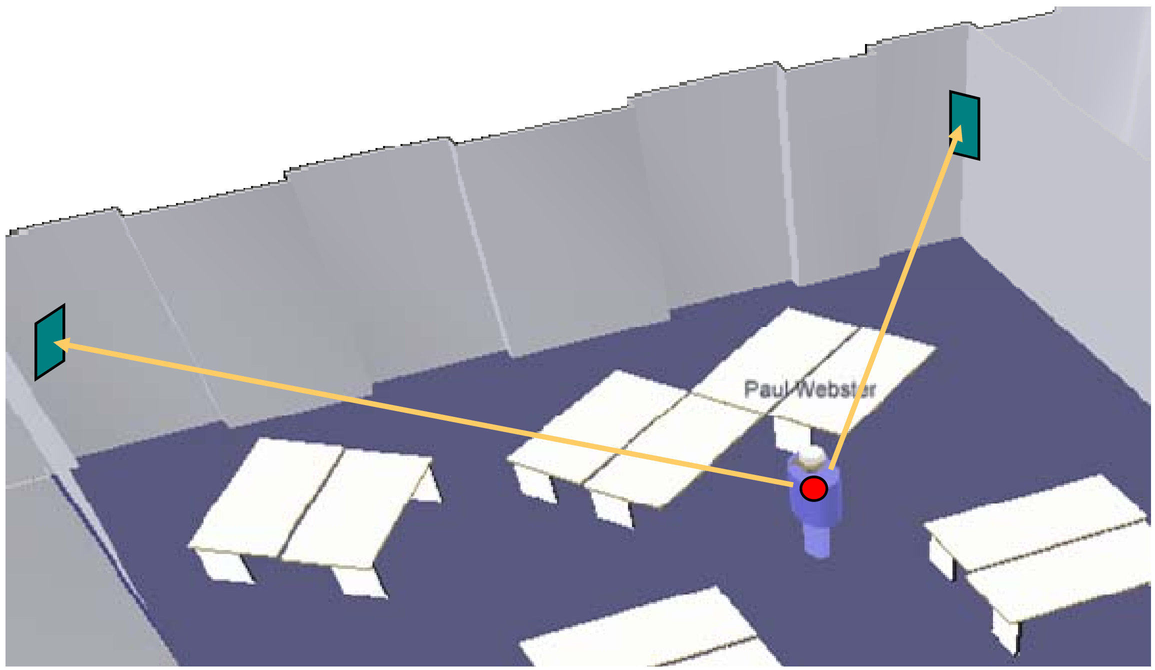


World Model

- Sensing
  - World is already full of sensors but more is to come
  - Publishing data
- Storing
  - Create a global repository
  - What are the data and computational models?
  - Consistency
- Indexing
  - Web pages
  - Sensor data
  - Shift from query-based to event-based (“where is” to “there is”)
- Interpreting
  - Observation and reaction
  - Classification
  - Optimisation
  - Prediction

Sensing Indoors: A Key Component

Ubisense



- Ultrawideband location system
- Measure pulse time-differences-of-arrival and angles-of-arrival

