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EUROPEAN ORGANIZATION FOR EXPERIMENTAL PHOTOGRAMMETRIC RESEARCH

WORKSHOP ON NATIONAL MAPPING AGENCIES AND THE INTERNET

Report by R. Gower

PRECISION TERRAIN MODELS FOR CIVIL ENGINEERING

Report by A. Flotron and O. Koelbl



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Workshop on
National Mapping Agencies and the Internet
“Developing Strategies for Geospatial Data in the New E-Age”
held at Ordnance Survey GB, Southampton,
8–10 March 2000

(with 2 figures, 8 tables and 3 appendices)

Report by Rob Gower
Ordnance Survey GB

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Summary

Aims and objectives of the workshop

The aim of the workshop was to stimulate the thinking within European National Mapping Agencies about the Internet and the electronic collection & delivery of geospatial data. It was an opportunity to assess the impact of the Internet on the way we carry out our business. The stated objectives were to:

- *provide an overview of trends and developments*
- *provide an opportunity for NMAs (National Mapping Agencies) with established services, and those planning new services, to exchange experiences*
- *promote of best practice / discuss future developments and issues*
- *get the system vendor's view of NMAs*

The workshop took the form of presentations to the group in plenary followed by a series of breakout sessions. Following the presentation the group was split into two teams for informal workshops led by a facilitator. Each breakout had a theme that focused on particular issues explored by the speakers with the emphasis being on the exchange of knowledge, ideas and experiences. Terminals with full Internet access were available for demonstrations in the breakout sessions.



Findings

The main conclusions from the workshop are that the world of e-commerce is changing fast, it is incorporating not just the desktop but mobile communications and associated services. New service providers require content and NMA's are content providers. Service providers require timeliness and have a disregard for quality, NMA's therefore need to ensure their services are responsive and are fit for purpose.

NMAs who do not fully embrace this new world and are slow to adapt or inflexible are going to find the future tough. There are external environment issues over which NMA's have little immediate control and therefore **need to anticipate changes and adapt**. In doing this NMA's **need to review their role** and clearly determine what they contribute uniquely and what they do best in this dynamic environment in which we now operate. This is likely to require that NMA's deliver better currency, better data services and will **need to work with customers and partners** to achieve much of this change. There will always be constraints of some kind, and **these constraints should be treated as variables** that can be adjusted to maximise the operating environment in ensuring that the NMA role is preserved in supplying a key underpinning national role for the future.



Key messages were:

- Transaction and subscription-based pricing and licensing models will have to be developed by NMAs.
- The 'business to business' rather than 'business to consumer' market is the primary area for growth.
- New partnerships will be necessary if NMAs are to succeed in reaching the new internet markets. It will be the Application Service Providers who will deliver total solutions to the end users.
- The NMAs are evaluating their role as information providers, with that information being highly maintained and to the specification required for national/regional infrastructures.
- Primary focus of NMAs should be data capture and maintenance.
- The benefits of Internet working not only make geospatial data more accessible to more users but also have the benefits of lower data supply costs, easier updating, self-auditing and reduced time-cycles.

Session 1 - The Impact of the Global Economy

Presentations:*)

Menno-Jan Kraak (ITC, Enschede): National Mapping Organizations and the Web

Peter Woodsford (Laser-Scan Ltd., Cambridge): The OpenGIS Web Mapping Testbed

*) see appendix C

Key issues:

- Map as an index to other information
- Data integration
 - More important in future
- Timely delivery
 - Need to be ready when customers want data
- Data services (rather than simple data provider) role for NMA's
 - Include basic services such as
 - Relevant level of currency
 - In-line processing (e.g. image/projection etc.)
 - Interactive services
- Impact of new players - e.g. Microsoft

Breakout session

The session addressed the following question:

What are the impacts of the global economy/use of data on the European geo-information infrastructure?

Team 1 - feedback

OPPORTUNITIES	THREATS
• Reduce the cost of distribution	• Expectations of low/lower costs
• Create new products for the web	• Expectation that data is today's data
• Exploit NMA's ability to maintain and provide up to date data	• EU moving towards the US model (cost of distribution approach)
• Working with partners to build the services	• Loss of the 'crown jewels'/assets
	• NMA's cannot get their collective European act together - loss of markets
	• NMA's do not have clear strategies for dealing with commercial data/service providers.

Team 2 – feedback

ISSUES & CHALLENGES	
• Defining the role of NMA's? ○ Data provision and/or ○ Service provision/facilitation	
• Skills required – Data collection & maintenance, Internet sales & marketing ?	
• Pricing ○ Who pays ○ Downward pressure on prices ○ New pricing policies needed	
• Managing differences in legislation ○ National ○ Regional - European	
• Managing customer expectations across different markets and cultures	
• Balancing competition and partnership	
• Understanding the new global market requirements	
• Understanding and working with different institutional and organisational cultures	

Session 2 - Intellectual Property (IP)

Presentations:*)

Veijo Pätynen (National Land Survey Finland): Internet based GI-Services at the National Land Survey of Finland

Pelle Pettersson (National Land Survey Sweden): Internet at Lantmäteriet in Sweden

*) see appendix C

Key issues:

- Integrated cadastre and mapping
- Free mapping - to some - e.g. national consumers
- Payment mapping - business users
- Develop own systems or buy-in packages or contract?
- Importance & role of Metadata Referencing, e.g. by place-name
- Charging (can still use existing methods)
- Some services fail (accept this and move on)
- New technologies (WAP, XML)
- New service opportunities (e.g. personal navigation)
- What is the future role of NMAs?

Breakout session

The session addressed the following question:

How can we promote access and use of geo-information whilst maintaining intellectual property rights?

Team 1 - feedback

PROMOTE ACCESS THROUGH	PROTECTING IP BY
• Increase customers through: New applications New uses/products Increase awareness New forms of presentation	• Link terms to usage
• Increase use: New terms New prices Knowledge of data (meta-data)	• Define “use” carefully
	• Watermarking
	• Making it cheaper to be honest
	• Chasing criminals (if they behave like criminals)
	• Employing 3rd parties to manage distributed sales

Other questions:

- Will intellectual property rights continue to survive?
- Do we need to consider "protecting the investment in the database" rather than intellectual property rights.

Team 2 - feedback

PROMOTE ACCESS THROUGH:	PROTECTING IP BY:
Free or cheap data	- Legal measures - Technological means - Restrictions on usage by: data type eg. raster vs vector, user i.e. different users have different access rights, geographical area, size of images
Usage of GI to aid decision making	Different problems if data is free
3rd party usage of NMA data	Restrictions on use of free data
Use of value added resellers	Watermarking (monitoring when used)
Advertising banners - tacky?	Negotiation and contract
Identifying user requirements	Enforcement: of licensing terms and conditions, litigation as a final option
Developing "hot links" & gateways	Clear licensing terms and conditions to avoid ignorance/misunderstanding
Integrated development	Free raster information availability
Maximum visibility - all search engines	Maintaining "firewalls" to prevent hacking
Simplifying licensing	Developing "stand-alone" databases
Domain name registration	Being aware of possible employee problems
Interactive/synergy with video games	Monitoring of who is connecting to our web-sites & analysis of that info
Exploiting entertainment value	
Case study applications of our own data	
Providing education - to children	
Governmental promotion	
Lucrative links - financial incentive & reward	
Advertising strategy	
Good website design	
Consultancy	
Website kept up to date & different	

Session 3 - E-Commerce

Presentations:*)

Duncan Shiell (Ordnance Survey GB): Ordnance Survey and the Internet

François Salgé (IGN, France): IGN France and the Internet

*) see appendix C

Key issues:

- Government directives
 - timescales dictated by government - no choice - must address
- Solutions - joint ventures
 - different roles of players (e.g. France Telecom payment collection)
- Differences in national statutes (personal information)
- Information Age Society

Breakout session

The session addressed the following question:

How can NMA's meet the challenge of e-commerce?

Team 1 – feedback

ISSUE	POSSIBLE APPROACHES
Maintaining profitability	Define split between free and chargeable products
Ensuring appropriate security measures are in place	Develop new types of product (especially for the public)
Maximising new distribution channels	Develop collaborations
Managing the effect on retailers and traditional business channels	Use international standards & common approaches
How much do we ourselves and how much do we outsource?	Use traditional retail channels supplemented by enhanced delivery services
What products are most suitable?	Identify and adapt core role of NMA
	Develop new pricing models
	Do not treat Internet publication as a threat to traditional sales publication
	Examine the potential for advertising revenue
	Develop product browsing with hot links to “buy”
	Invite feedback & comment and provide infrastructure to handle it

Team 2 - feedback

ISSUES	MEETING THE CHALLENGE
Time-distance rapidly changing our business environment	E-commerce will bring more products into the free access group
Is NMA culture naturally to be leading?	Users will need to better understand the fitness for purpose, therefore there is need for an education process
What is the role of partners in e-commerce ?	We must continue to satisfy our major & key customer but using new e-commerce methods
Are we retailers or wholesalers?	Growth in mobile communications will alter the nature of data usage through greater interactions with the customer
We must understand the enabling technology	E-commerce will continue to develop on the back of emerging communication technology
Understanding the customers needs in new environments	Must involve partners in investment for managing changing technology
Maintaining the balance between national interests & commercial profit	NMA's must ensure their datasets are fit for e-commerce channels
Maximising access & therefore utilisation through web technology	Formats must be seamless, flexible and increasingly fitting to global standards dictated by communications technology.
NMA's must at very least provide the (e-) framework	New product content must fit emerging technology demands
Economic issues crucial for the business of NMA's	New transaction backed pricing & licensing models will be required
This is "just another channel" but it will become dominant	Our business models must be fit

Session 4 - The Industry View

Presentations:*

Vanessa Lawrence (Autodesk Ltd): National Mapping Agencies and the Internet – A View from a Software Company

Peter Beaumont (ESRI (UK) Ltd): National Mapping Agencies and the Internet – A Vendor's Perspective

*) see appendix C

Key issues:

- **Winners**
 - BIG vs Small
 - FAST vs Slow
- **NMA's as content providers**
 - Need to improve content services
 - Fit for purpose
 - Better currency
 - Easier to use data
 - Establish big pipes
 - One stop shop for geodata
 - Content for those setting up portals for information
 - Metadata - different languages (users are international)
- **Urgent Urgent Urgent**
 - Internet time is measured in days/weeks not months/years
 - If you fail, re-invent yourself quickly
 - New demands by large companies:
 - 15 weeks deployment
 - plug & play with legacy systems
 - std operating environment
 - business based
 - component based architecture

Mobile Communications

- Major user of e-commerce
- Will revolutionize way we do things
- Eg workflow on-site & downloading of data from head office "on the job"
- Data warehouse is already old technology -
- Web Browser technology enables flexibility
- "access enterprise data in the field"
- "synchronise with the enterprise db"
- any data, any where
- **Customers**
 - B2B now needs treating as consumer approach
 - Data leasing will become the norm
 - Competitive (fast movers will have the edge)

Breakout session

The session addressed the following question:

How can NMA's work with industry partners to develop the tools to make data easier to access and use?

Team 1 - feedback

WHAT MUST WE DO ?	
GI industry must work together	Manage and adapt to the speed of change
NMA's must be 'fair and open'	Government departments must act together
Ensure the value of data does not change (i.e. cost of updating) – investment and institutions must be preserved	Manage risk – fail fast not an option
Maintain the NMA core data i.e. the National framework	Maintain and manage traditional partnerships
Provides means of data integration	NMA's are not instigating - therefore be prepared to take new ideas of others
NMA data must evolve	Work with Internet Service Providers and Application Service Providers
Ensure data is always fit for purpose	Ensure data is interoperable
Develop partnerships	Encourage vendors to provide tools
Be prepared to transform databases (requires time)	Decide how much we will let partners change and develop our data

Team 2 - feedback

WHAT MUST WE DO ?
• Clearly define our core business (provision of richer geo-data management ?)
• Change our image to being fast, cheap, flexible to do business with
• Find new friends
• Develop partnerships with Application Service Providers to process the NMA data and prepare it for new applications e.g. WAP etc

Four point summary of all breakout session topics and findings

1. EXTERNAL ENVIRONMENT

NMA's have little or no immediate influence over these issues but need to anticipate and adapt.

- Global Competition
 - US influence/business values
 - Mobile communications (where Europe leading)
- **Rate/Speed of Change (THIS IS VERY IMPORTANT) "internet speed"**
- International/National Government directives
 - Government policy
- Technology advancements

2. [CHANGING] ROLE OF NMAs

These issues are mainly in the Control of NMA's

- Role - NMAs should provide leadership
 - Map providers - NMAs need to be providers of better services and delivery mechanisms providing e.g. better currency and consistency
- NMAs need to identify themselves as **content providers**
- Providing the geo-information framework
 - 'Hooks' for other people to hang their data on
 - Joining up other peoples data
- Developing partnerships
 - Including other data providers

3. CUSTOMERS/LICENSED PARTNERS

NMAs can work solutions out together with customers/partners to solve these

- Fit for purpose data
 - Form of that data
 - Up to date (is cost related to timeliness?)
 - Better delivery/access to data
- Joining up geo-information
 - Framework data and linking many different datasets
- Being easier to do business with
 - Price/terms
 - Simpler...

4. CONSTRAINTS

These are variables that can be managed by NMA's to advance the position

- Pricing
- Intellectual Property -> Preserving the investment in the database
- Security of the data (this will be eased by other bigger players in the info society)

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Chairmen and Facilitators

<u>Session 1</u>	<u>Session 2</u>	<u>Session 3</u>	<u>Session 4</u>
Keith Murray (chairman) - OS Nick Land (facilitator) - OS Malcolm Havercroft (facilitator) - OS	Les Rackham (chairman) - OS Paul Bullock (facilitator) - OS Ian Evans (facilitator) - OS	Malcolm Havercroft (chairman) - OS Les Rackham (facilitator) - OS John Rollin (facilitator) - OS	Lars Calvert (chairman) - OS Trevor Steenson (facilitator)- OS Ian Evans (facilitator) - OS

Summary of Feedback Questionnaire

12 completed forms received

	low			high	
1. Please give an indication of the overall value of the event to you:	0	0	1	4	7
	no		mostly		yes
2. Were your areas of interest covered?	0		3		9
3. What should we do next?					
	7		More workshops?		
	4		A project?		
	6		A European User Group?		
	2		A central forum for promote “best practice”? (perhaps through MEGRIN)		

Comments and quotes (in no specific order):

- an annual workshop?
- A user group/forum managed by CERCO/MEGRIN but.....not a talking shop. Job definition must be precise, eg
 - to identify technological developments (within and without NMAs), especially in the internet/telecomms sector
 - impact of tech developments on data model and structure
 - transaction service based licensing/pricing policy.

If such a forum is to work, strict deadlines would be necessary and non-NMA expertise needs to be involved, particularly from the internet/ASP/telecomms sectors.

- a project/workshop focussing on geospatial data in the mobile comms environment?
- it is essential to keep in contact to discuss problems and opportunities
- worth a follow up
- a CERCO working group?

- a workshop with potential users?
- how do business people see the role of the NMAs?
- very well put together
- direction is more or less clear but progress depends on different levels of development in different countries
- can we get a European standard to provide information and data on the WWW?
- hoped for a more technical exchange but understood that there are too few operating solutions yet.
- we have had a lot to learn from each other's experiences
- a project to create an 'inventory of experiences'? - could include the effects of e-commerce on conventional sales, pricing policies, experiences with new products/services, comparison of activities on the web.
- 'internet audits' to establish use of NMA's use of geospatial data on the WWW?

Presentations

- ❖ Menno-Jan Kraak
National Mapping Organizations and the Web
- ❖ Peter Woodsford
The OpenGIS Web Mapping Testbed
- ❖ Veijo Pätynen
Internet based GI-Services at the National Land Survey of Finland
- ❖ Pelle Pettersson
Internet at Lantmäteriet in Sweden
- ❖ Duncan Shiell
Ordnance Survey and the Internet
- ❖ Francois Salgé
IGN France and the Internet
- ❖ Vanessa Lawrence
A View from a Software Company
- ❖ Peter Beaumont
A Vendor's Perspective

Precision Terrain Models for Civil Engineering

(with 35 figures and 21 tables)

Report by A. Flotron and O. Koelbl

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- Figure 3 - Orthophoto of the Test area A1 with 1.0m contour lines; terrain type "smooth, weakly inclined".
- Figure 4 - Aerial photograph of the Test area A2 with indications of the control points, the perimeter of the test area and the model area.
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- Figure 6 - Aerial photograph of the Test area B1, with indications of the control points, the perimeter of the test area and the model area.
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Table 4 - Residual height errors on specific control points, as they were observed by the different centres.

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Abstract

The present publication should be understood as an empirical study, treating the data capture of digital terrain models (DTM) by photogrammetric stereoscopic measurements. Exclusively analytical plotters have been used for the measurement. The main part of the work is dedicated to the presentation of the measuring methods of the different centres and a detailed precision analysis. In total 7 centres participated in the test, all using their specific techniques also applied for their routine work.

The scope of the study resulted from the elaboration of the planning documents for the new high speed railway transition lines of Switzerland. Rather precise digital terrain models are needed for this project. For economical reasons, mainly photogrammetric measuring techniques were used; furthermore, the new DTM measuring techniques like Laser altimeter or Radar techniques were not yet available. Due to the high mountainous character of the country it is hardly possible to use larger photo scales than 1:6,000 with wide angle lenses. Consequently, the required height precision was fixed at $\pm 20\text{cm}$. 5 Test areas were available with different terrain characteristics, beginning with smooth weakly inclined, through rolling strongly inclined up to rough terrain.

With the exception of two test sets, all centres obtained the required precision of $\pm 20\text{cm}$. However, in certain zones considerable individual point errors have been detected exceeding up to 4 times the root mean square error. Furthermore, it showed that one has to take into account a considerable systematic error component of 5-10cm or 0.05-0.1‰ of the flying height.

The following methods have been applied for the arrangement of the mass points:

1. Adaptive sampling;
2. Profile measurements;
3. Measurement of a regular grid.

The adaptive sampling proved very efficient, as far as the number of measured points is concerned. On the other hand, it showed that the measurement of a regular grid requires a very high point density, especially in rough terrain. In general the point density lay between 3-12m, depending on the terrain and the measuring technique. Furthermore, the systematic modelling of roads, water courses, dam sites and terrain slopes by break lines is of great importance. It should be noticed that all slope changes, meaning the upper and lower edge of a dam site must be measured. Whereas structure lines in the terrain should only be drawn for clear features, otherwise it is more efficient to use some additional spot heights.

Based on the practical investigations and some theoretical considerations an attempt was made to establish a functional relation between the measured point density, the precision of terrain approximation and the specific terrain type. According to these considerations, the relative error of interpolated points can be estimated according to the formula $\sigma = \alpha \cdot d$; (α = coefficient depending on the terrain type and also on the required precision and d = the mean point distance of the supporting points). For α we obtained 0.01 for flat and smooth terrain, 0.02 for rolling terrain and up to 0.04 for rough terrain for a precision of $\pm 20\text{cm}$. One should also take into consideration that there is a “constant” or systematic

error component of 5-10cm or 0.05 to 0.1‰ of the flying height and the final precision formula should then read:

$$\sigma = \sqrt{[(\alpha * d)^2 + \text{constant}^2]}$$

This formula allows one to estimate the necessary point density for random distributed mass points. Under optimal conditions, a precision of $\pm 20\text{cm}$ or 0.2‰ of the flying height can be reached.

Thorough quality control is also of great importance. The present investigation was based on the precision analysis of a grid with a mesh width of 25m. This grid was measured photogrammetrically; in principle one can recommend such a grid for internal precision analysis. However, measuring problems on specific terrain features are more clearly detected on terrain profiles with narrow path length. Most probably it is advisable to have both control elements, a regular grid and some profiles measured and analysed by the photogrammeter for thorough quality control. Nevertheless, additional terrestrial control measurements are recommended, in order to determine the absolute precision, including possible systematic error components.

It is remarkable that all analytical plotters used (Kern DSR, Leica BC1 oder BC3, Zeiss P3) showed about the same precision of the data sets and it was not possible to detect any dependency on the instrument used. Furthermore, neither was there any dependency on the different software packages used (Intergraph Terrain Analyst, SCOP Univ. Stuttgart and Vienna, CIP-Wild).

1 Introduction

1.1 General objectives of the study

Digital terrain models provide essential basic information for all types of engineering tasks and the relative planning activities. One needs only think of the various road and railway projects, tasks of rural engineering and reallocation, flood control and numerous other activities. In spite of this large application, practitioners responsible for data acquisition for a DTM have few guidelines for the proper measurements and the process control. As a rule, we find relatively detailed precision specifications in the terms of reference; however, practitioners have to elaborate procedures for data acquisition and for precision control in a quite cumbersome way. The present OEEPE study aims to provide practitioners with decisive help in the conception of DTM measurements, based on the experience of various topographic institutions.

The experimental work on this project was preceded by intensive discussions within Commission III of the OEEPE. In order to make a contribution to the above listed questions, it appeared necessary to proceed to a larger test based on comparative measurements. For this task, the pilot centre chose a series of test sites with various terrain types. The aerial photographs of these test sites were placed at the disposal of the various plotting centres. Detailed instructions were elaborated for the model orientation and the

measurement of reference points; the proper disposal of the measurements for the modeling of the terrain was left fairly open. It was only specified that the terrain should be described “as precisely as possible” and the precision of an interpolated point should not exceed $\pm 20\text{cm}$.

The objective was then to determine the possible precision for various terrain types in applying reasonably justified efforts for the measurements. Furthermore, the intention was to derive a general formula which would allow practitioners to determine the point density according to various terrain characteristics and to estimate a priori the obtainable precision.

1.2 Review of some earlier experimental investigations

Before conceiving the OEEPE-Test, the Working Group studied a number of earlier investigations concerning the determination of precision digital terrain models. A brief overview of these investigations is given below. However, there was only a very limited number of publications available concerning ‘high resolution’ or ‘high precision’ DTMs for the range of accuracy which is required for civil engineering purposes.

1.2.1 The research of the University of Stuttgart 1979

Ackermann [1] in Stuttgart was probably the first, to make experimental investigations of high resolution DTM data sets which were qualified for detailed civil engineering projects. He found approximately a linear relationship between DTM accuracy and the density of observed points and expressed the results in the formula

$$m_z^2 = \beta^2 + (\alpha \cdot d)^2$$

m_z = r.m.s. error of interpolated height values

α = terrain characteristic

d = mean point distance of observed points

β = standard error of primary data and noise of terrain surface

and he estimated from a limited number of tests the terrain characteristic α as follows:

$\alpha = 0.004$ for smooth terrain

$\alpha = 0.010$ for medium type terrain

$\alpha = 0.022$ for difficult terrain

The specific terrain type is not specified in detail. This formula of Ackermann and the above indicated values are used today in practical civil engineering work.

1.2.2 ISPRS tests 1986

An ISPRS commission headed by Torlegård [2] investigated the accuracy problems on 6 different test sites by comparative measurements. Two test sites were covered by small scale photographs, three by medium scales and one by large-scales. Only one example refers to a high resolution DTM. He summarized the result of this test as follows:

- (a) The standard error in photogrammetrically derived DTM's is in the range of 0.2-0.4% of the flying height in flat or moderately undulating terrain. In very hilly terrain the standard error increases to approximately 1-2%. The maximum error is about 4-8 times the standard error.
- (b) The number of blunders in a DTM varies from 0% up to 3% where 0.5% is a median value. Blunders occur more frequently in difficult terrain, but the size of the blunder is independent of the terrain type.
- (c) The participants in the test have, with a few exceptions, usually underestimated the standard errors in their DTM's. There is apparently a need for better methods for accuracy prediction and estimation of DTM's.

1.2.3 A study by the Technical University of Denmark 1986

Paul Fredericson and others [3] investigated the possibility of terrain classification by Fourier analysis. They investigate cross sections of 300 paces of 1m path length. The spectrum is used in order to predict the accuracy of digital terrain models and to calculate the relation between type of terrain, accuracy of measurements, point density and surveying expenses.

1.2.4 An investigation by Li 1992

The purpose of Li's investigation [4] was 'to find some relationship between DTM accuracy and the density of the data set for certain types of terrain using certain data patterns'.

He used three of the ISPRS data sets to investigate the relation between accuracy and point density, both of regular grid points and of 'composite data sets' and regular grid points with supplementary feature-specific points.

He analyses the data primarily according to the formula of Ackermann, assuming (contrary to Ackermann) that the accuracy may especially be influenced by the slope of the terrain. He finds the model of Ackermann confirmed for two samples, but he states for the third data set that the standard error versus the grid width is rather a power function of greater than 2.

The summarised conclusions are:

- (a) The accuracy of a DTM highly depends on the grid density if only mass points are used.
- (b) When feature-specific points (including break lines and form lines) are added to the data set, the accuracy of the data set can be improved.
- (c) Large residual errors can occur but the occurrence frequency of these residual errors being greater than 4 times the standard error is usually very small.
- (d) The accuracy of the DTMs is correlated with the slope angle.
- (e) The accuracy results obtained from two data sets of the same area may be quite different, even if the sampling interval is the same for both of them.

2 Test sites and photo material of the OEEPE Test

Crossing the Alps by highspeed railways, linking the industrial centres of Germany and northern Europe with those of Italy is currently a major preoccupation in transport planning in Switzerland. The planning of engineering work required precise and up-to-date topographic data, which were derived mainly by photogrammetric measuring procedures. One of the zones recently mapped is the Kandertal, in the south of the province of Bern. Within the cited project, it was necessary to establish a high precision DTM for which a maximal allowable standard deviation of $\pm 20\text{cm}$ for an arbitrarily interpolated point was prescribed. It appeared appropriate to also select a number of models of this photogrammetric material for the OEEPE test.

2.1 Geographical and geomorphological characteristics of the test sites

The Kandertal, stretching over 25 km, is one of the important north-south valleys of the northern Alps. It begins at the Lake of Thun near the town of Spiez at an altitude of 550m and ends in Kandersteg at an altitude of 1100 m. The latter small town is situated at the foot of the mountain ridge of Blüemlisalp-Wildstrubel which separates the Kandertal from the Wallis valley. The bottom of the Kander valley has an average width of about 1km and mounts smoothly up to the village of Frutigen. From there on, we observe a number of steps until Kandersteg. The portal of the new basic tunnel is planned below Kandersteg at an altitude of 850m.

From a tectonic point of view, the valley lies in the sediments of the helvetic cover, composed mainly of chalk and Jura-chalk. These hard rocks which limit the valley form abrupt rock walls and steep but vegetated scree slopes. The bottom of the valley is in general flat to hilly, and was formed by moraines and sediments of the Kander river during the glacial period; the river itself has eroded a deep bed, in parts up to several meters.

2.2 Description of the test areas

Along the Kander Valley, 5 different test sites of about 10 to 20 hectares were selected by the pilot centre. The areas represent different types of terrain: smooth (A1,A2), rolling (B1,B2) and rough (C1) terrain. Again for each different type, two sites were chosen - the one weakly inclined (A1,B1,C1) and the other strongly inclined (A2,B2). One should mention a C2 test site (rough, strongly inclined) was also available, but there was only one set of measurements, performed by the pilot centre. Therefore this test site was later omitted. An extraction of the map 1:200,000 in figure 1 shows the location of the test sites in the Kander valley.

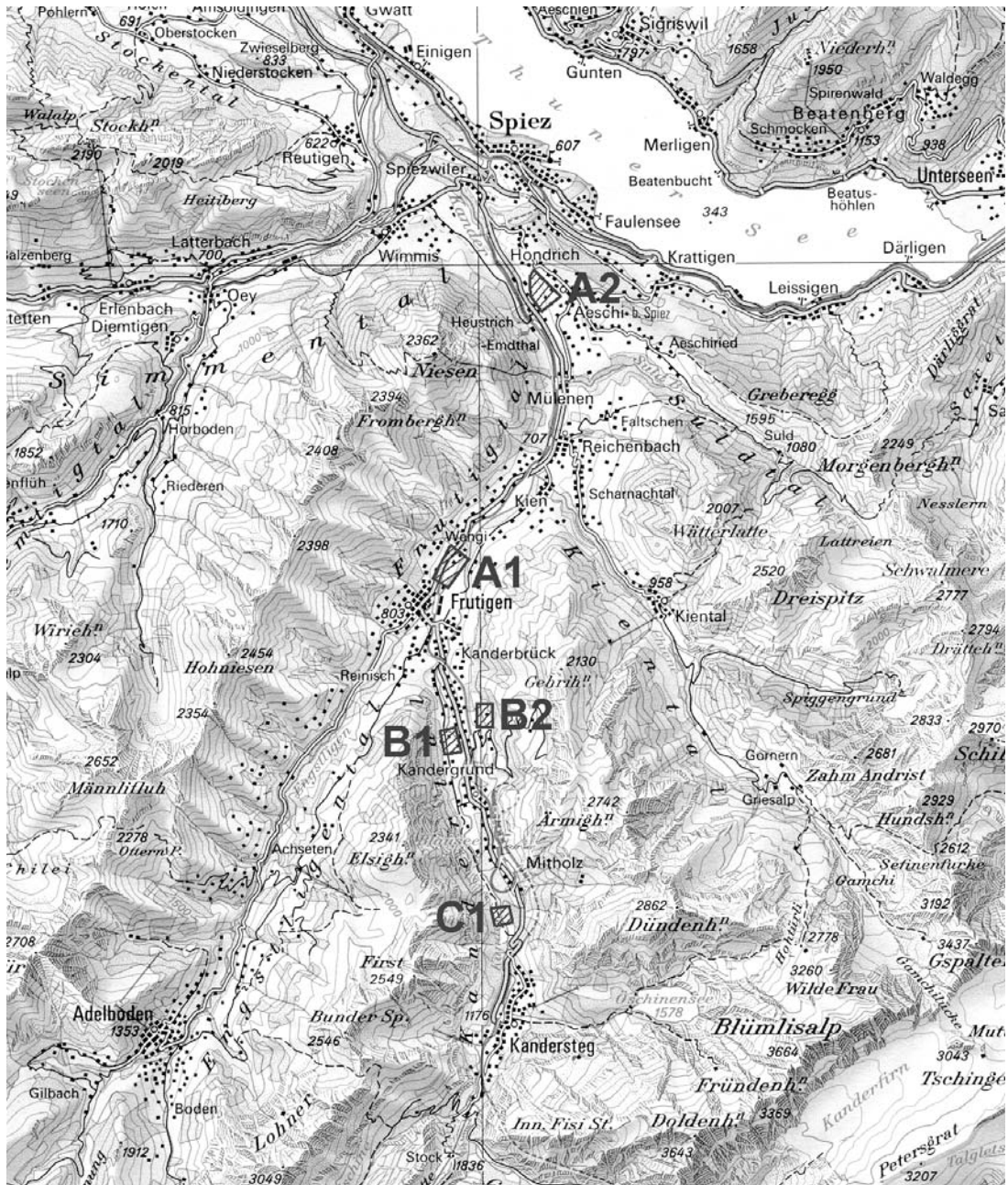


Figure 1:

Extraction of the topographic map of 1:200,000, showing the Kandertal with the various test areas (by courtesy of Federal Office of Topography, BA002043).

In the following we give a verbal description of the 5 test areas. The description is complemented by the reproduction of the aerial photograph with the delimitation of the test area and the control points and an orthophoto with superimposed contourlines. Reference is also made to table 1, which gives a summary of the parameters of the test sites. The slope inclinations were calculated from a grid model with a mesh size of 20 m, derived from the TIN models. The slope inclinations derived from the original triangular models are about 10-20% larger, as the 20m grid shows already a considerable generalisation, however it was the intention to indicate average values and to avoid extremes.

Table 1:

Overview of various parameters of the test sites

Test area	Characteristic	Length	Width	Total area	Built up area	Height difference	Mean Incl.	Max. Incl.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A1	Smooth, weakly inclined	700 m	400 m	20.6 ha	1.2 ha	22m	4 %	15 %
A2	Smooth, strongly inclined	650 m	450 m	15.8 ha	1.1 ha	110m	21 %	40 %
B1	Rolling, weakly inclined	500 m	500 m	20.6 ha	0.9 ha	15m	7 %	35 %
B2	Rolling, strongly inclined	500 m	500 m	19.6 ha	1.3 ha	175m	46 %	105 %
C1	Rough, weakly inclined	450 m	350 m	11.4 ha	0.9 ha	30m	21 %	75 %



Figure 2:

Aerial photograph of the Test area A1, with indications of the control points, the perimeter of the test area and the model area. (All the aerial photographs shown in this publication have been taken by the Federal Office of Topography on March 12, 1991 and are reproduced by courtesy of that institution).

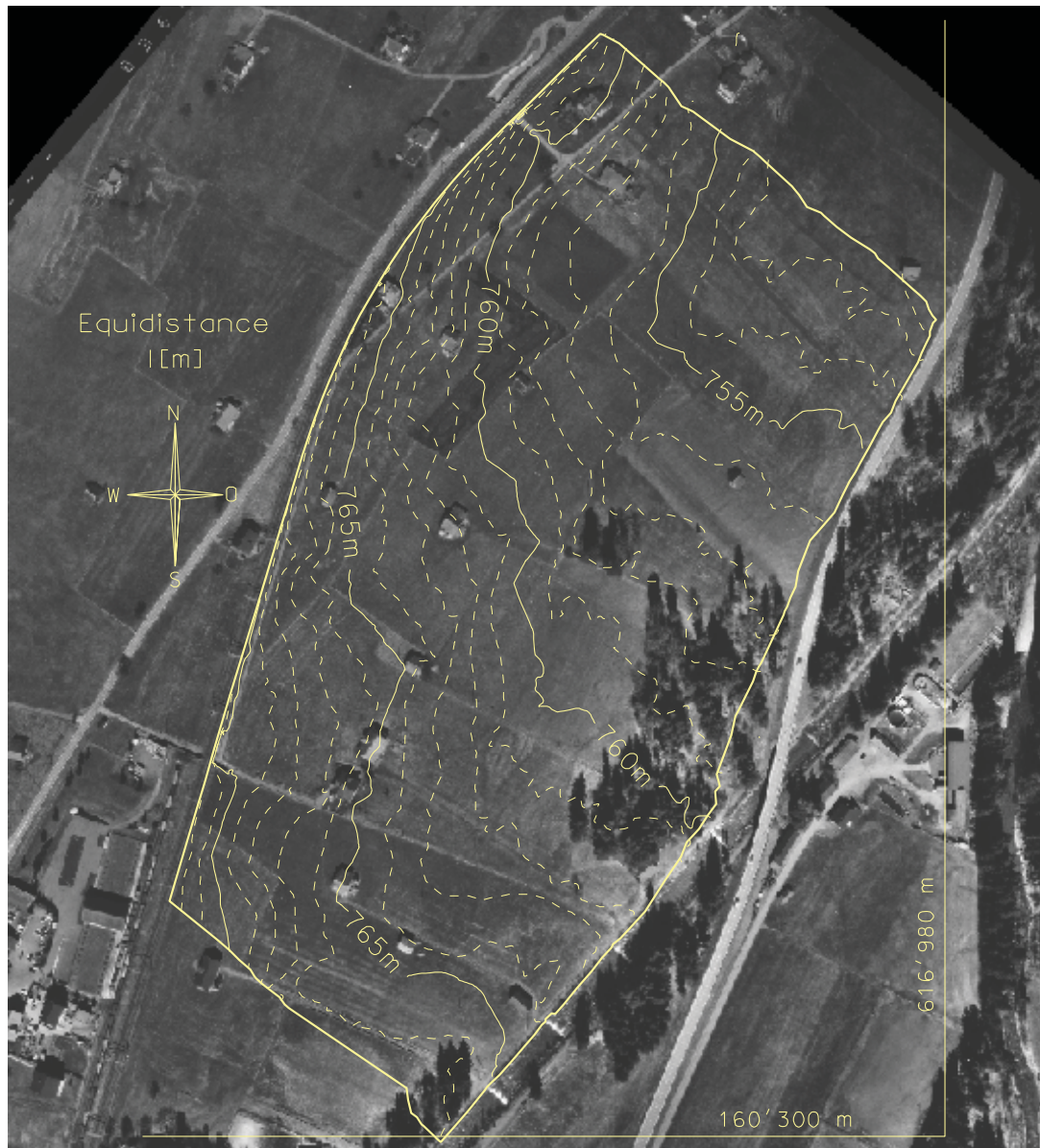


Figure 3:

Orthophoto of the Test area A1 with 1.0m contour lines; terrain type "smooth, weakly inclined". A rather flat and even farming area in the plain of the valley. It is crossed by 3 minor roads, includes a small wood and there are 14 farm houses or other buildings for agricultural use. The area is limited to the south-east by the bank of the Kander river and to the north-east by the current railway line of the BLS. The test area has an extent of 400 by 700m and covers 20.6ha. The terrain undulates slightly, there are some gullies and flat ridges. The average terrain inclination is 4%, the maximal inclination 15%; the largest height difference is 22m.

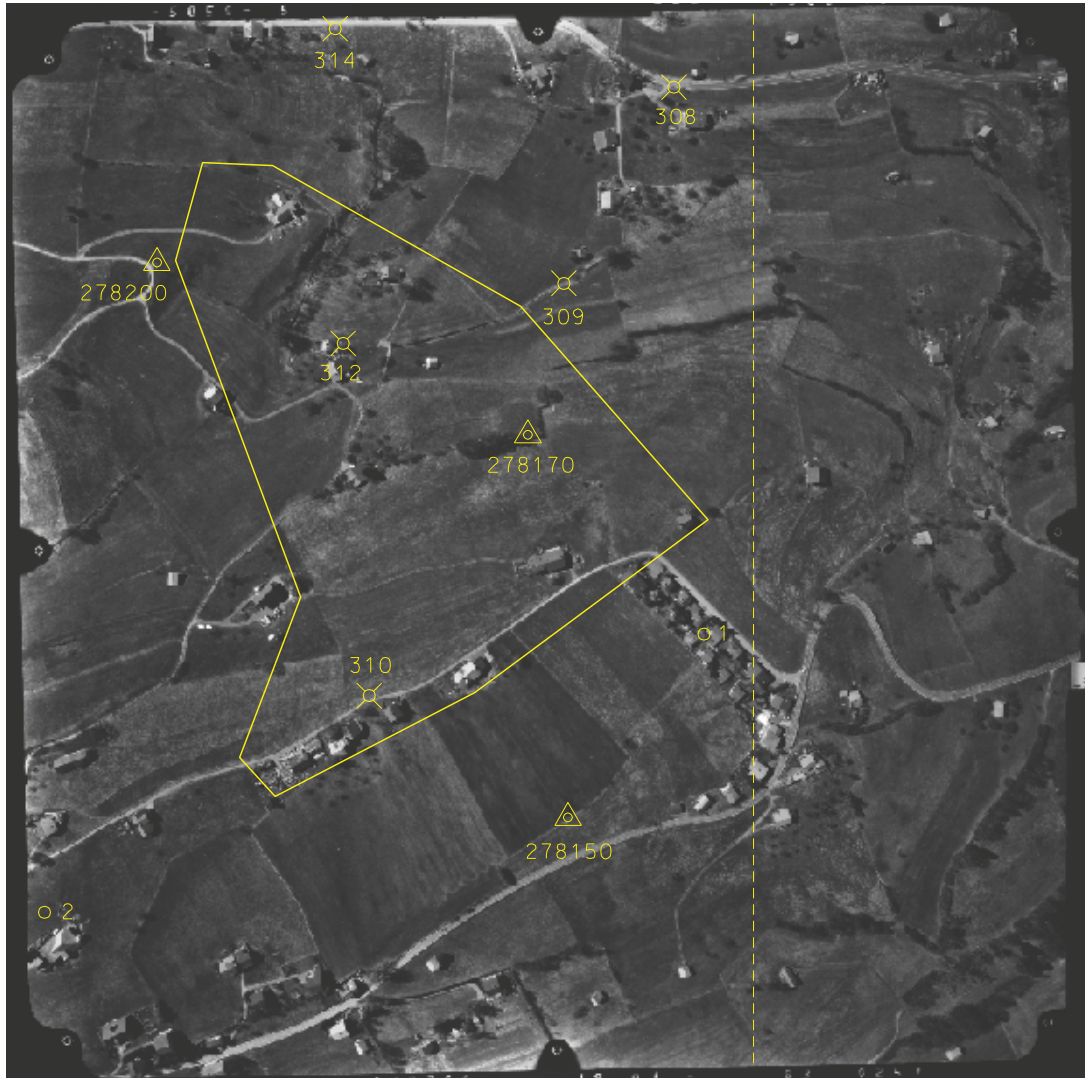


Figure 4:

Aerial photograph of the Test area A2 with indications of the control points, the perimeter of the test area and the model area.

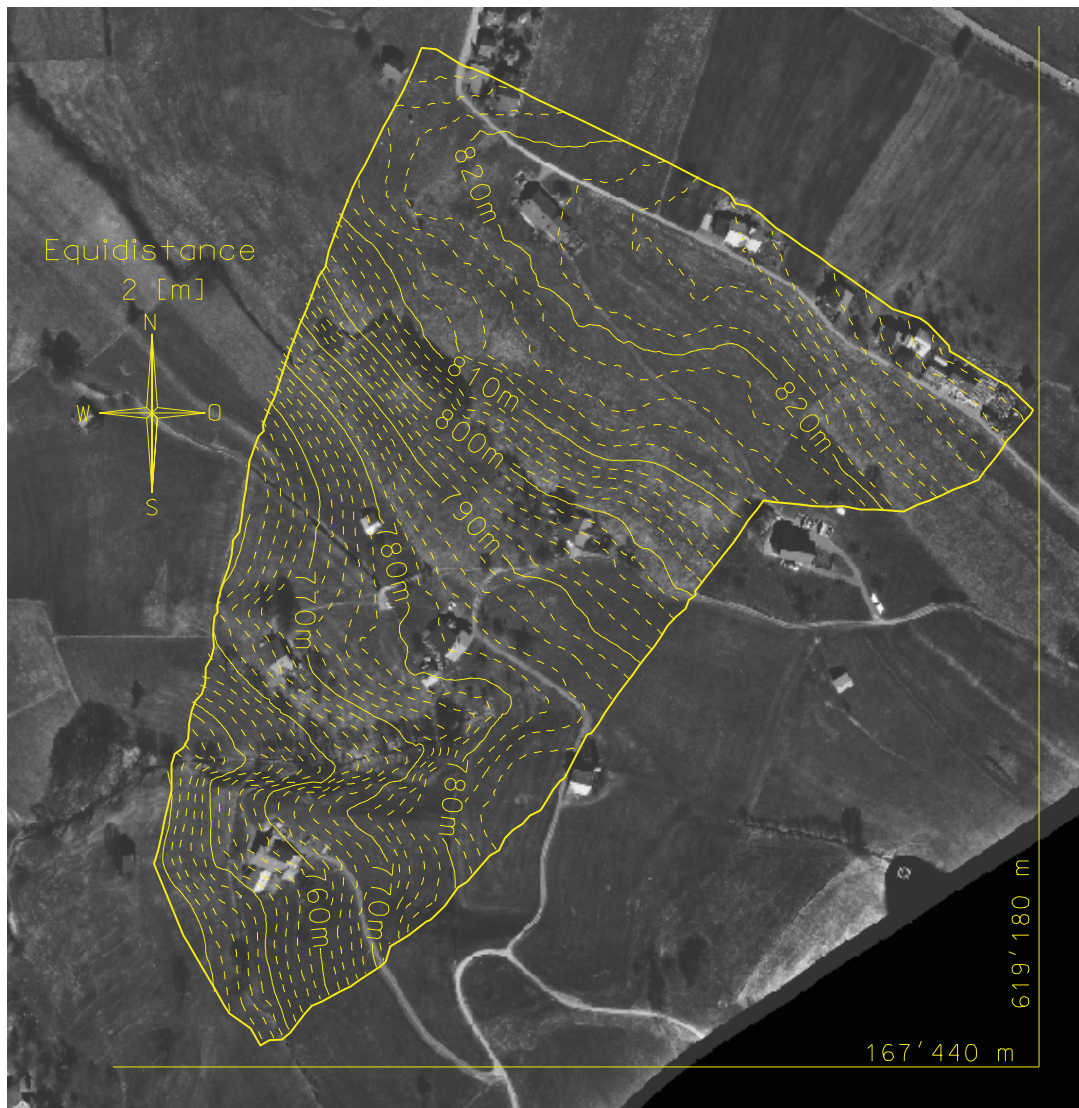


Figure 5:

Orthophoto of the Test area A2 with 2.0m contour lines; terrain type "smooth, strongly inclined". A uniformly inclined area for cattle grazing; the upper part of the area is crossed by a traffic road 4m wide, partly with embankments; there are some other minor roads leading to and from the 8 buildings, mainly for agricultural use. Some ditches bordered by trees cross the area. The area has a triangular shape of 450 x 650m, covering 15.8ha and is inclined on an average of 21% (slopes between 10 and 40%). The greatest height difference is 110m and the topography of the terrain is similar to A1 but much more strongly inclined and more rolling. The upper part is formed by a flat ridge; the central part is uniformly inclined and the lower part is characterised by a gully and a narrow and a larger small valley.

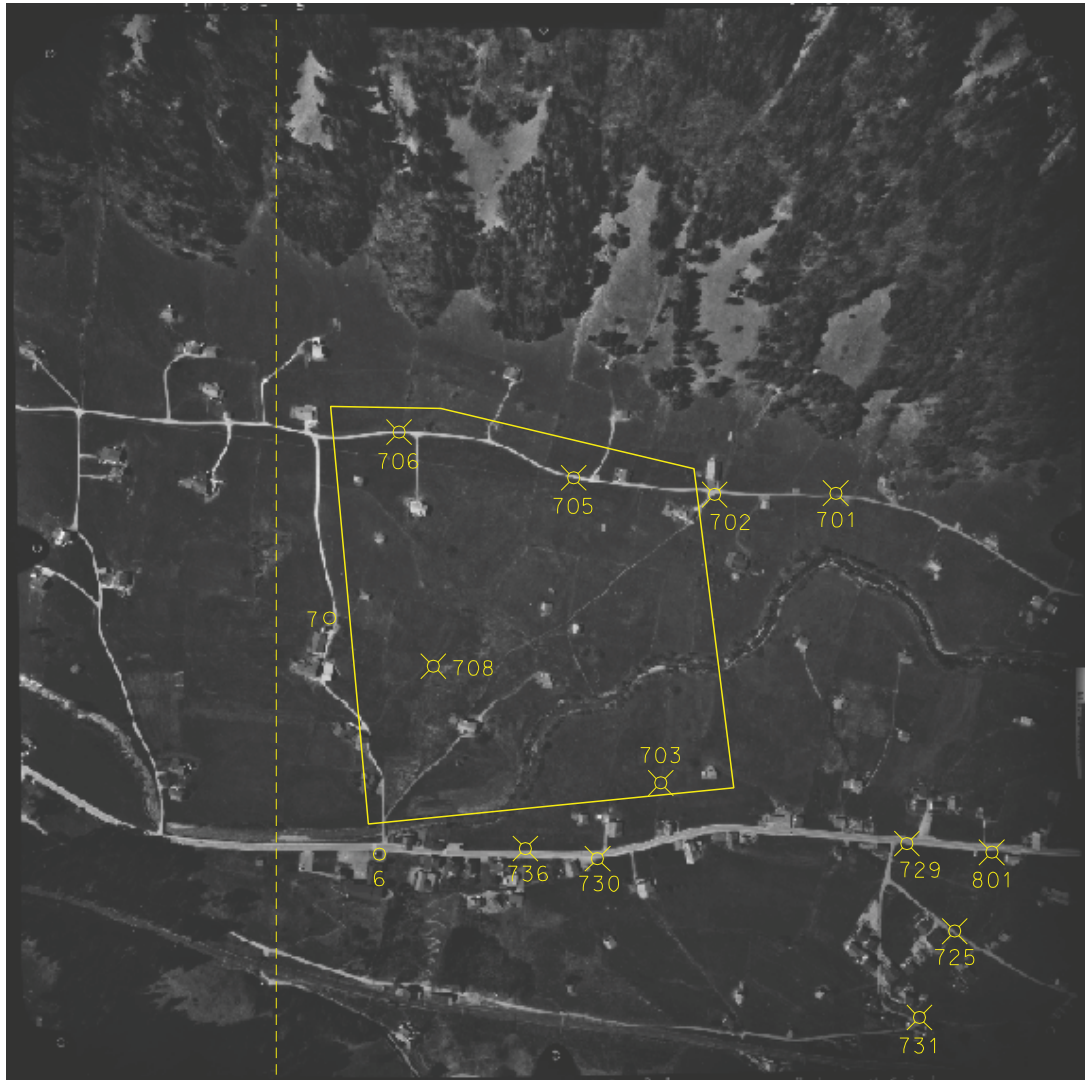


Figure 6:

Aerial photograph of the Test area B1, with indications of the control points, the perimeter of the test area and the model area.

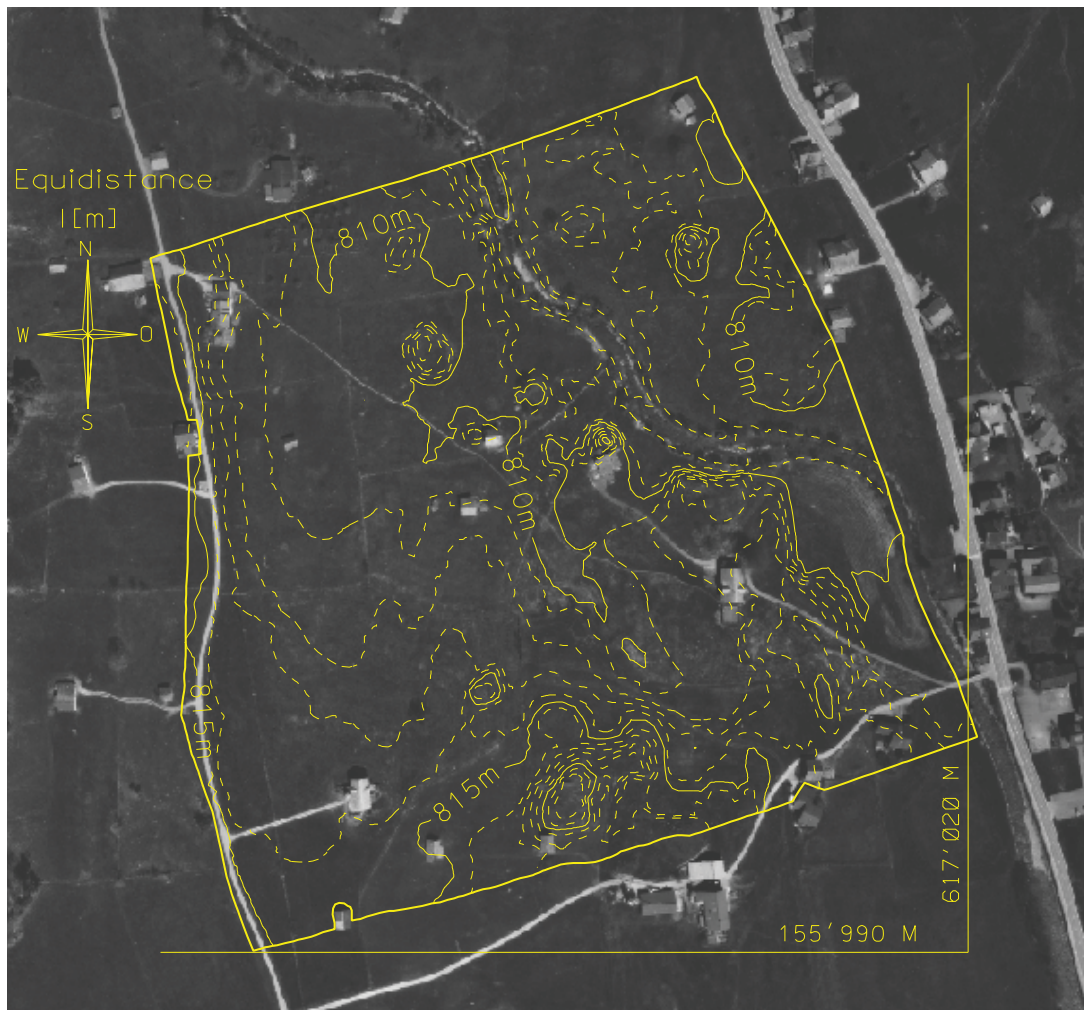


Figure 7:

Orthophoto of the Test area B1 with 1,0m contour lines; terrain type "rolling, weakly inclined". Rather flat area used for cattle grazing and farming; it is covered by a great number of erratic cones (little drumlins). The Kander river crosses the area over a stretch of 400m and has a width of 10 to 20m; the river bed is about 4 m deep. The river banks are protected with great boulders against erosion and are covered by trees. The rest of the area is without trees or shrubs. The southern border of the area features a 450m stretch of the provincial cross road, with embankments enlarged recently to 7m; the 4 farmhouses can be reached by asphalt covered roads of a width of 4m; the other 8 agricultural buildings have gravel roads leading to them. The test area has an extent of 500 by 500m and covers an area of 20.6ha; the maximum height difference is only 15m; the local drumlins and cones show height differences of 2 to 10m.

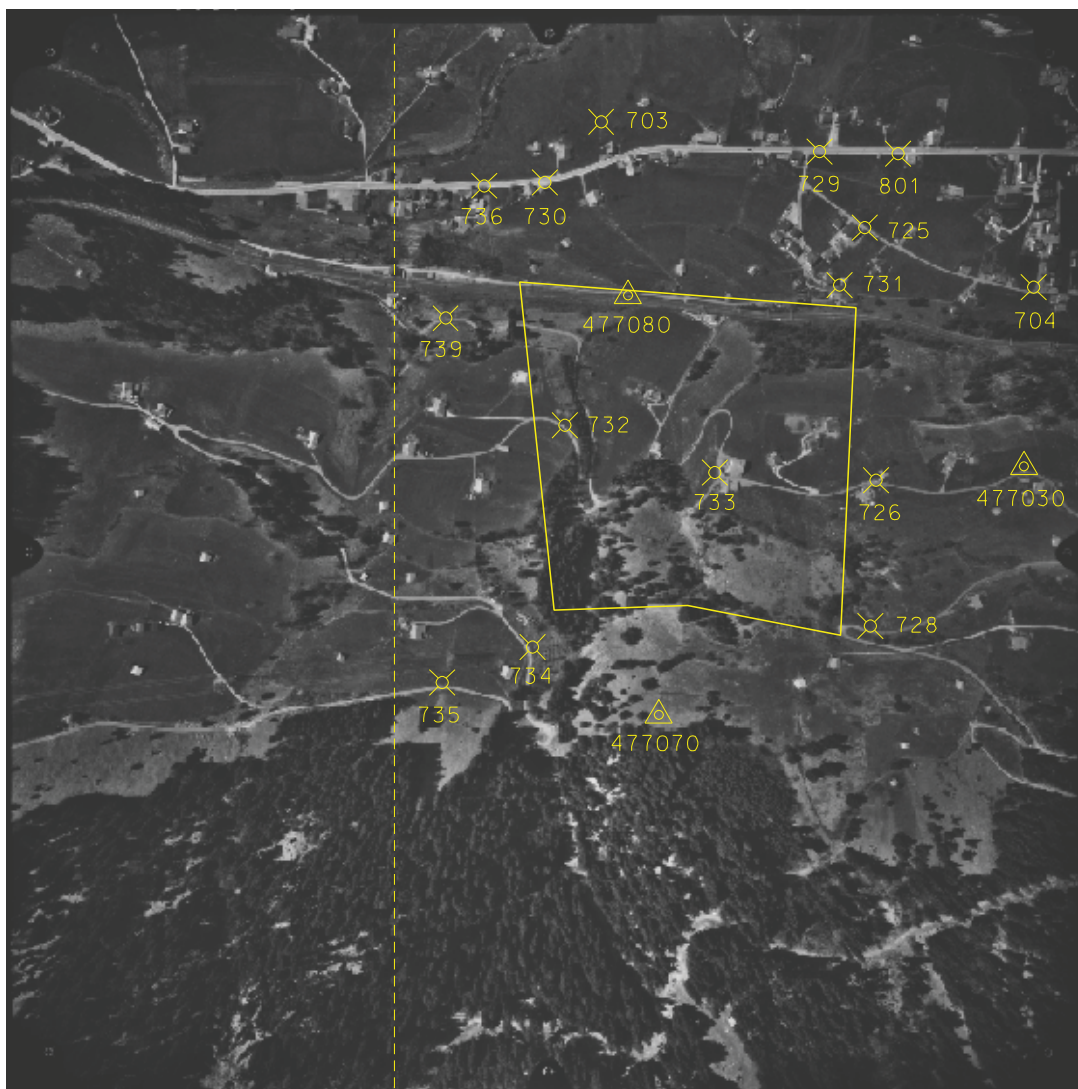


Figure 8:

Aerial photograph of the Test area B2, with indications of the control points, the perimeter of the test area and the model area.

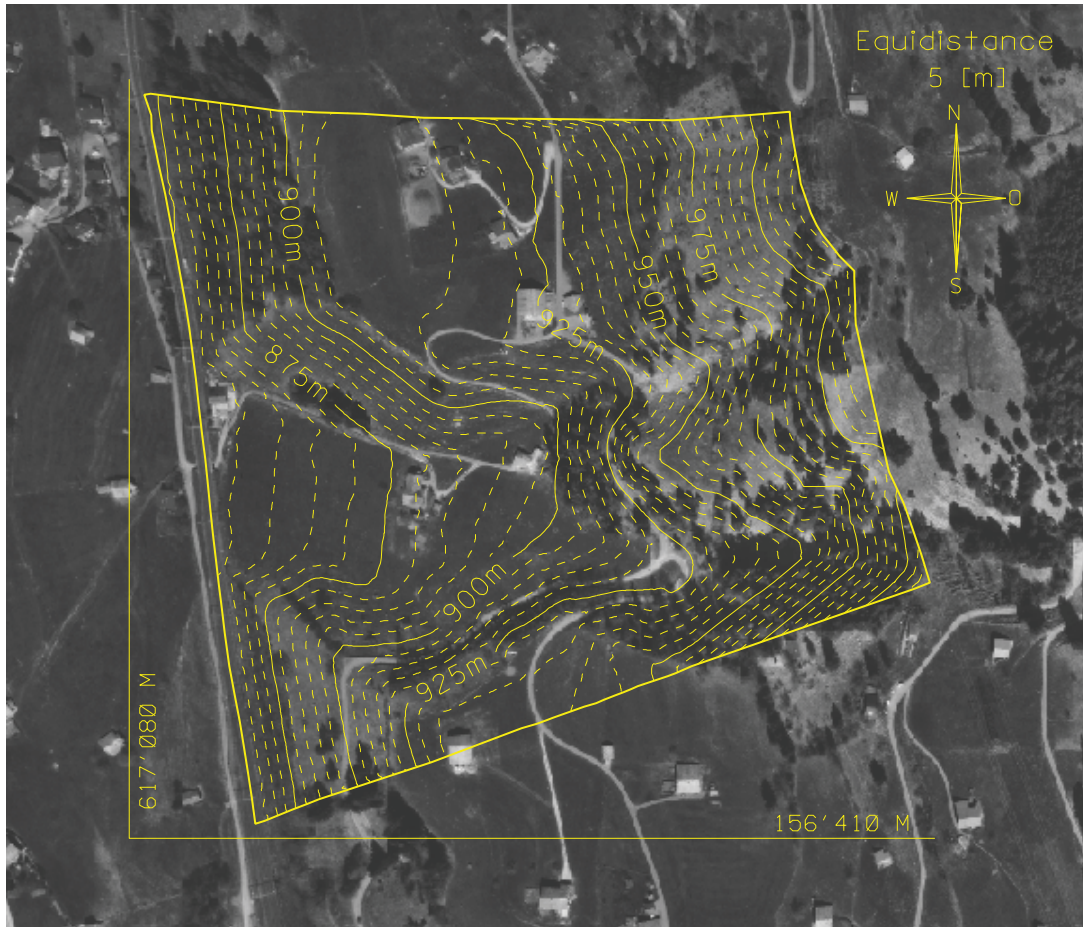


Figure 9:

Orthophoto of the Test area B2 with 5.0m contour lines; terrain type "rolling, strongly inclined". This test area lies in the west exposed valley slope of the Frutig valley above Kandergrund. The upper part is a steep slope with an inclination of about 70%, crossed by 2 torrents which have eroded deep gorges. These valleys meet in the central part of the test area, where the water has eroded a nearly 200m wide glacial terrace. The torrents empty in the lower part of the area where they again form steep slopes of about 70%. The western part of the area includes the railway line of the BLS over a length of 200m. Some 8 agricultural buildings are reached by minor roads. The terrace and cross valley are intensively used and the terrain cover is similar to B1. The steep slopes are partly dense forests, partly pastures covered by trees. The area has an extent of 500 by 500 m and covers an area of 19.6 ha. The largest height difference is 175m; the average slope is 46% (range from 5% to 105%).

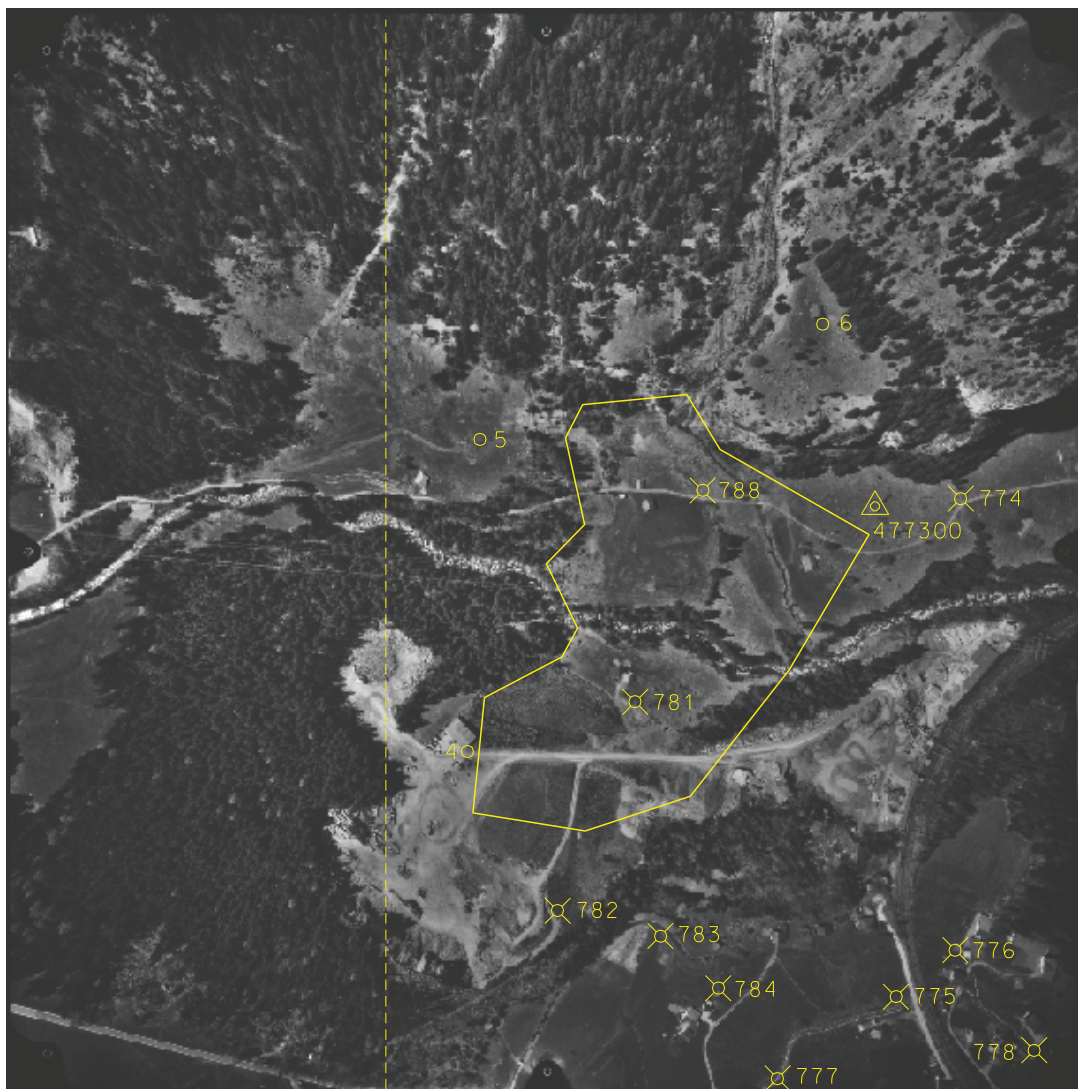


Figure 10:

Aerial photograph of the Test area C1, with indications of the control points, the perimeter of the test area and the model area.

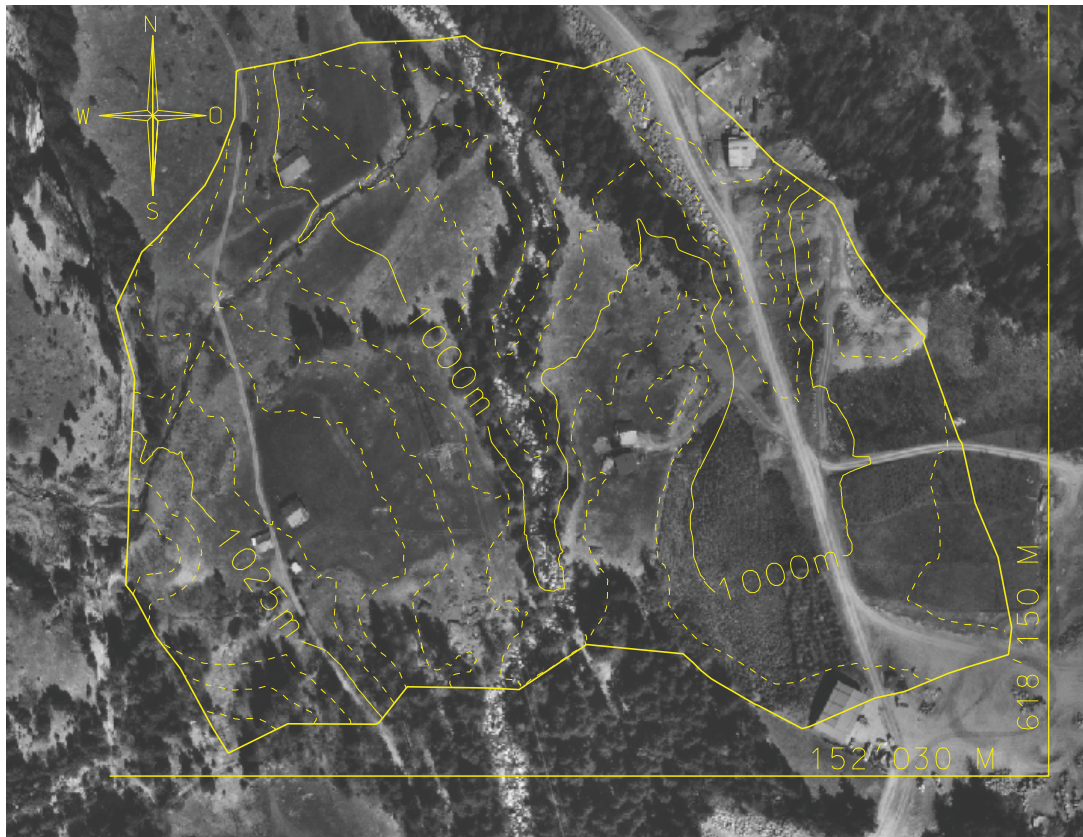


Figure 11:

Orthophoto of the Test area C1 with 5.0m contour lines; terrain type "rough, weakly inclined". This test area lies in the bottom of the valley at a height of 1000m; the area is crossed by the Kander river which is still a torrent at this height. About 2/3 of the area is a torrent alluvium with a thin cover of humus used as pasture. This pasture is crossed by an other 3-5m deep torrent. The terrain is rough, interleaved by numerous rocks and boulders. The river bed of the Kander, bordered by groups of trees on both sides, is also clearly visible to a great extent. The remaining part of the area is used for gravel excavation and intermediate deposits. The topography is also rough due to the numerous excavations and deposit heaps. The area shows 5 sheds, reached by small roads; the gravel-pit is also crossed by various tracks. The area has an extent of 350 by 450m and covers an area of 11.4ha, the average inclination is 21% (minimum 0% and maximum 75%); the maximum height difference is 30m.

2.3 Aerial photographs

The aerial photographs of the test were taken by the flight service of the Swiss Directorate of Cadastre with a Twin Otter, a twin-engine aircraft. The aerial camera used was a RC10A Leica camera with the UAGA-F wide-angle lens with a focal length of 152.85mm, camera aperture 1:4.0. The mean value of the exposure time was 1/350sec; the overlap in the flight axes about 60%. The photographs were taken on black and white Kodak Plus-X Film, on an average scale of 1:6000. The flight took place on March 12th 1991 at about noon in brilliant sunshine, shortly after the snow had melted but before the trees had leaves and the vegetation begun to grow.

2.4 Previous photogrammetric measurements

The pictures have already been used for the above mentioned plotting project. A surface of 4000ha was covered by aerial photographs, requiring 28 strips with a total of 500 photographs (sidelap 60%). The ground control was based on the Swiss official triangulation network which was fully updated by terrestrial measurements one year before the flight.

Prior to plotting, an aerial triangulation was performed. The block contained 270 images, measured by two private photogrammetric firms, both using Kern analytical plotters DSR with the software AETRI. The bundle block adjustment was calculated with the BUND program, developed by the Geodetic Department of the Swiss Federal Institute of Technology. According to the precision analysis of the block adjustment as delivered by the computer program, a standard deviation of $\sigma_0 = \pm 3.5 \mu\text{m}$ was achieved and the resulting mean square errors in the terrain points amounted to $\pm 2.1 \text{ cm}$ in planimetry and $\pm 2.4 \text{ cm}$ in height.

Large-scale maps, mainly in the scale 1:1000, were subsequently drawn up as well as a high precision DTM over an area of 2000ha. The area mapped was mainly the bottom of the valley, but also included a good part of the steeper slopes and rocky walls on both sides of the valley.

2.5 Photo material made available to the photogrammetric centres

The Photogrammetric Centres received primary film copies on Agfa duplicating films, processed by the Swiss Federal Office of Topography. A copy of the record of the camera calibration, including the coordinates of the fiducial marks, were delivered.

3 Measuring instructions and participants in test measurement

High precision can be obtained by photogrammetric measurements, as shown by daily routine work. It seemed essential to take advantage in this test of the practical experiences of the different plotting centres and to avoid prescriptions which might disturb the high standard achieved in the mapping organisations. Consequently a minimum of instructions were given, intended only to ensure that comparable results were obtained.

3.1 Photogrammetric plotting instruments

The type of the plotting instrument was left open; it was only specified that high precision analytical plotters should be used. Furthermore, there were no plans to allow for any automation.

3.2 Model orientation

For the model orientation, signalised points were available; the co-ordinates of the control points stem from aerial triangulation as described in the sub-paragraph 2.4. The precision of the control points is in the order of $\pm 5\text{cm}$, if referred to the resulting $\sigma_0 = \pm 3.5\mu\text{m}$ of the aerial triangulation. Each of the test sites is covered by a single model occupying about 40% of the model area. The control points intended for model orientation are located in the model corners; additional points were located in the effective test area.

3.3 Data acquisition for the DTM

As already mentioned in the beginning, specific instructions were not given for the proper measurement of the DTM. It was only suggested that participants should measure the following elements usually used for the DTM determination:

1. Mass points;
2. Break lines;
3. Dead areas, in order to exclude specific zones for modelling.

Nor were specific instructions made regarding the DTM program intended for use. It is understood that the data acquisition for a DTM should be in accordance with the functionality of the interpolation program. For example, structure lines specifying ridges with a rather smooth transition of the slope angle can only be used in programs allowing a non-linear interpolation. Furthermore, programs with non-linear interpolation very often require fewer mass points than programs with linear interpolation. Consequently, one must consider it as a simplification when the procedure for the numerical treatment of the data is not specified prior to the measurements. However, it appeared to complicate matters too much if a detailed description were to be given in the beginning of the interpolation procedure; additionally, not all elements of the data evaluation were defined in the beginning.

It was the intention to give complete freedom to the plotting centres and to take advantage of their specific experience and to analyse their specific procedures only at a later stage.

Also, the definition of the “dead areas” was left to the responsibility of the operators. Again, it seemed important to learn from the current practice of the plotting centres, but it is evident that the final precision might vary considerably when different areas of the same test site are modelled or eliminated as “dead areas”.

3.4 Determination of check elements for the DTM

The main concern of the present study was the analysis of the precision of the derived DTM. Various aspects have to be taken in consideration. In general, the error of an interpolated point of a DTM is composed of several factors, partly due to the data acquisition, partly due to the interpolation procedure. Very often the following components are sepa-

rated:

1. Orientation precision of the photogrammetric model;
2. Possible systematic errors of the measuring procedure;
3. Measuring precision of the elements of the DTM;
4. Interpolation precision of the DTM software;
5. Natural terrain roughness.

It was decided to rely only on photogrammetric measurements for accuracy assessment, as in general the measuring precision in photogrammetric models is considerably higher than the precision of interpolated points of a DTM. It is understood that it is not possible to make an overall accuracy analysis with only photogrammetric measurements as the vegetation height or specific terrain variations can not be taken into account in this way. However, for practical reasons it was not possible to provide a sufficient number of control points by field measurement.

Two types of points had been chosen for the precision analysis:

1. Distinct terrain points;
2. Points distributed according to a grid ('grid points').

3.4.1 Distinct terrain points

About 30-50 distinct points had been chosen in each of the different test sites by the pilot centre. These points are situated in smooth zones and are easy to identify. Furthermore their location was defined by their planimetric co-ordinates. These points should serve mainly for the control of the model orientation and of other systematic errors.

3.4.2 Grid points

Additionally to the distinct points, the test requirements involved measuring a grid with a mesh width of 25m. The planimetric co-ordinates of these points are well defined, and the idea was that these points are measured in height according to their predefined location. In this sense it was recognised that they might fall in open terrain with a good visibility but might also lie under trees or in other difficult areas. The hope was to obtain in this way a general impression of the overall measuring accuracy. Depending on the size of the test areas, it was necessary to measure some 200-300 points.

3.5 Participants in the test measurements

As usual, the members of the working group and also the institutions of the members of the steering committee as well as other photogrammetric offices were invited to participate in the test. Finally, 6 different institutions and the pilot centre participated in the test. The participants included one government institution, 3 private offices and 3 universities and engineering schools. The restitutions were made by experienced operators with the exception of the restitution Centre 5, where students performed the measurements. The plotting centres used the instruments normally incorporated in daily production work.

