Traditional and Modern GIS Architectures

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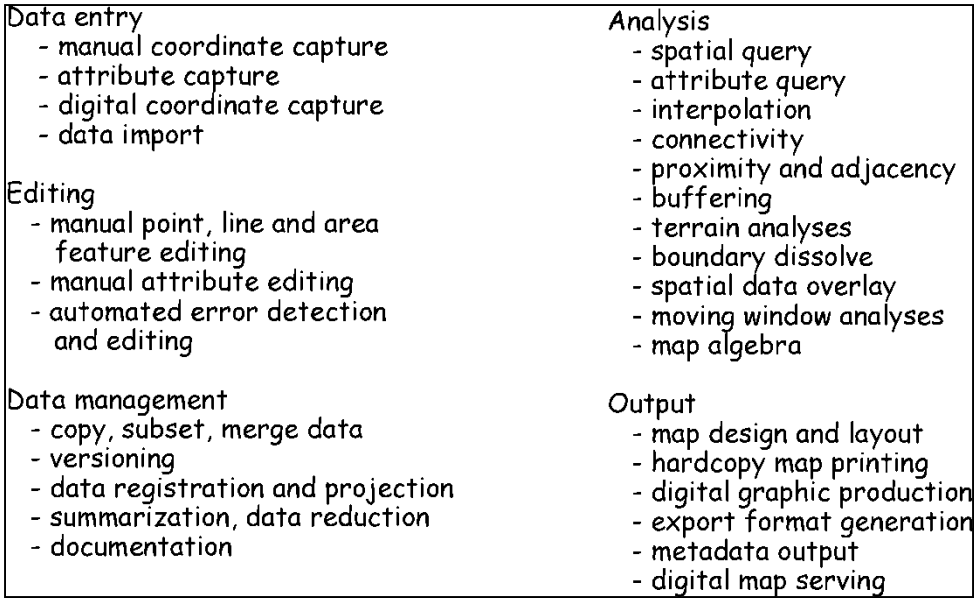
What is a GIS

- GIS are the result of linking parallel developments in many separate spatial data processing disciplines
  - Cartography, photogrammetry, CAD, surveying, interpolation of point data, remote sensing
- Different from parallel disciplines
  - CAD
  - Computer Graphics
  - Game Theory
  - Mapping



© Paul Bolstad, GIS Fundamentals

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Components of GIS

- People
- Hardware
- Software

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GIS People

- Caveman
- Technicians
- Analysts
- Developers
- Managers

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GIS Hardware

- CPU
- Memory
- Storage
- Local Area Networks/Internet
- The Cloud

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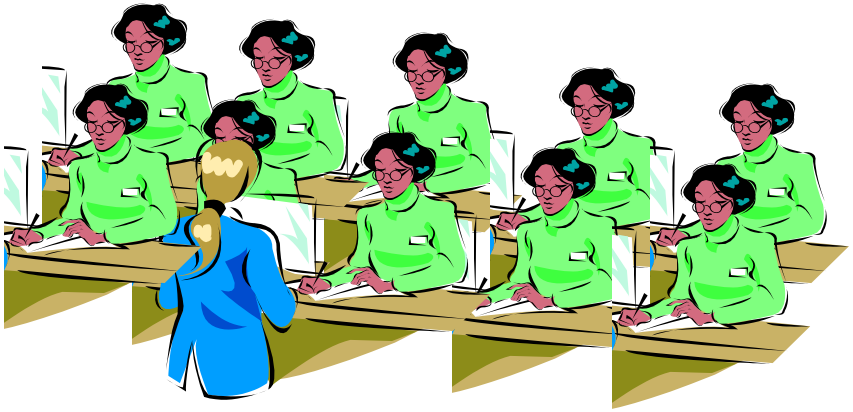
Multi-threading and Parallel Processing

- **Single processor** – at H&R Block, imagine if only one accountant is there to handle everyone's taxes.

- **Multi-threading** – by adding more accountants, each person's taxes can be handled by a separate accountant.

- **Parallel processing** – adding more accountants to each person's tax case will allow one accountant to handle income, another deductions, another investment, charitable gifts, property taxes, etc. At the end, they will merge everything back together .

Parallel processing



- Significant changes have to occur in order to efficiently allow multiple accountants to handle your taxes in parallel
  - Someone has to coordinate the work
  - You may have to have your tax information stored in an efficient manner (W2 forms in one folder, mortgage information in another) in order to efficiently get it to the different accountants (it can't all be in a big messed up box)
  - Some tax information depends on other information that may be with another accountant (your interest income eventually factors into your total income calculations, or your property tax is added to your charitable contributions for an overall deduction.

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Parallel Processing demonstration

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Hardware input

- Digitizers
- Scanners
- Handheld devices
- Sensors (the Cloud, again)

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Handheld devices

- GPS
- Camera
- Video recorder
- Sound recorder
- Browser
- Smartphones
  - GPS
  - Video recorder
  - Sound recorder
  - Browser

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Hardware: Output

- **Printers and Plotters**:

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Data Collection

The LIRR used a remote sensing technique that incorporated on-the-fly global positioning system technology with the use of a scanning reflectorless laser

