2007 ESRI Petroleum User's Group Workshop

Truth or Consequences

What would we do without Correct Names, Addresses and Telephone Numbers?

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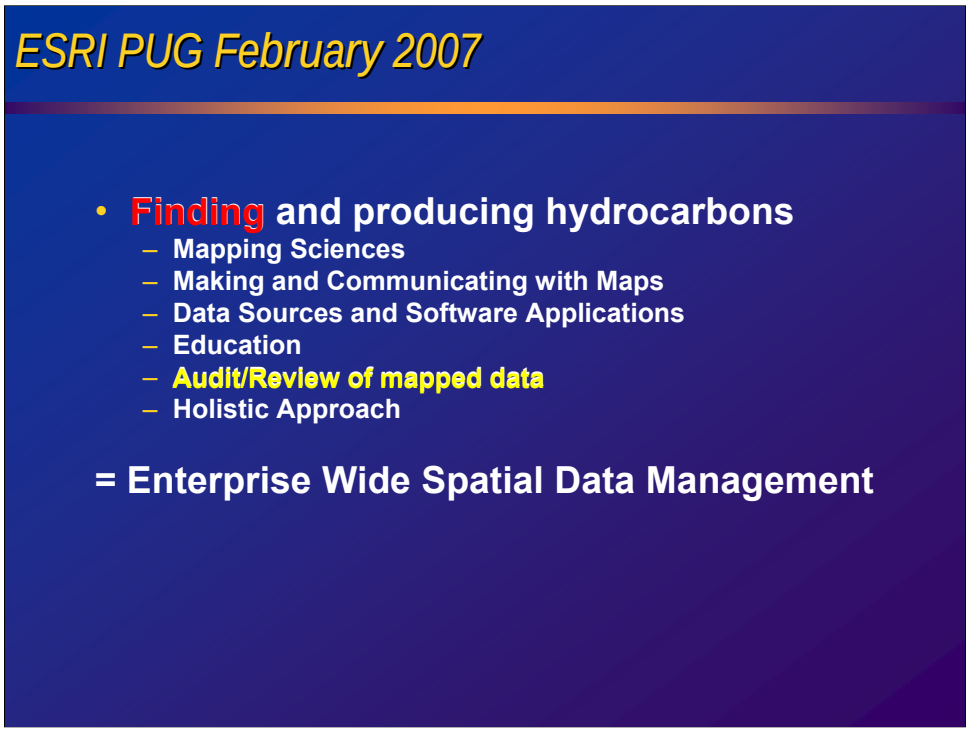

There are some who say that surveying, mapping and spatial data management are not core competencies for a oil and gas exploration and production company.

Since half the task of Finding and Producing hydrocarbons is the "Finding" part, this is in fact not true.

There are several components of spatial data management in a large oil and gas company. These are listed. The overall purpose of my talk is to paint a realistic picture or model of the process that I believe will lead to a stable, reliable and holistic spatial data management system, leading to a high degree of success in our stated goals.

I hope that this talk will provide a coherence to this conference I hope you will see your connection to the larger enterprise and be better equipped to support and drive those pieces over which you have influence.

Failure to approach the task in a way similar to this, will lead to a state of spatial data anarchy and loss of significant impact and revenue over a long period of time.

Audit/Review of mapped data

- **50% of all surface well locations from industry sources are wrongly mapped by over 100ft and often as much as 500ft and many of them contain no vertical data**
- **25% of all directional survey data are wrongly mapped by over 500ft in 3 dimensions**
- **16% of all seismic data loaded in workstations for interpretation have significant disagreement in spatial data between components**
- **All versions of the Texas Land grid have problems that are manifested, so far in the mapped boundary placement of the units, mineral tracts and any feature placed in relation to them, such as well spots**

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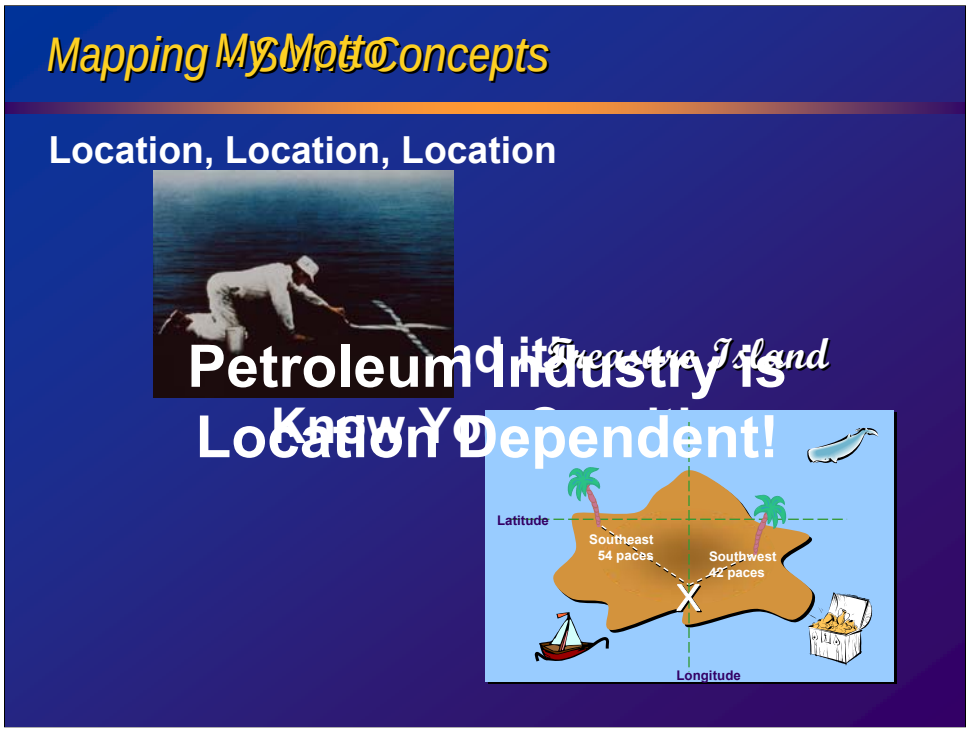
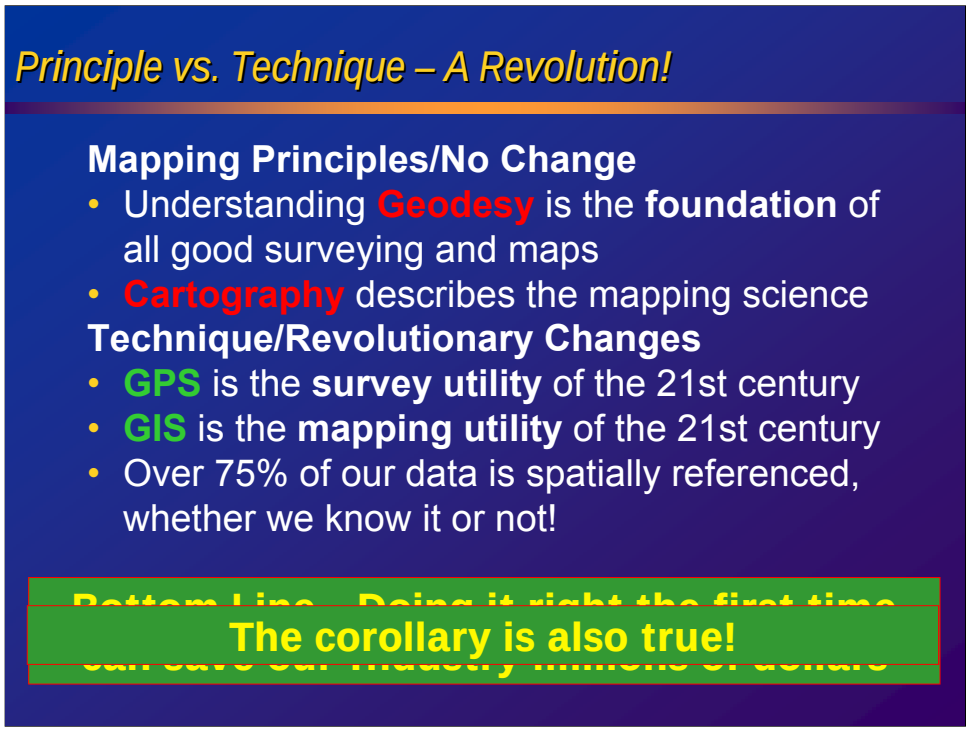


