Bits of Geography: Maps and Mapping in the Digital Age

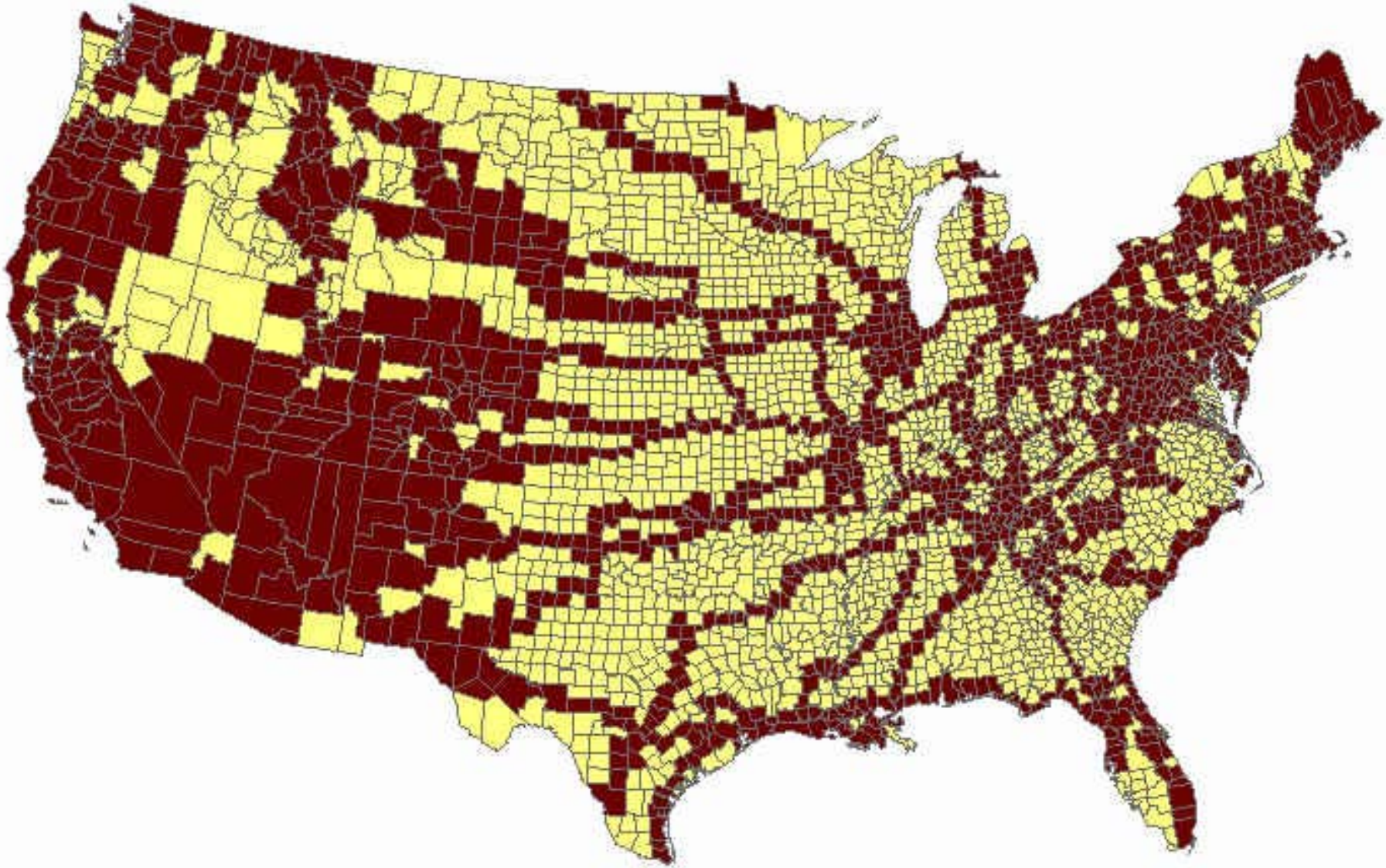
Michael F. Goodchild
University of California
Santa Barbara

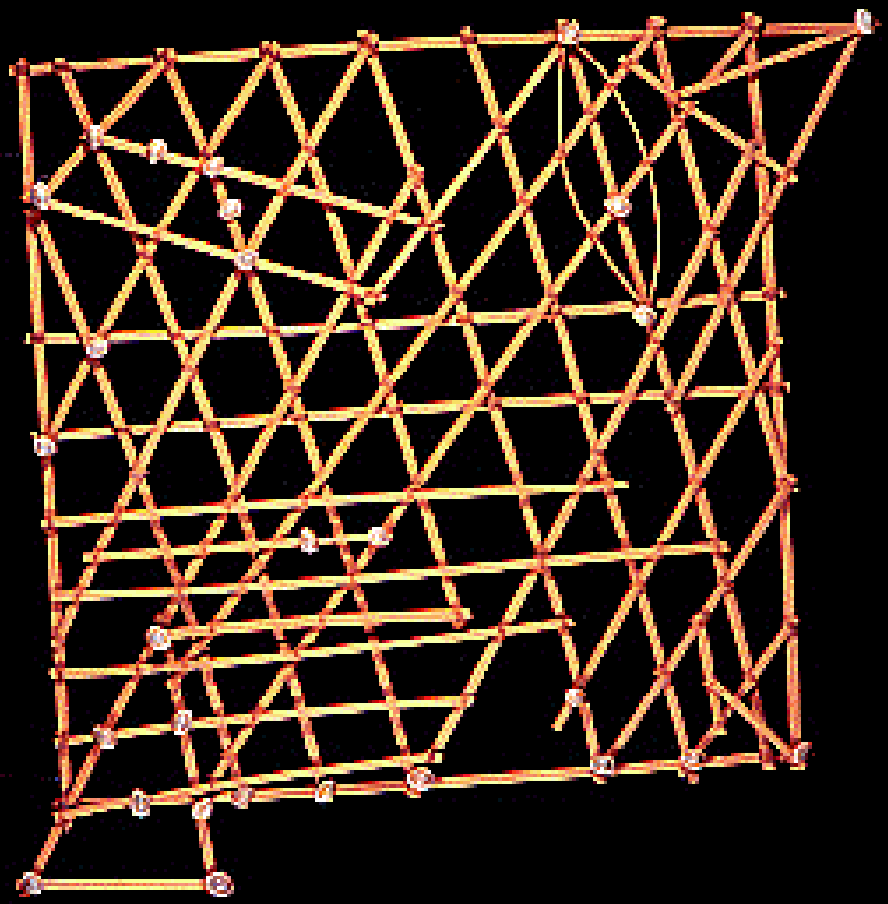
Exploration: a slow process

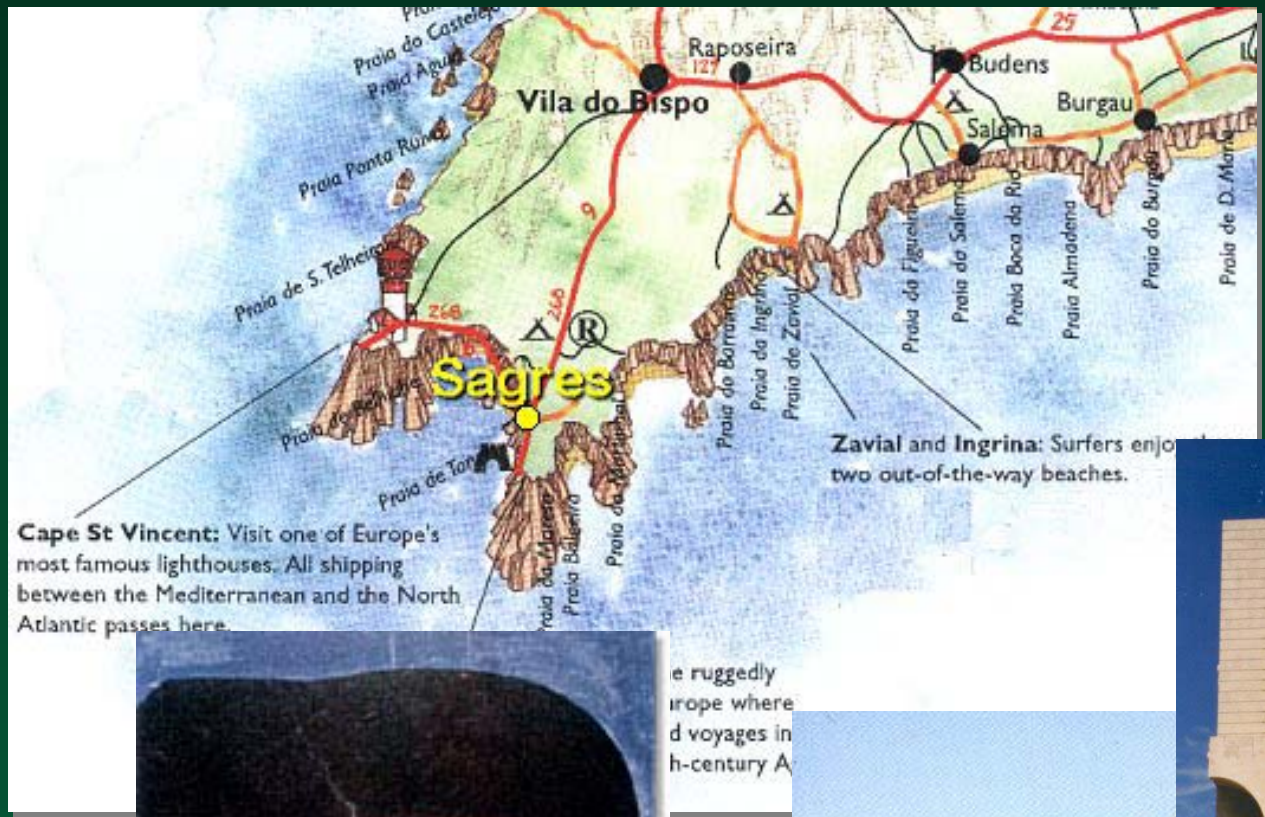
- 10 km horizon
  - 100 km/day covers 2000 km^2/day
  - 350,000,000 km^2 of oceans
  - 150,000,000 km^2 of land
  - peaked in 19th Century
  - completed in 20th

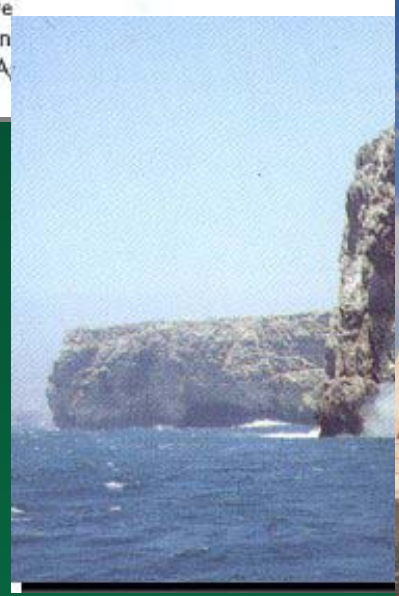
Exploration continues…

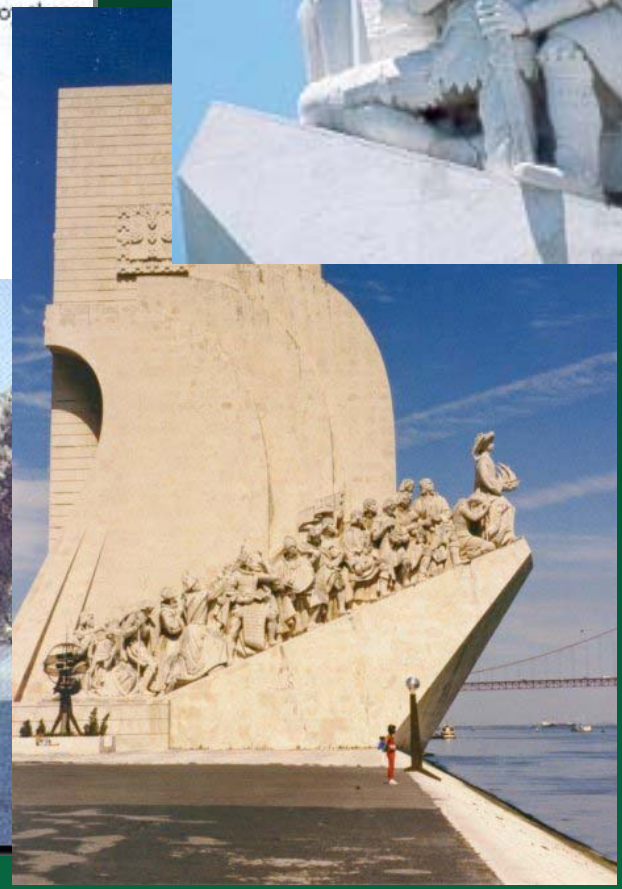
- The few remaining places
  - caves
  - the ocean floor
- Greater detail
  - Vespucci's spatial resolution
  - exploring microbiology
  - the Antarctic Dry Valleys
- Personal discovery
  - standing on Everest