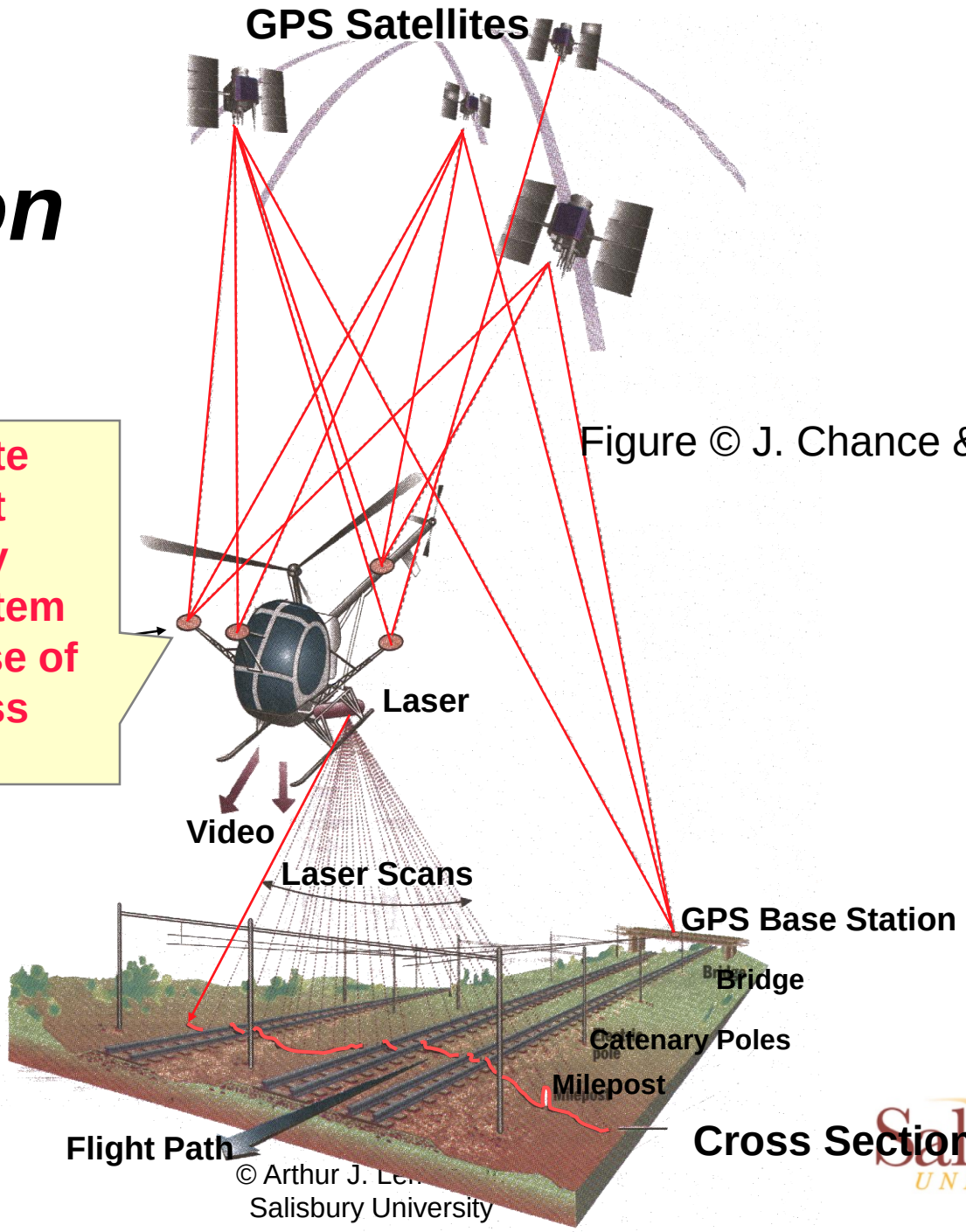

Figure © J. Chance & Associates

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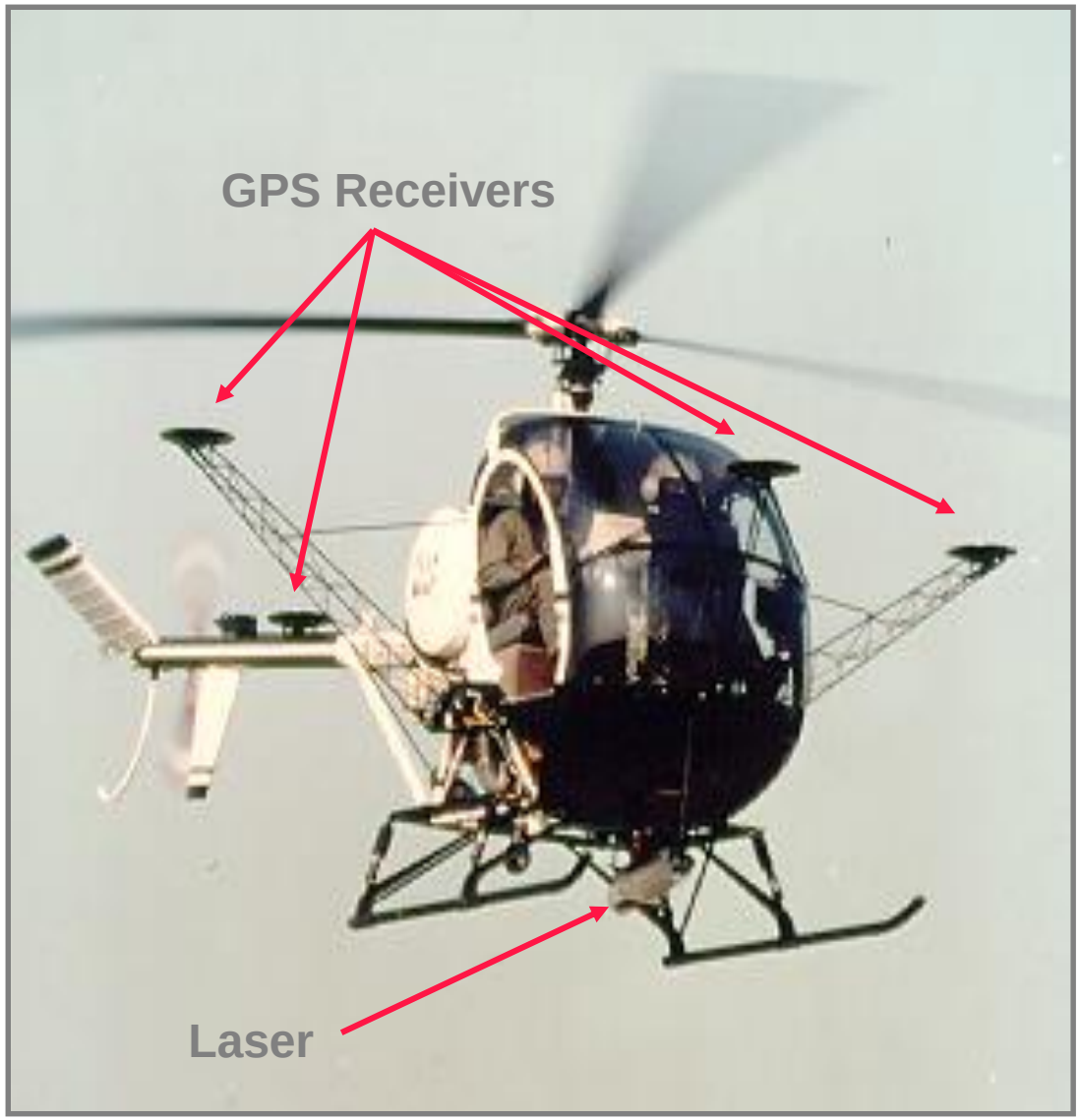

Figure © J. Chance & Associates

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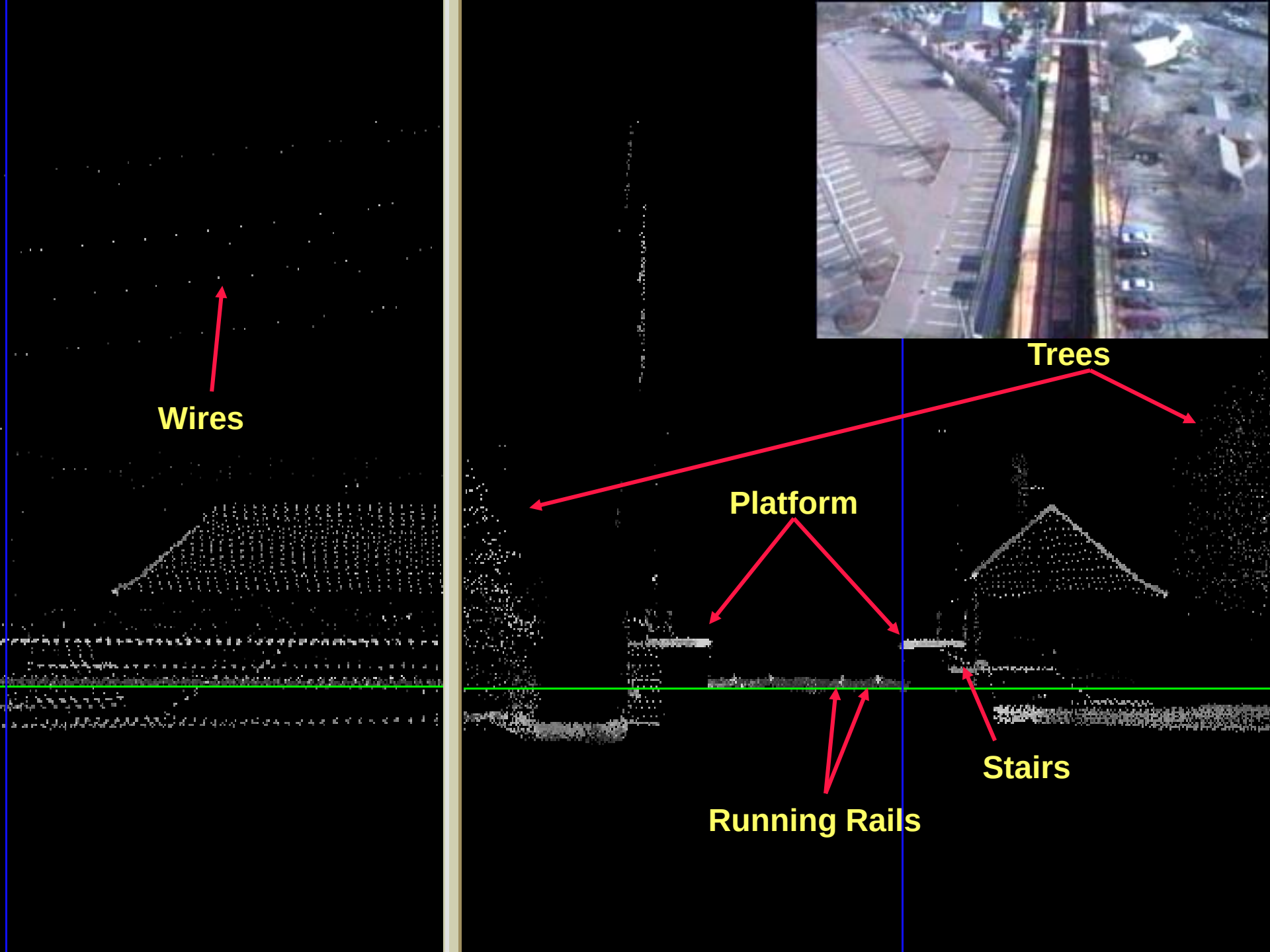
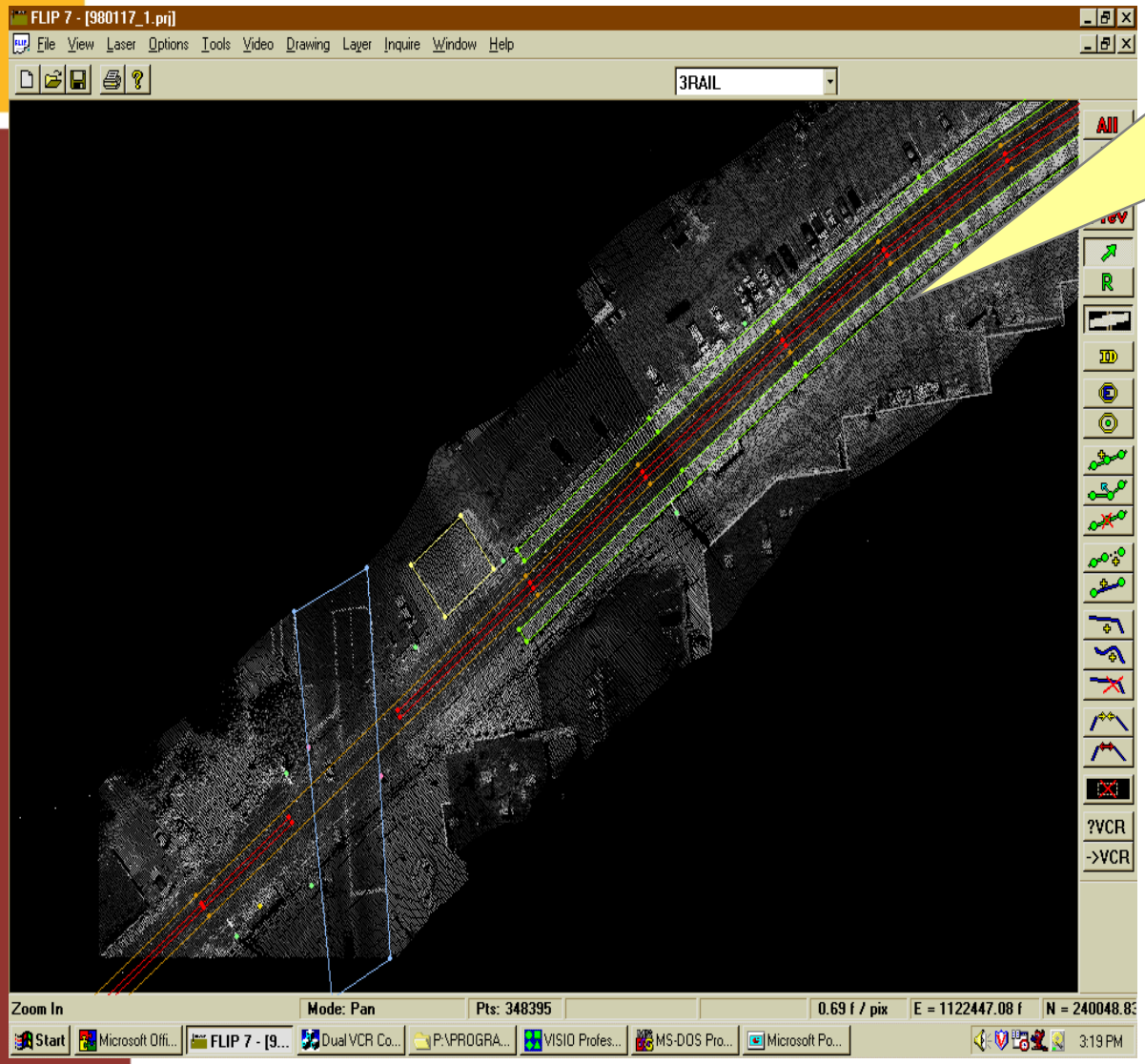