A conceptual view of offshore positioning – with credit to Teledyne Hastings Raydist,

When we are searching for buried treasure, an excellent map is a pre-requisite.

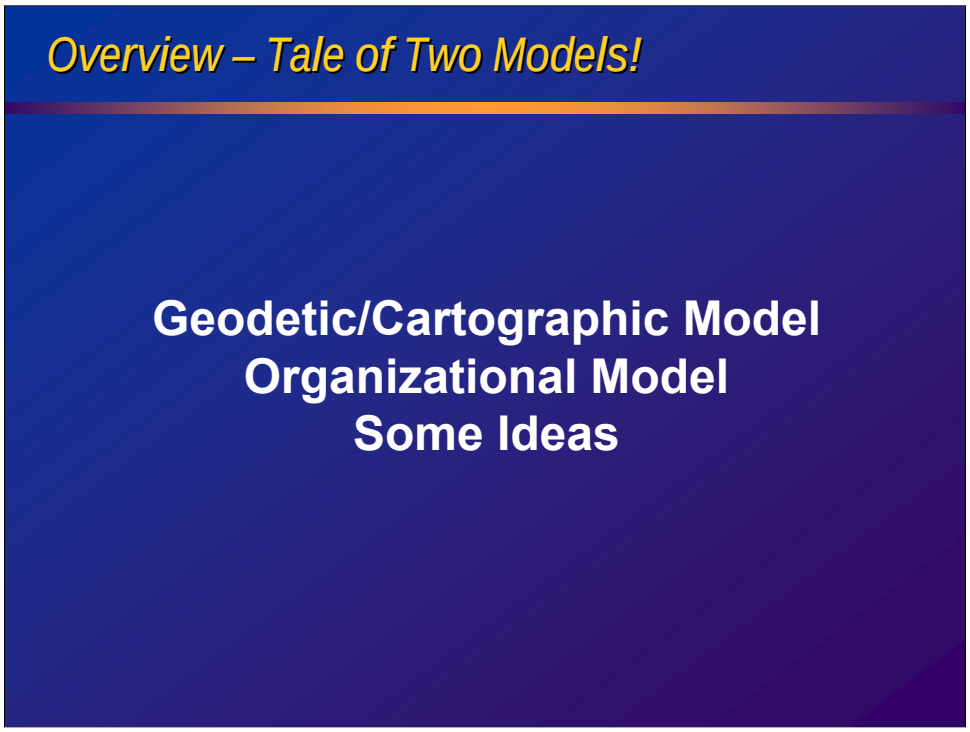
Excellent maps only come from proper management of spatial data in an organization.



GPS and GIS tools are spectacular if they are used properly.

In most cases they are not.

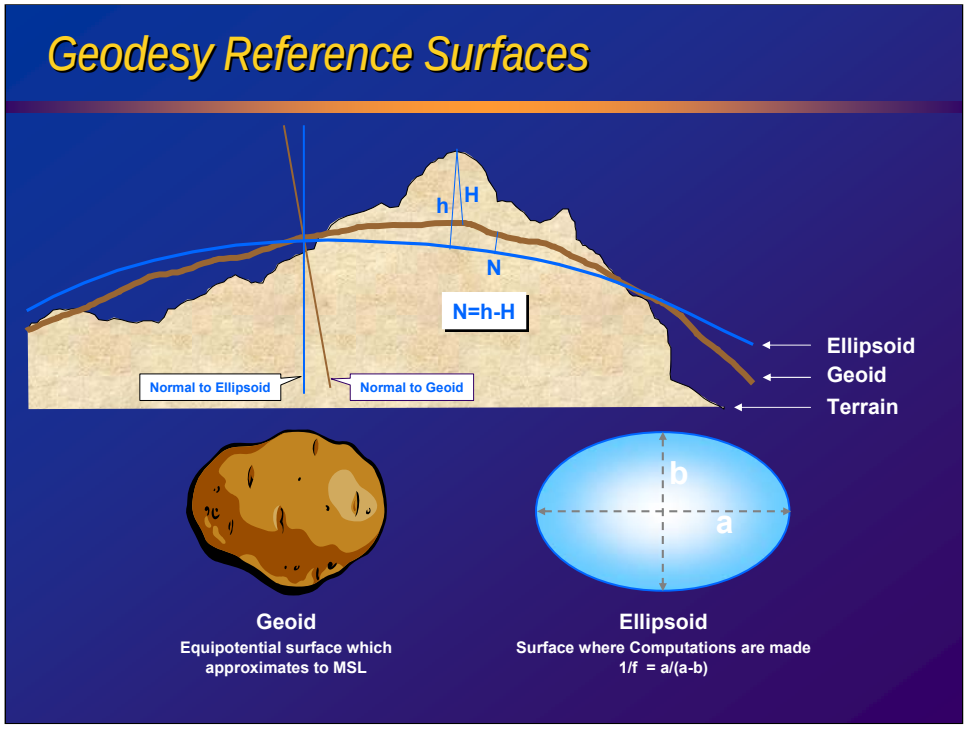
This creates a crisis in 9 out of 10 activities



I will discuss 2 models and then make some additional or concluding remarks.

The first model is technical and is 7 slides summarizing the most important principles of geodesy and Cartography. This is a VERY abbreviated view and if you do not understand it, it is time to go back to school! Every Professional in E&P should be thoroughly familiar with these concepts and know how to provide leadership in their projects on this issue.

The second model is an organizational one that shows how spatial data management is a critical component of every major function and is a foundational component of all projects.