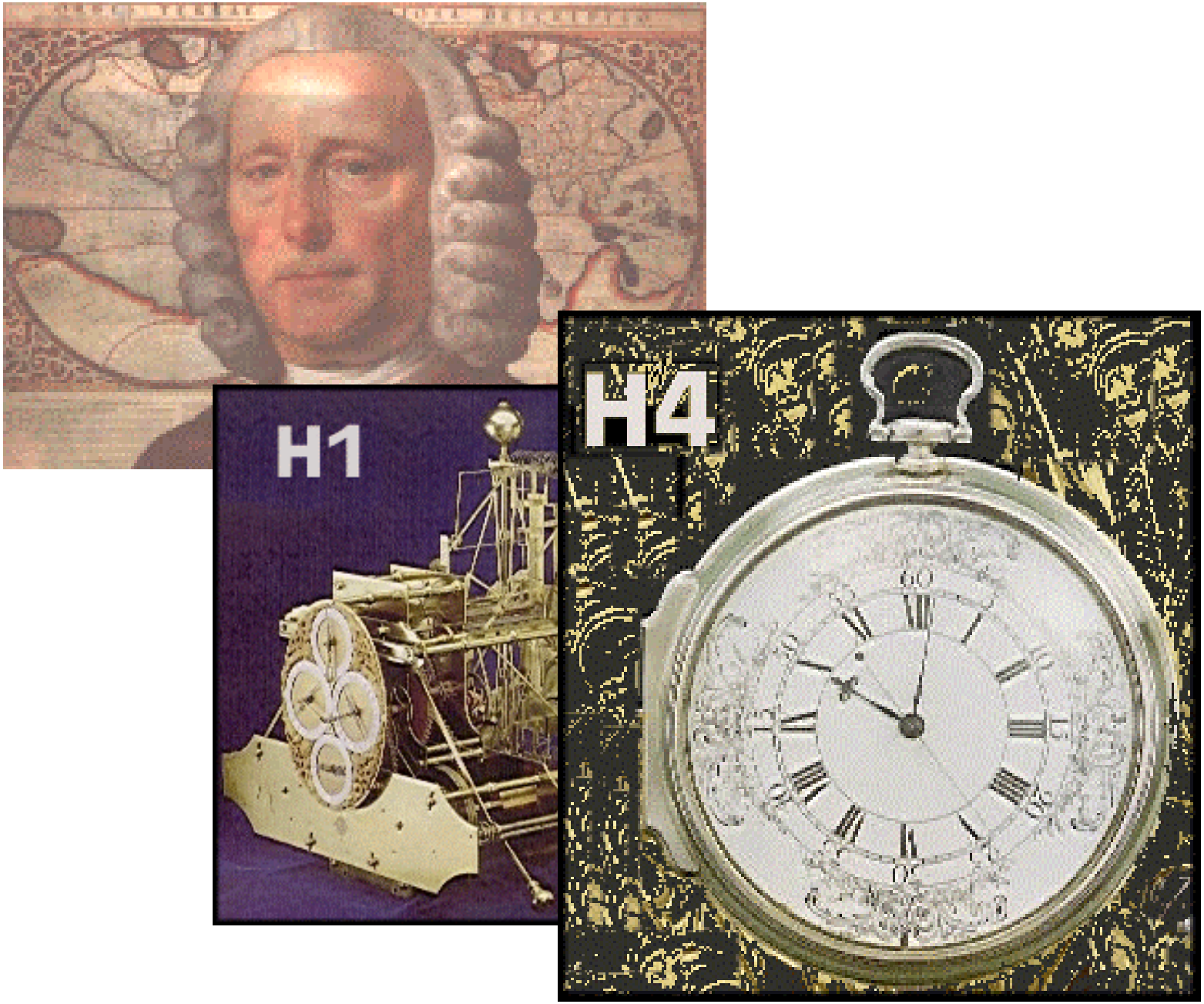


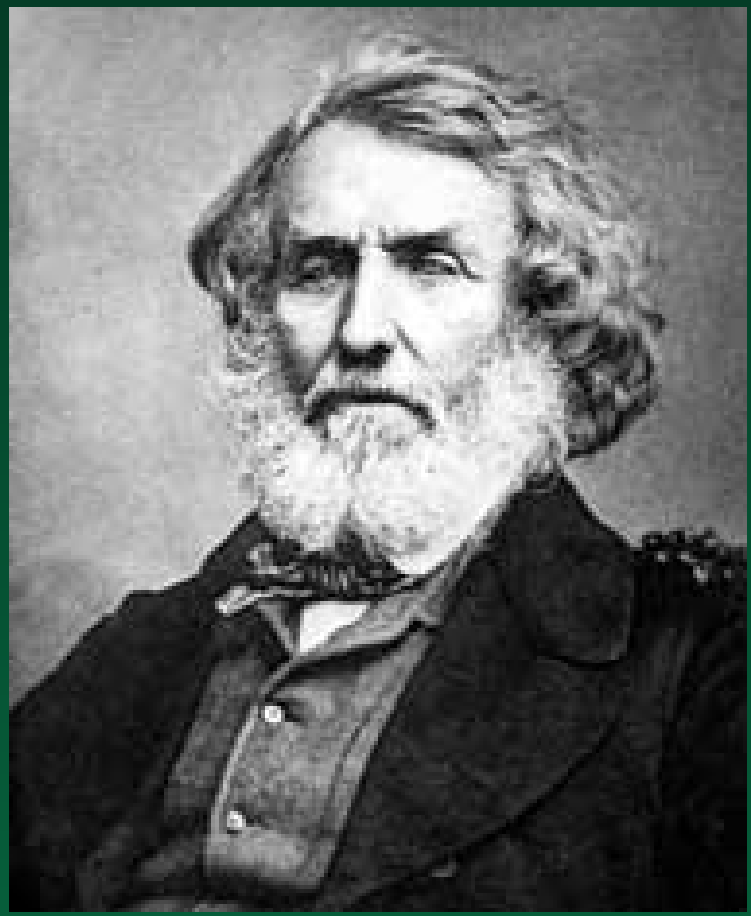


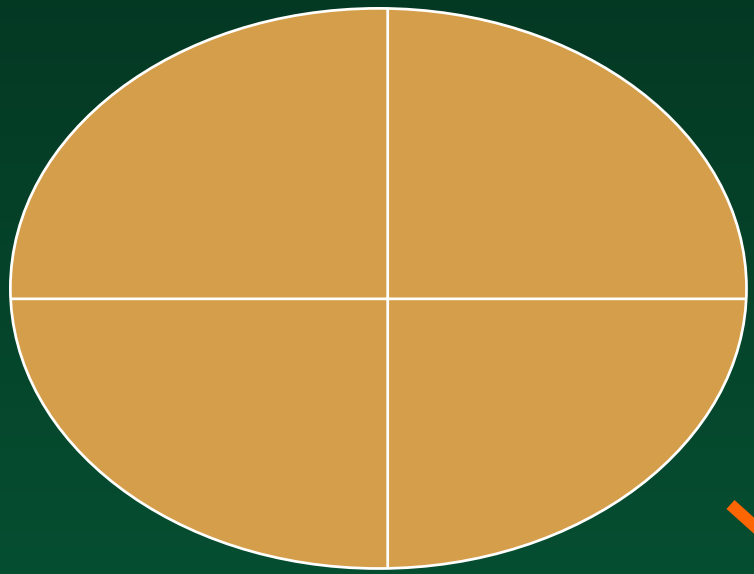

Raposeira
Vila do Bispo
Budens
Burgau
Salema
Sagres
Praia do Castelejo
Praia Ponta Ruiva
Praia de S. Telheiro
Praia do Burgau
Praia de D. Maria
Cape St Vincent: Visit one of Europe's most famous lighthouses. All shipping between the Mediterranean and the North Atlantic passes here.
Zavial and Ingrina: Surfers enjo
two out-of-the-way beaches.






