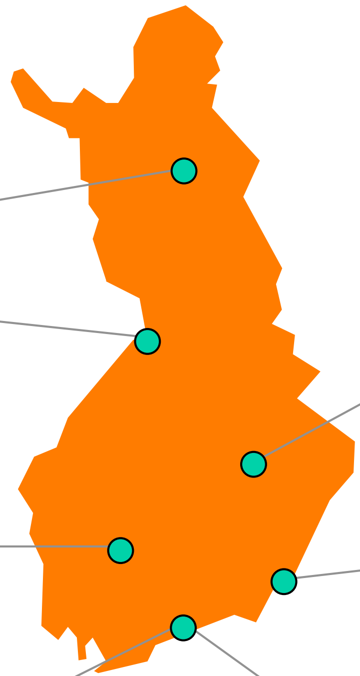
Finnish Centre of Excellence in Inverse Problems Research

Overview of activities 2008-2009

Samuli Siltanen
University of Helsinki

Trilateral workshop, March 4, 2010

Finnish Centre of Excellence in Inverse Problems Research



OULUN YLIOPISTO UNIVERSITY of OULU

UNIVERSITY OF KUOPIO

TAMPERE UNIVERSITY OF TECHNOLOGY

LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

TEKNILLINEN KORKEAKOULU
TEKNISKA HÖGSKOLAN
HELSINKI UNIVERSITY OF TECHNOLOGY

HELSINGIN YLIOPISTO

http://math.tkk.fi/inverse-coe/

CoE received funding from these sources:

Standard funding was received from universities,
Academy of Finland, and Finnish Technology Agency (TEKES).

Additional and external funding:
Forest Cluster Ltd. project funding,
Three academy research fellow positions,
Academy postdoctoral projects,
Academy programme on computational science,
TEKES programme "modelling and simulation",
Individual TEKES projects with industrial support,
Graduate schools (inverse problems, **computational science**),
Grants from various foundations.

Scientific output of the CoE in 2008-2009:

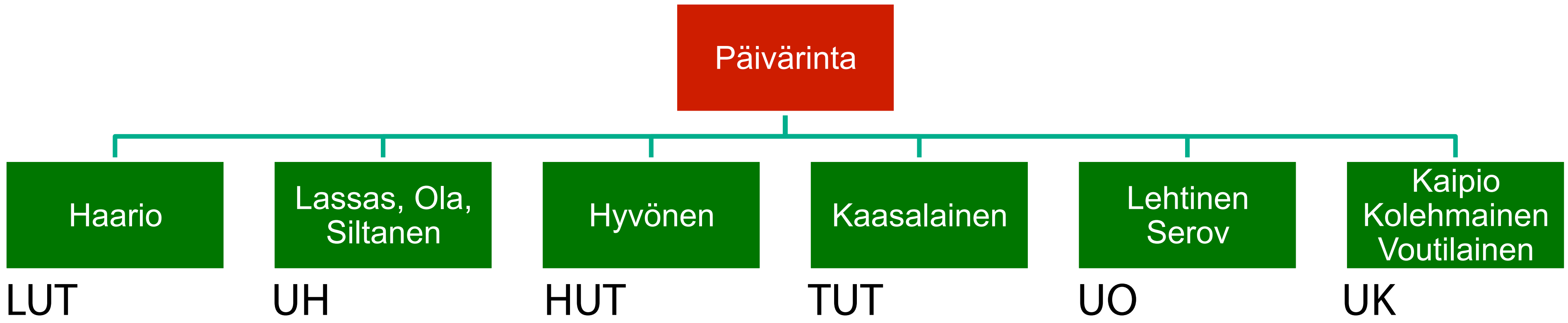
125 peer-reviewed publications, with **44** more submitted,

5 PhD theses,

4 international conferences or minisymposia, and

2 patents.