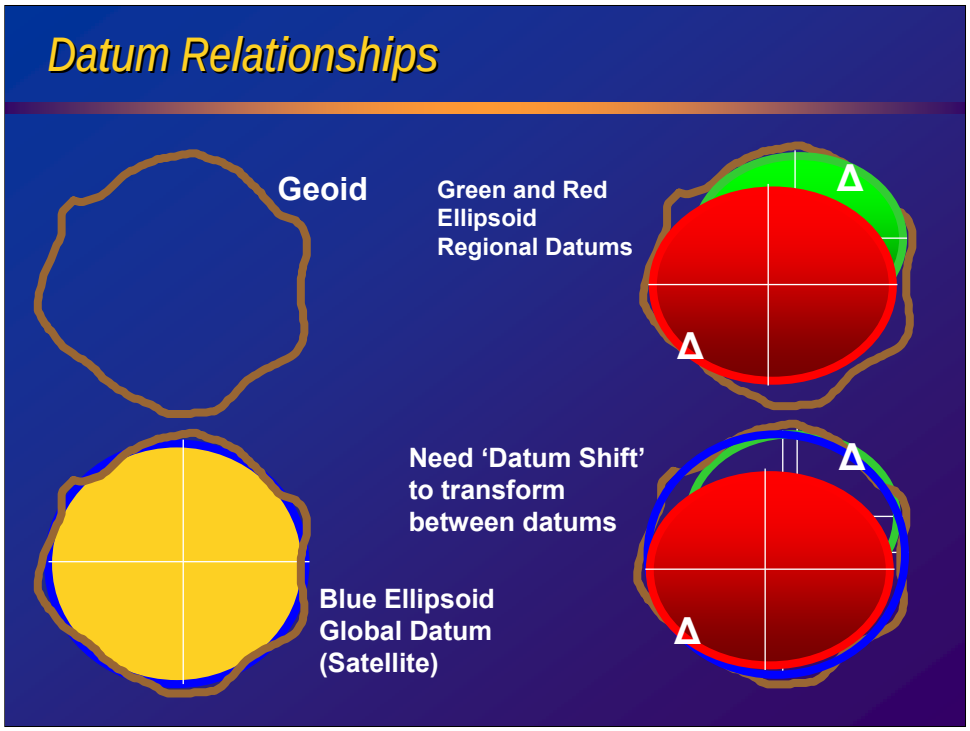


This represents the fundamental issues of establishing a Geodetic Datum.

In making any sort of measurement to define the shape of an Ellipsoid or to define a Datum-related Geographic Coordinate Reference System (GeogCRS) with resulting latitude and longitude values, astronomic and gravitational measurements are taken or used. The localized gravitational " pull " on the instrument's plumb bob or level effects the values of the measurements being used, and the assumption is made that the ELLIPSOID and GEOID are coincident, or their separation is somehow defined.

This results in a term called "Deflection of the Vertical" which has a significant affect on these measurements. Different locations produce different deflections (e.g. the flat areas at Meades Ranch, Kansas for NAD 27 , the Himalayas and Pacific trenches near Tokyo Observatory for Tokyo Datum).

These, together with the limited technologies available at the time of the observations being made, affected the results (e.g. Timing issues of the Dutch East Indies Survey from Bombay to Indonesia).

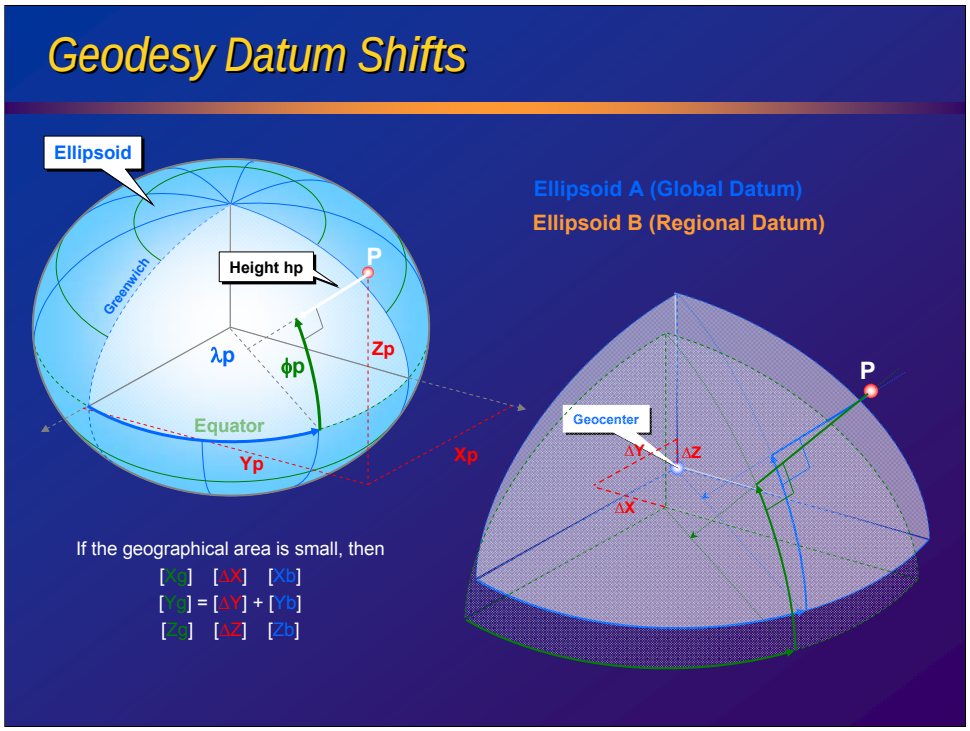


This is a summary in cartoon form of the previous discussion.

The geoid is a single entity, if imprecisely known.

The green datum is a regional datum – highly exaggerated difference. It is attached at the triangle point. In US this is Meade's ranch, Kansas (NAD27). The blue datum is a global datum and fits the earth's geoid pretty well (worst case + or – 100 meters in areas of high gravity distortion – i.e. mountain ranges and ocean abysses)

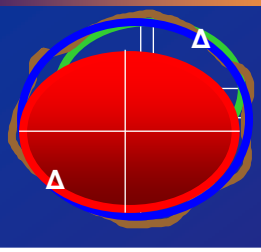
The last picture shows the two co-matched – the key thing to note is the difference in the centers of the datums. These centers are the origins respectively. A same physical point on one will have a different Cartesian (XYZ) and Latitude Longitude and height than the other. The difference is related to the X.Y.Z offset of the respective origins.