The following list gives an overview of the different institutions, the equipment used and the test sites measured:

1. **Cen1: Bundesamt für Eich- und Vermessungswesen, A 1080 - Wien**
Instrument: Analytical Plotter Leica Aviolyt BC3
Restitution of Test Area A1, B2 und C1;
2. **Cen2: Tampere University of Technology, SF - 33 101 Tampere**
Instrument: Analytical Plotter Leica Aviolyt BC2
Restitution of test areas A1 and A2;
3. **Cen3: SITO Finnish Consulting Engineers LTD, SF - 02100 Espoo**
Instrument: Analytical Plotter Wild Aviolyt BC1
Restitution of test areas A2 and B1;
4. **Cen4: Flotron AG, CH - 3860 Meiringen (Pilot centre)**
Instrument: Analytical Plotter Kern DRS14
Restitution of test areas A1,A2,B1,B2,C1,C2;
5. **Cen5: Fachhochschule beider Basel, CH - 4132 Muttenz**
Instrument: Analytical Plotter Leica DRS15
Restitution of test areas A1,A2 and B2;
6. **Cen6: FM KARTTA OY, SF - 00 510 Helsinki**
Instrument: Analytical Plotter Zeiss P3
Restitution of test areas B2 and C1;
7. **Cen7: Ecole Polytechnique Fédérale, CH - 1015 Lausanne**
Instrument: Analytical Plotter WILD Aviolyt BC1
Restitution of test area A2.

The centres were invited to use their standard procedures for the measuring and the recording of the data. The data were delivered in various formats and the pilot centre took responsibility for converting the data into a standard format. The old, well-known BC2 - format was used (Point number, Easting, Northing, Height, Pen code) because it was convenient as input for the various software packages.

4 Internal analysis of the measuring precision

Photogrammetric measuring techniques allow a number of precision checks in order to determine the internal precision of the measurements. The pointing precision from repeated measurements and the precision of the absolute orientation already give important information in this respect. In the following sections, this internal precision is analysed based on the following elements:

- Residuals of model orientation;
- Observation errors of the 'distinct terrain points';
- Observation errors of the 'grid points'.

In the next chapters, the precision of these elements is discussed in more detail. One will notice that the standard deviation of the interpolated points is about two to three times larger than the measuring precision of the points. Furthermore, systematic errors are present which are also in the order of the measuring precision of the individual point.

4.1 Precision analysis of the model orientation

In table 2 the mean square errors of the absolute orientation as they were recorded by the different plotting centres are presented. The precision of the absolute orientation appears to be quite satisfying as the residuals in the control points are $\pm 2\text{-}3\text{cm}$ in planimetry and $\pm 3\text{-}7\text{cm}$ in height. The height precision in the control points is slightly lower than stipulated, according to the results of the aerial triangulation.

However, when studying in more detail the residuals on the control points, one recognises that they might have an influence on the overall precision. In table 2 we already indicated the maximal residual height errors and the corresponding number of points. Additionally in table 3 we summarised the residual height errors of specific control points of the test-sites B2 and C1. It should be noticed that all centres observed a negative height error between 5 and 8cm in point 728 (Test site B2). The aerial photographs in figure 8 shows the distribution of the control points and the location of the test area. One observes that the corner of the test area B2 is bent up and will be modelled 5-8cm too high, a value which is already in the order of the DTM precision.

The point 728 is a minor control point which was not signalised nor materialised in the field, however point 477080 is a triangulation point which might serve as connection point for complementary measurements in the field. This point showed a residual error of +9cm (cf. table 2, Cen4), this value will enter fully as systematic error between terrestrial and photogrammetric measurements.

It should also be noticed that plotting centre 2 has much lower residuals ($\pm 0.4\text{-}0.9\text{cm}$ instead of $\pm 3\text{-}5\text{cm}$) than all other centres. Also the maximal residuals are much lower (-0.6cm for test-area A1 and -1.8cm for test-area A2 –cf. table 2). The BC2 software allows a one step model orientation, combining relative and absolute orientation. The image coordinates and the control points are then considered as stochastic variables. A strong weighting factor of the control points then hides the errors in the control point. This can be a dangerous procedure, when the operator does not control the precision of the orientation points in some other way.

4.2 Precision of point measurements

4.2.1 Distinct terrain points

The distinct terrain points and the grid points were intended as check points for the precision analysis of the interpolated points with the help of the DTM software packages. The restitution centres observed these points according to the instructions. From the measurements of the different centres, it is possible to compute a standard deviation in order to characterise the spread of the measurements. The centres measured between 40-50 distinct terrain points; the deviation from the mean of these various measurements were used to compute of the root mean square error. Table 4 gives an overview of the determined spread of the measurements of the distinct terrain points. According to this table, a root mean square error of ± 2.3 to $\pm 3.4\text{cm}$ was obtained. Moreover, we have to realise that there appears to be a systematic deviation between the measurements of the different centres, which vary between 2-4cm (column 3 of table 4). The systematic errors observed are statistically significant and by far exceed the standard deviation of the mean.

Table 2:

Recapitulation of the precision of the photogrammetric model orientation, as communicated by the different Centres. The given parameters are the root mean square (r.m.s.) of the residuals in the control points in [cm] (columns 2,3,4) and the maximal residuals (columns 5,6,7) with the number of points in brackets (column 7). Attention is drawn to the residuals of Centre 2, which are considerably lower than for all other centres due to different weighting.

Restitution Centre (1)	R.M.S. residuals in cm			Maximum residual (absolute) in cm			
	σ_x	σ_y	σ_z	σ_x	σ_y	σ_z	
	(2)	(3)	(4)	(5)	(6)	(7)	
Test Area A1 10 signalized control points, 2 from terrestrial measurements and 8 from aerial triangulation							
Cen1	2.7	1.8	2.6	3.4	3.9	+4.0	(53610)
Cen2	1.0	0.7	0.4	1.5	1.1	-0.6	(!!!)
Cen4		2.4	1.4	4.0	5.0	± 2.0	
Cen5	2.8	1.7	2.2	4.0	3.0	± 5.0	
Test Area A2 10 signalised control points, 3 from terrestrial measurements and 7 from aerial triangulation							
Cen2	0.8	1.1	0.9	1.2	1.6	-1.8	(!!!)
Cen3	1.8	2.0	4.4	3.1	3.2	-8.3	(310)
Cen4		2.4	4.9	7.0	2.0	+8.0	(309)
Cen7	2.2	2.1	3.8	3.9	3.9	-7.8	(310)
Test Area B1 17 signalised control points, 2 from terrestrial measurements and 15 from aerial triangulation							
Cen3	2.3	2.9	2.6	3.5	5.9	-4.8	
Cen4		1.9	2.6	4.0	3.0	+5.0	
Test Area B2 16 signalised control points, 3 from terrestrial measurements and 13 from aerial triangulation							
Cen1	3.2	4.4	4.4	5.8	10.4	+11.4	(477030)
Cen4		2.5	6.8	4.0	4.0	+9.0	(477080)
Cen5	2.9	1.9	3.6	7.0	4.0	-7.0	(728)
Cen6		2.7	5.5	3.8	5.6	-9.0	(733)
Test Area C1 16 signalized control points, 1 from terrestrial measurements and 15 from aerial triangulation							
Cen1	1.3	2.0	3.0	3.1	3.8	+6.0	
Cen4		1.9	4.3	5.0	4.0	+7.0	
Cen6		2.0	3.4	3.9	4.2	-5.2	

Table 3:

Residual height errors on specific control points, as they were observed by the different centres. One remarks the consistency of the height deviations in distinct control points.

Height residuals in cm observed by the different plotting centres						
Model, point	Cen1	Cen4	Cen5	Cen6	Mean deviation Δ	Standard deviation σ
B2 / 728	-7.8	-8.0	-7.4	-4.6	-6.9	1.4
B2 / 733	-5.9	-8.0	-4.0	-9.0	-6.7	1.9
C1 / 111123	-3.6	-4.0	-	-5.2	-4.2	0.7

4.2.2 Precision analysis of the grid points

The other group of check points, intended for the precision analysis of the interpolated DTM, are the grid points. The centres were asked to measure a terrain point every 25m, the location of which was defined by co-ordinates. This type of points finally proved far more efficient, as these points are scattered all over the test area, whereas easily identifiable points are by definition in rather easy terrain and not really representative. The mean of the individual point measurements of the various restitution centres then served as height values of the check points used for the subsequent precision analysis.

3-4 centres have supplied the measurements for the various test sites and table 5 again gives a precision analysis of the data. The aim was to receive four data sets of each test area. Unfortunately, the test areas B1 and B2 were dealt with by only 3 centres and C1 only by two. Centre 6 didn't measure the grid points.

In analysing the spread of the measurements, we realise that the distinct terrain points show a much lower r.m.s. error then the grid points. In easy terrain (A1 and A2) the difference of precision is about 20-30%, whereas in rough terrain (B2 and C1) the precision of the grid points diminished up to a factor of 3. This indicates that the precision of the photogrammetric observation is dependent on the roughness of the terrain.

The systematic errors of the height measurements are also somewhat larger then for the distinct points. However, it does not seem possible to give a plausible explanation for this fact.

Table 4:

Estimated spread of the measurements of the distinct terrain points; the given values are the root mean square error (column 2), the mean of the residuals (column 3), designated as systematic errors and the standard deviation or relative error after subtraction of the systematic component. In column 5 we indicate the maximum relative error (in terms of positive and negative signs); no residuals are larger than 3 times the standard deviation

Festification centre	Errors in cm				Number of deviations
	Root mean square of observations	Systematic deviations	Standard deviation	Maximum deviation	
	m	Δ	σ		
(1)	(2)	(3)	(4)	(5)	(6)
Test Area A1	Measured check points = 41				
Cen1	3.2	-1.9	2.6	3 / -9	0
Cen2	2.8	-0.6	2.7	6 / -7	0
Cen4	4.5	2.5	2.4	11 / -6	0
Test Area A2	Measured check points = 34				
Cen2	2.5	1.0	2.3	7 / -3	0
Cen3	2.4	-0.6	2.3	4 / -6	0
Cen4	3.1	-0.3	3.1	8 / -5	0
Test Area B1	Measured check points = 50				
Cen3	4.8	3.4	3.4	10 / -3	0
Cen4	4.8	-3.4	3.4	3 / -10	0
Test Area B2	Measured check points = 41				
Cen1	3.9	2.3	3.1	7 / -4	0
Cen4	3.9	-2.3	3.1	4 / -7	0
Test Area C1	Measured check points = 54				
Cen1	3.5	1.0	3.4	9 / -6	0
Cen4	3.5	-1.0	3.4	6 / -9	0

Table 5:

Recapitulation of the measuring precision in the grid points (spacing 25m), as they were measured by the different centres, with reference to the mean value of all measurements. The values presented are the mean square error (column 2), the mean of the residuals (column 3) and the standard deviation derived from the mean square error after reduction of the systematic component. Column 5 indicates the maximum relative error; furthermore, the number of residuals exceeding the standard error by a factor of 3 and 4 is also given. All values are in [cm]; the indicated point number is the maximal possible number, however not all centres measured all points.

Restitution Centre (1)	Errors in cm				Errors greater than	
	m_{obs} (2)	Δ_{obs} (3)	σ_{obs} (4)	Maximum error (5)	$3\sigma_{obs}$ (6)	$4\sigma_{obs}$ (7)
Test Area A1 Slopes up to 15%; Terrain Type = smooth, weakly inclined; 300 points						
Cen1	4.8	-2.9	3.8	13 / -36	1	1
Cen2	4.0	-1.9	3.5	25 / -9	3	2
Cen4	4.6	2.6	3.8	19 / -56	3	2
Cen5	4.0	2.2	3.3	26 / -13	2	1
Test Area A2 Slopes up to 40% Terrain Type = smooth, strongly inclined; 233 points						
Cen2	3.4	0	3.4	7 / -40	2	2
Cen3	3.4	0.5	3.3	30 / -10	1	1
Cen4	3.1	1.4	2.8	20 / -7	2	1
Cen7	3.0	-1.9	2.3	11 / -7	2	0
Test Area B1 Slopes up to 35% Terrain Type = rolling, weakly inclined; 316 points						
Cen3	7.0	5.2	4.7	37 / -8	2	2
Cen4	5.4	-3.0	4.5	10 / -18	1	0
Cen5	5.5	-2.2	5.0	8 / -28	3	1
Test Area B2 Slopes up to 105%; Terrain Type = rolling, strongly inclined; 213 points						
Cen1	9.4	-3.6	8.7	60 / -11	3	2
Cen4	11.4	7.9	8.2	18 / -63	10	7
Cen5	7.6	-4.3	6.3	36 / -40	6	3
Test Area C1 Slopes up to 75%; Terrain Type = rough, weakly inclined; 145 Points						
Cen1	9.5	1.4	9.4	59 / -48	4	3
Cen4	9.5	-1.4	9.4	48 / -59	4	3

5 Precision Analysis of Interpolated Points

5.1 DTM Computation with the Terrain Analyst of Intergraph

An important part of this study was the precision analysis of interpolated points. The centres delivered the DTM measurements in the form of mass points, break lines, form lines and “dead areas”; these are exclusion zones in which photogrammetric measurements are not possible with the predefined precision or zones which are not presented with the DTM like houses. The dead areas were surrounded by polygons. A detailed discussion of the specific conception of the DTM measurements by the different plotting centres will be given later. In a first phase it appeared important to get an overview of the obtained precision. As the DTM software package Terrain Analyst, a module of the Intergraph MGE environment, was commonly used by the pilot centre, it appeared logical to use this package for a first assessment of the data. More details on the specific software package are given in the next section.

The main criteria for the performance analysis is the precision of the interpolated grid points. Other arguments are the manner and efficiency of the terrain capture as well as an assessment of the size of the excluded zones (dead areas). On average, some 200 to 300 grid points were measured in the various test areas with the exception of C1; in that test area only 100 points were available. Lets stress again, that the check points were only determined by photogrammetric measurements that there was no absolute control available.

From the means of the grid points we computed the root mean square errors of the individual deviations (m); however, it quickly became apparent that considerable systematic deviations were observed as already indicated earlier. Consequently, we also computed the mean of the residuals (Δ) and the remaining standard deviation after the reduction for the systematic component:

$$\text{Relative error} \quad \sigma = \sqrt{\left[\sum \frac{(l - \Delta)^2}{n - 1} \right]} \quad l = \text{deviations between interpolated height and check point height}$$

It is also of interest to highlight possible blunders; that means residuals exceeding 3 or 4 times the standard deviation. Furthermore, the maximum residuals are shown, along with the number of triangles formed by the software package according to the Delaunay triangulation.

The results of the precision analysis using the "Terrain Analyst" of Intergraph are given in table 6. However it should be noted that the results are not directly comparable, as the individual centres eliminated different zones considered as dead areas. Consequently, the number of check points varies from one centre to the other: it is understood that a centre which tried to measure in difficult areas also might obtain a lower precision than one which limited itself to easy areas. In order to obtain comparable results, we defined a set of check points which was used by all participants and re-computed the table (cf. table 7).

The calculations show that for the areas A1, as well as for A2 and B1, a standard deviation of ± 7 to ± 12 cm was reached, whereas for the rough terrain B2 and C1 we have values between ± 14 and ± 30 cm. Furthermore, a systematic component of 5-10cm showed up, which is independent of the terrain type.

Table 6:

Precision analysis of the height of the grid points (spacing 25m) interpolated with Terrain Analyst in comparison with the measured height (mean square error of all measurements). The values presented are the root mean square error (column 2), the mean of the residuals (column 3) and the standard deviation derived from the mean square error after reduction of the systematic component (column 4). Column 5 indicates the maximum error; furthermore the number of residuals exceeding the standard error by a factor 3 and 4 are given; all values are in [cm]. The number of measured points is given in column 9 and column 10 shows the percentage with respect to the total number of points. For test area B2 two values are shown for Centre 4; the first value was obtained after eliminating additional zones as dead areas, in the following we refer only to this value, although it does not correspond with the values of the other centres.

Restitution Centre	Errors in cm				Errors greater than		Number of Triang- les	Checkpoints within the area	
	m_{TA}	Δ_{TA}	σ_{TA}	Max. error (abs)	$3\sigma_{TA}$	$4\sigma_{TA}$		Num- bers	% of the total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Test Area A1									
Slopes up to 15%; Terrain Type = smooth, weakly inclined; Total Check Points = 300									
Cen1	9.2	-6.0	7.0	35	1	0	15'344	298	99
Cen2	7.5	-4.0	6.4	35	2	1	12'399	293	98
Cen4	12.1	5.8	10.6	40	1	0	14'314	288	96
Cen5	13.0	6.9	11.1	40	1	0	4'963	299	100
Test Area A2									
Slopes up to 40% Terrain Type = smooth, strongly inclined; Total Check Points = 233									
Cen2	10.2	0.0	10.2	93	4	2	13'625	232	100
Cen3	11.6	-5.1	10.3	39	1	1	10'241	231	99
Cen4	11.8	0.1	11.7	65	3	1	9'025	224	96
Cen7	12.3	-9.9	7.2	53	1	0	33'841	228	98
Test Area B1									
Slopes up to 35% Terrain Type = rolling, weakly inclined; Total Check Points = 316									
Cen3	11.4	0	11.4	58	1	0	12'584	316	100
Cen4	10.2	-4.1	9.3	55	3	2	19'981	315	100
Test Area B2									
Slopes up to 105%; Terrain Type = rolling, strongly inclined; Total Check Points = 213									
Cen1	29.6	7.8	28.5	181	1	1	11'039	209	98
Cen4	14.0	5.8	12.7	50	2	0	13'500	181	85
(Cen4*)	27.7	8.5	26.4	181	6	2	11'477	205	96
Cen5	31.7	-7.1	30.9	157	4	1	4'692	207	97
Cen6	22.0	1.6	21.9	113	3	1	7'453	201	96
Test Area C1									
Slopes up to 75%; Terrain Type = rough, weakly inclined; Total of Check Points = 145									
Cen1	17.7	7.7	16.0	61	0	0	18'125	128	88
Cen4	23.8	-5.5	23.2	192	2	1	10'479	141	97
Cen6	21.1	1.7	21.1	148	2	1	10'235	143	98

Table 7:

Precision of point interpolation with Terrain Analyst using a uniform set of grid points as check for all plotting centres. Otherwise the same explications as for table 6, only in column 8 we indicate the mean point distance instead of the number of triangles.

Restitution Centre	Errors in cm				Errors greater than		Mean Point dist. in meter	Checkpoints within the area	
	m_{TA}	Δ_{TA}	σ_{TA}	Max. Error	$3\sigma_{TA}$	$4\sigma_{TA}$		Num- bers	% of the Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Test Area A1 Slopes up to 15%; Terrain Type = smooth, weakly inclined; Used Check Points = 282									
Cen1	8.9	-6.1	6.5	25	1	0	5.4	282	100
Cen2	7.4	-4.1	6.2	31	1	1	6.0	282	100
Cen4	12.1	5.8	10.6	28	0	0	6.8	282	100
Cen5	13.0	6.8	11.2	44	1	0	9.4	282	100
Test Area A2 Slopes up to 40% Terrain Type = smooth, strongly inclined; Used Check Points = 219									
Cen2	7.8	0.0	7.8	44	2	1	5.1	219	100
Cen3	11.3	-5.1	10.1	66	2	1	6.0	219	100
Cen4	11.5	1.1	11.4	65	3	1	5.8	218	100
Cen7	12.3	-9.9	7.3	43	1	1	3.0	219	100
Test Area B1 Slopes up to 35% Terrain Type = rolling, weakly inclined; Used Check Points = 315									
Cen3	11.4	0	11.4	58	1	0	5.9	315	100
Cen4	9.9	-3.1	9.4	60	2	1	4.3	315	100
Test Area B2 Slopes up to 105%; Terrain Type = rolling, strongly inclined; Used Check Points = 175									
Cen1	25.4	7.8	24.1	85	2	0	5.8	179	100
Cen4	15.1	7.5	13.1	51	3	1	4.1	179	100
Cen5	27.9	-4.1	27.7	121	4	1	9.2	179	100
Cen6	19.6	1.5	19.4	88	4	1	8.2	175	98
Test Area C1 Slopes up to 75%; Terrain Type = rough, weakly inclined; Used Check Points = 124									
Cen1	17.5	8.3	15.4	53	0	0	3.4	124	100
Cen4	16.9	-6.6	15.6	89	1	1	4.0	124	100
Cen6	15.0	2.9	14.7	48	1	1	4.8	124	100

5.2 Comparison of Different DTM Software Packages

The precision of an interpolated point depends on the measurements of the terrain features and on the interpolation technique used by the DTM-software package. A great number of DTM-packages are in use in the different engineering firms and mapping centres. Currently in Switzerland, Intergraph software packages (Terrain Analyst, Site-Work and Modelar), CIP (Leica), C-Plan (Pöpping, Switzerland), Moss (England) and Macao (France) are largely used in engineering projects. It was not possible within the frame of this study to make an extensive analysis of the different DTM-packages and we refer here to an earlier study by the co-author (cf. [5]). The main result of this comparative study was that the standard deviation of interpolated points is rather uniform, except when using simplified algorithms like a weighted mean. The main difference is observed regarding the number of large errors three times in excess of the standard deviation. For a rather rough area algorithms using plane interpolation yielded about 3-4% of blunders whereas algorithms with bicubic interpolation (like MOSS and C-Plan) showed only about 2% of blunders, which means about 30% less than when using a plane interpolation. However the data for the terrain approximation used for the OEEPE test are much more consistent and show considerable less blunders than in the above mentioned analysis.

In order to ensure in this study too that the precision analysis would be representative, we used three software packages in all:

- Terrain Analyst by Intergraph;
- SCOP developed by Ackermann-Kraus;
- CIP developed by Wild (Steidler).

5.2.1 Terrain Analyst (TA)

The Terrain Analyst is distributed by Intergraph within their MGE software package, providing a triangulation within all measured height points; the height of an interpolated point is computed by a bi-linear interpolation within the triangle surface. The break lines are taken into account for the triangulation, a smoothing for measuring errors in the support points is not possible.

5.2.2 SCOP

The DTM-package SCOP was developed at the Universities Stuttgart and Vienna, using the collocation for point interpolation, after a rough terrain interpolation by a grid model. Depending on the choice of the correlation function and the random component, one obtains a smoothing effect of the measuring points. The collocation would also allow one to compute the precision of an interpolated point; however, this option is not implemented in the program. At break lines and dead areas, the collocation is interrupted. The computation was performed by the firm Aviosoft, based in Berneck, Switzerland.

5.2.3 CIP

The "Contour Interpolation Program" CIP was developed by Wild (today Leica) in the eighties, but is no longer supported. The CIP program is characterised by Steidler [6] as follows: 'Construction of a triangular net by the procedure proposed by Delaunay. Surface

normals are computed at each node or vertex. The surface is defined by Zienkiewicz functions which include all neighbouring points and the normals are computed from tangent planes, derived from a least-square fit'.

The program also uses a triangulation, based on the break lines and mass points. The form function of the finite elements, meaning the triangles, is however a bicubic parable; for the computation of the form parameter, one also uses the tangents to the terrain surfaces computed in the supporting points by an approximation. The surface normal is computed by passing an approximation plane through the surrounding support points within a predefined distance specified by the longest triangle side going through the point under consideration. CIP also allows the use of structure lines, meaning break lines, which do not have sharp edges that have to be rounded off; smoothing is not possible.

5.2.4 Comparison of the precision of point interpolation

Table 8 gives an overview of the precision of point interpolation. One notes that the differences between the three DTM-packages are rather small and it would be difficult to decide which of the packages gives better results. The SCOP-package gives a great variety of free parameters to the user, especially regarding the choice of the correlation function and the smoothing effect. When applying an a priori error of the height measurements equal to 0.1 ‰ of the flying height ($\pm 7\text{cm}$) we obtained a considerably lower precision in the interpolated points, that means a higher r.m.s. value, than when reducing the a priori error to only 0.02‰ equal to $\pm 1\text{cm}$. This means that practically no smoothing was applied.

As already mentioned there are also only small variations between the three packages in terms of the gross errors (cf. table 9) and it would be difficult to confirm in this context that a non linear interpolation would be preferable. Consequently, we can state that it would be difficult to find a software package which can supply significantly better results for the test data then obtained by the Terrain Analyst by Intergraph and the further analysis can be based on the results obtained with this software package. The user interface for the Terrain Analyst is also very comfortable and appeared superior to the other packages at least at the time when running the computations (1997).

6 Analysis of the specific terrain capture of the plotting centres

In the following illustrations we try to present the specific manner of the terrain capture of the different plotting centres. We present a plot of the break lines, form lines and the delimitation of dead areas; we also give a plot of the triangulation produced by the Terrain Analyst in order to show the structure of the finite elements used for interpolation. Furthermore we present the residuals of terrain approximation in the "grid points". All these plottings are superimposed on to the orthophotos of the test areas, which allow one to evaluate the procedures chosen by the different centres. These figures are complemented by a verbal characterisation of the measuring procedure with some indications concerning the precision obtained. Summary statistics of the number of points used for the different point and line elements are also given for the various test sites.

Table 8:

Comparison of the precision of interpolated points computed with different software packages (SCOP Terrain Analyst and CIP). Different configurations of dead areas have been used in Test Area B2 for Centre 4 in ¹⁾ and ²⁾.

Restitu- tion Centre (1)	Mean Square Error m			System. Comp. Δ			Standard. dev. σ		
	TA (2)	SCOP (3)	CIP (4)	TA (5)	SCOP (6)	CIP (7)	TA (8)	SCOP (9)	CIP (10)
Test Area A1 Slopes up to 15%; Terrain Type = smooth, weakly inclined; Total Check Points = 300									
Cen1	9.2	10.2	9.7	-6.0	-6.2	-6.5	7.0	8.1	7.2
Cen2	7.5	7.6	7.6	-4.0	-4.3	-4.2	6.4	6.2	6.3
Cen4	12.1	11.8	12.1	5.8	5.6	5.8	10.6	10.4	10.6
Cen5	13.0	13.0	12.9	6.9	6.5	6.8	11.1	11.3	10.9
Test Area A2 Slopes up to 40%; Terrain Type = smooth, strongly inclined; Total Check Points = 233									
Cen2	10.2	9.4	9.8	0.0	0.0	0.0	10.2	9.4	9.8
Cen3	11.6	11.1	11.8	-5.1	-4.9	-5.4	10.3	9.9	10.5
Cen4	11.8	11.0	13.9	0.1	0.1	0.0	11.7	10.9	13.9
Cen7	12.3	13.3	13.8	-9.9	-10.8	-10.7	7.2	7.7	8.7
Test Area B1 Slopes up to 35%; Terrain Type = rolling, weakly inclined; Total Check Points = 316									
Cen3	11.4	10.8	11.0	0.0	0.0	0.0	11.4	10.8	11.0
Cen4	10.2	9.2	9.8	-4.1	-2.3	-2.7	9.3	8.7	9.4
Test Area B2 Slopes up to 105%; Terrain Type = rolling, strongly inclined; Total Check Points = 213									
Cen1	29.6	30.6	28.4	7.8	7.3	6.6	28.5	29.1	27.6
Cen4	27.6 ²	13.9 ¹	26.8 ²	5.8	5.5	8.2	12.7	12.8	25.5
Cen5	31.7	28.1	32.1	-7.1	-5.4	-6.1	30.9	27.6	31.5
Cen6	22.0	24.5	24.6	1.6	-1.2	0.1	21.9	24.5	24.6
Test Area C1 Slopes up to 75%; Terrain Type = rough, weakly inclined; Total of Check Points = 145									
Cen1	17.7	20.4	22.1	7.7	6.6	8.3	16.0	19.3	20.5
Cen4	23.8 ¹	20.7 ¹	29.6 ²	-5.5	-5.6	-9.7	23.2	19.9	28.0
Cen6	21.1	21.1	21.3	1.7	0.0	1.0	21.1	21.1	21.3

Table 9:

Comparison of the extreme interpolation errors for the 3 DTM software packages: Terrain Analyst - SCOP – CIP.

Restit Centre	Terrain Analyst					SCOP					CIP				
	Min	Max	>3x	>4x	points	min	max	>3x	>4x	points	min	max	>3x	>4x	points
A1															
Cen1	- 19	+ 35	1	0	298	- 40	+ 34	2	1	289	- 24	+ 29	1	0	293
Cen2	- 17	+ 35	2	1	293	- 27	+ 30	1	0	300	- 18	+ 29	2	0	293
Cen4	- 40	+ 34	1	0	288	- 45	+ 1	1	0	293	- 40	+ 37	2	0	289
Cen5	- 40	+ 28	1	0	299	- 29	+ 46	1	0	300	- 32	+ 48	1	0	294
A2															
Cen2	- 33	+ 93	4	2	232	- 18	+ 88	3	1	233	- 21	+ 93	3	2	219
Cen3	- 39	+ 34	1	1	231	- 44	+ 50	2	1	233	- 49	+ 67	3	1	226
Cen4	- 65	+ 40	3	1	224	- 51	+ 35	3	1	224	- 67	+ 45	5	2	226
Cen7	- 17	+ 53	1	0	228	- 72	+ 11	3	1	229	- 71	+ 41	2	1	231
B1															
Cen3	- 58	+ 33	1	0	316	- 52	+ 33	2	1	316	- 58	+ 33	2	1	303
Cen4	- 55	+ 45	3	2	315	- 33	+ 35	1	0	315	- 48	+ 36	2	0	306
B2															
Cen1	- 181	+111	1	1	209	- 163	+105	2	1	207	- 183	+109	2	1	207
Cen4	- 50	+ 41	2	0	181	- 45	+ 46	1	0	179	- 03	+241	4	2	205
Cen5	- 157	+ 81	4	1	207	- 120	+ 62	3	1	207	- 113	+167	5	2	210
Cen6	- 113	+ 86	3	1	201	- 149	+ 78	3	1	207	- 114	+ 91	4	1	206
C1															
Cen1	- 61	+ 45	0	0	128	- 101	+ 47	2	1	129	- 69	+123	4	2	144
Cen4	- 83	+192	2	1	141	- 81	+136	3	2	141	- 175	+112	6	1	141
Cen6	- 148	+ 56	2	1	143	- 145	+ 29	4	2	145	- 143	+ 59	2	1	141



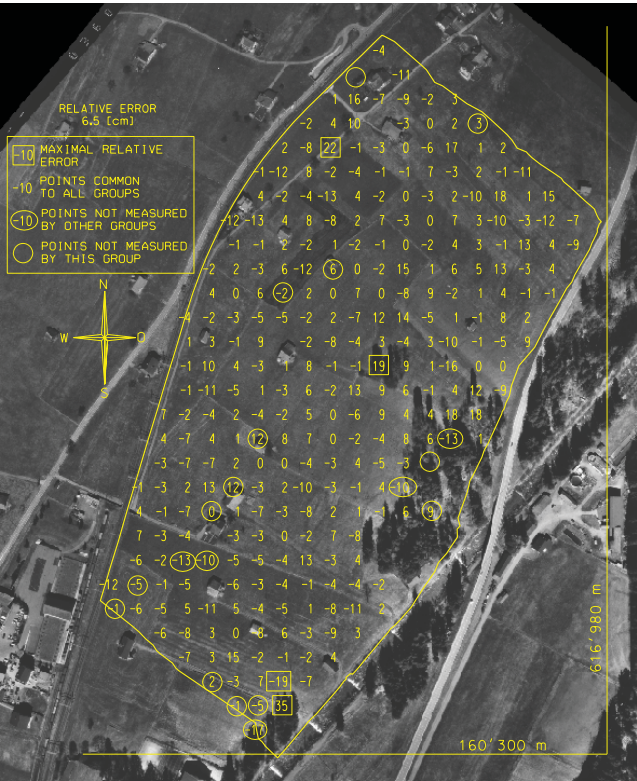
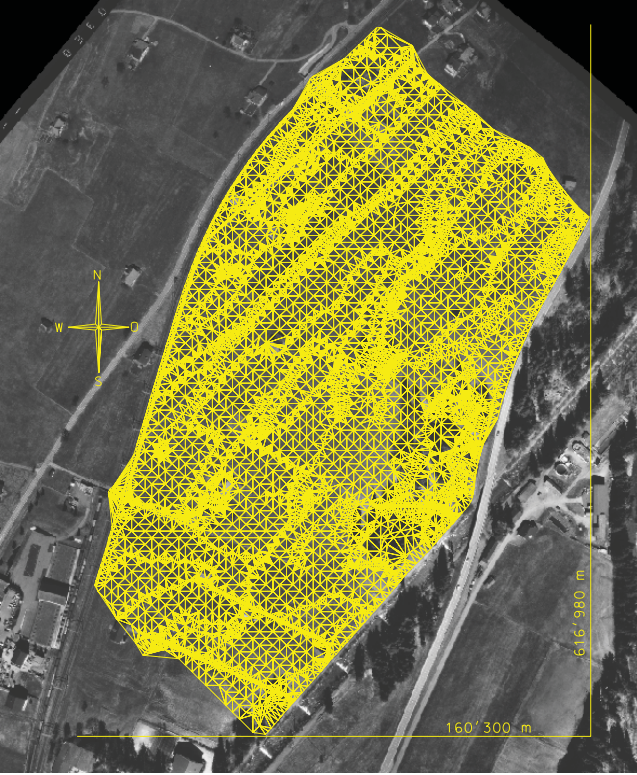
Figure 12:

Test area A1 “smooth, weakly inclined”, measured by Centre 1, Vienna. Presented are the orthophoto with the break lines, structure lines and dead areas (above¹⁾), the orthophoto with Delaunay triangulation (opposite page, above¹⁾), the orthophoto with the numerical values of the residuals in the 25m spaced grid points (opposite page, below¹⁾) and a description of the main characteristic of the measurements and of the precision analysis.

This centre measured a regular grid with a mesh width of 10m; in all some 2000 grid points were measured. Additionally, some 100 spot heights of characteristic terrain points were determined. This point configuration was completed by ample break lines and structure lines in the open terrain over a length of 9km. The centre measured 7911 points in all, the maximum number for this test area. The number of points on line elements is high, above 70%. The mean point distance in open terrain is 5.4m, or 343 points per ha. No areas were marked as dead zones and the small forest to the east of the test area has also been modelled.

The precision obtained of $\pm 6.5\text{cm}$ (standard deviation in the grid points after reduction of a systematic component) is high, although a systematic error of -6.1cm was determined. The precision on the check points is very homogeneous, a maximum error of 35cm is found in the S-E part of the test area on the very edge, whereas the errors in the inner part remain under 16cm.

¹⁾ Figures 13 to 28 likewise arranged.



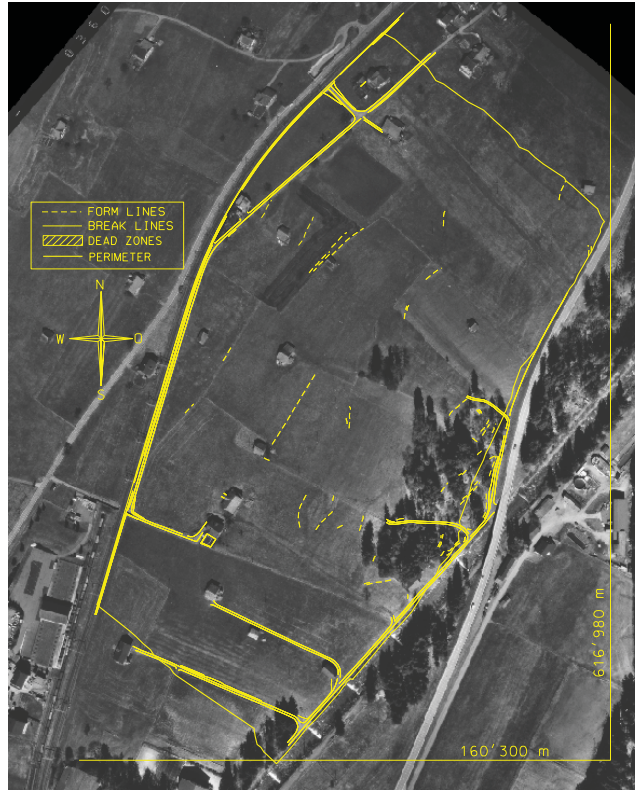


Figure 13:

Test area A1, "smooth, weakly inclined", measured by Centre 2, Uni. Tampere.

This centre used the adaptive sampling approach and measured more than twice as many mass points (5152) than Vienna (Centre1). On the other hand, few characteristic lines were plotted, only break lines along the roads and very few structure lines in the open terrain. No zones were marked as dead areas. About 18% of the points are on lines of a total of 6284 or 305 points per ha. No dead areas were designated.

This centre obtained the best result on the check points with a standard deviation of $\pm 6.2\text{cm}$; the systematic error component is small, at -4.1cm . The precision on the check points is very homogeneous, maximum deviations of 35cm are observed on the periphery, whereas the check points in the inner part do not show errors larger than 10cm.

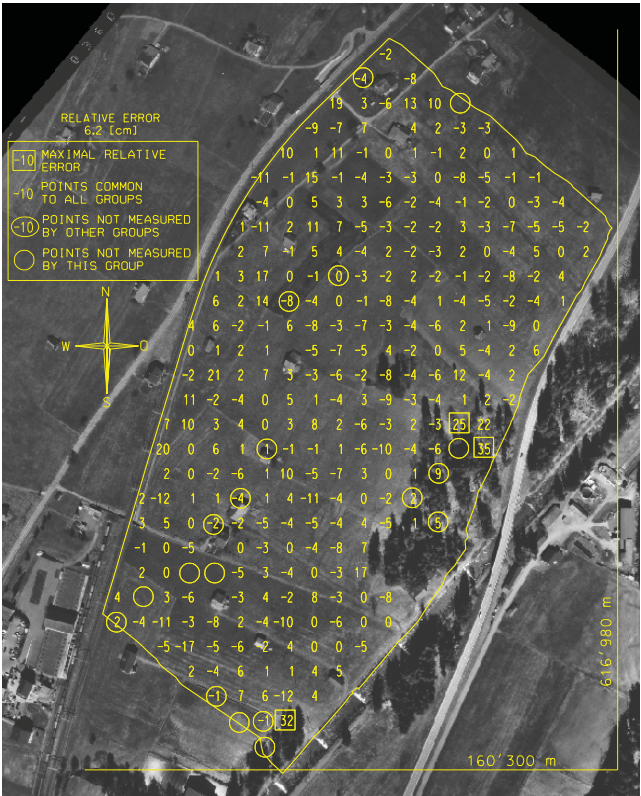
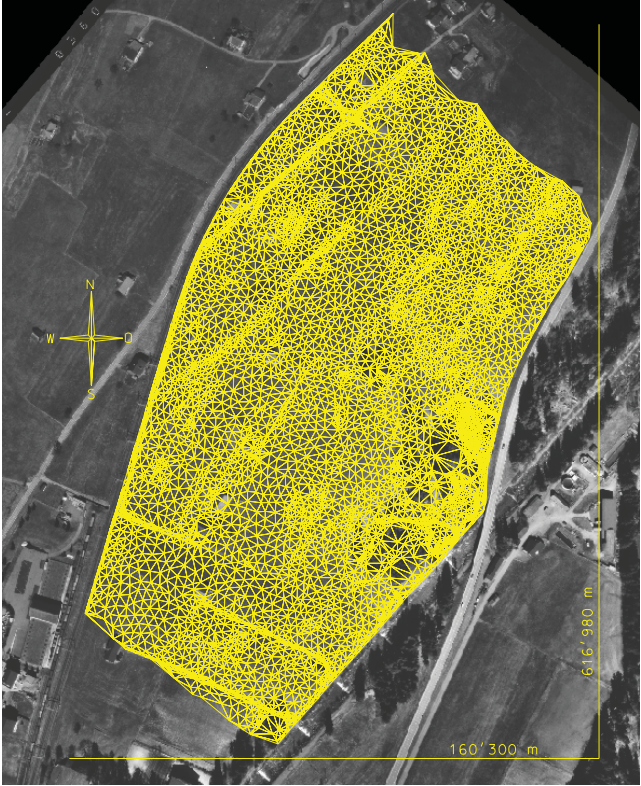




Figure 14:

Test area A1, "smooth, weakly inclined", measured by Centre 4, Flotron.

This centre chose a profiling mode for the location of the grid points. The average distance of the profiles is 12m; only in the southern part were the profiles placed much denser, up to 4 m; the point distance varies between 4-12m, selected by the operator according to the terrain requirements. In total 1688 mass points were measured. Moreover, the open terrain was approximated by break lines and structure lines of a length of 6km; all roads were delimited as well as the building courtyards (4.8km); some 3196 points were measured on these lines, corresponding to 65% of the total points. The small forest and all houses were eliminated as dead zones. A total of 4884 points were measured. The mean point distance in open terrain is 6.8m or 219 points per ha.

The mean square error in the check points is $\pm 10.6\text{cm}$ with a systematic component of $+5.8\text{cm}$. Moreover, the model shows a small inclination in northern direction of about 8cm. The maximal errors in the check points are up to 40cm, including the central part of the model.

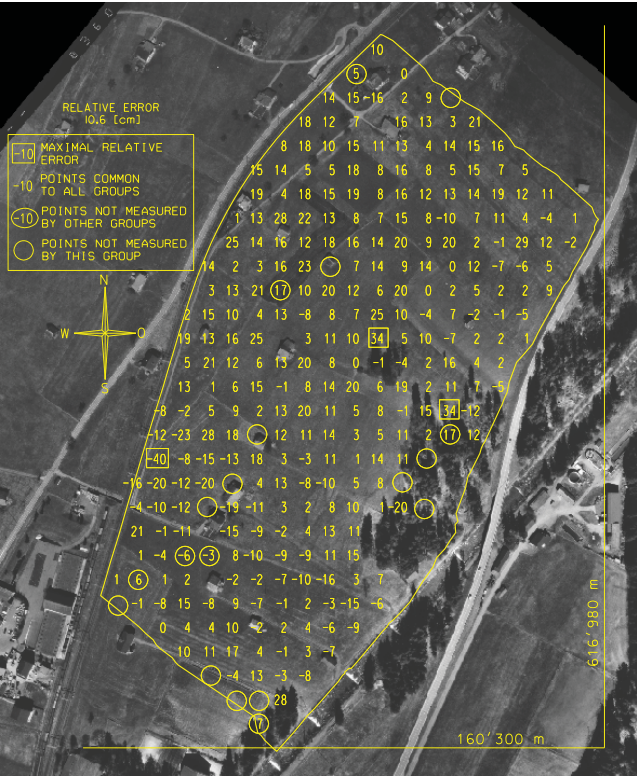




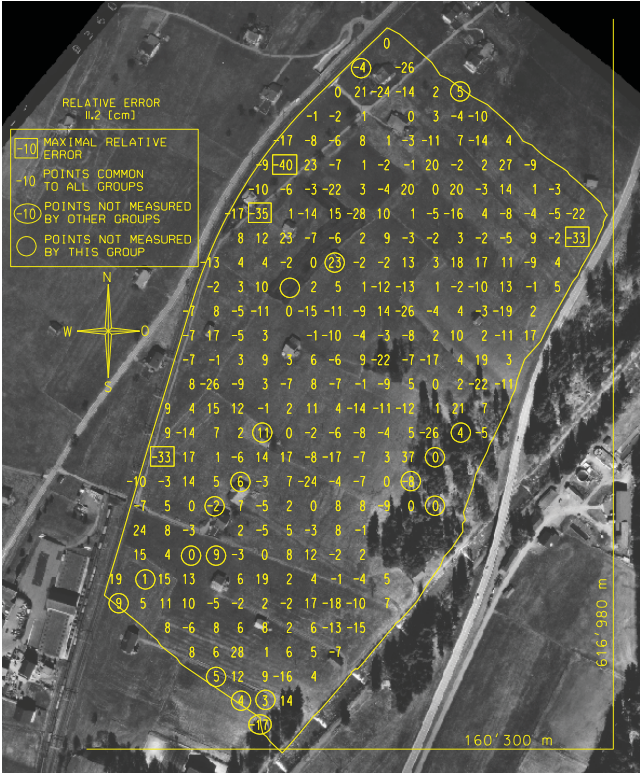
Figure 15:

Test area A1, “smooth, weakly inclined“, measured by Centre 5, Muttentz.

This centre measured the mass points according to the adaptive sampling technique. The number of mass points, at 1665, is very similar to Centre 2, Vienna and Centre 4, Flotron. Break lines (3.6km) were measured along the roads, along with a modest number of structure lines in open area (2.5km). In total 2639 points have been determined; the average point distance in open terrain is 9.4m or 114 points per ha. Buildings and the small forest were delimited as dead areas.

The relative precision on the check points is $\pm 11.2\text{cm}$ and very close to Centre 4. The systematic error component is $+6.8\text{cm}$.

The maximal residuals are 40cm on the periphery and up to 28cm in the inner part of the model.



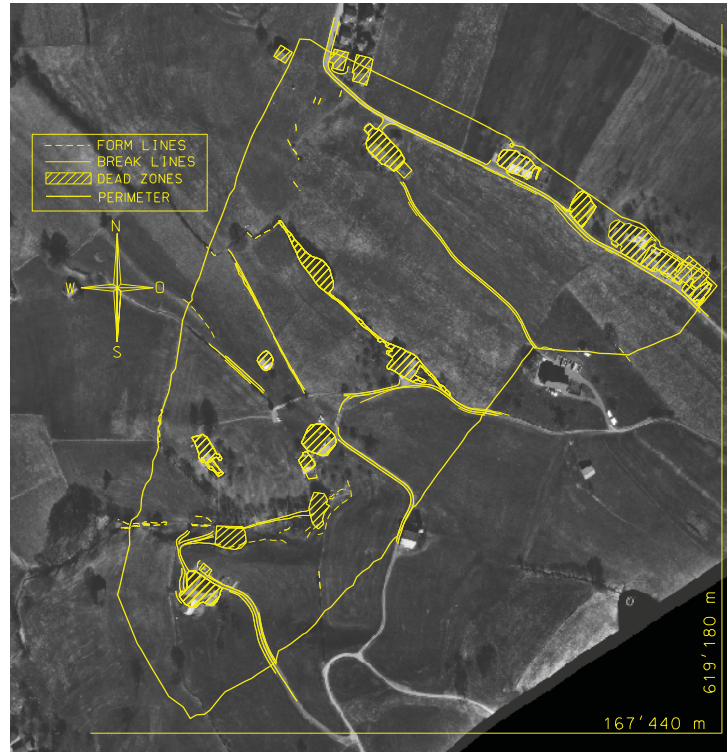


Figure 16:

Test area A2, "smooth, strongly inclined", measured by Centre 2, Uni. Tampere.

Again centre 2 applied the adaptive sampling approach and measured 5435 mass points. Only 150 points (3%) were measured on structure lines and 1268 points were measured on break lines along roads and building courtyards (21%). The centre measured in this way a total of 6853 points and reached in open area a point distance of 5.1m corresponding to 383 points per ha.

With a standard deviation of $\pm 7.8\text{cm}$, the centre obtained an excellent result, the systematic error component is zero. The largest residual of 93cm was observed on the periphery, whereas all other residuals remained under 50cm.

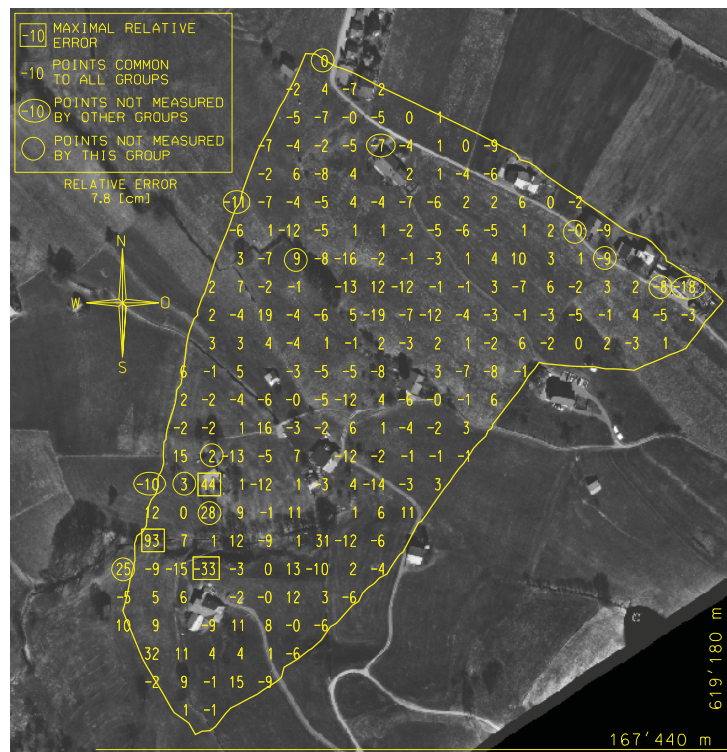
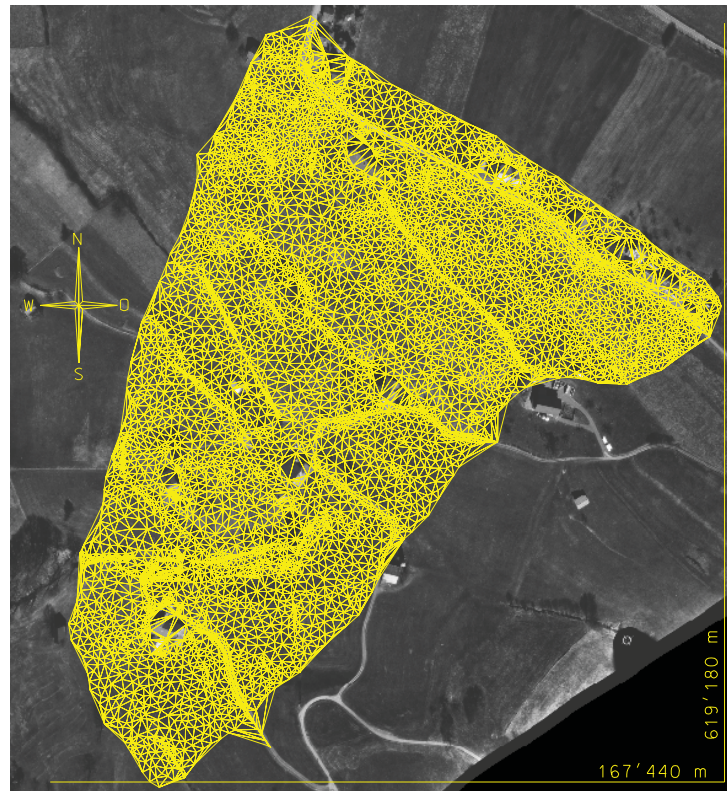




Figure 17:

Test area A2, "smooth, strongly inclined", measured by Centre 3, SITO Espoo.

This centre also worked with adaptive sampling, but measured only 2773 mass points. Another 1205 points were measured on structure lines in the natural terrain and 1270 points on break lines for the building delimitation of roads and building courtyards. No dead areas were indicated. The mean point distance was computed at 6.1m for open terrain and 2.9m for built-up areas; on average, 334 points per ha were measured.

The precision obtained on the check points is $\pm 10.1\text{cm}$, a value somewhat less favourable than the one of Centre 2, which also applied adaptive sampling but with a much higher number of points. The systematic error was determined at -5.1cm . The largest residual error is -39cm ; the centre consequently obtained a very homogeneous result.



Figure 18:

Test area A2, "smooth, strongly inclined", measured by Centre 4, Flotron.

This centre measured profiles with a distance varying between 4 and 12m; in total 3105 mass points were measured. In the southern part (open terrain) structure lines were measured over a length of 1.2km with a total of 1250 points. The traffic area was modelled by 2.2km of break lines with a total of 800 points. Nearly 40% of the total number of points lie on break lines. The small forest area and other difficult areas were designated as dead areas. The mean point distance is 5.8m or 300 points per ha.

The measurements show a precision of $\pm 11.4\text{cm}$ with a systematic component of only 1cm. The largest residual error is 65cm in the peripheral area and 30cm in the central part of the test area.





Figure 19:

Test area A2, "smooth, strongly inclined", measured by Centre 7, EPF-Lausanne.

This centre used a regular grid with a very dense mesh width of only 3m. This procedure required the measurement of 16,603 mass points. Break lines were measured only along roads and a few lines in the terrain (77 points). The buildings were measured along the roofs, to indicate them as dead areas. This caused some confusion during computation, as the dead areas had also been partly included as part of the terrain model. The precision of $\pm 7.3\text{cm}$ is very favourable as a function of the high point density. However these measurements show a large systematic component of -9.9cm . Furthermore, a systematic component resulting from a remaining error in model orientation of 10cm was determined, corresponding to an inclination of 0.15% . Two large residual errors of 53cm and 29cm are located, whereas all other check points are below 18cm ; the technique chosen led to very homogeneous terrain modelling.



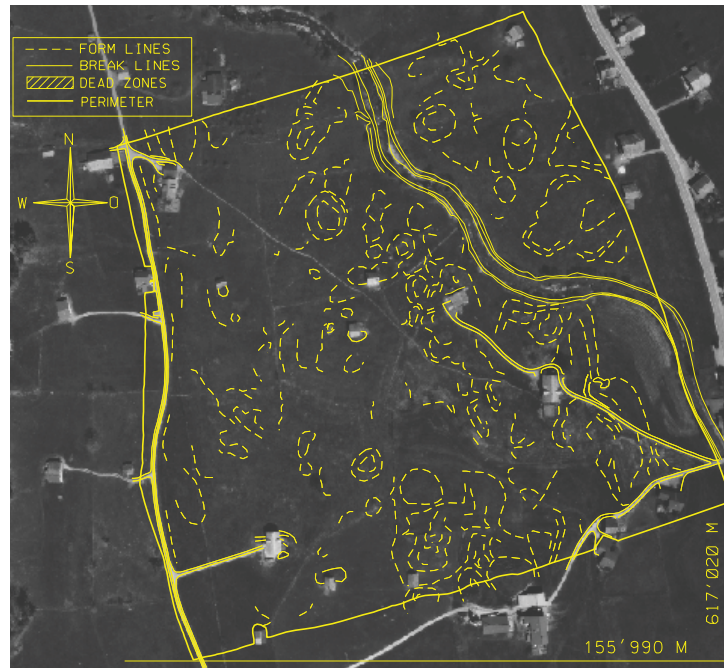


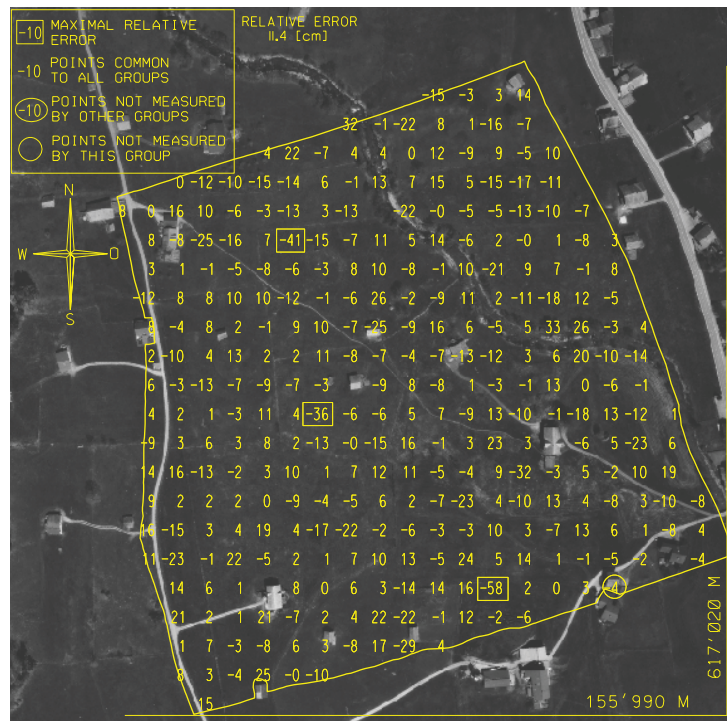
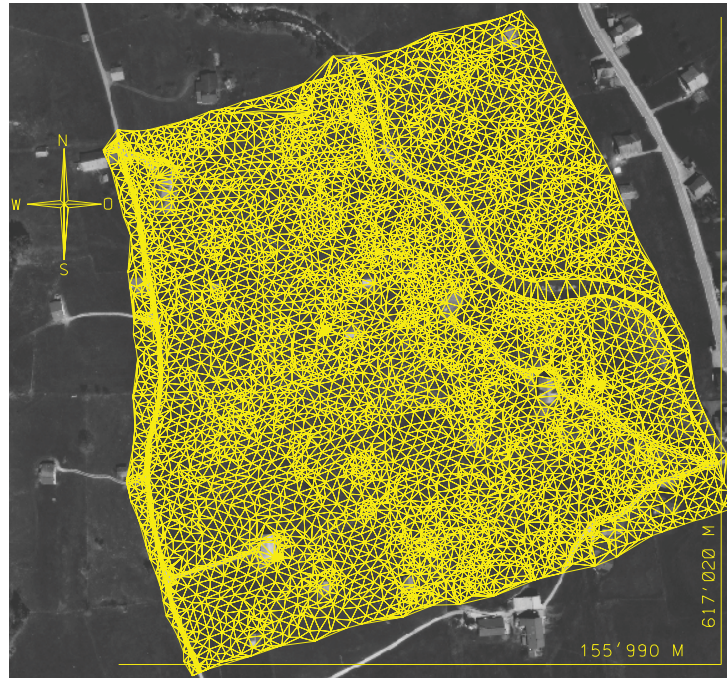
Figure 20:

Test area B1, "rolling, weakly inclined", measured by Centre 3, SITO-Finland.

This centre measured a fairly dense pattern of mass points (3695 points), according to the technique of adaptive sampling. Furthermore, some 2090 points were measured in open areas on structure lines and 586 points as break lines along roads. No dead areas were defined. The mean point distance was computed at 5.9m.

In spite of the rather irregular and moving terrain, a standard deviation of $\pm 11.4\text{cm}$ was reached. That is a value which corresponds to the much smoother areas A1 and A2. No systematic error components were observed.

The largest residual is four times in excess of σ_0 in a rolling area (58 and 41cm) and it is difficult to explain why this rather large error occurred.



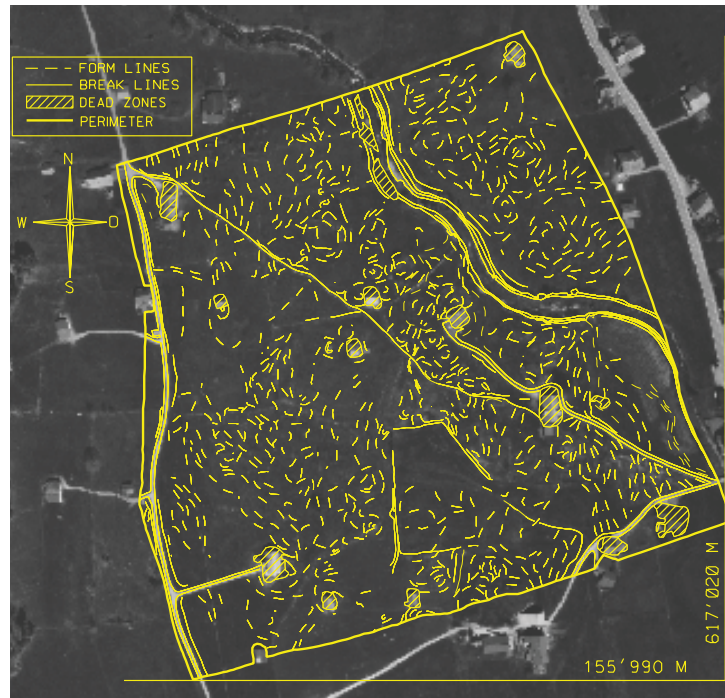
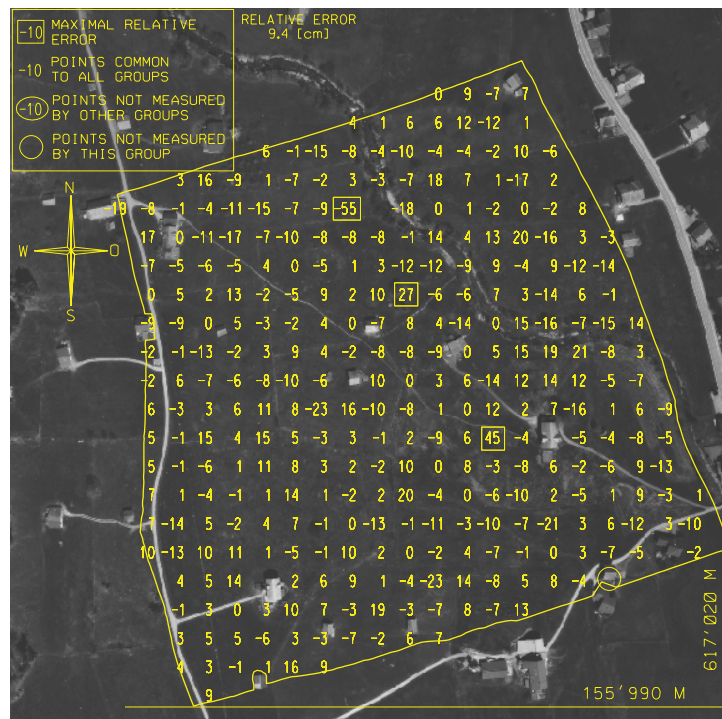
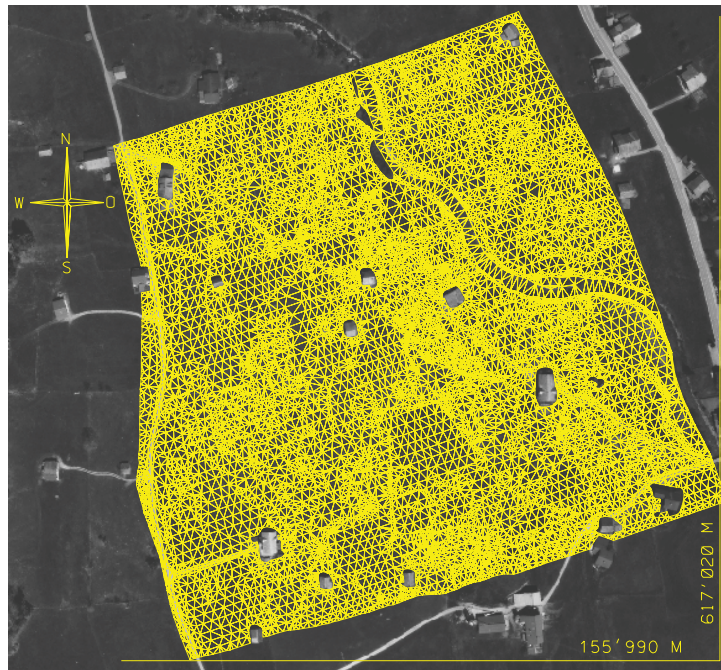


Figure 21:

Test area B1, "rolling, weakly inclined", measured by Centre 4, Flotron.

The measuring disposition of Centre 4 is similar to Centre 3; however, 3786 mass points were measured in this case according to a profiling mode, parallel to the south-eastern border of the area. The profile distance varies between 3 and 11m. Additionally in open terrain 6686 points on structure lines and break lines were measured. The roads were modelled with 650 points (2.6 km). Two small tree groups along the river Kander were delimited as dead areas.

The achieved standard deviation of $\pm 9.4\text{cm}$ is about 20% lower than of Centre 3. The largest residual is five times in excess of σ_0 in a rolling area (55 and 45cm) and again it is difficult to explain why these rather large errors occurred.



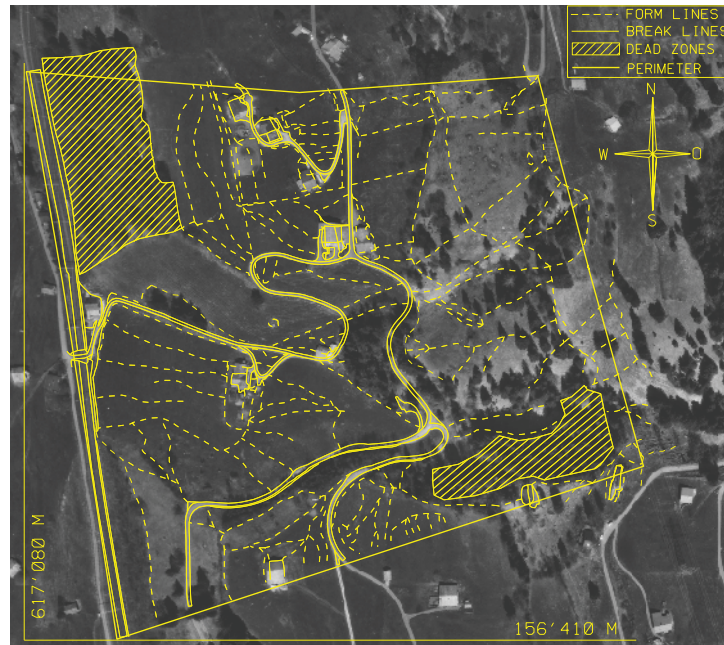


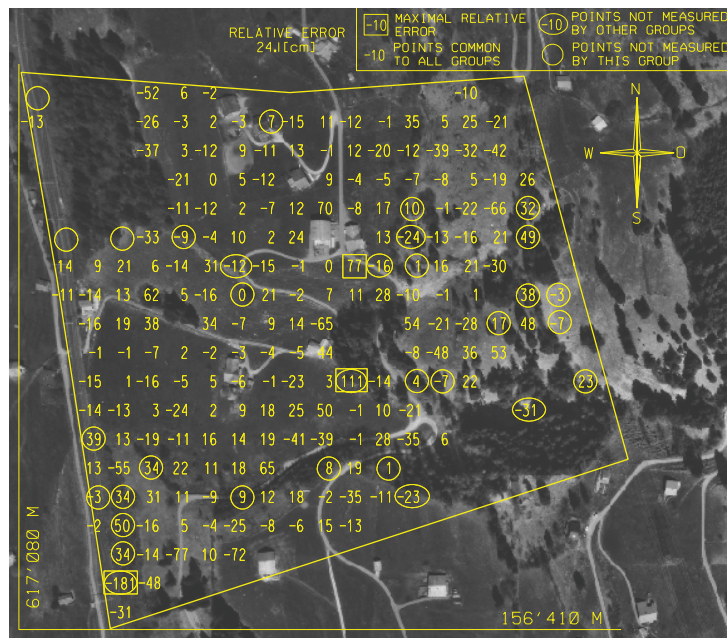
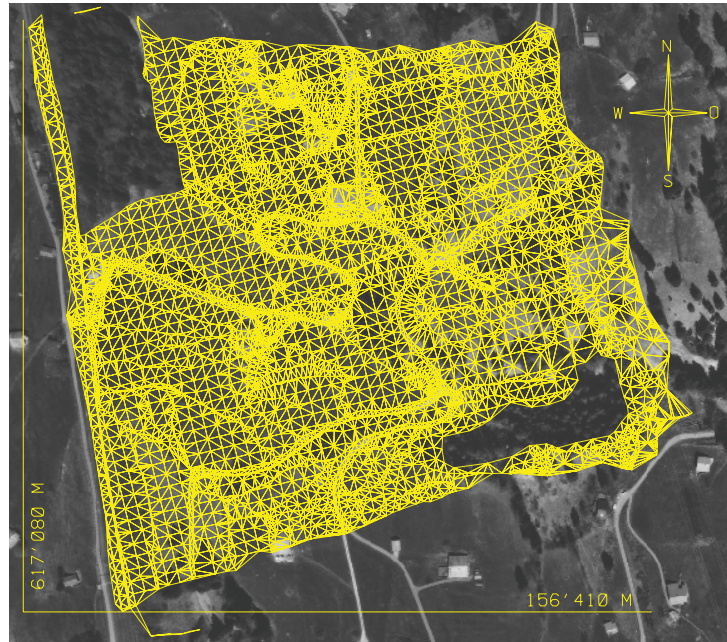
Figure 22:

Test area B2, "rolling, strongly inclined", measured by Centre 1, Vienna.

1538 mass points were measured, located in a regular grid with a mesh size of 10m. This grid was complemented by 155 spot heights located on singular terrain points. Additionally, some 14km of break lines and form lines were measured; nearly $\frac{3}{4}$ of the total measured points are on these lines, exactly 72%. The break lines delineate roads and rail roads with a total of 1400 points. Furthermore, 2871 points were measured as structure lines in the open terrain. Two small forests were designated as dead areas.

The precision achieved of $\pm 24.1\text{cm}$ is rather low and would mean that the Centre failed in this case to respect the general goal of the measurements. There is also a rather large systematic component of 7.8cm , which leads to a mean square residual error of $\pm 25.4\text{cm}$.

The largest residual errors are along the railroad (-181cm) and close to the forest areas ($+111\text{cm}$). When analysing the regression line as a function of the number of points measured and the mean square residual, we realise that these measurements are nearly 40% above the line (cf. table 16, column 7) and indicate that there has been a useless oversampling on the break- and structure lines. Too many points were measured on the lines and the obtained precision would be higher if a different point distribution had been chosen. All this seems to indicate that a prefixed regular grid of 10m is too coarse for this terrain type, in spite of the measurement of spot heights and structure lines.



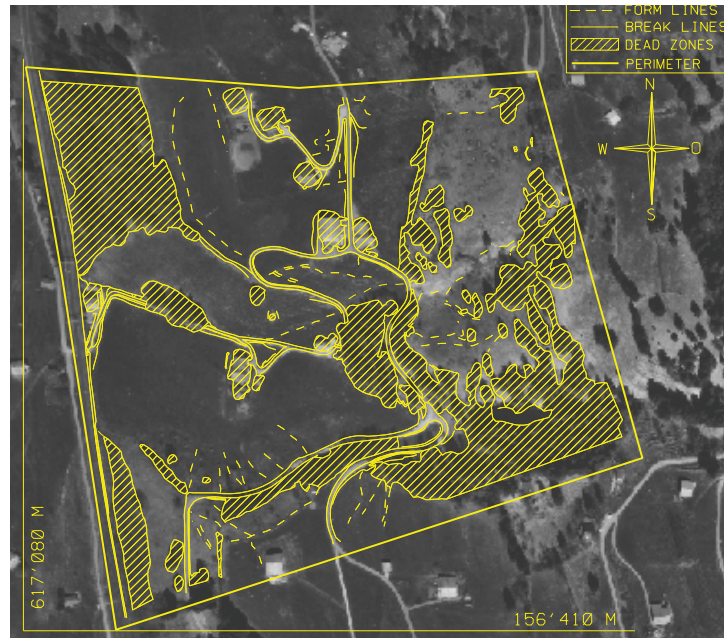


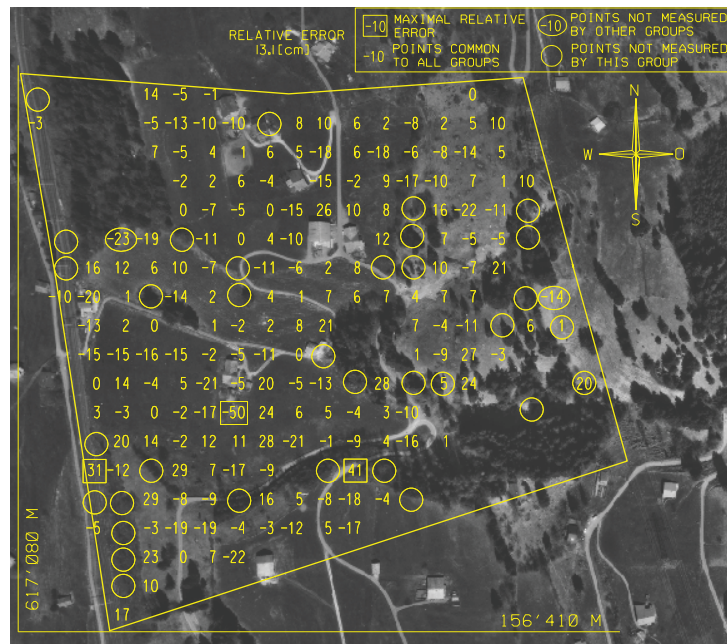
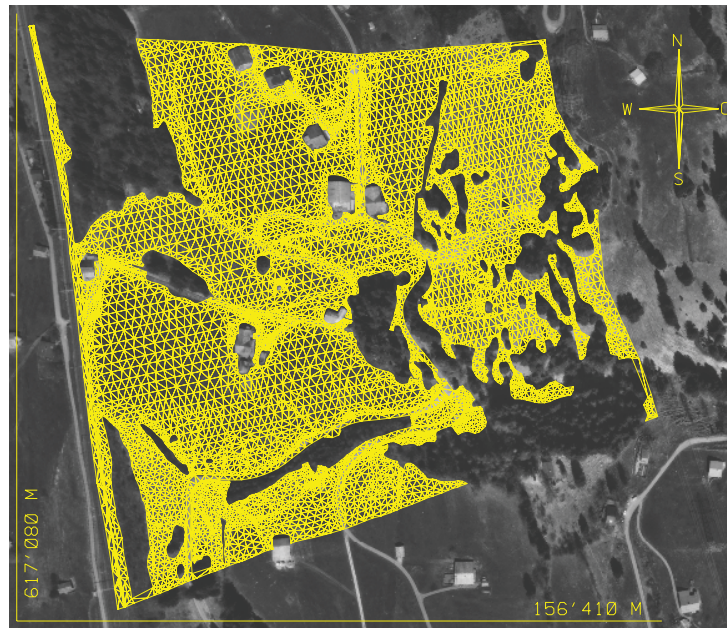
Figure 23:

Test area B2, "rolling, strongly inclined", measured by Centre 4, Flotron.

Some 4198 mass points were measured by that centre in a profiling mode; the profile lines are parallel to the south-eastern border line of the area. The profile distance and the point distance on the profile lines vary between 3 and 9m. Some 750 points were measured on structure lines in open terrain. Additionally, some 848 points were measured on break lines modelling the traffic areas and the courtyards of buildings. A particularity of these measurements were the exclusion of about 30% of the area as dead zones; these dead zones are partly very small and surround individual trees or shrubs. The delineation of the dead areas required the measurement of some 2400 points. The mean point distance in the open area is 4.1m, one of the smallest of all restitutions.

The standard residual error of $\pm 13.1\text{cm}$ achieved is rather favourable but might be due to the generous elimination of dead areas. These measurements appear in table 6 with an error twice as large when not all dead areas are respected. The systematic height error amounts to 7.5cm.

The largest residuals were -50cm and $+41\text{cm}$; however, many of the critical zones which created problems for Centre 1, for example, were not measured by this centre and were instead designated as dead areas as already mentioned.