Management of the CoE network is organized this way:

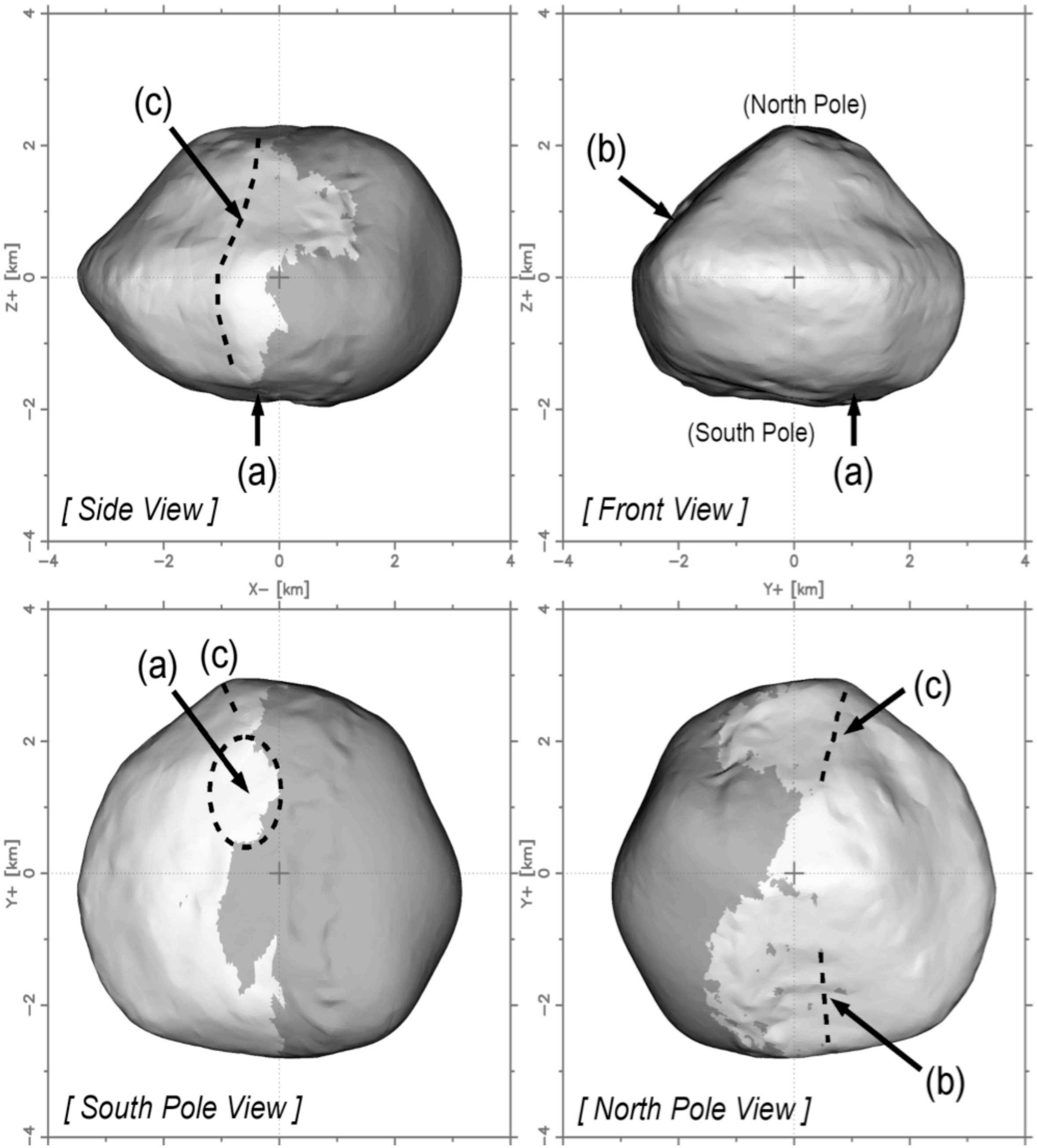


Responsibility areas of board members:

Päivärinta:	general planning and management, SAB relations
Kaipio:	budget and legal issues
Lehtinen:	rapid response and IPR issues
Haario:	Tekes projects and their documentation
Kaasalainen:	internal communications and documentation
Lassas:	meetings, visitors
Ola:	budget
Siltanen:	public relations and external communications

Lassi Päivärinta was appointed as a member of
the Research Council for Natural Sciences and Engineering
of the Academy of Finland for the period 2010-2012.

Science article by Kaasalainen et al.



Transmission Eigenvalues

Lassi Päivärinta and John Sylvester, SIAM Journal on Mathematical Analysis 40 (2008).

A body has a transmission eigenvalue if there is an incoming wave with zero scattering.

Similarly to the usual eigenvalues, which are clearly visible is near-field measurements, transmission eigenvalues cause high peaks in scattering observations, such as radar measurements.

Transmission eigenvalues lead to non-elliptic equations and their existence is now proven under general conditions.