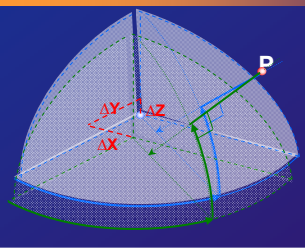


Getting from one datum to the other is conceptually simple but not well understood by the average field surveyor

or by most oil company project managers - many mapping technicians also need help

Mixing Projections - Brazil Example

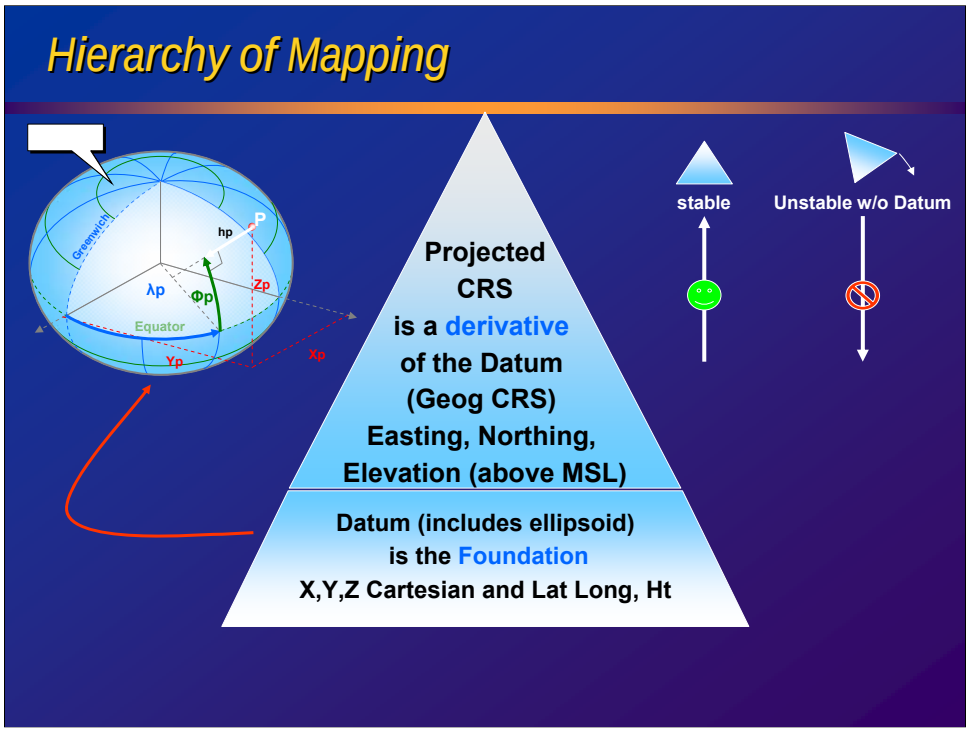




Datum	Latitude	Longitude	Local to WGS84	Local to Local
Aratu				eters
SAD69				
WGS84				
Datum				Local
Aratu				ters
SAD69	505,495.9	2,278,424.1	58.4 meters	
WGS84	505,464.2	2,278,473.1		

- This example showed coordinates of the SAME physical point
- Corollary: The same coordinates can represent different points depending on the reference origin (datum).
- 50% of purchased well data are not associated with a reference datum.

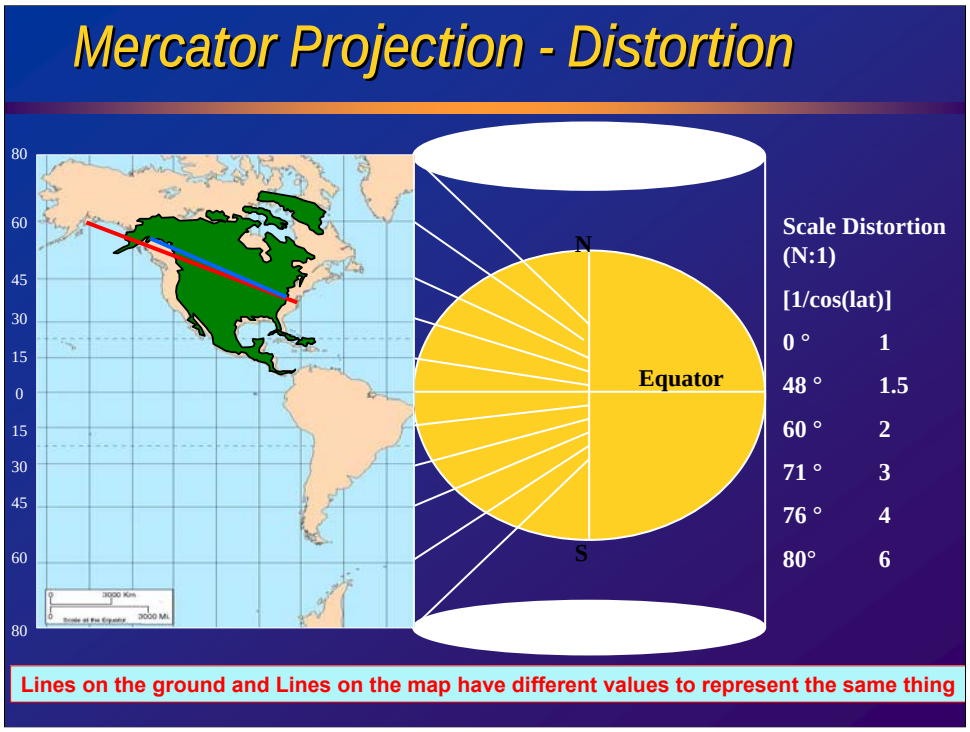
This shows the same example as we saw in the geodesy module, but includes now, the projection coordinate differences.



Before getting into the details of projection science, and as a follow on to the geodesy talk, it is important to understand the hierarchy of mapping.

The basis is the Geographic Coordinate Reference System (Geodetic Datum). As you have heard, a Geog CRS is “an ellipsoid of revolution attached to the earth in some manner”. If the Geog CRS is known then the ellipsoid is known as it is an integral part of the Geog CRS. The Geog CRS name is crucial, as it defines all other associated information. X,Y,Z cartesian coordinates are equivalent and interchangeable with Latitude, Longitude and Height measured in reference to the ellipsoid. The X,Y,Z nomenclature is a 3D set showing the relationship of a point to the center of the ellipsoid as it is attached for a particular Geog CRS, and has nothing at all to do with projection x,y,z (Projection CRS), which are referenced to the origin of the projection.

If the Geog CRS is known, coordinates can be transformed or converted from latitude, longitude and height to easting, northing and elevation (Projection CRS). If the Geog CRS is not known, it is not possible to convert, correctly, eastings and northings into latitude longitude and height or vice versa.