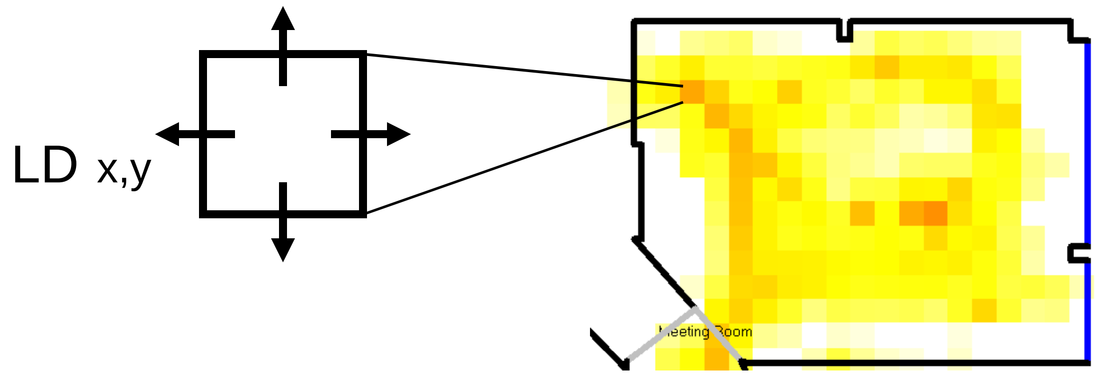
World Model

A real-world environment where people are wearing location tags

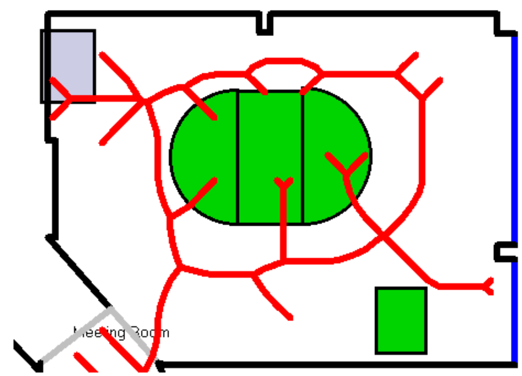
A 3D rendering of a **"World Model"** constructed and updated in real time using location and other systems

Interpreting World Model

R. Harle



- 2D linkage diagram of grid transitions
- Threshold updates using
  - maximum linkage time
  - minimum linkage length
- Various topological maps can be created



World Model - Consistency

R. Harle

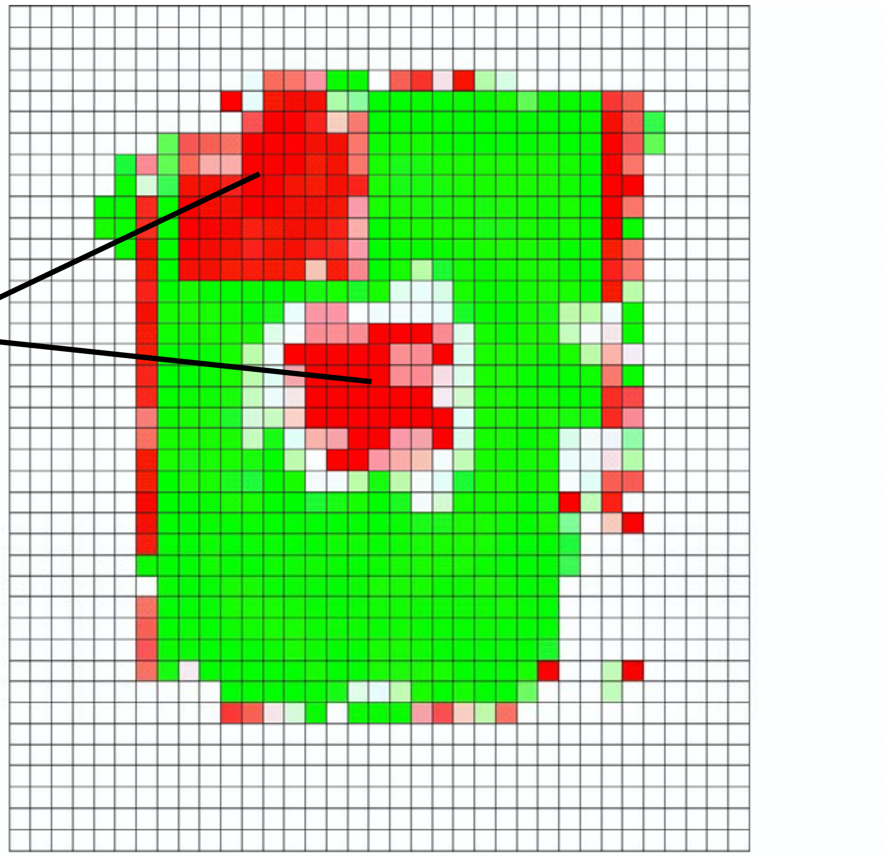


Table moved from middle of room to corner of room

Sensing Outdoors - Vehicles

J. Davies, D. Cottingham, A. Beresford, B. Jones

- Objective
  - Take a road vehicle
  - Embed power/processing
  - Add sensors (lots!)
  - Add storage (lots!)
  - Add networks (lots!)
  - Research platform
- Future platforms
  - Mobile "phone" as sensor?
  - Federated open Global Repository?

Concept

Reality

Mapping the Spectrum

D. Cottingham

- Measured 3G signal strength

- Red is poor reception
  Blue is excellent
  Orange circles are base stations

- Results sent to the Global Repository
  - What are the standards for exchanging data?
  - How is the data marked up?
  - How does this generalise for all data?