H1
H4





Clarke Ellipsoid of 1866

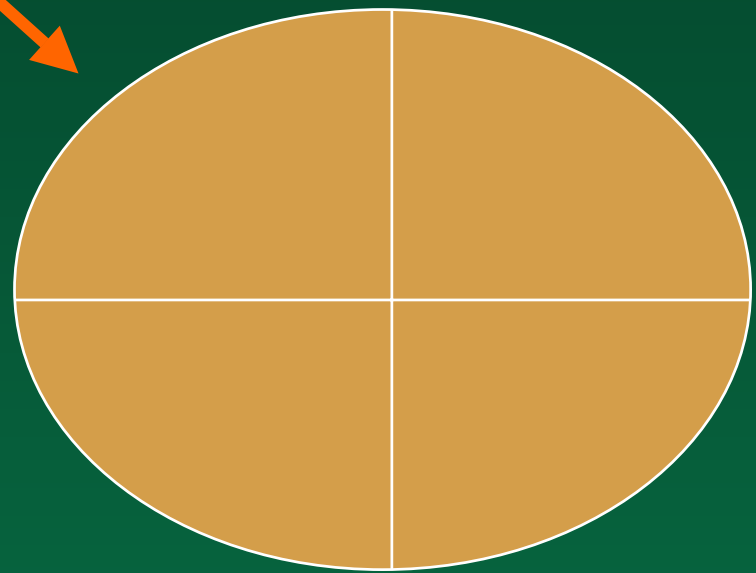
a = 6378206 m

$1/f$ = 294.98

World Geodetic System of 1984

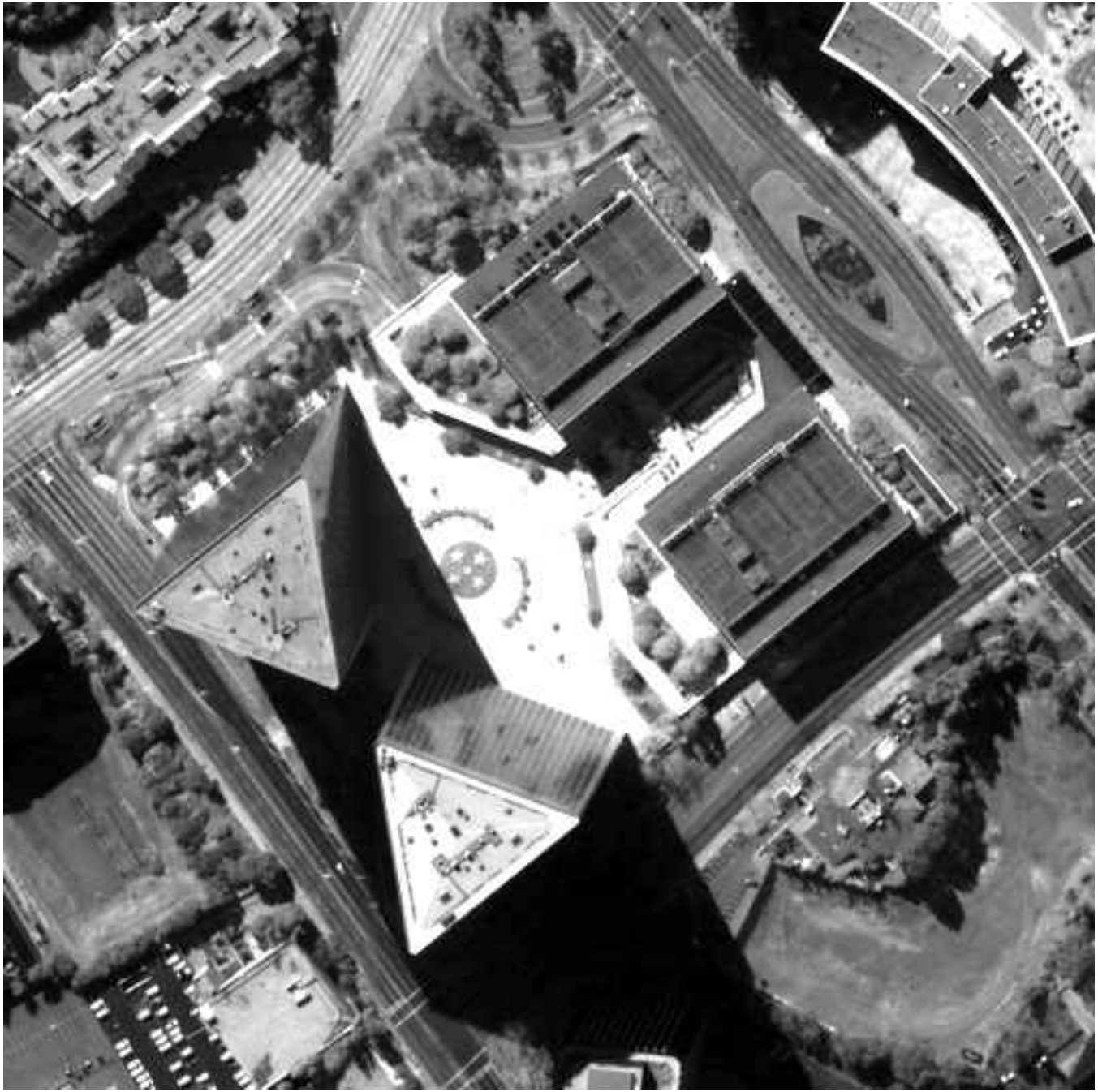
a = 6378137 m

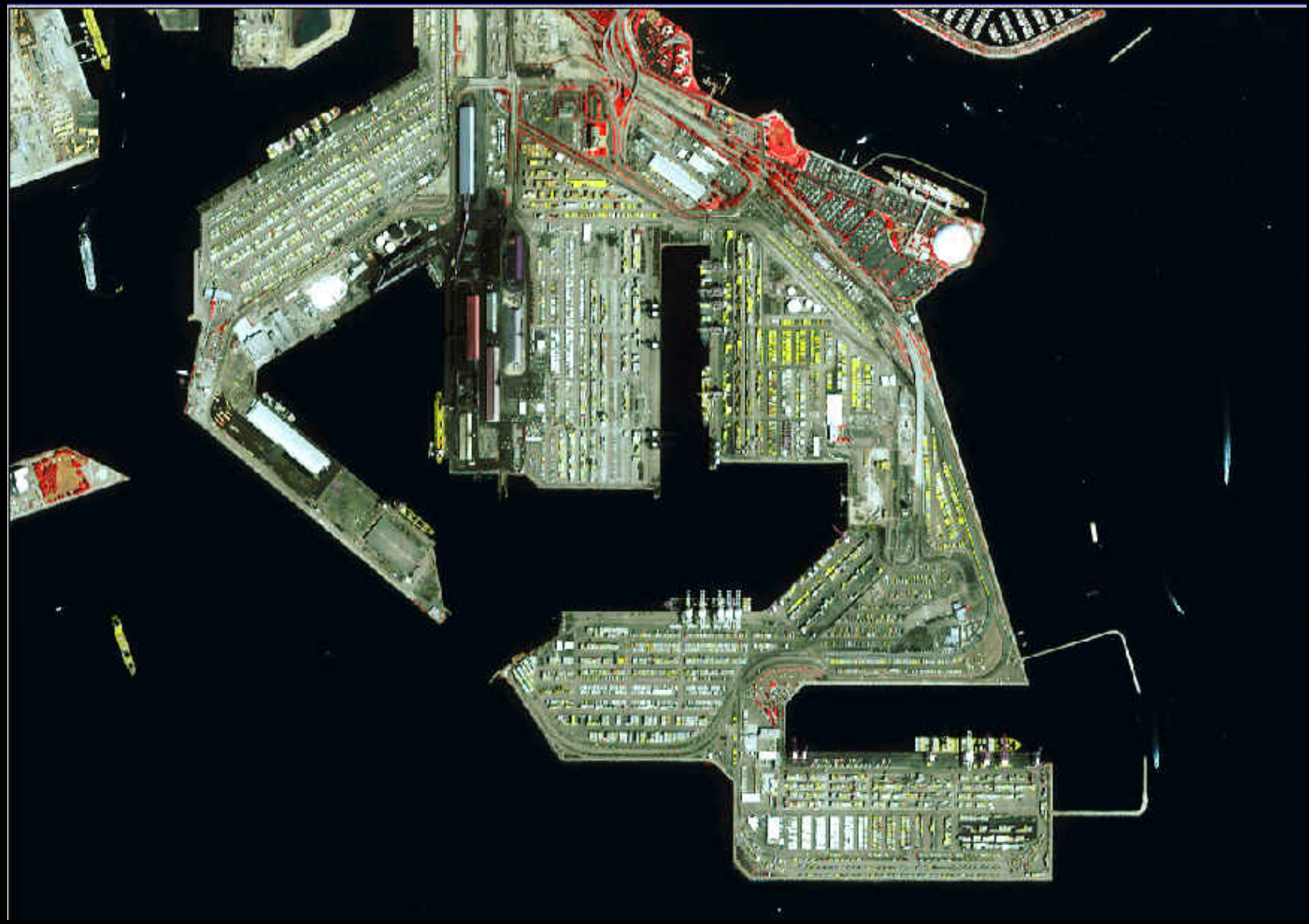
$1/f$ = 298.26

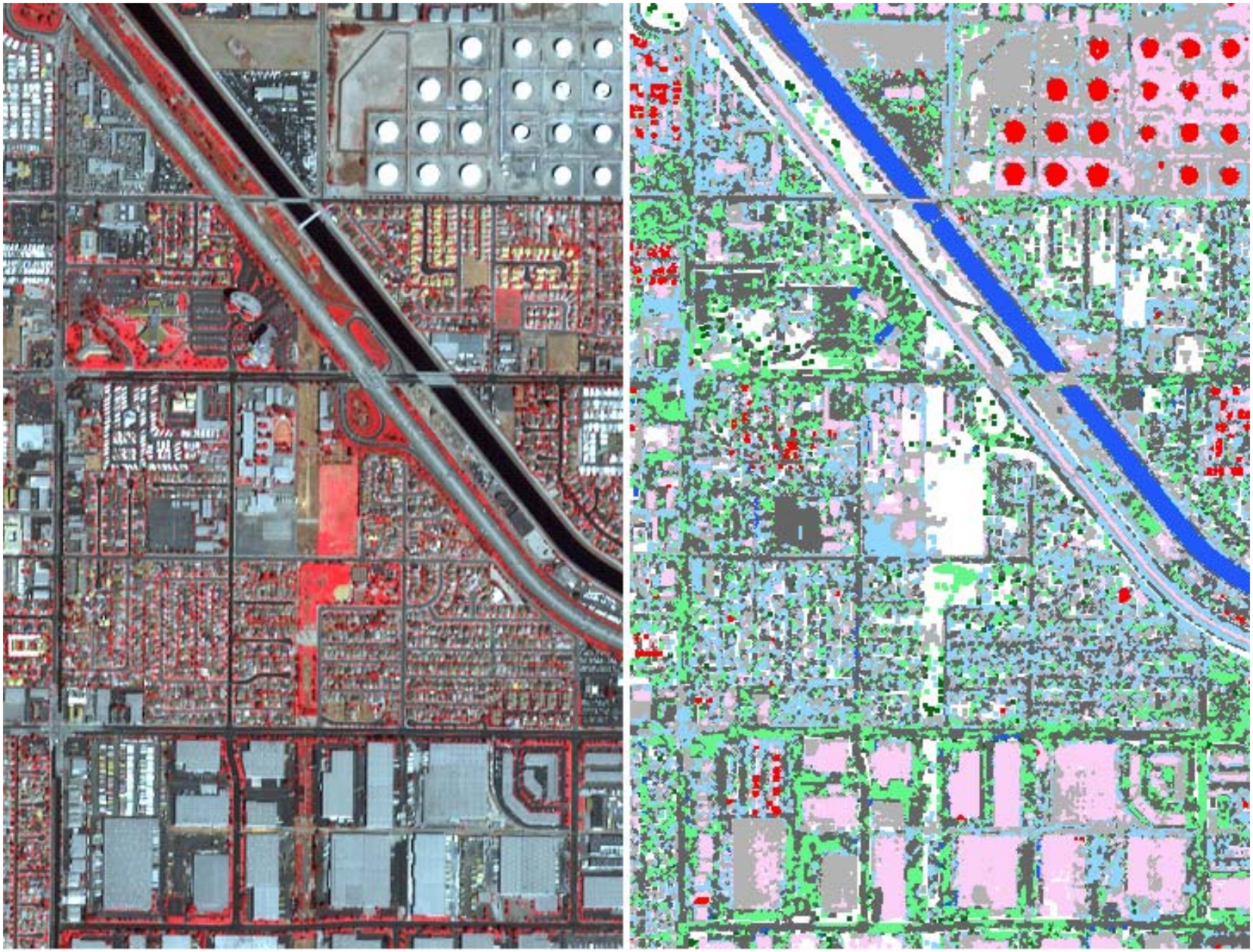


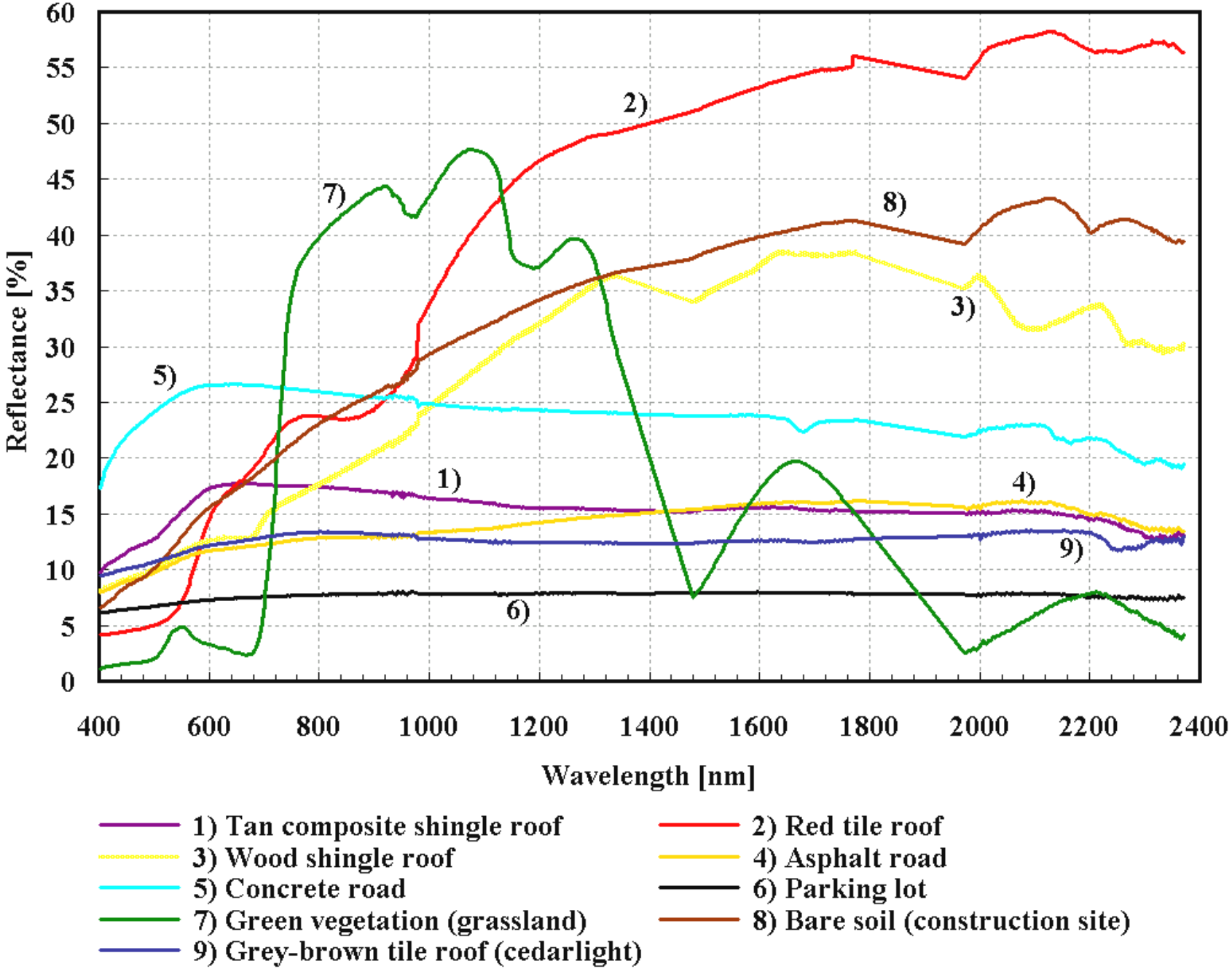
Three technologies

- Remote sensing
  - viewing the Earth from above
- Geographic information systems
  - digital representations of the Earth
- The Global Positioning System
  - direct measurement of location





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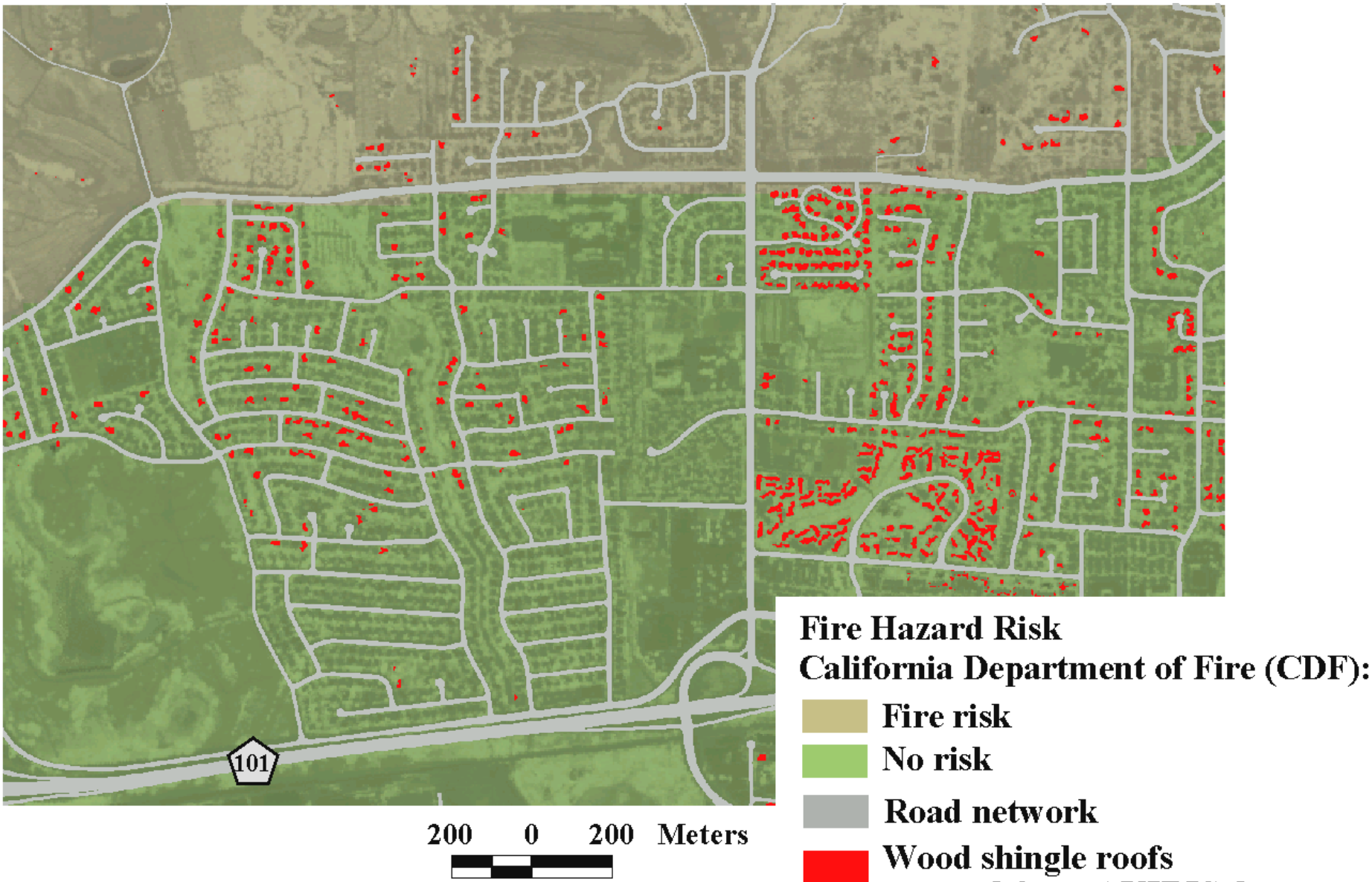
1) Tan composite shingle roof
2) Red tile roof
3) Wood shingle roof
4) Asphalt road
5) Concrete road
6) Parking lot
7) Green vegetation (grassland)
8) Bare soil (construction site)
9) Grey-brown tile roof (cedarlight)


101
200 0 200 Meters
Fire Hazard Risk
California Department of Fire (CDF):
Fire risk
No risk
Road network
Wood shingle roofs
mapped from AVIRIS data

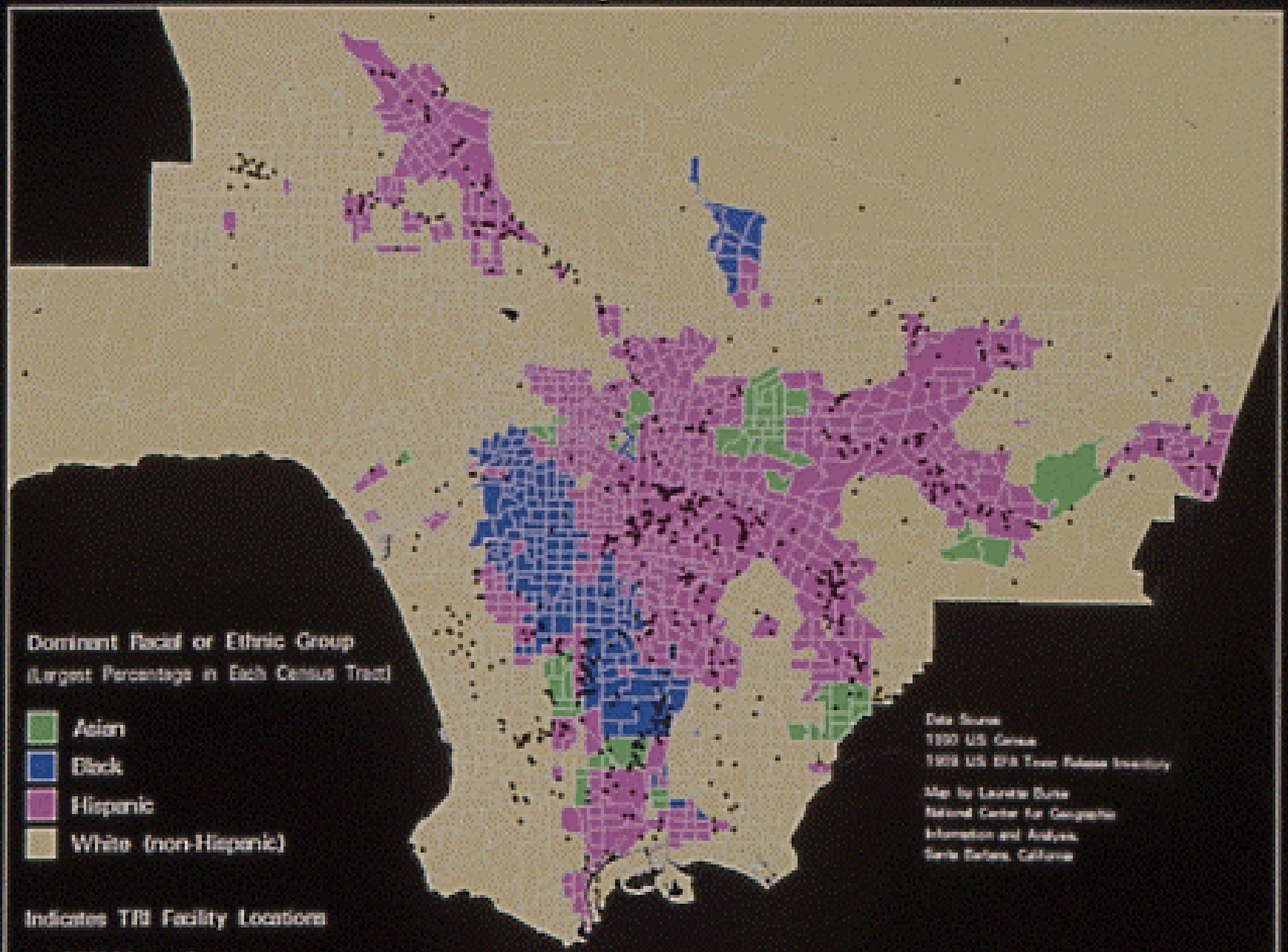
Geographic information system

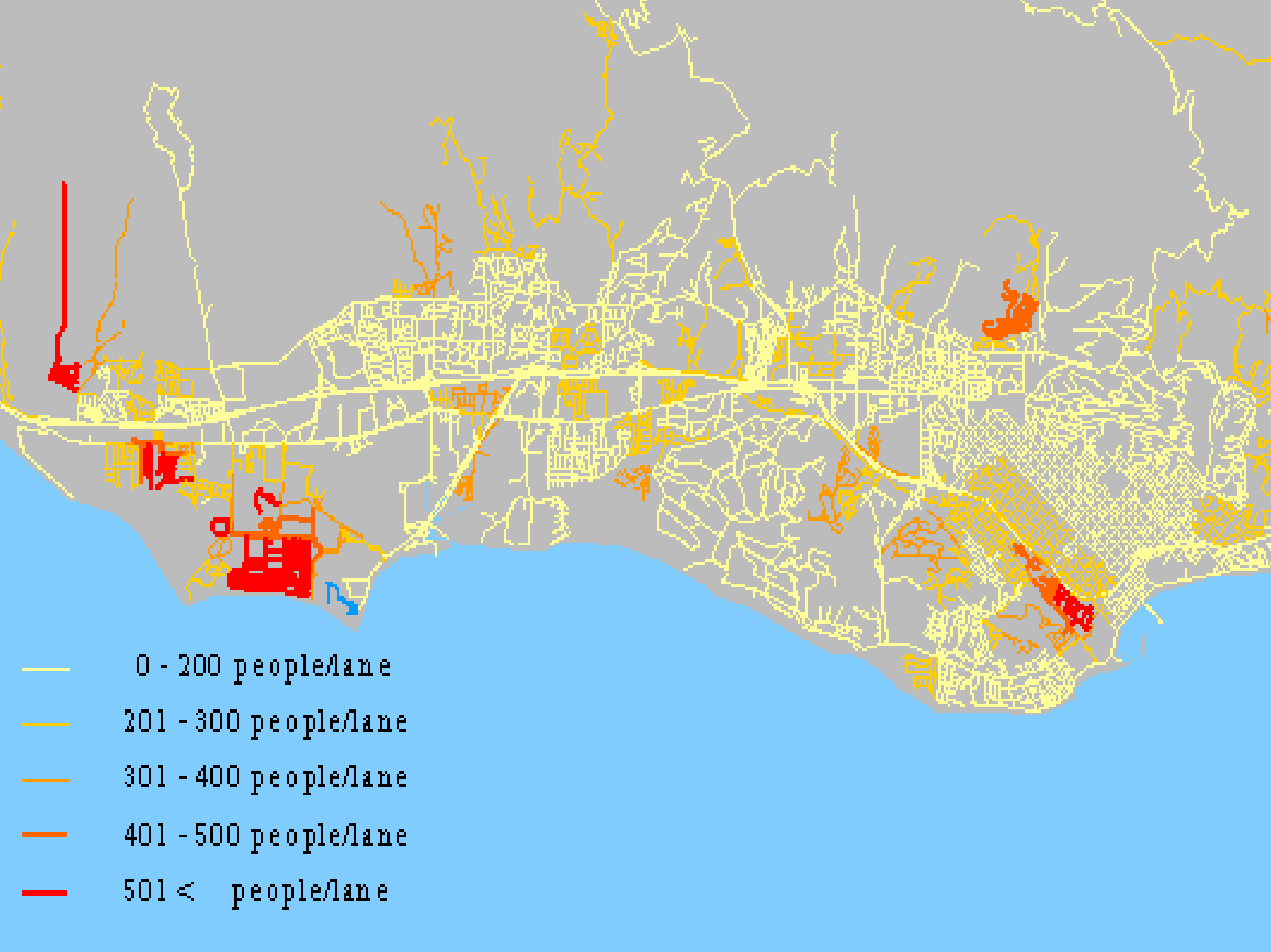
- System to acquire, store, transform, analyze, display, share, archive geographic information
- Geographic information
  - information about the specific characteristics of places on or near the Earth's surface
  - <***x***,***z***> where ***x*** is a location in space-time and ***z*** is some set of general properties

Standard coding schemes

- Music: MIDI, MP3
- Images: JPEG, TIFF, GIF
- FAX: CCITT
- Text: ASCII
- Planet Earth: ?