Wires
Trees
Platform
Stairs
Running Rails



Features were then digitized through a "heads-up" process. The features were collected with an accuracy better than 1/2 a foot.

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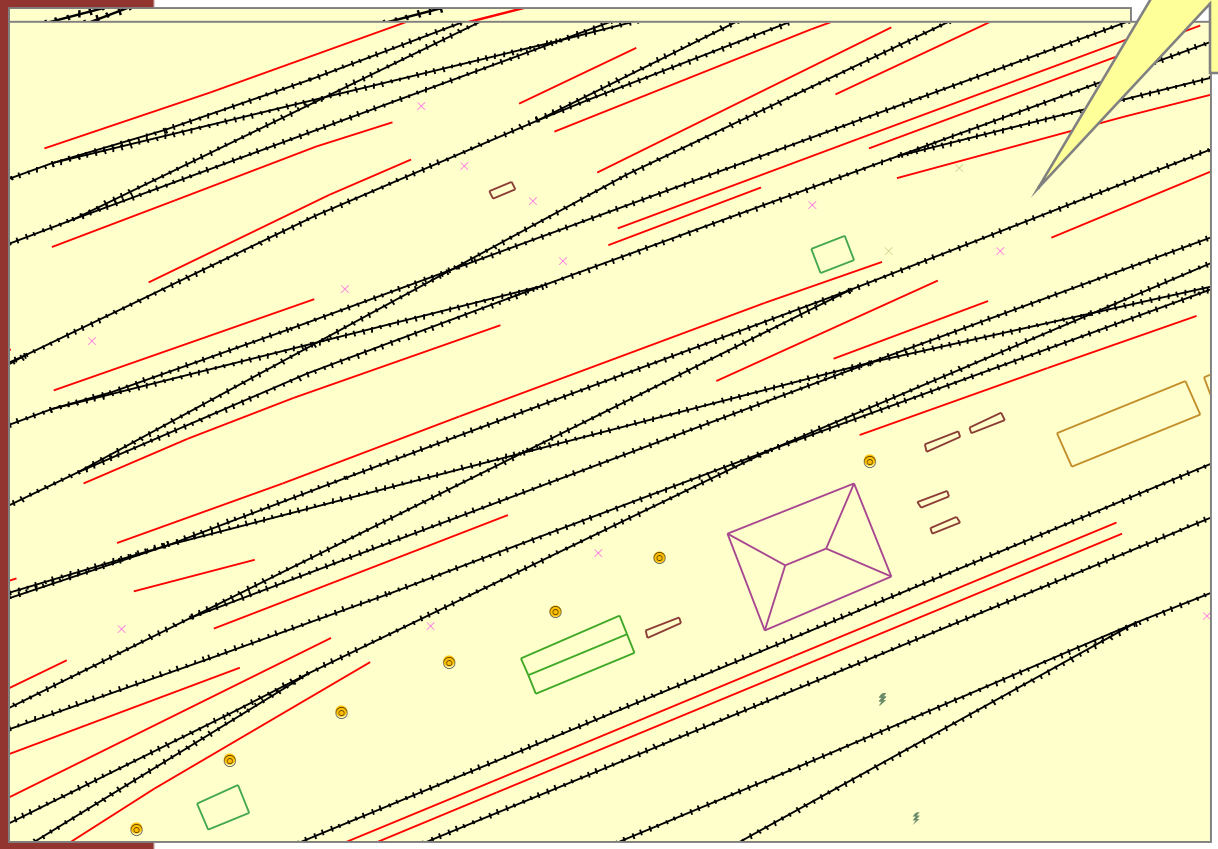

Using both the laser imagery and the time tagged video allowed digitizers to create a very detailed digital representation of the track assets