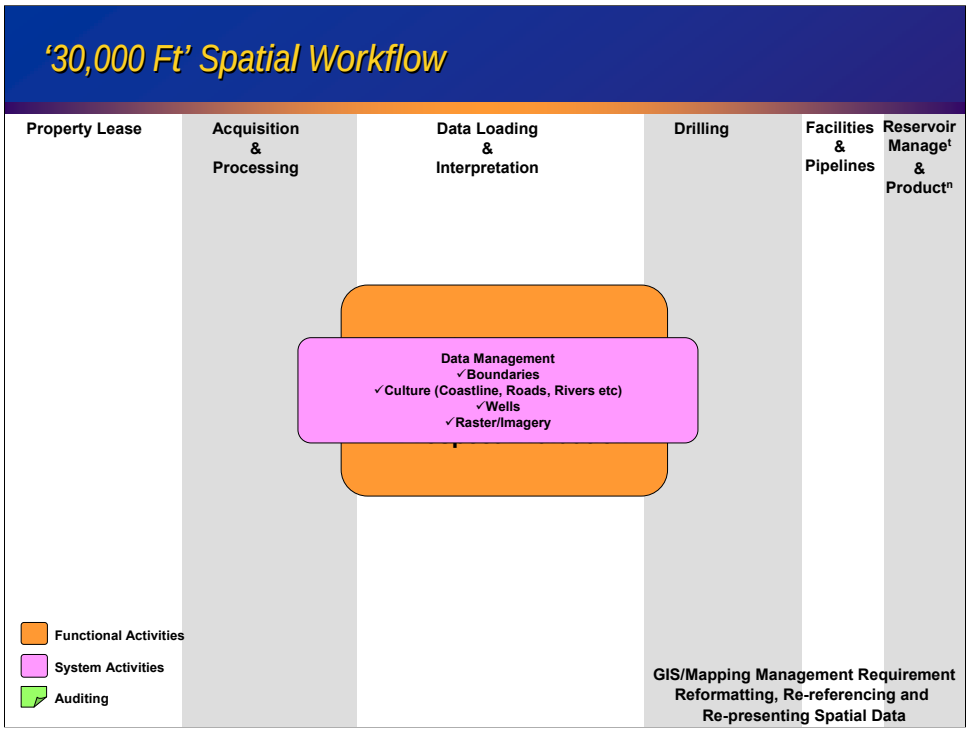
Mercator Projection. Secant of the latitude is used to project onto plane. This causes severe areal distortion in the northern latitudes, but has the property of making lines of constant azimuth straight lines – which is useful for vessel navigation.

The inset is from the Goode projection on the title page. It has its own distortions, but it shown juxtaposed with the Mercator to underscore the dramatic distortions at high latitudes.

If you remember nothing else…..

- **Latitudes and Longitudes are not unique unless qualified with datum name!**
- **Projection Coordinates are not unique unless qualified with Projection name, Zone and Datum!**
- **Heights are not unique unless qualified with Surface Reference (Vertical Datum)!**
- **Orientations are not unique unless qualified with Heading Reference!**
- **Units are not unique unless qualified with Unit Reference!**

Of all the lessons in the science and practice of geodesy and mapping, these 5 rules are the most important.



This is an organizational model related to spatial data, typical of a mid sized independent oil company. The model shows 6 major functions, often called 'silos' for the exclusive nature of each! Here is the first stage – Property Leasing. The legend is shown in the bottom left. Also the first 'corporatefunction – purchase of ancillary data that takes place prior to a lease purchase.

I use red for primary functions, grey for ancillary functions and purple for external data and applications

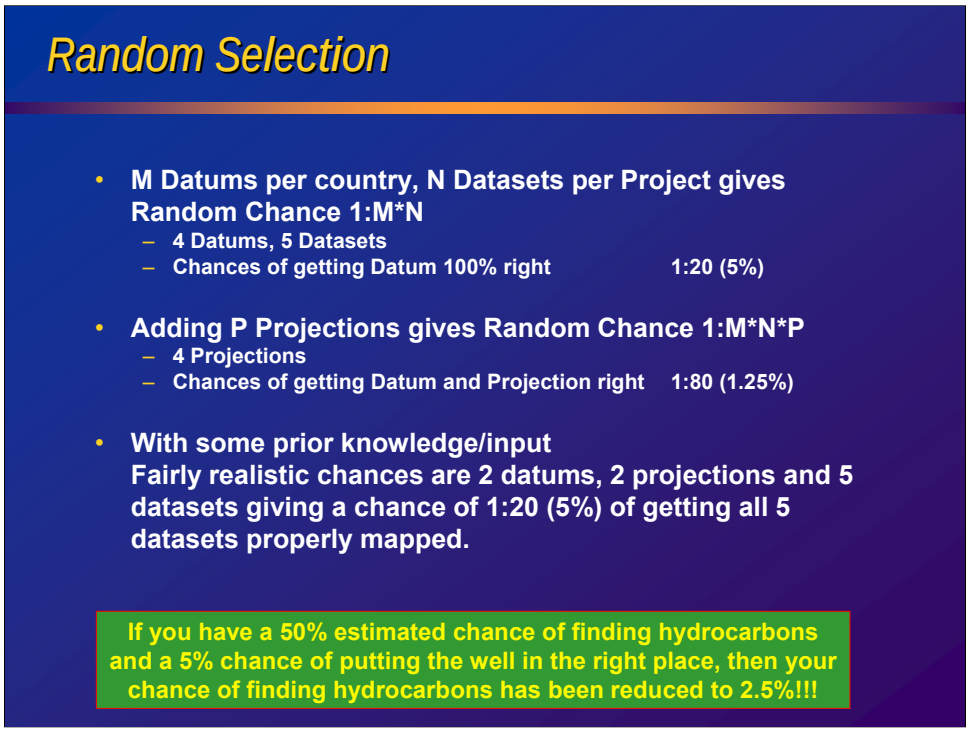
We have a pre-lease process – this requires us to load well and culture data, as well as satellite data in coastal regions, and block boundary information. At this stage, since we are not sure if we are going to actually obtain the lease, we usually try and limit the amount of money we wish to spend. Unfortunately, this means that the data maybe substandard with respect to coordinate and map information.

However, since we are now operating with huge databases, guess what – that data will form the core basis of our future work. It will never be replaced and will be used time and time again as a key foundation for our map based decisions. Wrongly placed wells from industry databases or our own archives may not cause too much problem in a regional overview, but will cause a great deal of wasted time later when someone uses them to make detailed inferences about the structures. Is anyone marking these data as sub-standard? Can our best industry programs do this. Even if they can, are staff taking the time to do so …..what do you think?

So….if it is poorly referenced, it will skew all the decisions made.

When we sign a production sharing contract, we should always insist that the coordinates defining the lease block are contained in the contract document, and that they are fully qualified.

Contract timing is an issue that militates against taking extra care. Many Production Sharing Contracts require seismic data to be acquired and wells to be drilled within a tight window or lose the lease. In fact this ought to engender more care, which ultimately will save time and create better decisions.



A GIS system is a mapping management process.