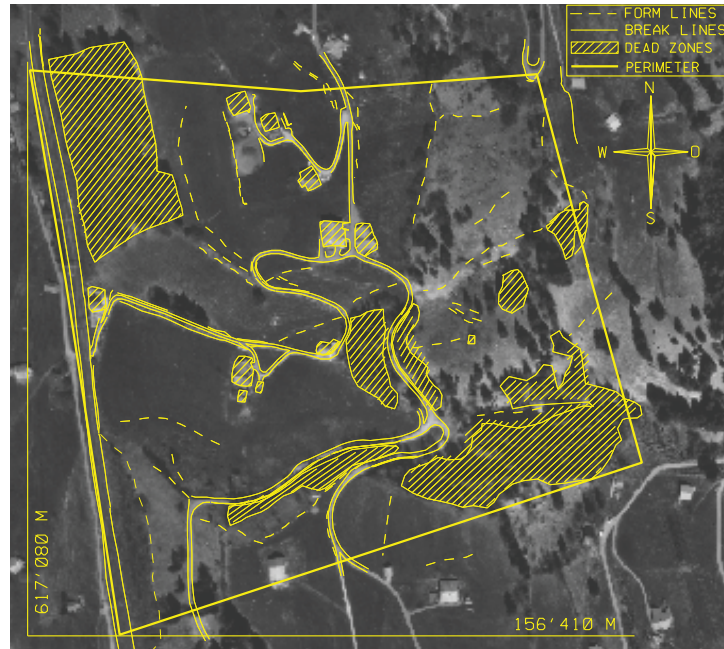


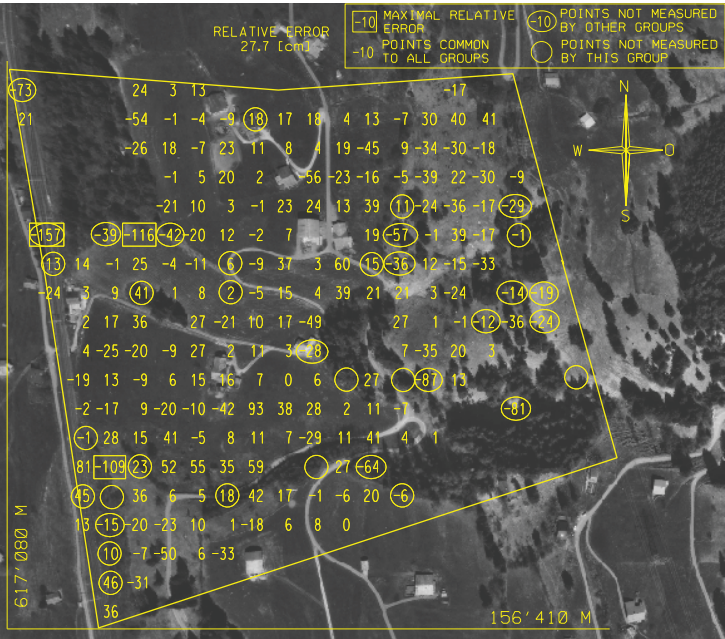
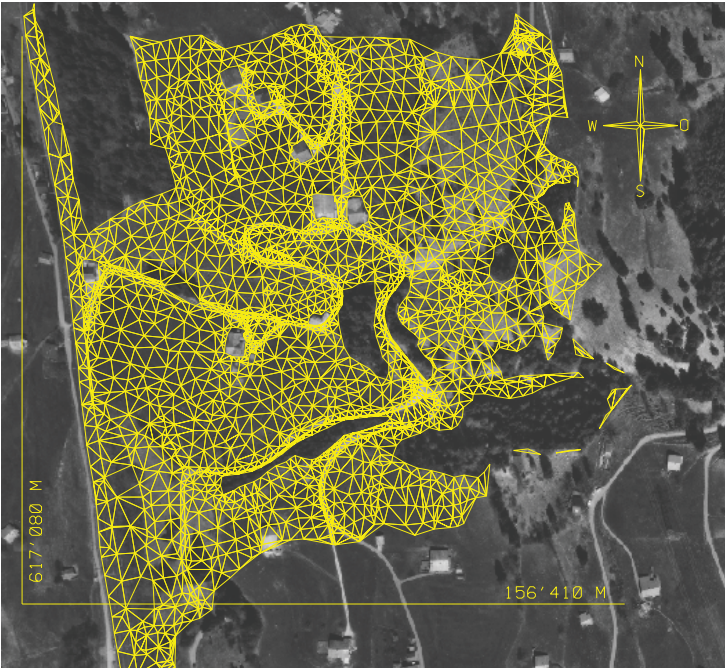
Figure 24:

Test area B2, "rolling, strongly inclined", measured by Centre 5, MuttENZ.

Centre 5 measured only 1029 points according to the principle of adaptive sampling. 128 points in open areas were measured on form lines, with a total length of 1.1km. The traffic area and the courtyards were modelled by break lines over a length of 5.3km, totalling 807 points. For the delineation of the dead areas, some 650 points were measured. The number of line points is rather high with 61%, the mean point distance in open terrain was computed at 9.2m

This centre achieved the largest standard deviation at $\pm 27.7\text{cm}$, due to the low number of points. The precision is 48% beyond the goal of the measurements. The systematic height error amounts to 4.1cm.

The largest residuals are -157cm and -116cm . Most of these points showing large residuals were for example not measured by Centre 4. Nevertheless, the number of outlayers is considerable.



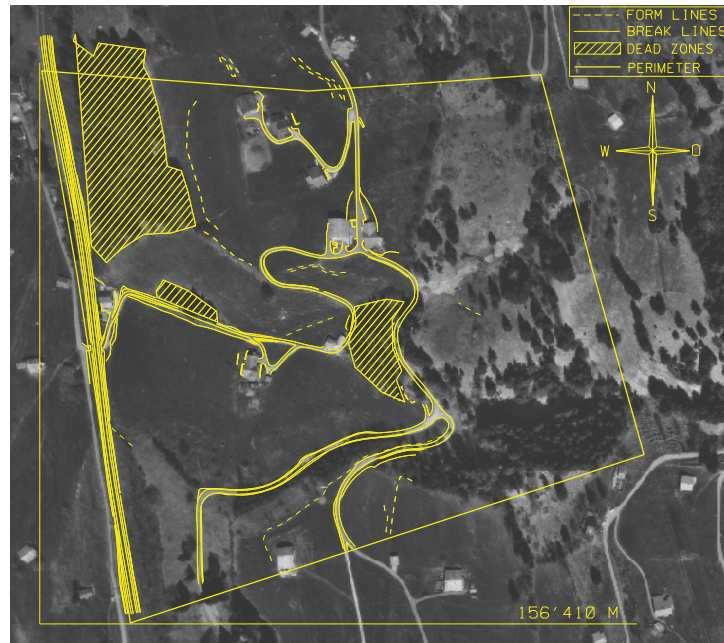
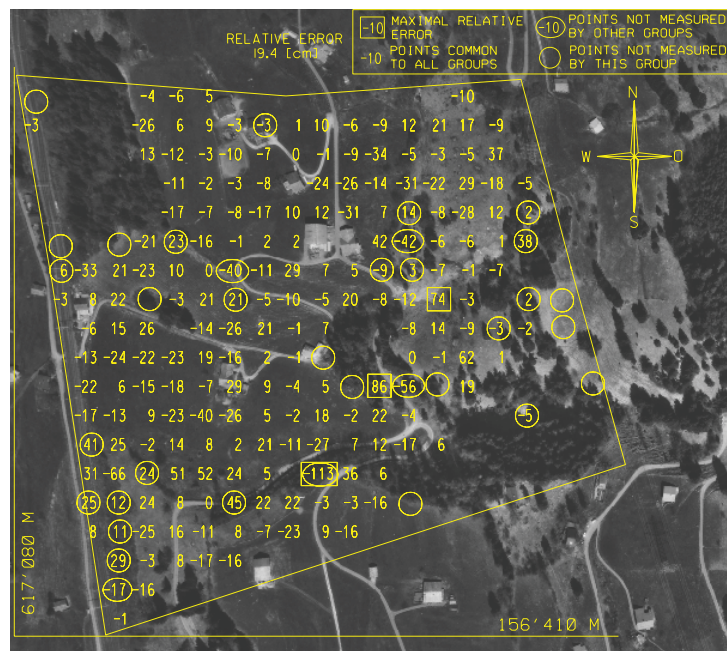
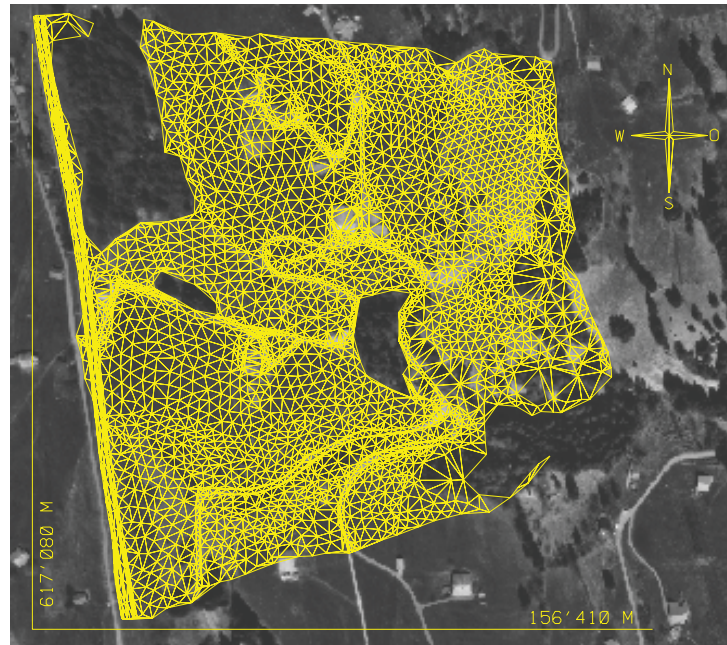


Figure 25:

Test area B2, "rolling, strongly inclined", measured by Centre 6, FM Kartta.

The centre measured some 2260 mass points, according to the principle of adaptive sampling. 219 points lie on structure lines 0.8km long (open terrain). The traffic areas and the courtyards were modelled by break lines of a length of 8.6km, totalling 1352 points. For the delineation of the dead area, some 180 points were measured. The percentage of line points is 41%; the mean point distance was computed at 8.2m

This centre achieved the smallest standard error of $\pm 19.4\text{cm}$ beside the Centre 4, the largest residuals were -113cm and 86cm .



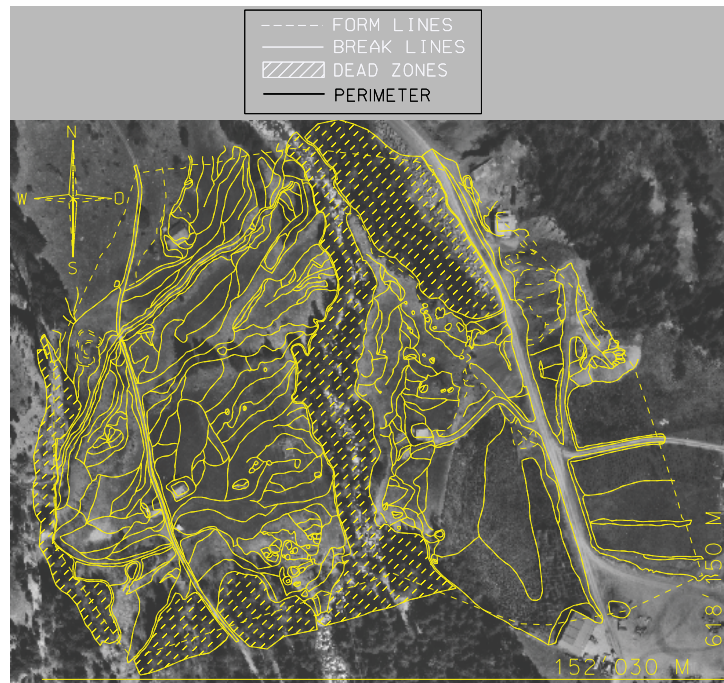


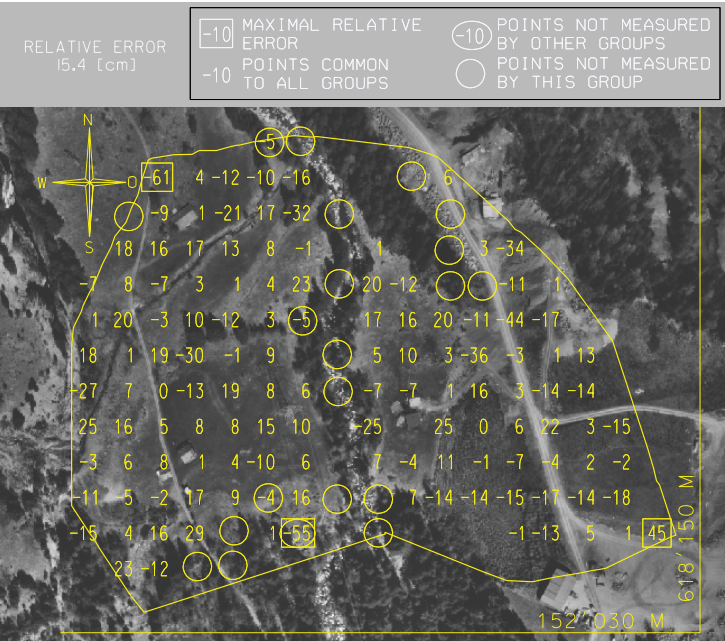
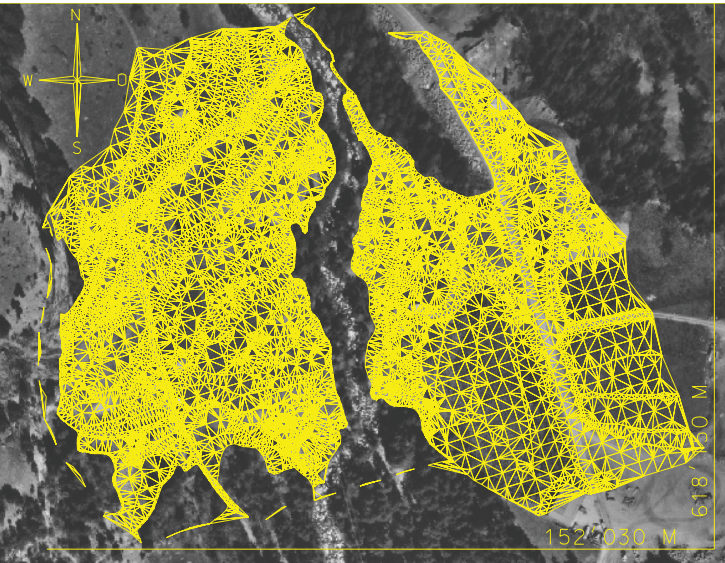
Figure 26:

Test area C1, "rough, weakly inclined", measured by Centre 1, Vienna.

In this region also Centre 1 applied its standard measuring procedure by using a basic grid with a 10m mesh size. Additionally, a few isolated points were measured on the summit of hills, totalling 1071 mass points. The bulk of the points, nearly 90%, were measured on form lines and break lines. 10% of the working area was delineated as dead zones. In total more as 10.000 points (exactly 10.509) were measured for modelling the area, about twice as many as by the other 2 centres.

The random part of the mean square residual error was determined at $\pm 15.4\text{cm}$, with a systematic component of $+8.3\text{cm}$ giving a total root mean square error of $\pm 17.5\text{cm}$.

The largest residuals are -61 and -55cm , values observed only on border points, within the area the residuals are under $2 \cdot \sigma_0$; consequently the area is very homogeneously modelled.



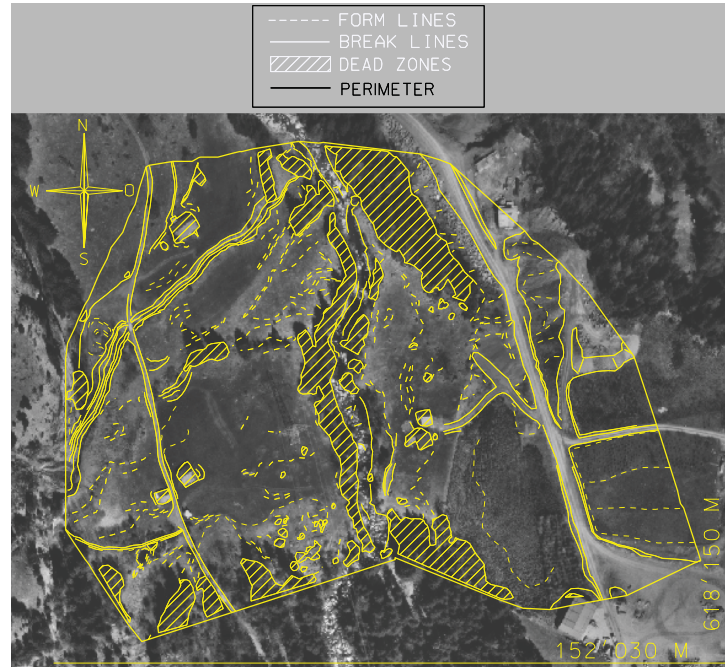
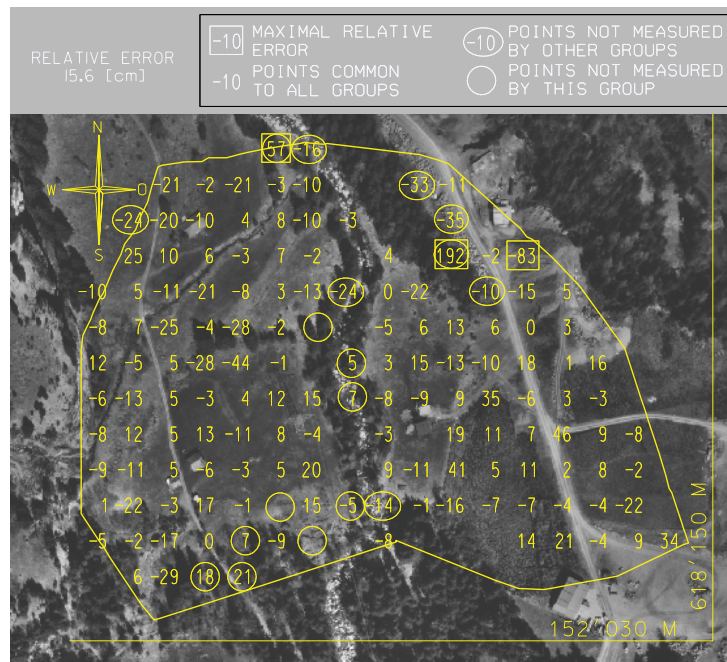
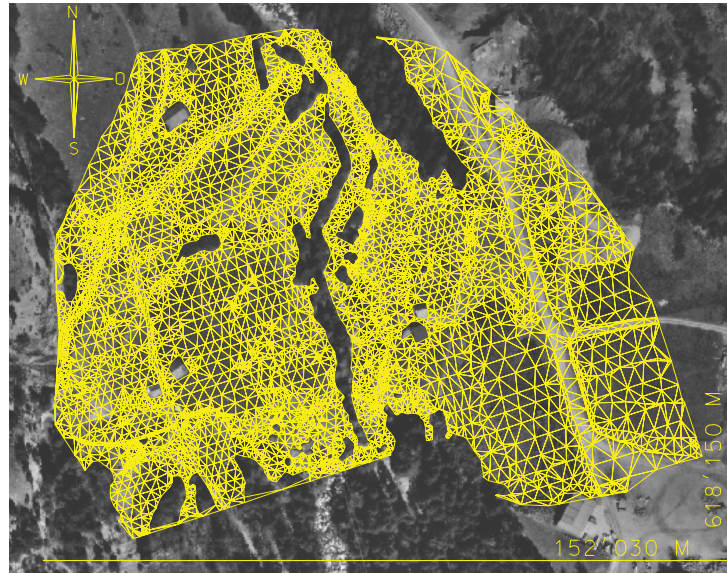


Figure 27:

Test area C1, "rough, weakly inclined", measured by Centre 4, Flotron.

Also for this restitution, the 1580 mass points were measured in the profiling mode, the profile lines parallel to the north-west delimitation of the area. Additionally 6.6km of structure lines with 4138 points were measured in the open terrain. The traffic area and the courtyards were modelled with 2.5km of break lines comprising 660 points. 13% of the area was designated as dead zones, requiring the measurement of 1136 additional points.

The centre obtained a precision of $\pm 15.6\text{cm}$ and a systematic error component of -6.6cm . The largest errors were observed on the edge of forest, with 1.92m near a dead area. Another error of -83cm appears on a scree.



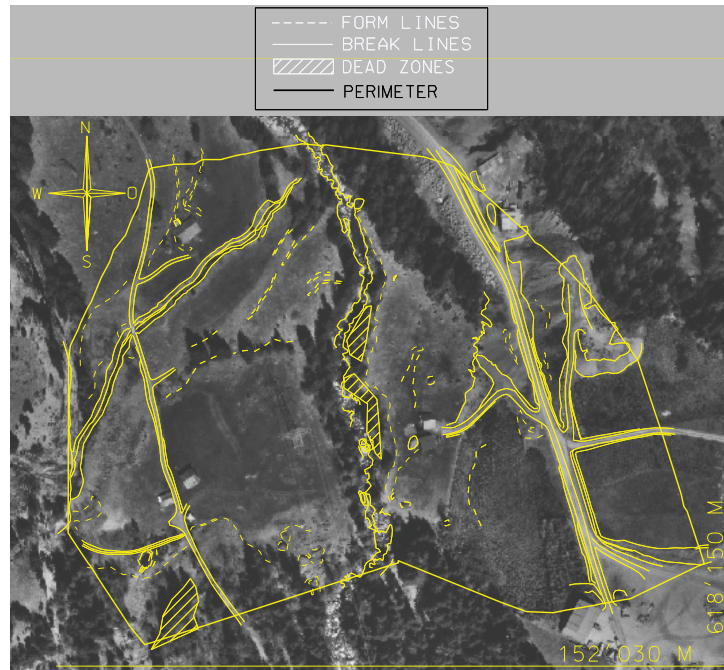


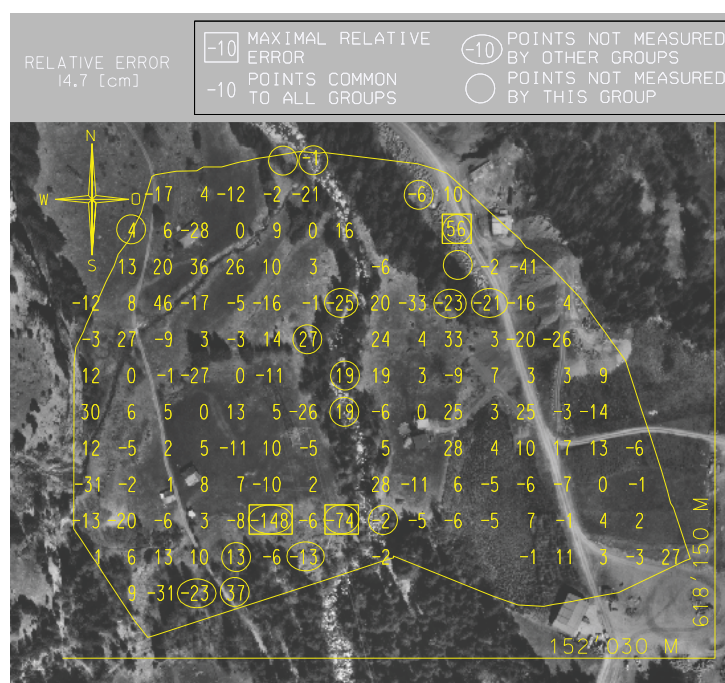
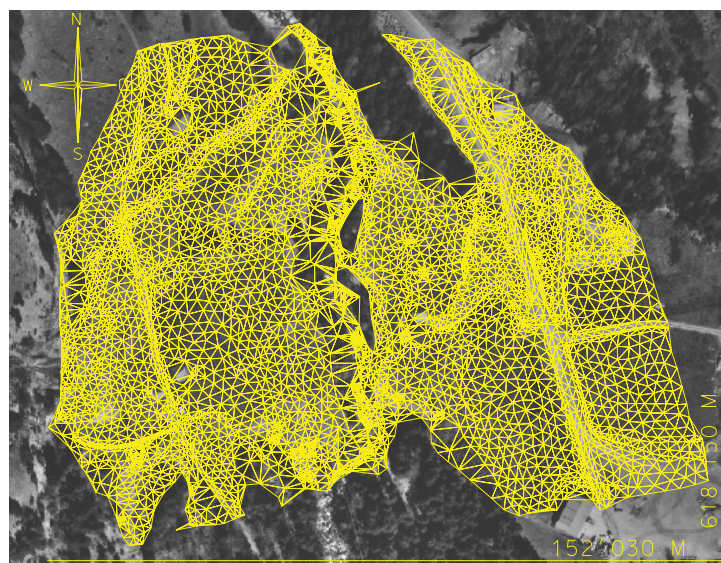
Figure 28:

Test area C1, "rough, weakly inclined", measured by Centre 6, FM Kartta.

Again the centre measured according to the principle of adaptive sampling and determined some 2523 mass points, also on peaks and depressions. 4.9 km of structure lines were measured in open terrain with a total of 1947 points. The traffic area was modelled by 3.4km of break lines (730 points). The delineation of the dead zones required 28 points; in all only 2% of the area was eliminated.

The precision obtained at $\pm 14.7\text{cm}$ is slightly better than that of the other centres. The systematic component is only 2.9cm.

Extreme residuals of -148cm and -74 are observed in the rolling, but open terrain.



6.1 General impression of test area A1 "smooth, weakly inclined"

This test area is a rather flat and even farming area, easy to model. It is crossed by 3 minor traffic roads and shows a number of farm houses. The terrain undulates slightly; there are some gullies and flat ridges. The average terrain inclination is 4%, the maximal inclination 15%; the largest height difference is 22m.

In total 4 centres measured this area and obtained a very high precision with a standard error between ± 6 and ± 11 cm. Centres 1 and 4 used a regular point distribution whereas Centre 2 and 5 used an irregular point distribution, corresponding to adaptive sampling.

All measurements show systematic errors between -6 and $+7$ cm; the systematic deviations are more or less constant for the measurements of centres 1, 2 and 5, whereas the measurements of Centre 4 show an inclination in north-south direction of 8 cm over 500 m, corresponding to an inclination of 0.15‰.

The measurements satisfy the initial accuracy specification of ± 20 cm, even in taking into consideration the systematic error component; the best measurements (Centre 2, Tampere) use only 37% of the allowance, whereas the weakest is close to 67% (Centre 5, Muttentz).

Table 10:

Compilation of the various parameters for data capture of test field A1. Most of the parameters are self-explained. Column 6 specifies that the following values are differentiated for open area, built-up area and for the total. Column 11 gives the percentage of the points on line elements.

Test area A1						Line elements					Surface			Point density	
(1)	Syst. error (2)	Precis. (3)	Error max. (4)	Type of meas. (5)	(6)	Mass pts (7)	Length (8)	Numb. of pts (9)	Total pts (10)	Line pts (11)	Meas. (12)	Dead zones (13)	Total (14)	Per ha (15)	Mean dist. (16)
Cen1	-6.1	± 6.5 cm	35 cm	10 m grid	Open	2089	9317 m	4561	6650		19.4 ha		19.4 ha	343	5.4 m
					Built		4815 m	1261	1261		1.2 ha		1.2 ha	1051	3.1 m
					Total				7911	74%	20.6 ha		20.6 ha		
Cen2	-4.1	± 6.2 cm	35 cm	Progr. sampling	Open	5152	554 m	312	5464		19.4 ha		19.4 ha	282	6.0 m
					Built		5515 m	820	820		1.2 ha		1.2 ha	683	3.8 m
					Total				6284	18%	20.6 ha		20.6 ha		
Cen4	5.8	± 10.6 cm	40 cm	4-12 m grid	Open	1688	6007 m	2414	4102		18.7 ha	0.7 ha	19.4 ha	219	6.8 m
					Built		4825 m	782	782		0.8 ha	0.4 ha	1.2 ha	978	3.2 m
					Total				4884	65%	19.5 ha	1.1 ha	20.6 ha		
Cen5	6.8	± 11.2 cm	40 cm	Progr. sampling	Open	1665	2451 m	491	2156		18.9 ha	0.6 ha	19.5 ha	114	9.4 m
					Built		3556 m	483	483		0.8 ha	0.3 ha	1.1 ha	604	4.1 m
					Total				2639	37%	19.7 ha	0.9 ha	20.6 ha		

6.2 General Impression of test area A2, "smooth, strongly inclined"

Test area A2 is generally inclined by about 21%, with a maximum inclination of up to 40%. The upper part is formed by a flat ridge; the central part is uniformly inclined and the lower part is characterised by a gully and a narrow valley and a larger one. It is mainly used for cattle grazing; the upper part of the area is crossed by a main road and some other minor roads lead to the eight buildings.

Again 4 centres measured this test area and obtained precisions between ± 7 and ± 11 cm, very similar to test area A1. In this case also two centres used a regular point distribution and two an irregular one. A very favourable result was achieved by Centre 2 with a standard error of ± 7.8 cm. This centre measured only 21% of the points on break or form lines and measured 5435 mass points in an irregular distribution (adaptive sampling). Centre 7 chose a very dense grid at 3m, the densest point distribution of all measurements, including the rough areas. The final standard deviation achieved by this centre was consequently very low at ± 7.3 cm, even slightly lower than Centre 2. However, Centre 7 has a large systematic error of nearly 10 cm.

The restitutions 2 and 4 show only very small systematic errors, hardly exceeding 1 cm, whereas Centre 3 has a systematic error of -5.1 cm and Centre 7, as mentioned, an error of -9.9 cm. The measurements of Centre 7 also show a small inclination of $+5/-5$ cm from the south-west to the north-east edge.

Table 11:

Comparison of the various parameters for data capture of test field A2.

Test area A2						Line elements					Surface			Point density	
	Syst. error	Precis.	Error max.	Type of meas.		Mass pts	Length	Numb. of pts	Total pts	Line pts	Meas.	Dead zones	Total	Per ha	Mean dist.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Cen2	0.0	± 7.8 cm	93 cm	Progr. sampling	Open	5435	397m	150	5585		14.6 ha		14.6 ha	383	5.1 m
					Built		4556m	1268	1268		1.1 ha		1.1 ha	1153	2.9 m
					Total				6853	21%	15.7 ha		15.7 ha		
Cen3	-5.1	± 10.1 cm	39 cm	Progr. sampling	Open	2773	6612m	1205	3978		14.6 ha		14.6 ha	272	6.1 m
					Built		5965m	1270	1270		1.1 ha		1.1 ha	1155	2.9 m
					Total				5248	47%	15.7 ha		15.7 ha		
Cen4	1.1	± 11.4 cm	65 cm	4-12 m grid	Open	3105	1212m	1250	4355		14.5 ha	0.1 ha	14.6 ha	300	5.8 m
					Built		2158m	800	800		0.6 ha	0.6 ha	1.2 ha	1333	2.7 m
					Total				5155	40%	15.1 ha	0.7 ha	15.8 ha		
Cen7	-9.9	± 7.3 cm	53 cm	3 m grid	Open	16603	781m	77	16680		14.8 ha		14.8 ha	1127	3.0 m
					Built		1949m	290	290		0.6 ha	0.4 ha	1.0 ha	483	4.5 m
					Total				16970	2%	15.4 ha	0.4 ha	15.8 ha		

6.3 General impression of test area B1, "rolling, weakly inclined"

The area is rather flat and mainly used for cattle grazing and farming; it is covered by a great number of erratic cones (little drumlins). The Kander river crosses the area over a length of 400m and has a width of 10 to 20m; the river bed is about 4m deep. The river banks are covered by trees and the rest of the area is completely open.

The southern border of the area is crossed by a provincial crossroad, with embankments; furthermore, the houses are served by minor roads. The maximum height difference of the test area is only 15m; the local drumlins and cones show height differences of 2 to 10m.

This flat but heavily rolling area was measured by only 2 plotting centres. Both centres used some 3500 mass points and 3000 to 6000 points on break or form lines. The precision obtained is very similar, namely ± 10 and ± 11 cm. Also the largest residuals are very similar and up to 60cm.

Table 12:

Comparison of the various parameters for data capture of test field B1.

Test area B1						Line elements					Surface			Point density	
	Syst. error	Precis.	Error max.	Type of meas.		Mass pts	Length	Numb. of pts	Total pts	Line pts	Meas.	Dead zones	Total	Per ha	Mean dist.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Cen3	0.0	± 11.4 cm	58 cm	Progr. sampling	Open	3695	10200m	2090	5785		19.8 ha		19.8 ha	292	5.9 m
					Built		2750m	586	586		0.7 ha		0.7 ha	837	3.5 m
					Total				6371	42%	20.5 ha		20.5 ha		
Cen4	-3.1	± 9.4 cm	55 cm	3-11 m profile	Open	3786	16655m	6686	10472		19.6 ha	0.1 ha	19.7 ha	534	4.3 m
					Built		2588m	650	650		0.7 ha	0.3 ha	1.0 ha	929	3.3 m
					Total				11122	66%	20.3 ha	0.4 ha	20.7 ha		

6.4 General impression of test area B2, "rolling, strongly inclined"

The eastern part of the test area is a steep slope with an inclination of about 70%, crossed by 2 torrents which have eroded deep ditches. These ditches meet in the central part of the test area, where the water has formed a nearly 200m wide glacial terrace. The torrents empty in the lower part of the area, where they again formed steep slopes of about 70%. There are only a few farm buildings served by minor roads. The steep slopes are partly covered by dense forests, partly by grass land dotted with a few trees. The area has a height difference of 175m; the slopes range from 5 to 105%.

The area was measured by four centres. Two centres obtained a precision of ± 24 and ± 28 cm and did not reach the goal of the measurements. Centre 6, using adaptive sampling, obtained a precision of ± 19 cm and Centre 4 ± 13 cm; however, the latter eliminated many critical areas.

Centre 1 with the precision of ± 24 cm, again used the grid structure with a mesh width of 10m, which is apparently too coarse, although many spot heights and structure lines were measured. In total 71% of the points were measured on line elements.

Centre 5 also used a far too coarse point density for that area. The number of the points is only half of that measured by Centre 1 and the precision is ± 28 cm.

Table 13:

Comparison of the various parameters for data capture of test field B2.

Test area B2						Line elements					Surface			Point density	
	Syst. error	Precis.	Error max.	Type of meas.		Mass pts	Length	Numb. of pts	Total pts	Line pts	Meas.	Dead zones	Total	Per ha	Mean dist.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Cen1	7.8	± 24.1 cm	181 cm	10 m grid	Open	1693	9288m	2871	4564		15.6 ha	2.5 ha	18.1 ha	293	5.8 m
					Built		4743m	1400	1400		1.5 ha		1.5 ha	933	3.3 m
					Total				5964	72%	17.1 ha	2.5 ha	19.6 ha		
Cen4	7.5	± 13.1 cm	50 cm	6 m profile	Open	4198	1918m	3151	7349		12.1 ha	5.2 ha	17.3 ha	607	4.1 m
					Built		3506m	848	848		0.7 ha	0.3 ha	1.0 ha	1211	2.9 m
					Total				8197	49%	12.8 ha	5.5 ha	18.3 ha		
Cen5	-4.1	± 27.7 cm	157 cm	Progr. sampling	Open	1029	2403m	781	1810		15.4 ha	3.6 ha	19.0 ha	118	9.2 m
					Built		5304m	807	807		1.2 ha	0.3 ha	1.5 ha	673	3.9 m
					Total				2617	61%	16.6 ha	3.9 ha	20.5 ha		
Cen6	1.5	± 19.4 cm	113 cm	Progr. sampling	Open	2260	812m	219	2479		16.5 ha	1.9 ha	18.4 ha	150	8.2 m
					Built		8600m	1352	1352		1.2 ha		1.2 ha	1127	3.0 m
					Total				3831	41%	17.7 ha	1.9 ha	19.6 ha		

6.5 General impression of test area C1, "rough, weakly inclined"

This test area is a high mountain pasture land at a height of 1000m, it is crossed by the Kander river which is still a torrent at this height. About 70% of the area is a torrent alluvium, with a thin cover of humus used as pasture. This pasture is crossed by an other 3-5m deep torrent. The terrain is rough, interleaved by numerous rocks and boulders. The river bed of the Kander, bordered by groups of trees on both sides, is also clearly visible to a great extent. The area shows 5 sheds, reached by small roads. The average inclination is 21% (minimum 0% and maximum 75%); the maximum height difference is only 30 m.

For this rough, but not very steep area we have 3 measuring sets with very similar precision, around ± 15 cm, whereas the number of points varies between 5000 and 10,000.

Centre 1 again used its regular grid and measured additionally a great number of form lines and break lines. Nearly 90% of the points measured are on line elements.

Centre 4 again measured its profiles with a distance varying between 5 and 9m. Additionally, a great number of line elements were measured; nearly 70% of the points lie on these elements.

Centre 6, with adaptive sampling, reached the relatively best result of ± 14.7 cm (weakest ± 15.6 cm) with only 5000 points. Here proportionally only 50% of the points lie on line elements.

Centre 4 and 6 have outlayers of more than 1.5m, whereas these critical areas were eliminated by centre 1; the largest error observed is -61cm.

Table 14:

Comparison of the various parameters for data capture of test field C1.

Test area C1						Line elements					Surface			Point density	
	Syst. error	Precis.	Error max.	Type of meas.		Mass pts	Length	Numb. of pts	Total pts	Line pts	Meas.	Dead zones	Total	Per ha	Mean dist.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Cen1	8.3	± 15.4 cm	61 cm	10 m grid	Open	1071	11544m	6888	7059		9.3 ha	1.2 ha	10.5 ha	856	3.4 m
					Built		4220m	2550	2550		1.5 ha		1.5 ha	1700	2.4 m
					Total				10509	90%	10.8 ha	1.2 ha	12.0 ha		
Cen4	-6.6	± 15.6 cm	192 cm	6 m profile	Open	1580	6650m	4138	5718		9.2 ha	1.2 ha	10.4 ha	622	4.0 m
					Built		2540m	660	660		0.6 ha	0.1 ha	0.7 ha	1100	3.0 m
					Total				6378	75%	9.8 ha	1.3 ha	11.1 ha		
Cen6	2.9	± 14.7 cm	148 cm	Progr. sampling	Open	2523	4900m	1947	4470		10.3 ha	0.2 ha	10.5 ha	434	4.8 m
					Built		3427m	730	730		0.6 ha		0.6 ha	1217	2.9 m
					Total				5200	51%	10.9 ha	0.2 ha	11.1 ha		

6.6 *Characterization of the data capture by the different methods*

6.6.1 Plotting Centre 1 (Test area A1, B2, C1)

A general characteristic of the measurements of this centre is a strict use of a prefixed regular grid of 10m mesh widths and the measurement of a great number of form lines. The mesh width was used independently of the terrain, whereas the number of points on form lines was increased heavily in rough terrain. The number of points on form lines exceeded the number of mass points partially by a factor of 3-5. That means that the grid points represent the area only to a small extent and the bulk of the work concentrated on the acquisition of the structure lines. Roads and buildings were systematically plotted as break lines. Dead areas were scarcely designated in order to allow for a maximum plotting area.

The strategy chosen required the measurement of a high number of points compared to the precision obtained. It appears that this approach is not too efficient concerning the number of points measured.

This centre worked with the Leica analytical plotter, Aviolyt BC3; the plotters are equipped with monocular image injection. The centre indicated that the measurements were checked after the data capture by injecting the contour lines into the stereo model. The measurements of the 3 test sites required 30 hours.

6.6.2 Plotting Centre 2 (Test area A1 and A2)

This centre worked with an irregular point distance varying between 3-9m and obtained very precise results in this way. The number of mass points is quite high, about double those measured by Centre 1. Roads and buildings were also marked out by break lines, but very few form lines were determined. This approach is very efficient and, as already mentioned, delivers a very high degree of precision.

6.6.3 Plotting Centre 3 (Test area A2, B1)

A rather detailed description of the measuring procedure used by the centre is given in the report. It worked with the analytical plotter Leica Aviolyt BC2. The program PMO-MAP was used for the DTM data capture and the program PMO-PM3 for the measurements of the check points. The report delivered by the centre explains that the technique used for DTM data collection is very commonly used in Finland. The operator first measures all break lines. Thereafter random points are measured. 3 surfaces are distinguished: terrain surface (1), rock surface (2) and “off DTM structures” (9) like buildings, bridges etc. The structure surface (9) can be measured as real 3D objects or in the conventional way. Areas covered by forest are normally measured in the field. Control measurements in the form of profiles are prescribed in Finland. For routine DTM determination one uses photographs in the scale 1:3300, a scale nearly twice as large as for the OEEPE test presented here. In this case, the standard deviation between the profiles and the interpolated points should not exceed $\pm 0.1\text{m}$ and the frequency of differences greater than 0.25m should not exceed 1%. It is further specified that the photogrammetric profiling serves only for the control of the point density used, but that for a thorough control one uses field measurements, either profiles or individual points.

The procedure used by this centre is very similar to the other Finish participants in the test (Centre 2 and Centre 6). However, this centre measured only half the number of points used by Centre 2. Nonetheless, a great number of form lines were measured in order to complement the mass points. The break lines were again measured on roads and buildings.

6.6.4 Plotting Centre 4 (All test areas)

The data capture of centre 4 is not quite homogeneous. The test areas A1 and A2 were measured with regular grids; the mesh widths were adapted to the zone of the terrain and varied between 4 and 12 m. Test areas B1, B2, C1 were captured by profiles at distances between 7 and 9 meters. For test areas A1, B1 and C1, a great number of form lines were measured; for B1 a total length of nearly 17km. Furthermore, this centre eliminated a great number of areas from measurements by designating them as dead areas. For B2 the delimitation line of the dead areas has a total length of 5.4km. We should mention in this context that the measurements of this centre were performed as contract work for the elaboration of the DTM of the entire Kandertal, and were not executed with a view to testing.

6.6.5 Plotting Centre 5 (Test area A1, B2)

This centre used also an irregular distribution of the mass points (adaptive sampling) but measured a very low number of points; for A1 and B2 the mean point distance was about 9m, whereas on average the other centres had a mean point distance of 5m. Consequently, the interpolation precision was rather low, about $\frac{1}{2}$ compared with the best results of the specific areas. Additionally, form lines and break lines were measured.

6.6.6 Plotting Centre 6 (Test area B2 and C1)

This centre also measured an irregular grid with a point distance of 4-10m, as well as break lines and a considerable number of form lines, especially for C1.

6.6.7 Plotting Centre 7 (Only test area A2)

This centre chose a very simple approach in measuring a very dense grid of 3m. Additionally, break lines were measured along the roads and houses, which were also designated as dead areas. This required the measurement of nearly three times more points than captured by centre 2, which obtained about the same precision, but used adaptive sampling.

6.7 *Ranking of the results according to the obtained DTM precision*

After the various analyses of the measuring procedure, it is of interest to attempt to rank the measuring procedures chosen. It is understood that such an approach is somewhat problematic and could be misunderstood. However, this attempt might help to classify the various procedures and to elaborate recommendations.

The easiest approach is without any doubt to classify the procedures according to the precision obtained. In table 15 the plotting centres are ranked according to the relative precision obtained on the grid points. We realise that the Centre 2 is always in a good position, whereas Centre 5 is rather low ranked. Although this ranking is not uniform, as the various centres did not measure all test zones, there results a clear sequence, with the exception of Centres 3 and 4 and we can make the following ranking:

- | | |
|-------------|--------------------------|
| 1. Centre 7 | dense regular grid |
| 2. Centre 2 | adaptive sampling |
| 3. Centre 6 | adaptive sampling |
| 4. Centre 1 | regular grid |
| 5. Centre 4 | profiling |
| 6. Centre 3 | coarse adaptive sampling |
| 7. Centre 5 | coarse adaptive sampling |

It is understood that it is not correct to put Centre 7 in the first place, as it only measured a very dense grid without considering efficiency. Effectively, this centre measured about three times more points than any other centre. Nevertheless, this ranking shows that Centre 2 and Centre 6, which both used adaptive sampling, obtained very favourable results, whereas centres which used a regular grid structure (Centre 1) or a profiling method (Centre 4) obtained less favourable results. In this sense this approach allows an assessment of the measuring results on a purely empirical basis.

6.8 Precision of terrain approximation in relation to point density

In the preceding paragraph the centres were ranked according to the general precision obtained. Below, an attempt is made to deepen these reflections by considering efficiency. As already pointed out, Centre 7 has apparently measured far too many points in comparison to the precision obtained, whereas Centre 5 measured very few points and had nevertheless respected in most of the cases the general goal, stipulating a precision below $\pm 20\text{cm}$.

An attempt was made to reach this objective with the help of a regression analysis between the precision and the point density used. This regression analysis can be used to estimate 2 parameters: a constant term and the multiplication term of the point density or by estimating only the multiplication factor and forcing the regression line by the origin; both approaches were followed.

The point density was derived from the square root of the surface to be modelled divided by the total number of points, that means mass points, individual height points and node points of the different line elements. In order to avoid a disturbing influence of the modelling technique of the built-up area, this has been excluded from the calculation. We are aware, that the value of the point density is somewhat disturbed as all points are used including points on break and structure lines. The regression lines are also presented graphically in figure 29 to figure 33 and the various parameters are listed in table 16.

Table 15:

Trial for making a classification of the different measuring results according to the obtained precision (*Centre 4 applied here a special technique for the elimination of dead areas).

Centre	Plotter	Arrangement of mass points	Sigma in cm	Deviation to the best in %	Ranking
(1)	(2)	(3)	(4)	(5)	(6)
Zone A1					
Cen2	BC2	Adapt.samp. 3-9m	6.2	0	2
Cen1	BC3	Regular grid 10m	6.5	-5	4
Cen4	DSR14	Regular grid 4-12m	10.6	-71	5
Cen5	DSR15	Adapt.samp. 3-12m	11.2	-81	7
Zone A2					
Cen7	BC1	Regular Grid 3 m	7.3	0	1
Cen2	BC2	Adapt.samp. 3-9m	7.8	-7	2
Cen3	BC1	Adapt.samp. 3-9m	10.1	-38	6
Cen4	DSR14	Regular grid 4-12m	11.4	-56	5
Zone B1					
Cen4	DSR14	Profiles 9m distance	9.4	0	5
Cen3	BC1	Adapt.samp. 3-9m	11.4	-21	6
Zone B2					
Cen4*	DSR14	Profiles 7m distance	13.1	0	5
Cen6	P3	Adapt.samp. 4-12m	19.4	-48	3
Cen1	BC1	Regular grid 10m	24.1	-84	4
Cen5	DSR15	Adapt.samp. 4-12m	27.7	-111	7
Zone C1					
Cen6	P3	Adapt.samp. 4-8m	14.7	0	3
Cen1	BC1	Regular grid 10m	15.4	-5	4
Cen4	DSR14	Profiles 9m distance	15.6	-6	5

Table 16:

Regression analysis of the modelling precision of the various test areas. Column 2 shows the point density in open terrain and column 3 the modelling precision; in column 4 and 5 are given the parameters of the regression analysis with two parameters and in column 6 the multiplication factor forcing the regression line through the point of origin. Column 7 gives the deviations of the individual measurement from the one parameter regression line in %, one notes that the measurements with a regular arrangement of the mass points are always above the regression line (negative values). In column 9 the coefficients between modelling precision and point density are computed, which correspond to the multiplication factor of the 1 parameter multiplication factor, but now determined for the individual centres.

Restit. Centre	Mean point distance	Standard deviation	Regression		Deviation of regr. line	Point distrib.	Empirical multipl. factor	
			2 parameters Multipl. factor	1 parameter Constant term				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Test area A1								
Cen2	6.0 m	0.062 m	0.013	0.000	0.013	-17.4%	Adapt. s.	0.010
Cen1	5.4 m	0.065 m				-4.5%	Regular	0.012
Cen4	6.8 m	0.106 m				24.6%	Regular	0.016
Cen5	9.4 m	0.112 m				-5.1%	Adapt. s.	0.012
Test area A2								
Cen7	3.0 m	0.073 m	0.011	0.037	0.018	36.1%	Regular	0.025
Cen2	5.1 m	0.078 m				-15.2%	Adapt. s.	0.015
Cen3	6.1 m	0.101 m				-7.4%	Adapt. s.	0.017
Cen4	5.8 m	0.114 m				9.8%	Regular	0.020
Test area B1								
Cen4	4.3 m	0.094 m	0.013	0.037	0.020	7.0%	Regular	0.022
Cen3	5.9 m	0.114 m				-4.0%	Adapt. s.	0.019
Test area B2								
Cen4	4.1 m	0.131 m	0.020	0.072	0.030	7.6%	Regular	0.032
Cen6	8.2 m	0.194 m				-20.7%	Adapt. s.	0.024
Cen1	5.8 m	0.241 m				37.4%	Regular	0.041
Cen5	9.2 m	0.277 m				0.1%	Adapt. s.	0.030
Test area C1								
Cen6	4.8 m	0.147 m	-0.005	0.174	0.037	-16.3%	Adapt. s.	0.031
Cen1	3.4 m	0.154 m				23.1%	Regular	0.045
Cen4	4.0 m	0.156 m				6.3%	Regular	0.039

Test area A1

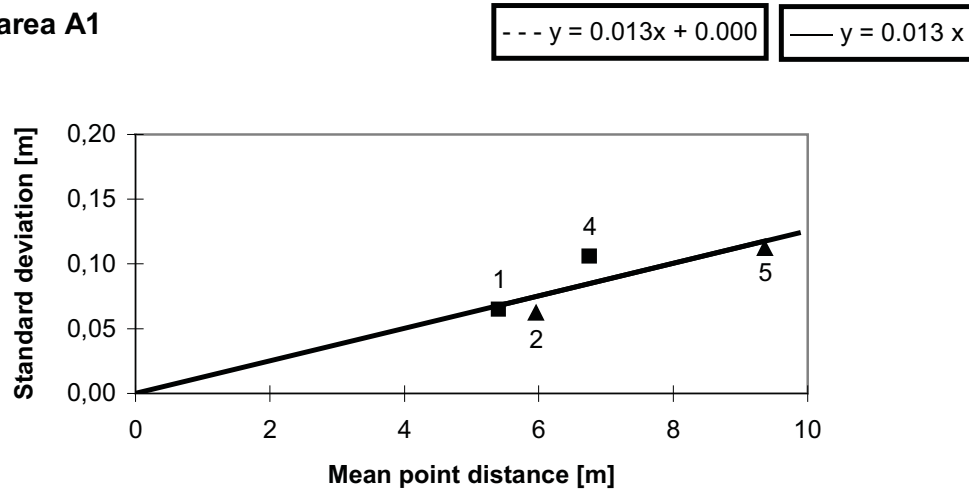


Figure 29:

Regression analysis of test area A1, relation between the modelling precision and the mean point density. The figures refer to the plotting centres, triangles stand for an irregular point distribution and rectangles for a regular one. For this test area the two parameter line corresponds with the one parameter line.

Test area A2

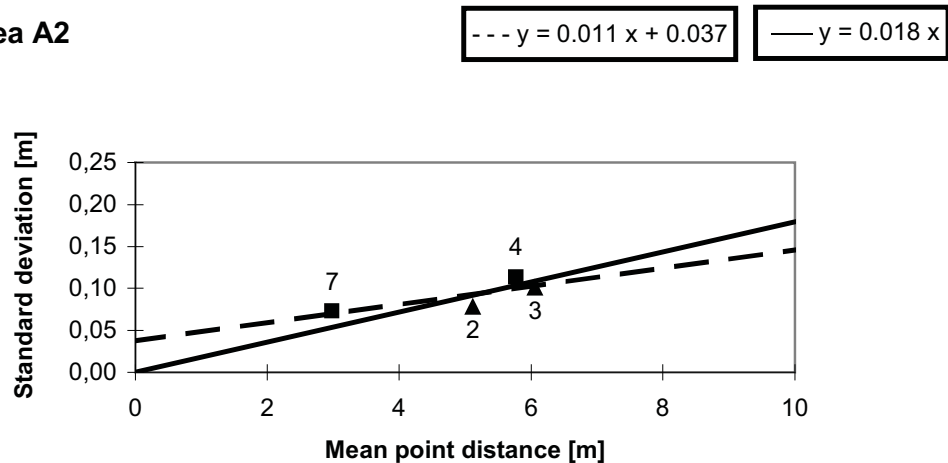


Figure 30:

Regression analysis of test area A2, dashed line for two parameters and continuous line for one parameter.

Test area B1

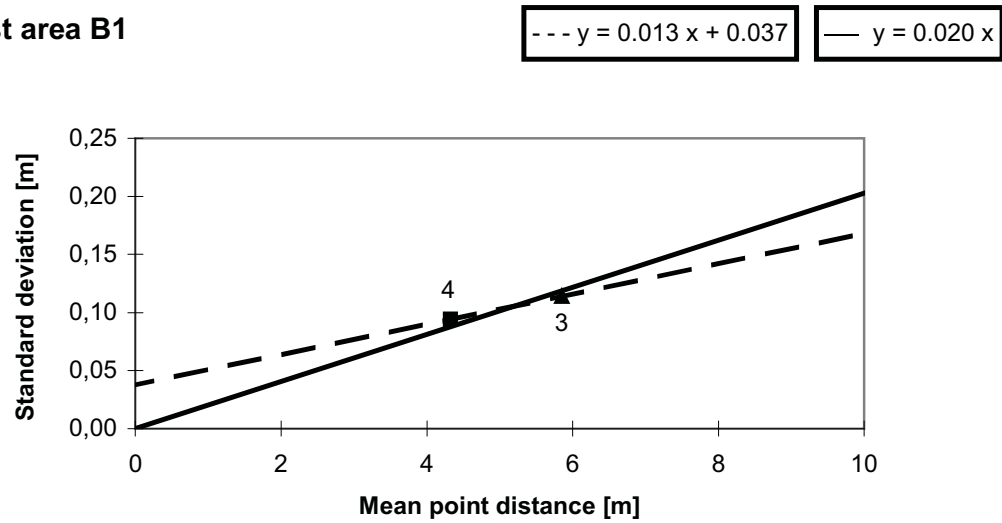


Figure 31:

Regression analysis of test area B1.

Test area B2

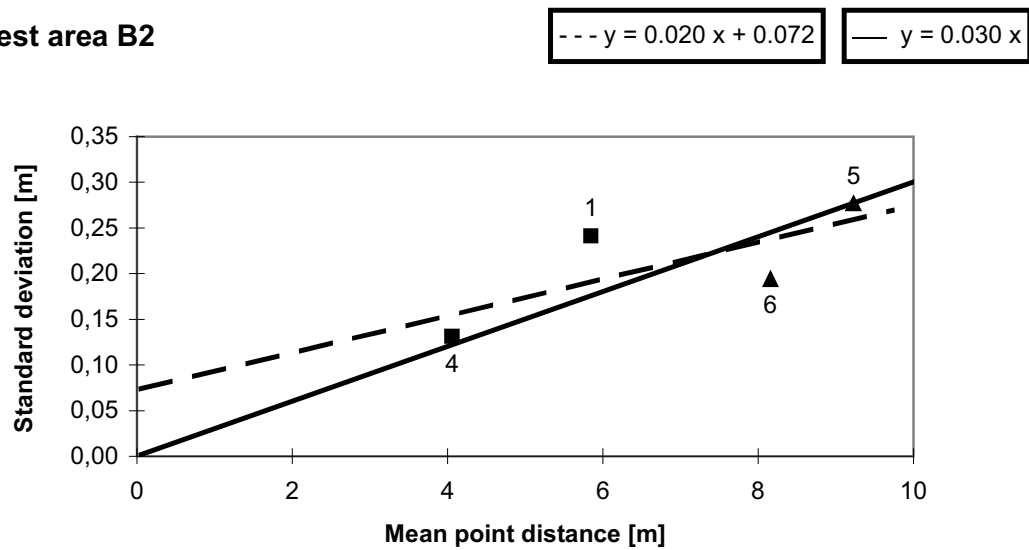


Figure 32:

Regression analysis of test area B2.

Test area C1

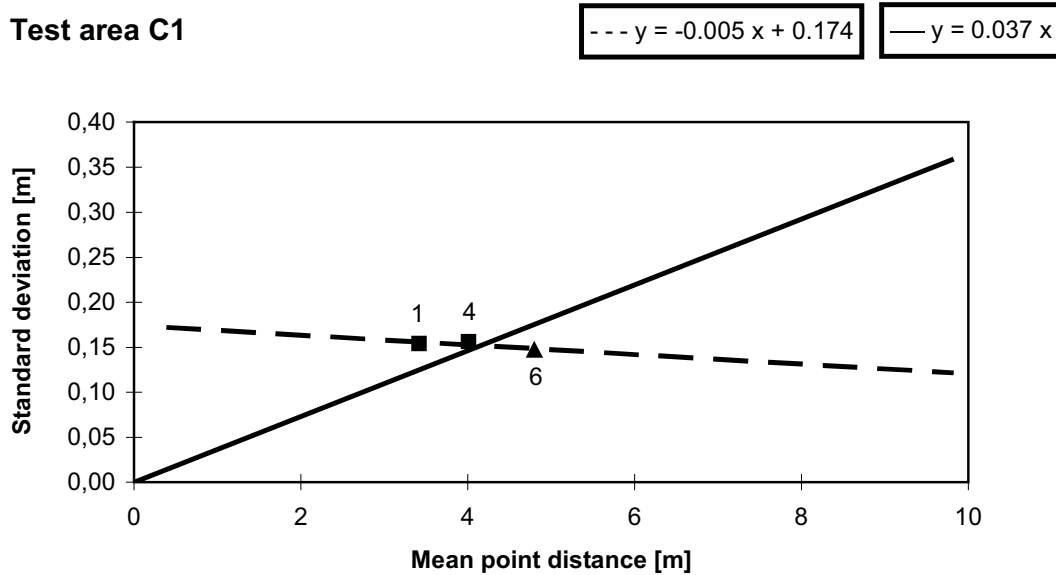


Figure 33:

Regression analysis of test area C1.

The regression line computed with the two parameters shows a clear relation between point density and modelling precision, apart from test site C1. The constant term should have expressed the general terrain noise, a value which defines the possible precision of terrain approximation. However this term is not very precise, due to other factors, and it seemed more useful to estimate only the multiplication factor. This seems confirmed by the theoretical considerations of chapter 7, at least as for profile approximations. When reducing the point distance we could not find a limit, showing a general terrain noise.

The regression coefficients obtained in this way are between 0.011 and 0.018 for the rather smooth areas and 0.030 and 0.037 for the rough test sites. The values of the coefficient are very similar to the values given by Ackermann: for “medium type” terrain ($\alpha=0.010$) and difficult terrain ($\alpha=0.022$). Only the modelled areas B2 and especially C1 seem even more “difficult”, than the areas characterised by him.

This approach also allows one to analyse the efficiency of the modelling by the different centres. The measurements of centres above the regression line are less efficient, as too many points were measured compared with those below the line. Here it becomes very obvious that Centre 7 has measured too many points when taking into consideration the precision obtained of $\pm 7.3\text{cm}$. From the graph one can read that the point for Centre 7 is about 40% higher than the regression line. These 40% were computed between the ordinate of the point and the corresponding value of the regression line. One could also state that this centre should have obtained a much higher precision. In general centres using regular prefixed point arrangements are above the regression line (Cen1, Cen4 and Cen7), whereas centres with an adaptive point distribution are below the regression line; this is specially apparent for Centre 6 which is nearly 20% below.

It is also possible to compute for each centre the relation between measuring precision and point density, which then leads to a spread of the multiplication factors (cf. table 16, column 9). According to this reasoning, we realize that the multiplication factors are systematically higher for a regular point distribution than for an irregular point distribution. The spread ranges between 0.011 to 0.016 for test area A1 and up to 0.033 to 0.047 for test area C1.

6.9 Influence of the measuring instruments

The very rich measuring material also leads one to study the influence of the measuring instrument on the DTM-precision. The various centres used analytical plotters BC1, BC2 and DSR 15 by the firm LH Systems (formerly Kern and Wild) and the P3 by Zeiss. The results of the different plotting centres are listed in table 15 separated according to the different test sites. Already in section 6.7, an attempt was made to work out a ranking of the centres. This list is reproduced here again, after adding the type of plotter used:

1. Centre 7	Reg. grid	BC1
2. Centre 2	Adaptive sampling	BC2
3. Centre 6	Adaptive sampling	P3
4. Centre 1	Reg. grid	BC3
5. Centre 4	Profiling	DSR14
6. Centre 3	Adaptive sampling	BC1
7. Centre 5	Adaptive sampling	DSR15

We realise that Centres ranked rather high used BC1 or BC2. However, the DSR was only used by Centre 4 and 5; Centre 5 especially applied concisely a very scarce point density and was therefore ranked very low; Centre 4 executed the measurements within contract work for a much larger project and might not be very representative either. Consequently it does not seem justified to deduce from this list any ranking of the plotters.

Another way would be to use the “efficiency” of the measurements for ranking; that means we establish the rank according to the quotient between the standard deviation divided by point density (cf. table 17). The order is quite well defined; only the test field A1 would give a slightly different ranking regarding the position of Centres 1 and 4:

1. Centre 2	Adaptive sampling	BC2
2. Centre 3	Adaptive sampling	BC1
3. Centre 6	Adaptive sampling	P3
4. Centre 4	Profiling	DSR14
5. Centre 5	Adaptive sampling	DSR15
6. Centre 1	Reg. grid	BC3
7. Centre 7	Reg. grid	BC1

The above ranking shows very clearly that the type of plotters did not really influence the measuring precision and we can assume that all plotters, independent of the make, supplied a sufficiently high precision for the terrain modelling. We realize however once again that adaptive sampling is far more efficient than the measurement of grids or profiles, at least as far as the number of points is concerned. Lets mention in this context that

also regular grids could be used in a sort of adaptive sampling; this would mean that the grid spacing is changed in accordance with the terrain particularities. However such an approach was not used here.

7 A priori estimation of the DTM precision by profile segmentation

7.1 Basic considerations

Up to now the considerations concentrated on the precision analysis of the empirical results. An attempt was made to derive the terrain characteristic “alpha (α)” from the empirical measurements. The parameter introduced by Ackermann gives an indication of the necessary point density if one wants to reach a certain precision in terrain modelling. However, the operator or the engineer who has to prepare the measuring instructions for the terrain modelling might have difficulties in determining the appropriate point density properly, prior to the measurements. Furthermore, it seemed interesting to verify whether there is a linear relation between the point density and the modelling precision.

Various discussions took place on this question and the co-author of the article tried to work out a simple procedure based on profile measurements. Profiles, even very dense profiles, are quite easy to measure and can serve after the measurements as an efficient tool for the quality assessment. At the time of contouring on analogue plotters, the control measurement of a profile and its comparison with the actual contour lines was an efficient means for the assessment of the precision. Profiles have been used already earlier for the characterization of the terrain roughness (cf. under others [3]). Very often Fourier Transformations are used in order to determine the terrain characteristics. However, the establishment of a direct relation between the coefficients of a Fourier Transformation and the sampling distance, corresponding to an irregular point distribution appeared not quite obvious. In order to obtain such a relation we used a “segmentation” of the terrain profiles. That means that the terrain profile is approximated by polygons of varying side lengths and the standard deviation is computed successively between the original profile and the approximation polygon.

7.2 Practical approach for profile segmentation

Practically speaking the approach chosen is as follows. In the first phase the whole profile is approximated by a single straight line passing through the beginning and end points of the profile and one computes the r.m.s. deviation between the profile and its approximation. Afterwards, one looks for the profile point with the maximum deviation and uses now two segments, one joining the beginning point with the detected maximum and the other joining the maximum with the end point (cf. figure 34) and again the root mean square deviation is computed. Then again the maximum deviation is derived and the corresponding segment is again split up. This process is repeated until the desired approximation is achieved. The quality of the approximation is expressed by the root mean square deviation between the terrain profile and the segments of approximation.

Table 17:

Ranking of the centres according to the measuring efficiency.

Centre	Plotter	Arrangement of mass points	Rank efficiency	Rank precision	Modelling precision	Point distance	Multipl. factor (efficiency)
(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Zone A1							
Cen 2	BC2	Adapt.samp 3-9m	1	2	6.2 cm	6.0 m	0.010
Cen 5	DSR15	Adapt.samp 3-12m	5	7	11.2 cm	9.4 m	0.012
Cen 1	BC3	Regular grid 10m	6	4	6.5 cm	5.4 m	0.012
Cen 4	DSR14	Regular grid 4-12m	4	5	10.6 cm	6.8 m	0.016
Zone A2							
Cen 2	BC2	Adapt.samp 3-9m	1	2	7.8 cm	5.1 m	0.015
Cen 3	BC1	Adapt.samp 3-9m	2	6	10.1 cm	6.0 m	0.017
Cen 4	DSR14	Regular grid 4-12m	4	5	11.4 cm	5.8 m	0.020
Cen 7	BC1	Regular grid 3 m	7	1	7.3 cm	3.0 m	0.024
Zone B1							
Cen 3	BC1	Adapt.samp 3-9m	2	6	11.4 cm	5.9 m	0.019
Cen 4	DSR14	Profiles 9m distance	4	5	9.4 cm	4.3 m	0.022
Zone B2							
Cen 6	P3	Adapt.samp 4-12m	3	3	19.4 cm	8.2 m	0.024
Cen 4	DSR14	Profiles 7m distance	4	5	13.1 cm	4.6 m	0.028
Cen 5	DSR15	Adapt.samp 4-12m	5	7	27.7 cm	9.2 m	0.030
Cen 1	BC1	Regular grid 10m	6	4	24.1 cm	5.8 m	0.042
Zone C1							
Cen 6	P3	Adapt.samp 4-8m	3	3	14.7 cm	4.8 m	0.031
Cen 4	DSR14	Profiles 9m distance	4	5	15.6 cm	4.0 m	0.039
Cen 1	BC1	Regular grid 10m	6	4	15.4 cm	3.4 m	0.045

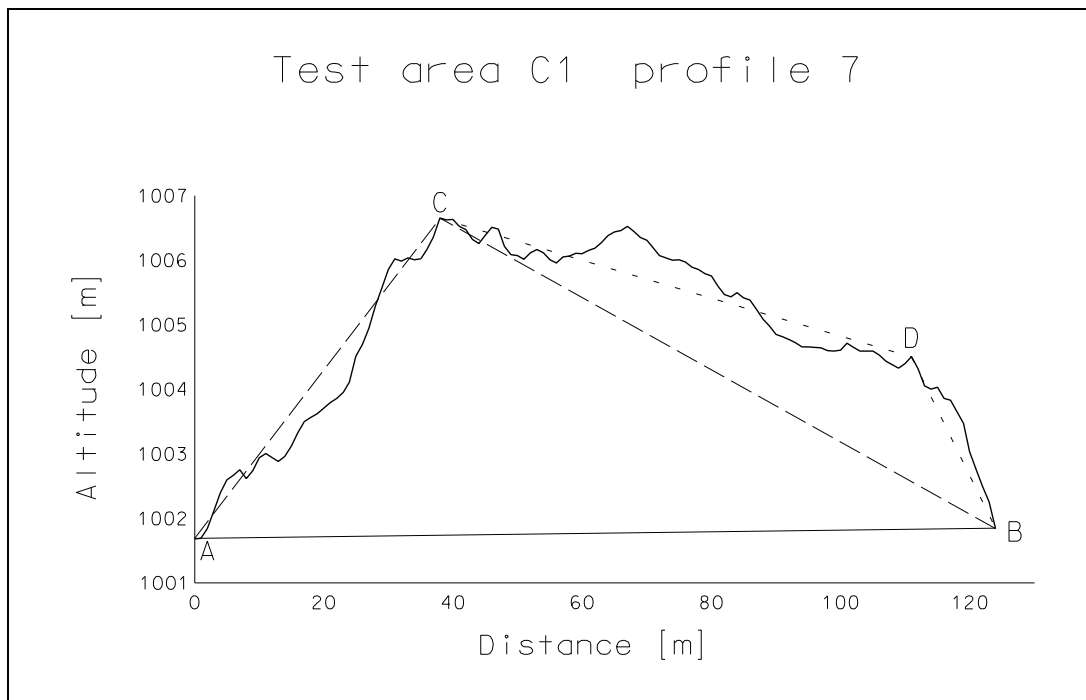


Figure 34:

Principle of terrain profile approximation by segments.

The successive reduction of the segments used for the profile approximation leads to an increasing precision of the approximation. The relation between the mean segment length and the precision of approximation is presented in table 18 and the values are presented graphically for the test area A1 and C1 (cf. figure 35). For practical reasons, the curves have been plotted in a double logarithmic scale, so that the supporting points appear in the same distance. When analysing the figures one sees that the graphs follows more or less straight lines, although a closer analyses reveals that the slope increases with an increasing point distance. This becomes quite evident in the table 18: Under the line “Test linear.” we present the double relation (e.g. quotient between segmentation length for $\pm 40\text{cm}$ and for $\pm 10\text{cm}$ divided by the quotient between 40cm and 10cm). In most cases we have for $\pm 40\text{cm}$ a value around $0.7\text{--}0.8$ and for the approximation with $\pm 2.5\text{cm}$ a value of 1.3 . So the slope or the terrain characteristic α reduces for about 15% when doubling the point distance (segmentation). That means that the mean point distance for a one-meter approximation is not 10 times larger then for a 10cm approximation but only 5 times larger.

Effectively the slope of the curve or the quotient between the terrain approximation and the segmentation distance corresponds to the terrain characteristic α , introduced by Ackermann. However, we have to take into consideration that a profile is easier to approximate than a surface. According to Matheron [7] the profile approximation would be twice as precise as the surface approximation for the same grid spacing. Consequently, one would read for the area of A1 a mean segment length of $s_m=24.6\text{m}$ for a terrain approximation of $\pm 10\text{cm}$ leading to an $\alpha=0.0081$. The spread for s_m ranges from $20\text{--}33\text{m}$. For the test field C1 one obtains a mean $s_m=9.5\text{m}$, a spread of $7.8\text{--}14.1\text{m}$ and a mean for $\alpha=0.021$ (cf. table 18).

It is understood that the segmentation leads to a certain spread which can be used to compute a mean square error. Furthermore, it is understandable that the ideal profile approximation leads to a rather long point distance, never achieved in practical work. Consequently, an attempt was made to compute a relation between the “alpha” obtained from segmentation and from practical work (cf. table 19). According to this comparison, we get a factor of 1.59 with a mean square error of ± 0.25 . In practice we have to admit that more points for about a factor of 1.5 to 2.0 have to be measured, especially when taking into consideration the rather great number of points on break or form lines. In this sense, we have to admit that Centre 1 chose the grid distance properly with 10m for test area A1. The mean segmentation distance for this area is 27.3m to be divided by 2 gives 14m , whereas a grid distance of 5m should have been used for the test areas B2 and C1 in order to still obtain a modelling precision of $\pm 10\text{cm}$. The grid distance of 10m should lead to a precision of terrain modelling of about $\pm 20\text{cm}$, as effectively achieved.

It should also be noticed that the profile approximation does not show a precision limit, due to terrain noise or other factors. It is true that the profiles have been measured photogrammetrically and might show a certain error. But from this experiments we have to deduce that the increase of precision is achieved more rapidly than expected from the point density. On the other hand through all this work we observed again and again systematic errors, which even might become more important when comparing these photogrammetric measurements with terrestrial measurements. Consequently the constant term β designated as terrain roughness might still be relevant, but might only reveal itself when using terrain measurements for control purposes and might mainly reflect systematic error components.

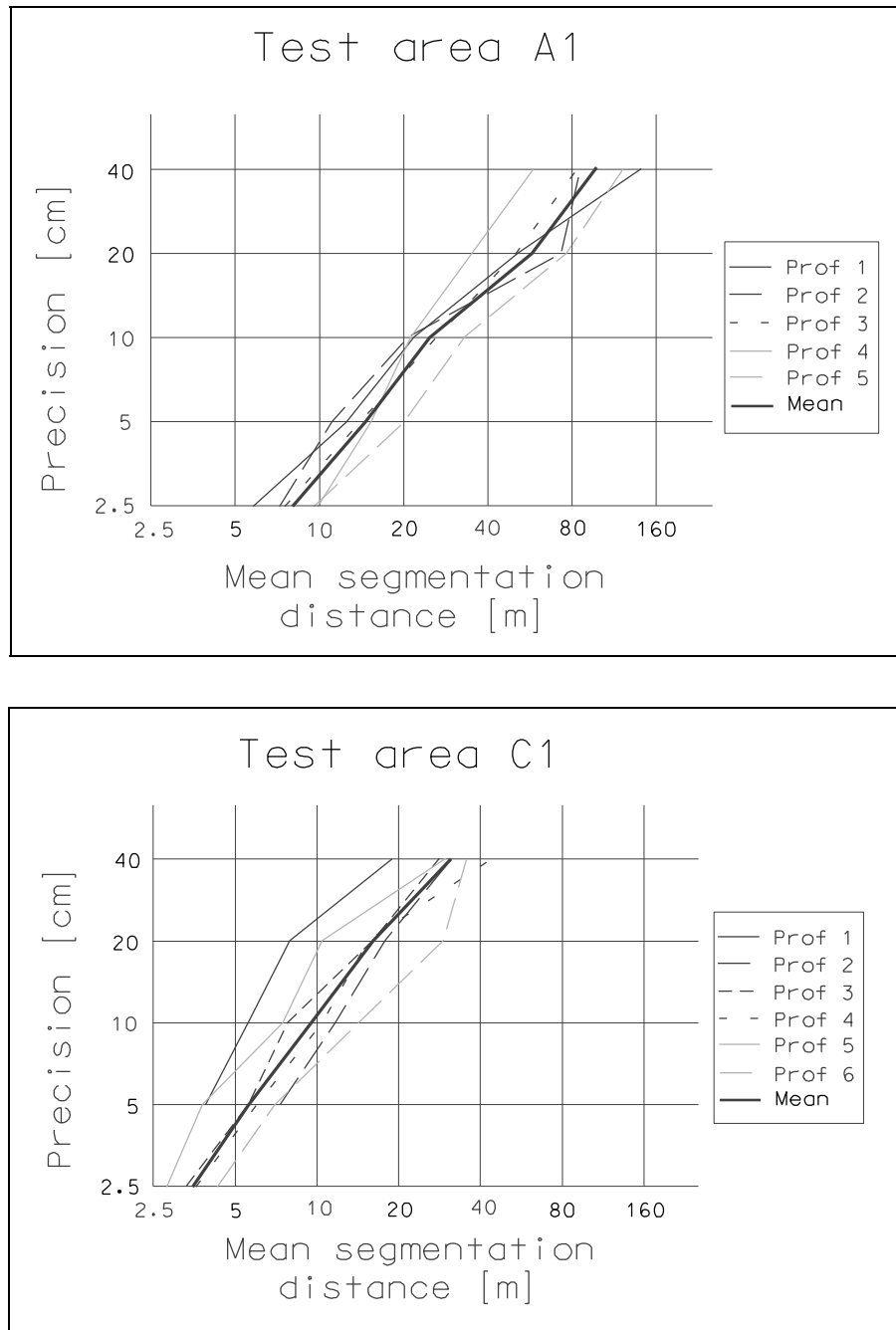


Figure 35:

Relation between the profile approximation and the mean segmentation length presented in a double logarithmic scale.

Table 18: Overview of the parameters for segmentation. Column 2 shows the profile length and column 3 the number of points measured. Although the operator tried to measure a point every meter he had to interrupt the measurements in areas with dense vegetation. Column 4 to 8 list the mean segmentation length required to obtain precision in meter indicated above. The mean values, the standard deviation and the double relation between segmentation and precision are then given in bold; the values for $\pm 10\text{cm}$ serve as a reference for the double relation. These values give an indication of the faint non-linearity of point distance and modelling precision.