Race, Ethnicity and TRI Facilities

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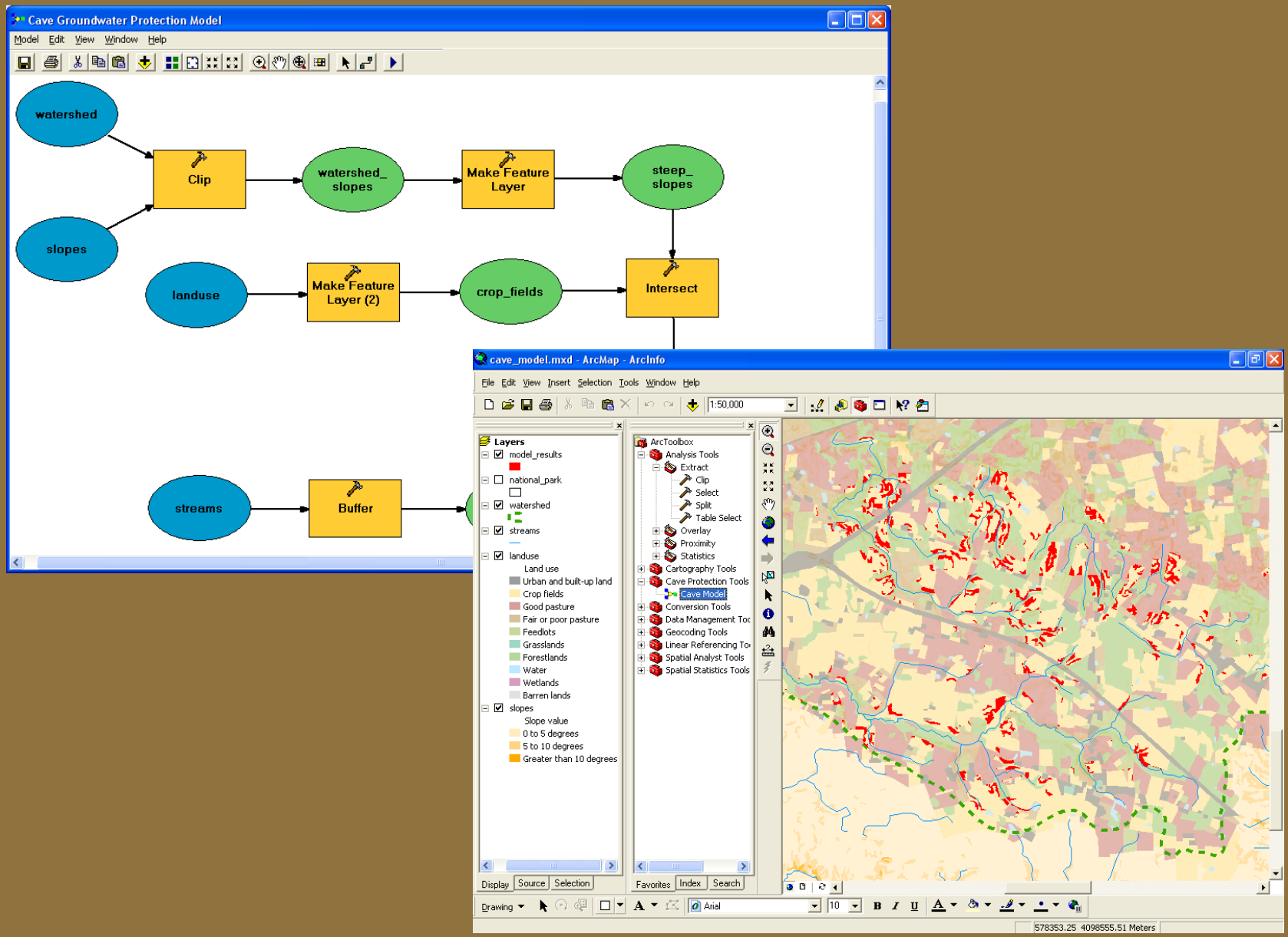
201 - 300 people/lane
301 - 400 people/lane
401 - 500 people/lane
501 < people/lane


Cave Groundwater Protection Model
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slopes
Clip
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streams
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Land use
Urban and built-up land
Crop fields
Good pasture
Fair or poor pasture
Feedlots
Grasslands
Forestlands
Water
Wetlands
Barren lands
slopes
Slope value
0 to 5 degrees
5 to 10 degrees
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Display Source Selection
ArcToolbox
Analysis Tools
Extract
Clip
Select
Split
Table Select
Overlay
Proximity
Statistics
Cartography Tools
Cave Protection Tools
Cave Model
Conversion Tools
Data Management Tools
Geocoding Tools
Linear Referencing Tools
Spatial Analyst Tools
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Favorites Index Search
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PASS

File View Tools Window Help

List View

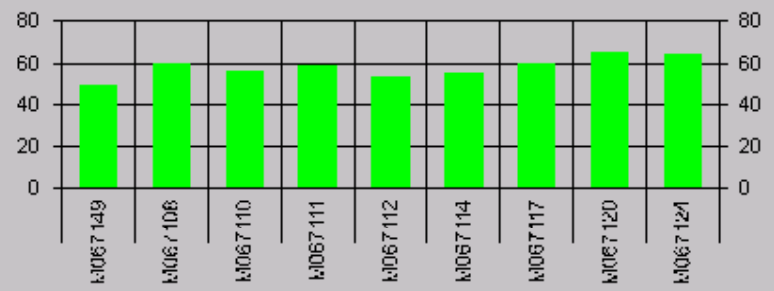
WorkCtr | Location | Visit

M067124

Name	Address	Units	Hrs/Mth	M	Type
1130 VERMONT	1130 VERMONT S	1	0.9	7	HY
625 NEW HAMPSHIRE	625 NEW HAMPSHII	1	0.9	2	HY
3611 WILSHIRE	3611 WILSHIRE BLV	1	0.8	6	HY
114 OXFORD	114 OXFORD S	1	0.8	3	HY
3099 OLYMPIC CAL KOREA B.	3099 OLYMPIC BLVI	1	0.9	5	HY
542 MARIPOSA GORDON CHI	542 MARIPOSA S	1	0.8	5	HY
140 MARIPOSA AVE	140 MARIPOSA AVE	1	0.9	9	HY
209 MARIPOSA S	209 MARIPOSA S	1	0.8	5	HY
2930 FRANCIS	2930 FRANCIS	1	0.9	4	HY
248 OCCIDENTAL	248 OCCIDENTAL	1	0.9	3	HY
601 WESTMORELAND	601 WESTMORELAI	1	0.7	4	HY
303 COMMONWEALTH	303 COMMONWEAL	1	0.9	9	HY
2830 FRANCIS	2830 FRANCIS	1	0.9	7	HY
187 OXFORD OXFORD VILLA	187 OXFORD	1	0.9	8	HY
601 ARDMORE PUBLIC COUI	601 ARDMORE AVE	1	0.7	5	HY
3535 SIXTH ST.	3535 W SIXTH	1	0.7	5	HY
1052 MARIPOSA AVE	1052 S MARIPOSA	1	1.0	0	HY
128 MARIPOSA AV S	128 MARIPOSA AV S	1	0.8	4	HY
449 KINGSLEY BLDG	449 KINGSLEY DRIV	2	1.9	2	HY
445 HOBART	445 HOBART	2	1.8	6	HY
350 CATALINA BLDG	350 CATALINA STRE	1	0.9	6	HY
3500 EIGHTH STREET BLDG	3500 EIGHTH STRE	1	0.9	5	HY
3020 WILSHIRE BLDG	3020 WILSHIRE BLV	2	0.0	0	HY

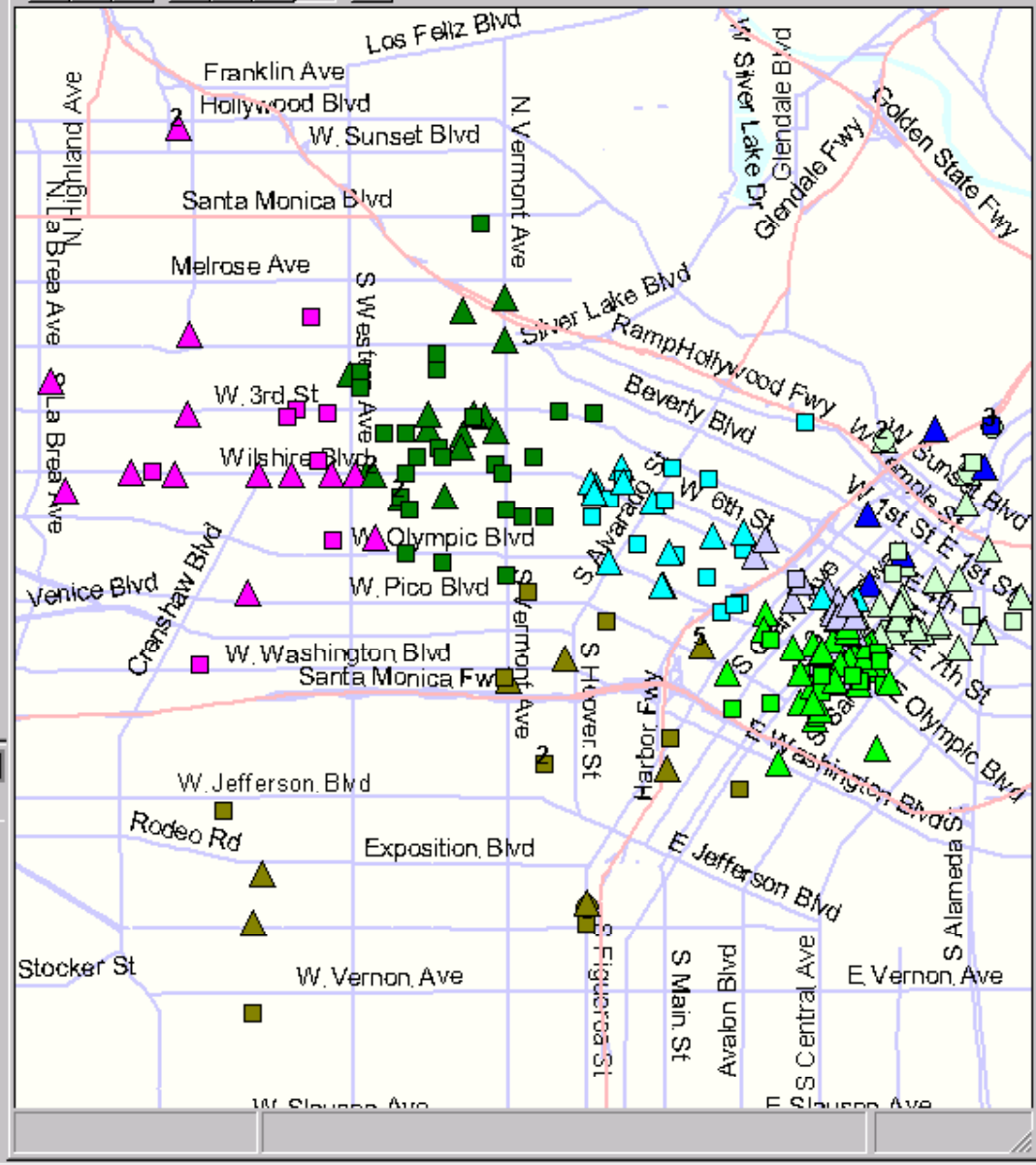
Chart

Chart All | Dollars | Units | Hours | C1



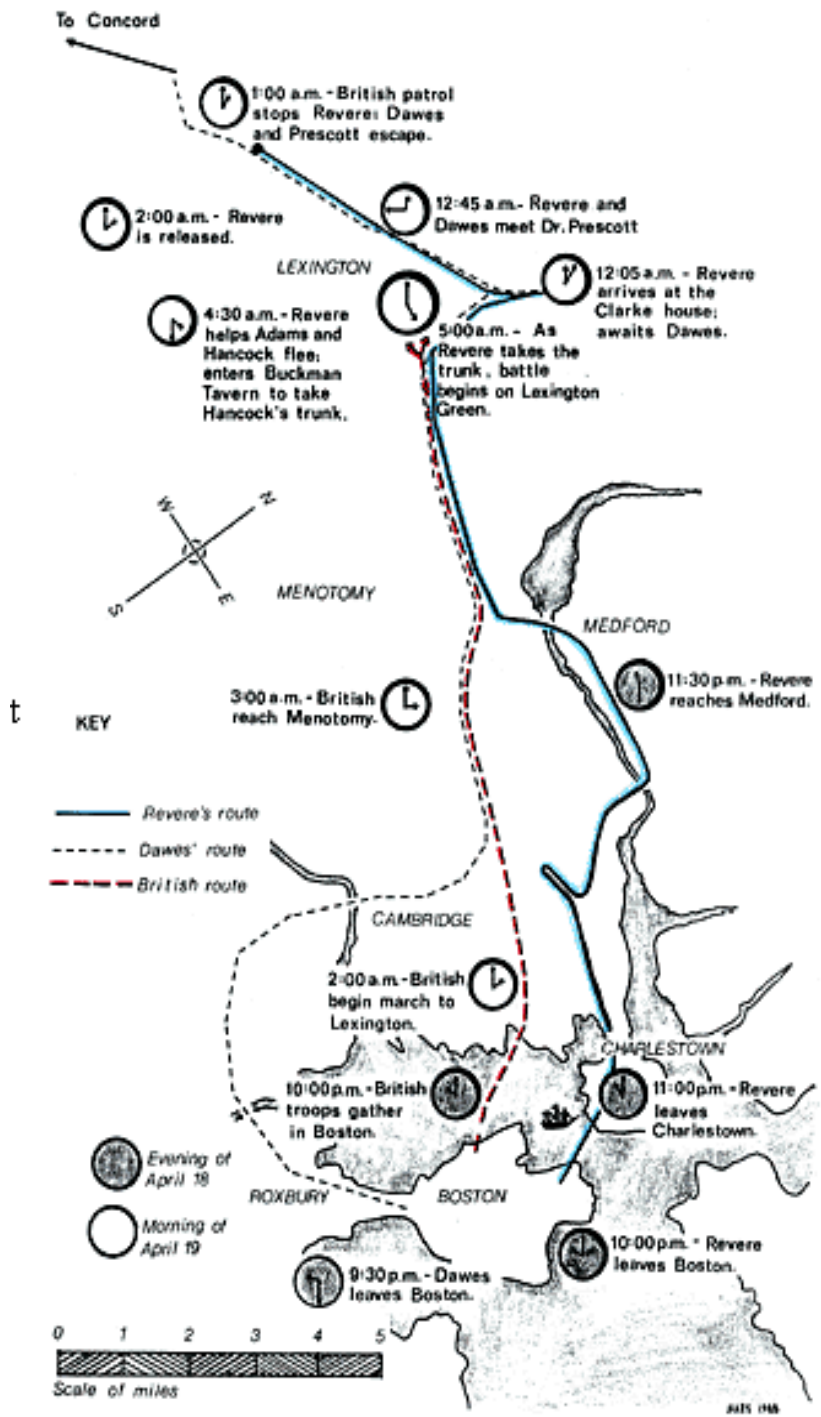
Map

Show selected only



9/12/99 10:39 PM

Directions	Distance
1: Start out going East on HENLEY ST towards WARREN ST.	0.1 miles (0.1 km)
2: Turn RIGHT onto WARREN ST.	0.0 miles (0.1 km)
3: Turn RIGHT onto CHELSEA ST.	0.0 miles (0.1 km)
4: CHELSEA ST becomes CHELSEA ST/CITY SQ.	0.1 miles (0.1 km)
5: Turn RIGHT onto CITY SQ/NEW RUTHERFORD AVE/SR-99 N.	0.0 miles (0.1 km)
6: Stay straight to go onto NEW RUTHERFORD AVE/SR-99 N.	0.2 miles (0.3 km)
7: Turn SLIGHT LEFT onto SR-99 N.	0.4 miles (0.6 km)
8: Turn SLIGHT LEFT onto SR-99 N/RUTHERFORD AVE.	0.1 miles (0.1 km)
9: Turn SLIGHT LEFT onto SR-99 N.	0.3 miles (0.4 km)
10: Turn SLIGHT LEFT onto SULLIVAN SQUARE OPAS.	0.4 miles (0.7 km)
11: Turn SLIGHT LEFT onto MYSTIC AVE.	0.7 miles (1.1 km)
12: MYSTIC AVE becomes MYSTIC AVE/SR-38 N.	1.2 miles (2.0 km)
13: Turn LEFT onto HARVARD ST.	0.6 miles (1.0 km)
14: HARVARD ST becomes WARNER ST.	0.2 miles (0.3 km)
15: Turn RIGHT onto POWDER HOUSE SQ.	0.1 miles (0.1 km)
16: Turn RIGHT onto BROADWAY.	1.0 miles (1.6 km)
17: Turn LEFT onto ALEWIFE BROOK PKWY/SR-16.	0.4 miles (0.7 km)
18: ALEWIFE BROOK PKWY/SR-16 becomes ALEWIFE BROOK PKWY/SR-16/US-3.	0.4 miles (0.7 km)
19: Take CONCORD TURNPIKE/SR-2 W.	4.7 miles (7.6 km)
20: Take the WALTHAM ST. exit, exit number 54B, towards LEXINGTON.	0.2 miles (0.3 km)
21: Merge onto WALTHAM ST.	1.9 miles (3.0 km)
22: Turn RIGHT onto MASSACHUSETTS AVE/MASS AVE/SR-225.	0.0 miles (0.0 km)
Total Distance:	12.9 miles (20.8 km)
Estimated Time:	24 minutes