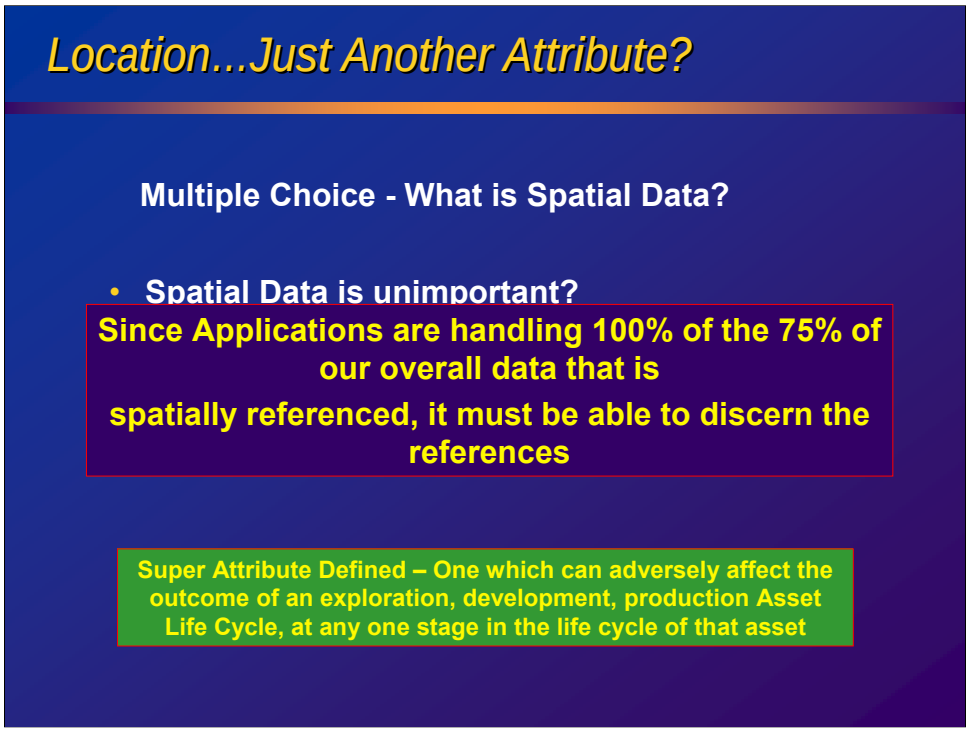
When we combine data in a GIS system, we put layers of data 'on top' of each other. The purpose is to obtain a picture of the relative juxtaposition of various features on each layer with features on other layers.

For sake of argument, let us use the "How many monkeys" principle, and make a statistical assumption that the process is done at random by people who are completely ignorant of maps and mapping sciences. We have M datums and N datasets per project, so we have a 1:M*N chance of juxtaposing them correctly.

Let's add P projections – now the odds, statistically are 1:M*N*P.

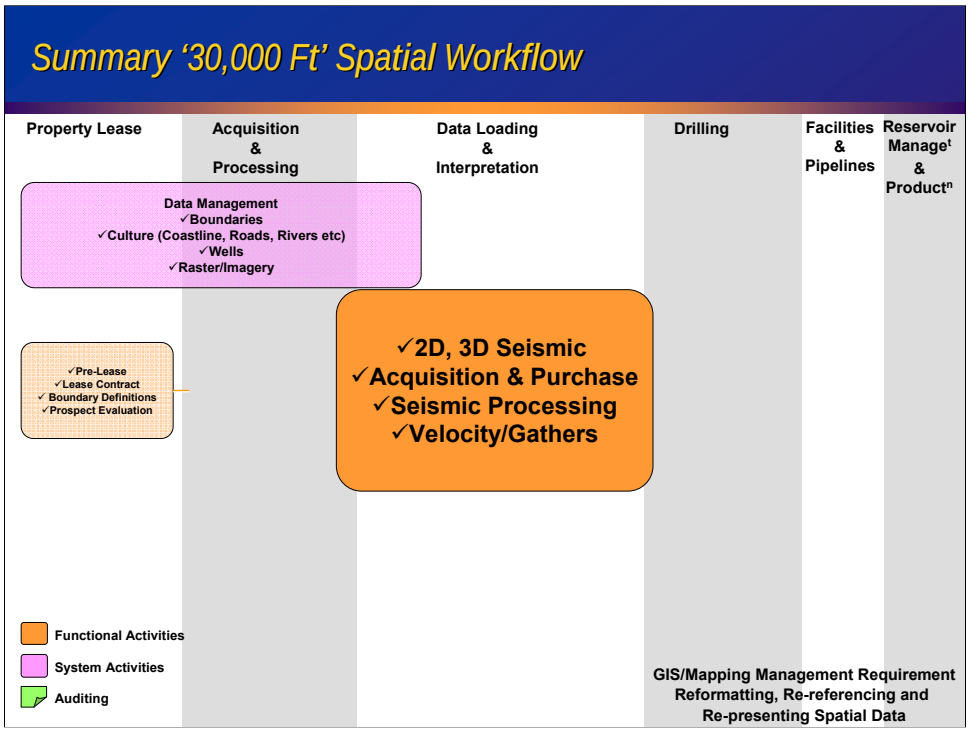
Even with some basic idea of the possibilities, the chances of getting 5 datasets matched in most countries today is 1:20. Including the United States. Note in this respect that there are 4 datums in use in the US and each State Plane projection has at least 2 and sometimes 3 sets of parameters.

Most oil and gas companies will not drill on a 95% risk of failure. Yet as an industry we have an appalling track record in respect of managing our spatial data. This leads us to take incredible high risks usually without knowing that we are doing so, because the basic science is so poorly understood by all levels of employees and contractors.



Spatial data is like a foundation – and just like a foundation as long as I is there, you don't even think about it. But often it is not there and the ability to build a sturdy and long-lasting structure is absent. It is also something you walk on all the time, and don't even think about until the walls start falling down. A situation that has existed systemically in the oil industry for several decades!

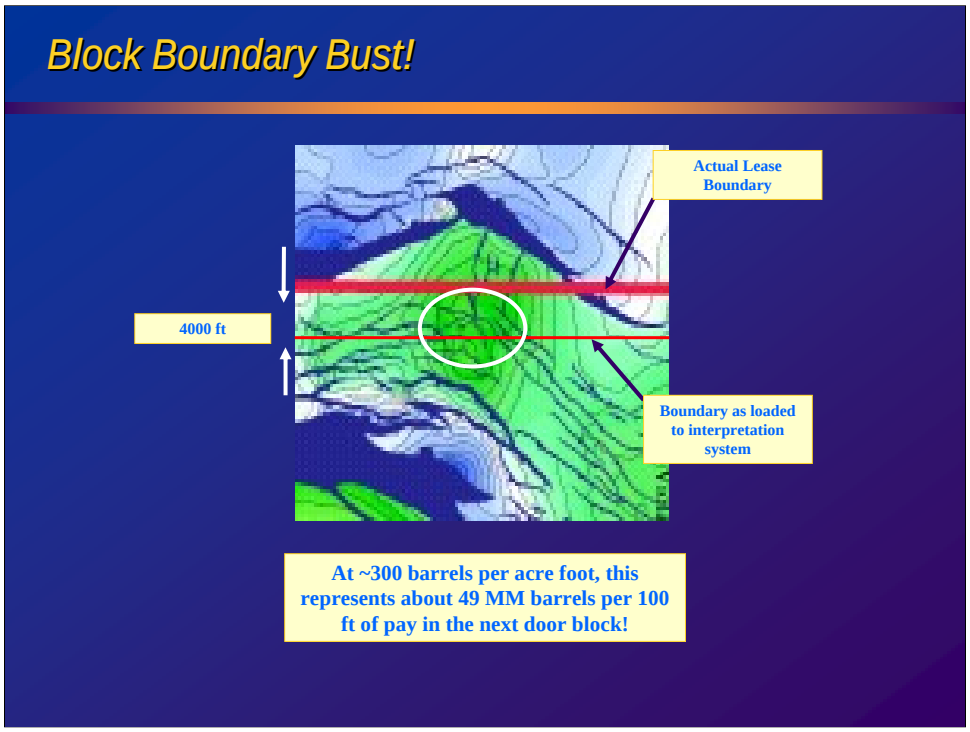
Note the definition of a super attribute.