(1)	Profile length (2)	Number of points (3)	Segmentation for a standard deviation of				
			± 40 cm (4)	± 20 cm (5)	± 10 cm (6)	± 5 cm (7)	± 2.5 cm (8)
Test area A1							
Prof 1	305	306	140.0	50.8	21.8	12.5	5.8
Prof 2	365	330	85.0	73.0	20.8	11.0	7.2
Prof 3	330	312	83.0	50.0	26.0	14.0	7.5
Prof 4	248	222	58.0	35.0	21.2	15.2	9.9
Prof 5	628	629	120.0	75.0	33.0	20.0	9.5
Mean			97.2	56.8	24.6	14.5	8.0
Stand.dev			32.6	17.0	5.2	3.4	1.7
Test linear.			1.0	1.2		1.2	1.3
Test area A2							
Prof 1	229	230	28.0	26.0	15.3	10.3	6.5
Prof 2	289	290	40.0	22.0	11.6	7.5	4.2
Prof 3	335	336	31.0	24.8	13.4	8.8	5.4
Porf 4	448	446	77.0	30.7	18.8	13.4	7.1
Mean			44.0	25.9	14.8	10.0	5.8
Stand.dev			22.6	3.6	3.1	2.5	1.3
Test linear.			0.7	0.9		1.4	1.6
Test area B1							
Prof 1	299	300	55.0	24.0	12.5	7.9	4.8
Prof 2	308	309	62.0	19.0	12.4	8.3	4.7
Prof 3	308	309	50.0	30.8	13.6	7.7	4.5
Prof 4	380	381	49.0	21.0	11.3	7.9	4.1
Mean			54.0	23.7	12.5	8.0	4.5
Stand.dev			5.9	5.2	0.9	0.3	0.3
Test linear.			1.1	1.0		1.3	1.5
Test area B2							
Prof 1	285	279	33.0	20.5	12.3	8.0	3.2
Prof 2	235	236	31.0	16.4	13.3	5.2	2.8
Prof 3	324	325	36.0	21.0	11.0	5.2	
Prof 4	254	255	26.0	12.6	8.2	4.2	
Mean			31.5	17.6	11.2	5.7	3.0
Stand.dev			4.2	3.9	2.2	1.6	0.3
Test linear.			0.7	0.8		1.0	1.1
Test area C1							
Prof 1	320	260	18.8	7.9	5.6	3.9	
Prof 2	410	375	31.2	17.8	11.7	7.3	
Prof 3	239	240	28.0	16.0	7.8	5.6	3.3
Prof 4	262	260	43.9	15.4	10.4	6.0	3.6
Prof 5	207	199	29.5	10.4	7.5	3.8	2.8
Prof 6	190	191	35.0	29.0	14.1	7.0	4.3
Mean			31.1	16.1	9.5	5.6	3.5
Stand.dev			8.3	7.3	3.1	1.5	0.6
Test linear.			0.8	0.8		1.2	1.5

Table 19:

Comparison of the empirical and theoretical terrain characteristic alpha (α). Column 2 shows the empirically determined value as a mean computed from table 16 (column 9) and column 3 gives the corresponding standard deviation. Column 4 reproduces the mean values for the segmentation for $\pm 10\text{cm}$ according to table 17, while column 5 shows the corresponding alpha: $(2 \cdot 0.1 / \text{segmentation})$; column 6 gives the relation between the alpha of empirical measurements and of the segmentation, and column 7 the alpha value corrected for the mean factor 1.59. Finally, we give the standard deviation of the segmentation and the corresponding standard deviation for alpha in columns 8 and 9.

Test area (1)	Mean α empirical. (2)	Stand. dev. α (3)	Segmen- tation in m (4)	α accord. Segment. (5)	Rel: $\alpha_{\text{emp}}/\alpha_{\text{seg}}$ (6)	α correct. (7)	Stand. dev. segment. (8)	Standard- dev α (9)
Test area A1	0.0129	0.0022	24.6	0.0081	1.58	0.0130	5.2	0.0017
Test area A2	0.0197	0.0034	14.8	0.0135	1.46	0.0215	3.1	0.0028
Test area B1	0.0202	0.0006	12.5	0.0160	1.26	0.0255	0.9	0.0012
Test area B2	0.0337	0.0076	11.2	0.0179	1.89	0.0285	2.2	0.0035
Test area C1	0.0376	0.0062	9.5	0.0211	1.78	0.0336	3.1	0.0069
Mean					1.59			
Stand. dev.					0.25			

The terrain profiles have been measured on an analytical plotter (Leica BC1) by an experienced operator. It is understood that the precision of the profiles corresponds to the possible measuring precision in photogrammetry. According to a rough estimation, the precision of the point measurement might be about $\pm 4\text{cm}$ in accordance with the measuring precision of the other centres. Consequently, each of the profiles can be considered as a sequence of check points and used as check points for the terrain approximation.

7.3 Conclusions regarding the profile segmentation

The complementary study concentrated on the use of profile measurements for the a priori determination of the required point density and for the quality assessment of digital terrain model. One realises that this approach is rather easy to handle and gives considerable information. The present study concentrated on the profile approximation by segmentation. This approach was chosen as it corresponds largely to a surface approximation by finite elements.

By way of conclusion one can summarise:

1. The a priori measured profiles allow one to estimate the required point density including the density of break lines for DTM measurements in order to satisfy predefined precision requirements.
2. There is no strictly linear relation between point density and precision of terrain approximation. When passing from a precision of 10cm to 1m the required point density should decrease for a factor 5 only whereas the precision decreases for a factor 10 according to a rough estimation.

3. The approximation does not show a precision limit, due to terrain noise or other factors. It rather suggests that an increase of precision is achieved more rapidly than expected from the point density. However as the profiles were measured photogrammetrically there might be a systematic error between terrain measurements and photogrammetric values leading to a constant error component.
4. Terrain profiles allow a detailed quality assessment after the completion of the measurement and should be used as standard tools.

8 Recommendations for data acquisition and conclusions

The present work shows that the natural terrain can be modelled by photogrammetric measuring techniques with a precision of about $\pm 20\text{cm}$ or even higher, with photographs in the scale of 1:6000 (flying height 800m above ground) in open terrain. This means that an arbitrary point in the terrain can be interpolated with this precision from the photogrammetric data sets. The present study concentrated mainly on the photogrammetric measuring techniques for data capture by an operator and the necessary precautions. There was no analysis of how automatic measuring methods could be applied; moreover complementary measurements in the field and controlled measurements are hardly discussed.

When discussing precision, it was possible to show that the quality of the terrain modelling depends essentially on the point density. However, serious limitations might come from systematic error components.

8.1 Systematic error components

In the preceding section, error components appeared again and again which can be controlled only to a limited extent by photogrammetric methods and which systematically affect the result especially in comparison with terrestrial measurements. In table 21 we tried to summarise the systematic error components. We can list the following components:

1. Model orientation
2. Control measurements
3. Data capture

Table 20:

Compilation of the measuring precision determined from model orientation and from repeated point measurements (distinct points, grid points) compared with the precision of an interpolated point of the TIN model; all values are in [cm].

Restitution Centre	Standard deviations of observation errors					
	Model orientation	Distinct points	Grid points	Range of observation errors	Interpolated points	Range of interpolat- ion errors
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Test Area A1 Slopes up to 15%; Terrain Type = smooth, weakly inclined						
Cen1	2.6	2.6	3.8	3-4	7.0	7-12
Cen2	0.4	2.7	3.5		6.5	
Cen4	1.4	2.4	3.8		10.6	
Cen5	2.2		3.3		11.2	
Test Area A2 Slopes up to 40% Terrain Type = smooth, strongly inclined						
Cen2	0.9	2.3	3.4	3-4	8.8	7-12
Cen3	4.4	2.3	3.3		10.6	
Cen4	4.9	3.1	2.8		12.0	
Cen7	3.8		2.3		7.5	
Test Area B1 Slopes up to 35% Terrain Type = rolling, weakly inclined						
Cen3	2.6	3.4	4.7	3-5	11.4	10-12
Cen4	2.6	3.4	4.5		9.4	
Cen5			5.0			
Test Area B2 Slopes up to 105%; Terrain Type = rolling, strongly inclined						
Cen1	4.4	3.1	8.7	3-9	24.0	13-28
Cen4	6.8	3.1	8.2		13.0	
Cen5	3.6		6.3		27.7	
Cen6	5.5				19.4	
Test Area C1 Slopes up to 75%; Terrain Type = rough, weakly inclined						
Cen1	3.0	3.4	9.4	3-9	16.0	16-20
Cen4	4.3	3.4	9.4		16.4	
Cen6	3.4				19.8	

Table 21:

Compilation of the systematic deviations determined between the measurements of the various centres; all values are in [cm].

Restitution Centre	Systematic deviations					
	Model orientation	Distinct points	Grid points	Range for point mea- surements	Interpolated points	Range
	(1)	(2)	(3)	(4)	(5)	(6)
Test Area A1 Slopes up to 15%; Terrain Type = smooth, weakly inclined						
Cen1	---	1.9	-2.9	2-3	-3.1	2-5
Cen2	---	-0.6	-1.9		-2.0	
Cen4	---	2.5	2.6		3.1	
Cen5	---		2.2		4.7	
Test Area A2 Slopes up to 40% Terrain Type = smooth, strongly inclined						
Cen2	---	1.0	0	1-2	-1.0	0-8
Cen3	---	-0.6	0.5		-5.7	
Cen4	---	-0.3	1.4		0	
Cen7	---		-1.9		-8.1	
Test Area B1 Slopes up to 35% Terrain Type = rolling, weakly inclined						
Cen3	---	3.4	5.2	3-5	-5.3	0-5
Cen4	---	-3.4	-3.0		-0.1	
Cen5	---					
Test Area B2 Slopes up to 105%; Terrain Type = rolling, strongly inclined						
Cen1	---	2.3	-3.6	2-8	13.6	0-4
Cen4	---	-2.3	7.9		0.1	
Cen5	---		-4.3		1.7	
Test Area C1 Slopes up to 75%; Terrain Type = rough, weakly inclined						
Cen1	---	1.0	1.4	1-2	6.8	2-7
Cen4	---	-1.0	-1.4		-6.8	
Cen6	---				1.8	

8.1.1 Model orientation

It is understood that no systematic error components showed up during the proper model orientation. The residual errors on the check points must however be considered as an indication of systematic error components. If we consider table 2 then for example in test area B2, the triangulation point 477080 has a residual error of +9cm. For control measurements or complementary measurements, one would use necessarily this point as a connection point. This means that there would be a systematic difference between terrestrial and photogrammetric measurements of the order of the said 9cm. We should mention in this context that it is absolutely necessary to determine the height difference between a signalised point and the natural terrain, meaning the height difference between the signal and the terrain, for it is very difficult for an operator to properly evaluate this height difference. Unfortunately, these values were not available for the test measurements. To a certain extent, one could reduce these errors of the model orientation by immediately using the orientation elements of aerial triangulation. However, this is seldom possible and one should not forget that aerial triangulation is normally done with self-calibration, whereas the additional parameters cannot be taken into consideration in the orientation process of individual models.

From the present work, we have to conclude that model orientation might cause systematic errors of up to $\pm 10\text{cm}$ or 0.1% of the flying height and that this component has to be controlled carefully in the measuring process.

8.1.2 Systematic errors in point measurements

As can be seen from table 21, the individual sets of measurements also show significant deviations from one centre to another. For example, Centre 7 has a systematic error of the mean control measurements of 10cm. Systematic deviations between 7 and 8cm are also observed for all other measuring series. We have to take into consideration that photogrammetric measurements show systematic errors, which should absolutely be controlled as well as possible. In principle, it is known that operators have a personal measuring error, which has to be taken into consideration. For example, the analytical plotter BC1 to BC3 allows one to introduce this constant. Similar possibilities are also given for all other instruments. It must be regretted that the protocol of the measurements of the various centres do not give an indication of such precautions. Similar systematic errors can also be caused by variations in temperature.

8.2 *Capturing and modelling of the terrain*

As already explained earlier essential aspects for terrain capture and modelling, in addition to the DTM software packages, are also the type of lines and points measured. In general, the terrain is approximated by mass points, break lines, form lines and the delimitation of dead areas.

8.2.1 Break lines

Break lines have a special significance for terrain modelling. According to the experiences gained one should absolutely model all roads, courtyards and the outskirts of houses as break lines; houses should be delineated at ground level, whenever these elements should also serve for terrain modelling. Furthermore, we have to add the delimitation of water flows, dam sites and other terrain edges. It should be taken into consideration that roads and railways should in general be modelled by 4 break lines, that means the upper edge of the slope and the break line between the slope and the natural terrain. In the present test, the transition line to the natural terrain was unfortunately frequently omitted.

The image of the break lines corresponds to a great extent to the content of a technical plan and it should be possible to combine this restitution with the plotting of planimetry. It is understood that great importance will be given to the height of the measuring points for terrain modelling. Consequently, great care has to be given to the proper height measurements. This should not be a problem when using individual registrations; however, an automatic point capture appears problematic as far too many mass points might be produced and the complementary height measurements will not always be done with the necessary care.

8.2.2 Form lines and other characteristic terrain lines

Form lines in general mark a gradual slope change in the terrain. Contrary to break lines, the particular advantages of form lines are less evident. For example, Centre 1 measured many form lines but was not able in this way to densify sufficiently the rather coarse grid of mass points. One cannot analyse here whether this is due to the different measuring precision on line elements and mass points, or due to other factors. Furthermore, it is understood that this statement concerns only the terrain types treated and is valid only in relation to the interpolation programs actually used.

8.2.3 Delimitation of dead areas and of areas of inferior precision

In general areas which should not be presented by the digital terrain model or which cannot be measured properly are declared as dead zones. That means that the contour lines should not cross houses which have to be designated as dead zones. Also areas which cannot be seen properly, such as dense forests, must also be excluded and must be complemented by terrestrial measurements. Whenever possible, it is recommended that one should measure the surrounding lines of dead areas properly on the ground in order to allow their use as break lines, although this precaution might require an additional effort and prove difficult to perform. Especially for houses, it is much more appropriate to plot the roof lines and ensure that the contour lines stop properly on the edge. The additional requirement that these lines should be properly on the ground further complicates the measuring process. In the present case, the principle that the delimitation line of dead areas should be on the ground was only partially observed. Moreover, the definition of dead areas was not uniformly handled. Various centres eliminated very generous dead areas, whereas others undertook to also capture rather difficult areas. It should be recommended to particularly designate zones which are difficult to measure and to provide connection points for complementary terrestrial measurements, as was specially suggested by Centre 2 (SITO).

8.2.4 Mass points and spot heights

The arrangement of mass points can be done according to various criteria :

- Regular grid (Centres 1 and 7);
- Profile measurements (Centre 4);
- Irregular, possibly according to the principle of adaptive sampling (Centres 2,3,5,6).

The best results with a relatively low number of points were achieved with an irregular point distribution. On the other hand, profile measurements, regular or irregular grids require more measurements. It is not quite clear whether this higher number of measurements in a regular grid really requires more time. According to various experiences, an operator can measure a grid very rapidly and can achieve a performance of up to 4000 points per hour. This high performance is possible as the operator can foresee where to measure the next points. However, this effect is lost when doing adaptive sampling and a lower performance is obtained.

8.2.5 Precision and point density

In the preceding section we dealt with the technique of profile segmentation. According to this technique, the relative error of interpolated points can be estimated according to the formula $\sigma = \alpha * d$; (α = coefficient depending on the terrain type and also on the required precision and d = the mean point distance of the supporting points). That formula corresponds quite well with the results effectively obtained. One may recall that in addition to these values, we have to take into consideration the systematic errors of 7-10cm or 0.1 to 0.15% of the flying height, designated as a constant term, above-discussed. The final precision formula should then read:

$$\sigma = \sqrt{[(\alpha * d)^2 + \text{constant}^2]}$$

For the various test fields, we obtained values for the terrain characteristic α of between 0.01 and 0.04.

8.3 *Software packages for terrain modelling*

The study presented is based mainly on the Terrain Analyst by Intergraph. Comparative computations with the programme package SCOP (Stuttgart-Wien) and CIP show hardly any differences. According to this study, it can be concluded that a plain interpolation with relatively small finite elements provides satisfactory results. CIP works with bicubic interpolation techniques and yields no better precision. Even the filtering of observation errors, as is possible with SCOP, did not supply any increase in precision. Rather the a priori point precision had to be set at about ± 1 cm in order to obtain the same precision as with the Terrain Analyst. Consequently, no real differences have been found in this study for the different software packages.

8.4 *Quality control of terrain modelling*

A great part of the study had concentrated on the control of the precision. Principally, we used a network of check points with a distance of 25 m. It is absolutely recommended that such a control network be introduced in order to achieve efficient quality control.

Additionally, one should also use profile measurements for quality control. As also discussed, it is rather easy to estimate from profile measurements the necessary point density for the terrain modelling, in order to obtain a predefined precision. Furthermore, the profile points represent an ideal series of check points, which should be included in the quality control.

8.5 Conclusions

The present study of OEEPE tries to summarise the state of the art of data acquisition for precision terrain modelling for civil engineering by photogrammetric stereoplottting. It is based on the standard procedures used in 7 different photogrammetric plotting centres from 3 different countries. The precision obtained with photographs in the scale 1:6,000 (flying height 900m) is about $\pm 20\text{cm}$ or 0.2‰ of the flying height. In this value are included a random component of $\pm 8\text{-}15\text{cm}$ or 0.1-0.15‰ of the flying height and a systematic component of 5-10cm or 0.05-0.1‰ of the flying height. The main part of the study is a direct comparison of the specific techniques of data acquisition of the different centres and the trial to analyse advantages and disadvantages of the different methods. The study presents herewith a reference for photogrammetric stereo plotting at a time when other techniques such as automated DTM capturing, Laser altimeters and Radar techniques are emerging. The study showed that photogrammetric DTM measurement is a precise technique giving a very compact data set, but requires certain precautions in order to guarantee a high standard.

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FM KARTTA OY, Helsinki, Finland

It is understood that the institutions of the authors also participated in the measurements. The private photogrammetric office Flotron AG acted as pilot centre, conceived the test and analysed the results. Later on a small working group was formed, which was chaired by the principal author and included Prof. Ackermann and the co-author. The presentation of the measurements and the analysis of the results proved quite complex and various hypotheses for the establishment of standard formulas for the prediction of the obtainable precision were worked out and later rejected. It was only at this phase that the co-author tried to take an active part in helping to compile the final report. The authors are very grateful for the valuable contributions of Prof. Ackermann and Prof. Dowman; they also acted as referees of the study.

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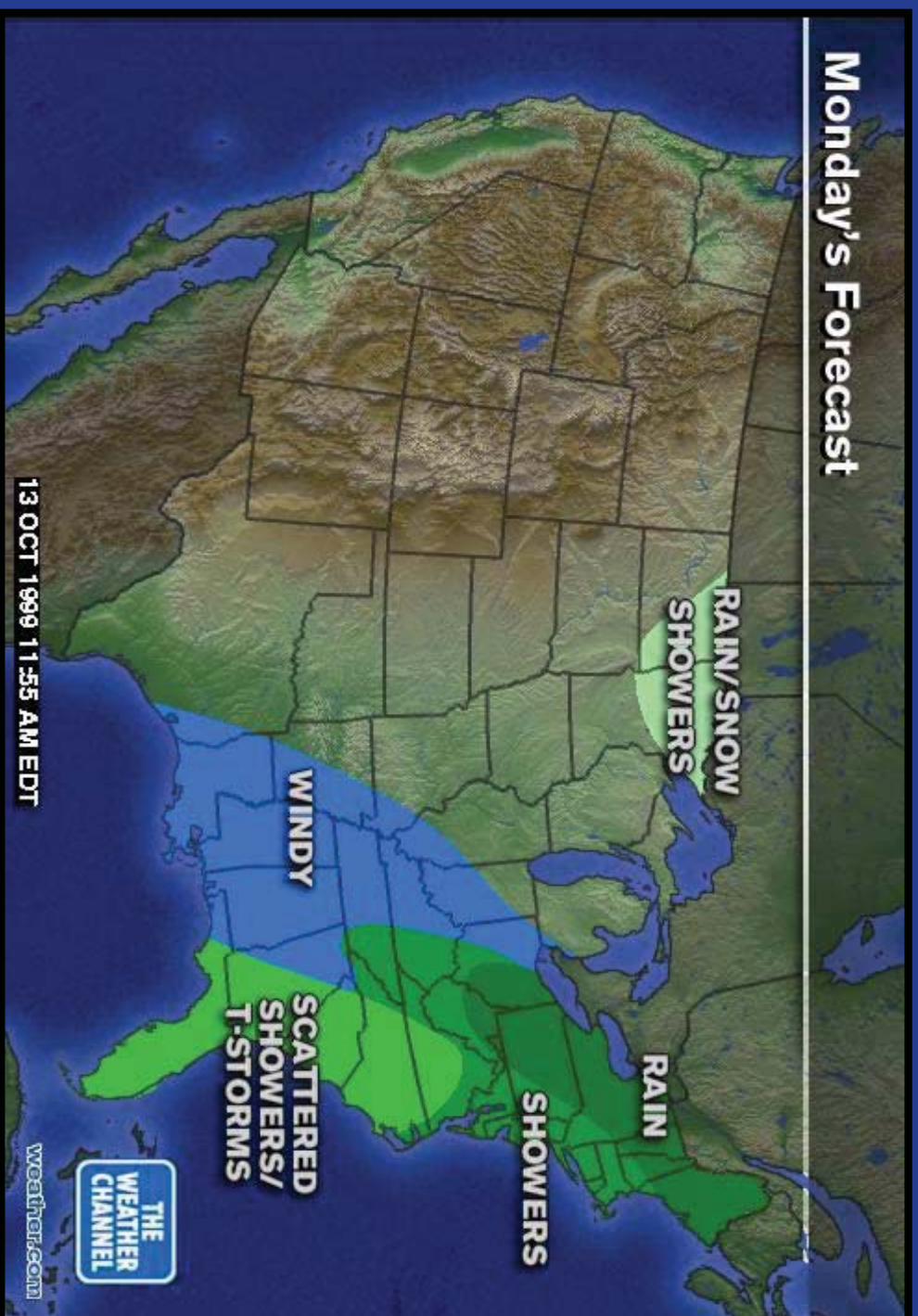
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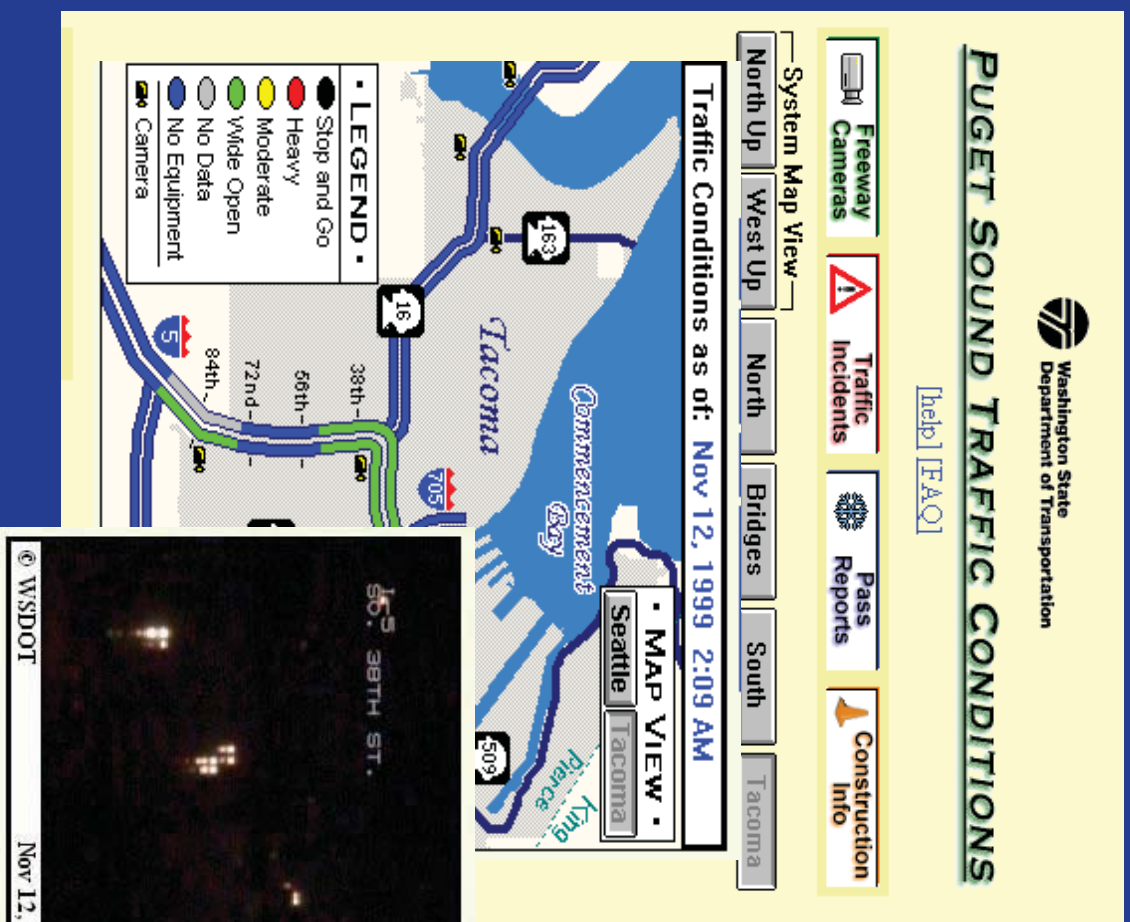
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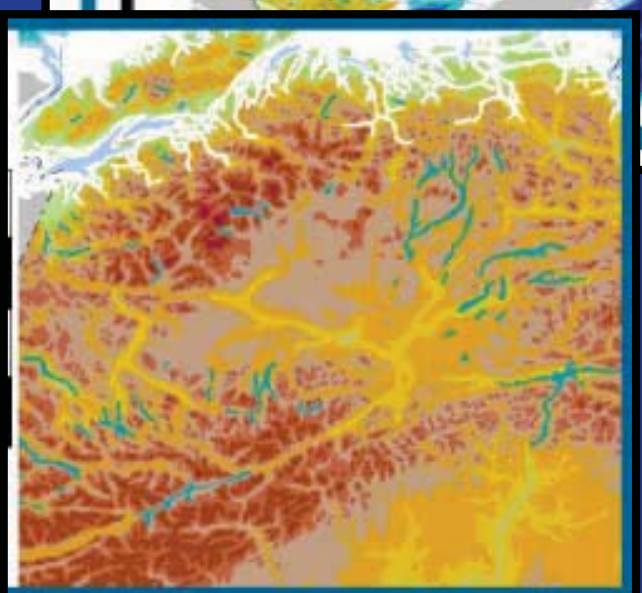
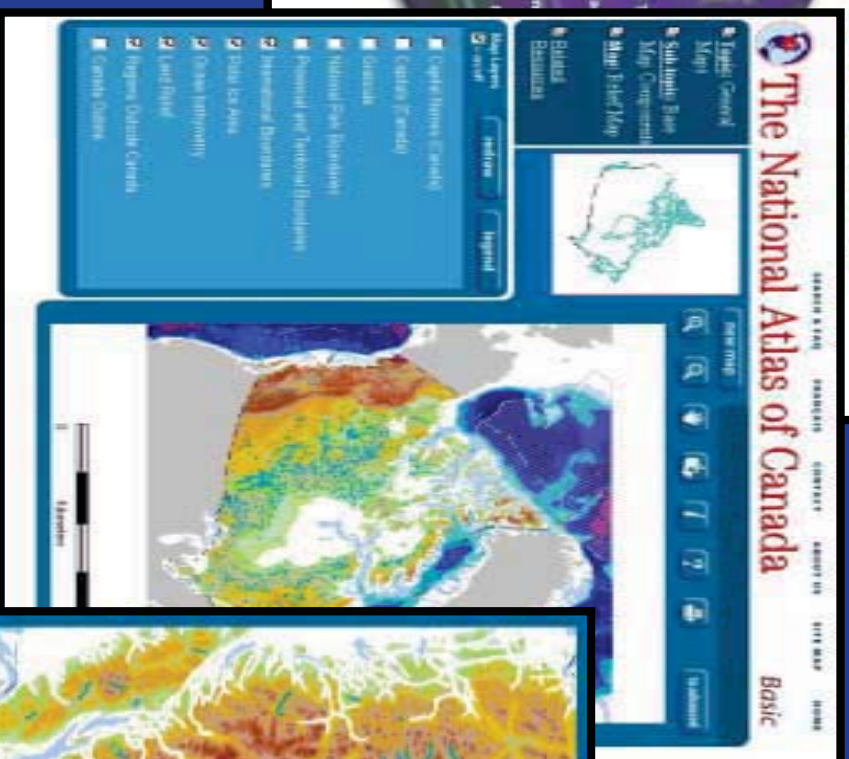
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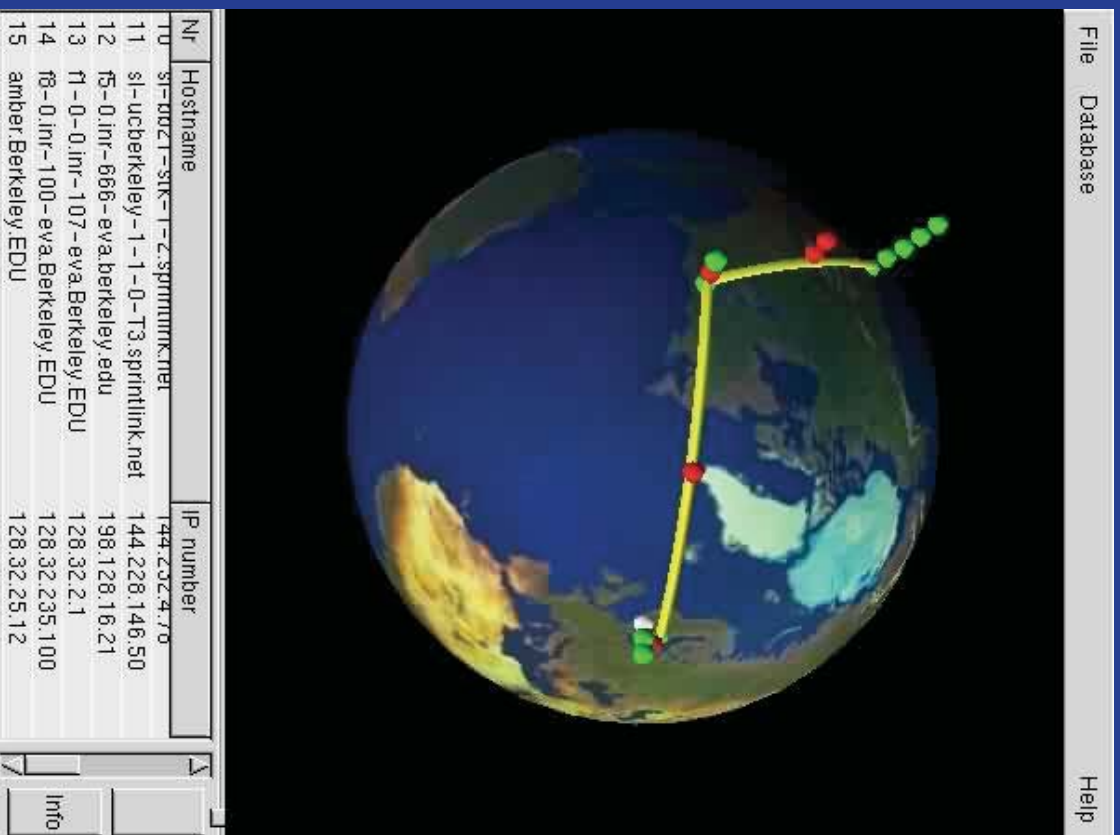
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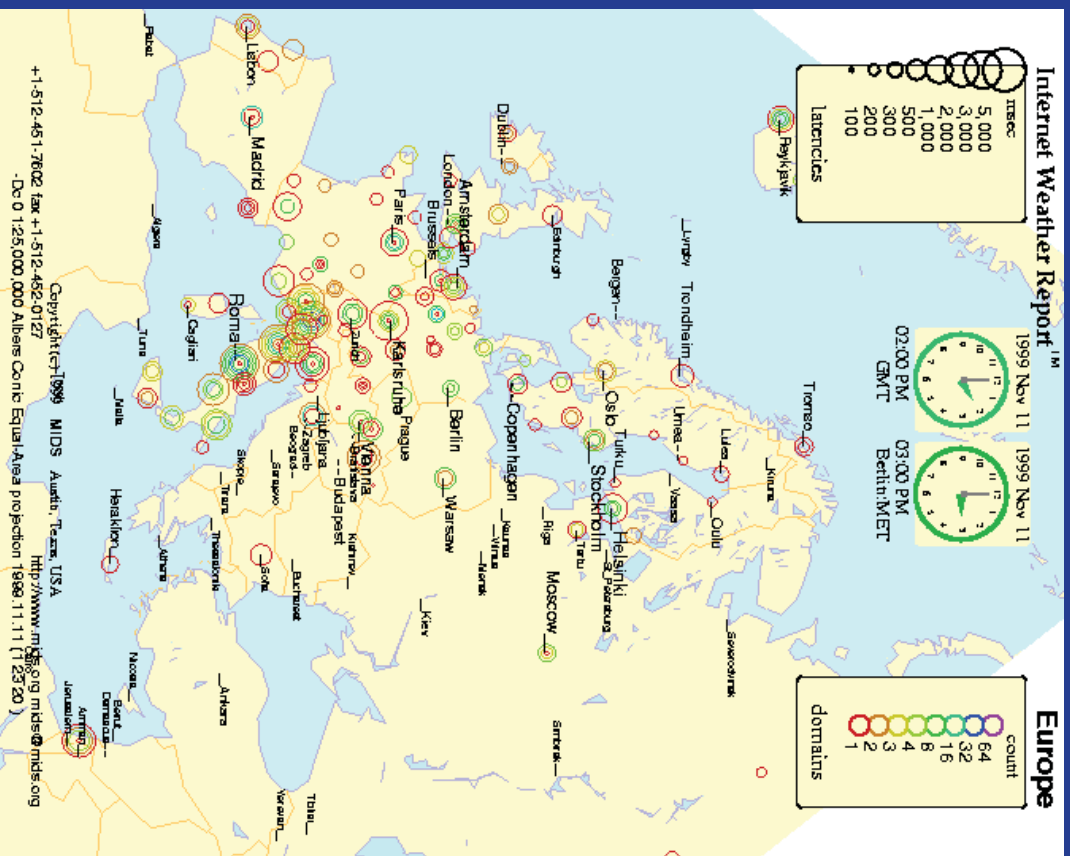
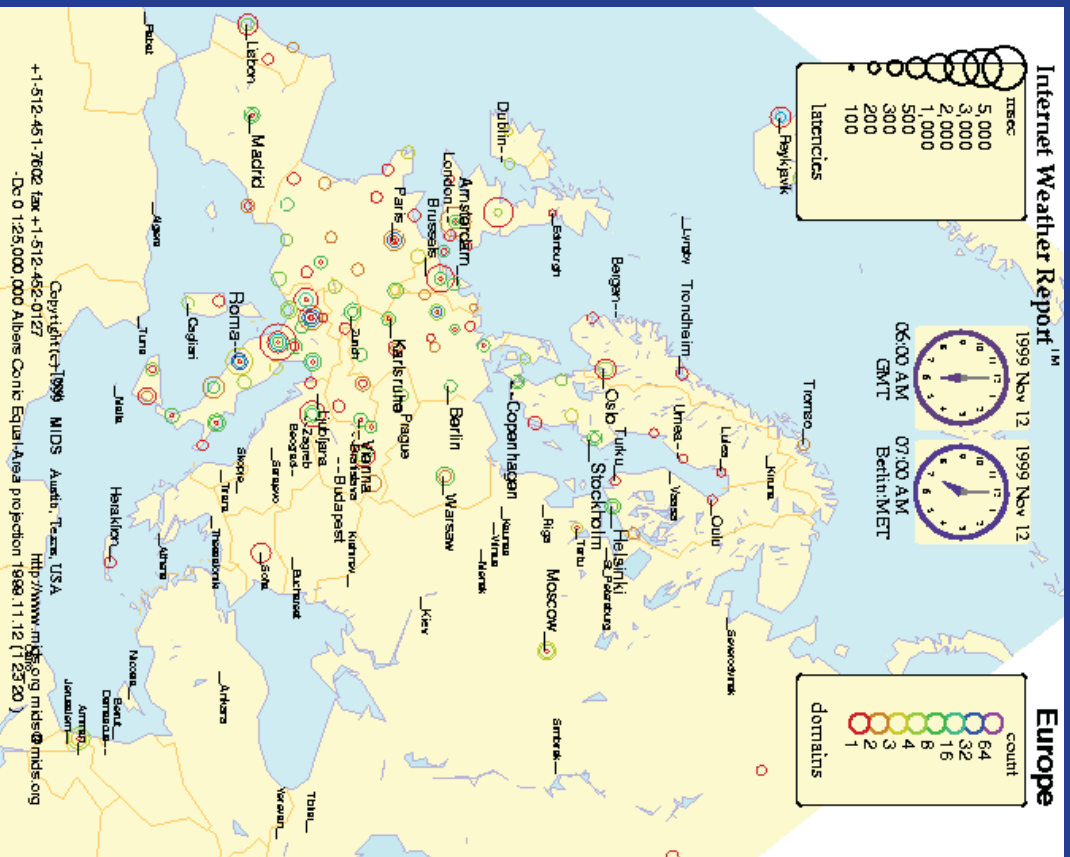
[Canada's Environment](#)
[Canada's Economy](#)
[Canada's Society](#)
[Canada's Geography](#)



new realms: mapping cyber space



new realms: mapping cyber space



new realms

geoinformatics, cartography & visualization

Conceptual

Artistic

Geographic

Cables & Satellites

Traceroutes

Census

Topology

Info Maps

Info Landscapes

Info Spaces

ISP Maps

Web Site Maps

Surf Maps

Historical

An Atlas Of Cyberspaces

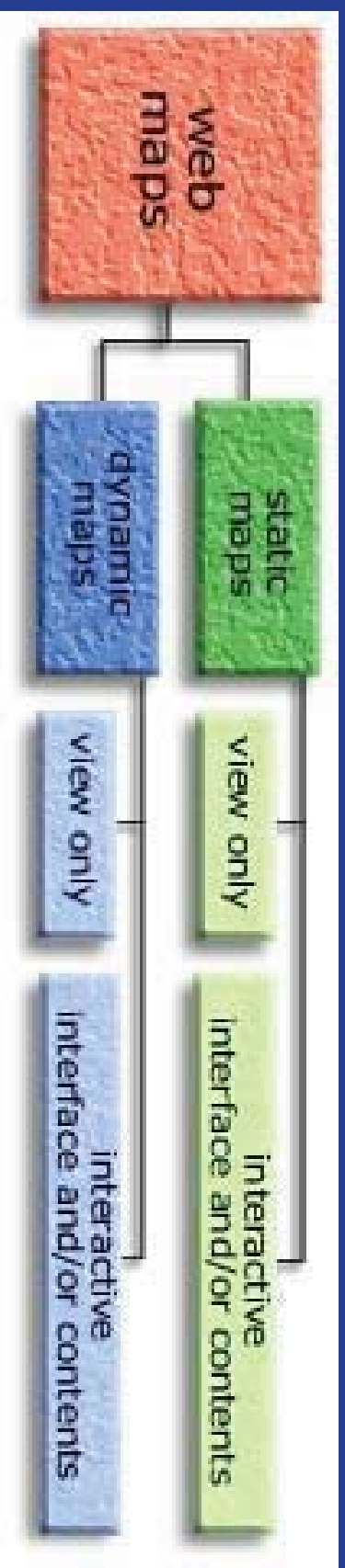
Welcome to the Atlas of Cyberspaces

This is an atlas of maps and graphic representations of the geographies of the Internet, the World-Wide Web and other emerging Cyberspaces.

These maps of Cyberspaces - *cybermaps* - help us visualise and comprehend beyond our computer screen, in the wires of the global communications network information resources. The cybermaps, like maps of the real-world, help us landscapes, as well being objects of aesthetic interest. They have been created in different disciplines, and from all corners of the world.

Some of the maps you will see in the Atlas of Cyberspaces will appear familiar, as they follow the conventions of real-world maps, however, many of the maps are much more innovative, using new metrics and grids. The atlas comprises fourteen

web cartography: classification of web maps



web maps static view only



web maps

static interactive



This image is protected by Crown copyright; please see the [full terms and conditions](#) of use.

Map Scale: 70,000

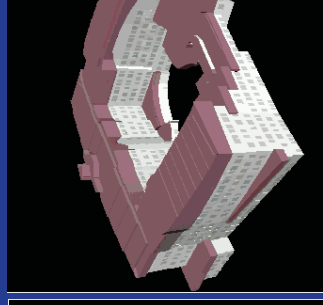
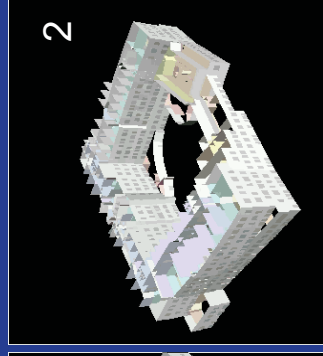
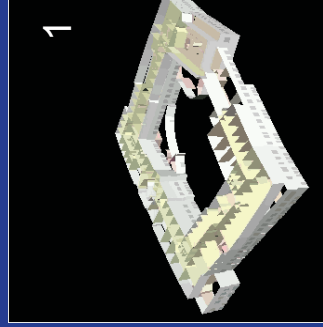
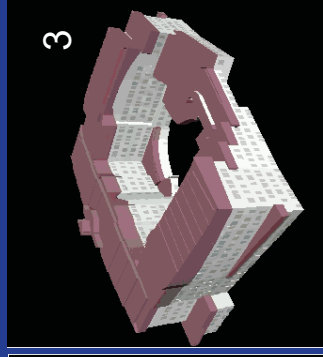
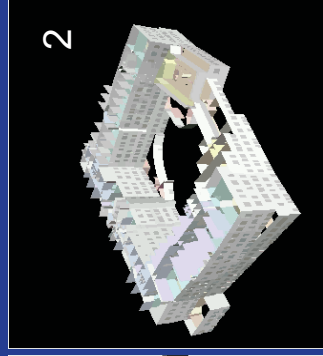
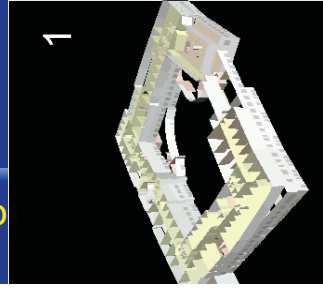
Go

GB Gazetteer

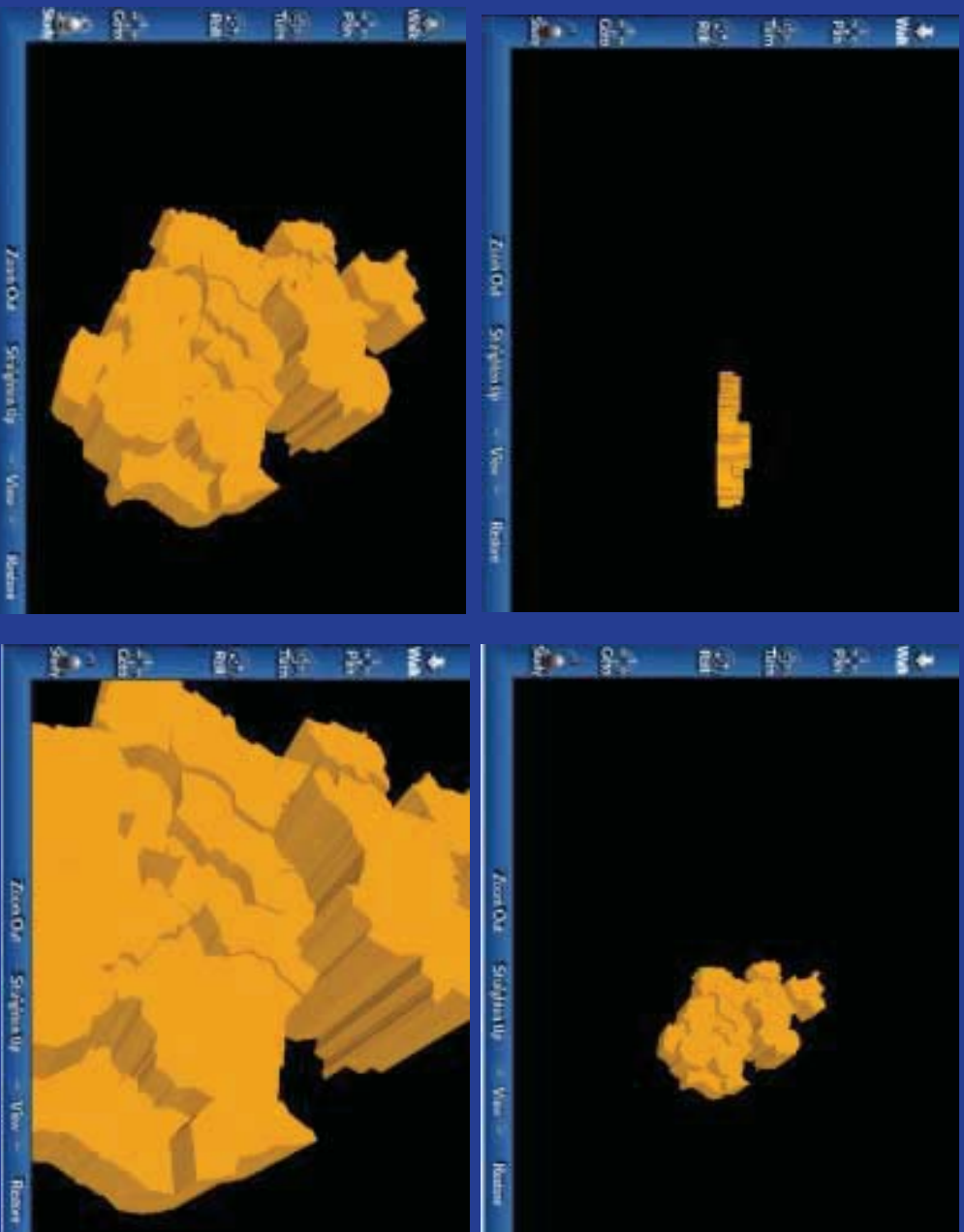


web maps dynamic view only

- animated gif (loop)



web maps dynamic interactive



- vrmf worlds

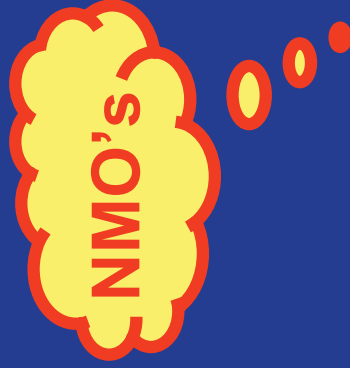
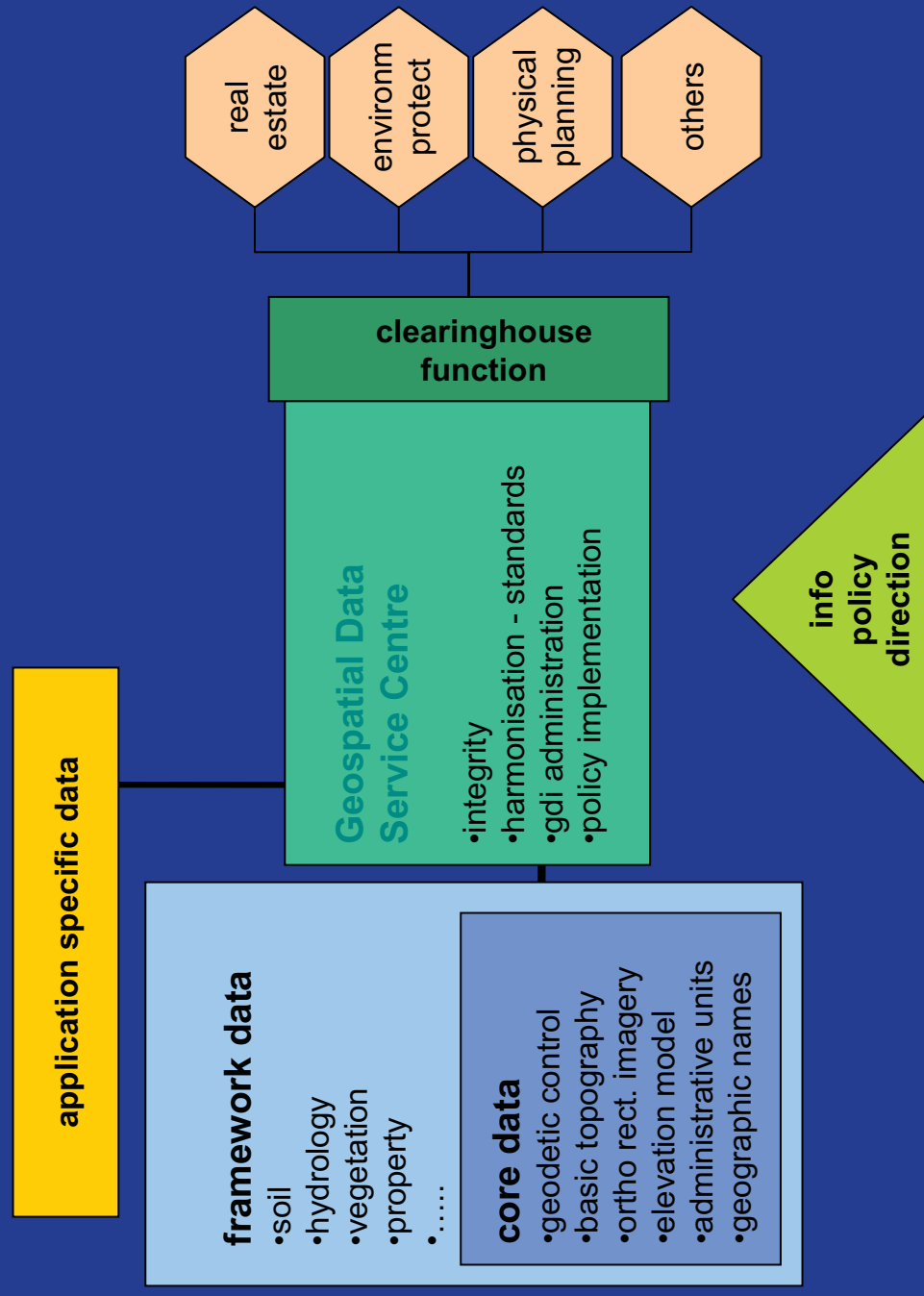
the (changing) environment of national mapping organizations

assume their task is.....

to ensure the **timely availability** of **up-to-date** topographic information of national scope, according to nationally accepted data standards, and standards of integrity, formats, etc.

...in the framework of the national geospatial data infrastructure

nmo's & structure geospatial data infrastructure



why web maps for NMO's?

- publish information about map data and services (supply driven)
- provide actual download of data sets (e-commerce)
- reply to specific requests (demands driven)

mmo's and e-commerce



Novelties

Beskrivning

Webbkarta

Nyheter

Exempel 1

Exempel 2

Exempel 3

Hjälp

Fastignets
address

Webbkarta

Beställ kartbild och fastighetsinformation via internet.

Tjänsten innebär att man med hjälp av angivnen fastighetsbeteckning, eller angivna koordinater, får ut en kartbild över detta område. Om fastighetsbeteckning anges fås även ett utdrag från Fastighetsdatasystemet, rörande denna fastighet. Inom tätortsområden redovisas inte fastighetsgränser.

Informationen skickas till ditt faxnummer eller till din e-post adress.

För att kunna använda tjänsten krävs att du är registrerad användare, och har ett avtal med Lantmätnverket. Detta avtal undertecknas och sänds in till Lantmätnverket, varefter ni registreras, och tilldelas ett lösenord för tjänsten.

Det är möjligt att prova tjänsten innan ett avtal skrivs. Max tre beställningar kan göras.

GeoInfo's and e-commerce



Webbkarta

.....

Beskrivning

.....

Webbkarta

Nyheter

Exempel 1

Exempel 2

Exempel 3

.....

Hjälp

.....

Fastighets

adress

Webbkarta

Enter Network Password

Please type your user name and password.

Site:

Realm:

User Name:

Password:

☐ Save this password in your password list

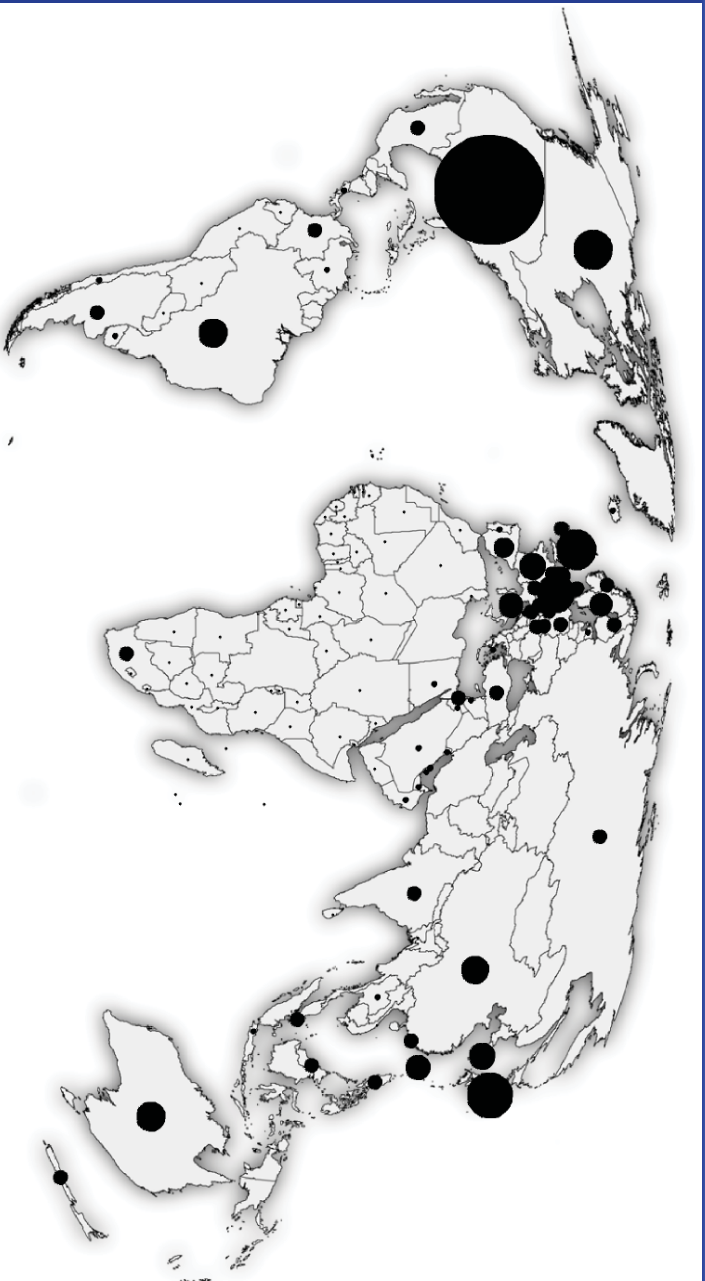
OK Cancel

angivna koordinater,
även ett utdrag från
edovisas inte

har ett avtal med
ket, varefter ni

r kan göras.

web access



Internet users

- 50 - 25,000
- 25,001 - 250,000
- 250,001 - 2,500,000

Top 15 nations (x 1 million)

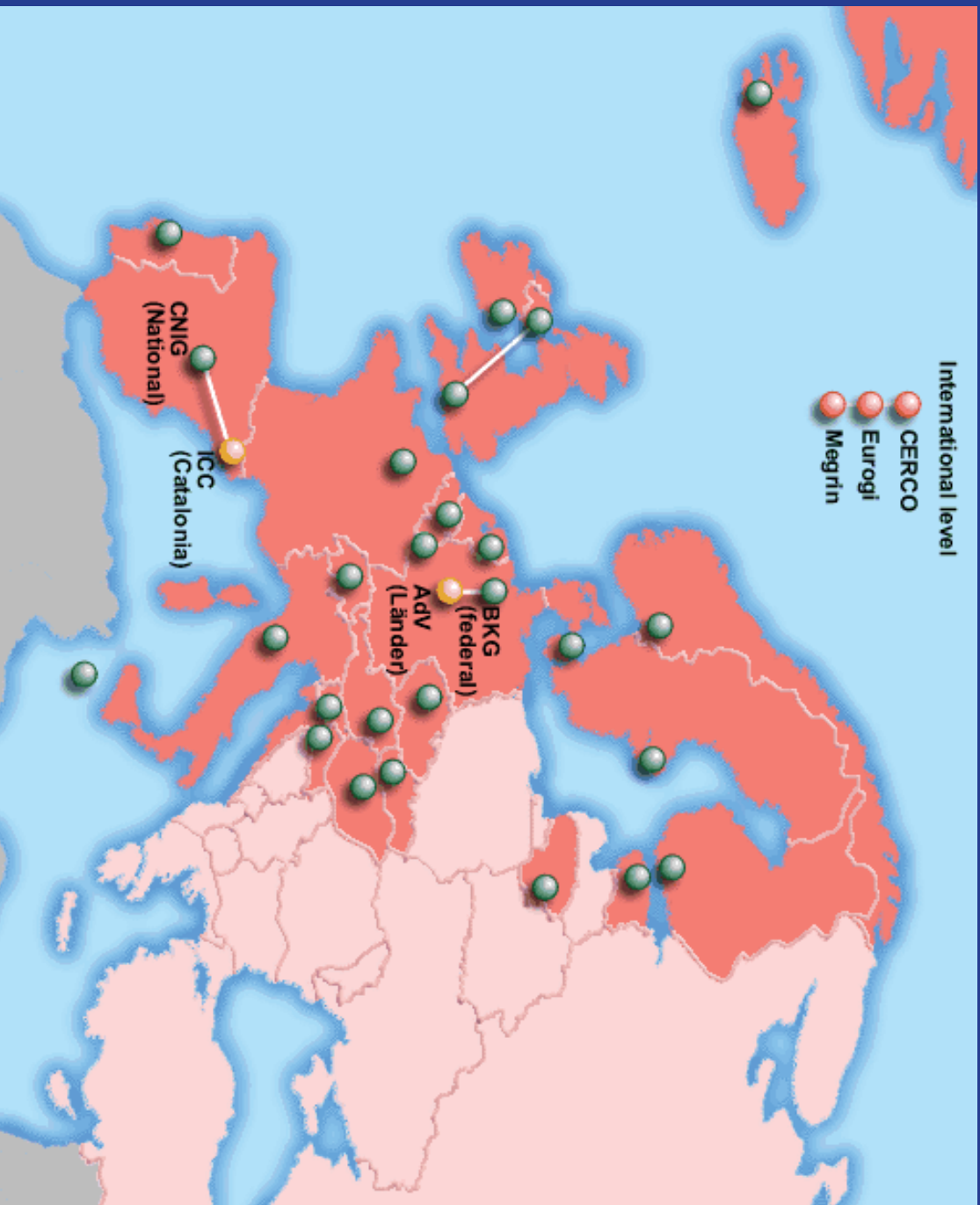
● Spain 2,9	● South Korea 5,7	● Germany 12,2
● Netherlands 2,9	● France 5,7	● Canada 13,3
● Sweden 4,0	● China 6,3	● United Kingdom 14,0
● Italy 4,7	● Brazil 6,8	● Japan 18,2
● Taiwan 4,8	● Australia 6,8	

● United States 110,8

presence on the www



presence on the www: europe



gazetteers



gazetteer sample



Australian Geographic Place Names (Gazetteer)

[What's New?](#) | [Search](#) | [Navigator](#) | [Comment](#) | [Home](#) | [©](#) |

Search for Australian Geographic Place Names

Place Name	southampton
Place Type	ALL (Must enter a value for Place Name) Aerodrome, Airfield, Airport, Landing Ground (AF) Anchorage (ANCH) Archipelago (ARCH) Bank, Bar, Sandbar (BANK)
Geographic Region	Australia ▼

gazetteer sample



Australian Geographic Place Names (Gazetteer) (teer)

Summary Report - 16 February 2000

This report lists information on Australian Geographic Place Names including the following fields:

What's IN

- Place Name
- State/ Territory
- Place Type
- Latitude/ Longitude in Degrees Minutes Seconds and Decimal Degrees
- 1:100,000 Map Sheet Code
- 1:250,000 Map Sheet Code

Place Name

Click on the place name(s) to produce a map and further details.

Place Type

- [Southampton](#)[[EnviroMaps Link](#)]
- WA
- Locality (unbounded), Place Name, Road Corner, Road Bend, Corner (LOOCTU)
- 33 52'59"S 115 58'02"E (-33.88298 , 115.96718)
- 2030
- SI50-06

Geograph

- [Southampton Reef](#)[[EnviroMaps Link](#)]
- QLD
- Reef (REEF)
- 20 39'00"S 150 28'00"E (-20.65 , 150.46667)
- 8956

gazetteer sample



Australian Geographic Place Names (Gazetteer) (teer)

Summary Report - 16 February 2000

This report lists information on Australian Geographic I

Details on Southampton (WA)

What's N

- Place Name
- State/ Territory
- Place Type
- Latitude/ Longitude in Degrees Minutes Se
- 1:100,000 Map Sheet Code
- 1:250,000 Map Sheet Code

Search

Place Na

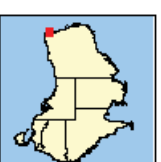
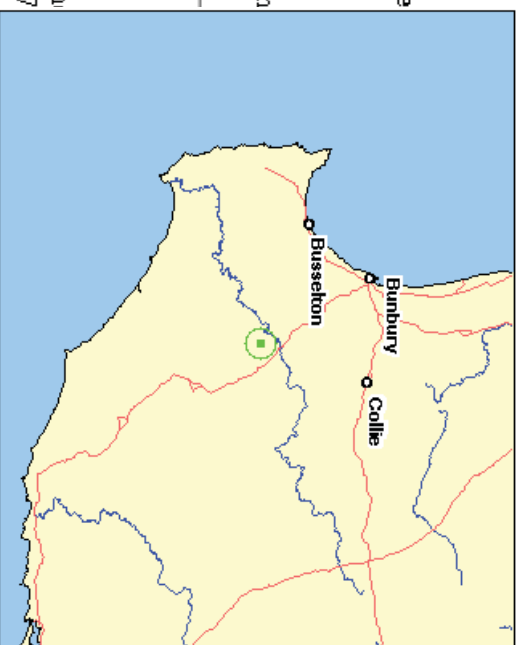
Click on the place name(s) to produce a map and furth

Place Ty

Geograph

- [Southampton](#)[[EnviroMaps Link](#)]
- WA
- Locality (unbounded), Place Name, Road Corn
- 33 52'59"S 115 58'02"E (-33.88298 , 115.967
- 2030
- SI50-06

- [Southampton Reef](#) [[EnviroMaps Link](#)]
- QLD
- Reef (REEF)
- 20 39'00"S 150 28'00"E (-20.65 , 150.46667)
- 8956



Geographic Place Name Report - 16 February 2000

Place Name	Southampton
State/ Territory	Western Australia
Place Type	Locality (unbounded), Place Name, Road Corner, Road Bend, Corner (LOCTU)
Latitude/ Longitude	33 52'59"S 115 58'02"E
1:100,000 Map Sheet	2030 Donnybrook 1:100,000 map sheet

what and how are they doing?

- nmo's web sites “generic quality”
- nmo's web sites “cartographic quality”

www site “generic quality”

- scope & purpose
- contents
- design
- workability / ease of use
- costs / copyright

www site “cartographic quality”

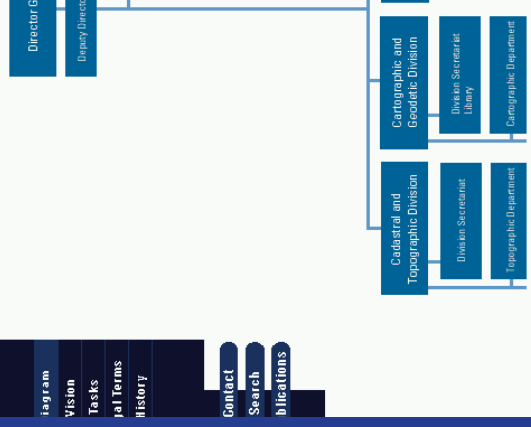
- **organisational aspects**
- **products**
 - analogue products
 - samples, index sheets, prices
 - digital products
 - downloadable samples, indexes, prices
- **additional services**
- **links**

organisational aspects the nmo as organisation

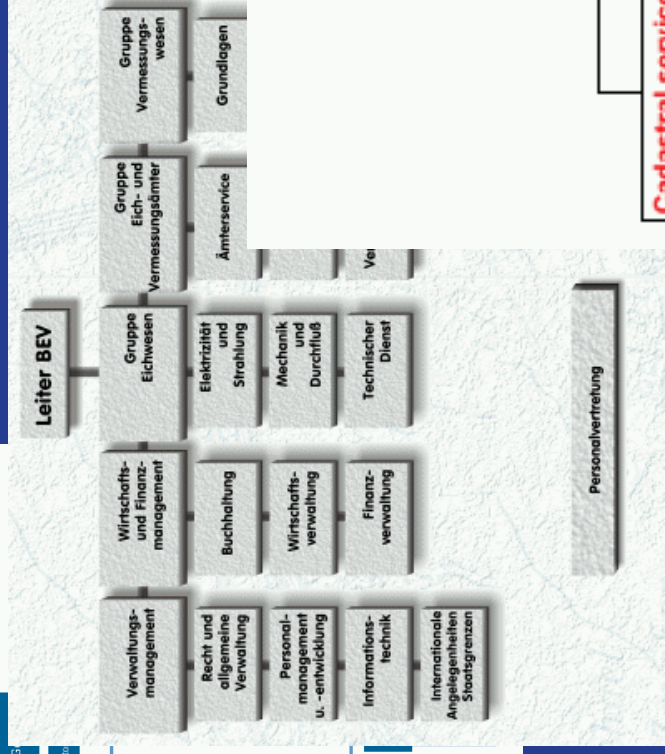
Denmark

About KMS
Organization · Jobs · Past, Present & Future · Key Numbers · Int. Co-operation

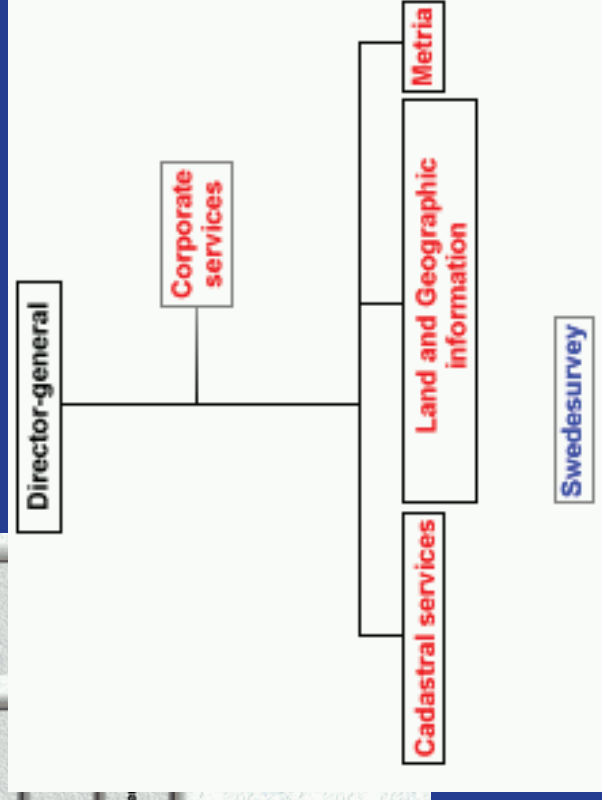
The KMS Organization



Germany

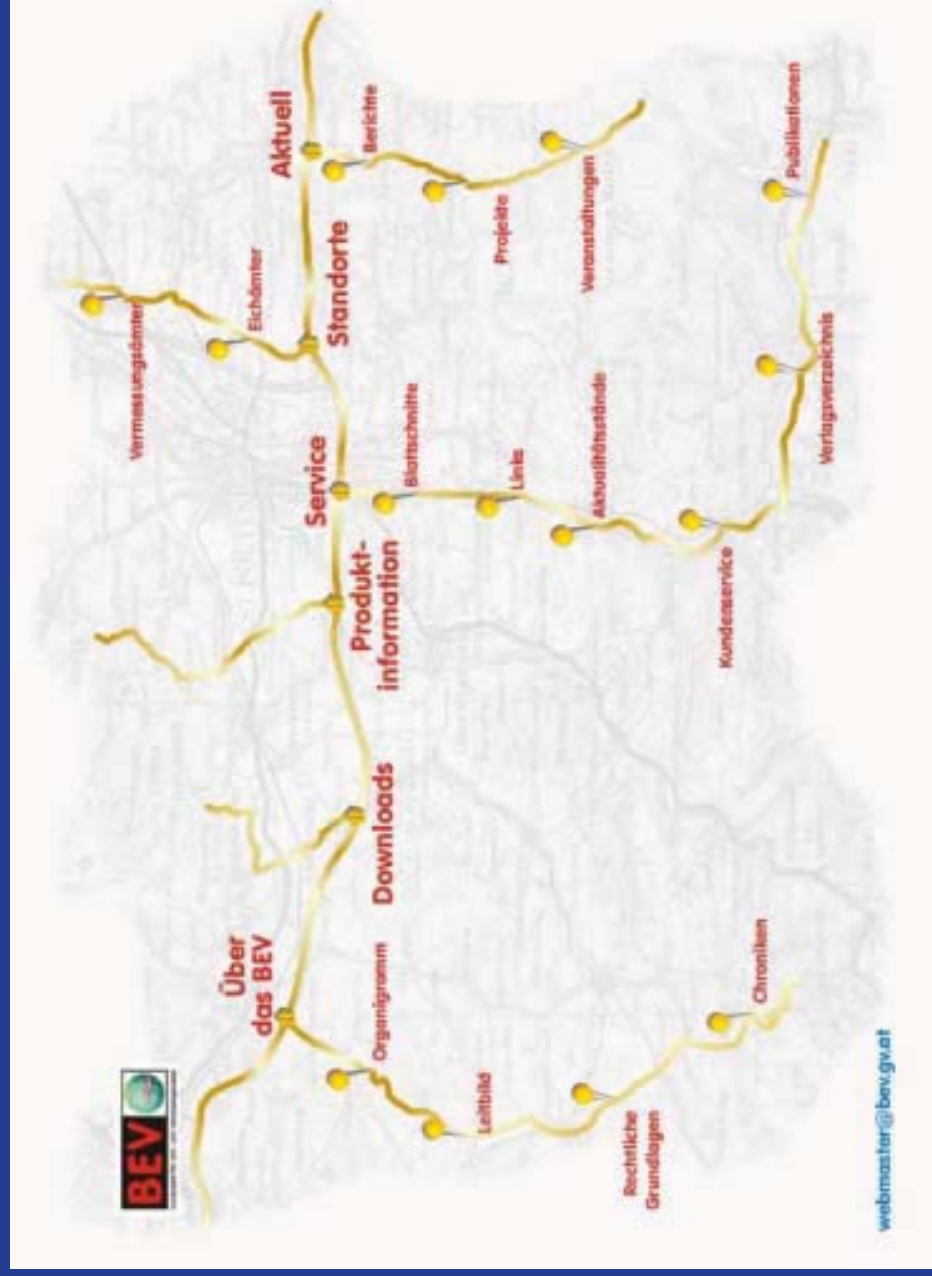


Sweden



organisational aspects web site organisation

Austria



products: analogue; samples

Topographische Übersichtskarten 1 : 200 000

Format: 59,5 x 65,0cm, einzelne Blätter: 75,6 x 48,5cm

Das Kartenwerk ist ein Gemeinschaftswerk des Bundesamtes für Kartographie und Landvermessung sämtlicher Länder der Bundesrepublik Deutschland.

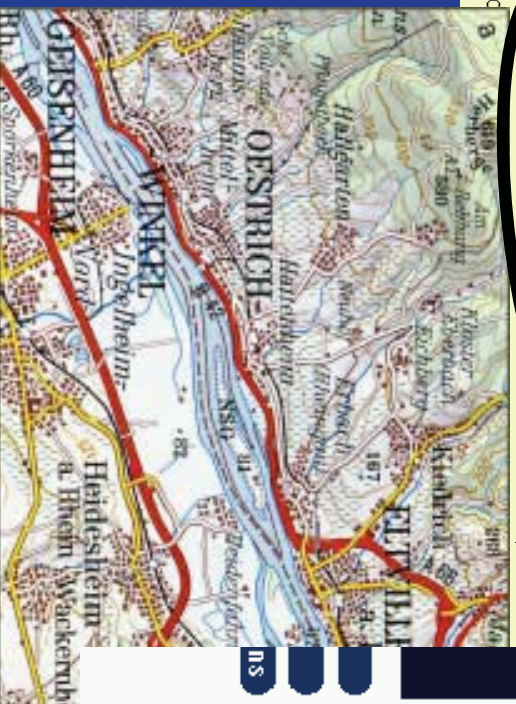
Blattübersicht TÜK 200

Normalausgabe

Kurzzeichen: TÜK 200 N

[Bildbeispiel aus der genannten Karte](#)

gefalzt und



Germany

Denmark 1:25,000 (4cm map)

Lot of details

Updating

This map is Denmark's official topographic map. 4cm on the map corresponds to 1km. The map is incredibly detailed and you can see even the smallest creeks and paths. Therefore the map is especially useful for hiking and biking in the countryside. You will find the map relevant whether you are a private person or a scout, someone involved in orienteering etc.