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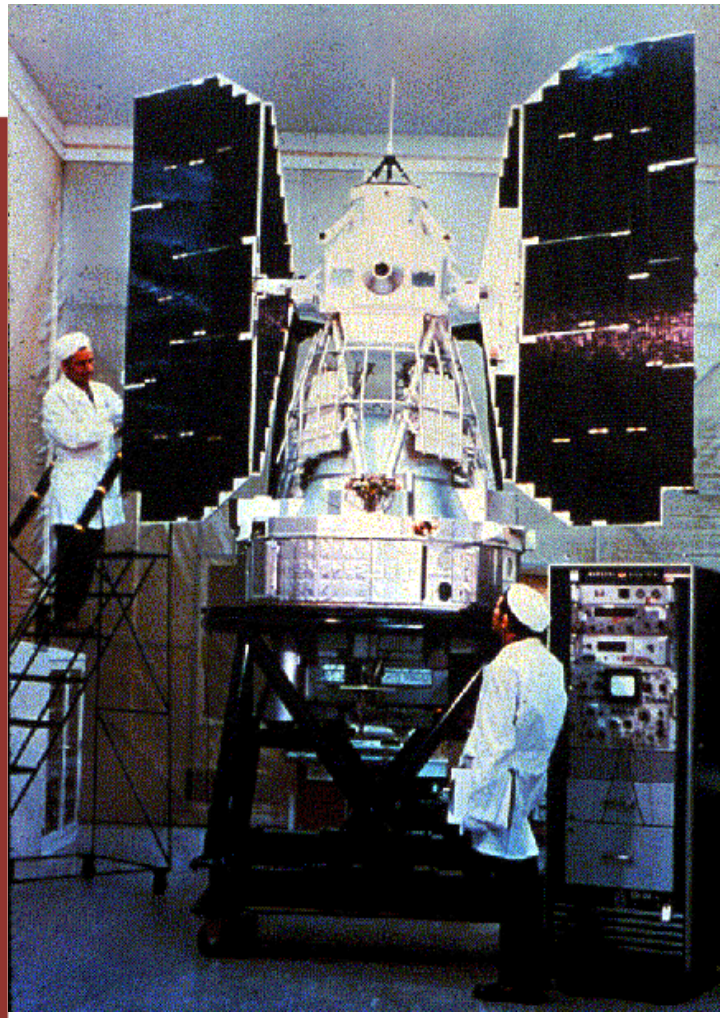
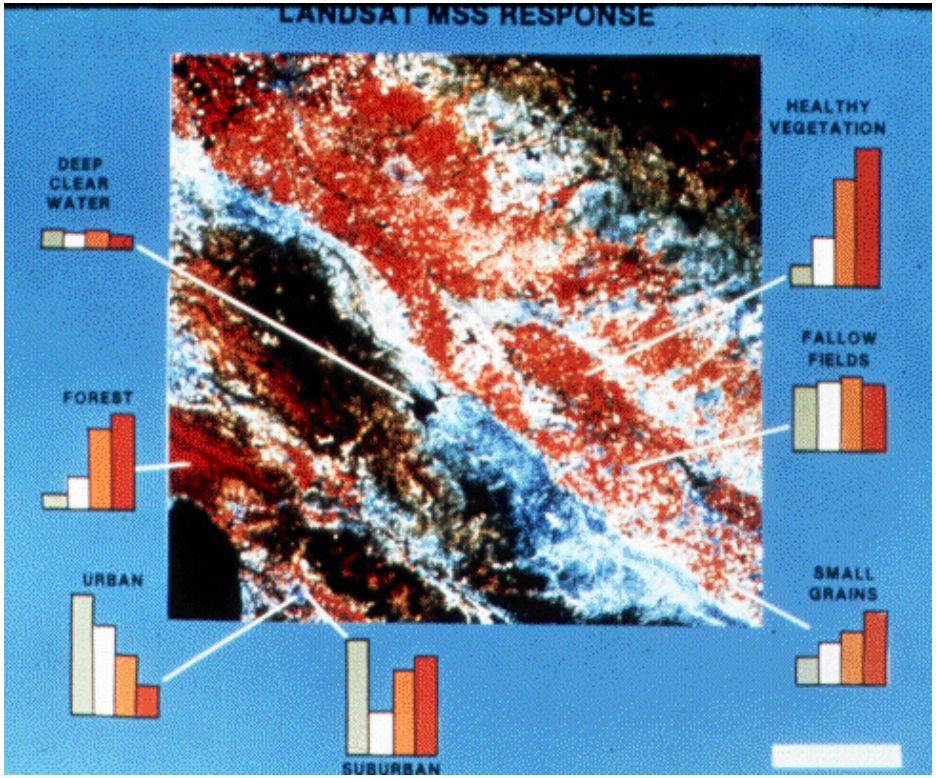
Sensing Devices





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Sensing Devices

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Dashboards

http://www.esrgc.org/webmaps/

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Software - analysis

- **Spatial queries:** where things are in relation to other things.
- **Attribute queries:** identify objects based on their attribute data.
- **Spatial interpolation:** predict some value at a geographic location that we have not measured.
- **Network analysis:** find a path from one point to another
- Buffer analysis: analyze the relationship of objects based on distance.
- **Terrain analysis:** perform three dimensional analysis.
- **Spatial overlay:** determine the relationship between different geographic features.
- **Geographic Visualization:** visualize geographic data in three dimensions, or through charts and graphs.
- **Mathematical functions:** apply algebraic, geometric, or statistical functions to geographic features.

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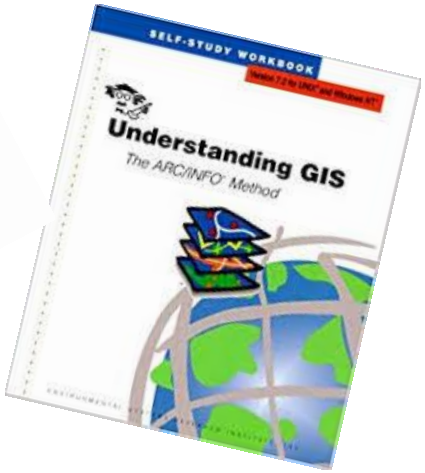
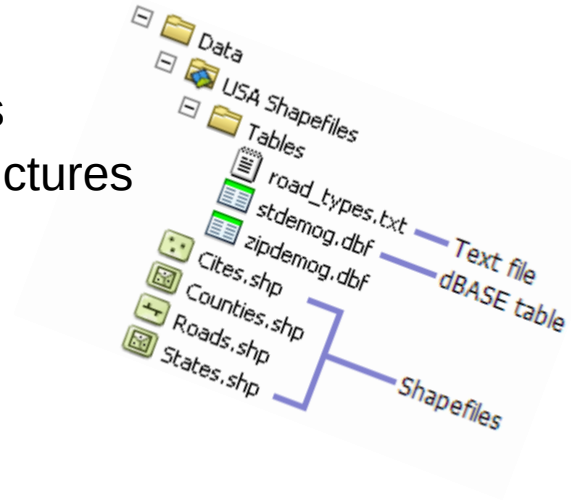
Data Storage and Management

- **Stores data about the geographic object**
  - Geometry
  - Attributes
  - Access Methods (indexes)
- **Formats of Feature Data**
  - Coverages
  - Shapefiles
  - Geodatabases
  - OGC data structures
  - Geopackage





Geometry Type Text Representations

Geometry Type		Well Known Text (WKT)
POINT		POINT(10 20)
MULTIPOINT		MULTIPOINT(10 20, 15 15, 20 15)
LINESTRING		LINESTRING (10 30, 15 15, 25 40)
MULTILINESTRING		MULTILINESTRING ((40 40, 30 30), (15 15, 9 9))
POLYGON		POLYGON ((10 10, 40 10, 40 30, 50 30, 50 50, 30 50, 30 40, 10 40, 10 10))
MULTIPOLYGON		MULTIPOLYGON (((40 30, 50 30, 50 50, 30 50, 30 40, 40 40, 40 30)), ((10 10, 40 10, 40 30, 30 30, 30 40, 10 40, 10 10)))
COLLECTION		GEOMETRYCOLLECTION(POINT(10,20), LINESTRING(40 40, 30 30), POLYGON((15 15, 30 15, 30 30, 15 30, 15 15)))

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Software – Database Management

- **Database Management**: As we previously said, the ***I*** in GIS allows us to integrate information and geography. This requires software to actually store and retrieve information. The most common methods for storing geographic information is in a database. Database technology allows the software to efficiently store and quickly retrieve information.
- More advanced database management systems within GIS allow us to keep track of updates, manage simultaneous users accessing the data, and provide documentation of the data.

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Software Data Models

- **Hybrid data model**
- **Object-relational data model**

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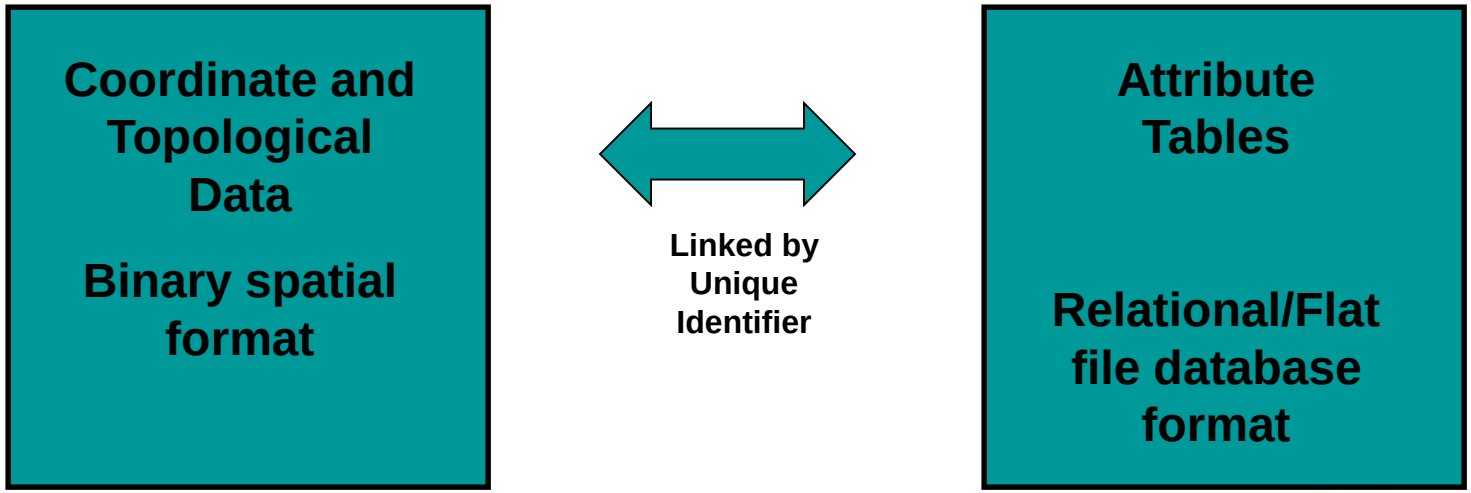
Hybrid Data Model