Trimble Placer GPS 400
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lan GPS Companion for Visor
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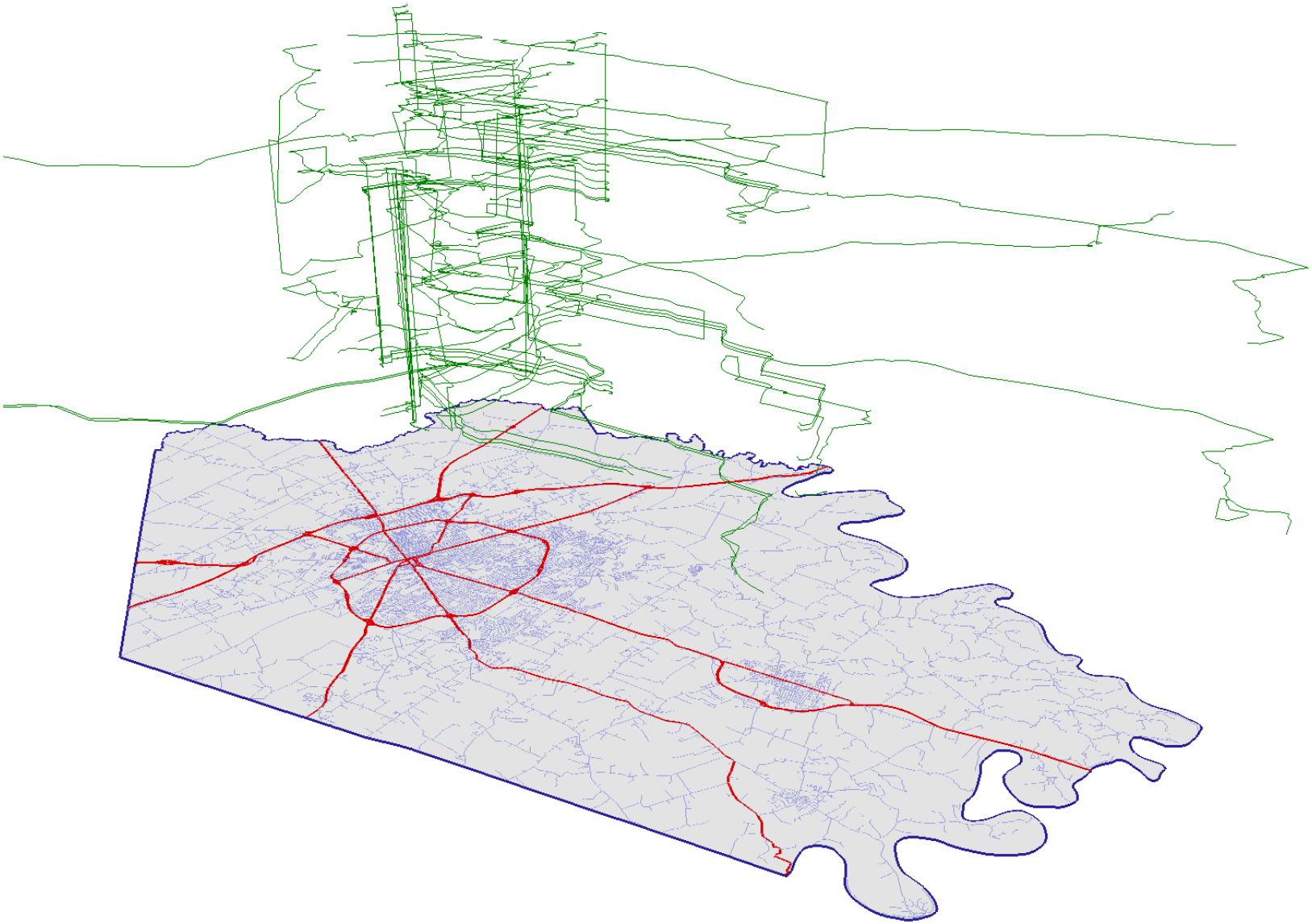

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Help

Low Graphics

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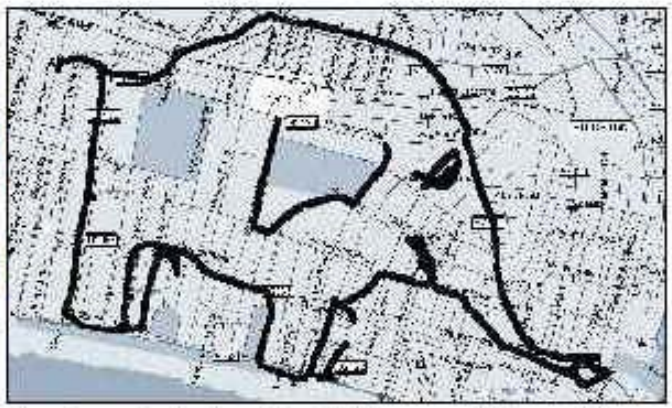
Monday, 15 October, 2001, 12:20 GMT 13:20 UK

Safari by satellite



The biggest elephant in Brighton - and the world

Satellite tracking is commonly used to avoid traffic jams. But it is now being used to find elephants in Brighton, writes BBC News Online's technology correspondent Mark Ward

The evidence of our effect on the land is all around us.

Roads divide landscapes, hills are shorn of their trees, tunnels are punched through mountains and cities pockmark the countryside with pavements and homes.

dot.life

Every Monday, the guide to getting buttoned up

- Phones, tones and music
- Write here, right now
- Fax machine rebellion
- Ads we can't avoid
- What if ET called us?
- Forgetful? Don't stress

See also:

- 05 Mar 01 | dot life
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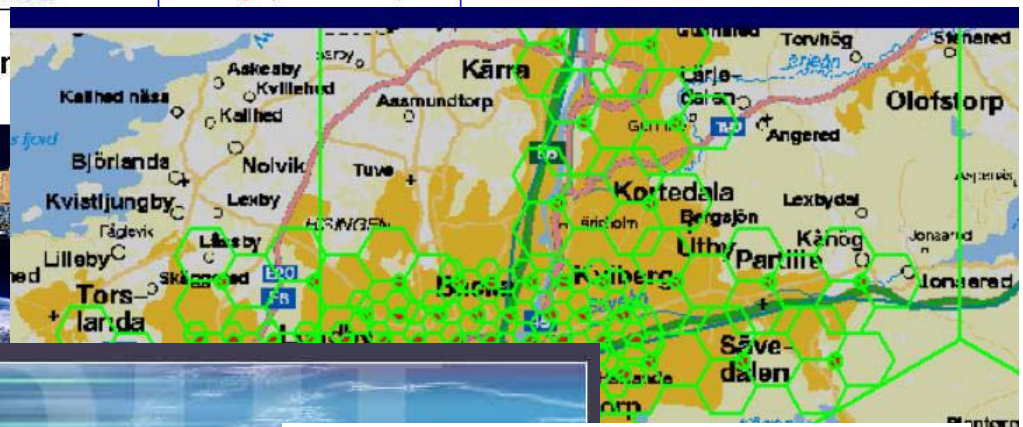
AEROASTRO
Making Space for Everyone

GPS NEWS

More Than 10 Million Subscr
Served by gpsOne

San Diego - Feb 13, 2003

Qualcomm has announced that more than 10 million gpsOne-enabled devices are now in commercial use in Japan, South Korea and the United States. Sales of phones



mMode

FEATURES

FIND FRIENDS

As part of mMode you get Find Friends—a cool new tool that enables you to see the locations of your favorite people and schedule a great place to meet up with them! It's the first service of its kind in North America, and only available from AT&T Wireless.

FEATURES

- Q & A
- Troubleshooting
- How-to
- Privacy

Bring everyone toge

Find Friends makes i

- Add friend list.
- See who's
- Call or ser
- Get direct pubs, and
- Make your
- Locate up
- Best part?

SMART MOBS

THE • NEXT • SOCIAL • REVOLUTION

Home | Ab

Mobile communication, pervasive computing, wireless networks, collective action.

About the Book

- » Table of Contents
- » Book Summary
- » Reviews, Articles, Interviews
- » Appearance Schedule
- » Bibliography

Smart mobs emerge when communication and computing technologies amplify human talents for cooperation. The impacts of smart mob technology already appear to be both beneficial and destructive.

more...

About the Book

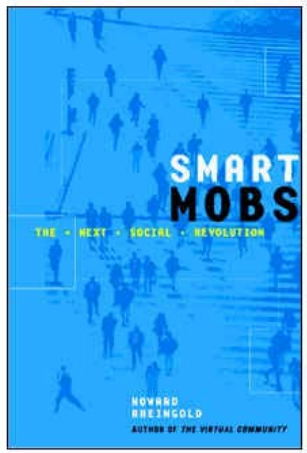
» **Table of Contents:**
The chapters of Smart Mobs, including summaries of each chapter and weblog entries for that chapter.

» **Book Summary:**
A summary of the book

» **Reviews and Articles:**
Links to outside evaluations of the book.

» **Appearance Schedule:**
See Howard Rheingold in your area discussing the book and its implications.

» **Bibliography:**
Information about resources used in the creation of Smart Mobs.



Smart mobs emerge when communication and computing technologies amplify human talents for cooperation. The impacts of smart mob technology already appear to be both beneficial and destructive, used by some of its earliest adopters to support democracy and by others to coordinate terrorist attacks. The technologies that are beginning to make smart mobs possible are mobile communication devices and pervasive computing - inexpensive microprocessors embedded in everyday objects and environments. Already, governments have fallen, youth subcultures have blossomed from Asia to Scandinavia, new industries have been born and older industries have launched furious counterattacks.

Location-based games

- Played on location-enabled devices
  - cellphones

Date Posted: January 18, 2003

False Alarm

Suspected car bomb turns out to be tracking device

By BRADEN BUNCH
Item Staff Writer

A device that appeared to be a bomb on a vehicle parked outside Simpson's Hardware and Sports on Wesmark Boulevard kept local and state authorities busy for nearly four hours Friday before the object was found to be a tracking system placed on the car by the driver's wife.

Sumter Police Chief Patty Patterson said police were called at 3:23 p.m. when a sales representative for Simpson's Sales Co., who was delivering an order of Browning firearms, spotted a suspicious package on the undercarriage of his Chevrolet Suburban as he came out of the store.

After a preliminary inspection indicated to authorities that the device could be an explosive, surrounding businesses were ordered closed and authorities evacuated the area within a mile of the vehicle.

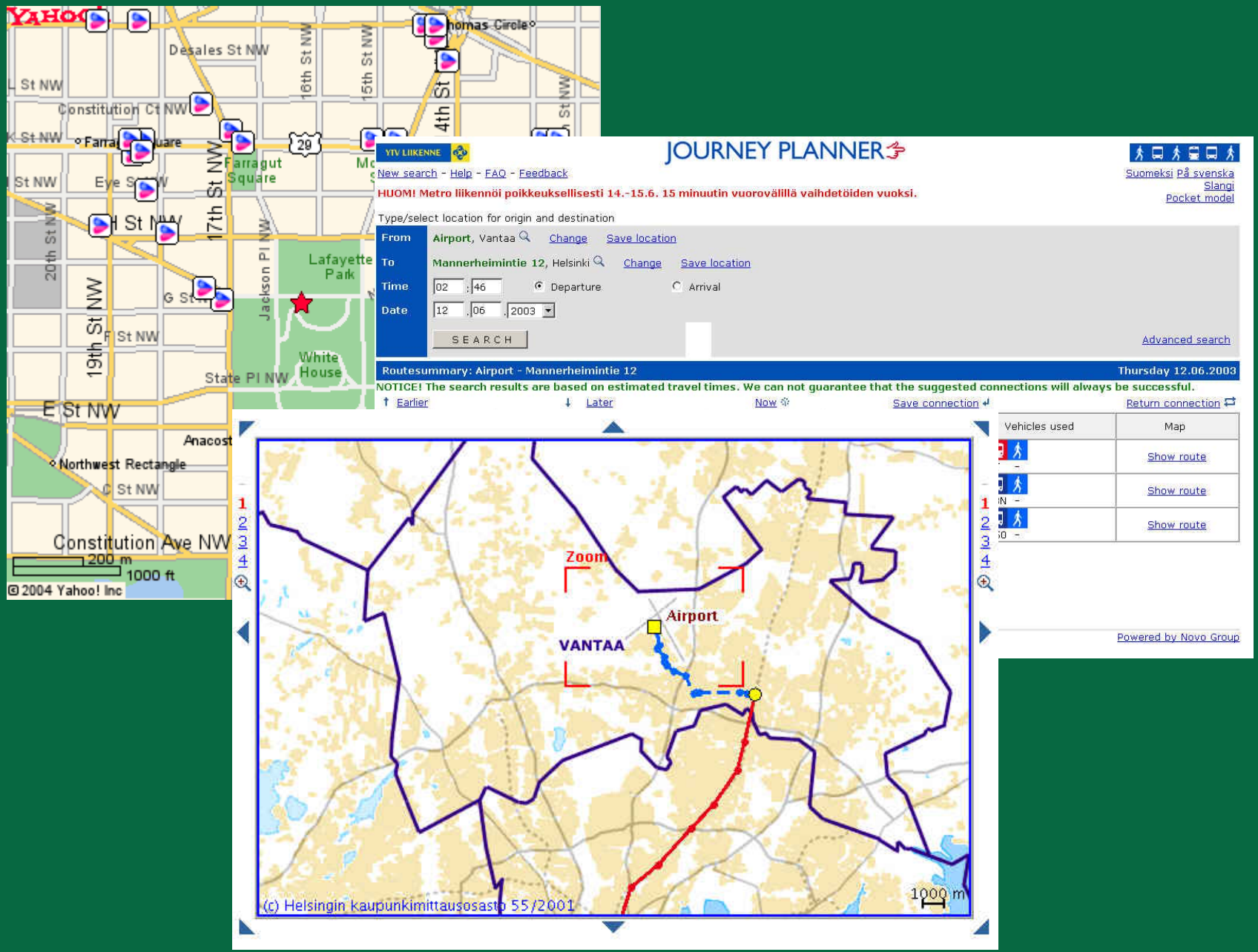
Described as a "very professional-looking device," the object was thought to be several sticks of dynamite with a remote detonation transmitter attached. The entire device, authorities said, was attached to the vehicle with duct tape.

Hours later, Patterson said, authorities learned from a call by the Florence man's wife that she had placed the tracking device on the car so she could keep tabs on her husband.

Soon after the initial 911 call, local police were joined by several dozen safety workers from Shaw Air Force Base, the State Law Enforcement Division, Sumter Fire Department, Sumter County Emergency Medical Services and the Sumter County Department of Public Safety.