Click at the map to see index of individual maps

Price per map: DKK 65.00

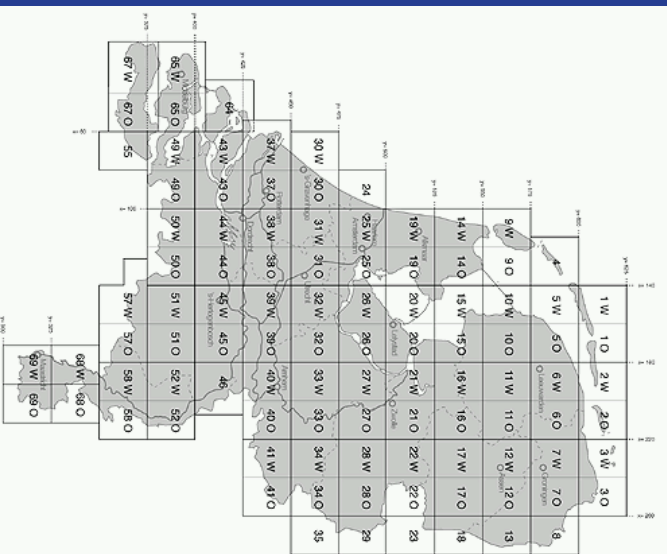
Denmark

products: analogue; index

Netherlands

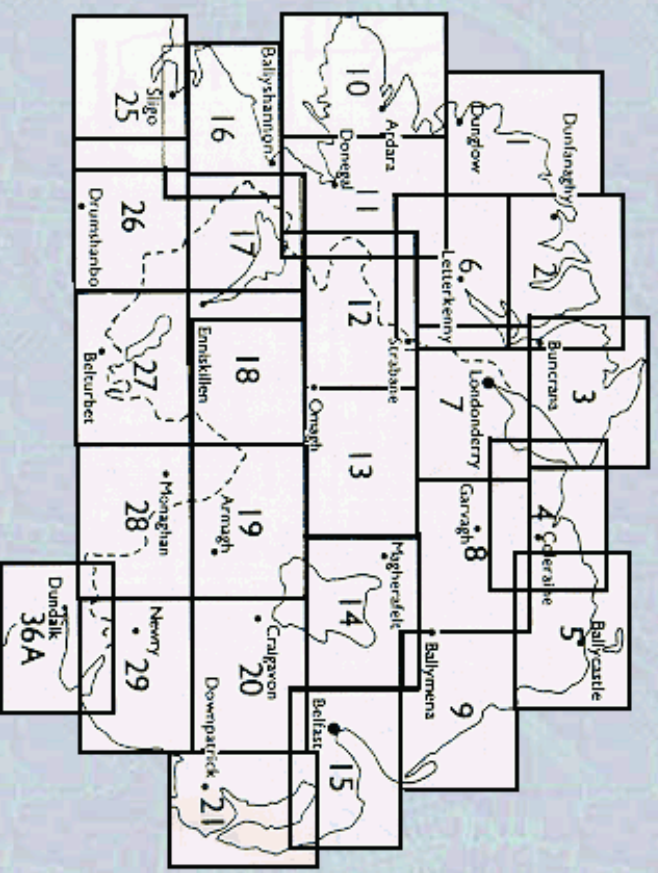
1:50.000

27 Oost Heerde
Uitgave: 1993 ISBN: 90 350 0279 2



Northern Ireland

Index To The 1:50 000 Scale Map Discoverer Series



products: analogue; prices

Denmark

Pricelist of Maps

Current prices including VAT, delivery not included.
All maps are available in plane editions.

Maps marked with * are available both in folded and plane editions.

Contemporary maps

Old Danish maps

- [Danish maps](#)
- [Greenlandic maps](#)
- [Faroese maps](#)
- [Swedish maps](#)
- [Norwegian maps](#)
- [The Royal Danish Academy of Sciences and Letters' maps](#)
- [The General Staff's maps](#)
- [Decorative maps](#)

KMS reserves the right to make changes to the price list.

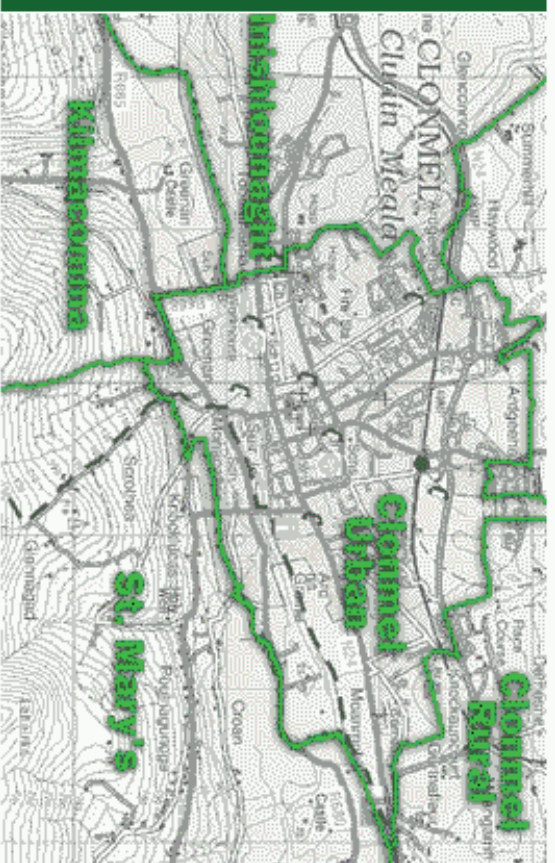
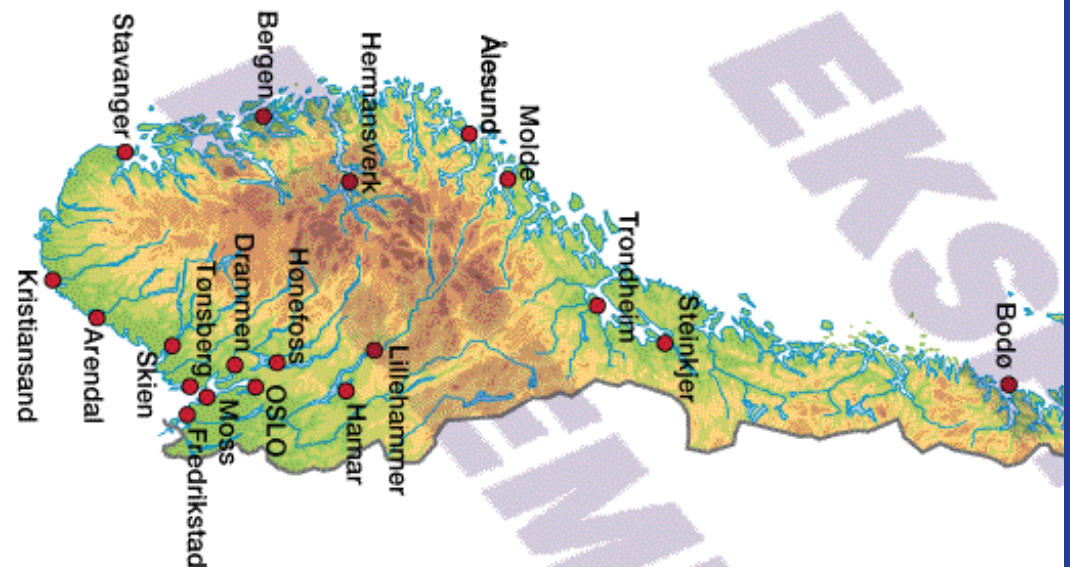
[To the top](#)

Contemporary maps

Danish maps 4cm map, Denmark 1:25,000*
405 map sheets. Per map sheet

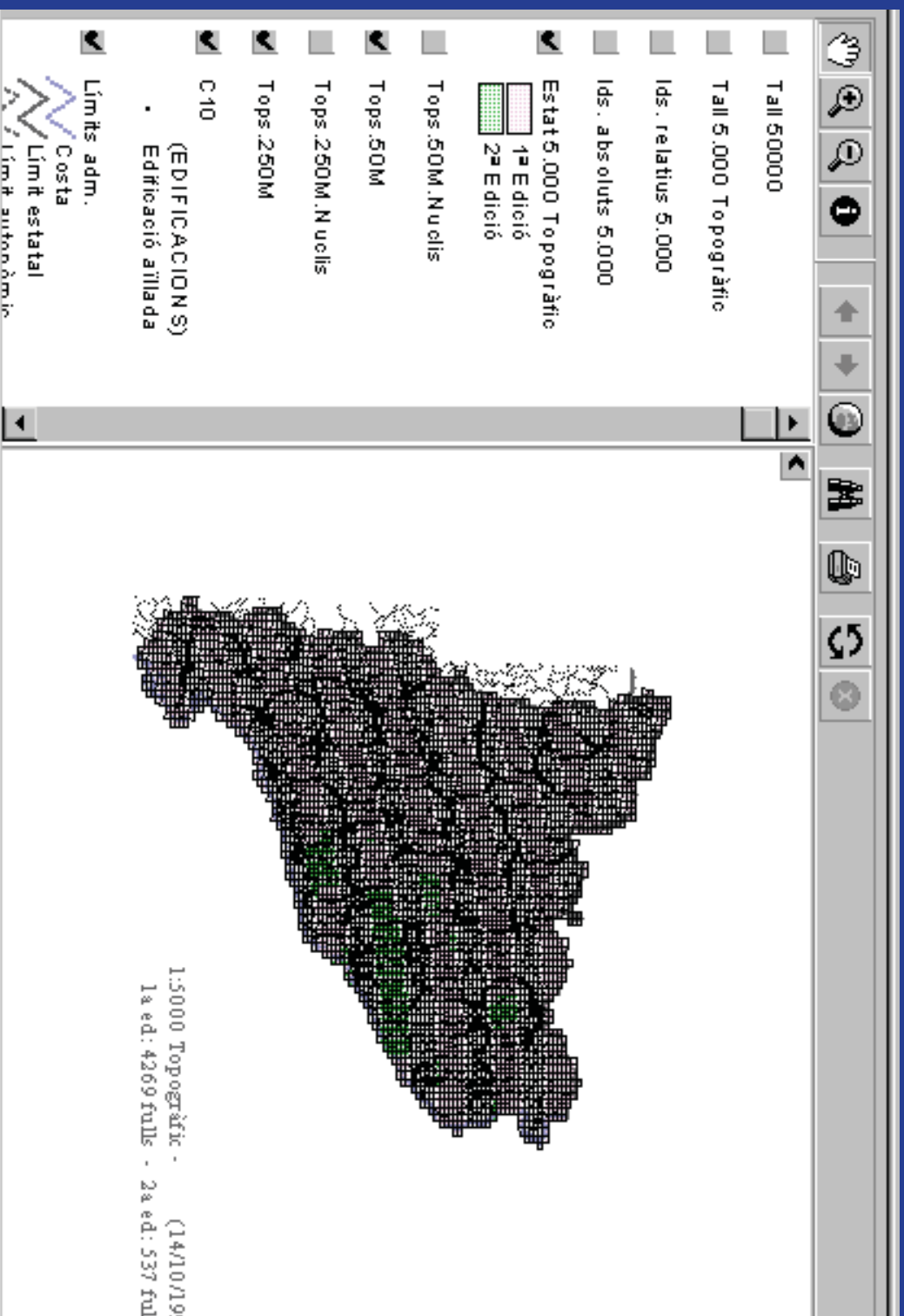
Extra map sheet (water level)	DKK 65.00
2 cm map, Denmark, 1:50,000*	DKK 26.00
110 map sheets. Per map sheet	DKK 65.00
Extra map sheet (water level)	DKK 26.00

products: digital samples

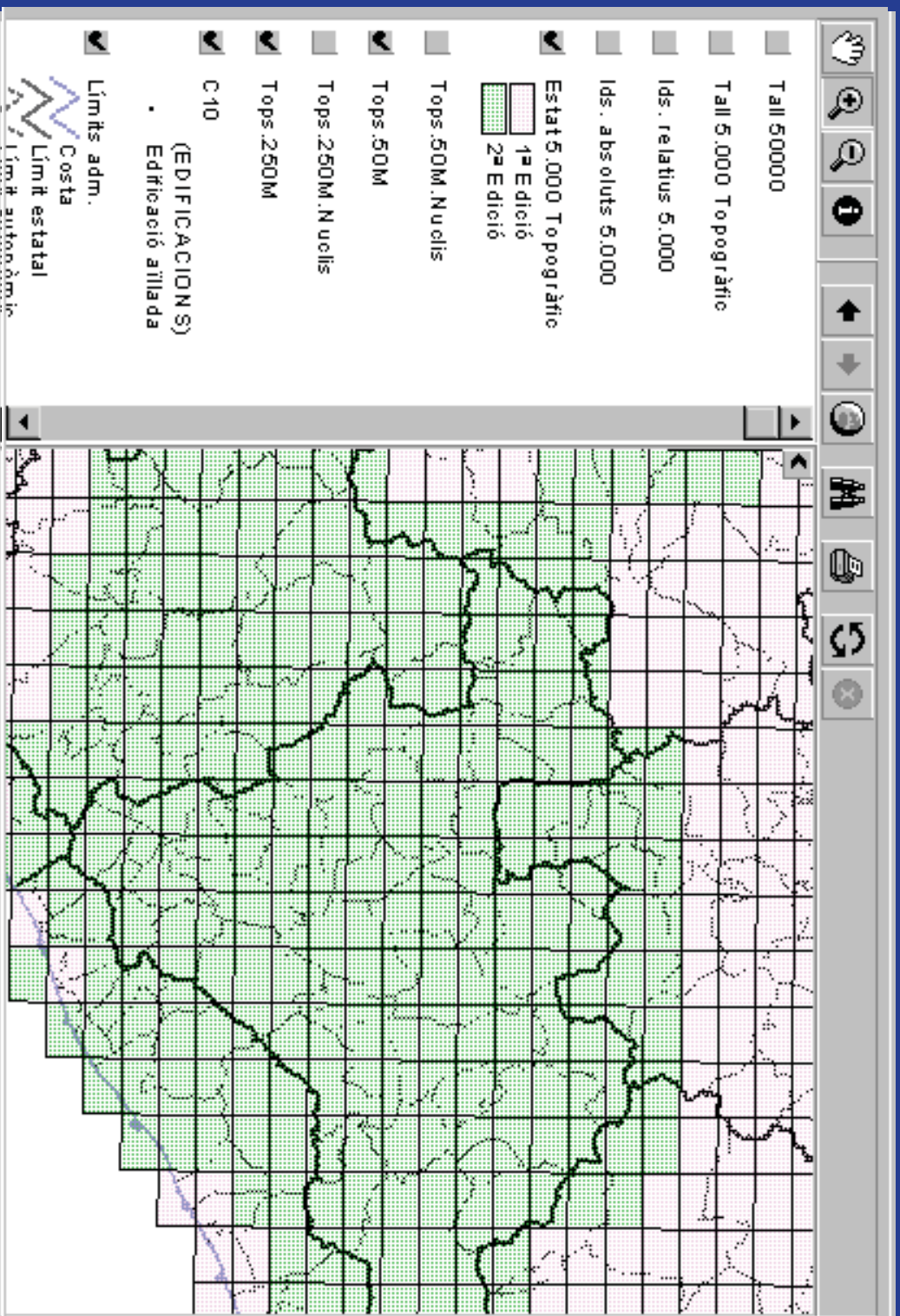


Ireland

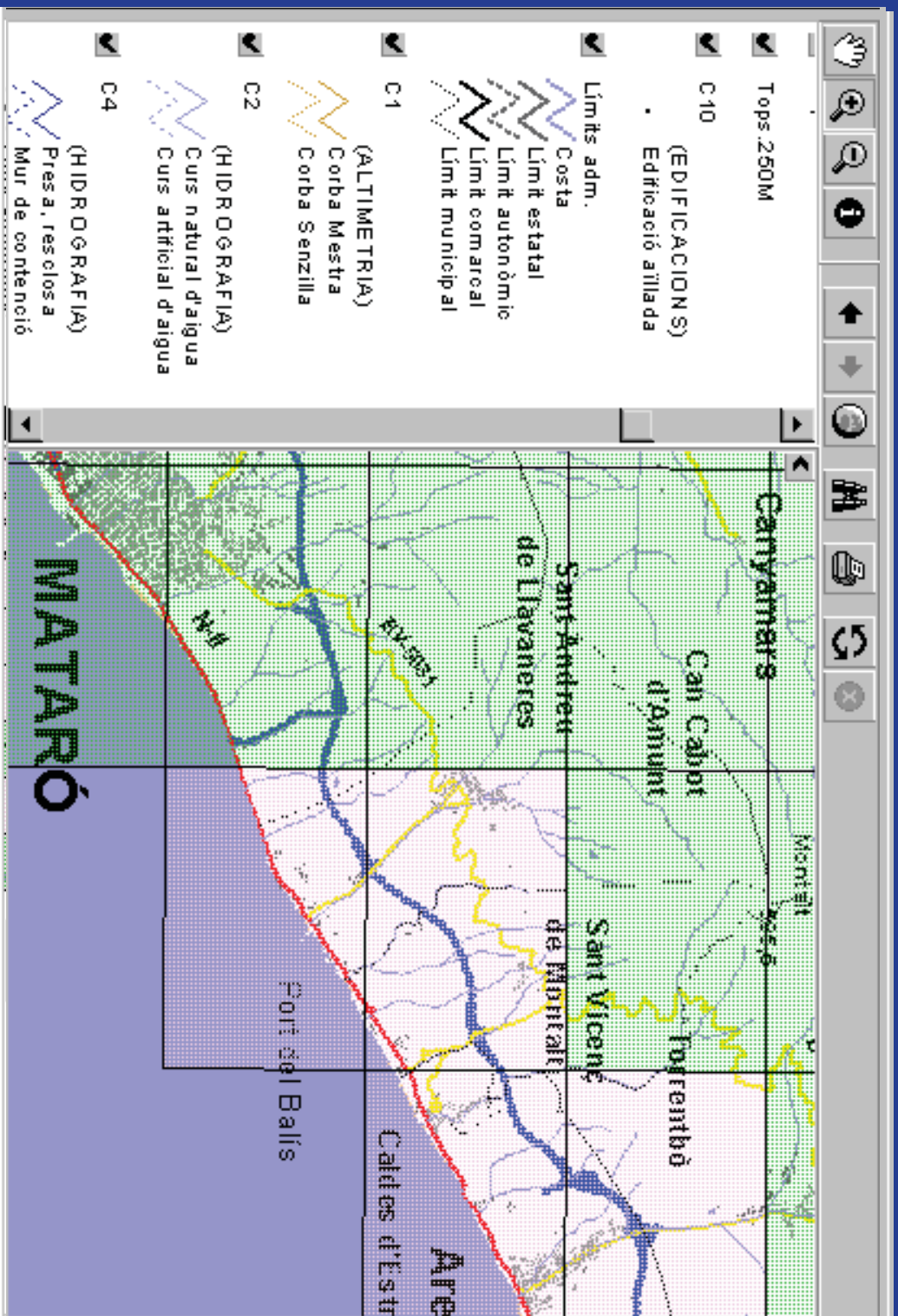
products: view the maps



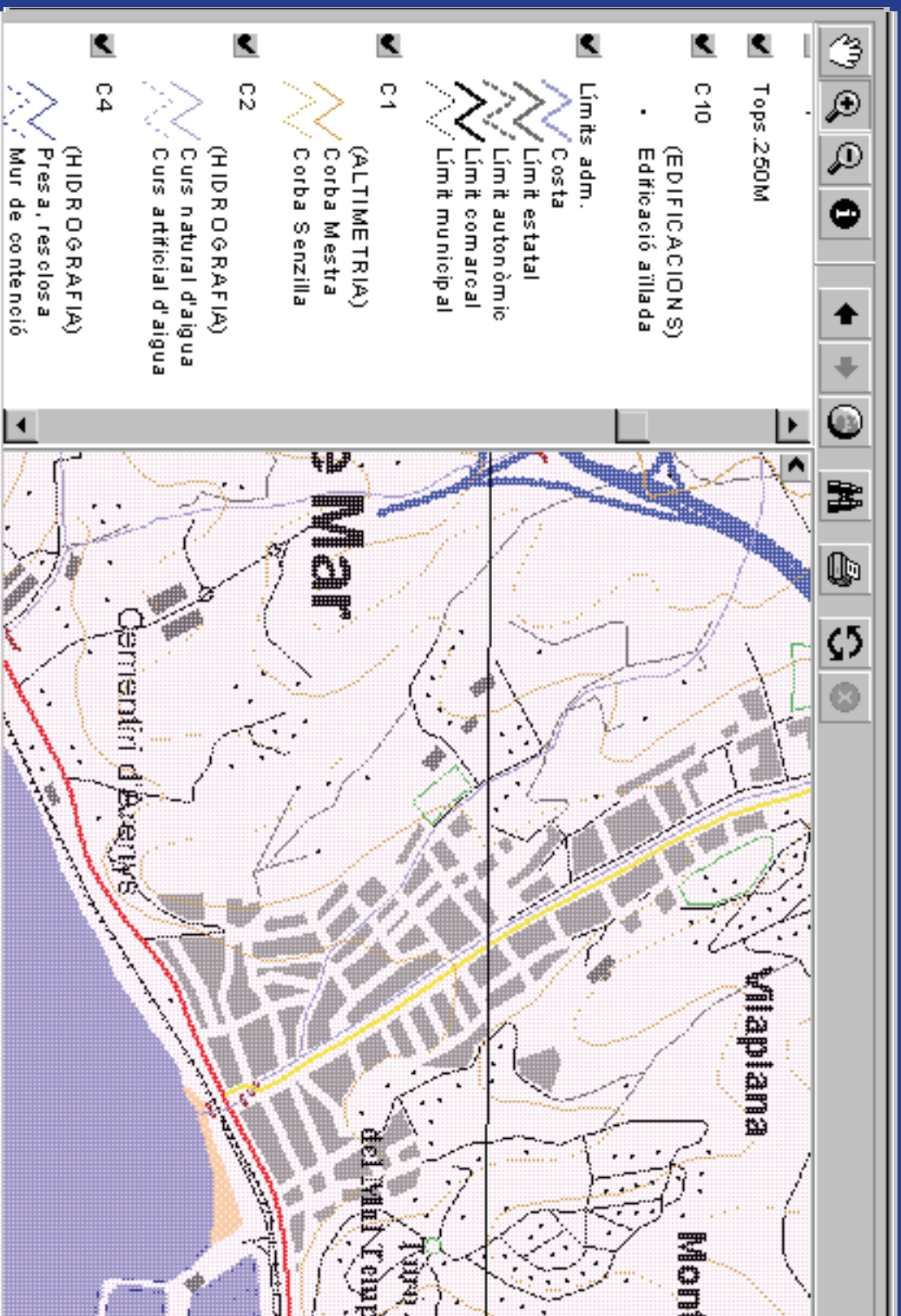
products: view the maps



products: view the maps



products: view the maps



products: digital; index system

Denmark



The screenshot shows the homepage of the 'Infodatabase on Geodata' website. At the top, there is a logo consisting of a stylized 'I' and a globe. Below the logo, a navigation menu includes links for 'Home', 'About', 'News', 'Search', 'Submit new dataset', 'Download', 'Links', and 'Feedback'. The main content area features the title 'Infodatabase on Geodata' in large, bold letters, followed by the flags of Denmark and the United Kingdom. A paragraph explains that the metadata database is a catalog describing digital maps and other metadata, providing a short overview of each dataset and where to find it. Below this text are three categories: 'Basemaps', 'Thematic data', and 'ABC'. Each category is represented by a 3D map icon, a database cylinder, and the letters 'ABC'. At the bottom, there are three links: 'All datasets ordered by title', 'All datasets ordered by organization', and 'All organizations'.

Infodatabase on Geodata

The metadata database is a catalog, describing the digital maps and other metadata database gives a short overview of each dataset, and where to

Basemaps

Thematic data

ABC

[All datasets ordered by title](#) [All datasets ordered by organization](#) [All organizations](#)

products: digital; formats, prices

Northern Ireland

Finland

Delivery Formats (=0, standard=*)

Dataset Standard Unit	Format				
	Maagis XL	Arc/Info Gen	Arc/Info Exp.	DGN	DXF M Fin
Topographic Database and Map Database 1:20000	*	*			
1:10000 sheet					
1:20000 raster					
1:20000 sheet					
<u>PerusCD</u> county					
<u>Basic Map 1:20000</u> - contours, fields - waters	*	*	*		
1:20000 sheet	*	*	*		
1:50000		*			
30x40km sheet					
1:100 000		*	*		
30x40km sheet					

DIGITAL TOPOGRAPHIC DATA

VECTOR

OSNI produces and maintains a fully structured digital topographic database data is leased to customers subject to appropriate copyright licensing arrangements.

1. Large Scale (1:1250/1:2500)

The Data is fully edgematched, multi-attributed, with full links and nodes set maintained and the lease fee provides for an annual fee.

Annual Leasing Charges

1-10 files	(accumulative per order) £ 27.00 each
11-20 files	£ 22.00 each
21+ files	£ 16.80 each

One file equates to one standard OSNI plan

2. Small Scale (1:50 000/1:250 000)

Here again full edgematching, multi-attributing and structuring apply where centre-lines, relief and drainage patterns being of particular interest. There Area, Ward, Townland and Enumeration district Boundaries.

[Click for PRICE LIST](#)

additional services: online ordering

Iceland

ORDER



The following maps are available for purchase over the internet. The total price is automatically calculated. If you wish to order maps not listed below, or receive further information, please contact us on the contact page.

Choose the maps you want from the following list:

1 sheets 1&2 West-Iceland 1:250 000 (price: 875)

Look at Put in basket

Amount Products from list

1 Map 1 North-West (1:250 000)

1 Map 4 Central North (1:250 000)

1 sheets 1&2 West-Iceland (1:250 000)

1 sheets 1&2 West-Iceland (1:250 000)

1 sheets 1&2 West-Iceland (1:250 000)

1 sheets 1&2 West-Iceland (1:250 000)

1 sheets 1&2 West-Iceland (1:250 000)

1 sheets 1&2 West-Iceland (1:250 000)

1 sheets 1&2 West-Iceland (1:250 000)

1 sheets 1&2 West-Iceland (1:250 000)

Total 2145

Where to get Map Products?

You can buy KMS map products in book shops, tourist offices, shops, camping grounds, gas stations, on ferries and at KMS own Map Shop at the address to the right. A series of products can also be ordered on-line.

If you want more information, please contact us.

You are also welcome to visit us at the following address:

Rentemestervej 8
DK-2400 Copenhagen NV
Denmark

On-line order of Maps

Telephone: +45 35 87 50 50

Fax: +45 35 87 50 68

E-mail: kms@kms.dk

Opening hours:

Mon. - Fri. 9:00 am - 15:00 pm

Denmark

additional services: customised services

Great Britain



Click here for our Homepage

search site

Looking for something in particular?

Ordnance Survey Solution Centre is the place to come if you are looking for a geographically-related business solution.

We undertake consultancy and project management work, data integration, analysis and management, and data capture. Our consultants have a wealth of experience and are committed to understanding your needs.

Our flexible service covers three main areas:

- [Customising products and services](#)
- [Consultancy services](#)
- [Managing and maintaining your solution](#)

For further information contact Solution Centre Enquiries (+44) 023 8079 2929 (792929 for Southampton callers before 22 April 2000)

Products & Services

- Digital maps
- Paper maps
- Wall maps
- Atlases
- Guides
- Historical & reference
- Education products
- CD-ROMs
- Videos
- Tailored solutions
 - Introduction
 - Customising
 - Consultancy services
 - Solution management
- International solutions
- News & Events
- In-depth & Technical
- Education
- Where to buy

links

ABOUT LMI

Great Britain



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☐ Products & Services

☐ News & Events

☐ In-depth & Technical

☐ Education

☐ Where to buy

☐ About us

☐ Network Sites & Links

☐ Millennium area

☐ Cycling event forum

☐ LandLine area

☐ Links to other sites

☐ Mapping organisations

☐ GIS internet links

☐ Other links

☐ Free

☐ What's new

☐ Get-a-map

Network sites & links

National Mapping Organisations

[Australia - AUSLIG Home Page](#)

[British Geological Survey](#)

[Canada - National Atlas Information Service](#)

[IGN - France](#)

[Geographical Survey Institute of Japan](#)

[National Land Survey of Finland](#)

[Land Information New Zealand](#)

[Norway - Statens Kartverk](#)

[Ordnance Survey of Northern Ireland](#)

[Portugal - SNIG](#)

[U.S. Gazetteer](#)

[U.S. Geological Survey](#)

European Mapping Organisations

[CERCO](#)

Committee of the National Mapping Agencies of Europe - includes links to web sites of all 30 members.

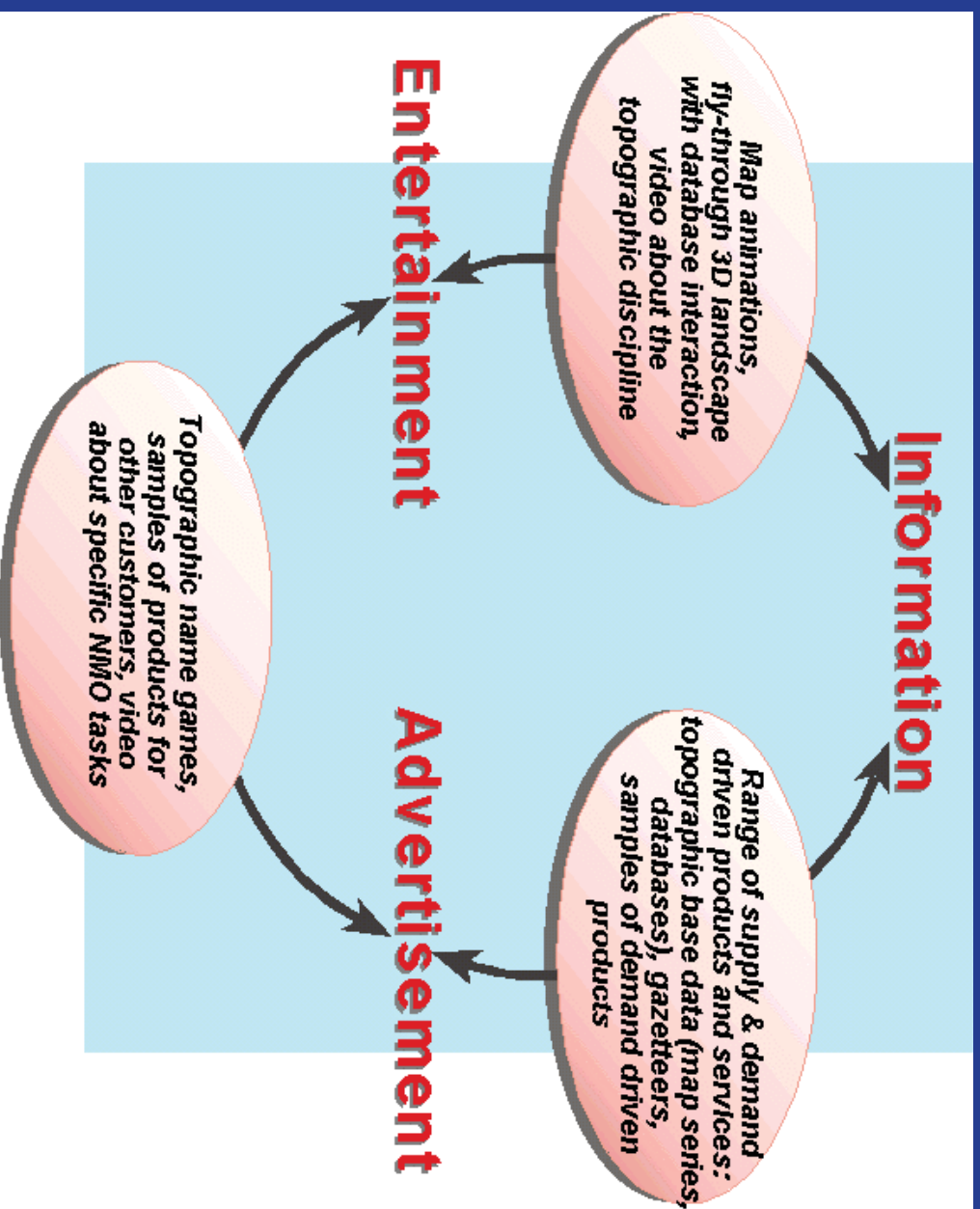
[MEGRIN](#)

The Multi-purpose European Ground-Related Information Network - a group of 18 European National Mapping Agencies.

geoinformatics, cartography & visualization

ITE

web site contents



info contents

information

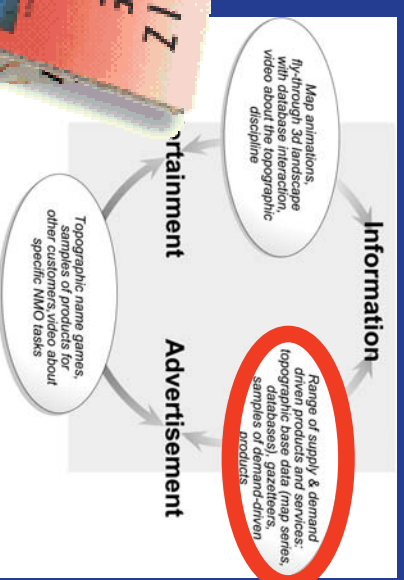


entertainment

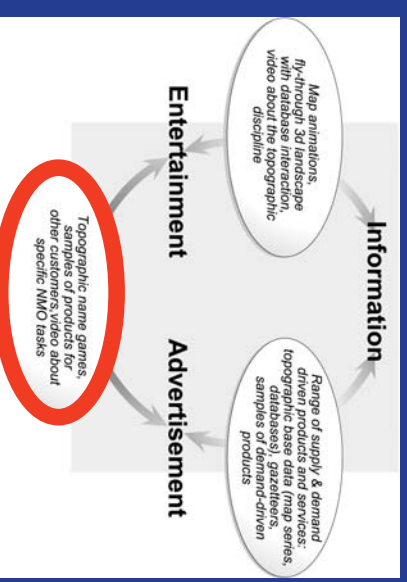
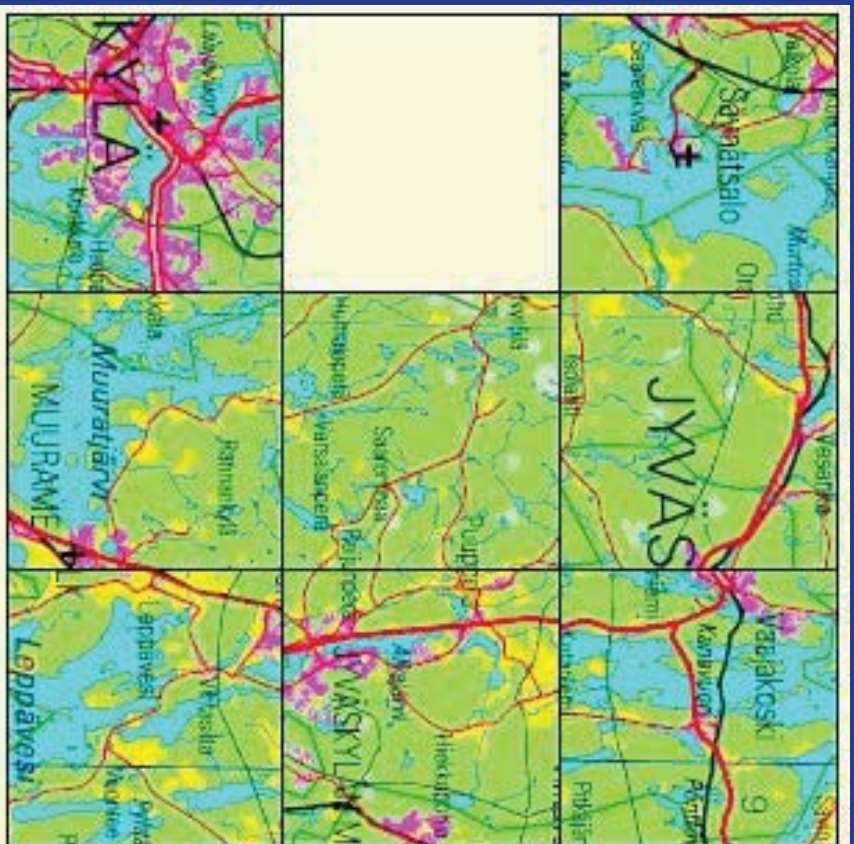


advertisement

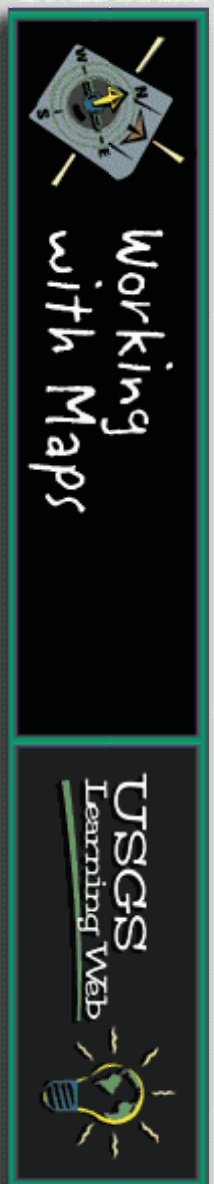
information and advertisement



entertainment and advertising

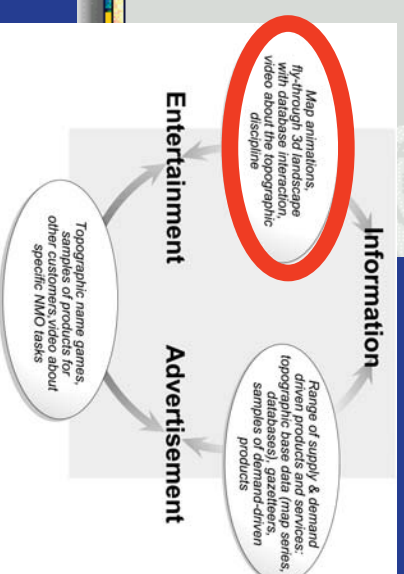


information and entertainment



What Do Maps Show (grades 5-8)

- [Introduction and Activities](#)
- [Shaded Relief Map](#)
- [Road Map](#)
- [Topographic Map](#)
- [Teacher Guide](#)



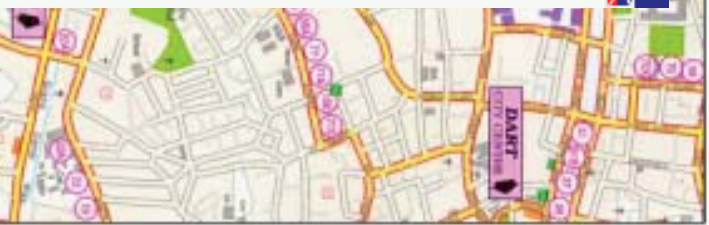
challenges and opportunities

- minimal requirements of the web site
 - supply driven
- towards a customer oriented web site
 - demand driven

St. James's Hospital Ordinance Survey Map

The map displays the St. James's Hospital complex, including the main hospital building, the Lifford Park, and the Lifford Park. The map is color-coded with green for parks and yellow for roads. A legend at the top right identifies symbols for 'ABOUT', 'CLINICAL', 'EXHIBITIONS', 'WALKS', 'MAP', 'BEACH SITE', 'CONTACTS', 'HOURS', and 'MEDICAL'. The map also shows the River Liffey and the Dublin City Centre.

towards a customer oriented web site



national mapping organisations

....and to actively promote the use of this information in value added applications relevant to the market, on the basis of prices which will....

recommendations

nmo's need to evaluate their current
www activities, since:

- the www will play a prominent role in national (global) geodata infrastructure: networking distributed data sets;
- the www can act as an advertising medium for nmo products and services (many people retrieve their first information on a subject from the www);
- the www can help explore new products and possibilities for nmo data sets.

Back to Content Presentations

The OpenGLS Web Mapping Testbed

Peter Woodsford

Deputy Chairman

Laser-Scan Ltd

“National Mapping Agencies and the Internet” Workshop, 8-10 March 2000



Acknowledgments

- *This presentation includes material prepared for the OpenGIS Consortium's Web Mapping Testbed demonstration event held in Washington DC, Sept 10th 1999. More material is available at:*

<http://www.opengis.org/wmt/>

- *Based on a paper by Dr. Adrian Cuthbert, Director of Technology, Laser-Scan*



OGC's Vision

OGC envisions the full integration of geospatial data and geoprocessing resources into mainstream computing and the widespread use of interoperable, commercial geoprocessing software throughout the information infrastructure.

OGC Mission

- Involve developers and users of geographic information resources -- including vendors, integrators, academia, government agencies, and standards organizations -- in collaborative development of interoperable geoprocessing technology specifications, and work to promote the delivery of certifiably interoperable products.
- Synchronize geoprocessing technology with current and emerging information technology standards based on open systems, distributed processing and componentware frameworks.
- Provide an industry forum that promotes cooperative business development initiatives related to distributed geoprocessing.

The Web Mapping Testbed

- The OpenGIS Consortium (OGC) organized a Web Mapping Testbed (WMT) to progress the development of standards relevant to ‘Web Mapping’.
- A Map is defined as the result of symbolizing a filtered subset of geospatial data based on location, scale and purpose.
- Web Mapping envisages a solution that is *multi-vendor* with resources *distributed* across the Internet.
- Why do we need *interoperability* for mapping over the Web?

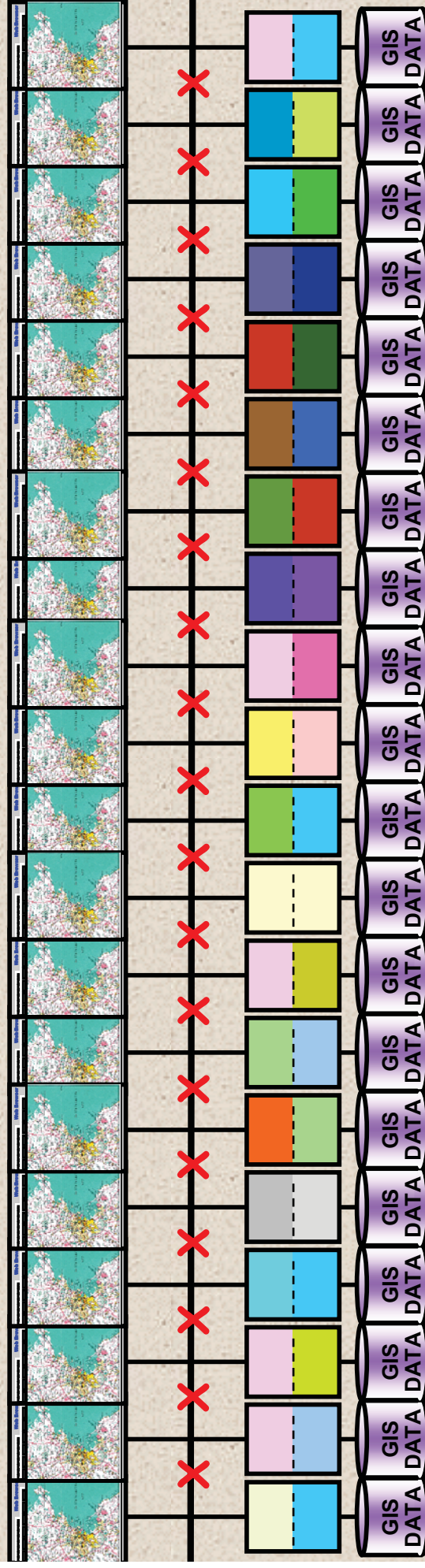


Open GIS Consortium

Spatial connectivity

for a changing world.

Some (non-interoperating) Web Mapping Systems



MapGuide™

TIGER Map Server

EnviroMapper

Internet Map Server

STAR Next Surf GLOBE Visualization

ELVIS

Orthophoto Browser

Spatial Web Broker NetGIS OGD I PARC Map Viewer GIS Viewer

ModelServer ImagerGeoMedia™ WebMap CARIS Internet Server

MapObjects IMS

MapXtreme™

Mapquest Internet TerraServer

Open GIS Consortium

Spatial connectivity

for a changing world.

A Concrete Example

TerraServer - <http://terraserwer.microsoft.com>



A Concrete Example

TerraServer - <http://terraserwer.microsoft.com>

MapQuest - <http://www.mapquest.com>

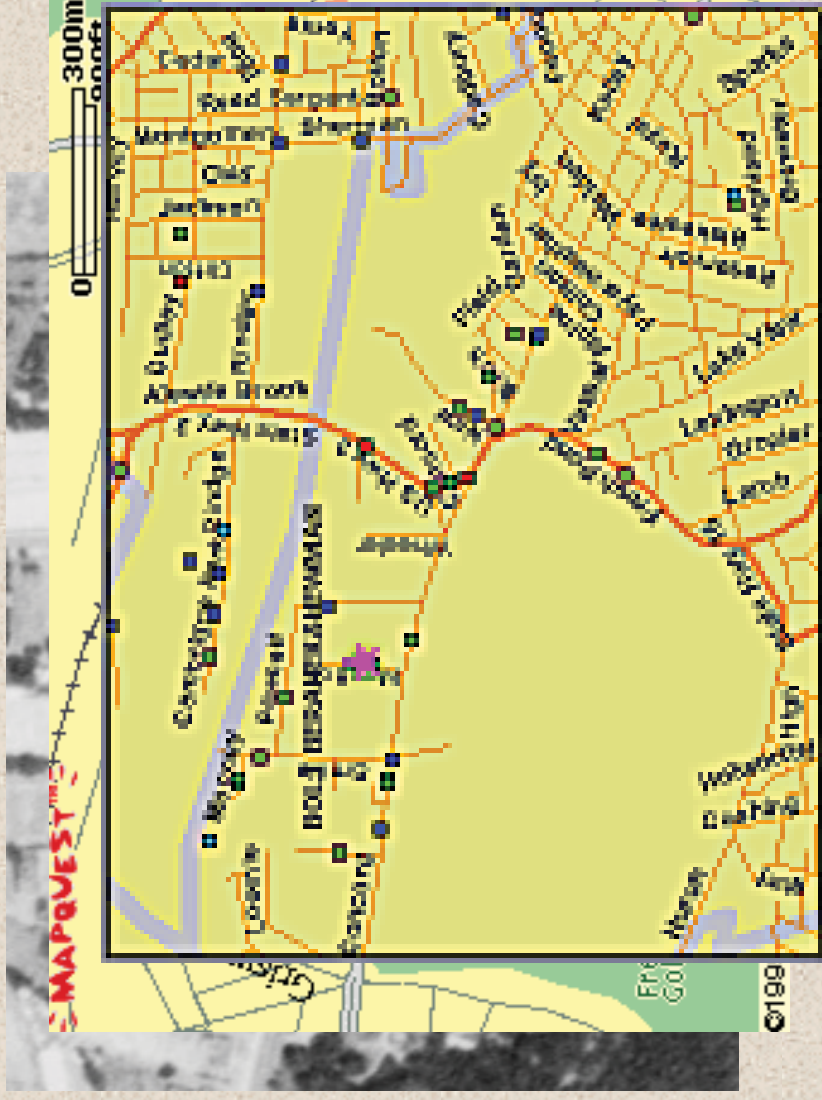


A Concrete Example

TerraServer - <http://terraservert.microsoft.com>

MapQuest - <http://www.mapquest.com>

EPA - <http://www.epa.gov/enviro/enviromapper.html>



WMT Foundations

- The OGC issued a request for technology to determine the variety of approaches people have taken to Web mapping.
- They sought to categorize these approaches as a number of different cases.
- The OGC issued a request for quotations to participate in the WMT, providing the above categorization as a ‘steer’ towards a common approach.



Categories of client software

Web Browser

Suitable for casual/infrequent users

Basic Web browser with no downloaded capabilities; makes use of html, images (gif or jpeg) and javascript.

Downloaded client

Suitable for deployment through out an organization

Client is downloaded over the Web and hosted by a Web browser; eg Java applets, ActiveX controls, plug-ins.

Desktop application

Primarily for frequent and/or expert users

Application runs on the desktop but uses the Internet as a mechanism for accessing data from remote sources.

Categories of Map Data

Image

Maps are returned as ‘dumb’ raster images (e.g. GIF or jpeg). One can only click on the map.

Vector

Maps are returned using a vector format (e.g. svg) allowing additional ‘link’ information to be attached to the vector elements, which can then be selected interactively.

Geospatial data

The geospatial data from which a map can be generated is transferred. The data still needs to be filtered and symbolized to produce a map.

The three Web mapping ‘cases’

	Image	Vector	Geospatial data
Web Browser	Picture case		
Downloaded client		Graphic Element case	
Desktop application			Data case

Initial Analysis

- A user always interacts with a client.
- Map servers provide access to ‘maps’ only.
- **Distributed:** a client can overlay output from multiple Map Servers located at different sites over the Web.
- **Multi-vendor:** a client from one vendor should be able to communicate with multiple Map Servers implemented by a variety of potentially different vendors

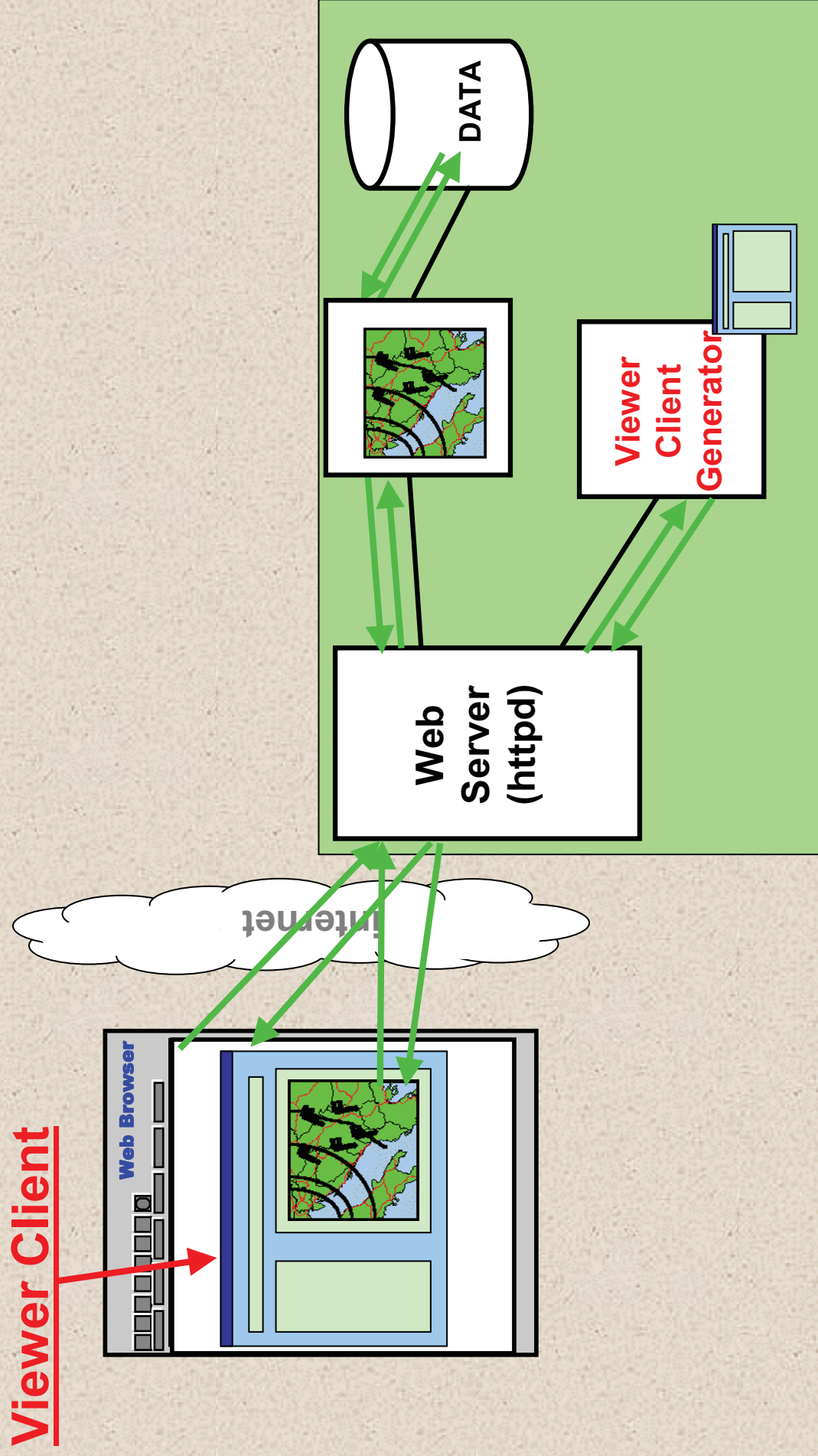
(use of standard Web technologies)



A Map Server ...

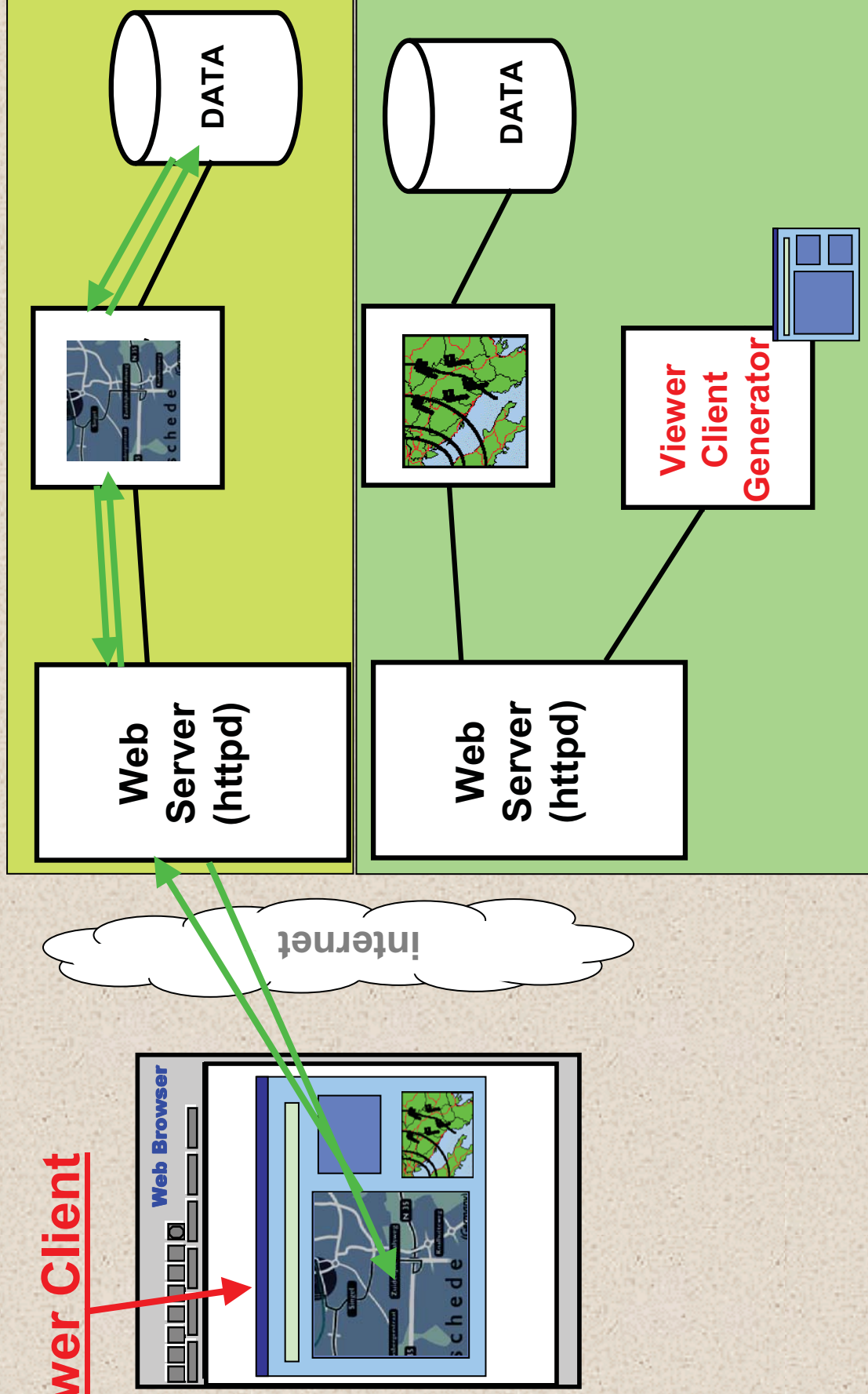
- specifies a map's appearance using a list of named layers and styles.
- must generate maps to a precise specification.
- hides the origin of the geospatial data ...
whether it be raster or vector based, can include near-live content.
- must be able to describe its own capabilities.
- may be able to 'transform' data to generate a map.
- may permit 'drill down' to access feature level data.





Viewer Client & VC Generator

Viewer Client



Data Discovery

- Map servers located over the Web mandate a mechanism for data/service discovery.
- The WMT prototyped a catalog service that used the ability of a Map Server to describe itself.
- Map Servers identification on the basis of:
 - descriptions and keywords relating to the geospatial data
 - extent of the geospatial data
 - coordinate systems in which the map could be generated



WMT Demonstration Event

- Held in Gaithersburg, Md., USA, 10th Sept 1999.
- The demonstration included use cases drawn from a disaster management scenario:
 - a hurricane hit on Mobile, Alabama.



Web Mapping Testbed Sponsors

- **National Imagery and Mapping Agency**
- **US Army Corps of Engineers Topographic Engineering Center**
- **Federal Geographic Data Committee**
- **US Department of Agriculture Natural Resources Conservation Service**
- **National Aeronautic and Space Administration**
- **Australian World Wide Web Consortium**

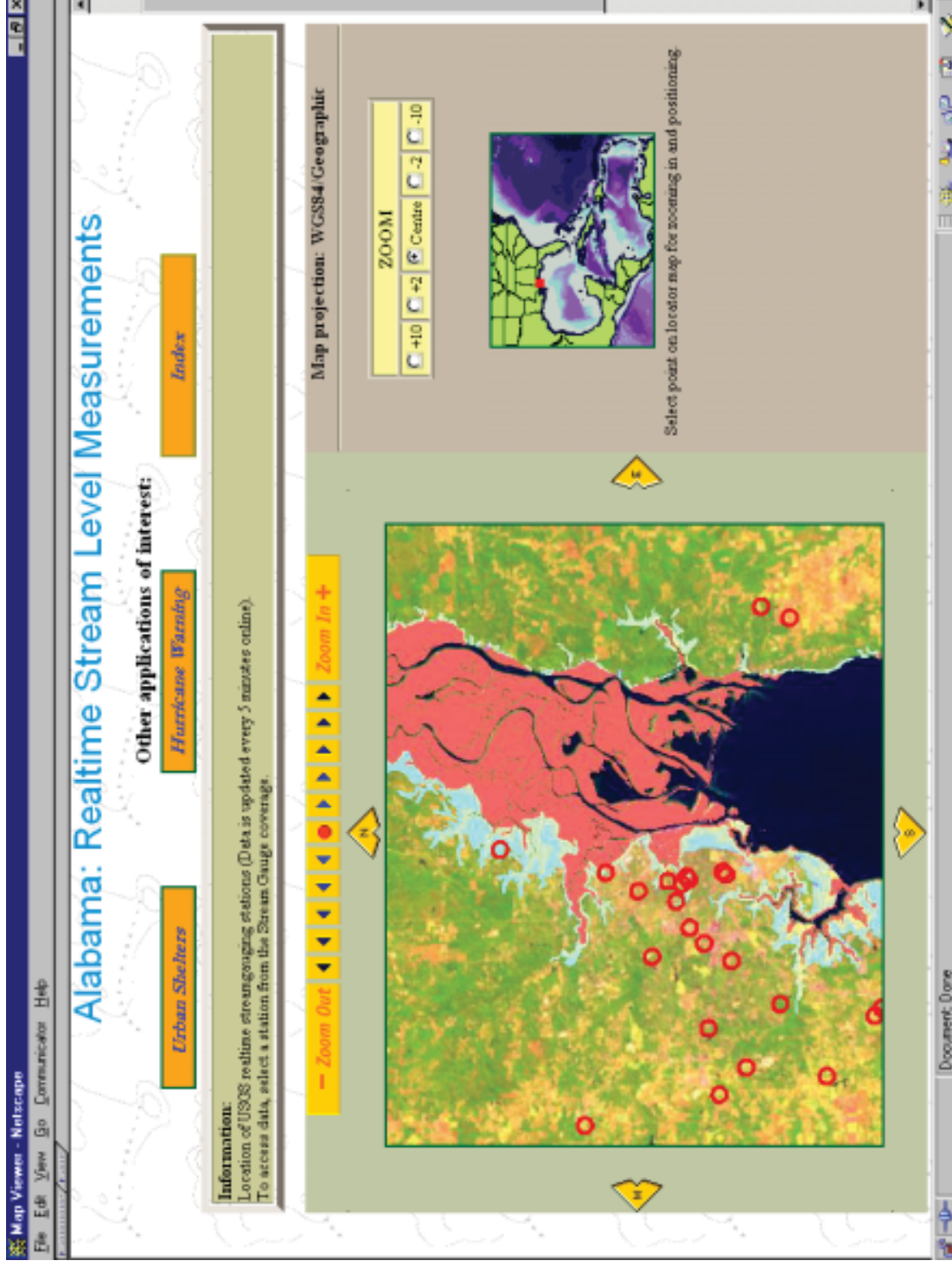
Web Mapping Testbed

Participants

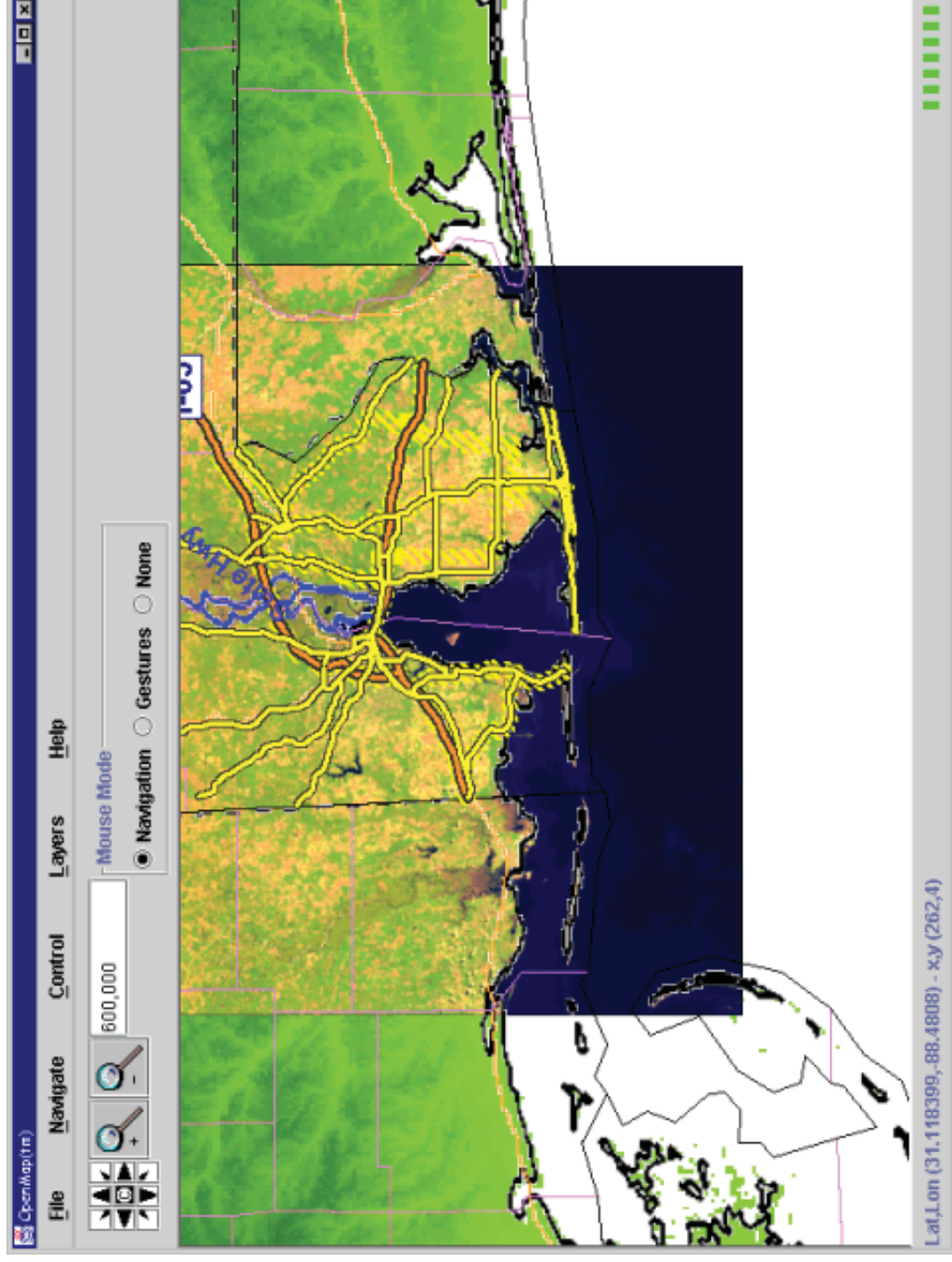
- Autodesk (US)
- BBN Technologies (US)
- Blue Angel Technologies
- Cadcorp (UK)
- Compusult (Canada)
- Cubewerx (Canada)
- ESRI (US)
- Galdos Systems (Canada)
- Geodan IT (Netherlands)
- Geomatics (Canada)
- Hitachi (Japan)
- ILOG (France)
- Intergraph (US)
- Ionic Software SA (Belgium)
- Laser-Scan (UK)
- Litton/TASC (US)
- Lockheed-Martin (US)
- MapInfo (US)
- Microsoft (US)
- MIT (US)
- Mitsubishi (Japan)
- NTT Data (Japan)
- ObjectFX (US)
- Oracle Corp (US)
- Ordnance Survey (UK)
- PCI Geomatics (Canada)
- Penn State University (US)
- SICAD Geomatics (Germany)
- Social Change Online (Australia)
- Sun Microsystems (US)
- Universal Systems (Canada)

WMT Demonstration Event

- Ten Map servers distributed over the Web:
 - Cadcorp
 - Cubewerx
 - ESRI
 - Geodan
 - Intergraph
 - Laser-Scan
 - MapInfo
 - MIT
 - NASA
 - Object/FX
- Five clients served locally:
 - BBN Technologies (*Java application*)
 - Cubewerx (*cgi script*)
 - ESRI (*ArcExplorer*)
 - Laser-Scan/Ionic Software (*Java applet*)
 - Social Change Online (*Java Server Pages*)



*Social Change
Online
Viewer Client
NASA
LandSAT Image
Laser-Scan
Surge Data
Shelters*



BBN Technologies
Viewer Client

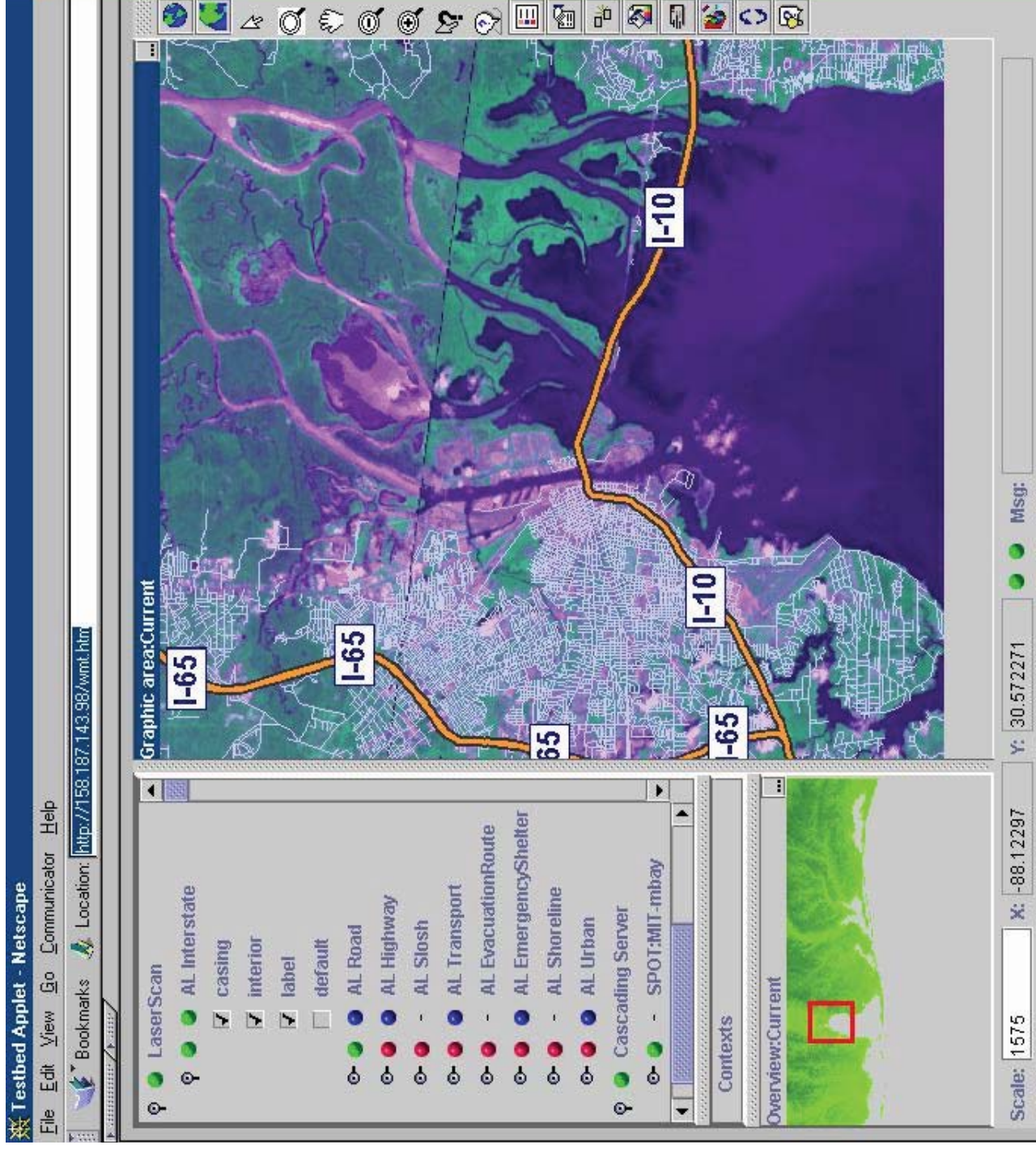
MIT

LandSAT image

Laser-Scan
Roads

Cubewerx
Relief

Ionic Software
Viewer Client
MIT
SPOT Image
Laser-Scan
Roads



Ionic Software
Viewer Client
MIT
LandSAT image
Laser-Scan
Roads
Object/FX
Hospitals



Testbed Applet - Microsoft Internet Explorer

FichierEditionAffichageAller àFavoris2

PrécédenteSuivanteArrêterActualiserDémarrer

Adressehttp://www.ionics.com/ionics/demo/wmt/wmt.html

Feature

key	value
x_max	395020.84375
Description	< 2626>Highway
y_max	3393940.5
fid	f:2626.12048962.102
number_of_vertices	111
featureType	ft:Highway
x_point	394968.0625
length	16104.057311
get_dimension	1
get_topological_dimension	-1
y_point	3393924.5
x_min	387503.1875
validate	OK
Name	Government

Warning: Applet Window

Graphic area

World Overview

Satellite Ground

World Topography

☒ D3JUC1 BaseMap

☐ D3JUC2 BaseMap Plus

☐ D3JUC3 Overlay

☐ D3JUC4 Flooding Hindrances

☐ D3JUC5 Emergency

☐ D3JUC6 Rescue Route

Overview:World Overview

Scale: 2528

X: -88.15238

Y: 30.623333

Msg:

Applet started.

Query feature (XML) by 1 click

Warning: Applet Window

Case review (Sept 10th)

	Image	Vector	Geospatial data
Web Browser	Picture case		
Downloaded client	Improved ergonomics		Individual feature data
Desktop application			

WMT conclusions

- **The WMT is a success!**
 - *multiple participants can work together to define useful specification in Internet time*
- The worth of a thin client architecture for Web mapping has been demonstrated.
- Map Servers provide a *service*, they are not mere *data providers*.
 - *currency of data*
 - *projection changes*
 - *basic image processing*



Feb 2000 - Web Map Server Interface Specification

- The Web Map Server Interface Specification from WMT 1 was accepted (with SFXML - feature encoding - removed). It covers:
 - how to talk to a Map Server
 - ask it what it is capable of
 - ask for a map (in a variety of formats)
 - ask for information about a feature aka 'drill-down' (in a variety of formats)
- will become public shortly

Feb 2000 - Geographic Markup Language (GML)

- RFC-11 plus SFXML was proposed as a Recommendation Paper. GML covers levels of encoding of Geographic Information
 - A Recommendation Paper is a mechanism for publishing something that is not a spec but represents OGC position on a volatile topic.
 - Combined product is to be known as GML with three profiles, GML.lite, GML.app, GML.core
 - GML.lite takes the role of SFXML in Web services. It is an XML encoding, that can be mechanically translated to give the result of a feature enquiry
- Shortly to be balloted electronically

Beyond WMT 1

- Initiatives to test and use current spec
 - European
 - US FGDC
 - local communities
- WMT 2 scheduled for Q2 2000
 - focus on portrayal and rendering
 - update??

Stages of Internet Evolution

- Access to data over the Internet:
 - the initial stage, offering millions of relatively static pages and images.
- Provision of services over the Internet:
 - the ability to go to Amazon.com and buy a book, emerging now.
- Use of federated services over the Internet:
 - the provision of services built upon a number of other services.
Incorporates the *distributed* aspect of the WMT.