RFeye™ DC-6GHz Node

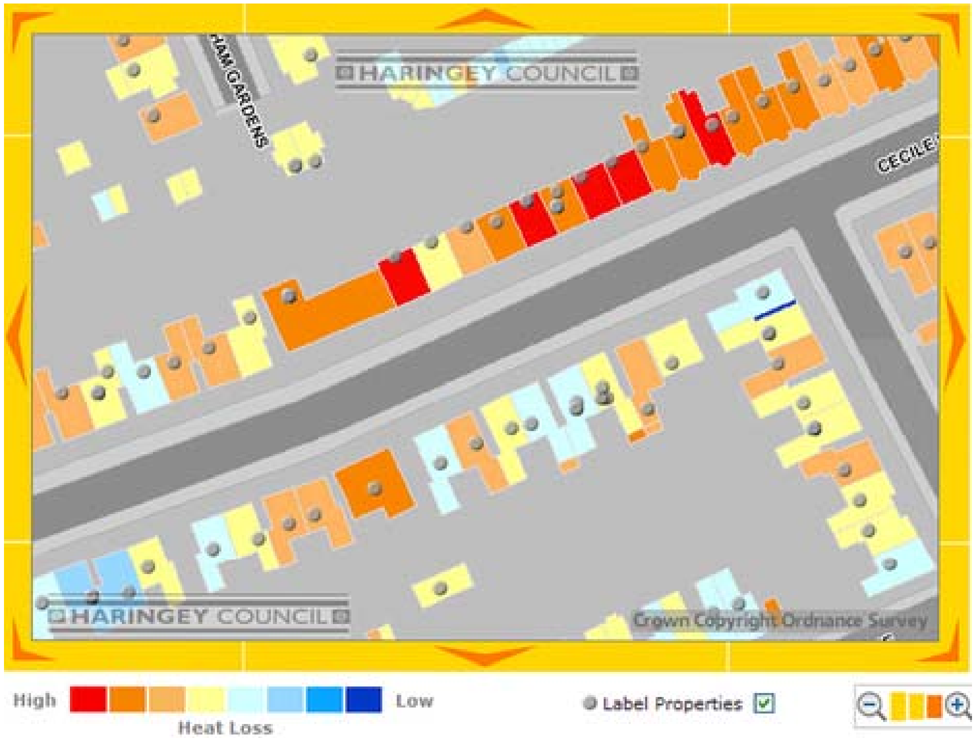
Sensing – Humans as Sensors

www.openstreetmap.org

- Openstreet map is an example of human sensing
  - Pubs, post boxes, potholes, etc
- Reward for content creation?
- Enticing and wealth creating for developing world?

Thermal Maps

www.seeit.co.uk/haringey/Map.cfm



- London Borough of Haringey used aerial survey to generate thermal images
- Should this be a real-time global service like GPS?
- What applications would be written if data was free?

Regulation/ Incentives/ Ethics/ Privacy

www.raeng.org.uk/policy/reports/pdf/dilemmas_of_privacy_and_surveillance_report.pdf