- File based storage of spatial data
- Basic premise is one cannot simultaneously optimize data storage mechanisms for spatial data and attribute data



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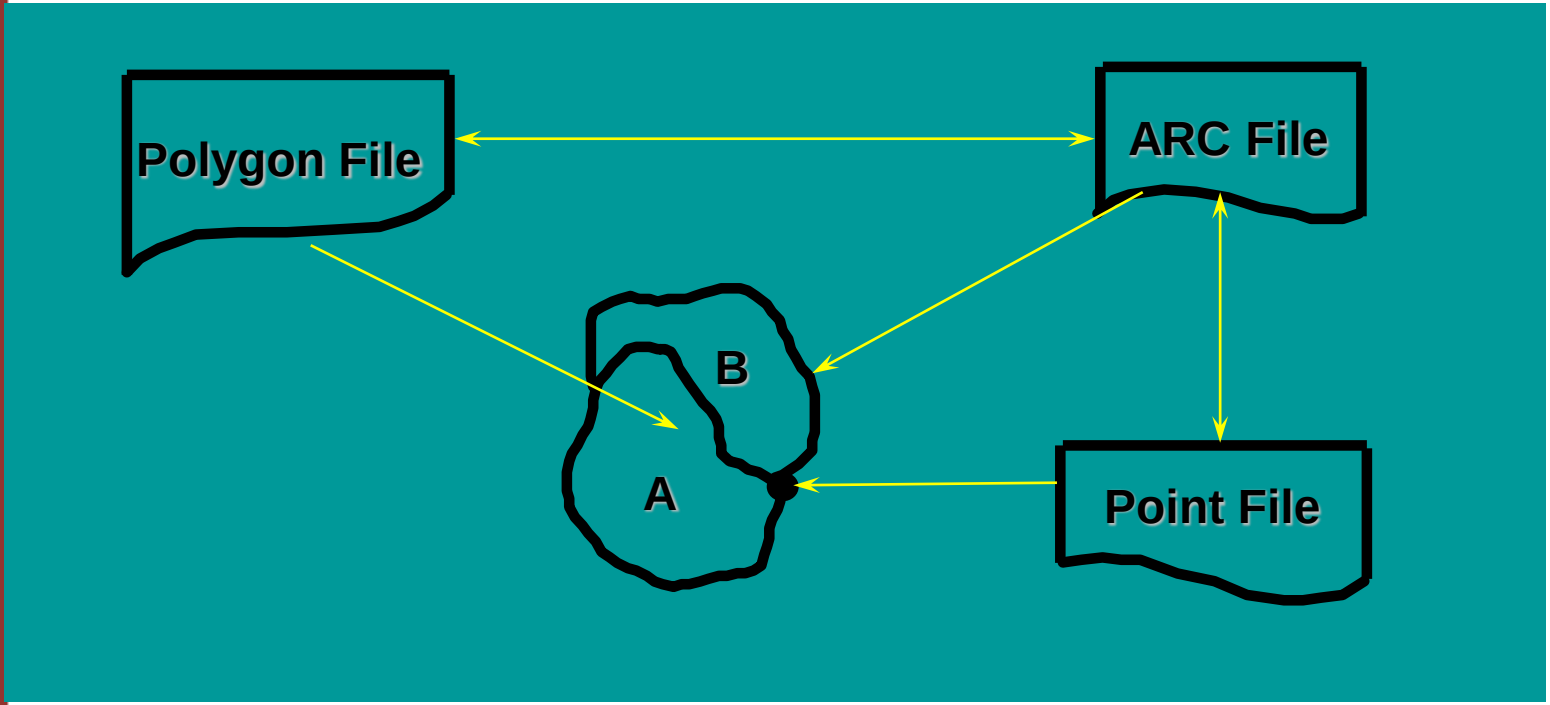
Traditional Hybrid Data Access

Topology encoded in data



Minimum of 3 Disk Accesses to Retrieve Object

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Three ring circus problem	Because the data required at a minimum three files, users had to keep track of all the files. If you did not have one of the three files, your data could not be read.
Data divorce problem	Because the data was in separate files, one had to be very careful about how data was accessed. For example, with the attributes in a .dbf (dBase) format file, it was possible to access the .dbf data through other programs that could read a .dbf formatted file (dBase, FoxPro, Excel). Unfortunately, any structural changes made to those files would be unknown to the .shx or .shp file. So, it was theoretically possible to sort data in the attribute table using a product like dBase or Excel. However, the .shx would not know about this change, and therefore would link the geographic elements to the wrong attribute record.
Rudimentary storage program	dBase was once a popular database format. However, technologically, the database format was based on 1980's standards. Therefore, the .dbf format has little capability to store more advanced data types such as dates, currency, or binary large objects (BLOBS). If you used shapefiles, then you were restricted to the severe limitations that the dBase format offered.
Security	with dBase files there was little to no security.
Multi-user problem	the hybrid format typically was limited to read-only, and sometimes an entire file could be locked.

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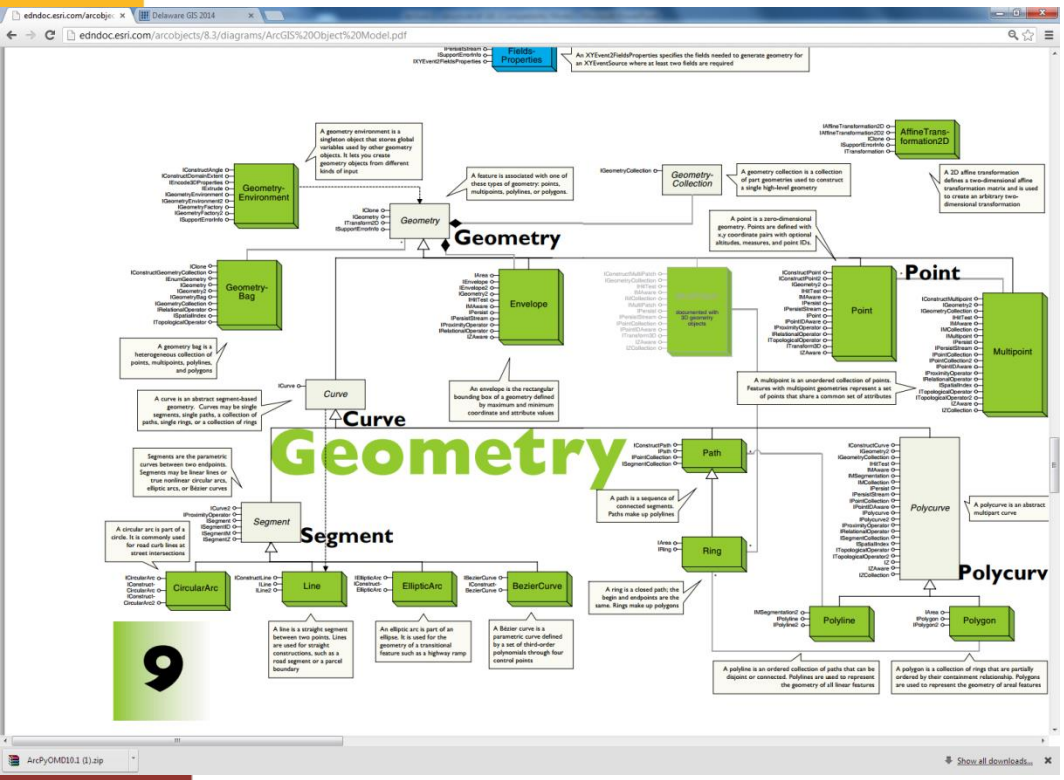