How do we make such systems pay for themselves?



it's moving at Internet speed!

peterw@lsl.co.uk

<http://www.laser-scan.com/>

<http://www.opengis.org/>

Back to Content Presentations



Internet based GI-services in National Land Survey of Finland

Veijo Pätynen
National Land Survey of Finland

”National Mapping Agencies and the Internet”
Workshop 8-10 March 2000
Southampton, United Kingdom



Content

- Background
- Directory Services
- MapSite Services
- Ordering Services (on MapSite)
- Future actions



Distribution of Duties

In Finland, cadastral survey and mapping tasks are handled by the government, municipalities and private consultants

NATIONAL LAND SURVEY

- Conducts land surveys
- Maintains the national cadastral system
- Carries out national mapping assignments
- Promotes the shared use of geographical information



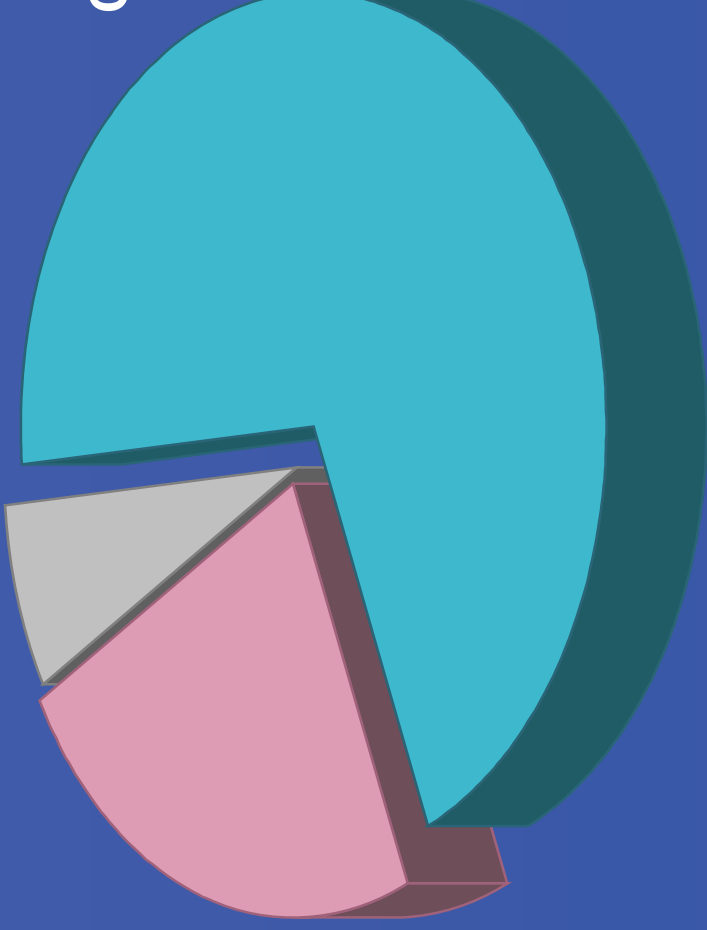
Number of Staff by organizational level 1998

1929 persons

General
administration
7 %

Mapping
services
23 %

Cadastral
services
70 %





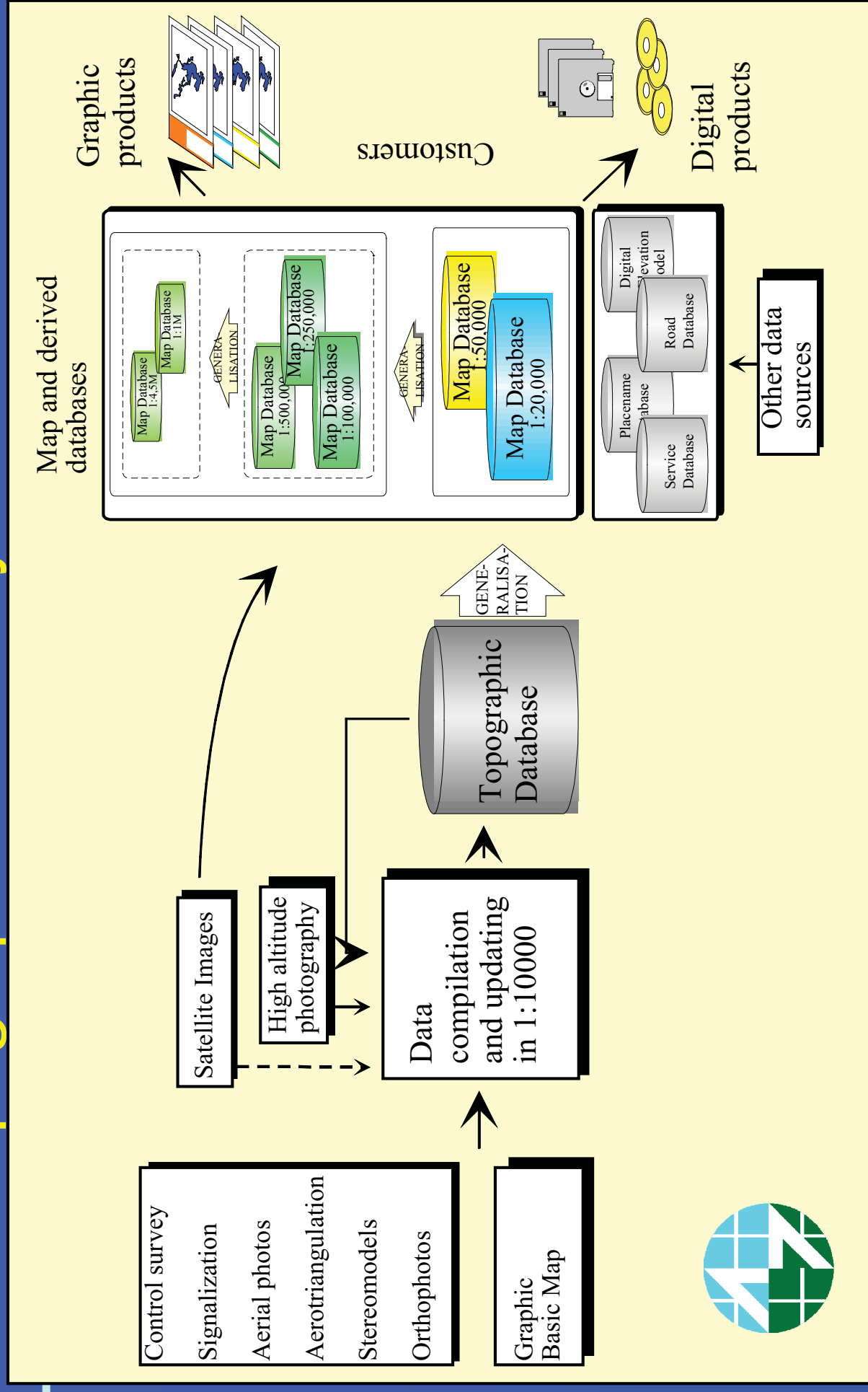
Organization

- Ministry of Agriculture and Forestry
- National Land Survey of Finland
 - 13 District Survey Offices
 - 5 Operational Units
 - Central Administration





Topographic Data System of NLS



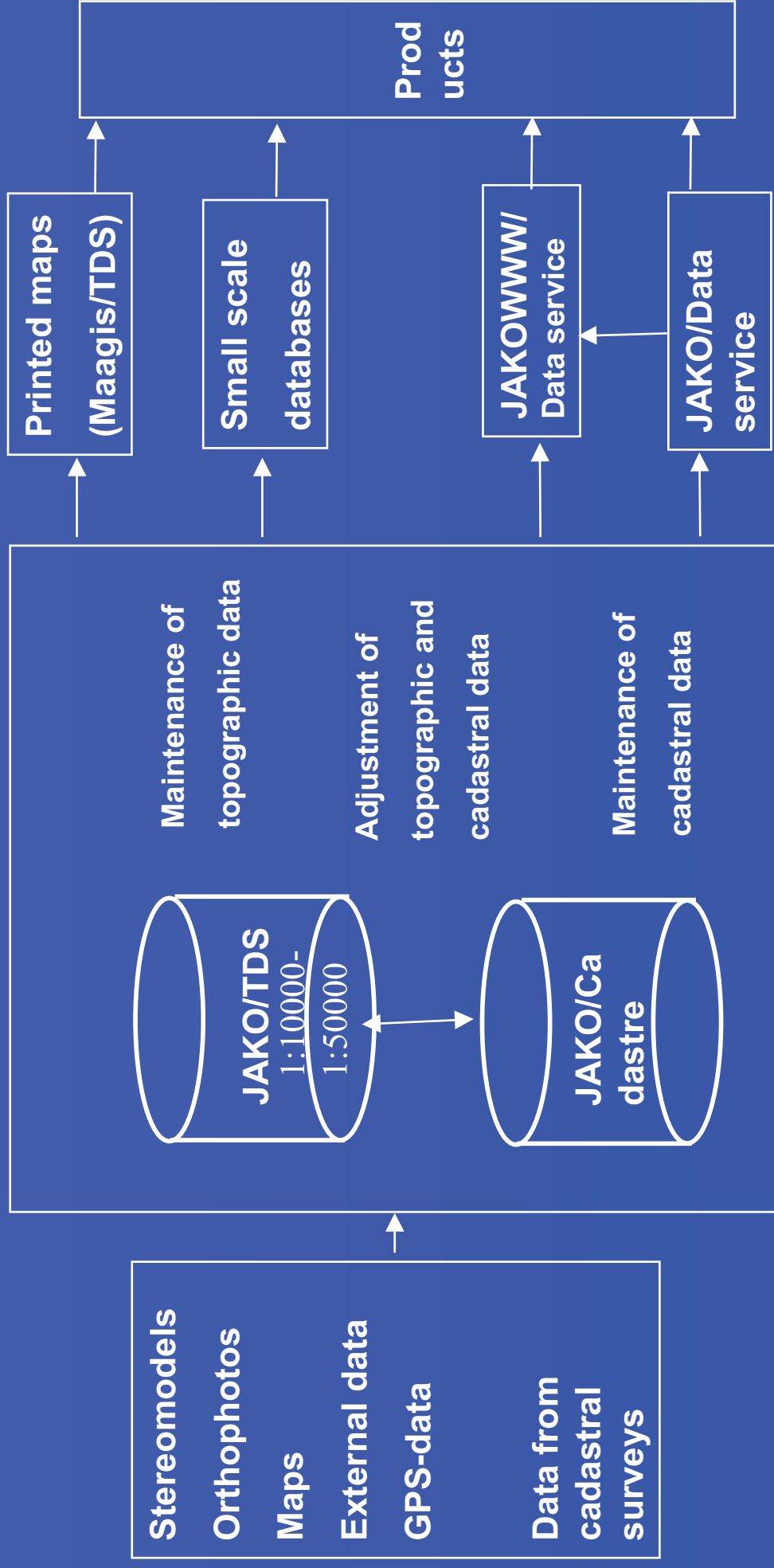


JAKO - Cadastral Information System of NLS

- Aims
 - cadastre maintenance
 - conducting of surveys
 - efficient information service
- Time table
 - 1990-1993: Determination of requirements
 - 1993-1994: GIS-software selected
 - 1995-1997: Development carried out
 - introduced in March 1998
- Based on Smallworld GIS
- 1000 workstations



JAKO-systems in NLS





Directory Services

- The Finnish Metadata Catalogue of GI
 - In public use since 1991
 - Since 1994 in the Internet
 - Provides descriptions about 320 datasets from 24 national and 44 local organisations
 - Over 30,000 hits per month



Finnish Metadata Catalogue of Geographical Information (GL)

Paikkatietohakemisto - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: <http://www.nls.fi/ptk/aineistot/>

Paikkatietoineistot organisaatioittain

Kunnat

Muut organisaatiot

	Geodeettinen laitos		Novosat Oy
	Geologian tutkimuskeskus		Oikeusministeriö
	Helsingin kaupungin liikennelaitos		Riista- ja kalatalouden tutkimuslaitos
	Ilmailulaitos		Suomen Posti Oy
	Ilmatieteen laitos		Suomen ympäristökeskus
	Keski-Pohjanmaan liitto		Tapiol
	Karttakeskus Oy		Sonera Oy
	Maanmittauslaitos		Telehallintokeskus
	Merenkulkulaitos		Tielaitos
	Merentutkimuslaitos		Tilastokeskus
	Metsähallitus		Väestörekisterikeskus
	Maa- ja metsätalousministeriön tietopalvelukeskus		
	Metsäntutkimuslaitos		

Hakemistossa on 320 aineistoa 29.11.1999.

Document Done



MapSite

- Internet map service of the NLS
- Launched in September 1996
- Topographic maps
 - seamless raster maps covering whole Finland
 - scales from 1:1,000 to 1:64 million
 - own efficient image file format
- Orthophotos 1 m resolution (coming)
- 28,000 place names, over 2 million addresses
- On-line Ordering Services
- 150,000 users, 11 million queries

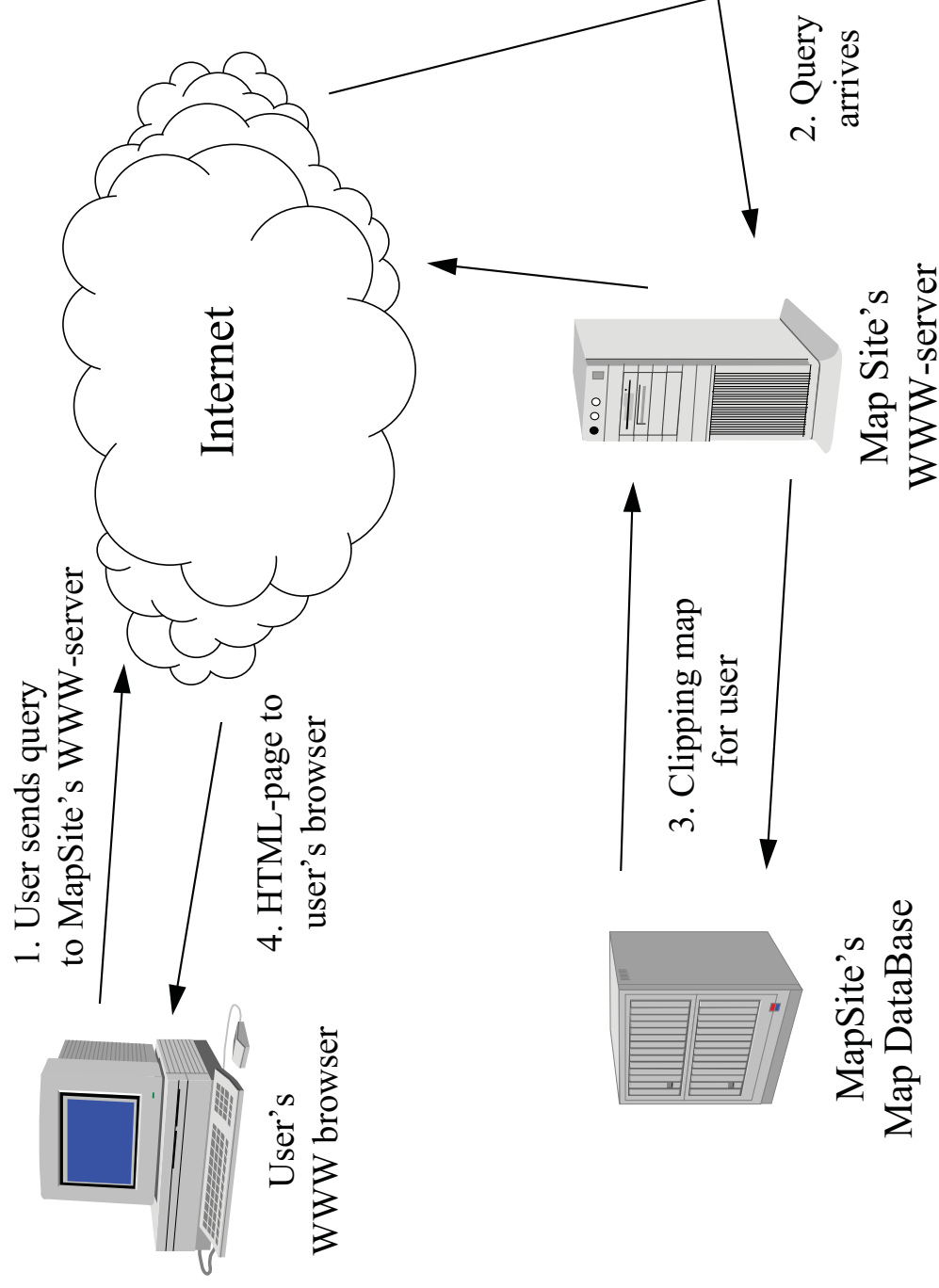


MapSite's user groups

- Citizen's MapSite (CMS)
 - Free of charge for Finnish Internet users
 - Registration is required
 - Less scales and services
- Professional's MapSite (PMS)
 - All maps and services
 - Coordinate information
 - Chargeable

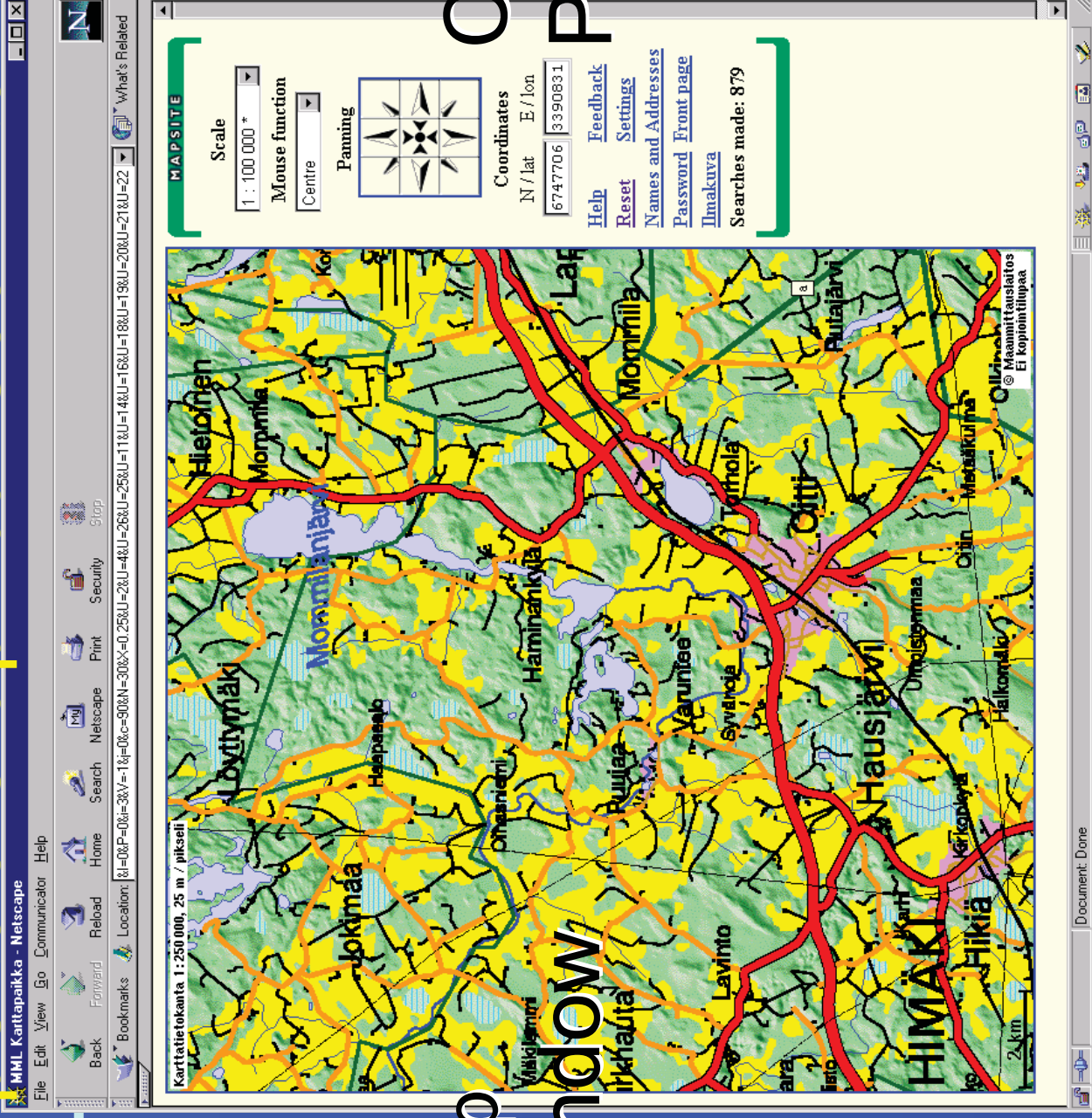


MapSite on the Internet





MapSite's Graphical User Interface

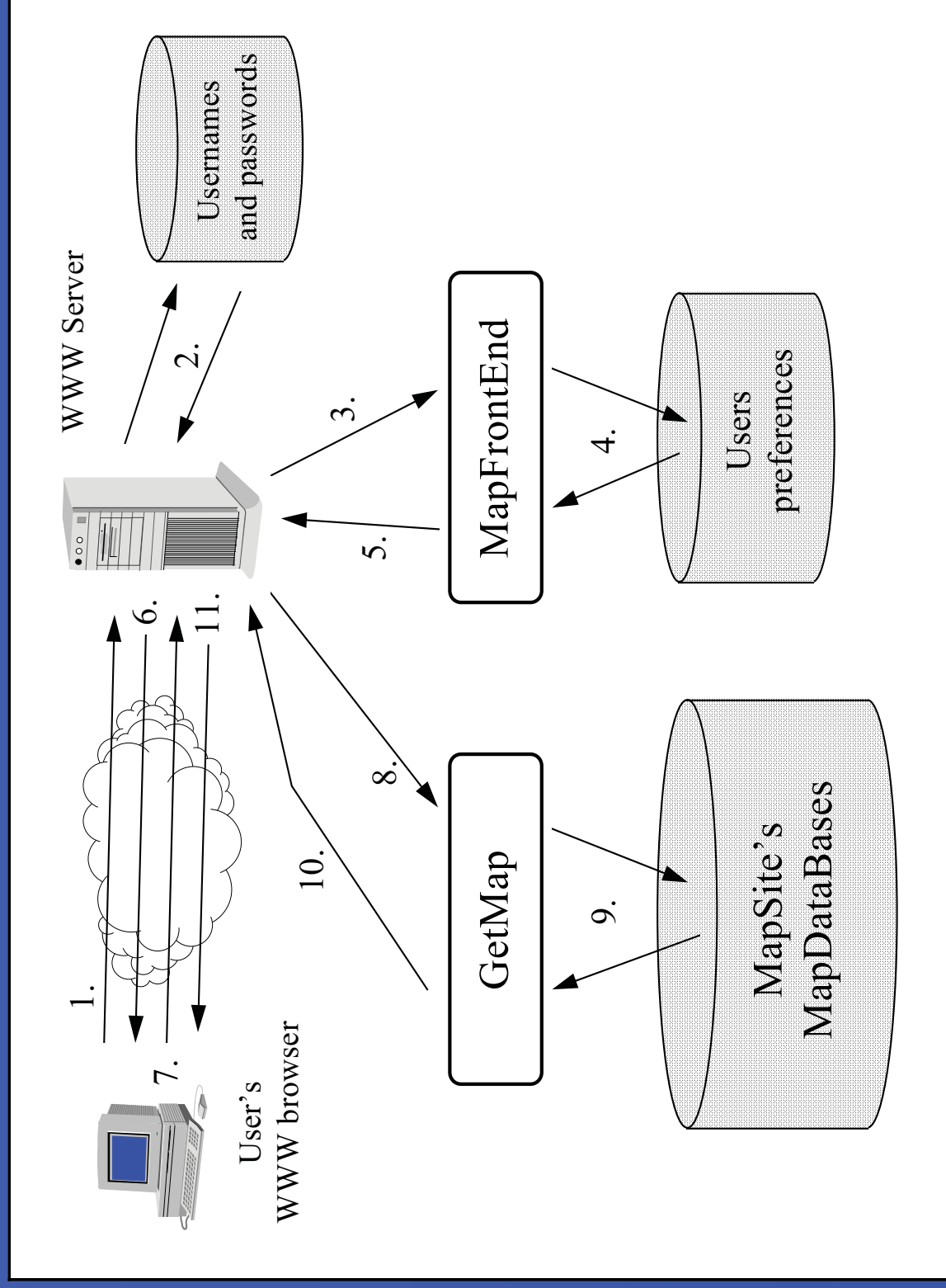


Control
Panel

Map
Window



MapSite's programs



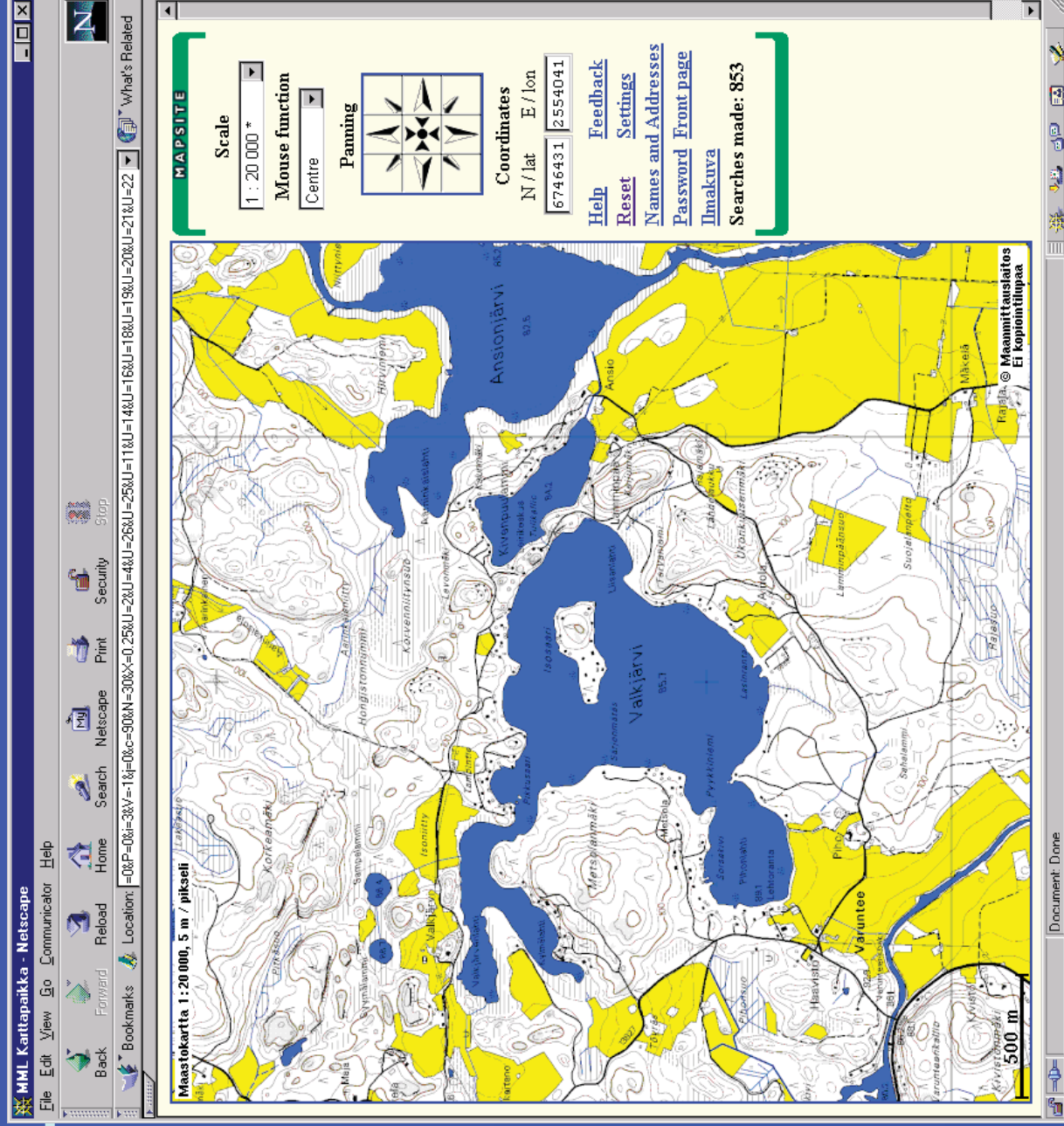


Maps of MapSite

• 1:8 milj ->	Maps from Internet	
• 1:4 milj	Map Database 1:4,5 milj	
• 1:2 milj	Map Database 1:1 milj	
• 1:800,000	Map Database 1:1 milj	
• 1:400,000	Map Database 1:500,000	
• 1:200,000	Map Database 1:500,000	
• 1:200,000	Map Database 1:250,000	PMS only
• 1:100,000	Map Database 1:250,000	PMS only
• 1:40,000	Topographic map 1:20,000	<i>PMS only</i>
• 1:20,000	Topographic map 1:20,000	PMS only
• 1:8,000	Topographic map 1:20,000	PMS only
• 1:4,000	Topographic map 1:20,000	PMS only
• 1:2,000	Topographic map 1:20,000	PMS only
• 1:1,000	Topographic map 1:20,000	PMS only

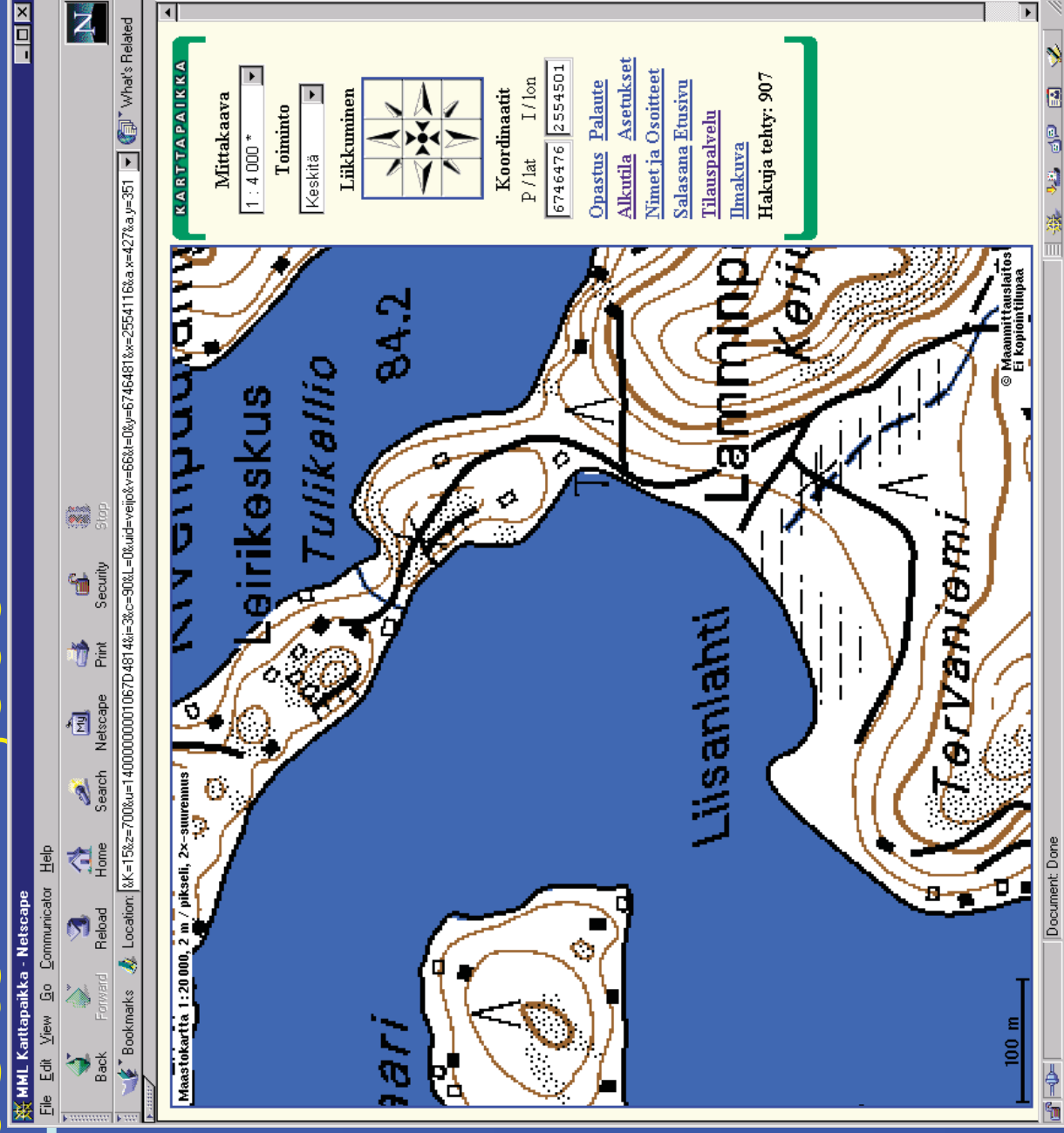


MapSite - 1:20,000



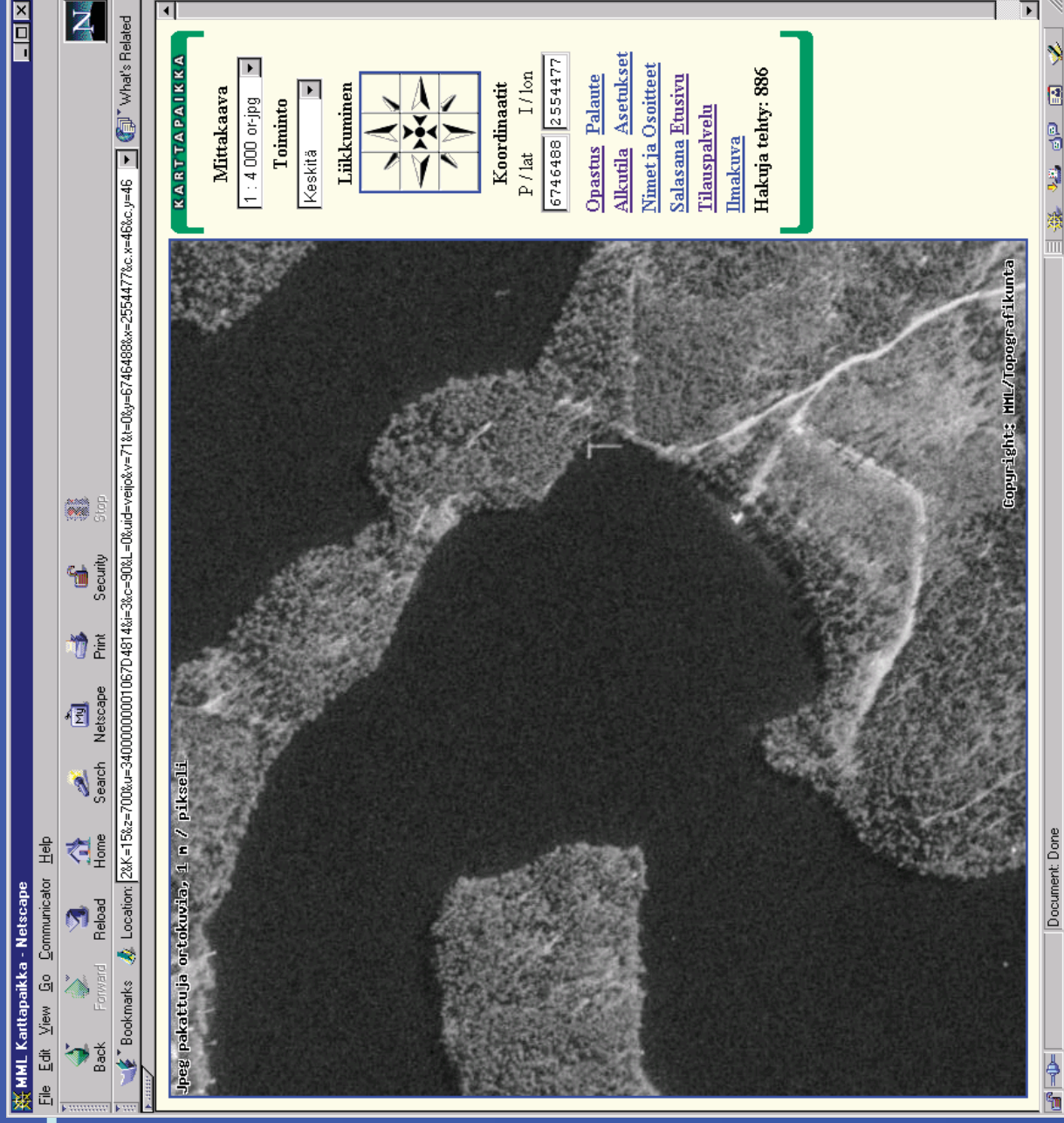


MapSite - 1:4,000





MapSite - Orthophoto 1:4,000





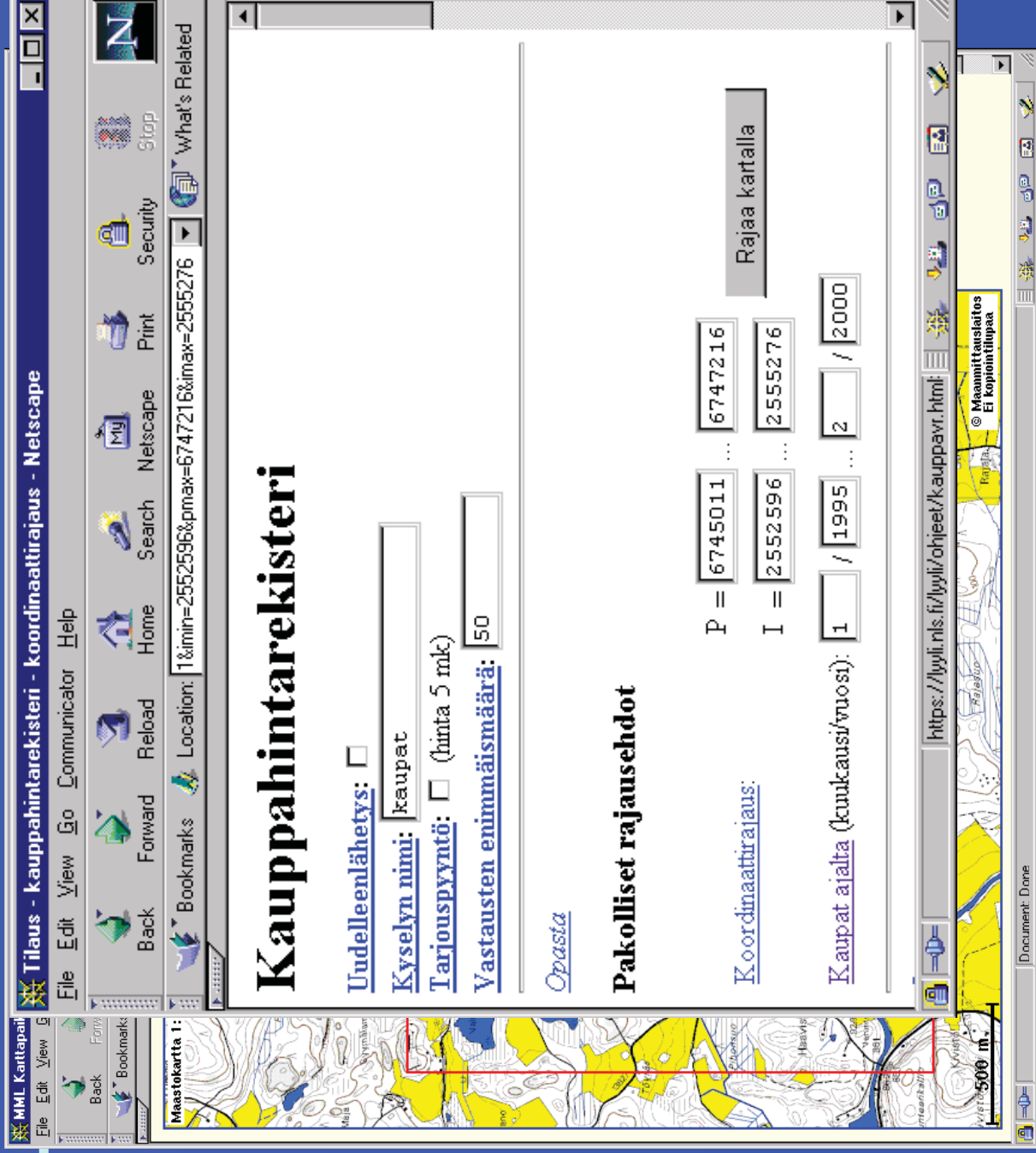
Ordering Services on MapSite

- Open since September 1997
- Order data from NLS's original databases
 - Real Estate Market Price Register
 - Digital Cadastral Boundary Map
 - Real Estate Register
 - Geodetic Control Points Register
- Browsing and/or downloading answers





Real Estate Market Price Register 2



Kauppahintarekisteri

Uudelleenlähetytys: ☐

Kyselyn nimi: kaupat

Tarjouspyyntö: ☐ (hinta 5 mk)

Vastausten enimmäismäärä: 50

Opasta

Pakolliset rajausehdot

Koordinaattirajaus:

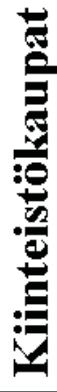
P = 6745011 ... 6747216

I = 2552596 ... 2555276

Kaupat aialta (kuukausi/vuosi): 1 / 1995 ... 2 / 2000

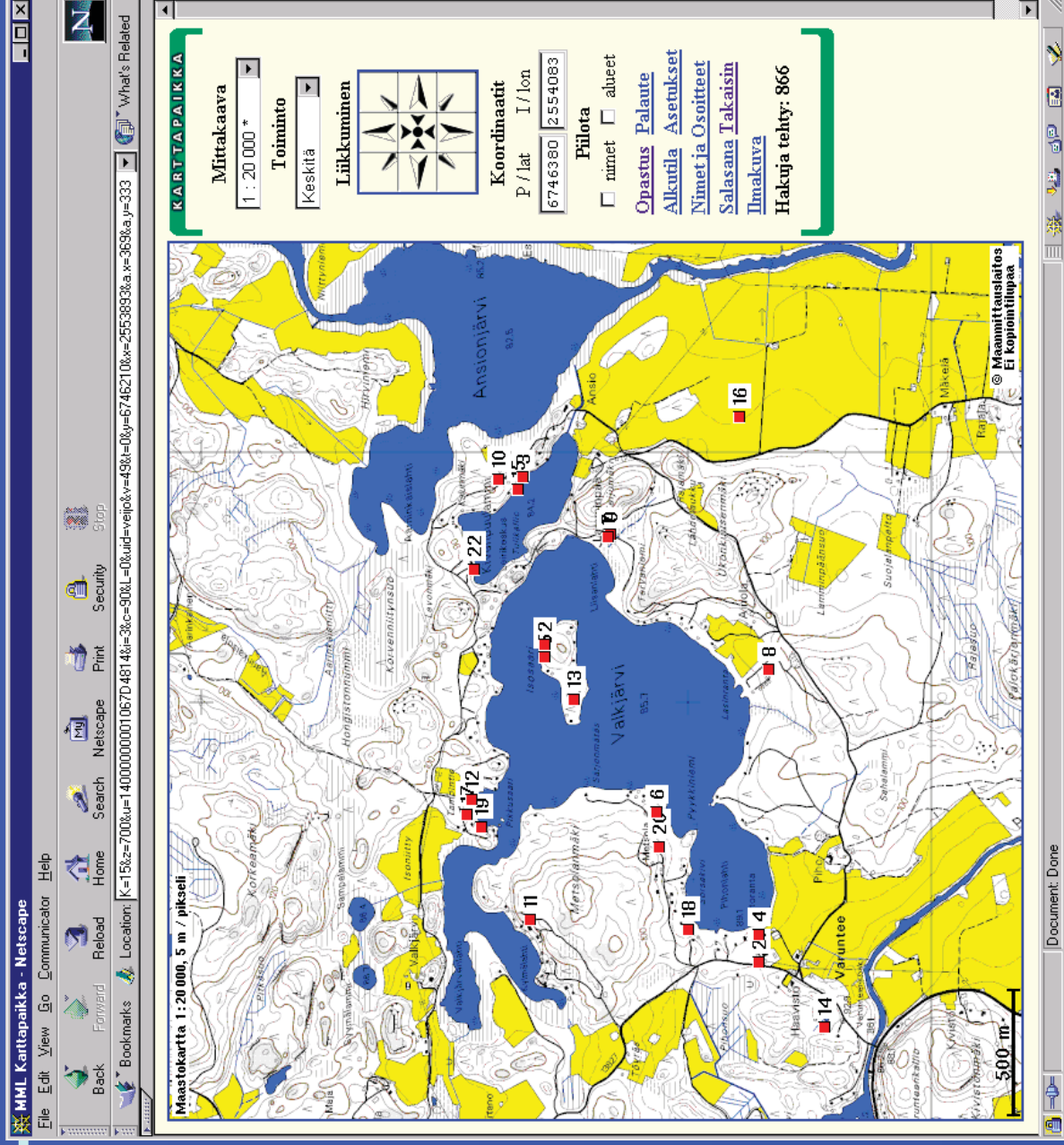
Rajaa kartalla

Maaomittauslaitos
© Maaomittauslaitos
Ei kopiointilupaa





Real Estate Market Price Register 4





Real Estate Market Price Register 5

Internet Explorer 5.0.1 Netscape 4.0.4

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: <https://hyj.knls.fi/hyj/vastaus.cgi/Knr-1731-28.1436>

What's Related

Kauppa

Kaupan numero vastauksessa: 2

Luovutuspäivä: 30.07.1999

Kokonaishinta: 365000

Kokonaispinta-ala: 4764

Käyttötarkoitus: lomarakennuspaikka

Kunnan nimi: Hausjärvi

Kaupunginosan/kylän nimi: PUUJAA

Koko kaupan kohteen laatu: koko kiint-/m-ala/m-osa

Luovutuksen laatu: kauppa

Sukulausluovutus: ei sukulaisia

Perustettavan asunto oyn lukuun: ei

Epäselvyyksiä: ei

Lisätietoja:

Asuinrakennusten lkm: 0

Liike tai teollisuusrak lkm: 0

Talousrakennusten lkm: 0

Muiden rakennusten lkm: 1

Kaavan laatu: ei kaavaa/ei tietoa

Kaavan mukainen käyttötarkoitus:

Tehokkuusluku:

Rakennusoikeus:

Viljeltyä maata: 0

Metsämaata: 0

Muuta maata: 0

Rantaan rajoittuvuus: rajoittuu rantaan

Yksikköhinta: 76

Saaajan laatu: Muu yksityinen

Saaajan kotikunta: Hausjärvi

Luovuttajan laatu: Kuolinpesä

Luovuttajan kotikunta:

p-koordinaatti: 6746590

i-koordinaatti: 2554230

Karttalehden numero: 21304

Kiinteistö: 086-411-0005-0119

086-411-0005-0077

086-411-0005-0092

Document Done



Real Estate Market Price Register 6

MML Karttapäikkä - Netscape
File Edit View Go Communicator Help

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Bookmarks Location: K=15&z=700&u=1400000000106704814&=3&c=90&l=0&uid=veip&v=66&t=0&y=6746578&x=2554205&a.x=359&a.y=352 What's Related

KARTTAPAIKKA

Mittakaava: 1 : 4 000 *

Toiminto: Keskittä

Liikkuminen

Koordinaatit: P / lat I / lon
6746574 2554223

Pilota: ☐ nimet ☐ alueet

[Opastus](#) [Palaute](#) [Alkutila](#) [Asetukset](#) [Nimet ja Osoitteet](#) [Salasana](#) [Takaisin](#) [Ilmakuva](#)

Hakuja tehty: 868

Maastrakartta 1:20 000, 2 m / pikseli, 2x-suurennus

Isosaari

Liisanlahti

alkjärvi

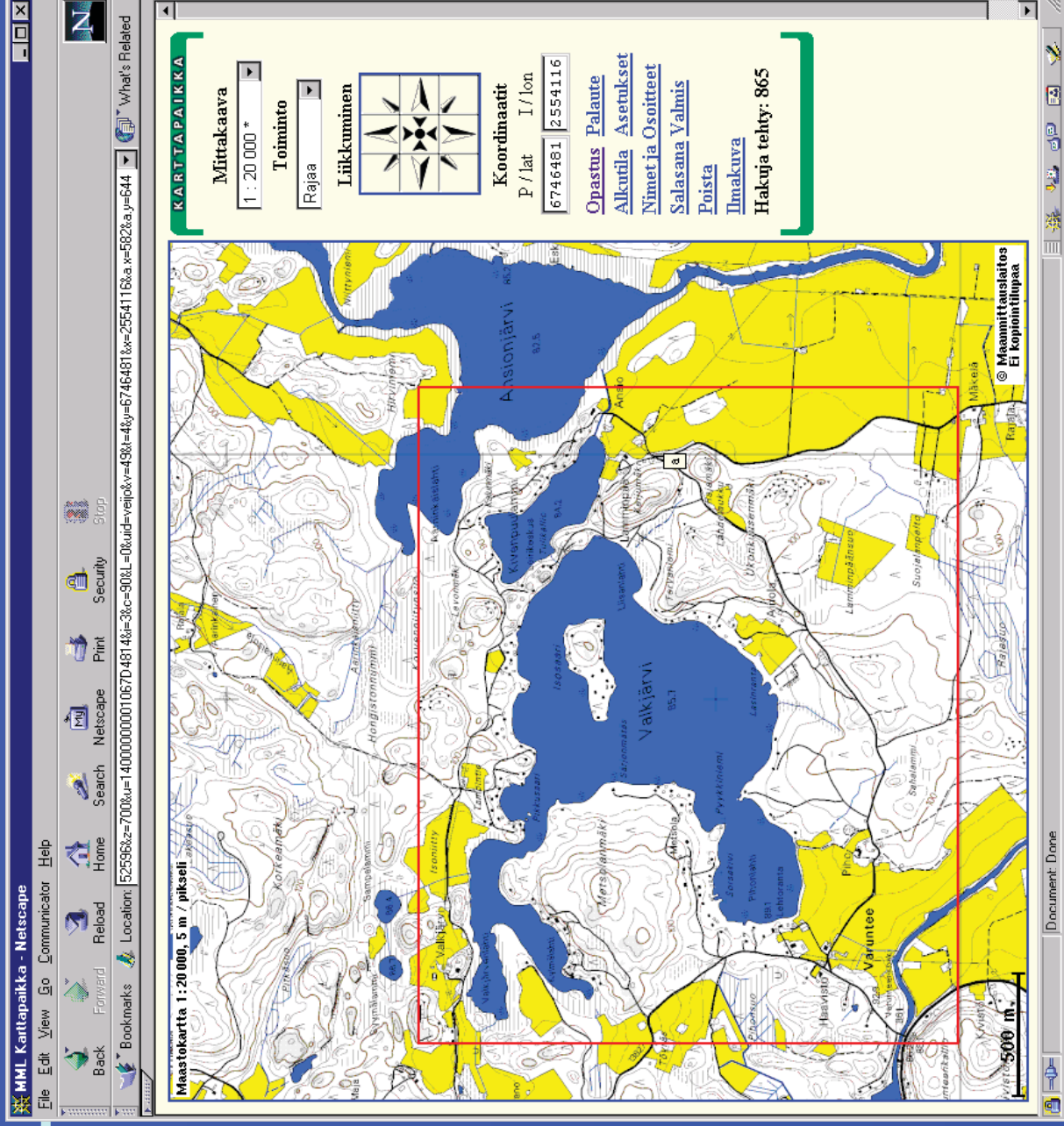
100 m

© Maanmittauslaitos
Ei Kopioitiluppia



Register of Geodetic Control Points

1





Register of Geodetic Control Points

2

Vastaus: Kiintopisteet - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: ps://lyyli.nls.fi/lyyli/vastaus.cgi/kpr-1731-30 What's Related

Kiintopisteet

[Takaisin](#) [Näytä vastaukset kartalla](#)

Viite: kpr-1731-30

Toimitetun tiedon hinta noin: 16.40

Tiedon määrä: 4

Muu viesti: Hinnat ilman arvonlisäveroa

Kiintopiste: 35:19P
35:19A
593473
831130

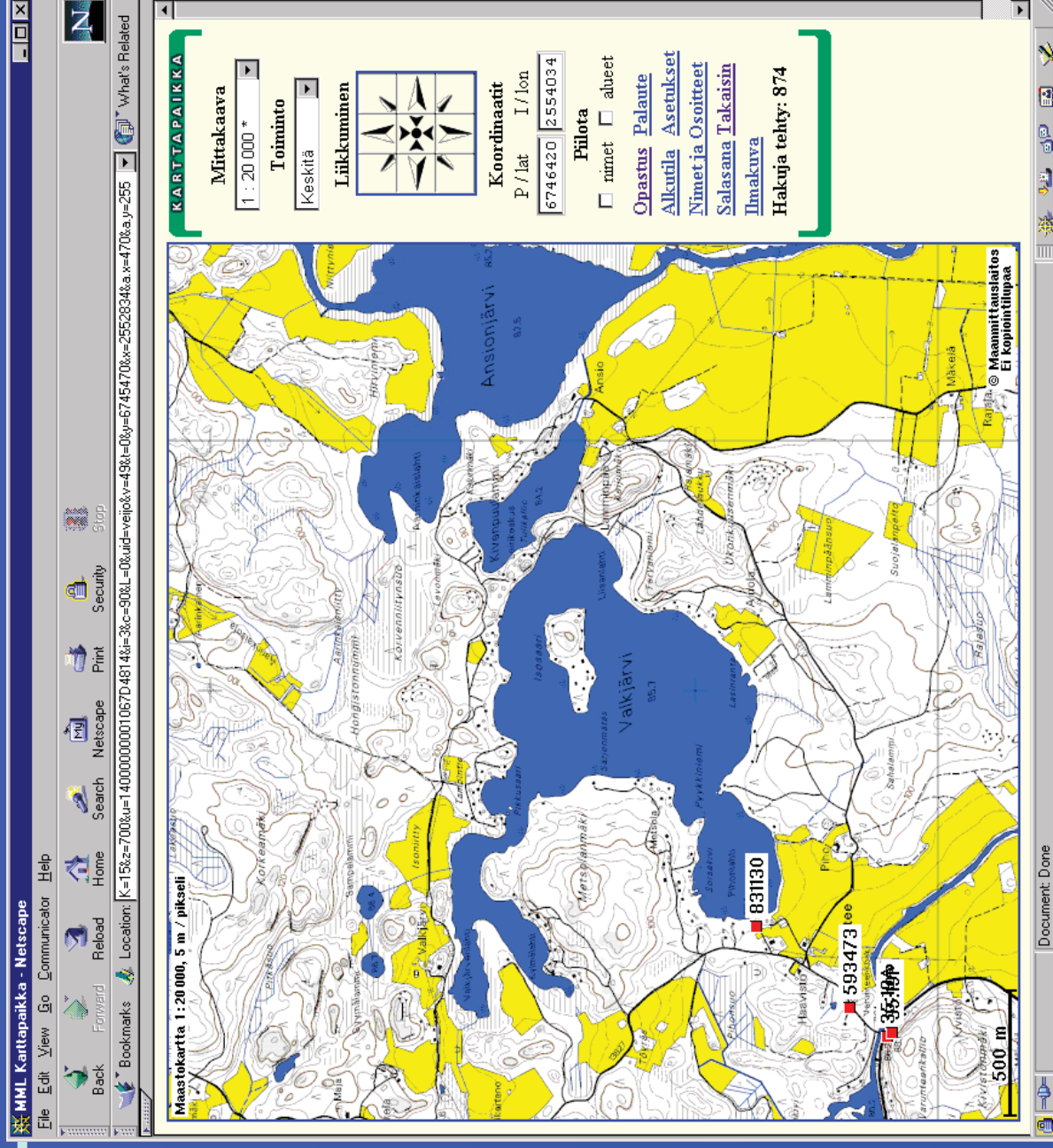
[Takaisin](#) [Näytä vastaukset kartalla](#)

Document Done



Register of Geodetic Control Points

3





Register of Geodetic Control Points

4

Vastaus: Kiintopisteet, Kiintopiste - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: lyyli.nls.fi/lyyli/vastaus.cgi/kpr-1731-30.1950 What's Related

Kiintopisteet

Kiintopiste

[Ylemmälle tasolle](#) [Edellinen kiintopiste](#)

Kiintopisteen numero:	831130
Kiintopisteen nimi:	
Viitenumero:	5934.7
Tasokoordinaattijärjestelmä:	KKJ
Tasotarkkuusluokka:	Pohjakarttamääritys
Korkeusjärjestelmä:	N60
Korkeustarkkuusluokka:	3.lk:n vaaituspiste
p-koordinaatti:	6745751.2
i-koordinaatti:	2553055.0
k-koordinaatti:	89.080
Karttalehti:	213304
Pisteen mitannut organisaatio:	Maamittauslaitos
Päivämäärä:	11.11.1991
Kunta:	Hausjärvi
Määrittystapa ja GPS-sopivuus:	
Rakenne lma:	
Havaintokorkeus:	
Keskusmerkin tyyppi ja alusta:	Pultti kalliassa
Kiintopisteen sijainti:	Tiestä itään 100 metriä
Sijainti maanpinnasta:	
Kiintopisteen selitys:	

MLL Kartapaikka - Netscape

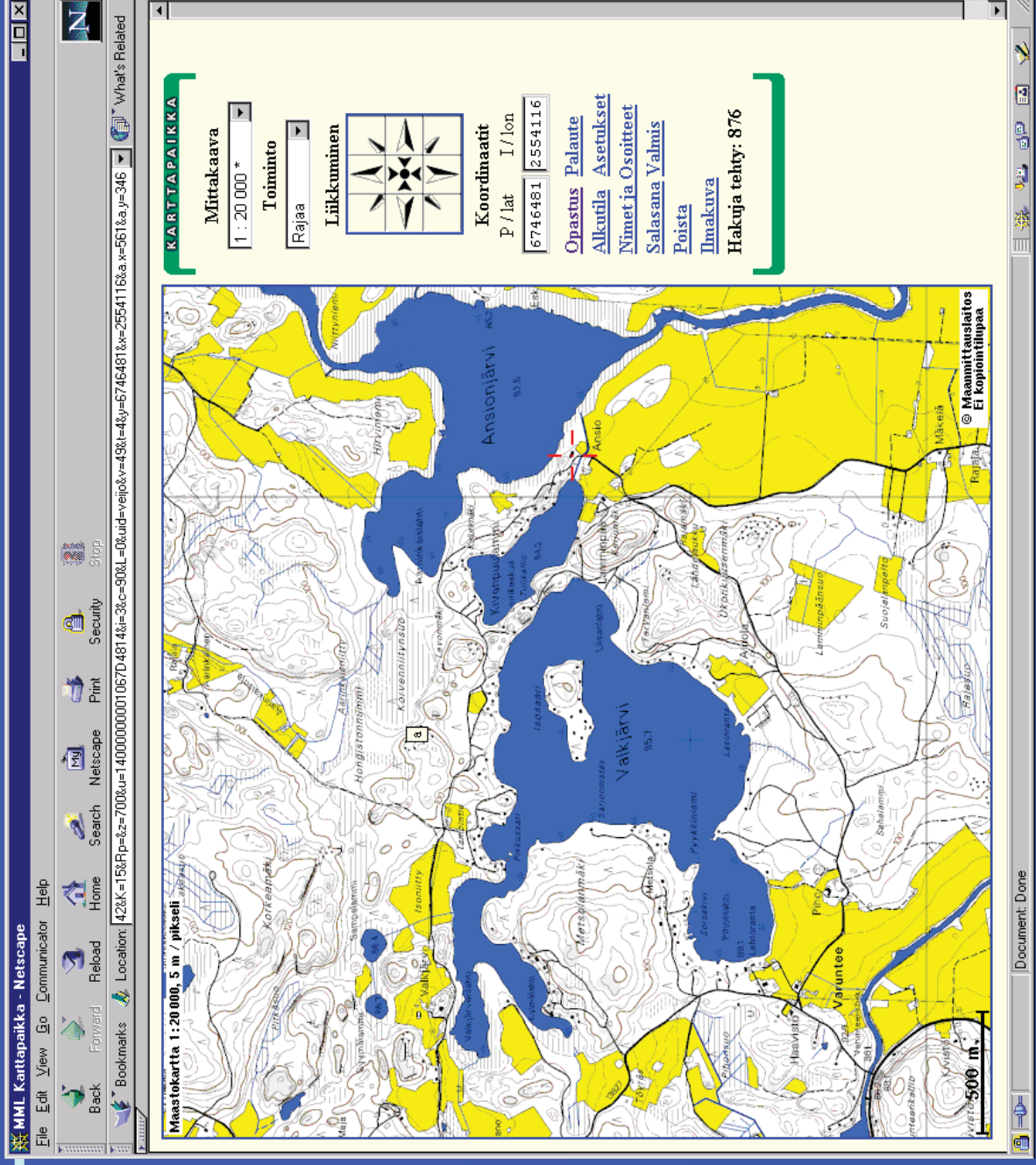
File Edit View Go Communicator Help

Back Forward Reload Home

Bookmarks Location: [K=15&](#)



Digital Cadastral Boundary Map 1





Digital Cadastral Boundary Map 2

Vastaus: Kiinteistörajat - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: <https://lyyli.nls.fi/lyyli/vastaus.cgi/nkr-1731-31> What's Related

Kiinteistörajat

[Takaisin](#) [Näytä vastaukset kartalla](#)

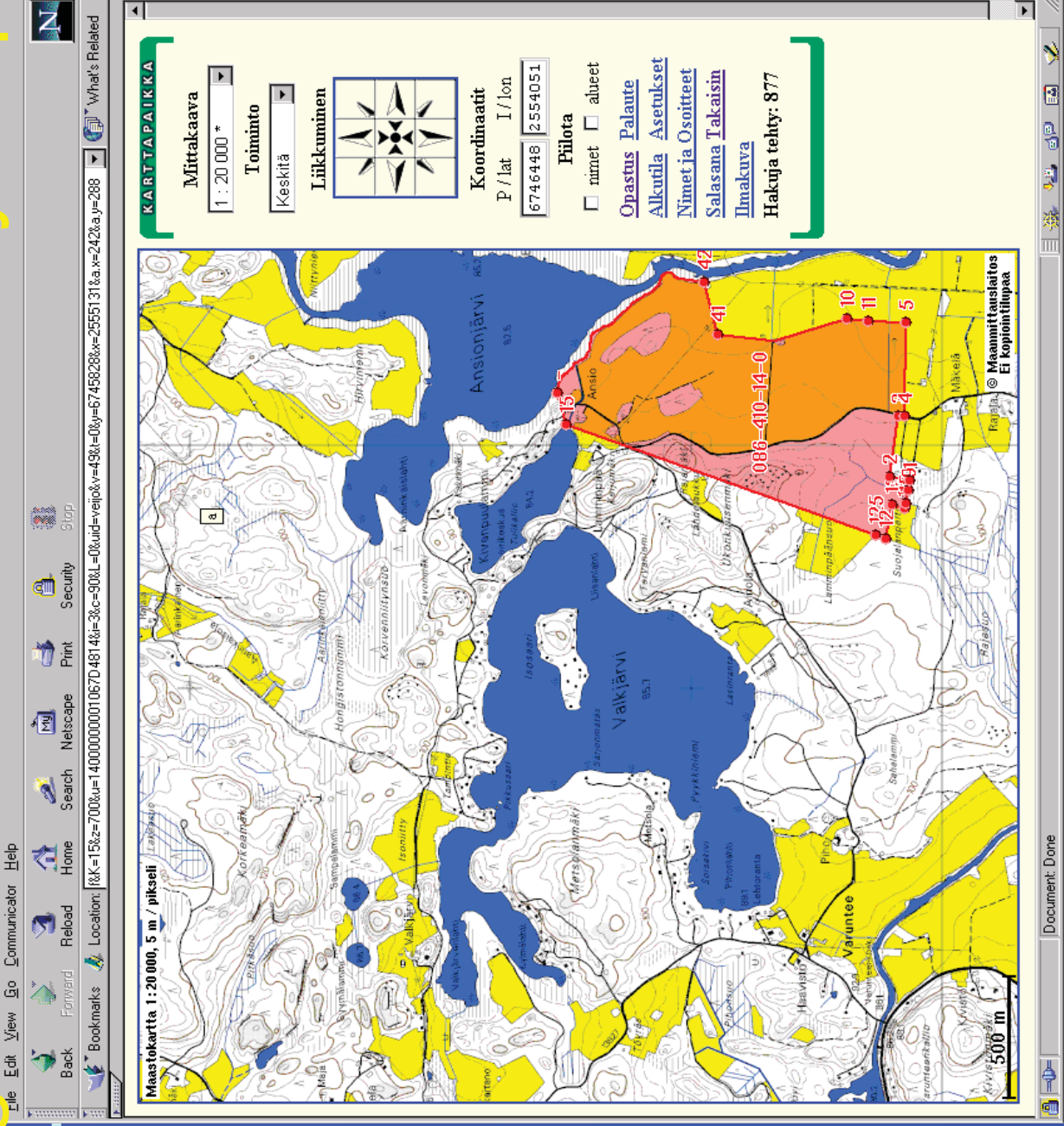
[Opasta](#)

Viite:	nkr-1731-31
Rajauksella löytyy:	1
Toimitetun tiedon hinta noin:	5.00
Muu viesti:	Hinnat ilman arvonlisäveroa
Muu viesti:	Toimitettu vain rajauksen alueella olevat
Koordinaattijärjestelmän tunnus:	KKJ
Koordinaatisto:	Yhtenäiskoordinaatisto
Korkeusjärjestelmän tunnus:	N60
Kiinteistö/palsta:	086-410-14-0

Document: Done



Digital Cadastral Boundary Map 3





Digital Cadastral Boundary Map 4

Maanmittauslaitos - Netscape

File Edit View Go Communicator Help

Back Forward Reload Location

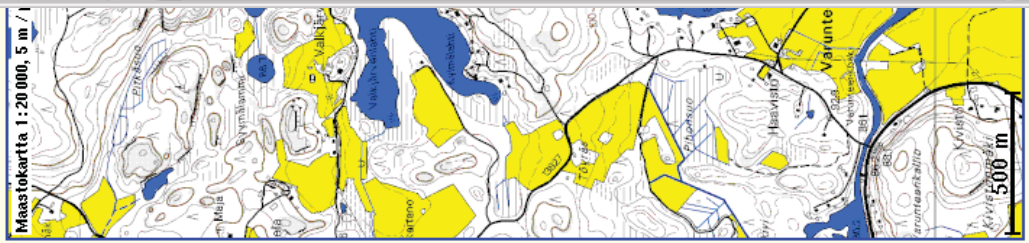
Home Search Netscape Print Security Stop

Vastaus: Kiinteistörajat, Rajamerkki - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: <s://lyyli.nls.fi/lyyli/vastaus.cgi/hkr-1731-31.14031> What's Related



Maastokartta 1:20 000, 5 m

Kiinteistörajat

Rajamerkki

[Ylemmälle tasolle](#) [Edellinen rajamerkki](#) [Seuraava rajamerkki](#)

Número:	15
Rajamerkin laatu:	Rajapyykki
p-koordinaatti:	6746500.300
i-koordinaatti:	2555084.100
Epävarmuusluku:	0.6
Rajamerkin rakenne:	Määrittelemätön
Rajamerkin olotila:	Rajapyykki on maastossa

[Ylemmälle tasolle](#) [Edellinen rajamerkki](#) [Seuraava rajamerkki](#)

Document: Done





MapSite - Financial Aspects 1

- Queries to chargeable maps (beforehand)
 - 100 queries 180 FIM
 - 250 queries 350 FIM (10 FIM = 1 GBP)
 - 500 queries 700 FIM
 - 1000 queries 1300 FIM
- After-reckoning 1 FIM / query
- Ordering Services
 - Real Estate Market Price: 7 FIM / sale
 - Geodetic Control Points: 5 FIM / point
 - Cadastral Boundary Map: 6 FIM / real estate
 - Real Estate Register: 3-30 FIM / real est.



MapSite - Financial Aspects 2

- MapSite's maps on WWW-pages of a company
 - one map 200 FIM
 - next 20 FIM a piece
- No electronic payment, NLS sends the bill via mail
- Incomes in 1999 1,7 million FIM
 - weighted to Ordering Services

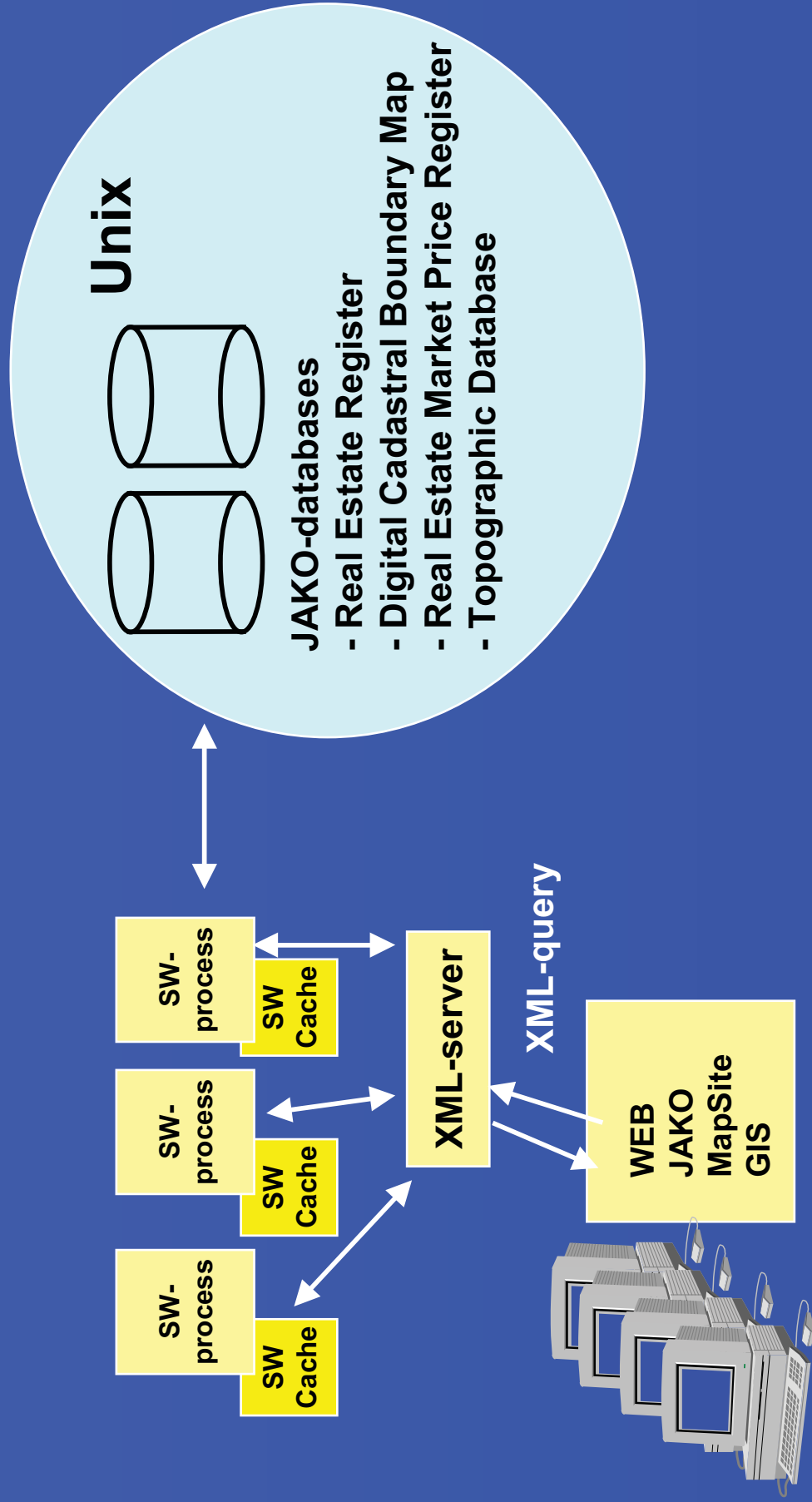


Strategy for data services of NLS

- Role of NLS and external consultants
- Redefinition of products and services
- Pricing
- New technologies
 - Mobile telephones, WAP
 - GPS, navigation applications
 - XML
- New national projects
 - DIGIROAD, Personal Navigation
- ...

