THE LONDON UNDERGROUND TUBE NETWORK

- Area served: 3240km²
- 45km N-S   72km E-W
- line length: 392km
- 80% (110km) cast iron
- Deepest tunnel 67.4m bgl
- Average tunnel depth 24.5m bgl
- 2.5million passengers/ day

Deep Tube Tunnels: 300km
Cut & Cover Tunnels: 100km
Bridges (number): 1000
Embankments & Cuttings: 220km
Existing Tunnels

• New construction interactions
  – pile driving nearby
  – neighbouring tunnel construction

• Long-term survival: what is the unexpired life?
  – chemical environment
  – earth and water pressures create ground loading
  – affected by construction, consolidation, creep, ageing
  – loads on lining must change as groundwater changes

• Design of new works
  – what ground actions to assume in what design life?
  – what influence from new construction activities?

• Network security
Monitoring

Limits of movement set for three main Parameters;
- Stress in tunnel lining
- Lining deformation/clearances
- Track geometry

Monitoring system must be tailor made to suit application and critical parameters e.g.:
- Rate of movement
- Extent of influence
- Need for accuracy
(1) MicroDetection using Computer Vision
Mosaicing and Super-Resolution
(1) MicroDetection using Computer Vision

Camera-Posing and Image Interpretation

Issues:

(1) Accuracy, (2) Interpretation methods, and (3) User-interface
(2) MicroMonitoring using MEMS

FE modelling
(2) MicroMonitoring using MEMS

Issues:

(1) Packaging, (2) Attachment, and (3) Power Harvesting
(3) MicroCommunication using WSN

![Diagram of wireless sensor network]

- Sensor Nodes
- Gateway
- Intel Imote
- Intel Stargate
- 802.11
- BT
(3) MicroCommunication using WSN

- Low-cost and fast deployment, especially in difficult-to-access areas
- Scalable: Enable dynamic system growth and extension
- Adaptive network configuration and operation in case of failure and unexpected events, resulting into improved reliability
- Take advantage of low-cost and low-power sensors

Two Small-scale Deployments as Proof-of-Concept
(a) Micro-Detection
Computer Vision
Cambridge (Leader)

(b) Micro-Monitoring
MEM strains sensors
CRN (Leader)

(c) Micro-Communication
Wireless communication
+ Power harvesting
Cambridge (Leader)

(d) Data Analysis and Expert System
Catalunya (Leader), Czech

(e) System Safety, Adaptation and Field Application
Czech (Leader), Catalunya, Cambridge

Business Plan and Integration
Cambridge (Leader), CNR, Catalunya and Czech

Associated Partners
Tube Line, Trans4M, Prague Metro, Barcelona Metro, Madrid Metro, GLOBAL, SOLDATA, Katholieke Universiteit Leuven
Data Analysis/Expert System

- Software for management of field data
- Code for estimation of parameters and evaluation of structural integrity & damage
- Development of a decision support system

System Safety, Adaptation, Field Application

- Evaluate the existing state of underground structures by different methods of site investigation
- Develop health, safety and security document for installing new sensors in underground infrastructure.
- Develop the best practice guideline on infrastructure monitoring and assessment.
Field Trials

- Prague Metro
  - starting this October

- London Underground – Tubelines and Metronet-Alliance
  - starting next January

- Barcelona Metro and Madrid Metro
  - Year 3
Progress so far…

- July 2006 - Kick-off meeting in Barcelona
- July 2006 – Meeting with MetronetAlliance on MicroDetection
- August 2006 – Meeting with Tubelines on MicroCommunication
- August 2006 – Czech-Cambridge, preparation for field trials
- September/October 2006 – CNR-Cambridge meeting on MEMS
- End of October 2006 – General Meeting in Prague