- Generating data, changing individual behaviour

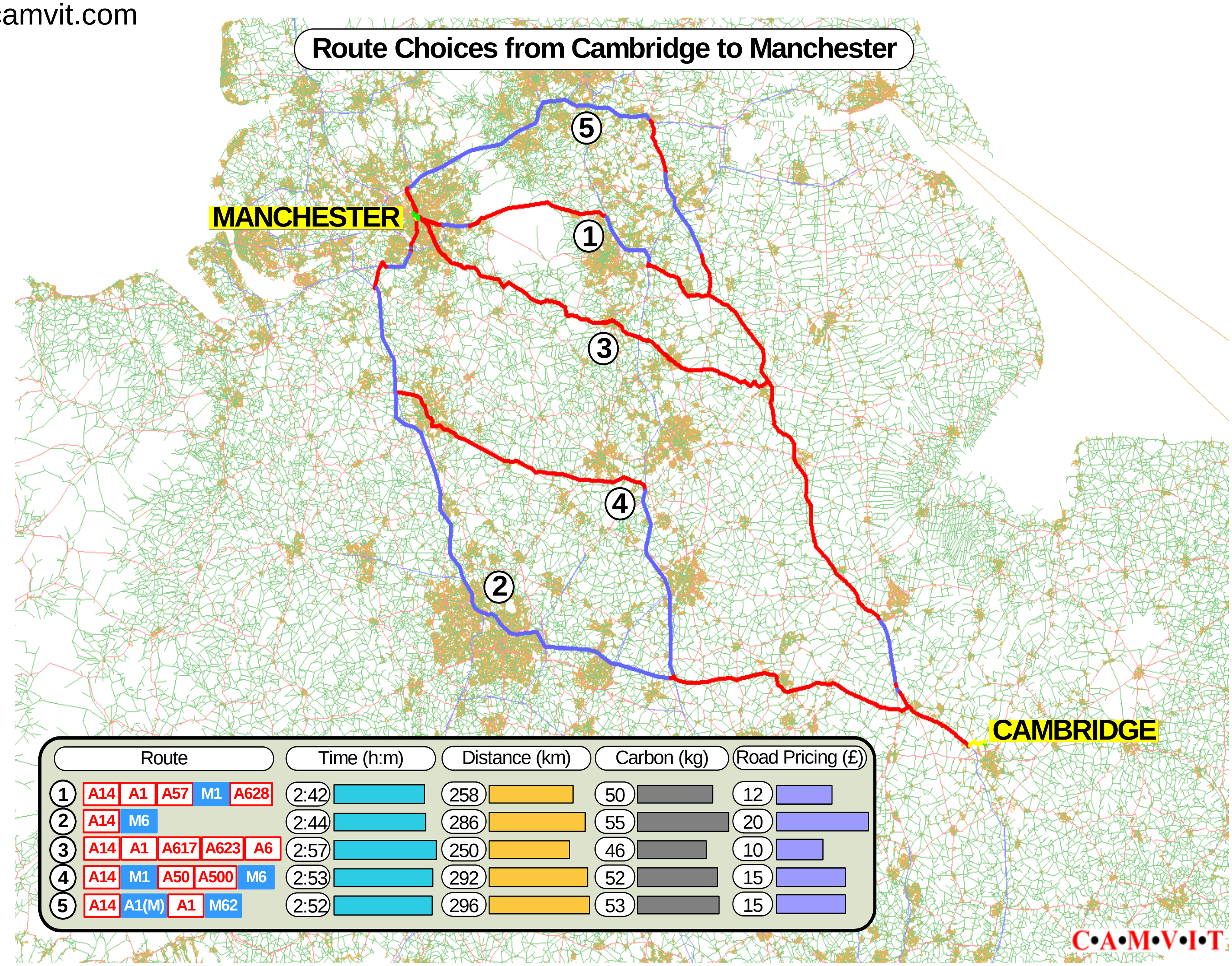
- Engineering
  – design out dangers
  – prepare for failure

- Dilemmas
  – of value, privacy, stakeholders, governance, etc
  – who to trust?

- Which surveillance scenario?
  – big brother, big mess, the citizens themselves
  – reciprocity: watching the watchers