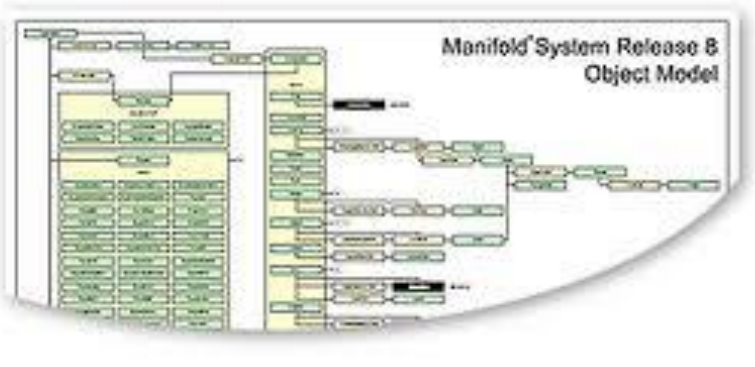

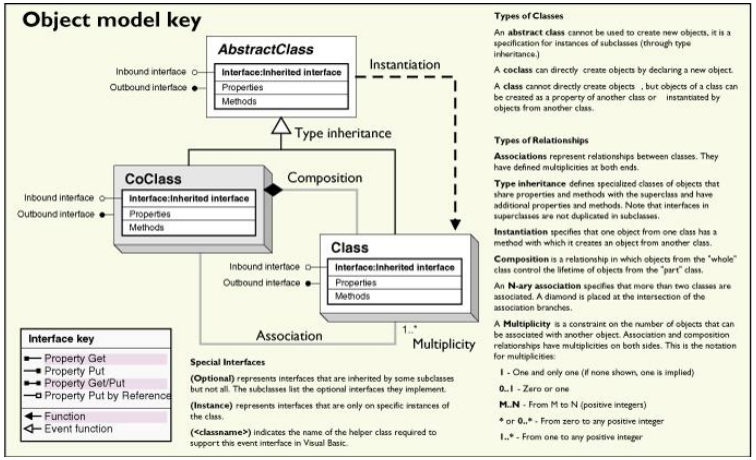

http://www.qgis.org/api/classQgsApplication.html

Object-relational Databases and Universal Servers

- Can create true objects within the database
- Supports indexing methods better suited for spatial data
- Support for user-defined functions that can be written in SQL extensions

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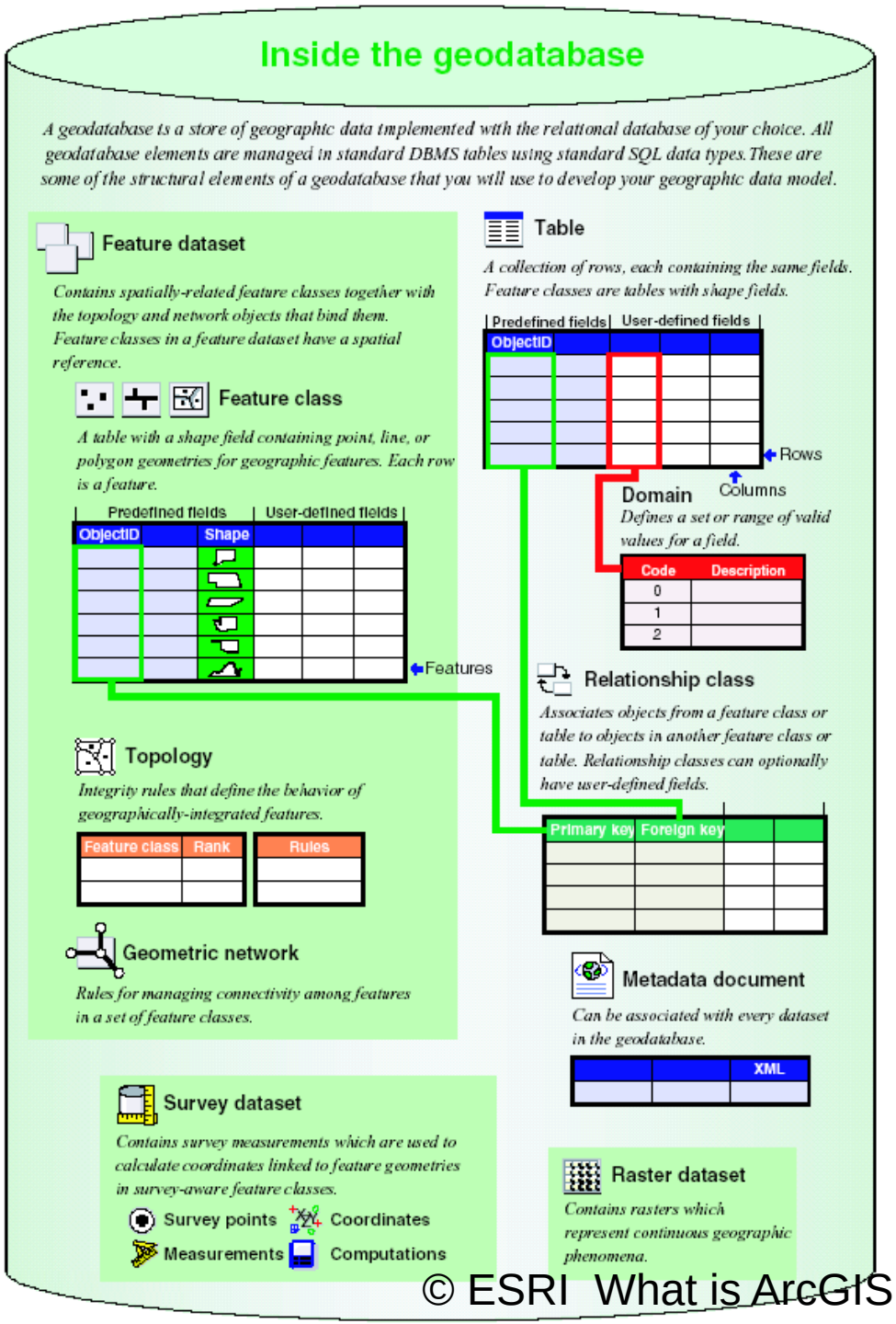
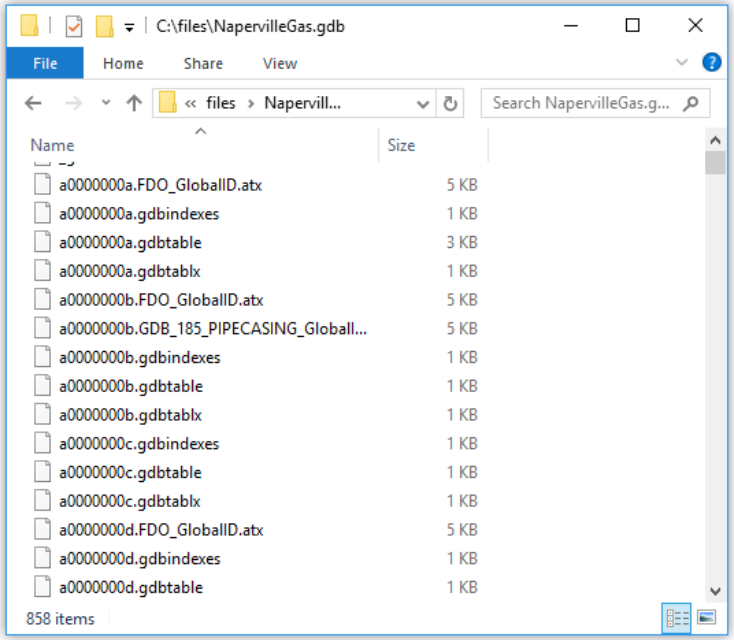
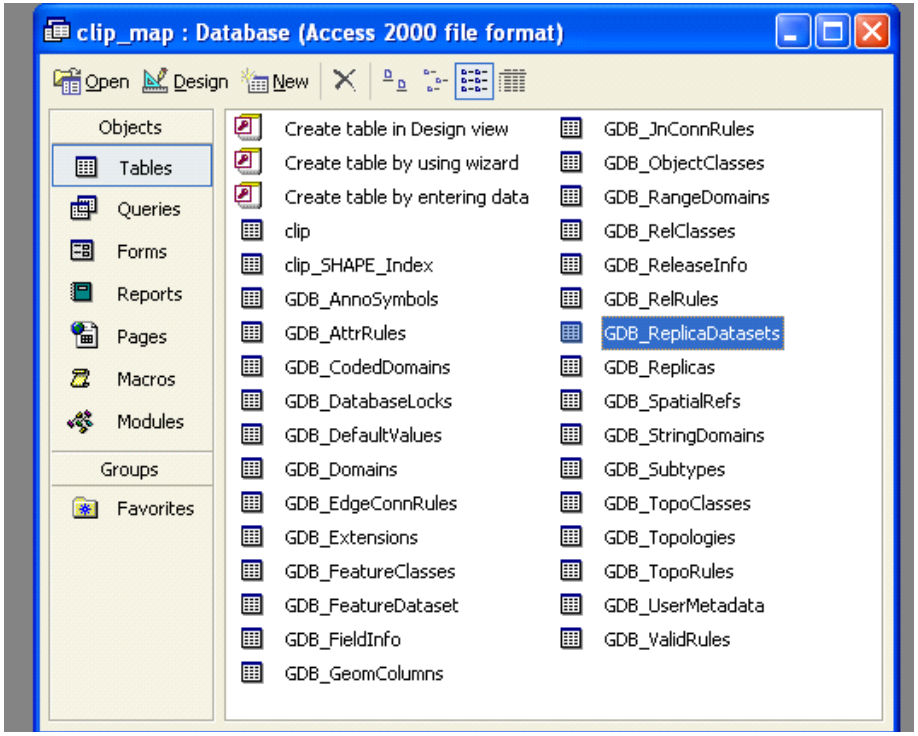
Geodatabase Feature Model