Invisibility results by Lassas *et al.* were widely featured. Here Nature:

OPTICS

Watch your back

Kosmas L. Tsakmakidis and Ortwin Hess

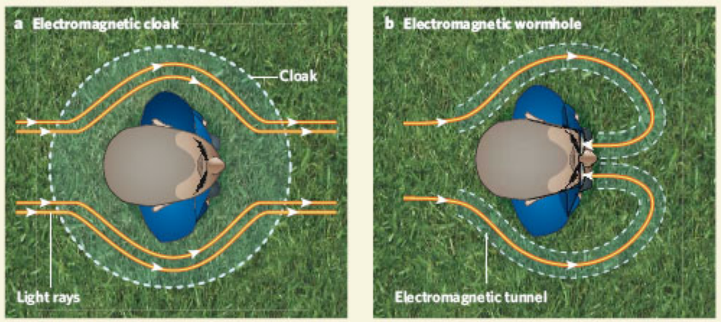
A proposal for transporting photons invisibly between two unconnected points in space seems worthy of a *Star Trek* plot. But it is in principle wholly realizable, and could open up new vistas — literally.

Imagine walking down a footpath, staring unconcernedly at the clear track in front of you. Suddenly, you stumble over an object. You look down, but there is nothing to be seen on the ground. You step back and try a different angle of view, again without success. But you know something must be there, because you can feel it.

This situation is brought a step closer to reality with a device dreamt up by Greenleaf *et al.*[1] and described in *Physical Review Letters*. The authors propose a way of creating an 'invisible tunnel' through which photons, the elementary particles of light, can propagate between two seemingly unconnected points. To an observer standing where they emerge from their tunnel, the photons seem to come from nowhere. To an external viewer, they seem to be teleported from one place to the other. And anything within the tunnel cannot be seen by anyone. In analogy to the infamous 'wormholes' — a prediction in general relativity of tunnels through space-time that connect distant areas of the Universe — the authors call their brainchild an electromagnetic wormhole.

The wormhole works (in theory) by neatly combining concepts from differential geometry, general relativity, electromagnetism and the theory of 'metamaterials'[2]. Metamaterials are composite, nanostructured materials with specifically tuned electromagnetic properties. The authors construct the tunnel wall of their wormhole using a metamaterial layer that is designed to bend light waves around it without reflection, much as water waves bend around a tree branch or similar obstruction lying just below the surface of the water. This layer thus renders whatever is inside it invisible. The idea draws on techniques proposed[3,4] for the creation of an 'invisibility cloak' (Fig. 1a) — a device that has already been constructed and proved viable, at both microwave[5] and optical[6] wavelengths.

The advance in Greenleaf and colleagues' scheme[1] is that a cloaked object can 'see' into the outside world at the end of the tunnel, because photons are also free to propagate through it. The tunnel 'deceives' photons into (other than staying on the surface of the cup) for getting from the one place to the other.



The key to the realization of this scheme is that this new photon-space does not naturally exist in real space. Rather, using suitable coordinate transformations, the authors tweak Maxwell's equations — the set of equations that describe the workings of electromagnetic waves — to simulate it. The equations retain their form on passing from the real to an artificial photon-space; the only thing that is required to complete the deception of the photons is to modify the values of the electric permittivity and magnetic permeability (numbers that codify the degree to which a material allows electric and magnetic fields to pass).

Such a concealed communication channel could be deployed for military purposes for the secret transmission of information or stealth technologies. But it might also find its way into civilian applications: rerouting mobile-phone signals around obstacles, for example, or shielding sensitive medical devices from interference by magnetic resonance imaging scanners. But the possibilities don't end there. Two of Greenleaf and colleagues' invisible electromagnetic tunnels, built into the frame of a pair of special half-moon spectacles, would effectively 'glue' the photon-space behind the head to the photon-space in front of the eyes, allowing one literally to watch one's back (Fig. 1b).