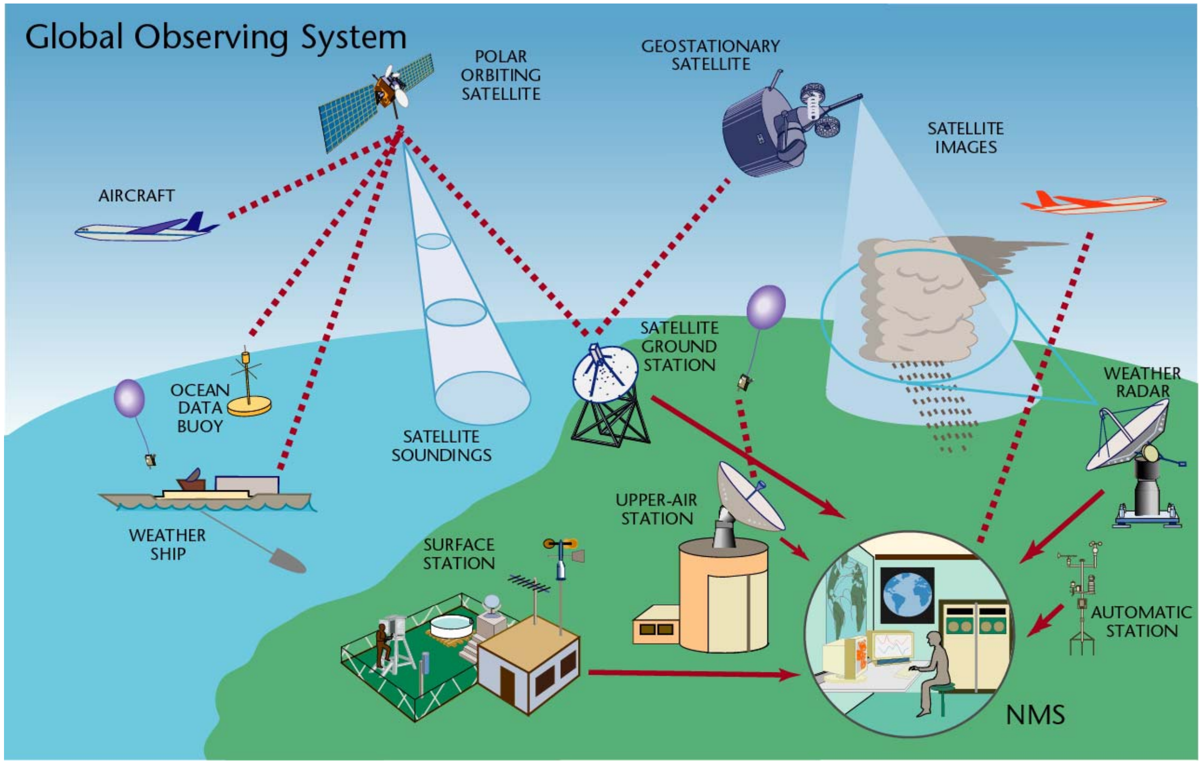
3 - Predict and React

www.camvit.com



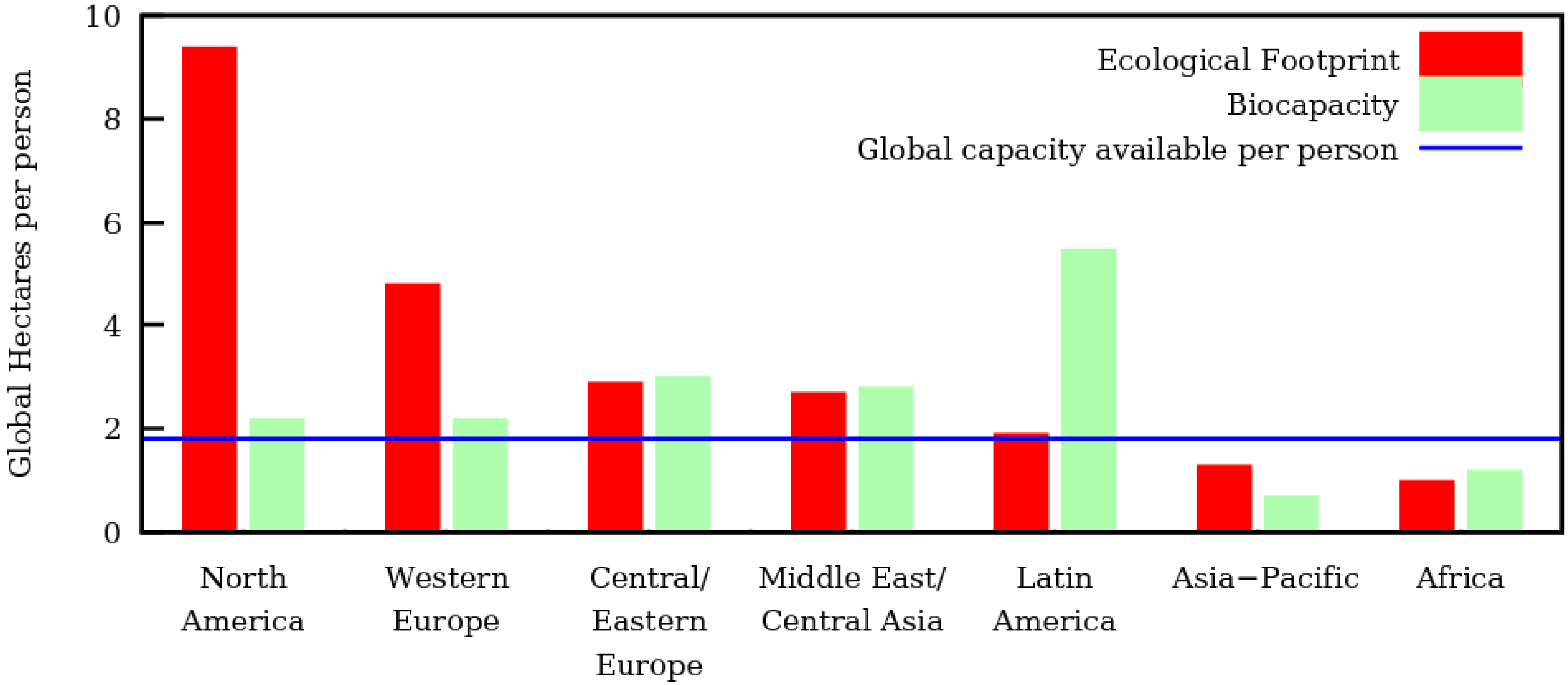
	Route	Time (h:m)	Distance (km)	Carbon (kg)	Road Pricing (£)
1	A14 A1 A57 M1 A628	2:42	258	50	12
2	A14 M6	2:44	286	55	20
3	A14 A1 A617 A623 A6	2:57	250	46	10
4	A14 M1 A50 A500 M6	2:53	292	52	15
5	A14 A1(M) A1 M62	2:52	296	53	15