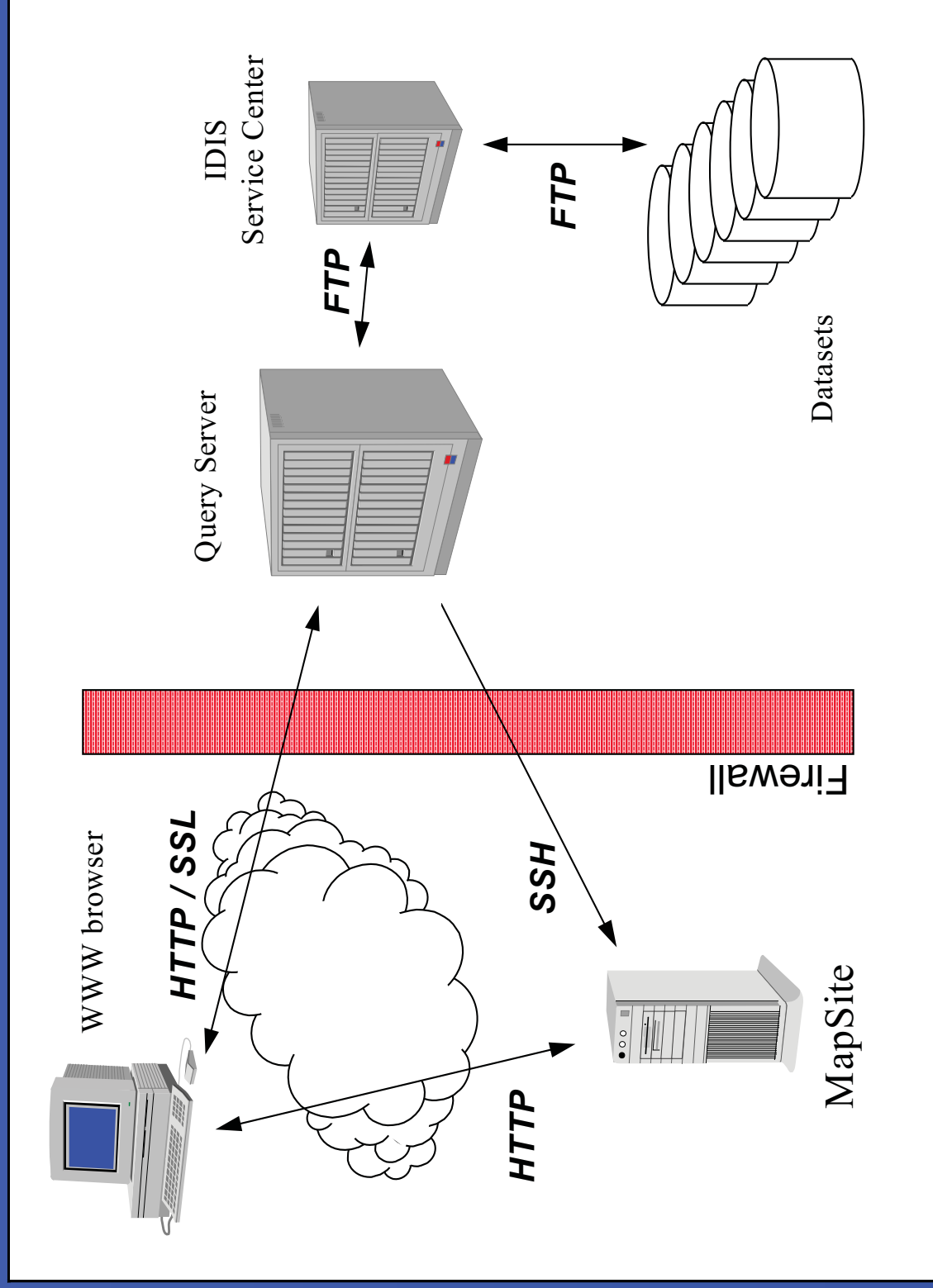


Data service based on XML





Ordering Service on MapSite



Back to Content Presentations

Internet at Lantmäteriet in Sweden

National Land Survey of Sweden

palle.pettersson@lm.se

Southampton

2000-03-09



Lantmäteriet's four-leaf clover



Lantmäteriet

National Land Survey

⇒ Annual turnover 1 400 MSEK (164 M €)

• Geographic- and Real property information

- by the government 400 MSEK (47 M €)
- fees from the users 300 MSEK (35M €)



Products

- Real Property register
- Geographic data sets
- Maps, printed and on cd-rom
- Aerial photographs and orthophotos
- GIS
- GIS- technology



Internet is not just *www*

- ⊖ Internal information on Intranet
- ⊖ External information, www.lm.se
- ⊖ E-mail communication
- ⊖ Market place, Map Store
- ⊖ Licensed application services
- ⊖ Data distribution, ftp

Geographic Information

Marketing policy

- Maps and Geographic data is protected by copyright law
- All use is licensed
- Several resellers



License policy

- Usage fee according to price list
- Reduced fee for a single application
- Internet fee, depending of:
functionality, time of use, no. of users etc.
- Annual fee or royalty fee

Maps on the WWW

- Usage right and market right
- Copyright to Internet maps and images
- Fees according to price list
- No personal particulars
- No real property information



Maps on the WWW

- From 1:2 mil. to 1:10 000
- Map images just in raster format
- No coordinates in nat. reference system
- Added customer information
- Annual fee for images on the WWW



www.lm.se

Lantmäteriet - Telia Internet Explorer

Arkiv Redigera Visa Gå till Favoriter Hjälp

Klicka här för textnavigation

- Kartor och flygbilder
- Fakta om fastigheter
- Fastighetsbildning
- Geografisk IT
- Forskning och utveckling
- Om Lantmäteriet
- Aktuellt
- Utland
- Kontakta oss
- Innehåll
- In English
- Till startsidan
- Till Metria

LANTMÄTERIET



Första digitala företagshypoteks-brevet

Ny tjänst FastighetSök

Pressmeddelande 2000 03 01

Gävleborgs fastigheter blir digitala

Fortsatt bra resultat för Lantmäteriet

Lantmäteridagar 2000

Gävle 10-11 maj

Nya namn på originalkartorna

Kartplan 2000

Hela Sverige kartlagt i 3D

Färdig

Zonen Internet



Statistics on a map

Statistics on a map

Selection:

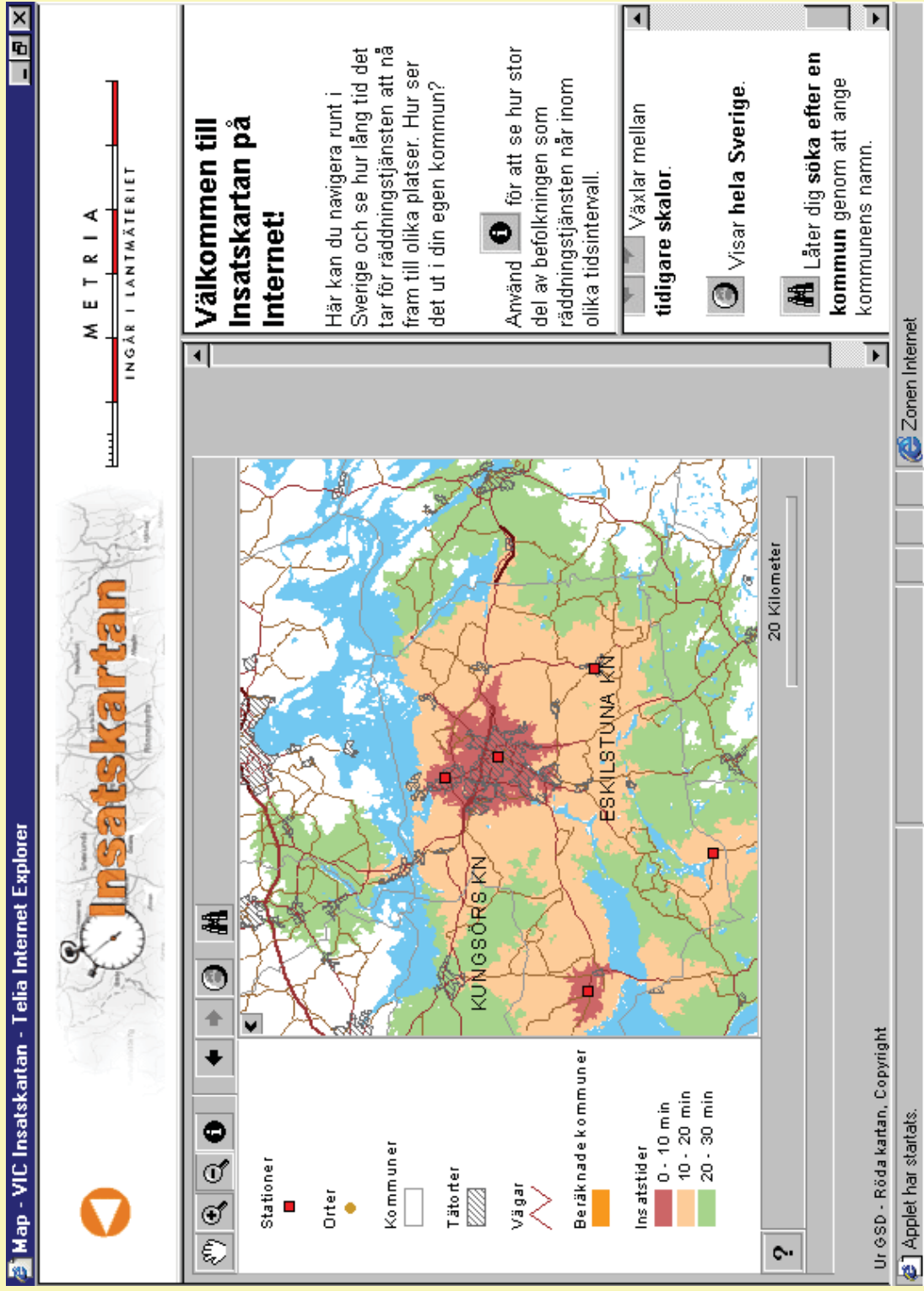
Senior citizens

Zipcode area

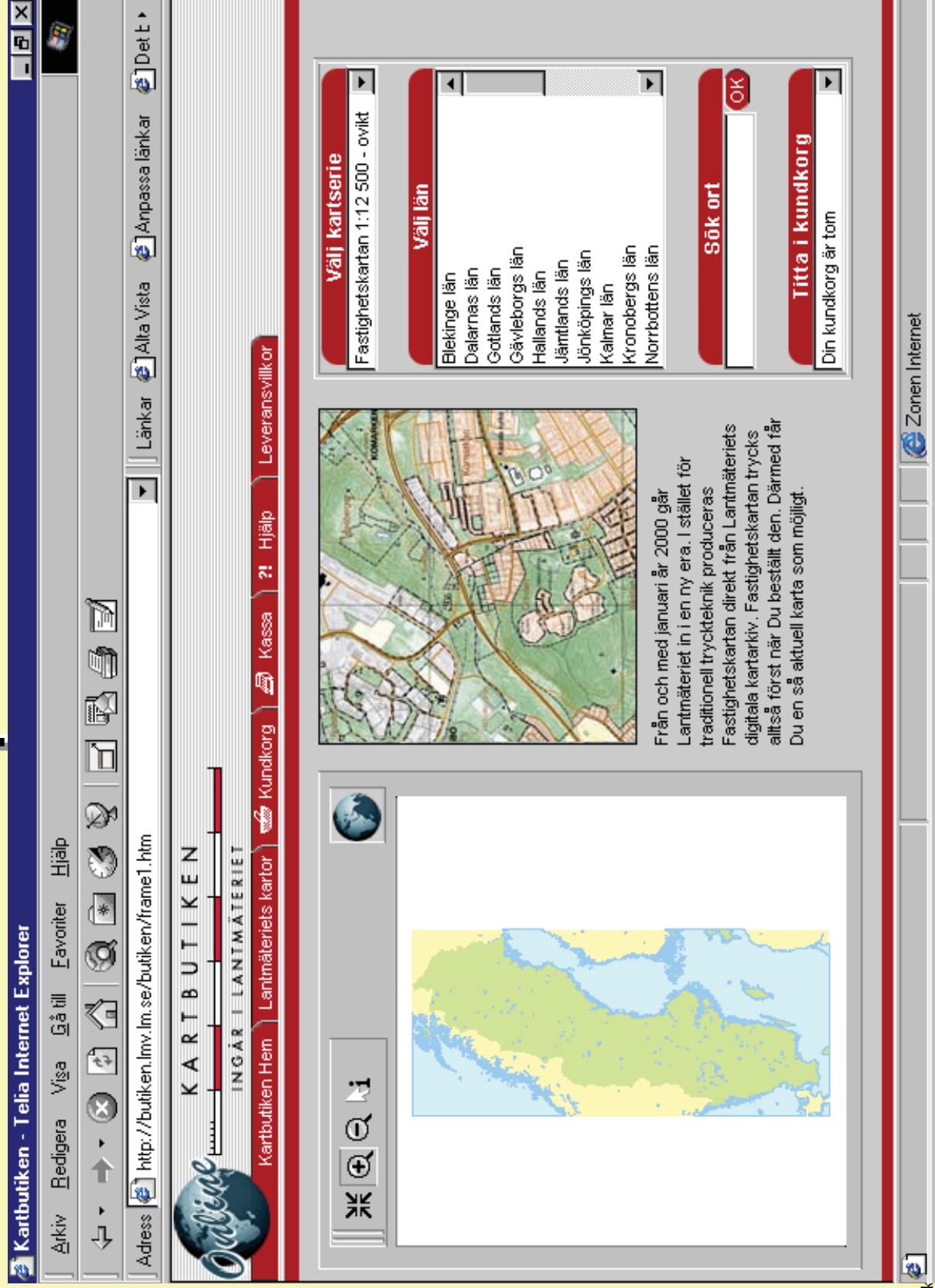


Fire department

Turn-out time



Map Store



Maps on cd-rom



Select a Real property

Taxeringsuppgifter

Index

Fastighet

Adress

Läge, Karta

Areal

Lagfart

Anteckningar

Inteckningar

Inskrivningar

Planer och bestämmelser

Taxeringsuppgifter

Andel i GA/Samf

Åtgärd

Ursprung

Taxeringsenhet

Småhusenhet, helårsbostad för 1-2 familjer (220)

Omfattar hel registerfastighet

Taxeringsvärde

625.000 SEK

Taxerad ägare

450722-0855

Pettersson, Gunnar Palle

Tullgrindsvägen 18

805 96 Gävle

470702-7563

Roeger, Eva Maritha

Tullgrindsvägen 18

805 96 Gävle

Taxeringsvärde

536.000 SEK

Andel

1/2

därrav byggnadsvärde

536.000 SEK

därrav markvärde

89.000 SEK

Juridisk form

Fysisk person

Uppgiftsår

1999

Ägandetyyp

Lagfart

Andel i gemensamhetsanläggnings/samfällighet

Gävle Hillevik GA:1

Åtgärd

Fastighetsrättsliga

Avstyckning

Datum

1989-03-30

Akt

21-89:194

Ursprung

Gävle Hillevik 1:9

LANTMÄTERIET



Gävle Hillevik 3:6

Område: 1

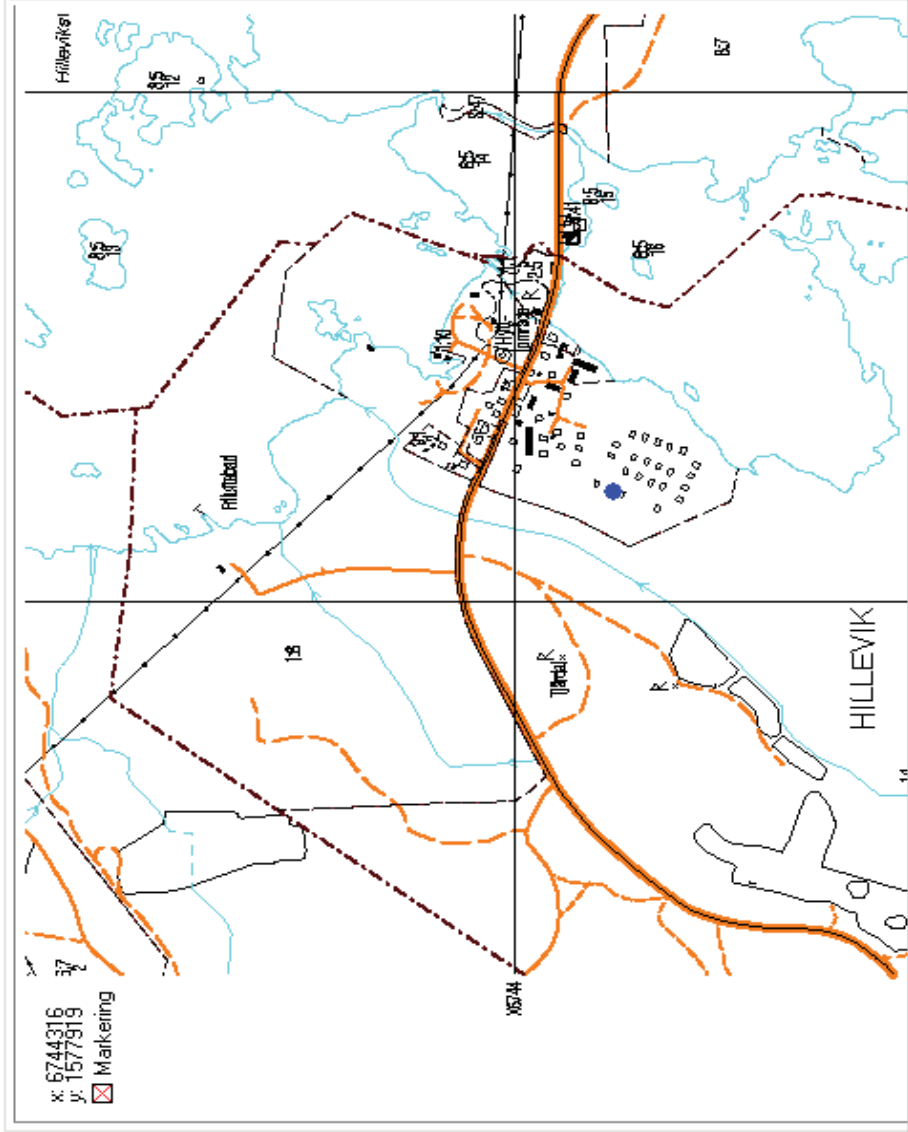
Skala 1:10000

Ändra skala

1:10000

x: 6744316
y: 1577919
☒ Markering

Visa kartan
Utan java



Select a Real property

License fee:

- Connection fee SEK 1 500 (175 €)
- Monthly fee SEK 50 (6 €)
- Transaction fee (per unit):

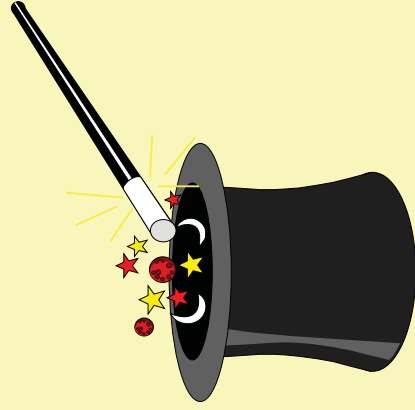
Real property info. SEK 18 (2.1 €)

Map SEK 10 (1.2 €)

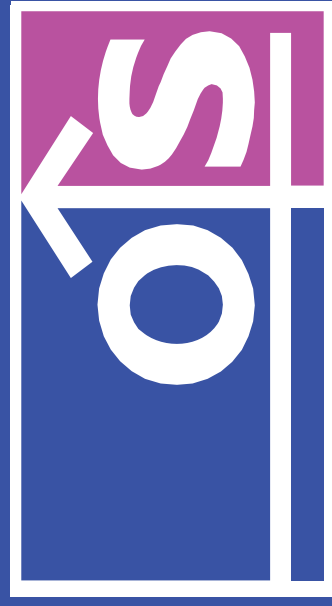


**For more information
visit our web-site**

HTTP:\\www.lm.se

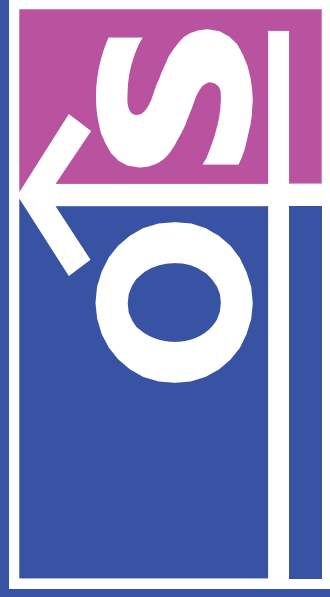


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Ordnance Survey

...linking you to the real world



Ordnance Survey

Ordnance Survey the Internet

Duncan Shiell
Director of Business, Strategy and Finance.

Overview

- UK Government Policy
- Challenges of E-business
- What Ordnance Survey does on the Internet today
- What Ordnance Survey wants to do tomorrow

Electronic Services & Modernising Government

- Forward looking policy making
- More responsive Services to the Citizen
- Quality public services
- Information age government
- Valuing public service



Information Age Government

- “We must modernise the business of government itself - achieving joined up working between different parts of Government and providing new efficient and convenient ways for citizens and business to communicate with government and receive services”

The 25% target

“We are setting a target that within 5 years, one quarter of dealings with Government can be done by a member of the public electronically - through their television, telephone or computer.”

“..we want 80% of central government’s routine purchases to be made electronically by 2002”

Tony Blair 1997 and later

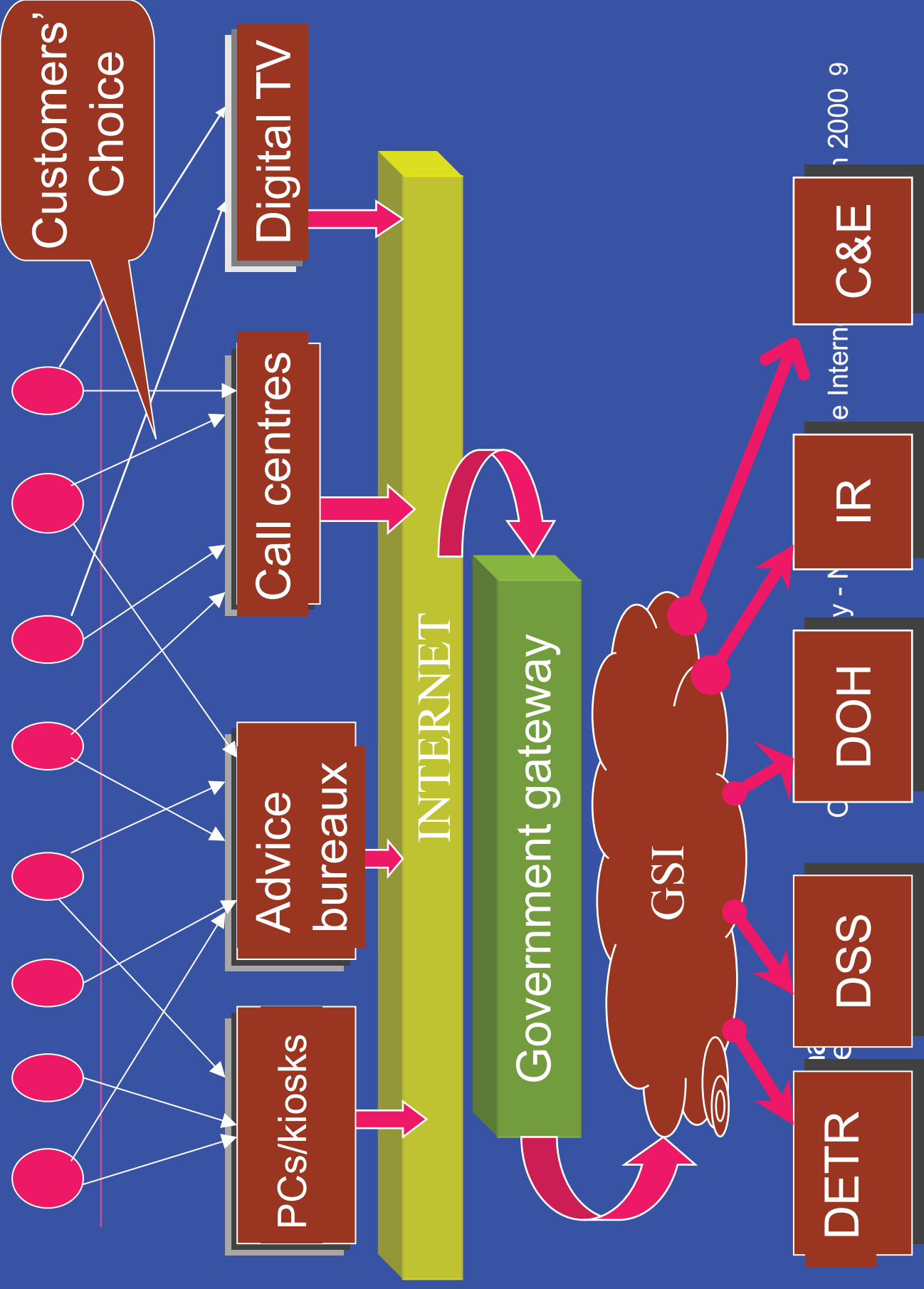
The 100% Target !!

- Electronic Records by 2004
- Achieve *ALL* dealings electronically by 2008

Examples of E-business - Government

- NHS Direct
- Registers Direct
- HMLR Direct Access Service
- 10 Downing Street Web-site
- E-envoy Web-Site
- National Land Use Database (NLUD)
- National Geospatial Data Framework (NGDF)
- Ordnance Survey

Citizens' access to Government services



Some E-Challenges for the future

- Web Site Design
- Call Centres
- Digital Television
- Smart Cards
- Digital Signatures
- Authentication

OS role in the 21st century (1)

- To provide a unique national referencing system for Geospatial information relating to Great Britain;
- To capture and maintain authoritative definition of the topographic features of the landscape - natural and man-made;

OS role in the 21st century (2)

- To associate selected non-topographic attributes and other non-topographic Geospatial information with this topographic information
- To make this information available in an affordable and usable manner to as wide a range of users as possible, but leave to them exactly how they use it

Ordnance Survey view of immediate E-business challenges:

- *customer care* vs simple product delivery
- 7x24 vs 5x7.5
- *new methodologies* vs conservative market
- *increased accessibility* vs higher security risk
- *highly customised products* vs standard offerings
- *customer ‘Pulling’* vs OS ‘Pushing’
- *flexibility* vs legacy systems
- *back-office connectivity* vs disparate processing
- *data warehousing* vs distributed databases

Problem? - What Problem?

TECHNOLOGY IS **NOT** THE DIFFICULT ISSUE

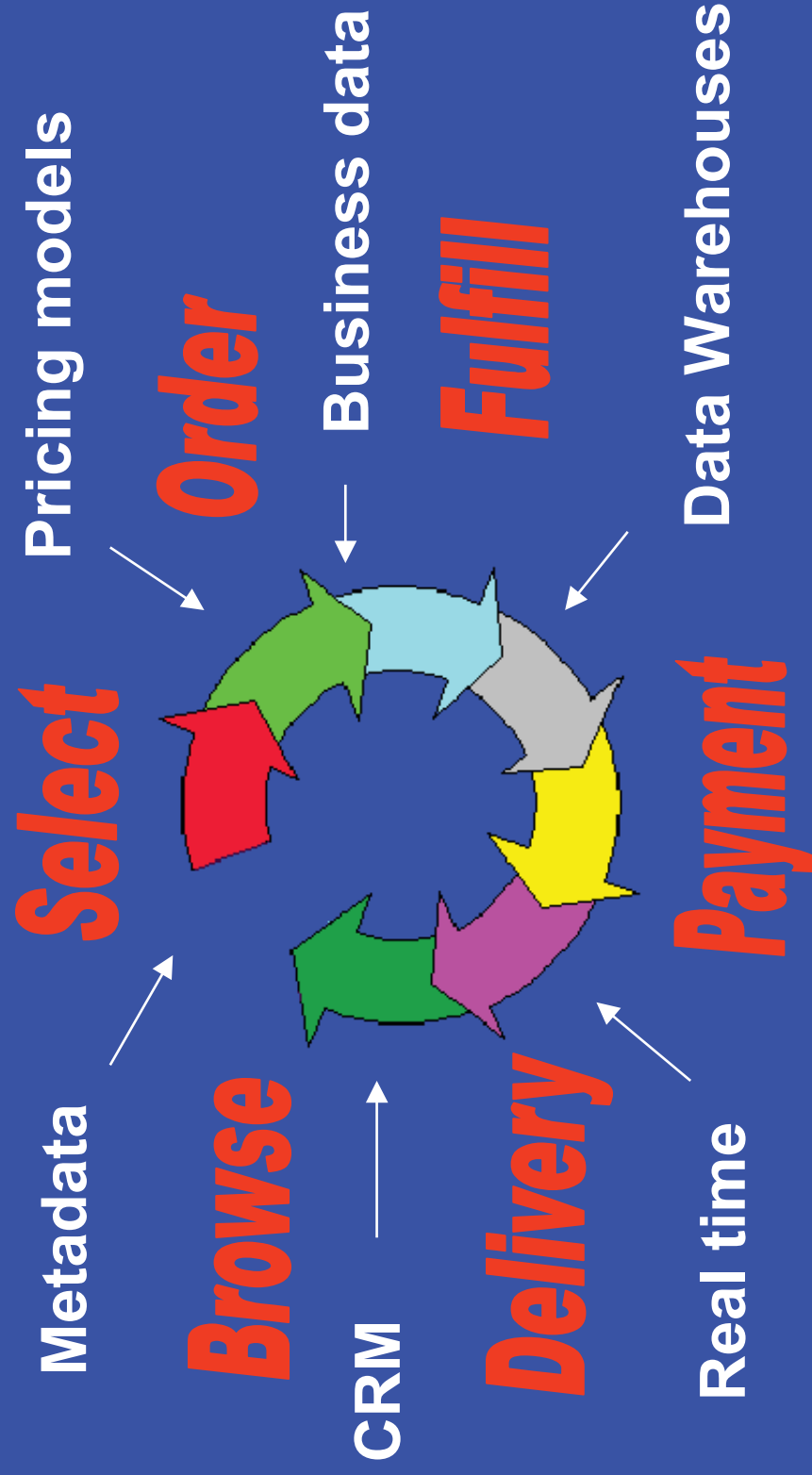
....there are more technical solutions
than there are problems!

THE DIFFICULT ISSUES ARE....

Where does OS stand in the E-market?

- What ‘products’ and to which customers?
- Which Distribution Channels
- Business $\Rightarrow$ B and/or B $\Rightarrow$ Consumer?
- Is OS a retailer or a publisher/wholesaler?
- What is our role in ‘Joined-up Government’?

The business process..



Infrastructure:

- OS world wide web site
 - promotional activities
 - services based on existing products
 - Sample data with viewers
 - database and service development
 - sector-flavoured micro-sites



Ordnance
Survey



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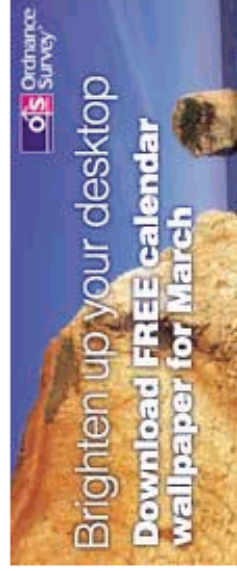
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Ordnance Survey

Welcome to Britain's national mapping agency, the best place to find a diverse and exciting range of mapping products, digital map data and services.



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FREE downloadable mapping for the whole of Great Britain at a variety of scales



Guide to map scales

If map scales have always baffled you then help is at hand!



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Free! Osview

A new version of the newly enhanced software that allows you to view digital map data products



Free wallpaper

Brighten up



Web Site development

- GIS Portal
- Mapping services - free and chargeable
- Greater provision of MetaData
- Two way communication
- Customer tailored sites
- Special interest Micro Sites
- Routine design changes



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Either just click on the map to start browsing, or alternatively, type in a [location name](#), [postcode](#) or [grid reference](#) and then press the Search button to go straight there!

Search for:

Among: ☐ GB Gazetteer ☒ GB Post Codes ☐ Grid Reference

Search

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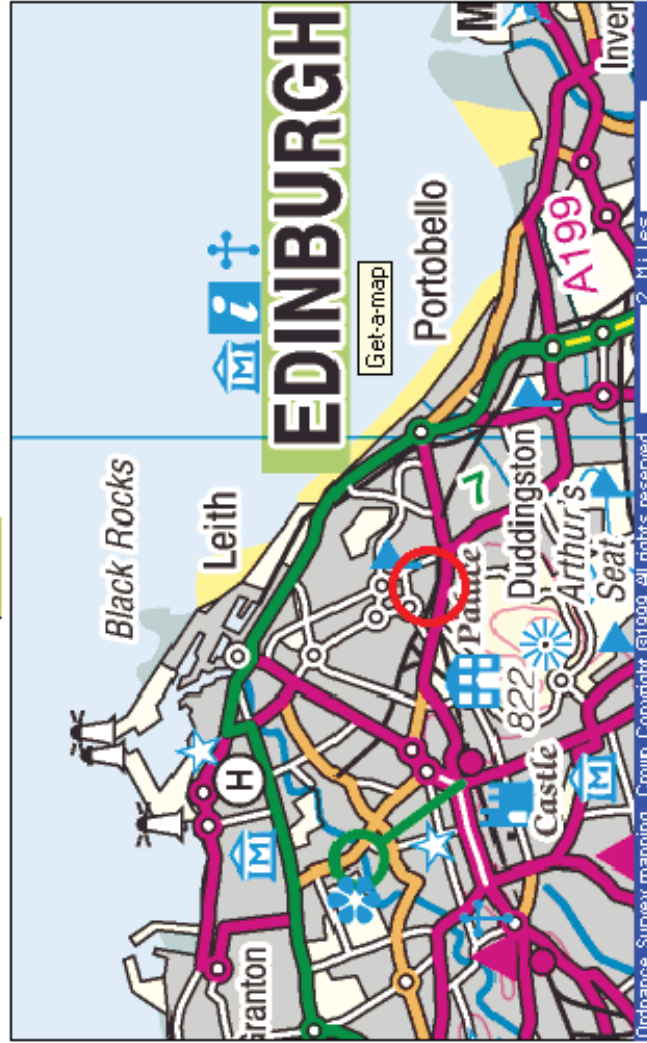
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Map Scale: 70,000

Go

You can zoom into the map by clicking the area you wish to see in more detail or choose

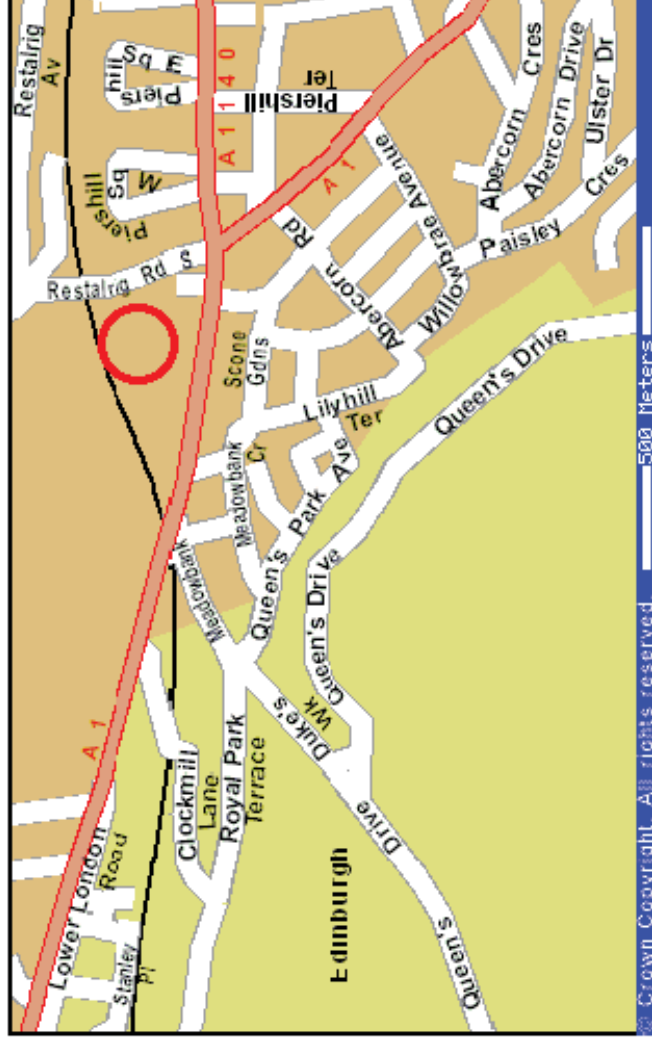
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in Edinburgh - City Centre

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Robertsons Thirty Seven Bar

37 Rose Street, Edinburgh, Midlothian,

Tel: 0131 2256185

[B](#) [S](#)

0 miles

The Basement

Broughton Street, Edinburgh, Midlothian,

Tel: 0131 5570097

[B](#) [S](#)

0 miles

Ferri's Restaurant

1 Antigua Street, Edinburgh, Midlothian, EH1 3NH

Tel: 0131 5565592

[B](#) [N](#) [S](#)

0 miles

St James Oyster Bar

0 miles

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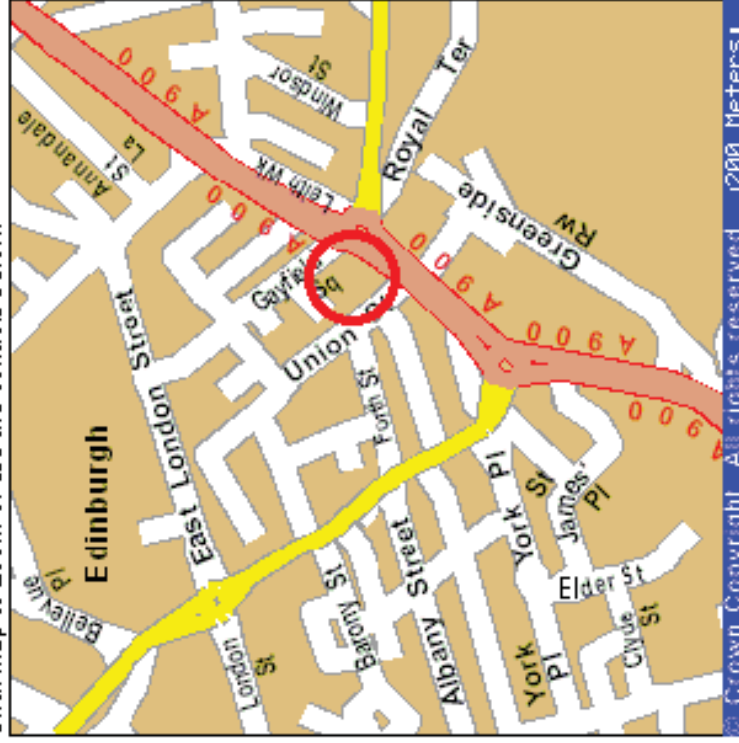
[S](#) SMS

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people finder

Map of EH1 3NH



Click map to zoom or use the controls below.



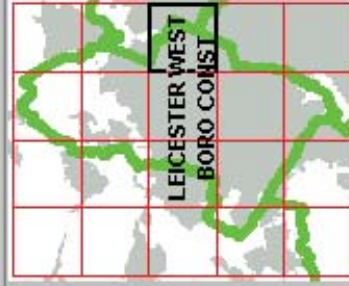
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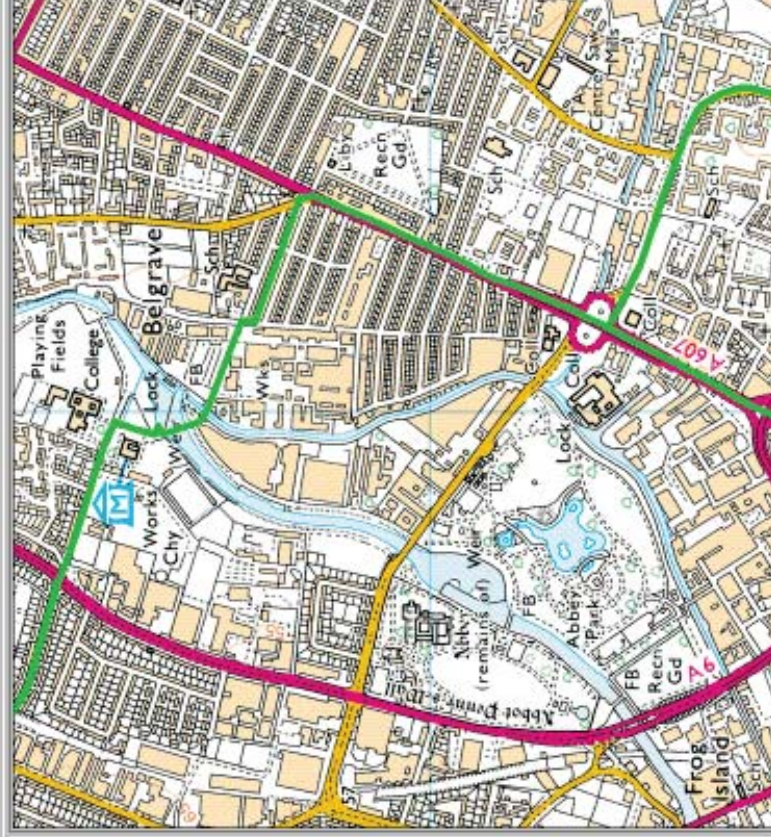


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Leicester West Borough Constituency



Click on the key map above to change the main view area.







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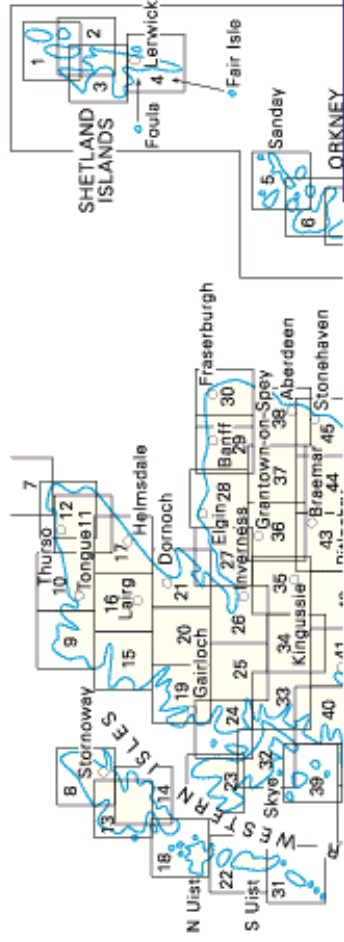


Landranger search

For more detailed information, enter a name and press 'submit' or click on a location

If you enter a name, all names found on Landranger maps *beginning with the letters you typed* will be displayed, along with the sheet numbers they appear on.

Submit



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Landranger sheet details

The search for "Meadowbank" found the following results:

Name	County	Description	Grid Reference	Landranger Sheet(s)	Latitude/Longitude
Meadowbank	Cheshire	City, town, village, etc.	SJ6568	<u>118</u>	53° 12.7' N 2° 31.0' W
Meadowbank	City of Edinburgh	City, town, village, etc.	NT2874	<u>66</u>	55° 57.5' N 3° 8.7' W
Meadowbank	Aberdeenshire	Other feature	NK0947	<u>30</u>	57° 31.1' N 1° 50.5' W
Meadowbank	Aberdeenshire	Other feature	NJ5125	<u>37</u>	57° 19.0' N 2° 48.3' W
Meadowbank	Perth and Kinross	Other feature	NO0014	<u>58</u>	56° 18.8' N 3° 36.5' W

The search returned 5 records

how can we help?



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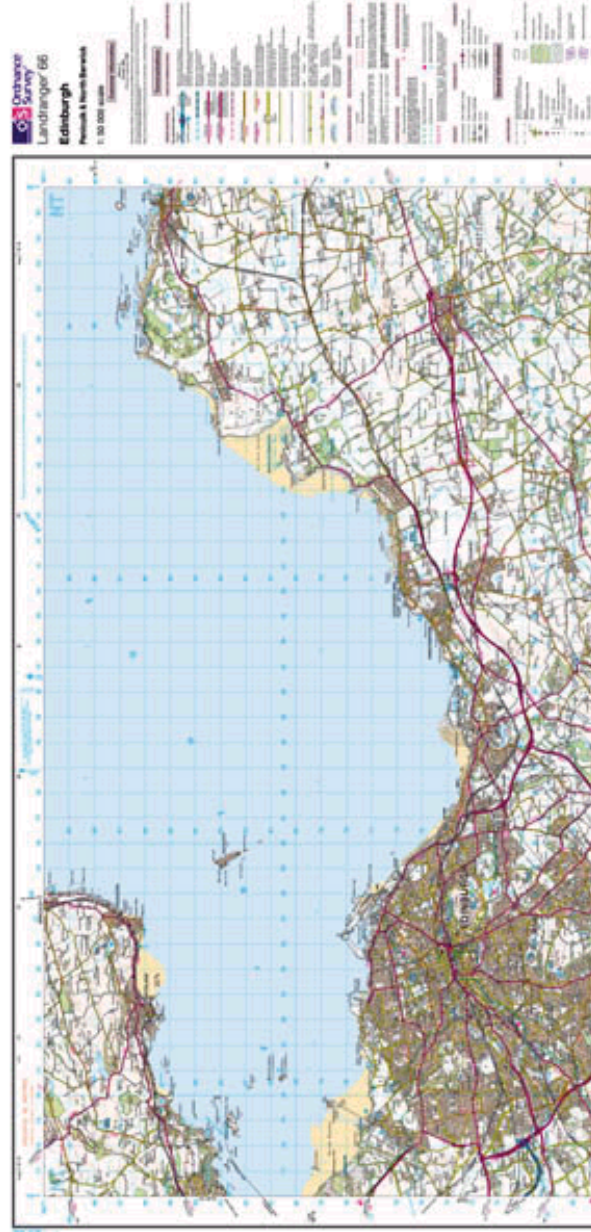
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Welcome



Landranger 66

Edinburgh, Penicuik & North Berwick



how can we help?



Folded ISBN:	0319 224066	£5.25
Flat ISBN:	0319 12407X	£5.25
Copyright Date:	1999	
Release Date:	09/09/1999	
Publication Date:	16/09/1999	
Edition:	C	
New specification title		

On-line ordering

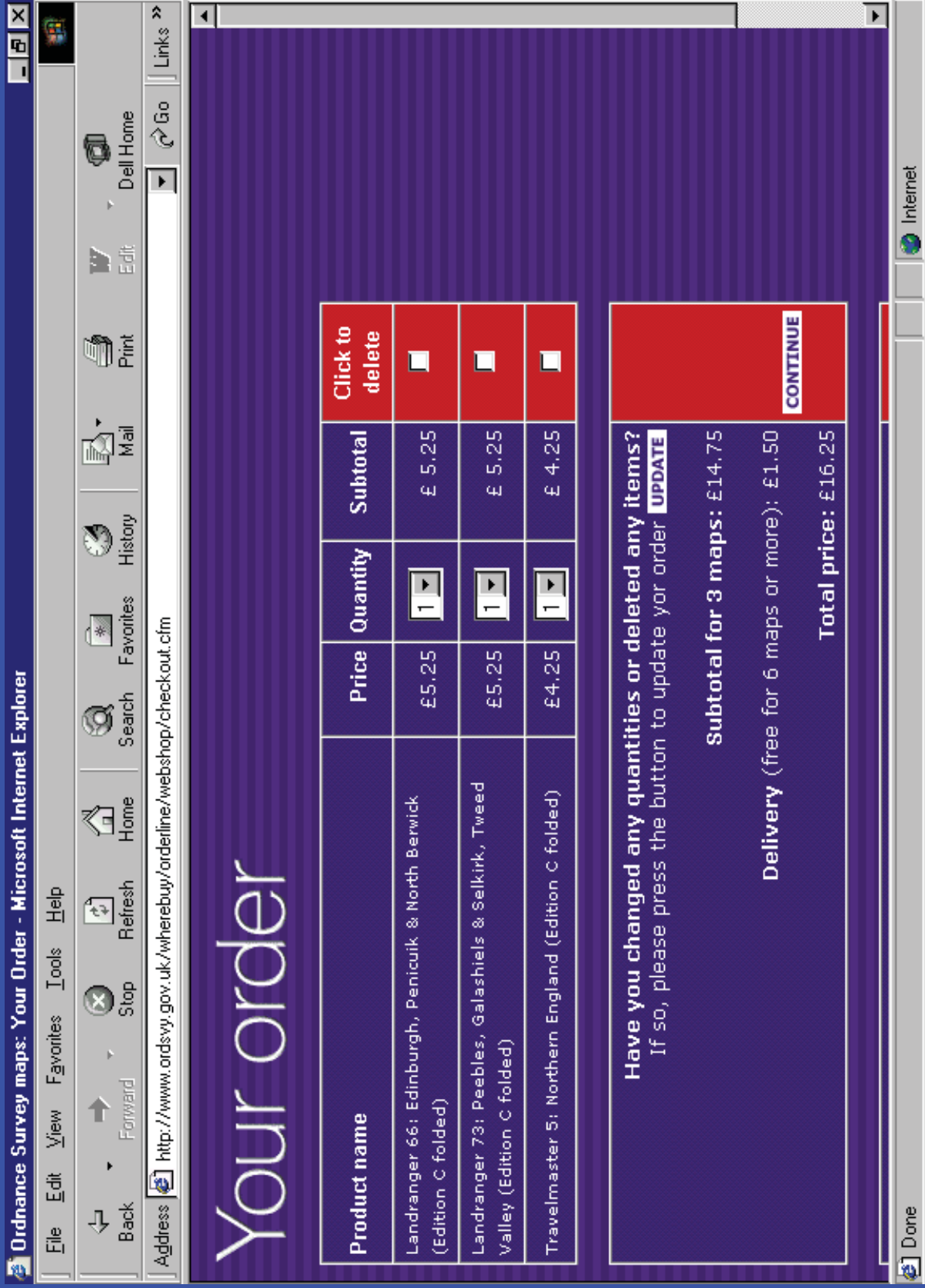
If you want to purchase the above map, click below.
(You can always change your mind later).

Add folded map

No maps are currently selected.

[Click here to see a preview of what the opened out map will look like](#)

[Click here to go to the Landranger search page](#)



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- ☐ Introduction
- ☐ Land-Line applications
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- ☐ Tech zone
- ☐ Price guide
- ☐ Q & A
- ☐ Stop press
- ☐ Order forms
- ☐ OS home page

search site

Looking for something in particular?

Land-Line®



Start view

From this page you can select an area to identify and browse the Land-Line coverage.

If you know exactly your area of interest, fill in the field(s) for **one** of the methods shown beneath the map and hit Next.

Alternatively, for a more detailed view of a particular region, either click on the map to zoom in directly or enter a placename in the box below and hit Next.

Grid Ref. E: 438730
6 figure e.g. -

N: 114790

Postcode: EH8 7AU
e.g. - SO16 4GU

Tile Def:

Next ▶

Place Name Search:

(search our database of over 42,000 Gazetteer entries)

Next ▶

computerised mapping

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search site

Looking for something in particular?

Land-Line®

2.00 km Sq.



Tiles view

This map shows the Land-Line tiles at the location you have chosen. You can use the tools to pan and zoom, but the extent is limited to between 1.25 and 10km.

Hit 'Start Again' to return to opening Tile Selector screen.

Click on a tile to add to list which can be copied and emailed to us.

Key

1:1250 - Urban

1:2500 - Rural

1:10 000 - Moorland

Tile list:

Clear

Annual payment form

Click here to restart from the beginning

computerised mapping

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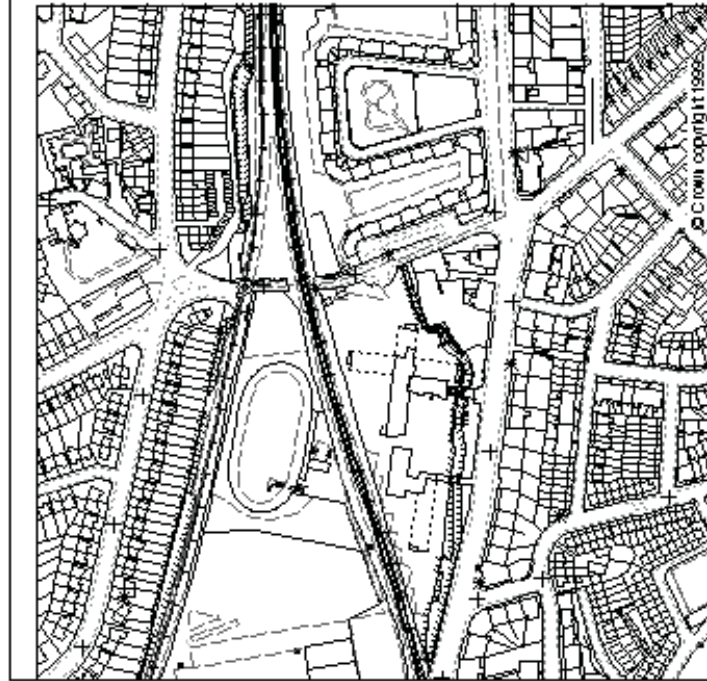
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- ☐ Tile selector
- ☐ Tech zone
- ☐ Price guide
- ☐ Q & A
- ☐ Stop press
- ☐ Order forms
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search site

Looking for something in particular?

Land-Line®

Thumbnail of NT2874SW



Land-Line Plus® thumbnail index

Scale 1:1250

Tile reference NT2874S/6

NTF file #128 0.541 MB

Average DXF file #128 0.670 MB

OS Ordnance Survey

This map shows the extent of the Land-Line tile number shown
computerised mapping

1

Age Group	Percentage
18-24	15%
25-34	20%
35-44	25%
45-54	20%
55-64	15%
65-74	10%
75-84	5%
85+	5%



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☐ Products & Services

- Digital maps

- Introduction
- Land-Line
- Meridian
- Strategic
- BaseData.GB
- Boundary-Line
- SABE
- ED-LINE
- Land-Form PANORAMA
- Land-Form PROFILE
- OSCAR Asset-Manager
- OSCAR Traffic-Manager
- OSCAR Route-Manager
- OSCAR Network-Manager

Welcome

Ordnance Survey

Welcome to Britain's national mapping agency, the best place to find a diverse and exciting range of mapping products, digital map data and services.

Brighten up your desktop
Download FREE calendar
wallpaper for March

**How to find
your National
Grid reference**

Find the right map

Europe

how can we help?

Leisure map line

Phone
0845 200 2712
Click here for more
information

Get-a-map

FREE downloadable mapping for the whole of Great Britain at a variety of scales

Guide to map scales

If map scales have always baffled you then help is at hand!

Free GB maps

Download small
scale maps of



Click here for our Homepage

☐ Introduction

☐ Products

☐ Events

☐ National

☐ Scotland

☐ North East

☐ Midlands

☐ Eastern

☐ Home Counties

☐ South East

☐ Kent

☐ Hampshire

☐ East Sussex

☐ West Sussex

☐ South West

☐ Contacts

☐ OS Homepage

search
site

Looking for something in particular?

Cycling event forum

CTC East Sussex

Midweek Section - Saturday Ride

09 Oct, 1999 : 10:30 AM

Start Middle Farm Tea Room, Firle

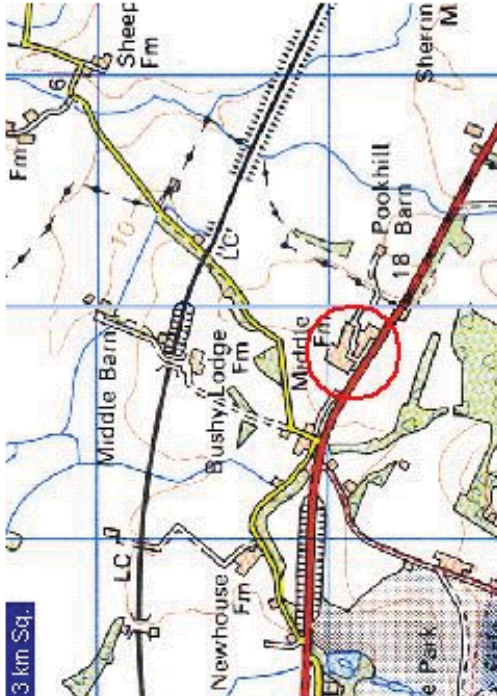
Contact Leader: Ray Gearing (01323) 486887

Map Landrangers 198 - Brighton & 199 - Eastbourne

Reasonably paced ride through the lanes with lunch at the "Laughing Fish", Isfield.

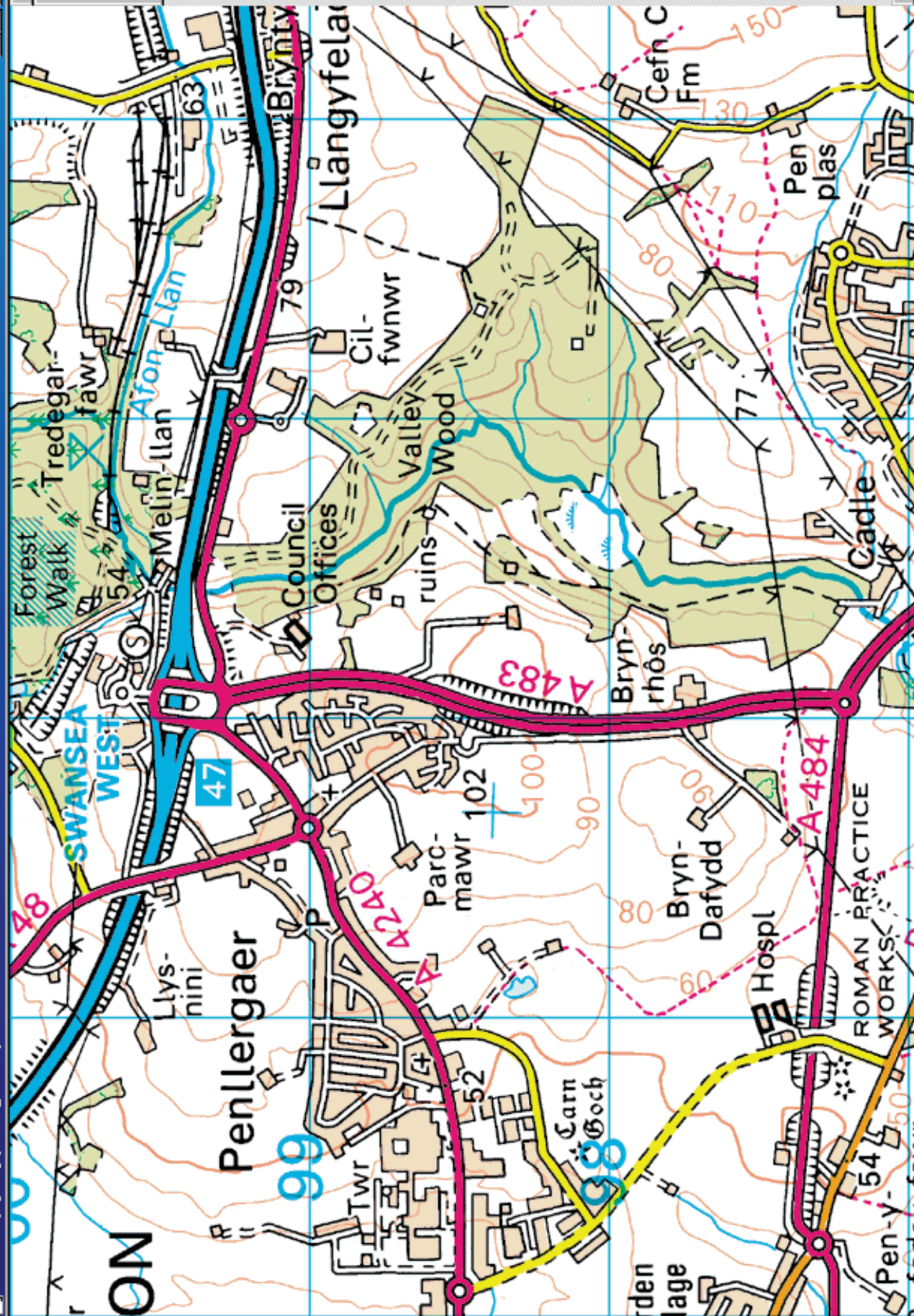
Grid reference : TQ488079

3 km Sq.

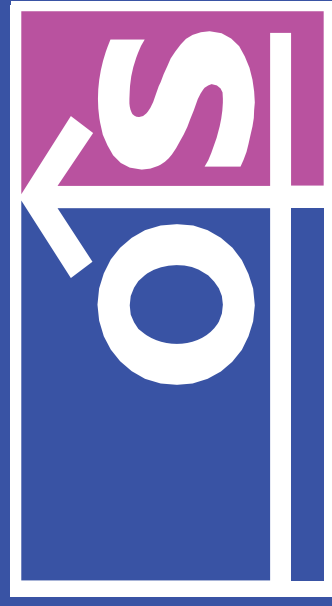


how can we help?

Ss68.bmp [1:1] (Background)







Ordnance Survey

...linking you to the real world

Back to Content Presentations

IGN-France and the Internet

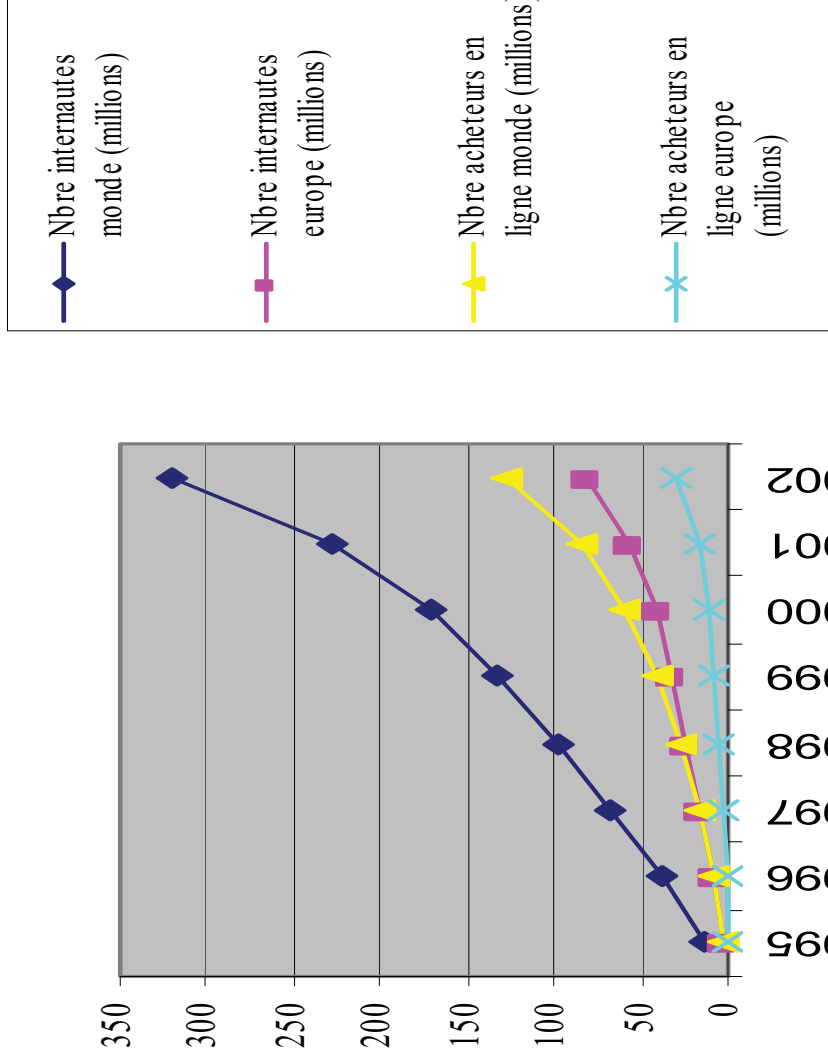
François Salgé

Director of International and
European Activities

François.salge@ign.fr

Internet & e-commerce Current World Market

Nbre d'internautes et d'acheteurs en ligne



1998 : 3 millions sites

350 millions pages

1999 : 7 millions sites

600 millions pages

Internet & e-commerce Current World Market

1998

- ➔ 28 millions buyers
- ➔ 30 billions €

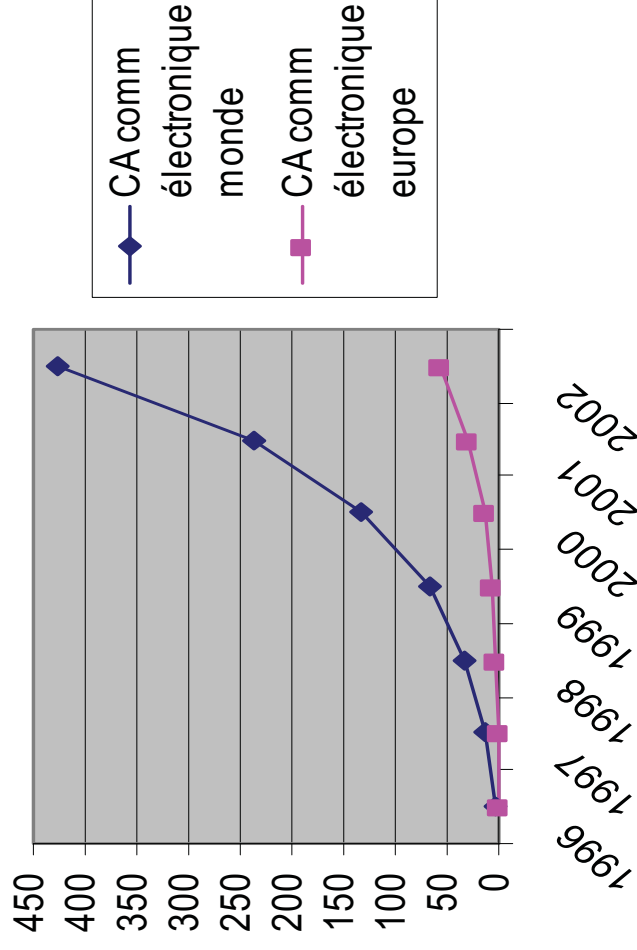
1999

- ➔ 42 millions buyers
- ➔ 70 billions €

forecast 2000

- ➔ 59 millions buyers
- ➔ 140 billions €

CA commerce électronique en Mds
dollars



Internet & e-commerce current French market

- ➡ High increase of Internet accesses :
4 millions Internauts end 99, 10 millions end 2000
- ➡ Market share :
 - 😊 1 to 2 % of the world Internet
 - 😊 0,5% of World e-commerce
- ➡ Who are the Internauts :
 - 😊 high social and organisational group, male, urban
 - 😊 mean connection time : 7,5 hours per week
- ➡ major barrier to purchasing: Transaction security

Internet & e-commerce

Legal context

Unsuited but about to be adequate:

- ➡ directive on legal aspects (evidence of legal acts ...)
- ➡ European directive on custom fares
- ➡ Electronic signature
- ➡ Personal data protection
- ➡ Legal protection on data

Internet & e-commerce

Païement et sécurité

Payment mechanisms: secured payments:

➡ off line

➡ SSL encoding

➡ on line with credit
cards

➡ SET protocol

(CyberComm solution)

➡ on line with

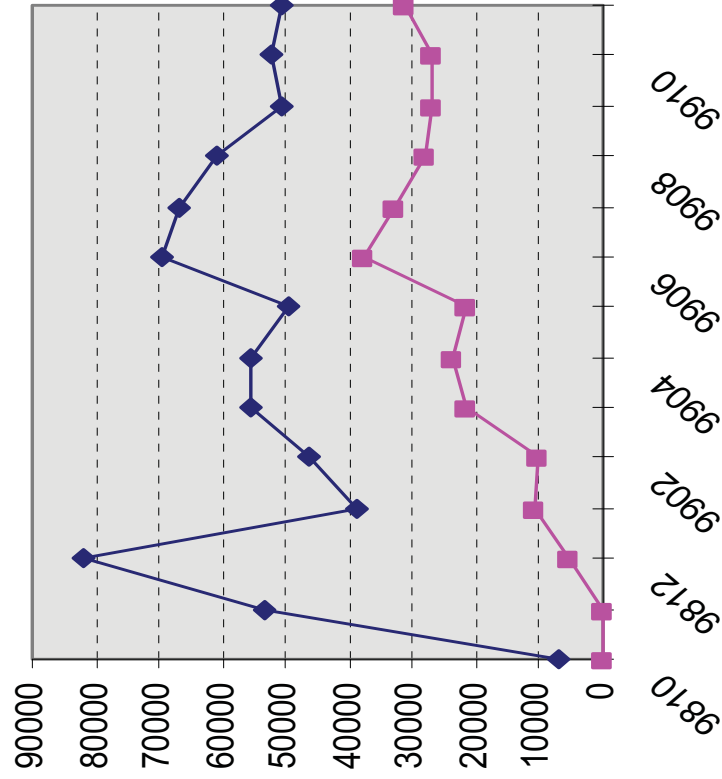
electronic money

IGN & e-commerce Current status

- ➡ shops: photos & maps since 98
- ➡ a kind of mail order selling
- ➡ « remote selling » for bank transactions
- ➡ Internal solving of dysfunctions
- ➡ Site visits (per month in average):
 - ➡ 37500 visitors
 - ➡ 300 000 pages
 - ➡ General public pages: 72% of visitors
 - ➡ professional pages : 16% of visitors

IGN & e-commerce Selling Analysis

CA mensuel HT France



François Salgé, janvier 1999

⇒ Yearly turnover France:

😊 maps : 30 KF

😊 photos : 50 KF

⇒ yearly turnover Export:

😊 maps : 6 KF

😊 photos : 4 KF

⇒ step by step growth

IGN & e-commerce Order analysis

France (92% des commandes)

	Cartes	Photos
Nbre moyen de commandes / mois	205	153
Nbre moyen d'articles / commande	2,5	1,7
Panier moyen	113 FHT	370 FHT

➡ Sold Products :

- 😊 maps : 60% SB, TOP25 et SO
- 😊 photos : 57% contacts
21% 50*50

➡ Buyers :

- 😊 32% Paris
- 😊 90% GP, 10% Pro

➡ buying rate : 1%

IGN & e-commerce Profit Analysis

- ➡ Profitable shops
- ➡ Margin on variable costs
 - 😊 84% maps
 - 😊 62% photos

Internet & e-commerce Trends in GI sites

- ⇒ More and more sites
- ⇒ From communication/cataloguing towards selling/distribution
- ⇒ Servicing the General Public free of charge and charged
- ⇒ Servicing professionals by subscription

IGN & e-commerce New Strategy

⇒ Side channel strategy

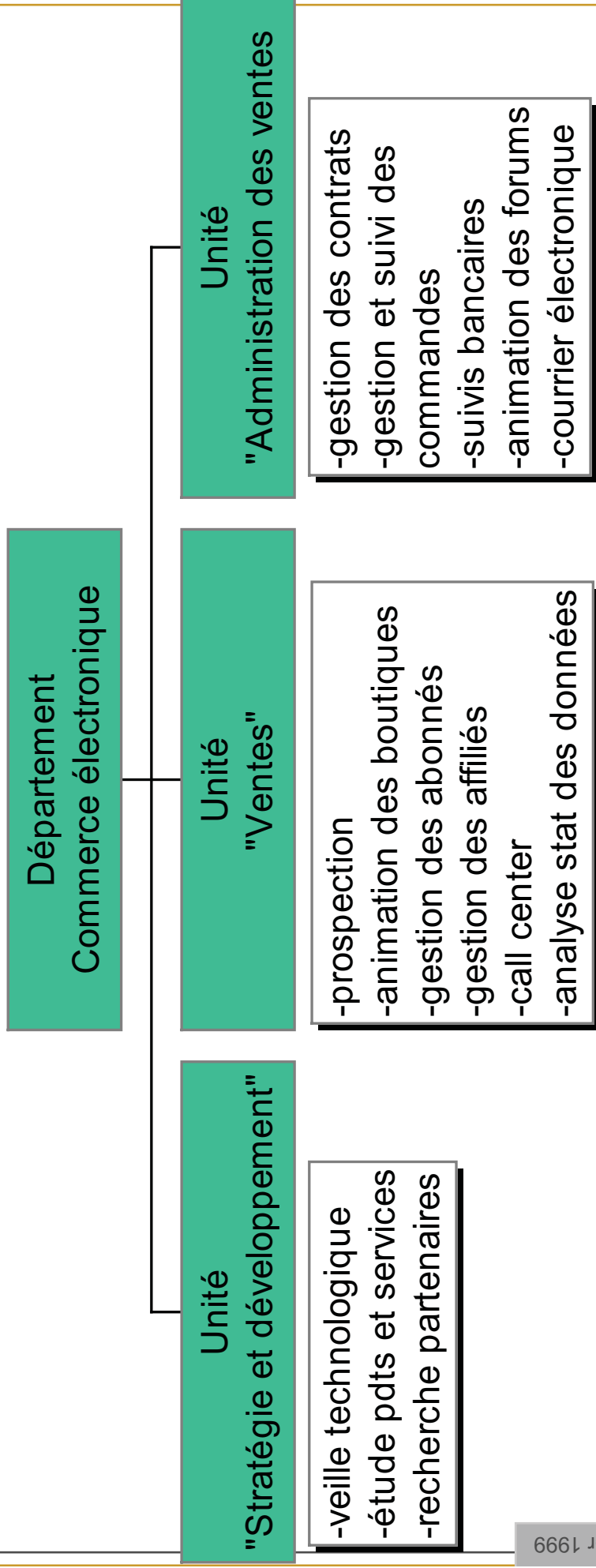
coupled with

⇒ taking advantage of digital strategy

IGN & e-commerce Next Actions

Very Short term	Short term	later
Improve shops	Improve visualisation	Subscription to updates
Improve Professional (metadata & test zones)	"Digital data" shop	On line services (Traffic planning/Environnement)
Minitel migration, online coordinate transf)	Online location service	
User forum	Call center (télconseil)	Geocoding Service picto positionning
Multilingual	Network of affiliated companies	Électronic shaded maps
mkg/comm/SAV	Qualification tools	Services on 25k (route picturing, picto...)

IGN & e-commerce New Organisation



<http://www.ign.fr>

Back to Content Presentations

National Mapping Agencies and the Internet: a view from a software company

Vanessa Lawrence
GIS Solutions Division
March 10th, 2000
Contact: vanessa.lawrence@eur.autodesk.com

The Web is changing everything

The winners will be:

- ⌘ Big versus small
- ⌘ Fast versus slow

Fail fast...reinvent...and get going again!!

A digital world

- ⌘ All devices are becoming digital
- ⌘ All information is becoming digital
- ⌘ A world information architecture

The world is:

- A connected world
- A world of standards
- A wireless world

The speed of information

- # Mobile phones:
 - Download speed in 2000: 9.6 kb/sec
 - Download speed in 2002: 115 kb/sec
 - Download speed in 2003: 2000 kb/sec
 - This is a special moment in history...embrace it or you will fail!

The web is changing everything

It is moving the geospatial industry customer from workflow automation to supply chain integration

Workflow automation

- # Automated mapping
- # Facilities management
- # Integration with operational systems such as work management systems and customer information systems

Supply chain integration

- # Customers are worried about **more** than maps
- # They want:
 - Automated build of materials and work scheduling generation
 - Online access to manufacturer's facility database
 - Purchasing and bidding online
 - Scheduling of work crews
- # But...location data is still vital to them

New strategic alliances

- ⌘ Old alliances: RDBMS and ERP companies
 - SAP, Oracle
- ⌘ New alliances: e-Commerce
 - e.g. Ariba and Commerce One

New players in the market

- ⌘ Traditional players
 - ESRI
 - Intergraph
 - Smallworld
 - Laserscan
 - Autodesk
 - MapInfo
- ⌘ Post-GIS era (*now!!*)
 - Mapquest
 - QMSOft
 - Object FX
 - Formida
 - Ilog
 - Symbian
 - Microsoft

New players in the market

- # Unfettered by legacy compatibility issues
- # By the 'old-GIS' mindset
- # Requires to access data on demand rather than from information silos
- # Aggressive
- # Energetic
- # Innovative
- # Blatant disregard for data quality

Be creative - reinvent yourself everyday!

Chief operating officer's directives

- # Deployable in 15 weeks or less
- # Plug & Play with legacy systems
- # Component-based architecture
- # Browser-based
- # Standard operating environment

COO, Telstra, a huge telecom company

Are we the glue?

If we are...we are likely to be a very rich glue if we get it right

e-commerce: in 1999 consumers spent \$8bn by surfing the web. Business to business sales for 1998 were \$43bn. By 2003, this figure is expected to be \$1.3trillion (Forrester Researcher, Cambridge MA, 1999)

Customer relationship management: CRM helps companies find and retain the most valuable customers via the web. CRM is expected to grow to \$11.5bn by 2002 (AMR Research, Boston, MA, Dec 1998)

Enterprise resource planning: ERP integrate the business processes and systems of a company

Supply chain management: deliver the right products to the right place at the right time. This market is expected to triple by 2001 (Rick Ruiz, director of marketing, IBM, Jan 1999)

Business intelligence: data mining helps many companies leverage on-line data for better decisions. This market will be worth \$1.13bn by 2002 (Palo Alto Management Group, August 1998)

The web of business applications presents an enormous opportunity for spatial data applications

Trends...

Graph showing B2B is a significantly greater opportunity than B2C

National Mapping Agencies and the Internet

- # Future business to business applications... this must be the opportunity?
- # Position yourselves as a part of the 'content' business of the new information economy
- # Become the industry-specific content provider of choice for geospatial-based data for ASP's and all portals

What does the Internet revolution mean to you as NMA's

How will people use your data

- # **Scenario 1:** I am an engineer for a local authority and I wish to edit my dataset as I am installing new cabling to the traffic lights in Acacia Avenue

How will people use your data

- # **Scenario 2:** I am shopping in Reading and wish to find the nearest bus stop. I scroll down to the bus stop on my WAP phone and up comes the location map and also voice directions. I am told what time is the next bus and whether the bus is full. It could also ask you where you want to get off it so that it could assess capacity

The Future....

- # Well..maybe it is the present...
- # Is everything I have talked about too far away to worry about....

NewMoon hosting services and AltaVista

- # Application Service Provision (ASP) is the future for software and data delivery
- # It will prevent data silos; data will always be the latest update
- # Provide users with the latest released software
- # Allows users to try out new features before buying their own copies from an e-store
- # Allows users to meet the changing demands of the workplace particularly when project work demands increased work shifts; also prevents unrecoverable software costs hitting the bottom line

New moon hosting services and AltaVista

- # Collaboration operational between Autodesk, NewMoon.com, AltaVista
- # Access AutoCAD 2000 anytime and anywhere. A field engineer can do design work on the fly via a web-browser over the Internet
- # Central management and web-based rentals
- # Gives them the most up to date version of AutoCAD 2000
- # *It is a first for us all; centrepiece of AltaVista's new technology channel*

Online GIS data in the palm of your hand

Need for mobile solutions

- # Access existing data in the enterprise database in the field
- # Up-to-date information on-site
 - Better decisions
 - Lower costs
 - Increase safety
 - 'Bite-sized' data
 - Fast database updates

The technology challenge

- # Handheld devices
 - multiple platforms
- # Small footprint -
 - 2Mb (application and data !)
- # Ability to access enterprise data -
 - Gb data volumes common
- # Low / unreliable bandwidth
 - 9600 bps at best...

The technology choice

- # Porting the existing current browser technology to the PDA
 - big footprint
 - Poor bandwidth
 - Does not fit use cases

The technology choice

- # Clip, download, view, update, upload!

Online GIS data in the palm of your hand

- # Access enterprise server spatial data using Maui viewer
- # Synchronise with Enterprise database using Oracle 8i spatial lite

Online GIS data in the palm of your hand

- # Maui Viewer
 - Raster/Vector data
 - Pan and Zoom
 - Tooltips
 - Redline
 - Attach notes to features

Online GIS data in the palm of your hand - field update

- # Oahu application
 - re-synchronise data

Chief Surveyor General of South Africa

Example taken from the www.csg.co.za or reached via a link in www.cf.co.za

So how does an NMA need to change to face the Internet

- # NMAs need to become national archives for the geo-spatial framework. NMAs should concentrate on the specification, assembly and quality assurance of the core geo-spatial data. This does imply that you will become the archive for other information not created by you!
- # The national archive is updated daily
- # The NMAs need to stop owning the channels for their information
- # The NMAs need to promote that the **ARE** the content providers for anyone wishing to use a map or other geospatial data within their business

How do NMAs make a financial return with this model

- # Once you are the content provider of choice then income will be derived from many sources unimaginable today.
- # These will include resellers and republishers of information who have mirror servers or who wish to bulk-break the information
 - who value-add the data
 - act as an ASP
 - sell to portal services

What will happen IF you choose not to embrace the Internet

- # Your business will remain important to traditional clients **until** new competitors move into your area of expertise
- # Your brand name will reduce in quality
- # Your business will be marginalised

Back to Content Presentations



National Mapping Agencies and the Internet – A Vendor *Perspective...*

Peter Beaumont

Business Solution Manager

ESRI (UK) Ltd



Presentation Structure

- **Vision**
- **Market trends**
- **Case Studies**
- **Directions for NMAs**



A Vision... Emerging Trends in IT

How have Spatial Systems reacted?