Chris Moore / The Item

A robot from the Shaw Air Force Base bomb squad approaches a Chevrolet Suburban in order to get a closer look at the truck Friday afternoon. The wire hanging below the Suburban was connected to a tracking device believed to be a bomb.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Constitution Ct NW
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17th St NW
Lafayette Park
Jackson Pl NW
White House
State Pl NW
19th St NW
20th St NW
Anacost
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YTV LIIKENNE
JOURNEY PLANNER
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NOTICE! The search results are based on estimated travel times. We can not guarantee that the suggested connections will always be successful.
Earlier Later Now Save connection Return connection
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Zoom
Airport
VANTAA
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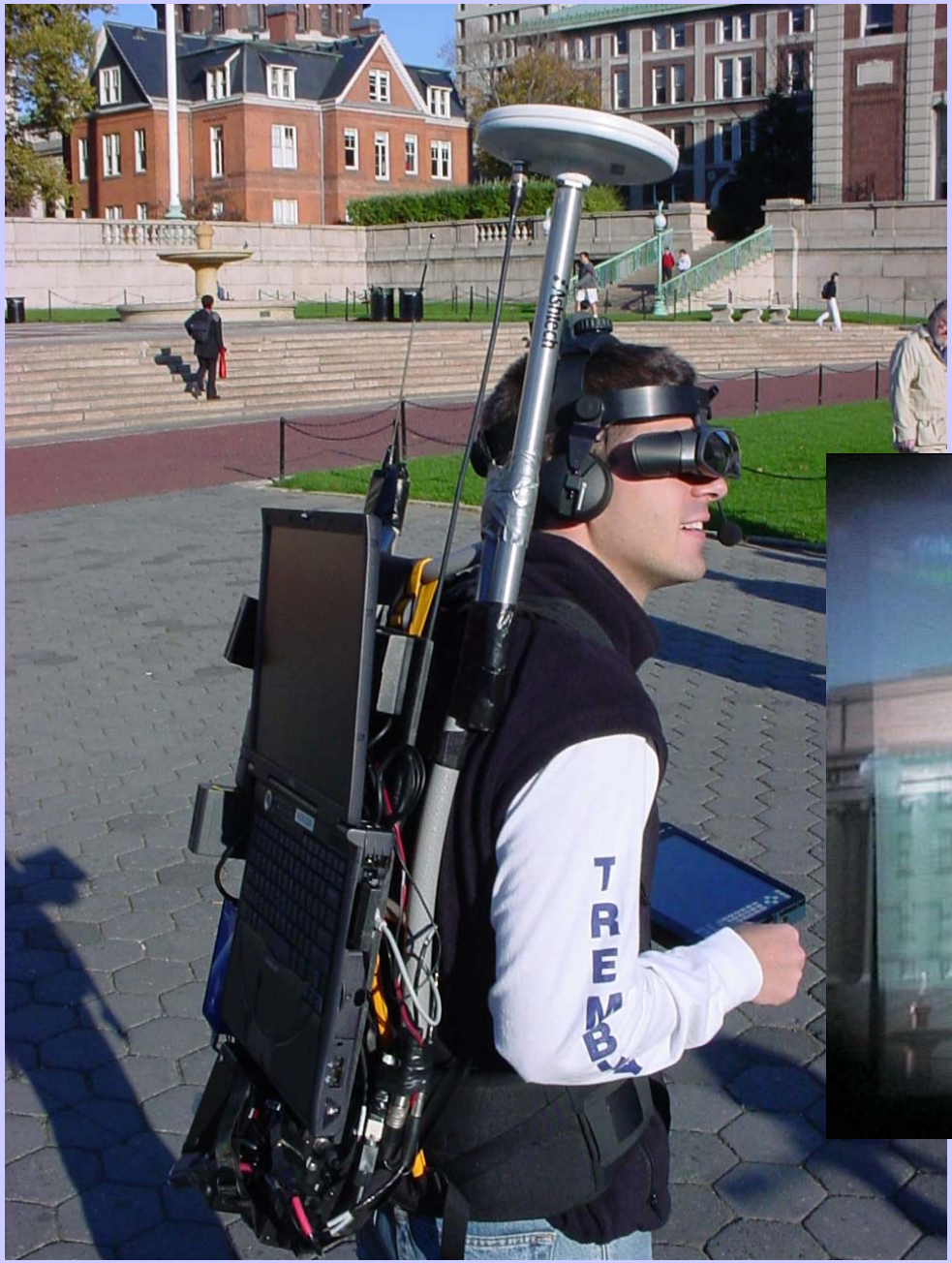

TREMB

Does geographic information have general properties?

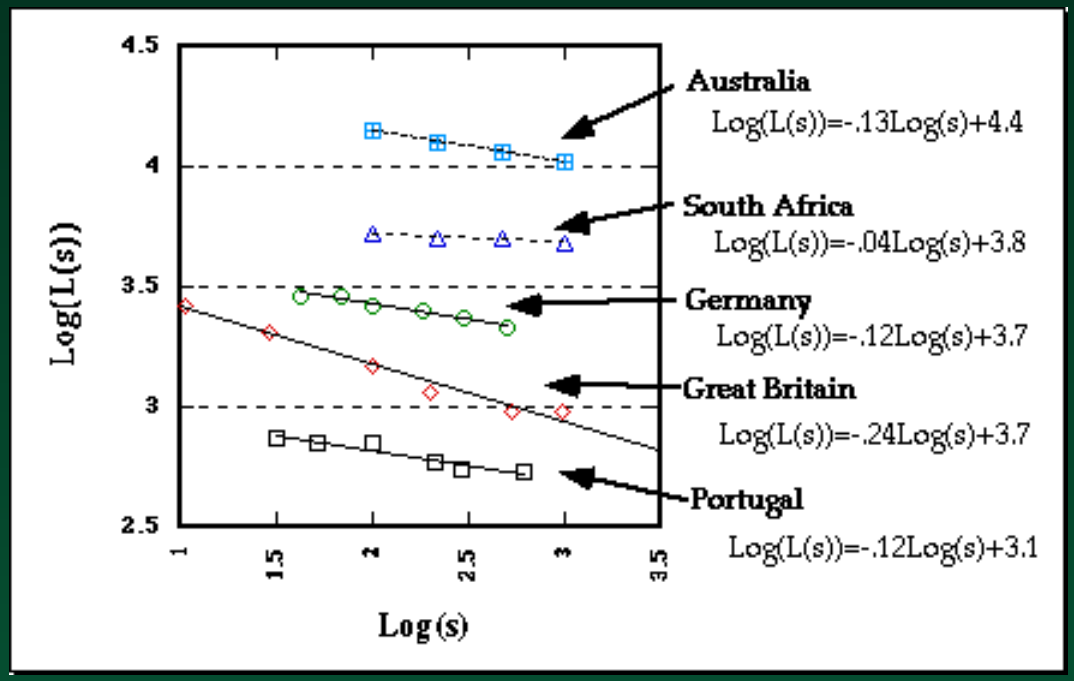
- The laws of GIScience
- Properties that can inform system design

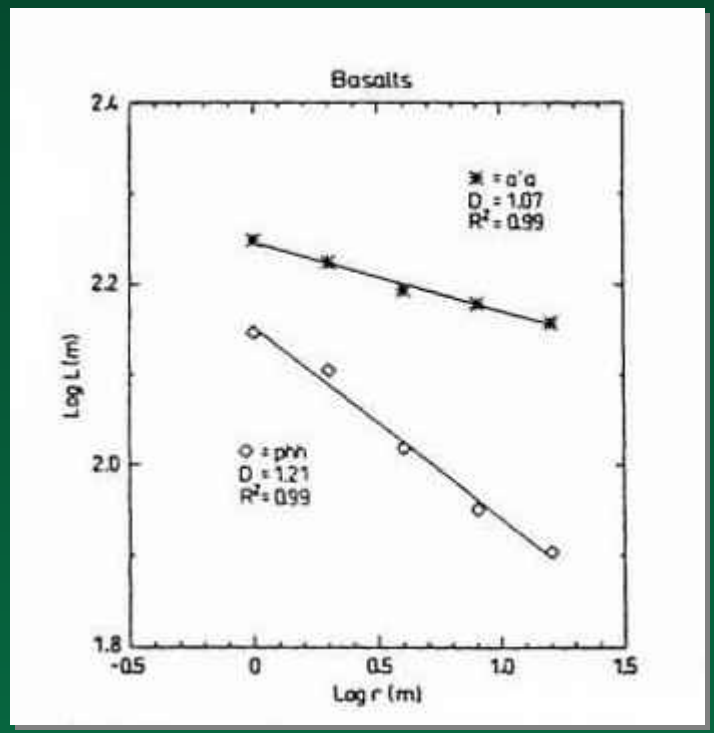
Tobler's First Law of Geography

- All things are related, but nearby things are more related than distant things
  - Tobler, W.R., 1970. A computer movie simulating urban growth in the Detroit region. *Economic Geography* 46: 234-240.
- Interpolation from limited observations
  - the nightly weather map
- Facts about areas
  - rather than facts about points

Other laws?

- A fractal law
  - the more closely you look the more detail you see
  - additional detail is revealed at a predictable rate
- How will information partition across scales?

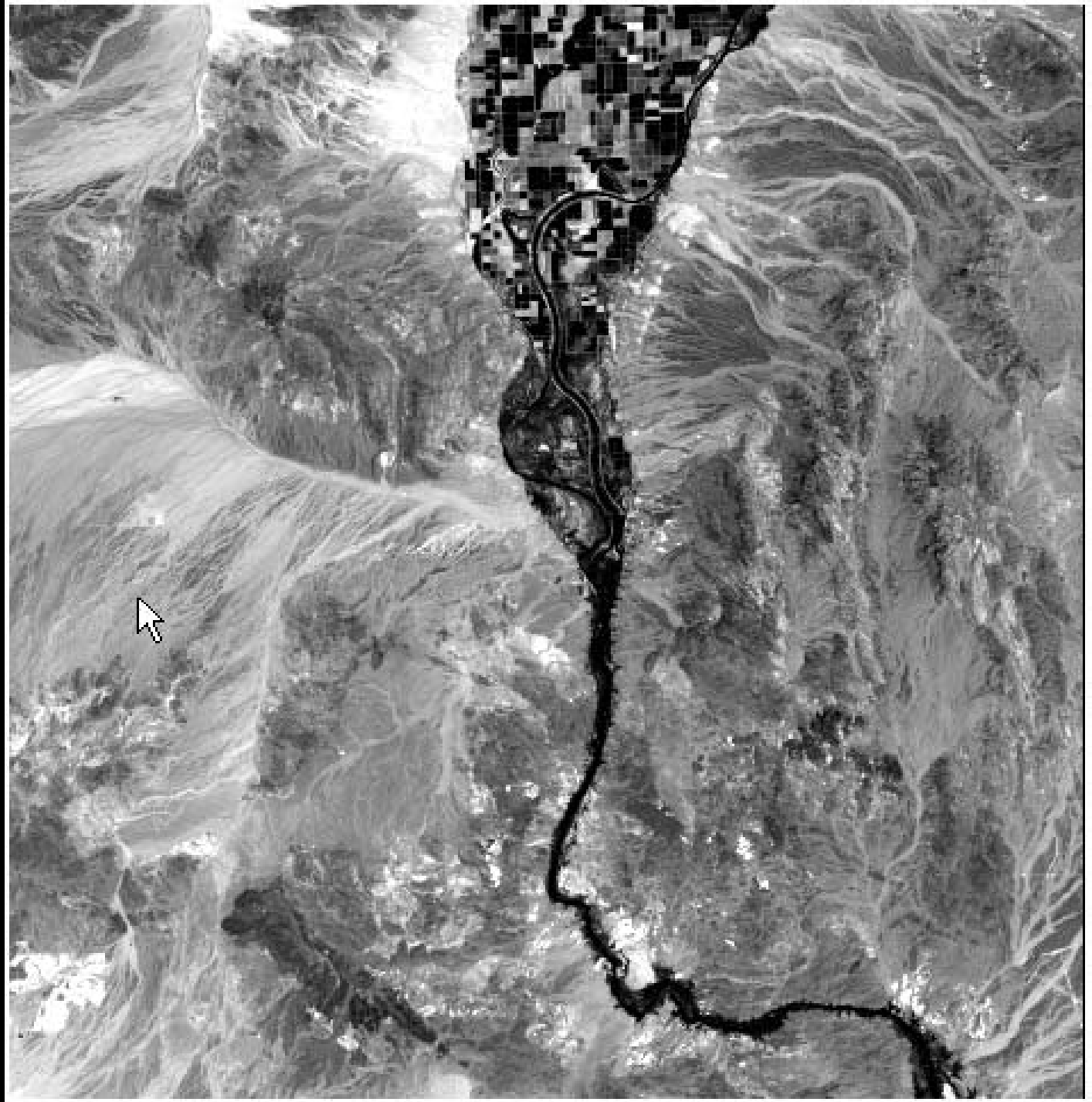

Australia
Log(L(s))=-.13Log(s)+4.4
South Africa
Log(L(s))=-.04Log(s)+3.8
Germany
Log(L(s))=-.12Log(s)+3.7
Great Britain
Log(L(s))=-.24Log(s)+3.7
Portugal
Log(L(s))=-.12Log(s)+3.1
Log(L(s))
Log (s)
4.5
4
3.5
3
2.5
1
1.5
2
2.5
3
3.5