Second stage in the model building.

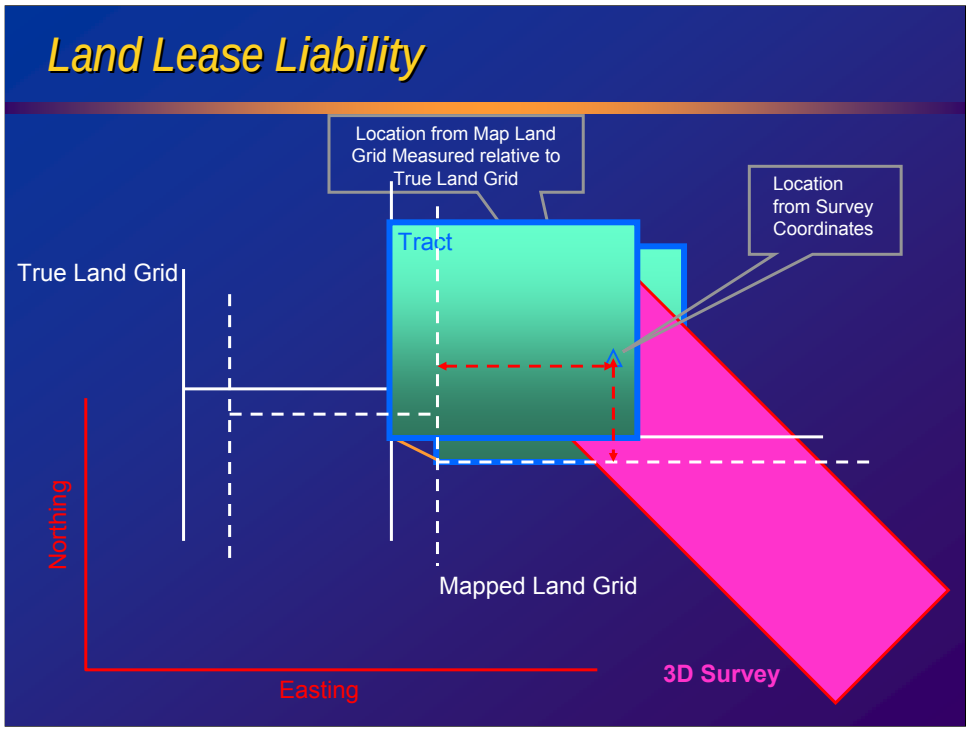
Now we move onto geophysical data acquisition and processing.

We acquire proprietary or spec data, and process it. We need to manage datum and projection in this process and a processed 'bin center' dataset is used to reference the absolute coordinates (easting and northing) to the relative inline and crossline 'coordinates' used to 'map' the interpretation – everything has to be properly located including ancillary data such as velocity information used in processing.



A lease block boundary issue – the Thick boundary line on top is the actual boundary. The thin line below is where the boundary was plotted in the interpretation system. The potential prospect is the oval area, and on the basis of the incorrect lease line location, would not be a suitable target for exploration in our block.

A potential loss of a major prospect!



The diagram shows a 3D survey in pink and a proposed well location. The dotted red lines show the anticipated calls from the section lines.

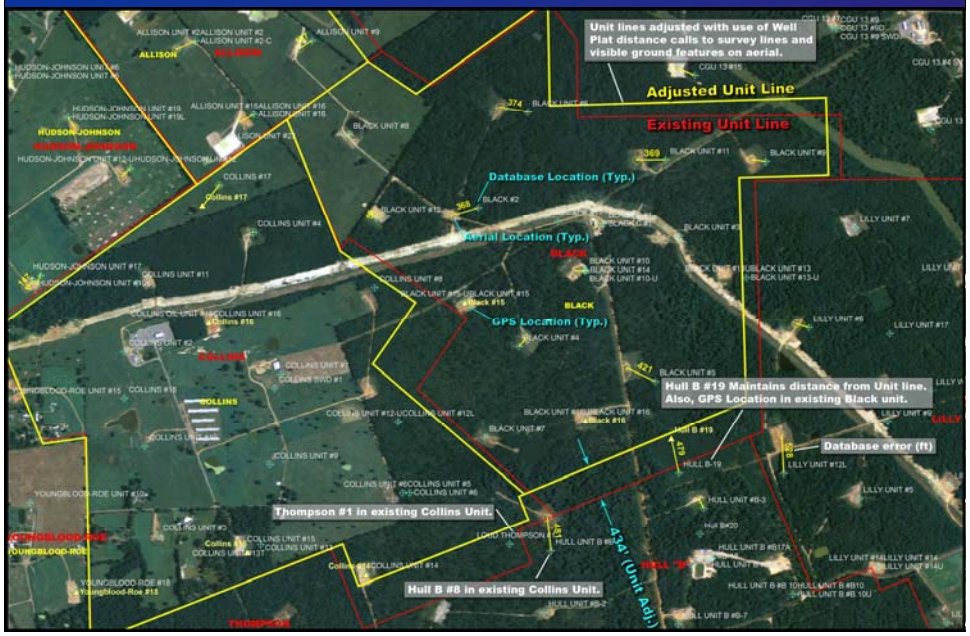
Unfortunately the mapped section lines are misplaced and are actually where the black solid lines are.

This will lead to a misplacement of the well relative to the seismic data equivalent to the offset of the section corner as shown by the green line.

To avoid this, have the land man provide a latitude and longitude with a GPS receiver and then send it in. Of course you will need to datum shift this to the project datum in order to make and apples to apples comparison. If it doesn't agree when you have done this, then don't drill the well until you have someone check it out