- Represents geographic information using standard relational databases with extensions.
- Data is managed through relational tables, and geographic objects can have *integrity rules* and *behavior*
- Example from *unique natural areas*
  - *Feature datasets*
  - *Feature classes*
  - *Topology rules*
  - *Relationships*



Complexity of geodatabases





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Storing geometry in tables

- A more modern approach that treats geometry as another database element.
- Takes the geometric information for each object and saves it into a special geometry column in a table using various types of technology. Tables storing geometry can be tables within a Manifold project or they can be tables in some external database system such as a SQL Server database.
- Geometry tables can be a very high performance solution that scales well for use by the very largest enterprise applications. Geometry tables provide tremendous flexibility and power. Drawings linked from geometry tables are editable, assuming the connection technology used is read/write and the user also has write permissions for the DBMS table used.
- Since a geometry is just another data type, drawings can then be dynamically created from queries

Query *

```
SELECT Geom(ID) AS [Geom], [Mexico_eg Drawing].* FROM [Mexico_eg Drawing];
```

Query *

Geom	ID	SQMI	SQKM	PC
<geom, area, branches: 1, points: 902>	1	26635.63	63068	20(
<geom, area, branches: 1, points: 686>	2	32089.18	73252	12
<geom, area, branches: 1, points: 527>	3	52374.05	123181	13
<geom, area, branches: 1, points: 22>	4	76106.63	182050	18
<geom, area, branches: 1, points: 2932>	5	23603.34	58328	22(
<geom, area, branches: 1, points: 8417>	6	31490.15	79384	22
<geom, area, branches: 1, points: 685>	7	26202.05	64924	30
<geom, area, branches: 1, points: 27>	8	29614.38	69921	16
<geom, area, branches: 1, points: 3119>	9	29732.4	73475	31

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Advanced advantages of ‘spatially enabling databases’

- Dynamically create geometry from tables or queries containing geometric data Faster performance, at times by a factor of 100 or more in interactive GIS operations as compared to older architectures.
- Reliable, conflict-free editing of complex data in a multi-user environment.
- Freedom to choose almost any DBMS vendor (as long as they can support the spatial datatypes).
- Heterogeneous, free form utilization of Enterprise servers.
- DBMS safety. If the DBMS crashes while working on an Enterprise project the project is still safe and can be saved with no loss of data.
- Network fault tolerance. If the network crashes while working on an Enterprise project the project is still safe.
- Ability to use Internet. The high bandwidth requirements of older architectures mean that connecting over Internet to a remote DBMS is not usually realistic.

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Formats we'll use in class

- **Coverages**
  - Coverages are stored in workspaces. A workspace is a folder in the file system. The workspace folder contains a folder named info and folders named for each coverage in the workspace.
- **Shapefiles**
  - Shapefiles are simpler than coverages because they do not store full topological associations among different features and feature classes. Each shapefile stores features belonging to a single feature class.
- **GeoDatabases**
  - Geodatabases implement an object-based GIS data model within a relational database. A geodatabase stores each feature as a row in a table. The vector shape of the feature is stored in the table's shape field, with the feature. This is the newest method for storing geographic information.
- **OGC Compliant data structures**
  - Well Known Binary (WKB) data type used by OpenGIS, and Well Known Text (WKT).

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Software – Data Output

- GIS software has the ability allow users to prepare GIS data for output. This topic is further discussed at the end of the year when we talk about *Cartographic Composition*. However, some of the functions for data output include:
  - **Creation of map layouts**: software tools are available to create visually impressive maps that communicate information. While some GIS output software is rather crude, other software products allow users to create the kinds of quality maps you would see in a professional atlas.
  - **Printing maps**: software tools prepare the data to interface with hardware devices such as plotters and printers.
  - **Creating digital maps**: newer innovations are now allowing for the creation of digital outputs in products such as Adobe Acrobat. Rather than printing to a sheet of paper, software modules allow users to print the maps to a file that can be shared digitally among many users.
  - **Writing data to different formats**: just as there were software modules to input data from different formats, there are software modules that allow a user to write information to different formats.

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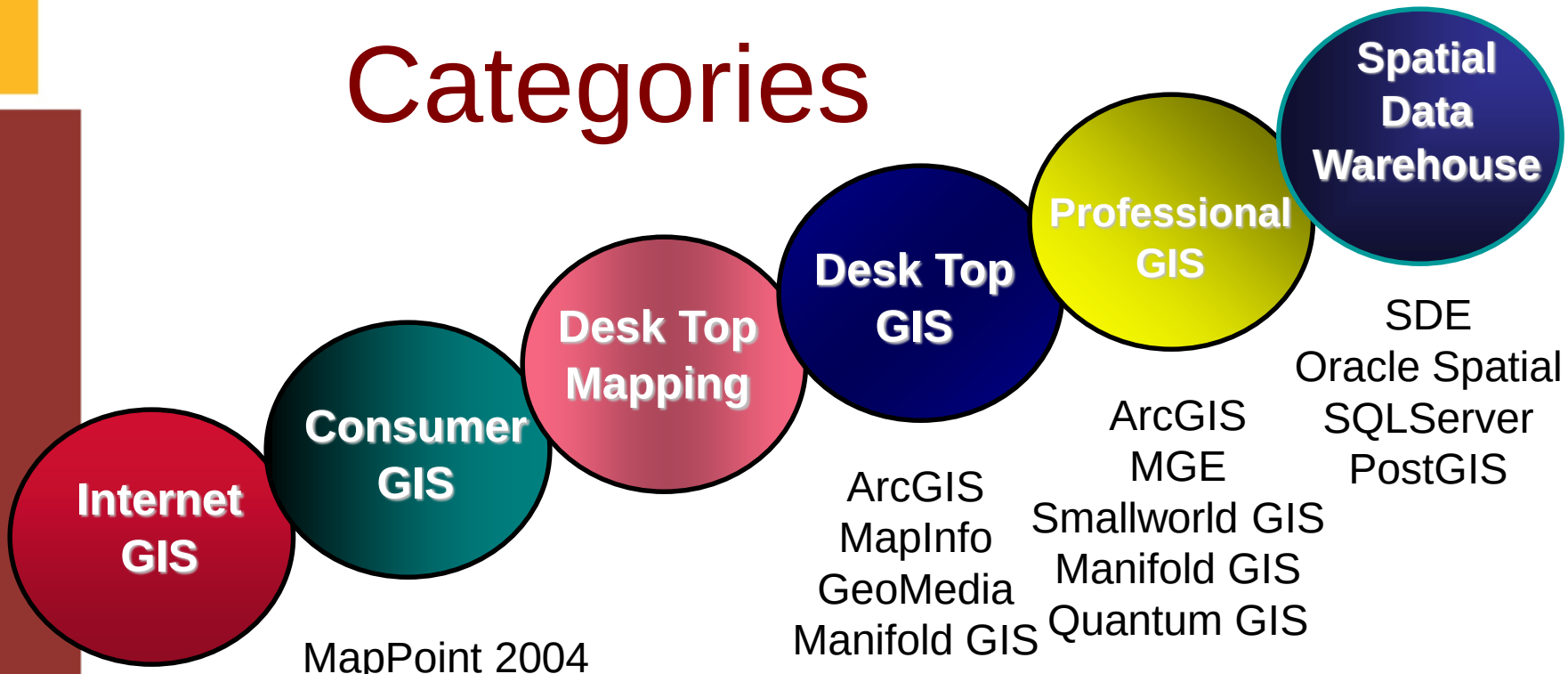
GIS Product Categories



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Embedded GIS

- A spatially enabling technology based on ActiveX/COM
- Utilizes open development tools
- Add geographic content to OCX-compliant applications
- Facilitates GIS implementation in a client/server architecture