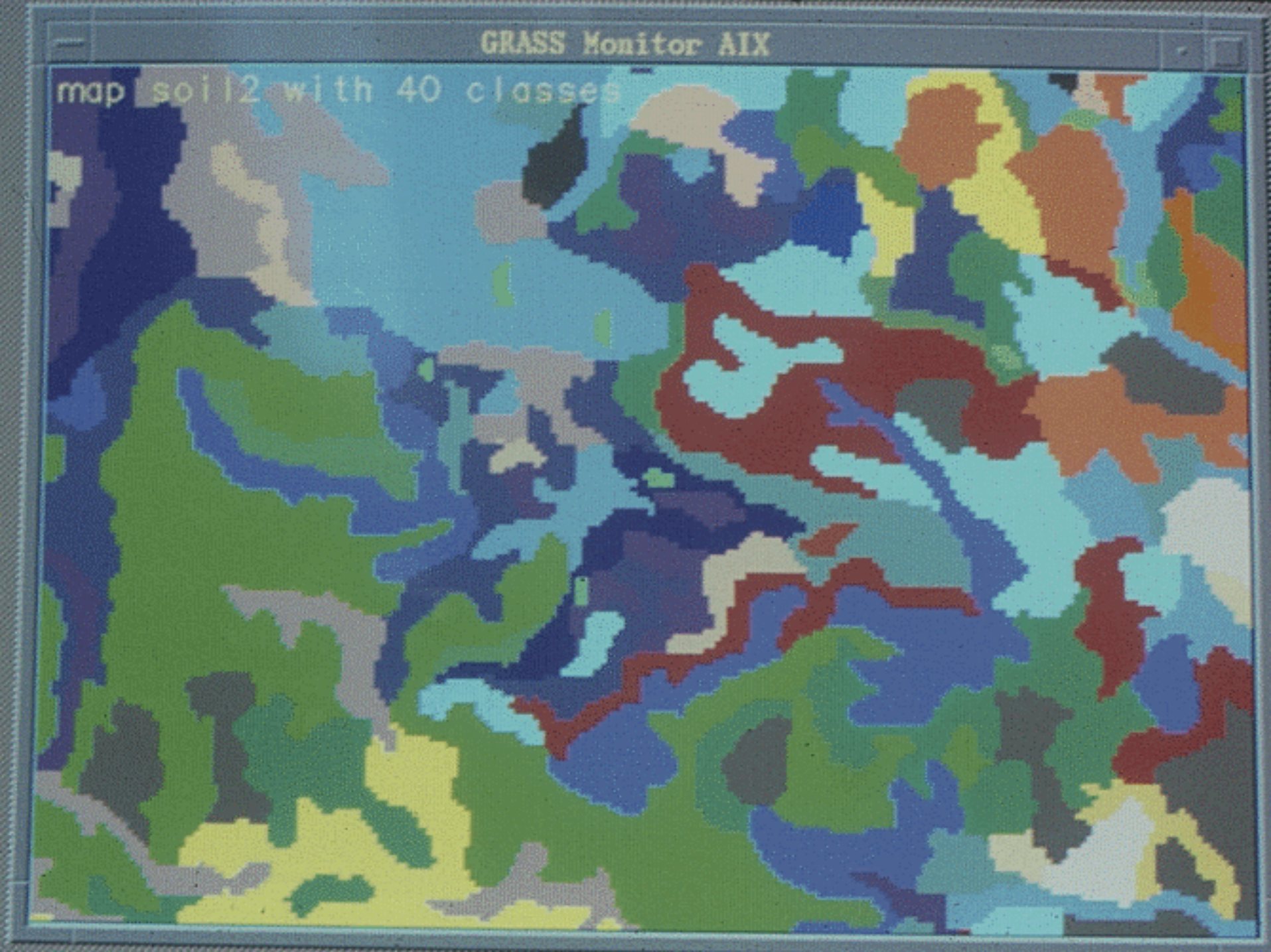

Basalts
Log L (m)
Log r (m)
2.4
2.2
2.0
1.8
-0.5
0
0.5
1.0
1.5

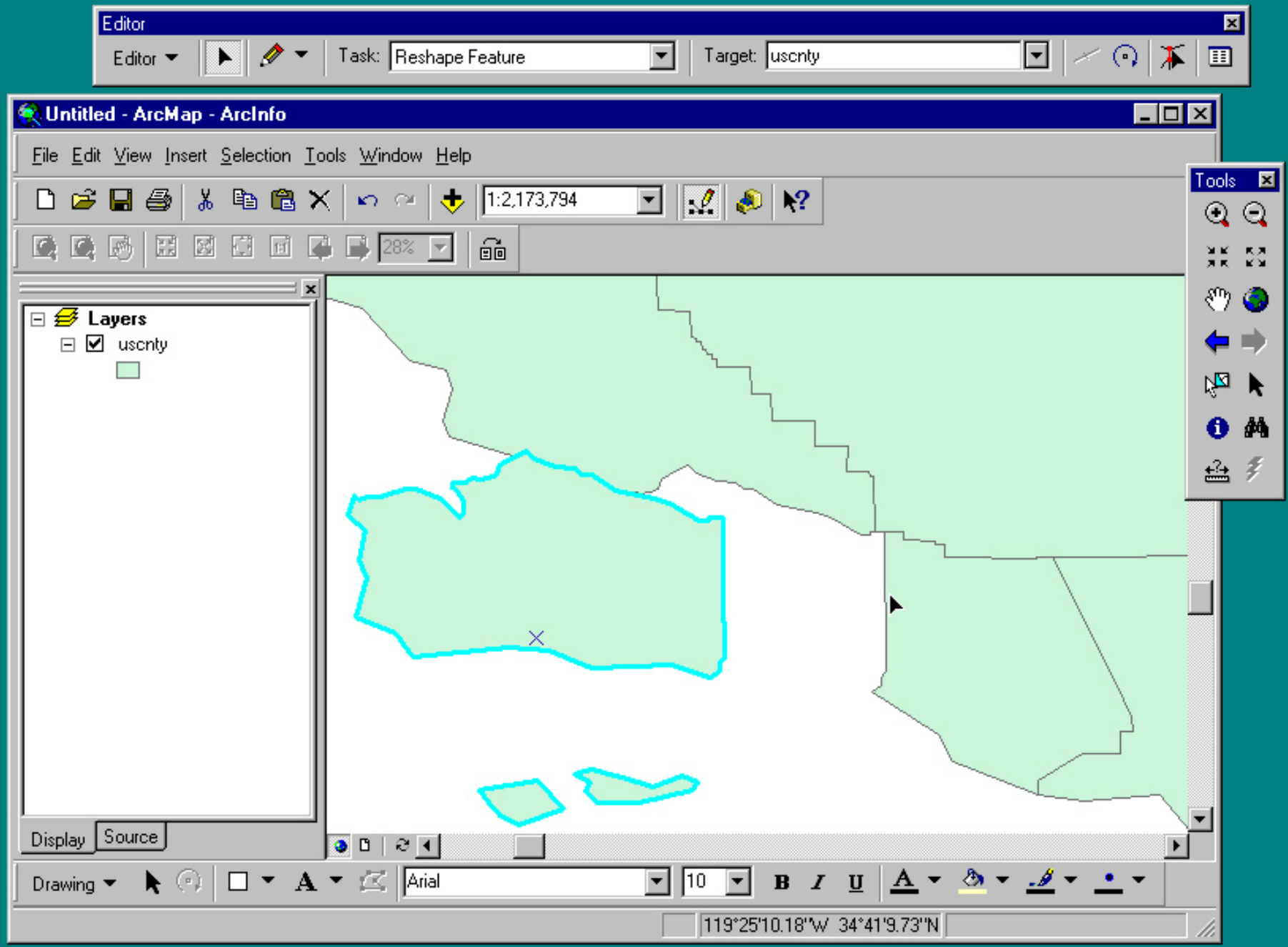
Objects and fields

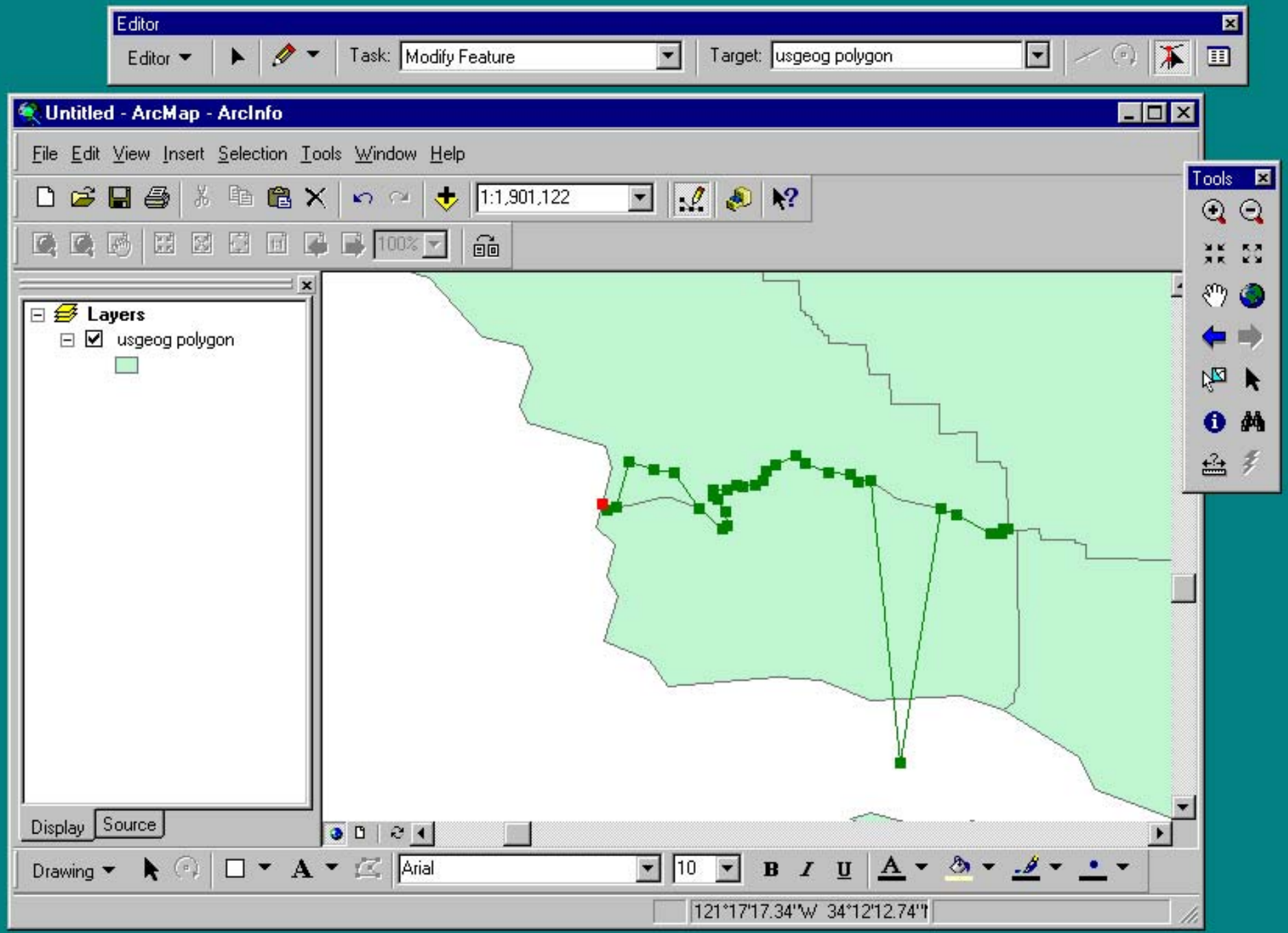
- Two ways of conceptualizing geographic variation


LVL=12,SOLID,WT=2,LC=SOL,CON,CO=3
Identify known point on digitizer
DIGITIZER SETUP (RESET TO EXIT)
(1) mge>
MGE
Fit
Select Feature
Set Feature
Make Feature
Digitize Mode
Define Attr
Auto loader
Geo db locate
Geo index locate
Display Mgr
Exit
Feature Code
Define
Keyin
Secondary Long Lat
East North
Secondary East North
Geocentric
Second Geocentric
Geodesic
Scale Factors
BROMLEY LN
HOPKINS AVE
MAIN ST



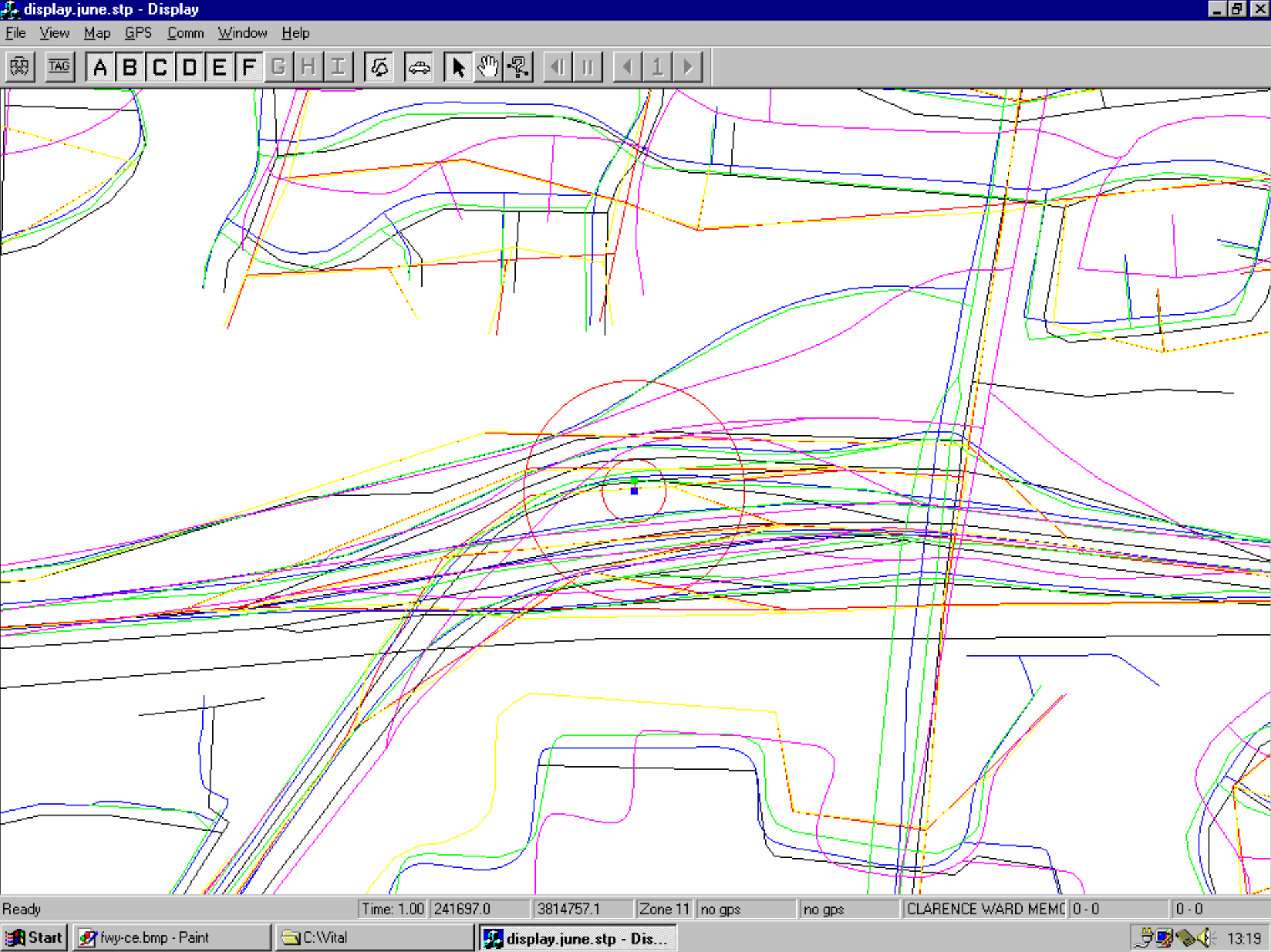

GRASS Monitor AIX
map soil2 with 40 classes


Editor
Editor
Task: Reshape Feature
Target: uscnty
Untitled - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:2,173,794
28%
Tools
Layers
uscnty
Display
Source
Drawing
Arial
10
B I U
119°25'10.18"W 34°41'9.73"N


Editor
Editor
Task: Modify Feature
Target: usgeog polygon
Untitled - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:1,901,122
100%
Tools
Layers
usgeog polygon
Display
Source
Drawing
Arial
10
121°17'17.34"W 34°12'12.74"

An uncertainty law

- It is impossible to measure location on the Earth's surface exactly
- All geographic data will be uncertain to some degree


display.june.stp - Display
File View Map GPS Comm Window Help
TAG A B C D E F G H I 1
Ready
Time: 1.00
241697.0
3814757.1
Zone 11
no gps
no gps
CLARENCE WARD MEMC
0 - 0
0 - 0
Start
fwy-ce.bmp - Paint
C:\Vital
display.june.stp - Dis...
13:19

A grand challenge of GIS

- To create useful, comprehensive digital representations of the enormous complexity of the Earth's surface in the limited space of a digital store, using a binary alphabet

“Imagine, for example, a young child going to a Digital Earth exhibit at a local museum. After donning a head-mounted display, she sees Earth as it appears from space. Using a data glove, she zooms in, using higher and higher levels of resolution, to see continents, then regions, countries, cities, and finally individual houses, trees, and other natural and man-made objects. Having found an area of the planet she is interested in exploring, she takes the equivalent of a ‘magic carpet ride’ through a 3-D visualization of the terrain.”

Is Digital Earth feasible?

- 500,000,000 sq km
  - 5 million at 10km resolution
  - 500,000,000,000,000 at 1m resolution

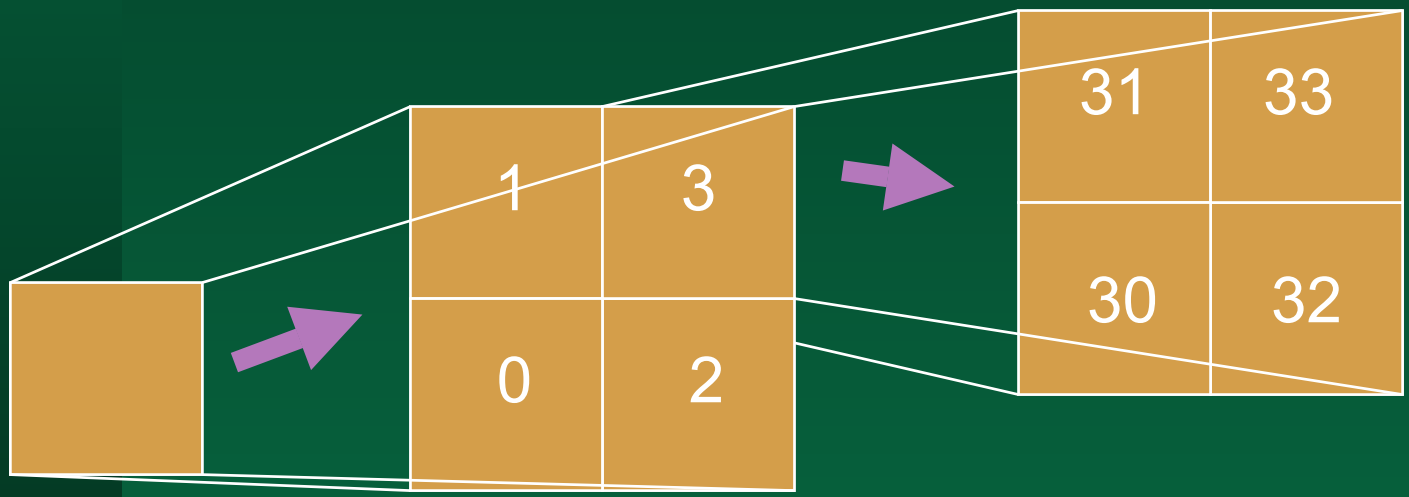
500,000,000,000,000 bytes
634,000,000 working years

The LS ratio

- Computer screen - 1000
- Digital camera - 1500
- Remotely sensed scene - 3000
- Paper map - 5000
- Dimensionless
- $Log_{10}L/S$ in range 3-4
- Human eye - 10,000