Currently, metamaterial technology allows the construction of invisibility cloaks that work well for only a limited range of frequencies. The electromagnetic wormhole in its present form can also be only short, otherwise the image of an object being transmitted through it becomes noticeably distorted. The true potential of such schemes will become clear in future experimental tests. What is plain now is that innovations are coming thick and fast in this burgeoning world of 'transformation optics'. ■

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e-mail: o.hess@surrey.ac.uk

1. Greenleaf, A., Kurylev, Y., Lassas, M. & Uhlmann, G. *Phys. Rev. Lett.* **99**, 183901 (2007).

The Kuopio group has produced two spin-off companies

Kuava: Computational engineering

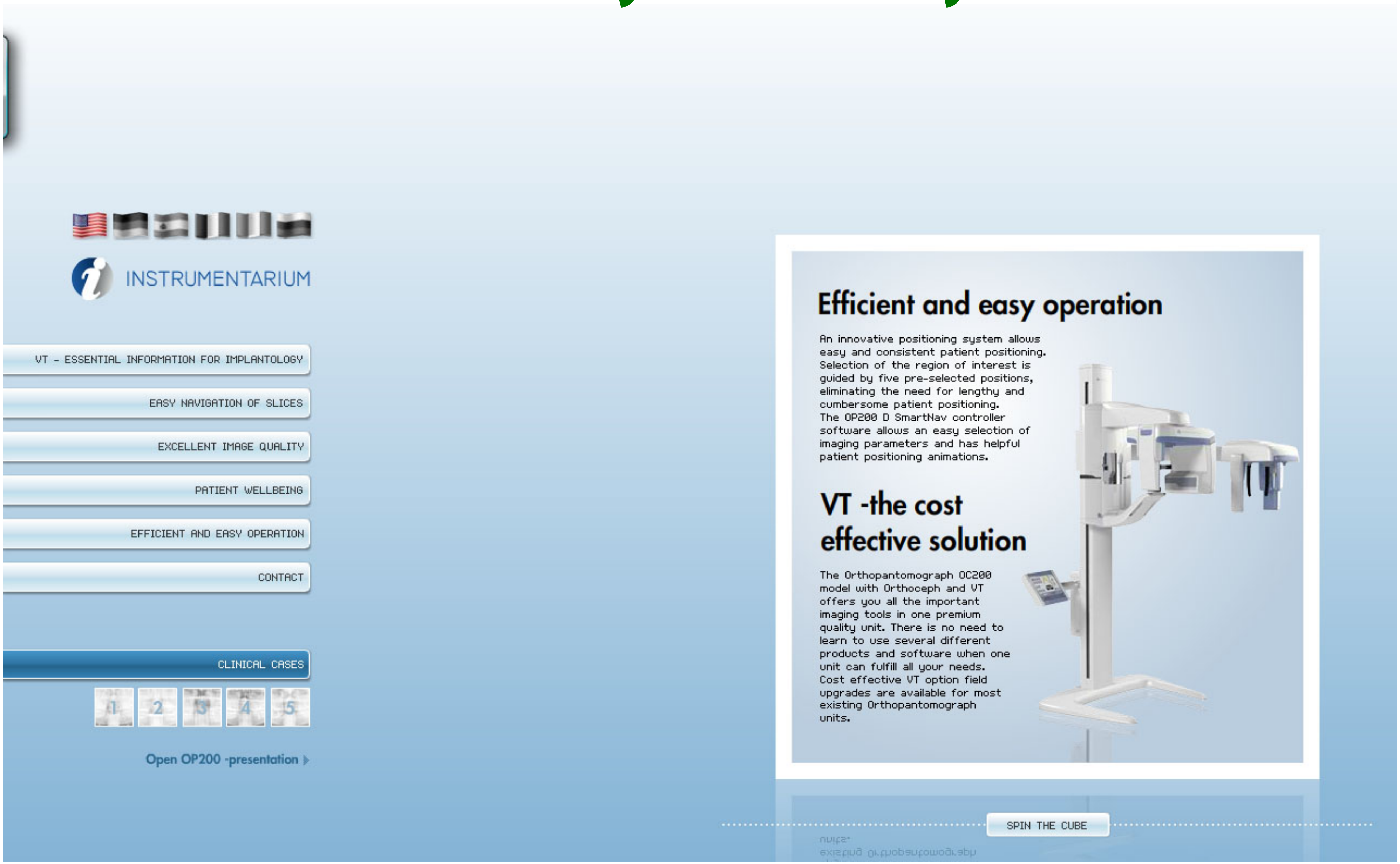
Numcore: Process control solutions

Winner of Venture Cup main award 2008

Lasse Heikkinen and Jari Kourunen
University of Kuopio

Medical imaging project 2001-2007 produced a new dental X-ray product

Traditional panoramic X-ray device is used in a radically novel way



Spin-off company from Lappeenranta: Arbonaut for forest inventory service

Bayesian estimation turns laser scanning data into estimates of forest parameters, such as timber volume, species distribution, tree height and stem count