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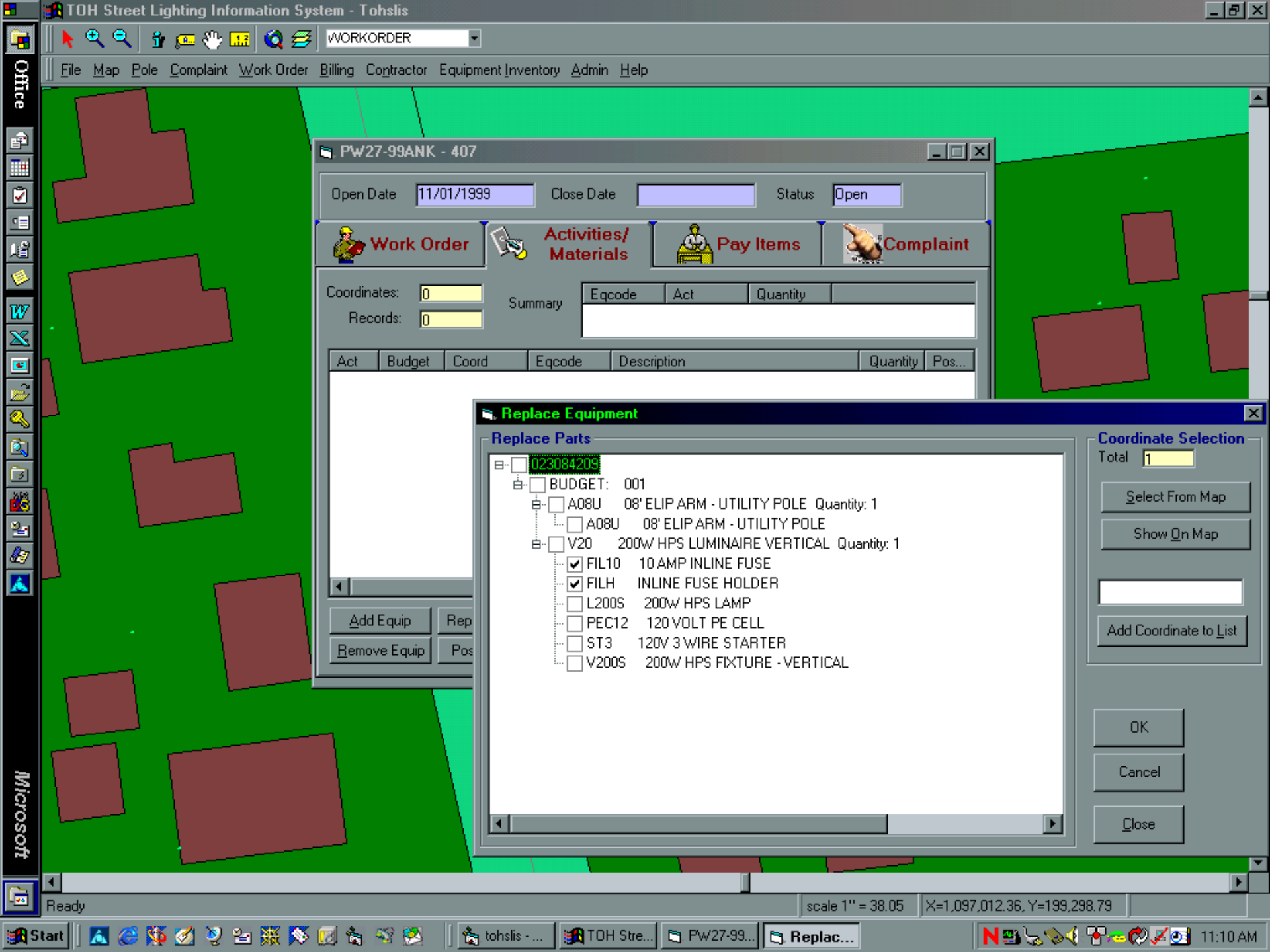
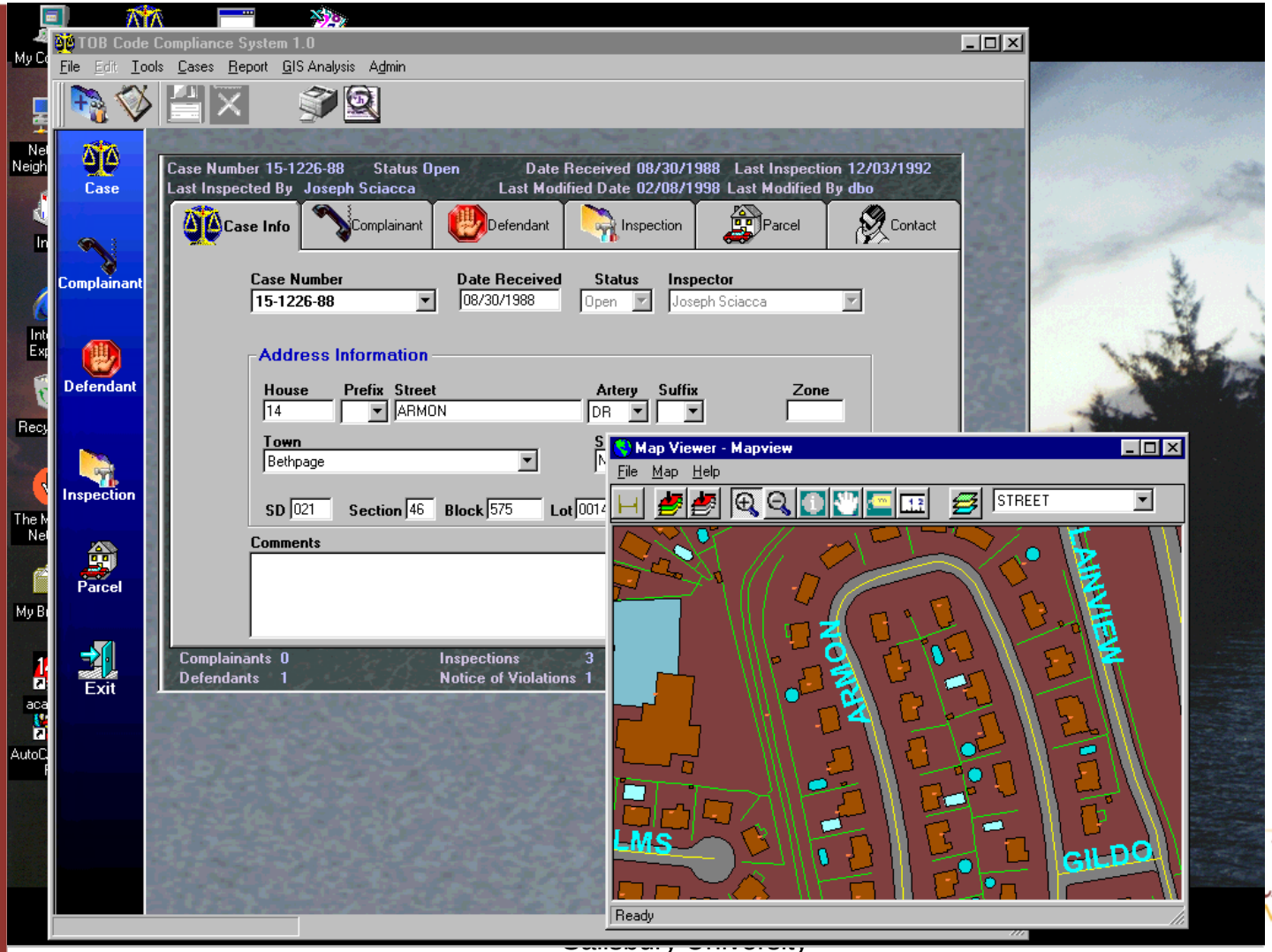

TOH Street Lighting Information System - Tohslis
WORKORDER
File Map Pole Complaint Work Order Billing Contractor Equipment Inventory Admin Help
PW27-99ANK - 407
Open Date 11/01/1999
Close Date
Status Open
Work Order
Activities/ Materials
Pay Items
Complaint
Coordinates: 0
Records: 0
Summary
Eqcode Act Quantity
Act Budget Coord Eqcode Description Quantity Pos...
Add Equip
Remove Equip
Replace Equipment
Replace Parts
023084209
BUDGET: 001
A08U 08' ELIP ARM - UTILITY POLE Quantity: 1
A08U 08' ELIP ARM - UTILITY POLE
V20 200W HPS LUMINAIRE VERTICAL Quantity: 1
FIL10 10 AMP INLINE FUSE
FILH INLINE FUSE HOLDER
L200S 200W HPS LAMP
PEC12 120 VOLT PE CELL
ST3 120V 3 WIRE STARTER
V200S 200W HPS FIXTURE - VERTICAL
Coordinate Selection
Total 1
Select From Map
Show On Map
Add Coordinate to List
OK
Cancel
Close
Ready
scale 1" = 38.05
X=1,097,012.36, Y=199,298.79
Start
tohslis - ...
TOH Stre...
PW27-99...
Replac...
11:10 AM

Code Enforcement



Fire Response