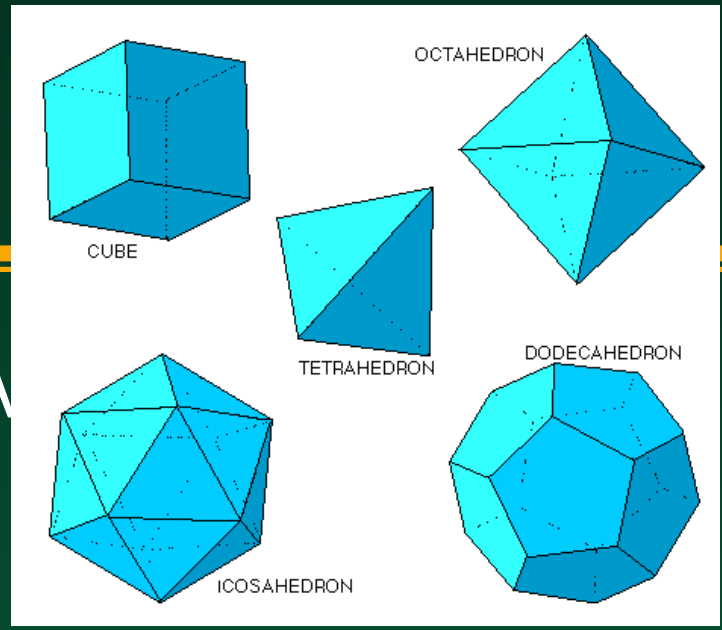
The quadtree

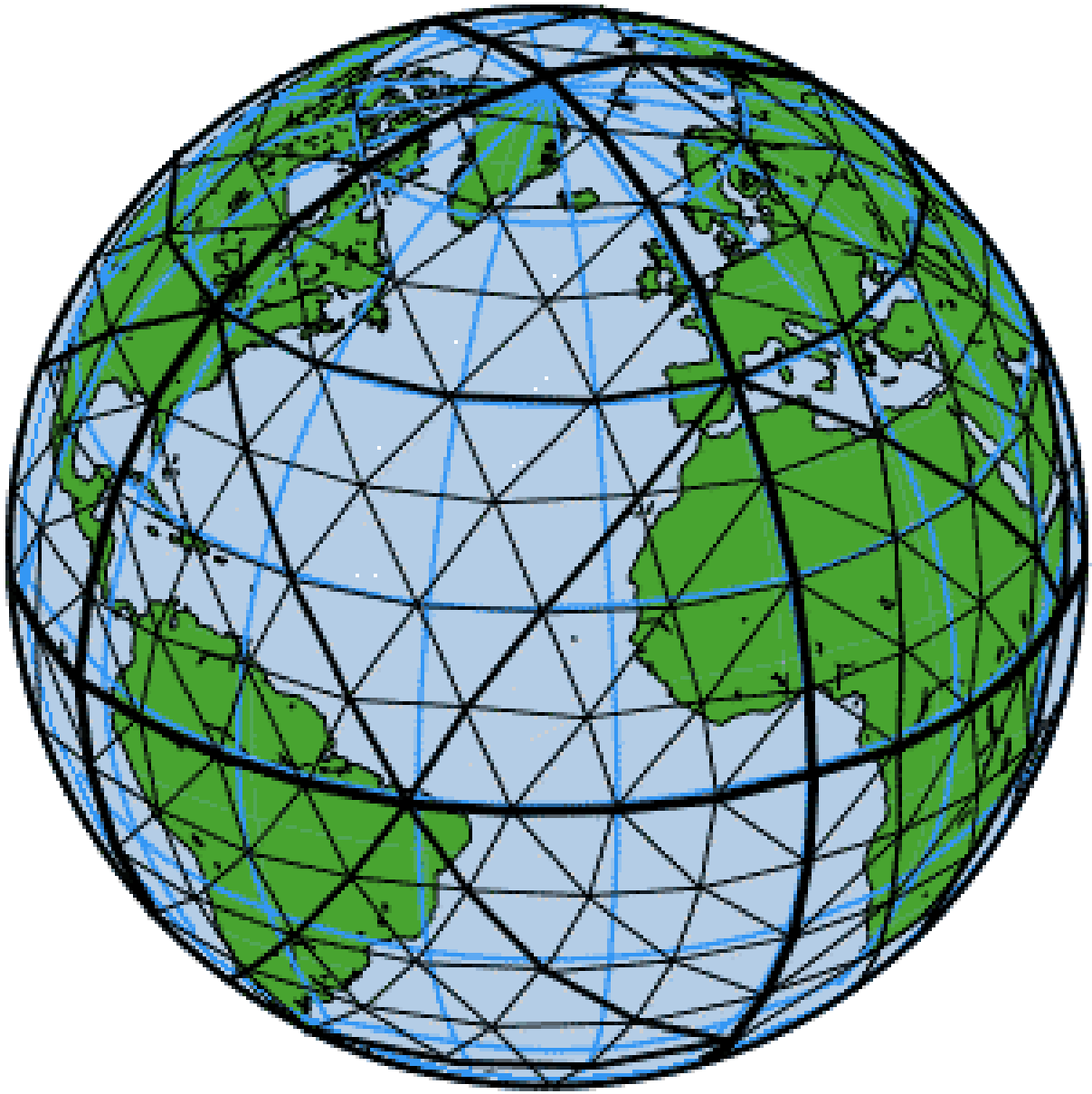
- Recursive subdivision
  - variable depth depending on local detail

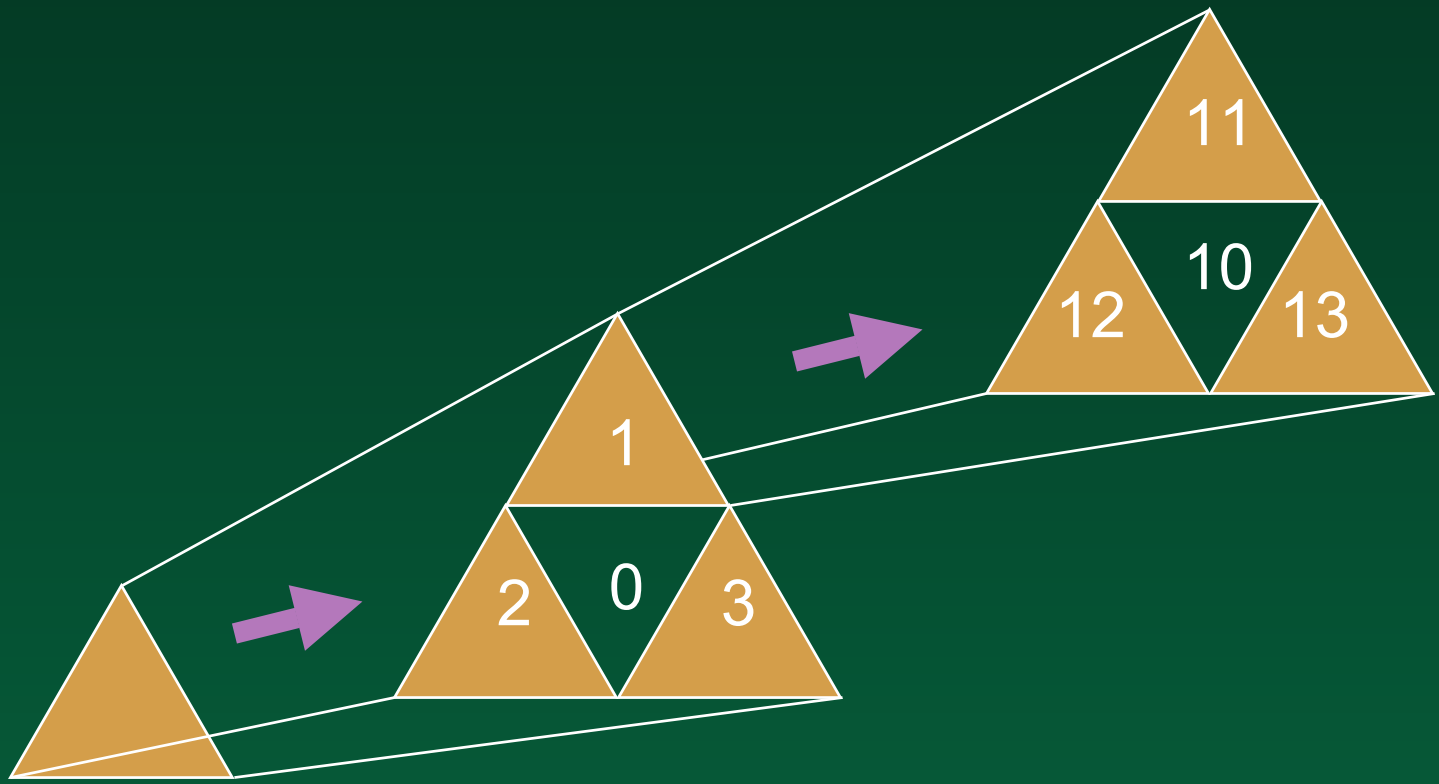


Grids on the globe

- Impossible to tile a curv
  squares
- Five Platonic solids
  - tetrahedron: 4 triangles
  - cube: 6 squares
  - octahedron: 8 triangles
  - dodecahedron: 12 pentagons
  - icosahedron: 20 triangles







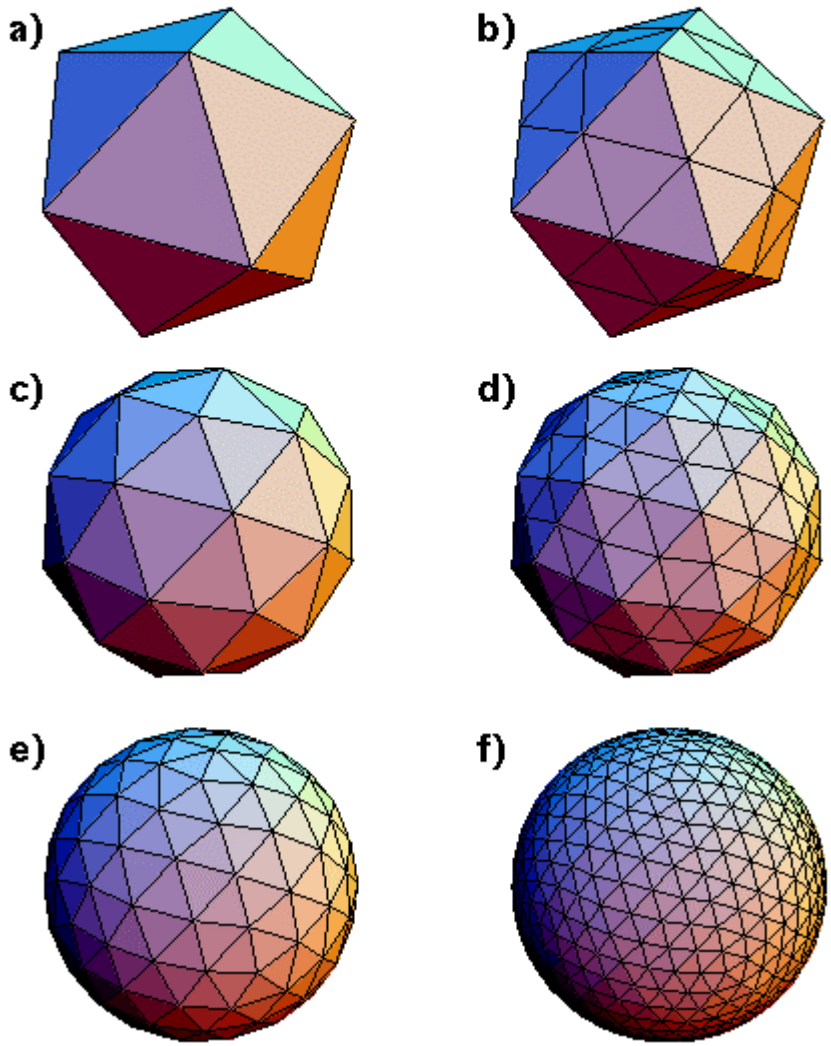
Octahedron: 1 base 8 digit plus unlimited base 4 digits

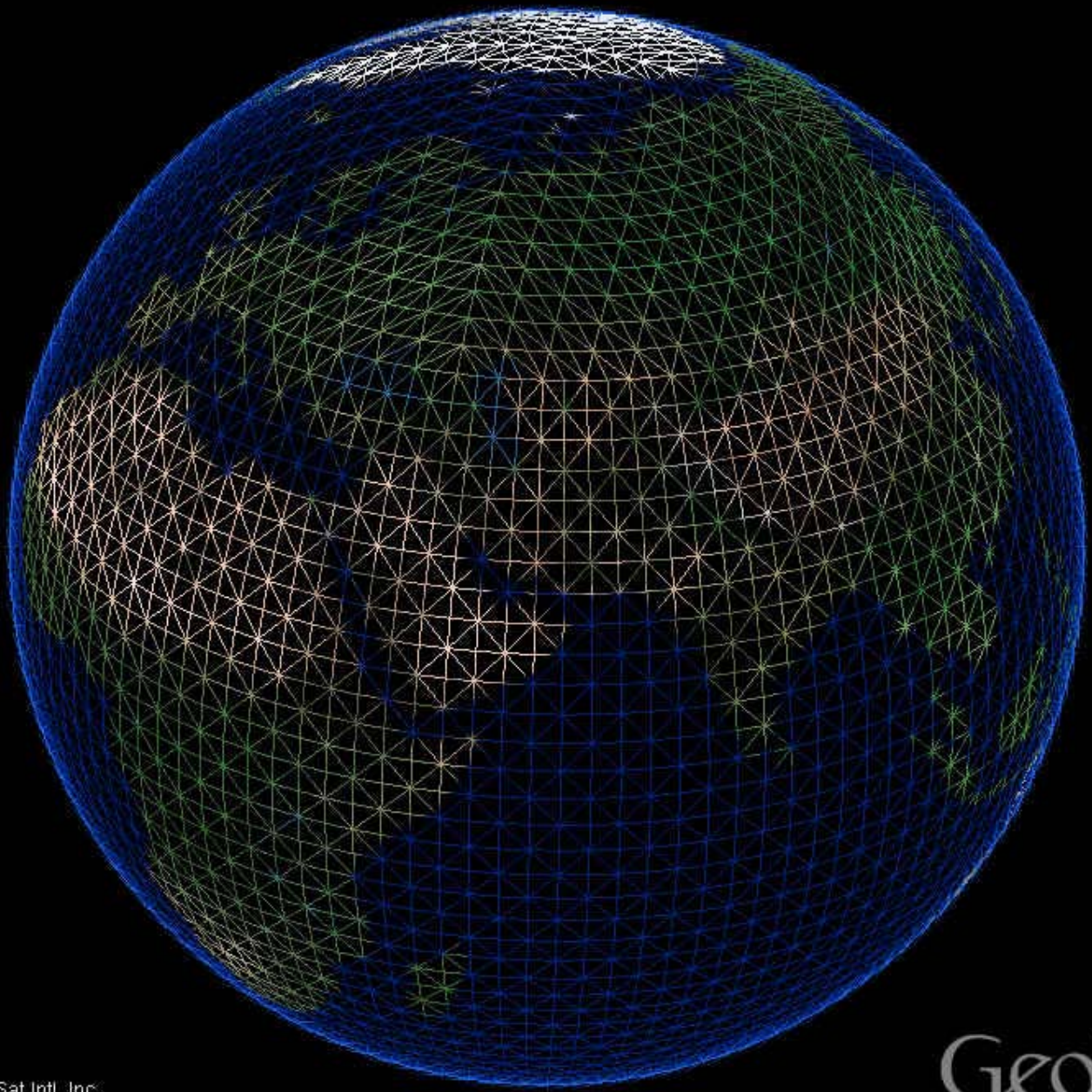
Discrete global grid based on the Icosahedron (20 triangles, 1:4 recursive subdivision)

Ross Heikes and David Randall, Colorado State University

Construction of a simple Icosahedral grid

a) Suppose we have an icosahedron inscribed inside of a unit sphere.
b) Bisecting each edge forms 30 new vertices, and partitions each equilateral face into four pieces.
c) Project the new vertices onto the unit sphere.
d) Bisect and partition again.
e) Project again.
f) And so on.... The result is a sequence of polyhedrons that increasingly approximate the sphere.





Imagery courtesy of WorldSat Intl. Inc.

GeoFusion

Imagery courtesy of WorldSat Intl. Inc.

GeoFusion