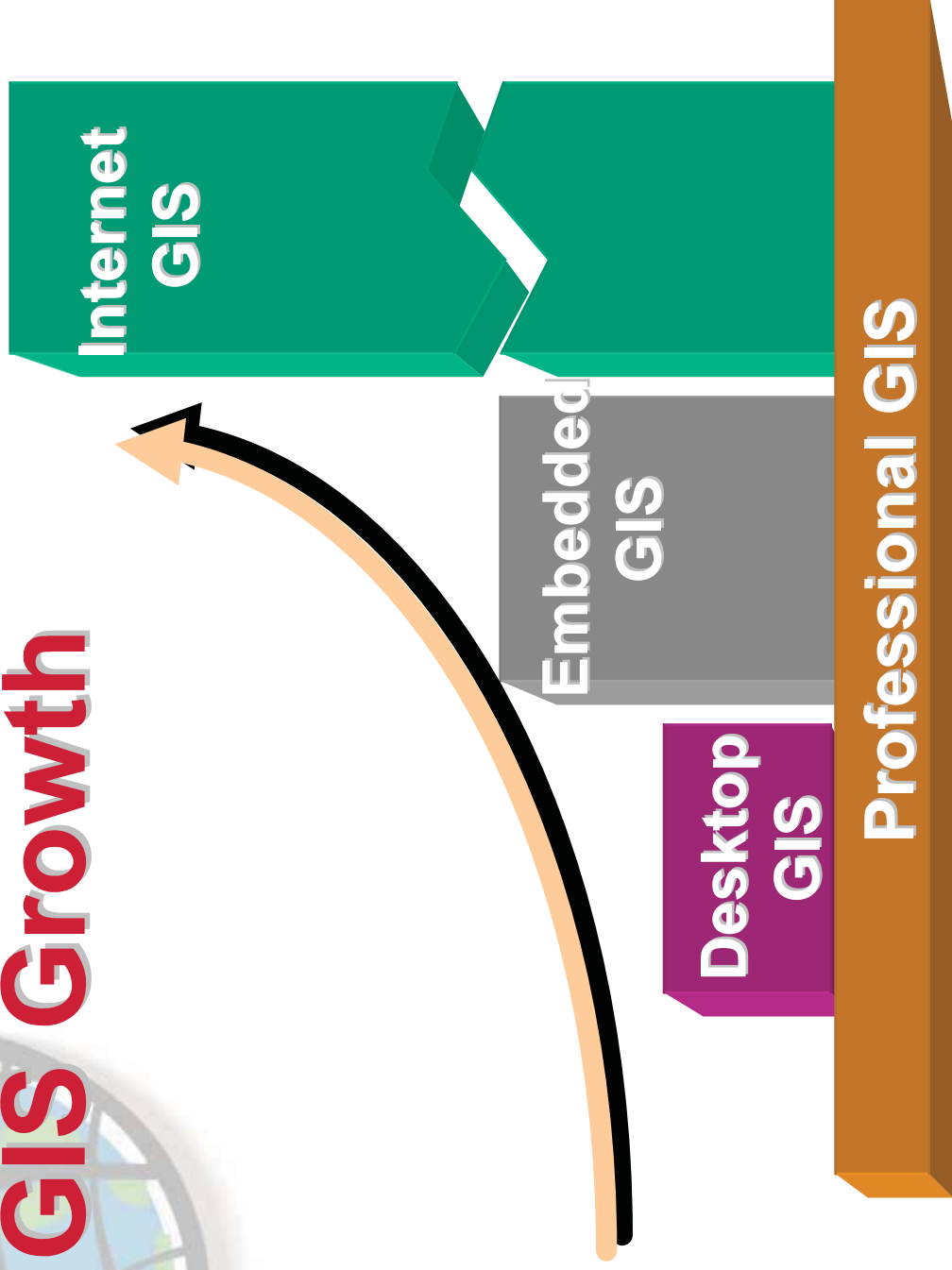


History – The Barriers to GIS Implementation

- **Difficulty integrating GIS with mainstream IT applications**
 - Lack of open API's
 - Proprietary data stores
 - Proprietary file formats
 - Seen as departmental – political barriers, limited IT 'buy-in'
 - Expensive software, hardware, data, staff
 - Perceived as technical rather than integral business solution



GIS Growth



The Foundation Is Important

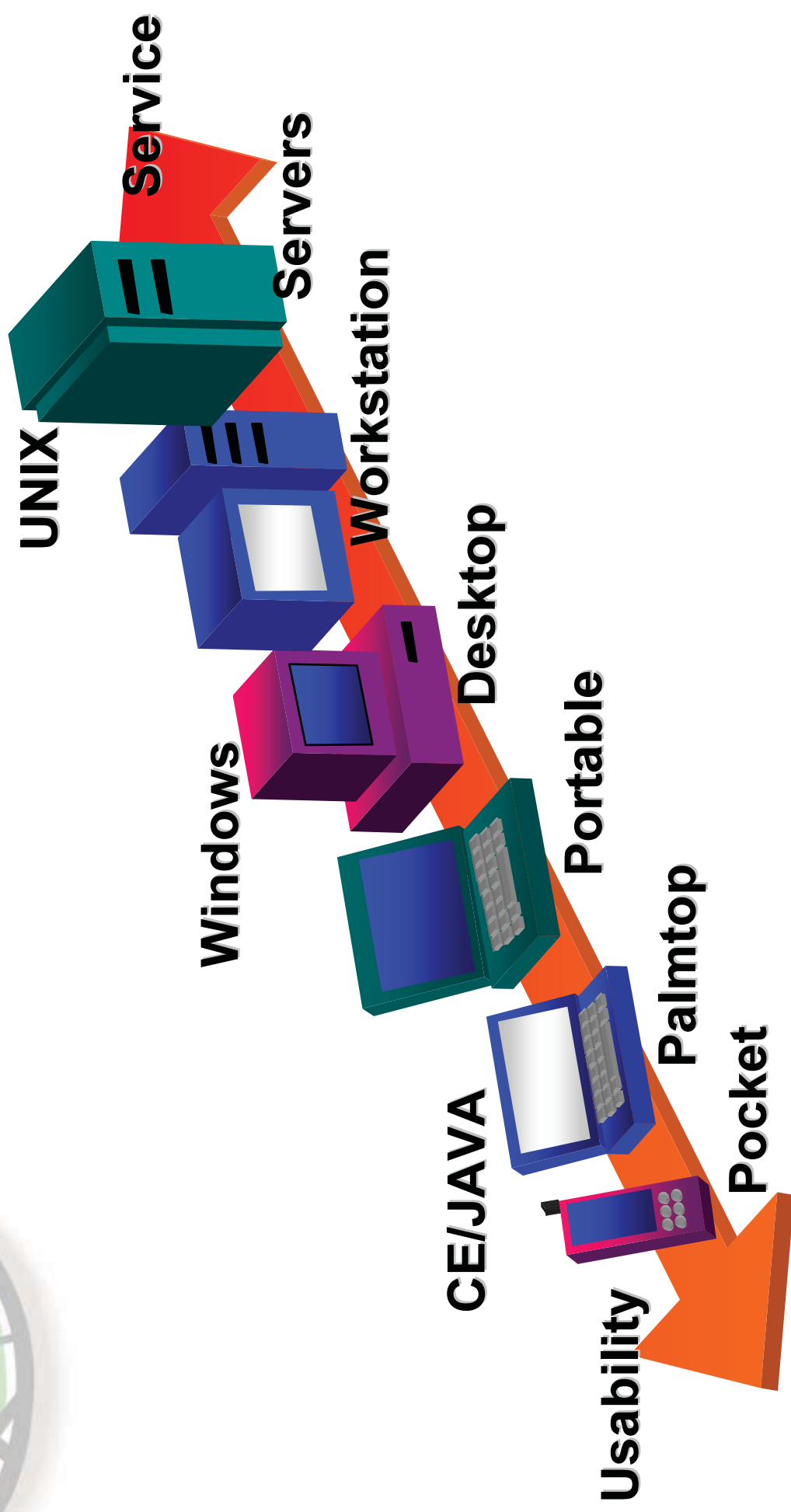


Computers Will Be Faster, Smaller and More Affordable

*What's Not Possible Today Will Be
Possible in the Future*



Scalable Computing

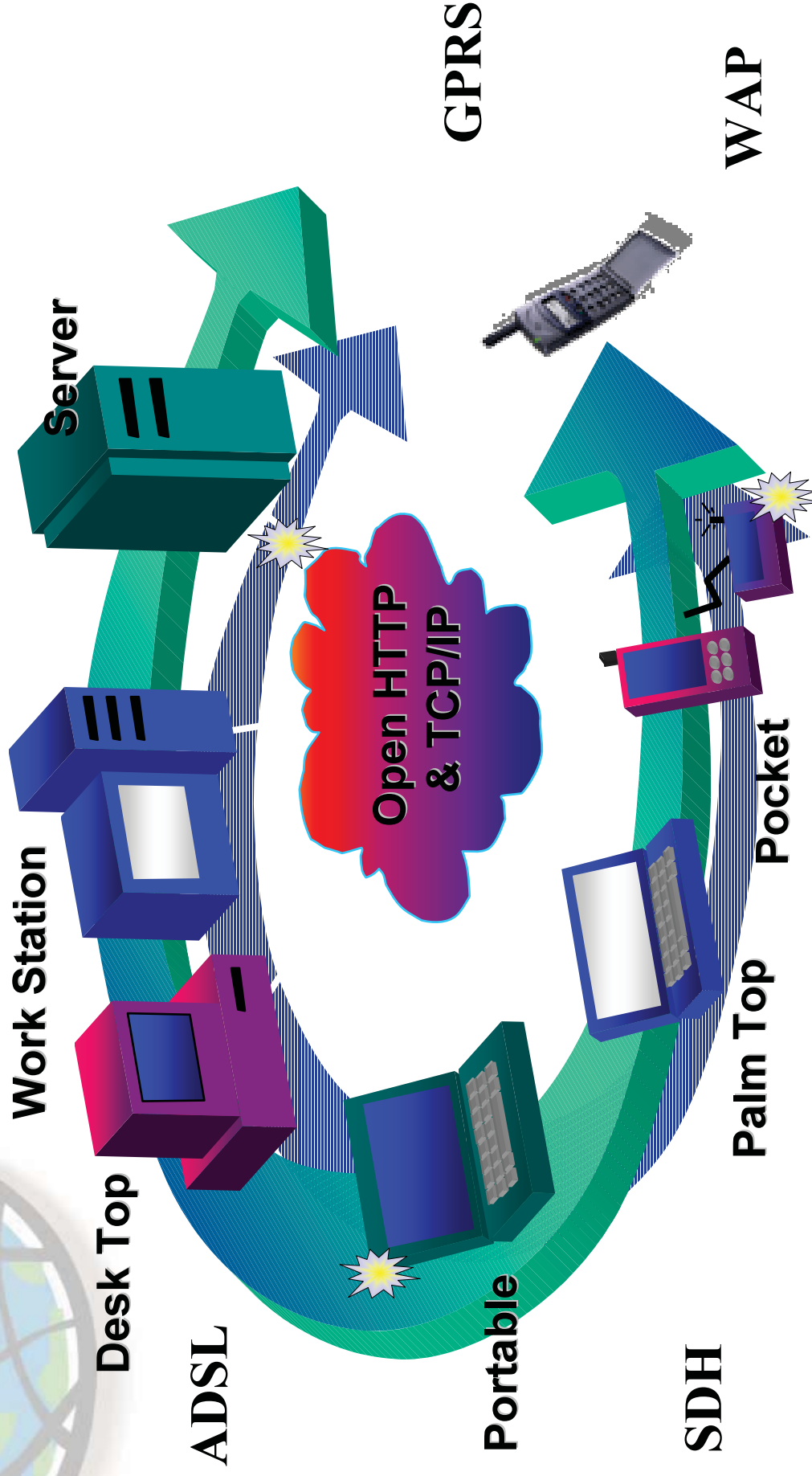




GIS Software and Data Are Being Distributed on Networks

The Reality of Networked GIS

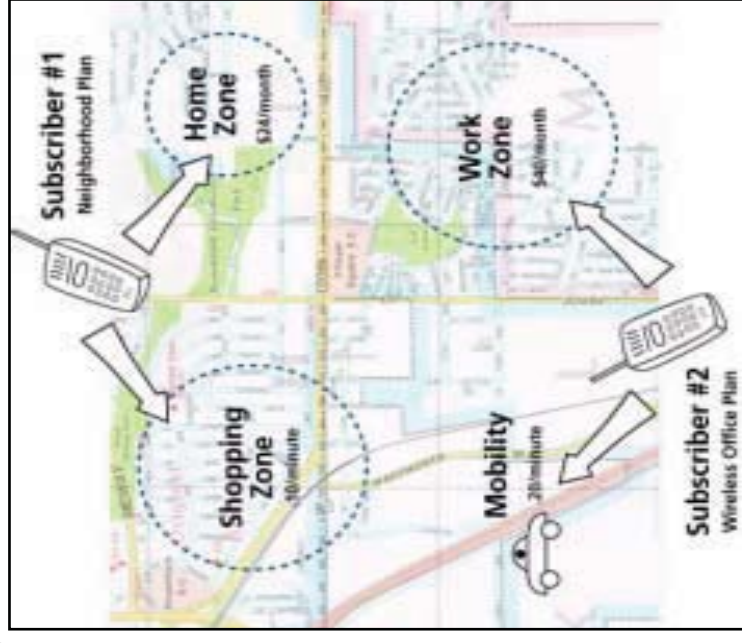
Computers are Scaleable and Networked



GIS Software and Data Are Being Distributed on Networks

“Wireless” Communication Will Dominate

- x,y Locations now
- GPS Enabled by 2002
- Wireless Location Services
- Wireless Information Devices



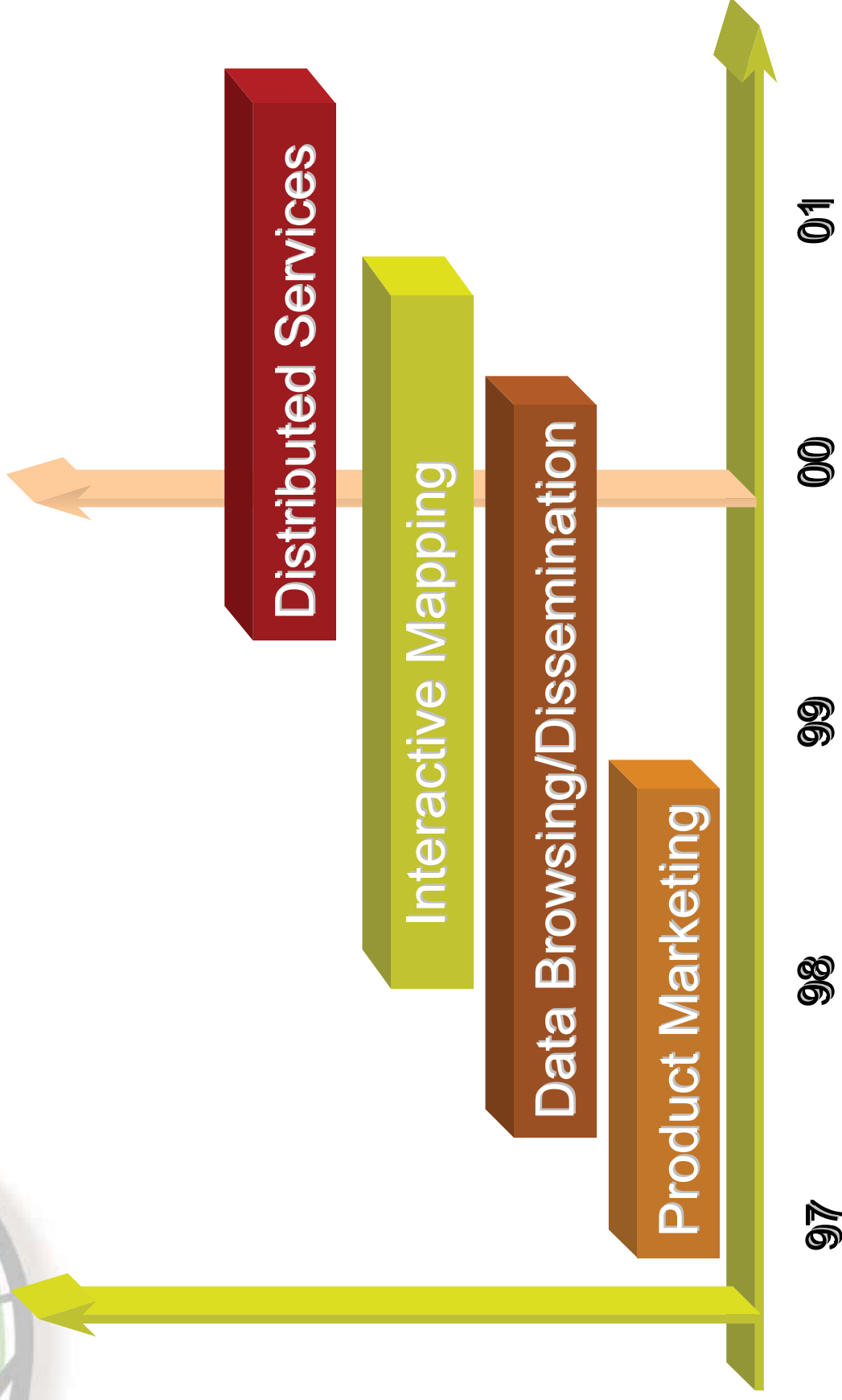


The Internet

....changes everything
next platform for delivering
location based services and data



Evolution of GIS on the Net





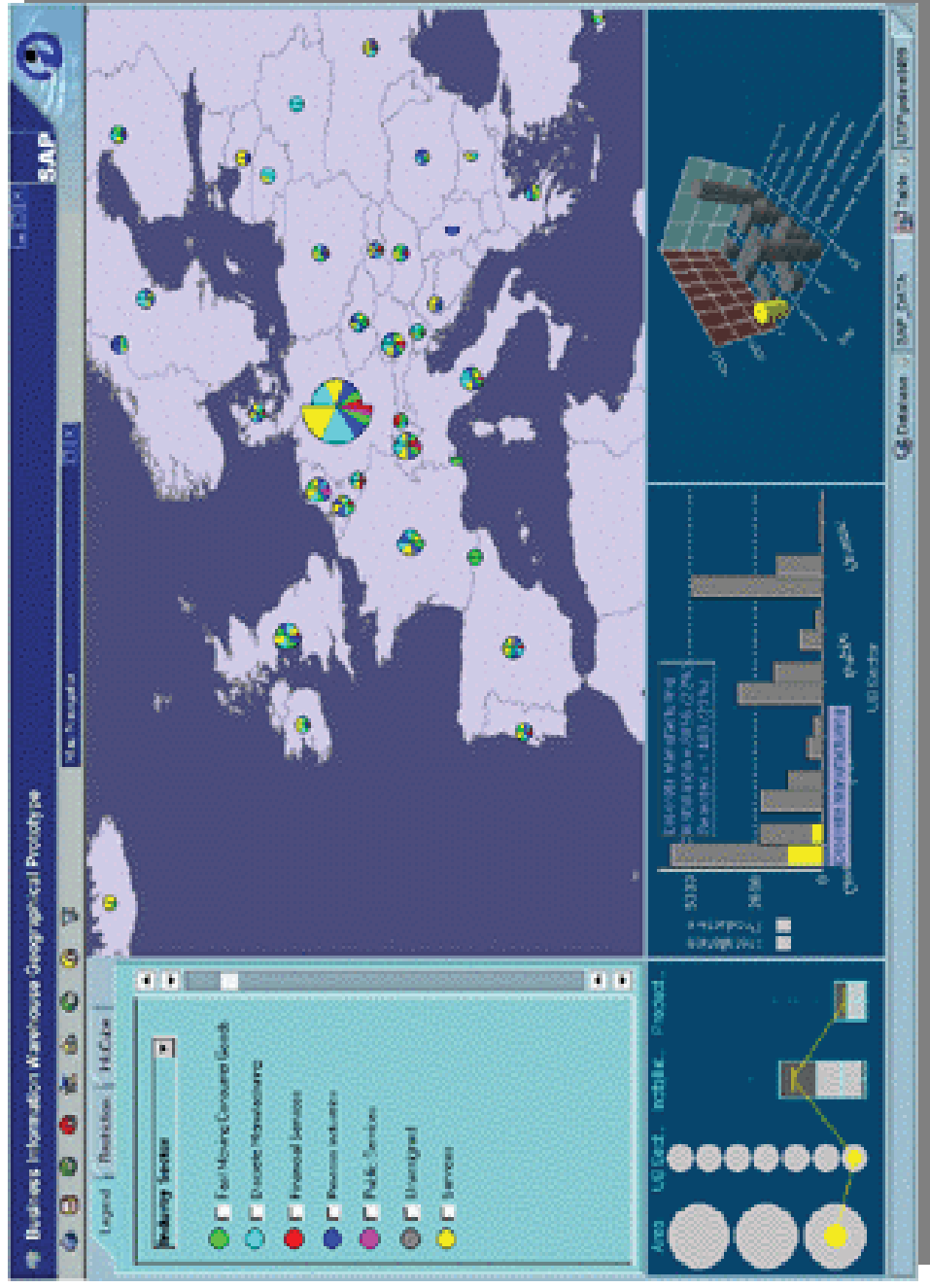
Internet GIS

- Distributed
- Inexpensive
- Familiar user interface
- Centralised data warehouse
- Server based applications



Changing Users profiles

GEO Data Aware Business Applications

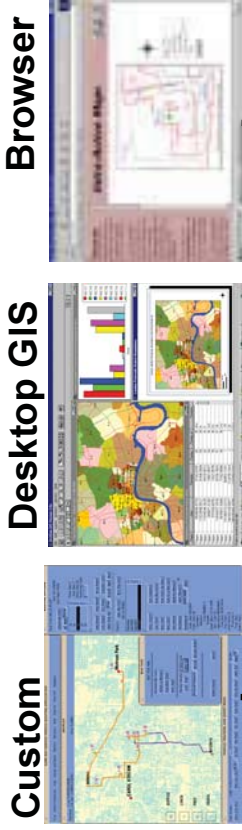




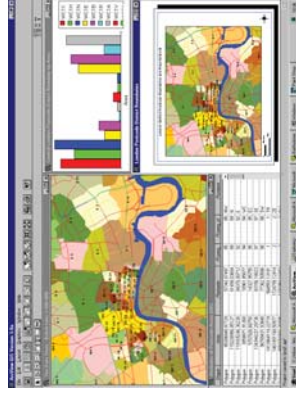
Changing Face of GIS

**GIS-Centric
Applications**

Spatially Aware Applications



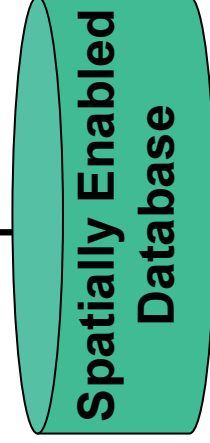
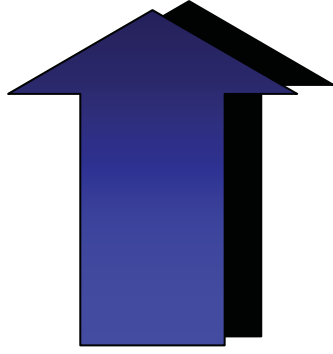
GIS



**Digital
Maps**

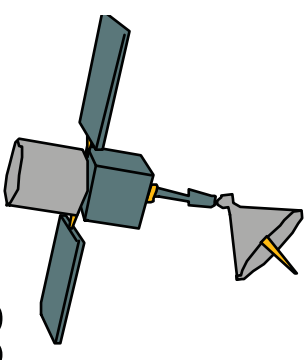


**Text
Data**



Society is becoming 'GEO Data empowered'

Databases

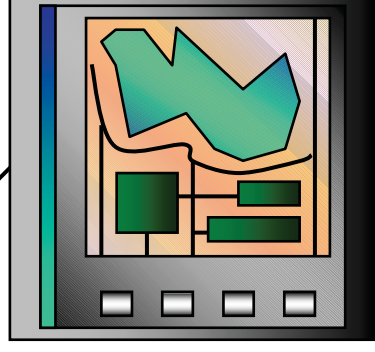


Remote Sensing

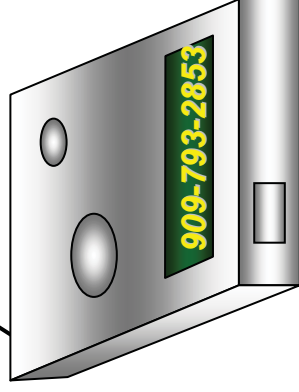
GPS



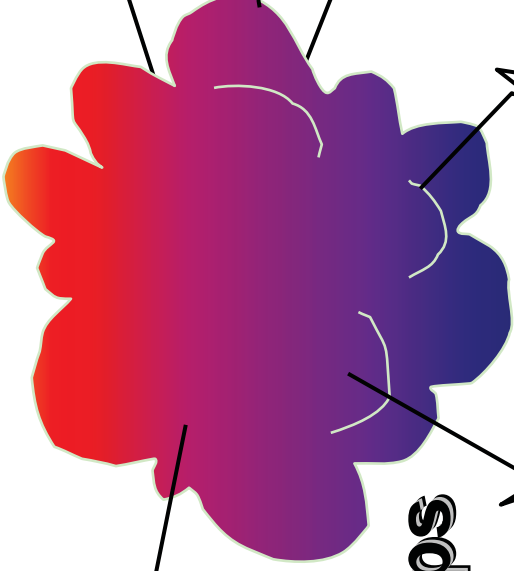
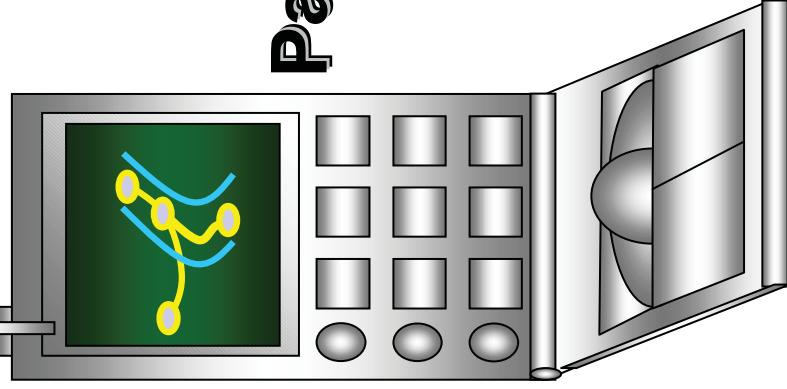
**Browser
Plug-ins**



Pagers

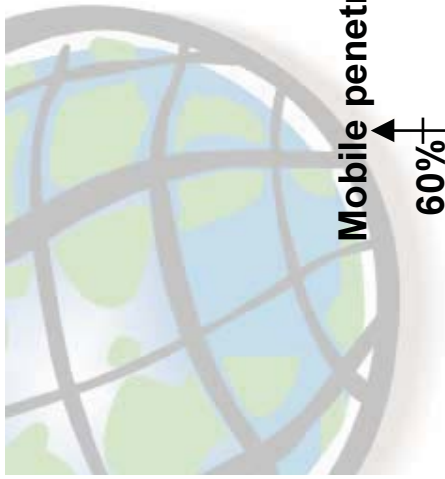


Palmtops

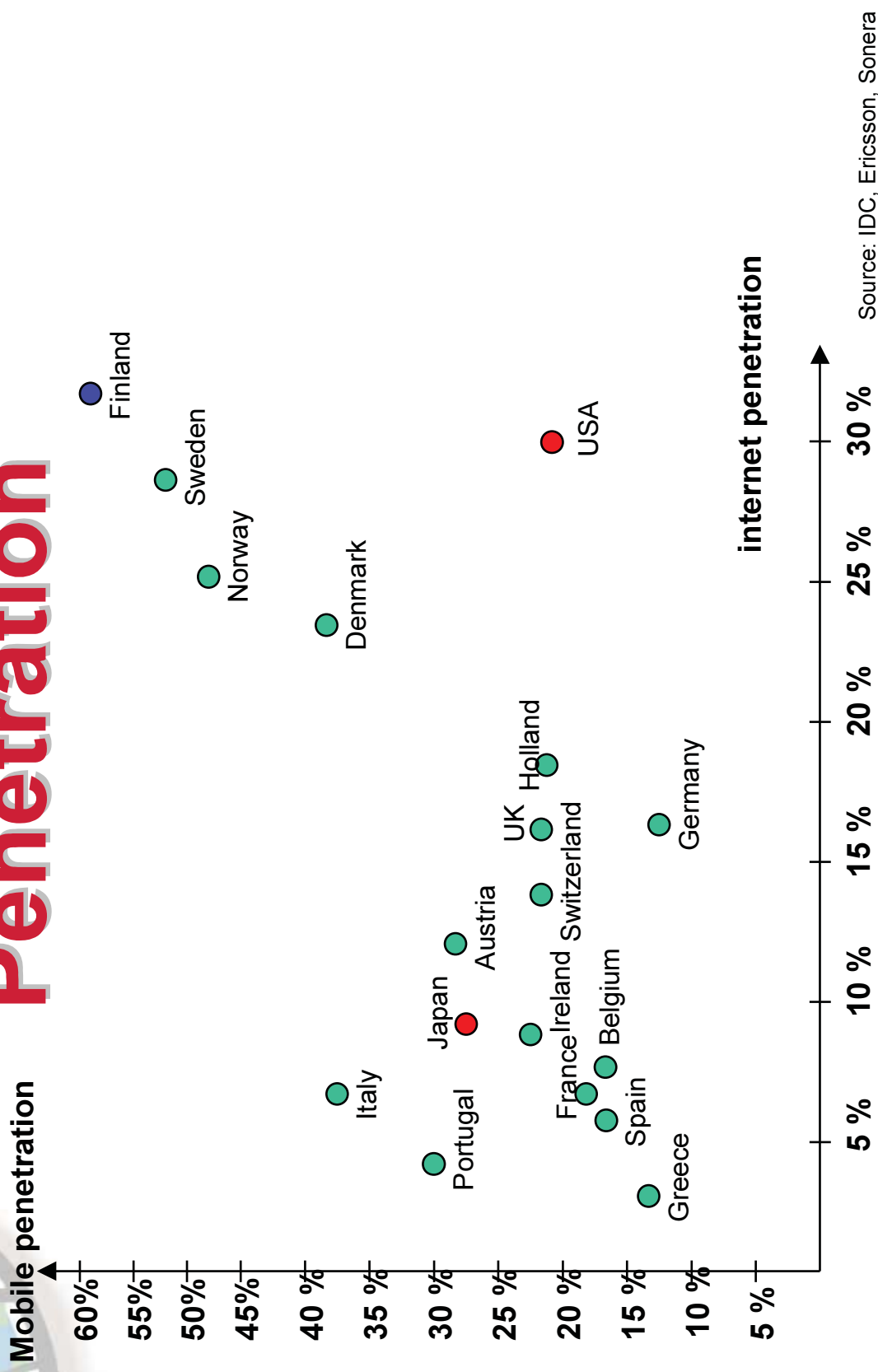




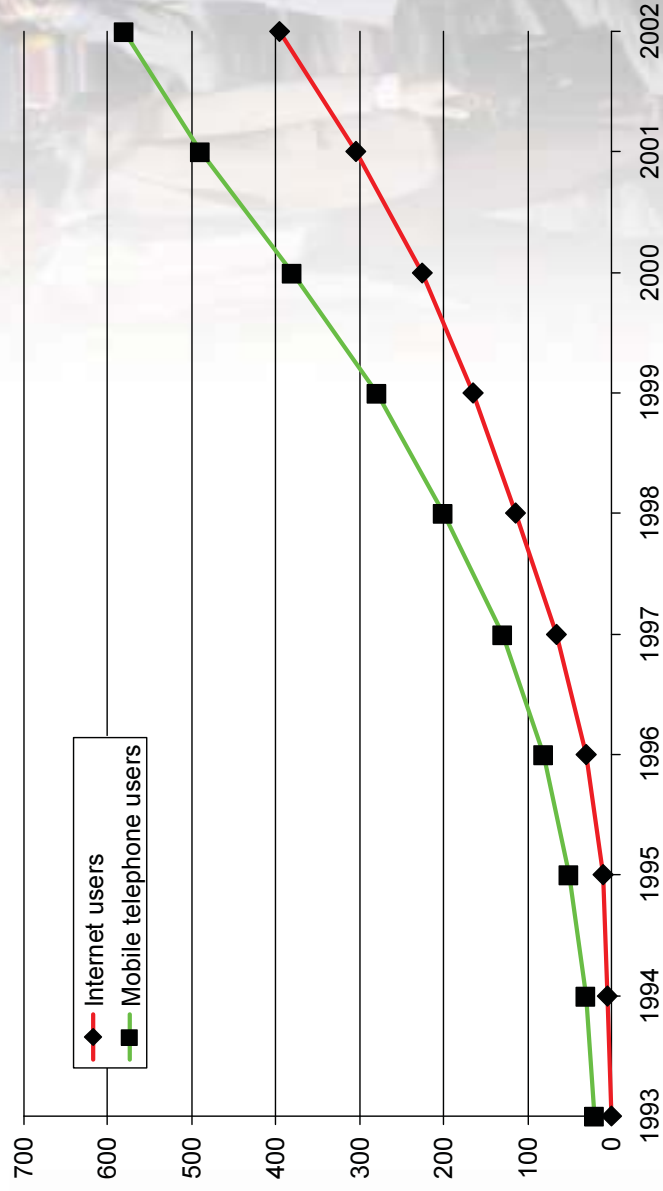
Market Trends



Mobile & Internet Penetration



Mobile & Internet Users



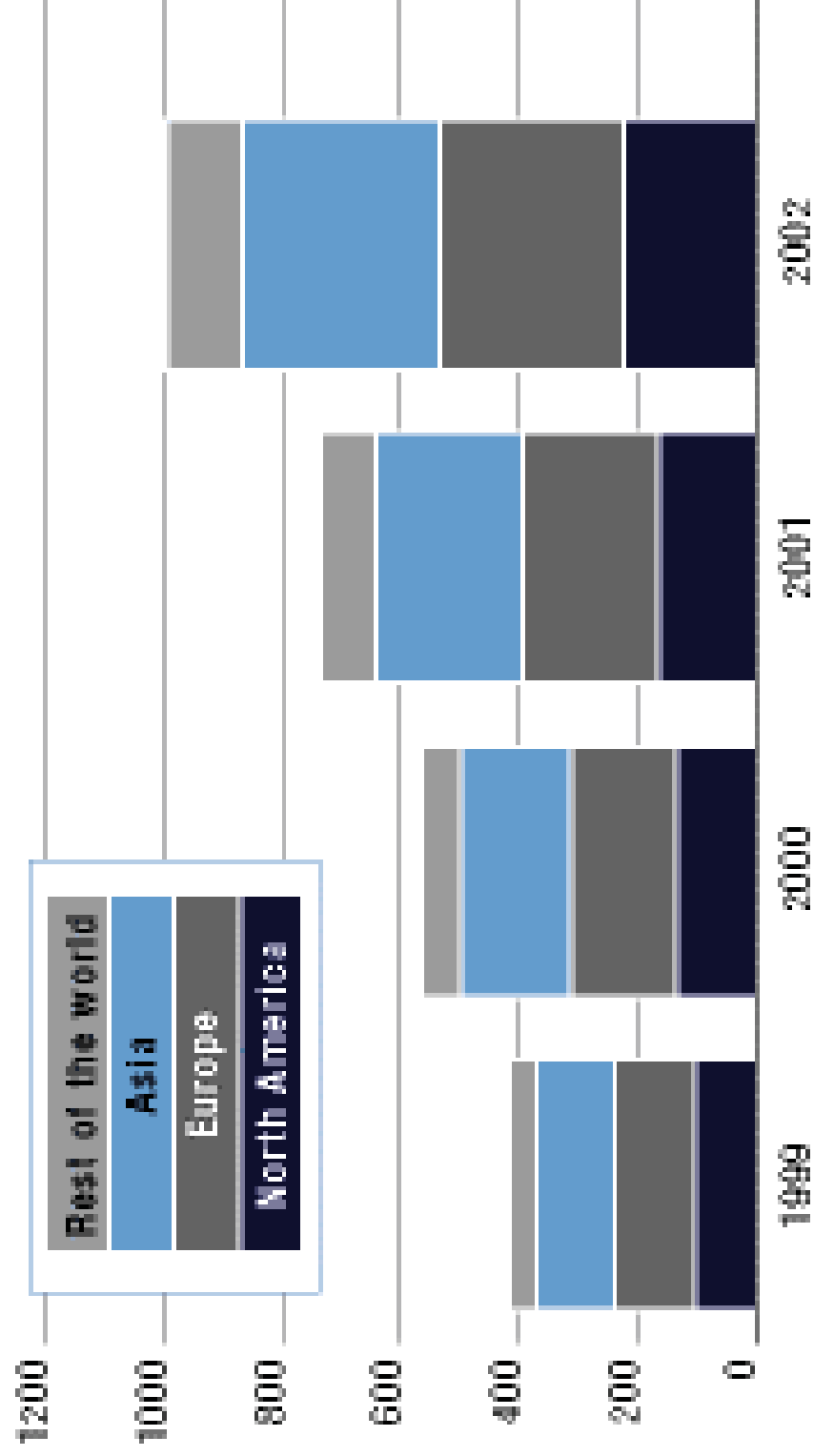
A man in a dark suit, white shirt, and patterned tie is looking down at a silver flip phone. He is holding the phone with his right hand. The phone's screen shows a colorful interface with a photo of a person. In the background, a large crowd of people is visible, suggesting a busy event or trade show. The man is standing behind a glass railing.

Currently:
300 million mobile phones
400 million PC's

Predict in 3 years:
500 million PC's
1 billion WAP phones

Estimated total mobile phone subscribers

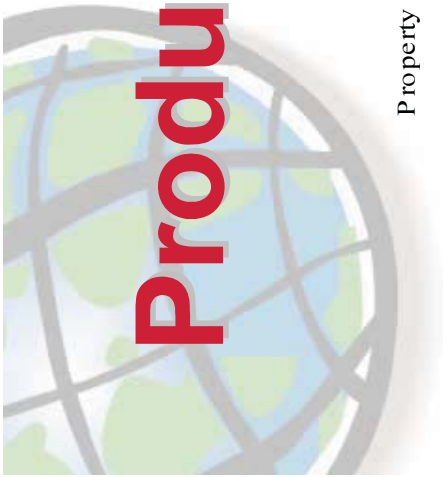
Million



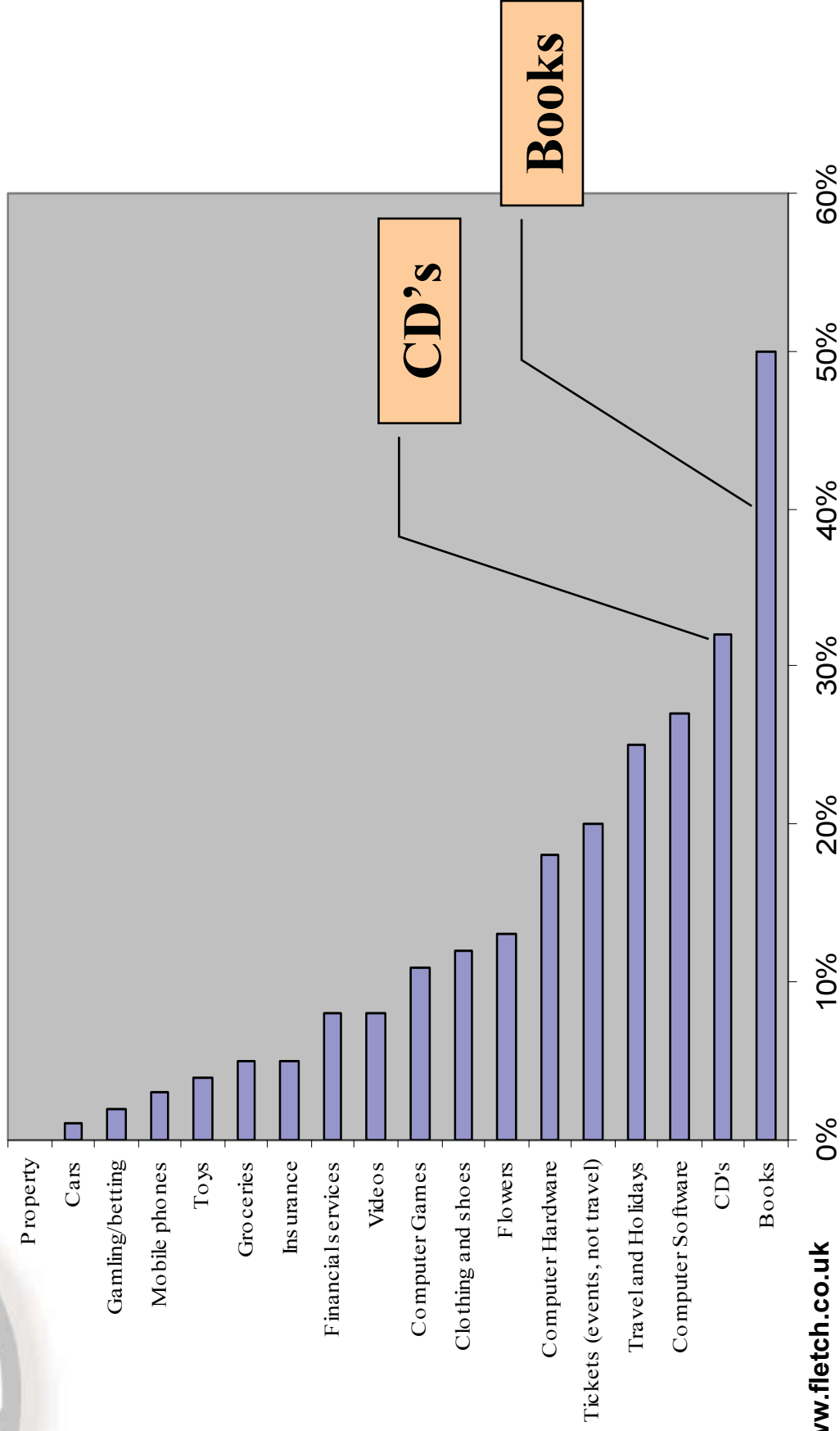
Source: Booz Allen & Hamilton analysis



Purchasing via the Internet

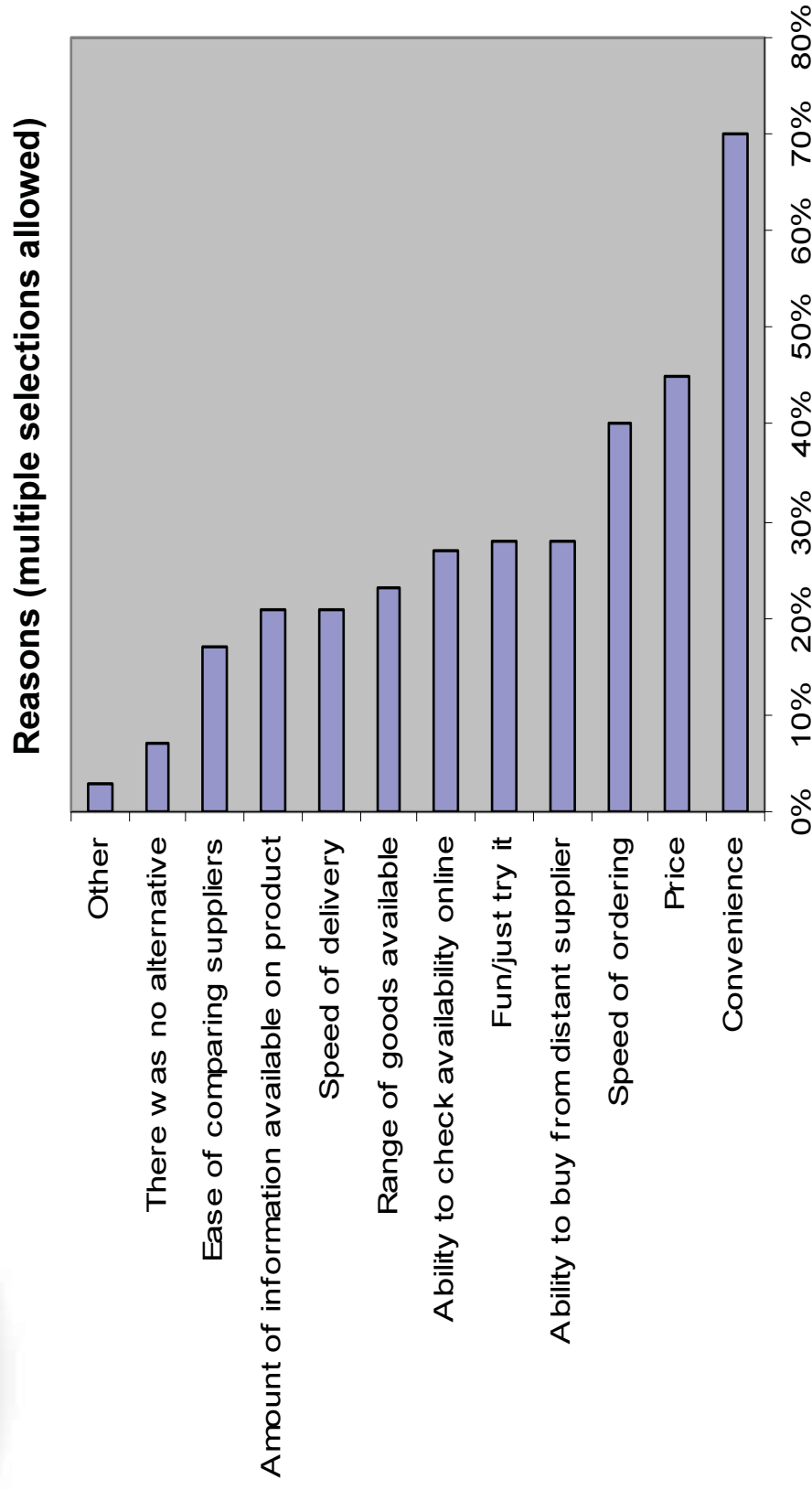


Products Purchased On-Line



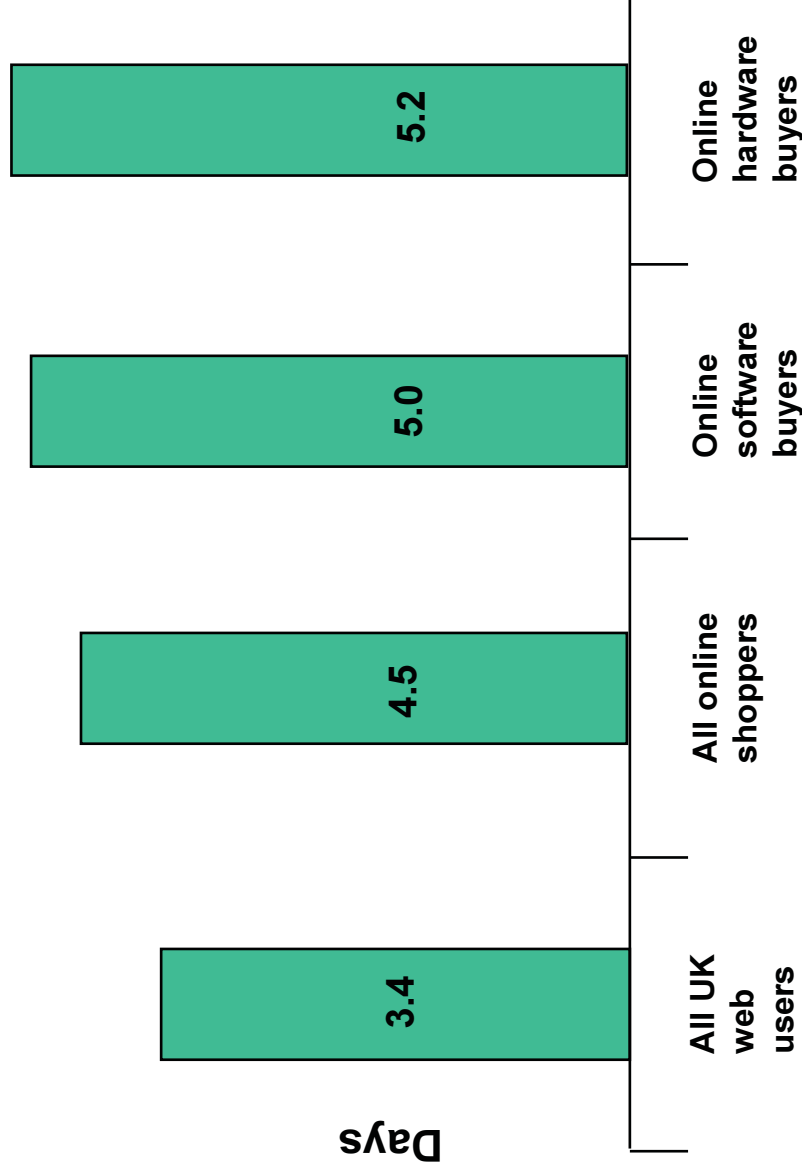


Reasons for Shopping on-line



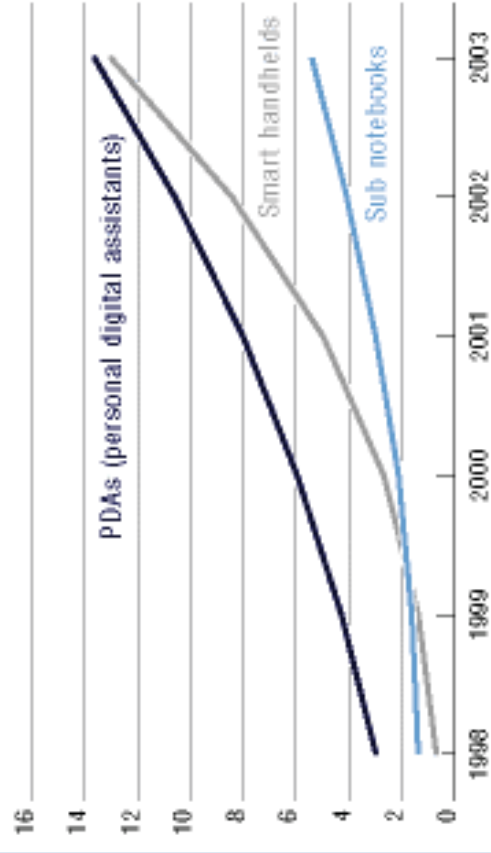


Frequency of Internet Usage

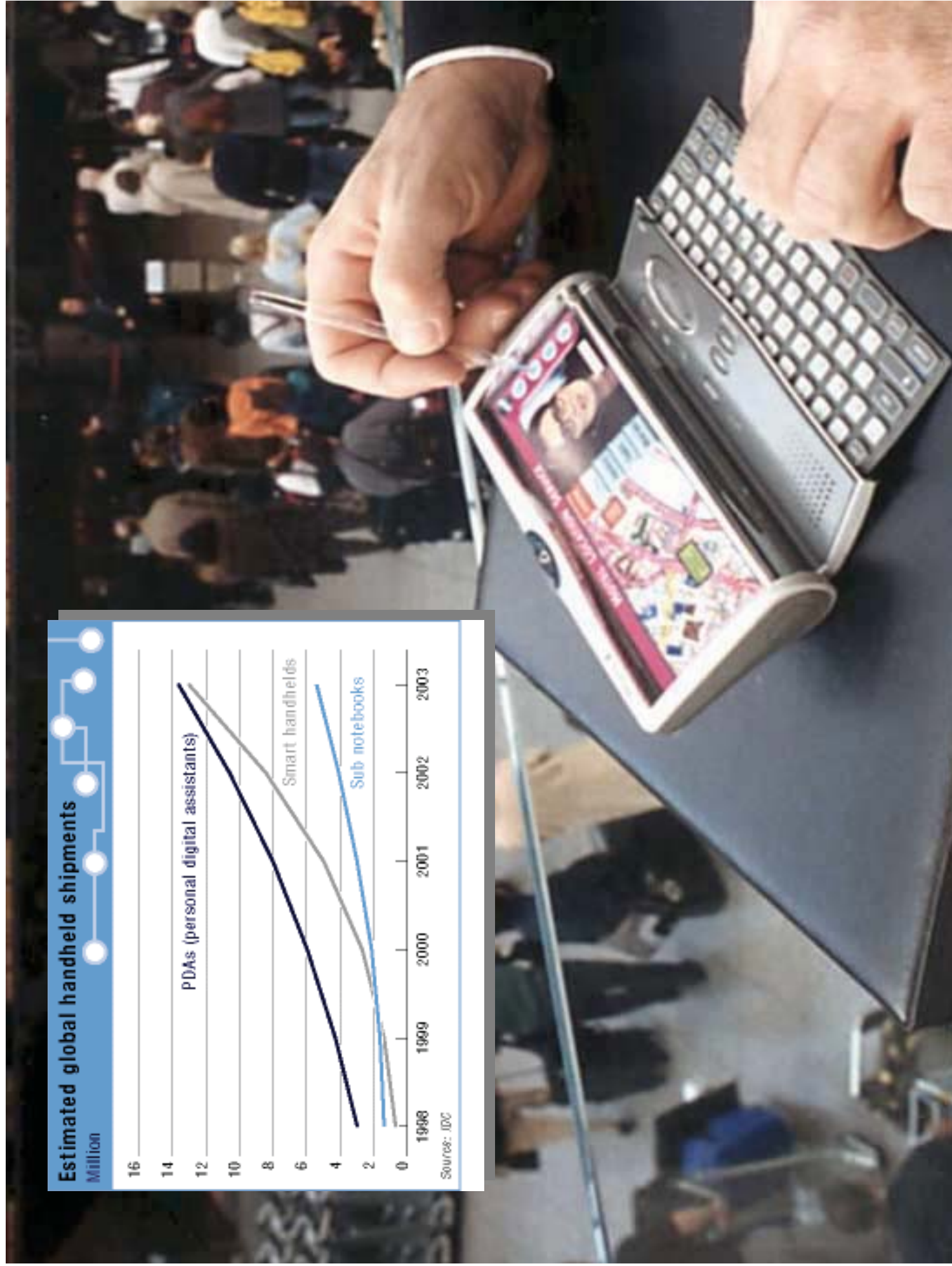


Estimated global handheld shipments

Million



Sources: IDC





Case Studies

National Geographic

Data-Store

NLIS

SignalSoft



National Geographic MapMachine

Example of internet map production

HOME | SEARCH

CREDITS

9

See My Saved Views

Printable Version

Maps on CD-ROM

MapMachine Query

Map Machine @ nationalgeographic.com - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search Favorites History Print Mail RealGuide

Address <http://plasma.nationalgeographic.com/mapmachine/> Go

NATIONALGEOGRAPHIC.COM

MapMachine
NATIONALGEOGRAPHIC.COM ESRI

DYNAMIC MAPS ATLAS MAPS FLAGS AND FACTS GIS DATA & TRAINING CREDITS

THEME: U.S. TORNADO TOUCHDOWNS **SELECT A NEW THEME**

wisdom...knowledge...awareness

Find a Place **GO**

MY MAPS
Save This View
See My Saved Views

MAP OPTIONS
SIZE: Small Large
Related Atlas Maps
Printable Version

DRAG IN MAP TO ZOOM, OR CLICK TO RECENTER

ABOUT THIS MAP
Map Key
Map Source

RELATED RESOURCES
Flags and Facts
More Map Sites
Map and Globe Store

OUR SPONSOR

FEATURED PRODUCT
Maps on CD-ROM

Internet



www.data-store.co.uk

*Example of on-line geographic data
mart*

DataStore Front Page

The DataStore online - Microsoft Internet Explorer

File Edit View Go Favorites Help

Links

Home The DataStore Buy & Download Case Studies Your Account Licensing

Welcome to the DataStore online

News | GIS Downloads | The Company | Map Gallery

At **The DataStore** we have GIS data, digital data, vector and raster products, geocoding data for mapping, demography, postal geography and geographical databases.

[Register](#) | [Log-in](#)

The DataStore has developed links with quality data providing companies, such as AA, Bartholomew, Geoplan, ED '91, Ordnance Survey, Arc, Philip's and World City. This means we can offer GIS solutions in a wide range of GIS software, small and large scale data and map bases, for all mapping information requirements. From street level data to postcode sectors to international city maps, The DataStore can provide the digital media you need.

You are welcome to [search](#) the products on our site, learn more [about us](#), or [contact us](#) if you have any other enquiries.

If you would like to read about the latest developments at The DataStore, please visit our [news](#) page.

Designers looking for ready to use location maps, please click on the [Map Gallery](#).

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ESRI (UK) Making Spatial Data work for you

Internet zone

DATA STORE

Search The Store...

Quick Search...

go

To help you search The DataStore please type your enquiry into the box above and click go!

More Search [Options...](#)

Call Me

Bartholomew
MAPPING SOLUTIONS
@ THE STORE

Web Graphics
Ready to use
Map Gallery

CLICK HERE

The screenshot shows a web browser window. The title bar at the top reads "The DataStore on". Below the title bar is a menu bar with the options "File", "Edit", and "View". The main content area of the browser displays the word "Global" in a large, bold, red font. The background of the page is a stylized globe with green landmasses and blue oceans, overlaid with a grey grid of latitude and longitude lines.

The screenshot shows a web browser window. The title bar at the top reads "The DataStore on". Below the title bar is a menu bar with the options "File", "Edit", and "View". The main content area of the browser displays the word "Global" in a large, bold, red font. The background of the page is a stylized globe with green landmasses and blue oceans, overlaid with a grey grid of latitude and longitude lines.

Ordering On-line

Buy and Download - Order Form - Microsoft Internet Explorer

File Edit View Go Favorites Help



Home

The DataStore

Buy & Download

Case Studies

Your Account

Licensing

Welcome to the DataStore online

News

GIS Downloads

The Company

welcome to
www.datastore.co.uk

Product Code	Product Title	User Licenses	Order Qty	Unit Price	Line Total	Estimated EUR
210001	Geoplan Local Map		2	£995.00	£1,990.00	3,061.68
350037	Bartholomew London Database	1	1	£100.00	£100.00	153.85
Subtotal:					£2,090.00	3,215.53
Inc. VAT:					£2,455.75	3,778.25

(The VAT inclusive price is indicated for EEC sales only and will not be charged for export orders)

(Shipping of £0.00+ VAT will be added for UK (Mainland) orders. £0.00+ (VAT, where appropriate) will be added to all others.)

Shop for More

Recalculate

Cancel Order

Save Order

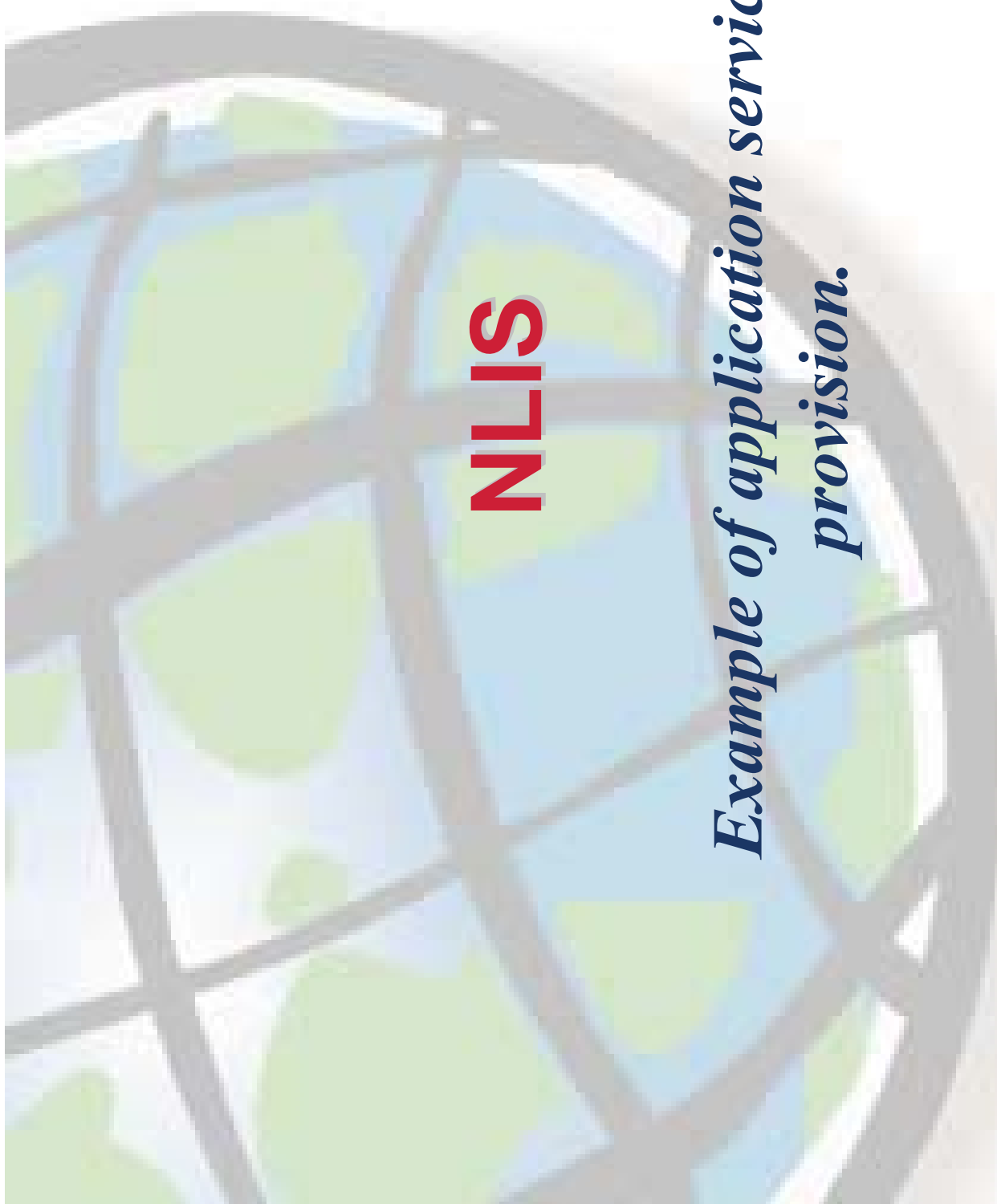
Buy Now

Auto-Calculate On

(If on, the checkout will recalculate each time you change a quantity, click to turn off)

Welcome to the DataStore online

Internet zone



NLIS

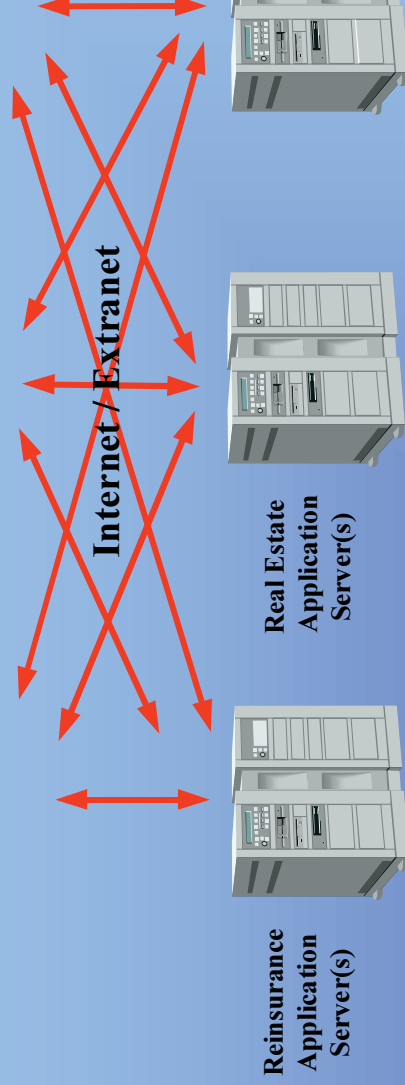
*Example of application service
provision.*

Three Tier NLIS Architecture

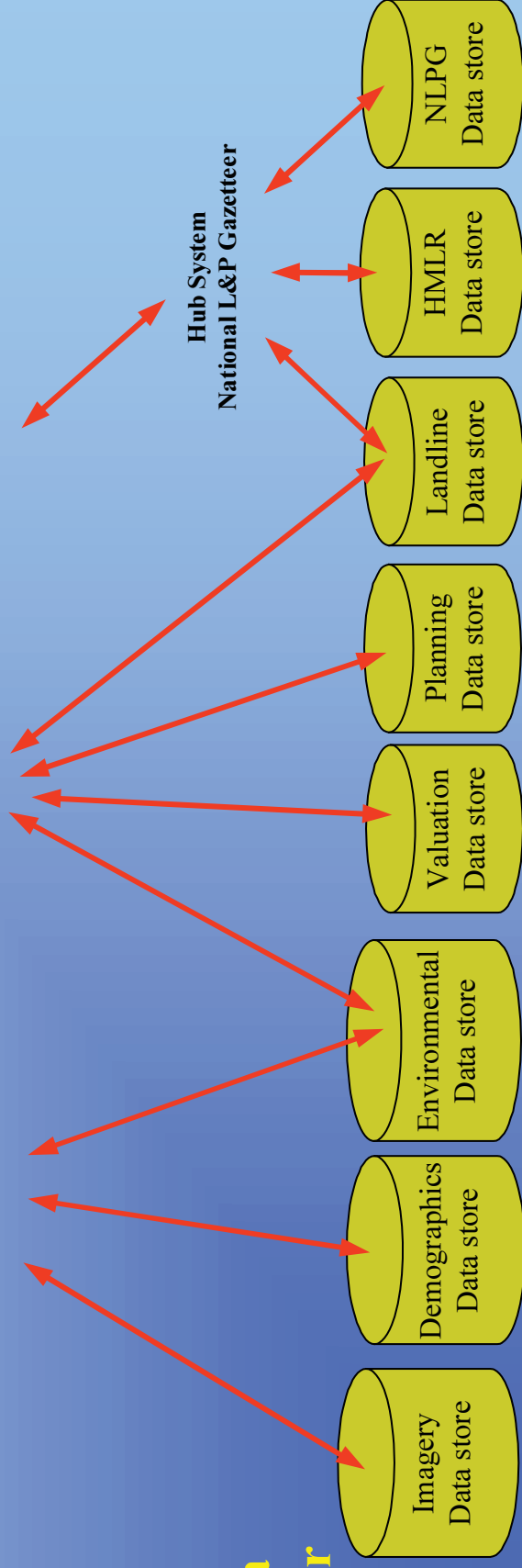
Presentation
Layer



Application
Layer



Data
Layer



Spatially Enabling the Enterprise



ESRI (UK)



NLIS Hub Application Architecture

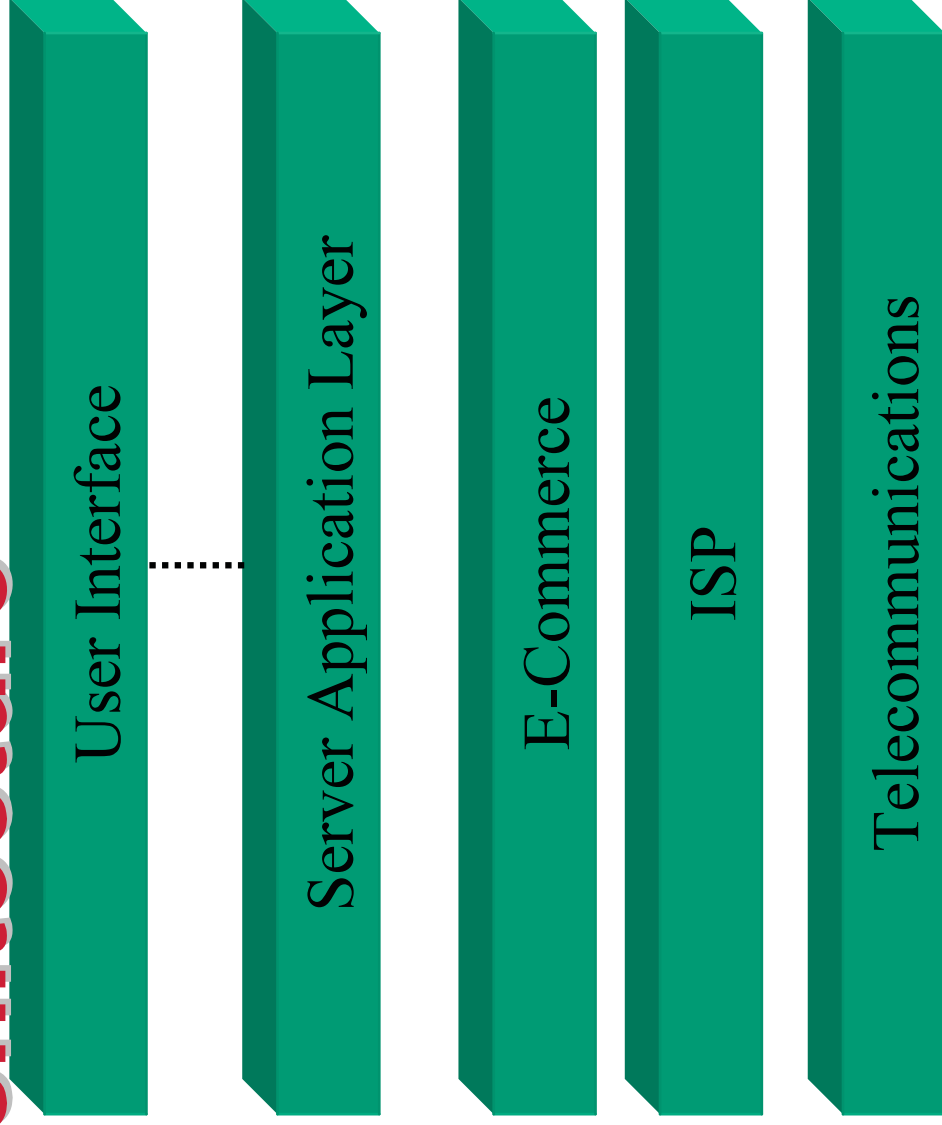
Web Browser plus Java applet(s)

Search area (NLPG) Interface,
Mapping Application, Metadata, Data
Provider interfaces, Call Centre
application, workflow.

Security, Transaction Management,
Accounts, Audit trail, Hub Database

Internet Service, Server Hardware

ISDN,
Government Secure Intranet

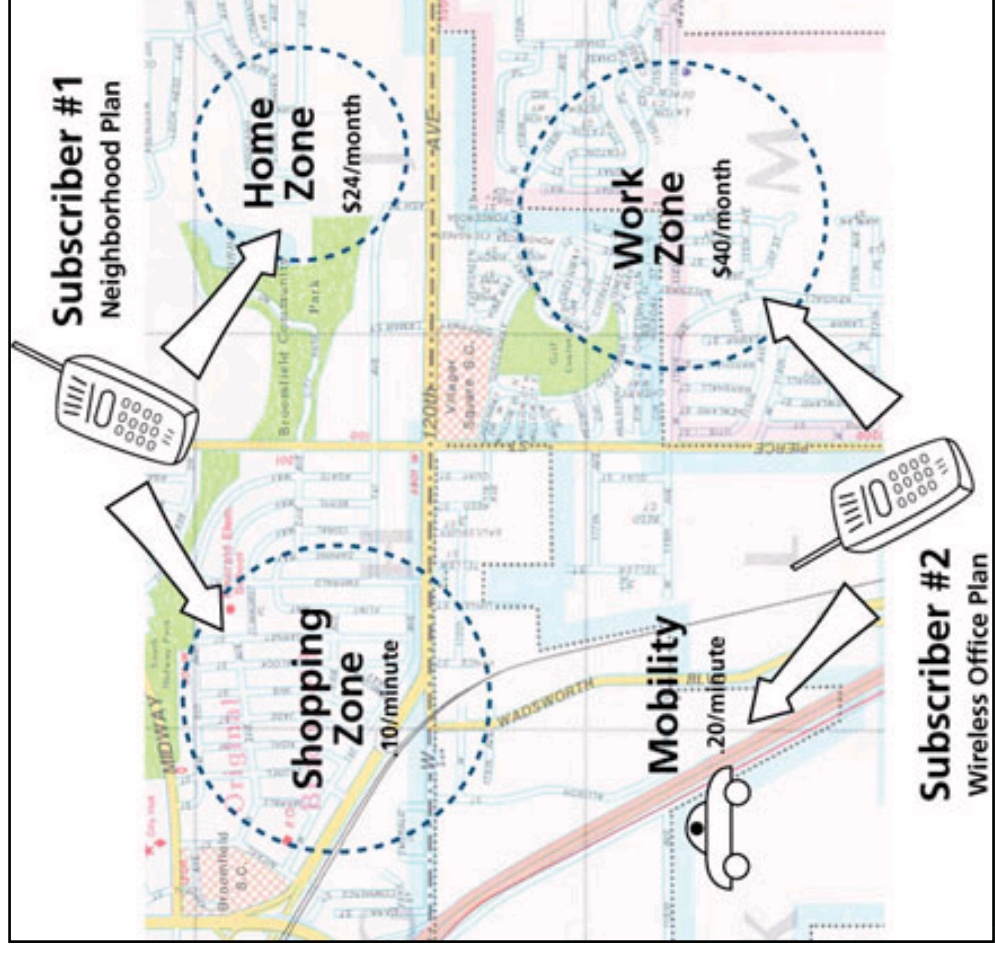




SignalSoft

*Example of applications using GI
but not visible.*

Location Sensitive Billing (Personalised Rate Zones)





What should the NMA's do?



Data on Demand - Today's requirement not Tomorrow's

Increasing demand for information within Business

Business 2 Business increasingly driven into a consumer model

Data has to be current and 'fit for purpose'

Businesses 'in the know' have a significant edge over competitors

Data Leasing already a reality, soon to become the norm



Internet Licensing / Pricing

- B2B adopting consumer model for internet trading
- Internet effective as perceived fast commerce
- Data selling over internet has same perception
- NMA's must react fast to requests and have licensing/pricing worked out
- Pricing need to be flexible – different pricing model for very active sites as internet advertising relatively immature
- If you cannot react quickly then the customer will go else where.



How should NMAs respond

- Work more closely with the private sector;
- Allow others to undertake the data distribution;
- Focus on currency of topographic base data;
- Buy big pipes.



Growth Potential

"The market for business to business e-commerce is set to skyrocket from \$145 billion last year to \$7.29 trillion in 2004"

Source: Gartner Group

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