Global “Scientific” Computing



- Requirements
  - Accurate and correct model
  - Verified code
  - Shared data, up to date data
  - Deadline driven computation
  - Scaleable computer power (and adaptive datacenters)

4 - Digital Alternatives



Physical to Digital

GuardianUnlimited network

- Move bits rather than people or products
  - iTunes, Tesco Online, etc
- Good news or bad news?

Personal Energy Meters

- Collect information about individual energy consumption (direct and indirect)
- Present itemised breakdown
  - travel, heating, water usage, transportation of food, etc
- Use World Model
  - upload own energy use to help digital optimisation
  - download energy profile of devices and goods
- Lots of lovely computing problems!
  - measurement, indexing, caching, event-delivery, prediction, use of social networking, security, privacy, correctness, etc

Shift to Cyberspace?

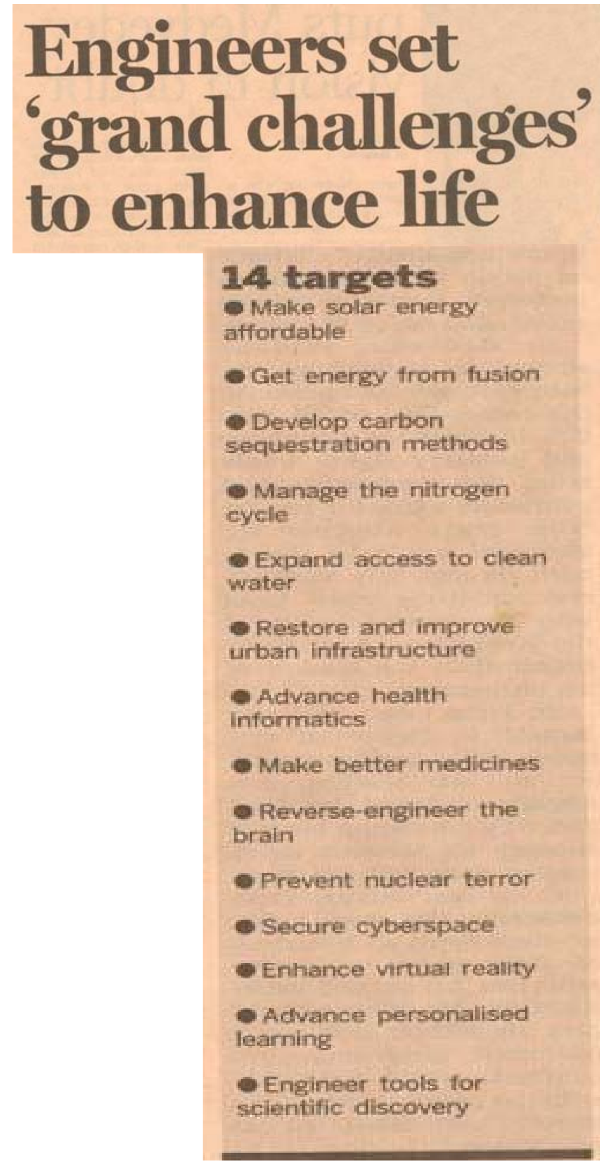
- Can we construct a digital world in which we can conduct our lives?
  - on a ultra-cheap open platform
  - using miniscule power
  - fed with sensor data from the real-world
  - accessible to every human

- Scaling up virtual worlds is a challenge
- Key to wealth creation in developing world?

Computing for the Future of the Planet

www.engineeringchallenges.org

- Complementary to NAE and UKCRC "Grand Challenges"
- Lists, dimensions, and quantifies computing problems
- Targets the world outside computing
- Invigorates the subject
- A vision and an architecture
- Contemplates the unbounded upside of computing!



Engineers set 'grand challenges' to enhance life

14 targets

- Make solar energy affordable
- Get energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Expand access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Make better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalised learning
- Engineer tools for scientific discovery