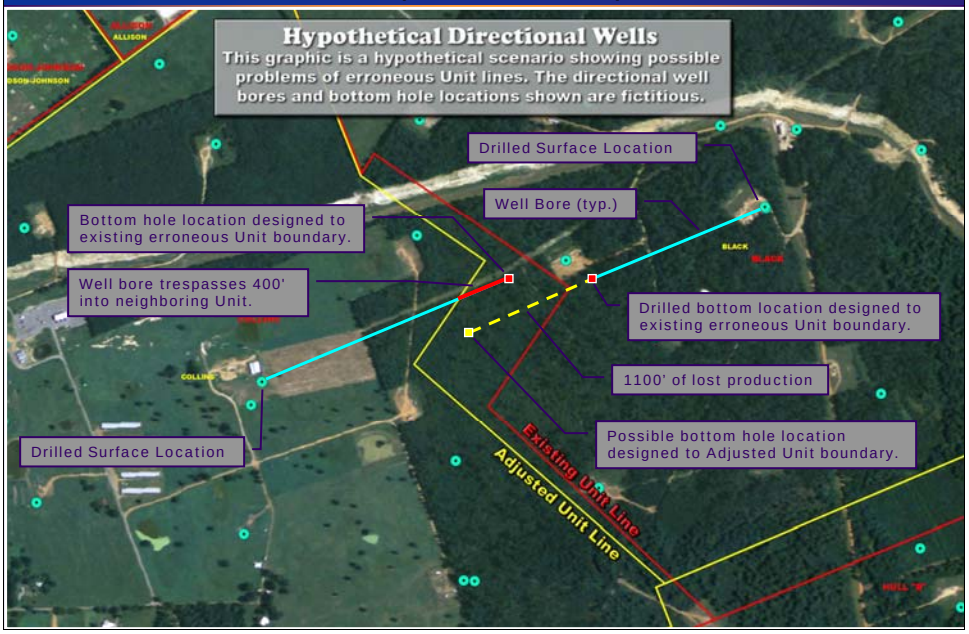
Unit Boundary & Wells

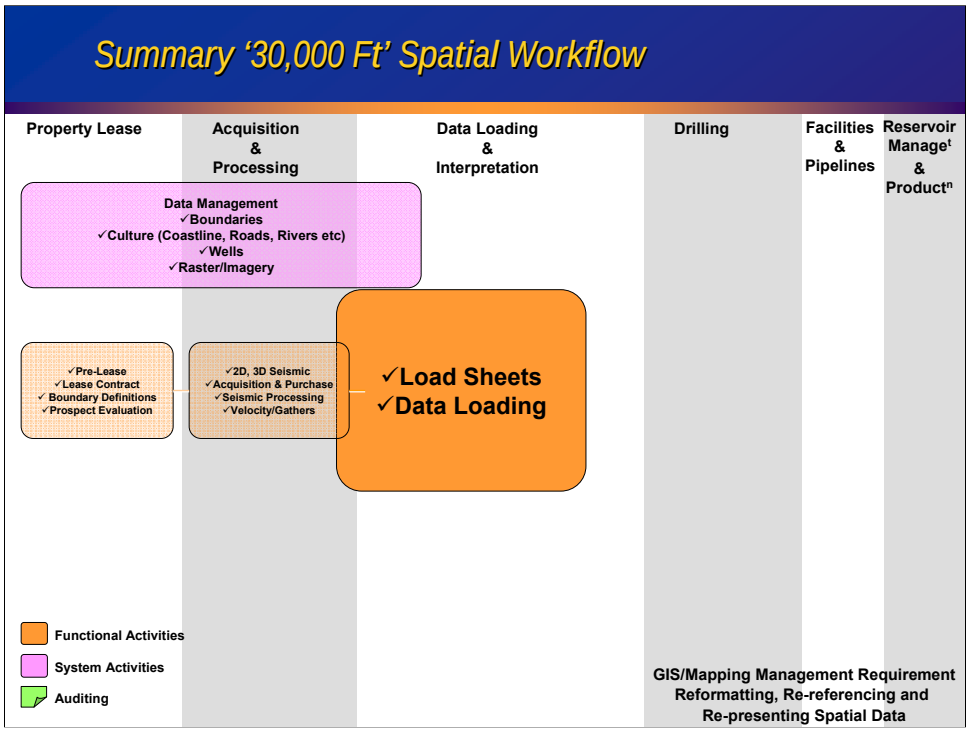
Unit boundary & Well database errors



Hypothetical Directional Wells

Fictional directional wells trespass and loss of production





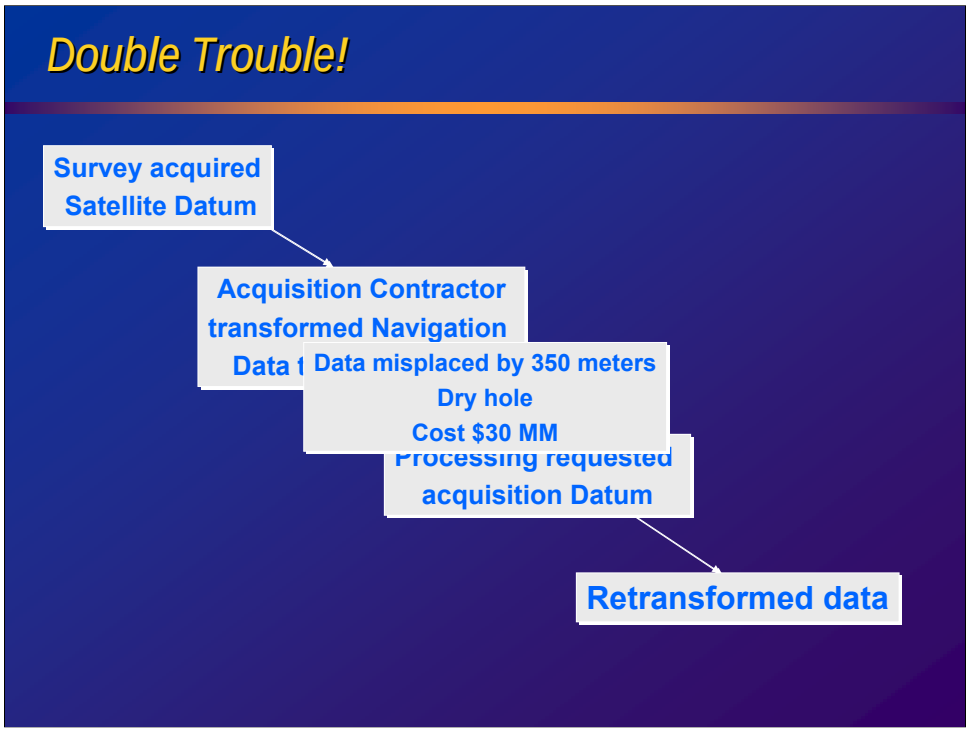
The third and fourth steps in the model I have built is probably the single most important. The data loading, interpretation and final proposed well location are the 'guts' of the 'data production line' within the process.

First we need to load the data – 2D and 3D are different, in that we load the actual coordinates of the CDPs for 2D, but in 3D we load 3 corners of a grid and the program interpolates between them. It is critical that this data is properly referenced. We have formal load sheet templates that we require, but often do not get in the form we want.

The interpretation work stations allow an array of possible manipulation of spatial data. These systems are de facto GIS systems, when used in their map mode. As well as the geophysical data, we load wells, boundaries, satellite data and culture, usually from industry databases. Scout data has to be properly referenced to be valuable once we move beyond regional analysis to detailed interpretation.

In order to be able to transfer data between applications, we have in the process 'Middleware' to allow 'translation' of the data into the correct application format. That is the theory anyway!

The last ancillary (at this stage) function is to make initial evaluation of potential volumes.



The example I give is that of a survey acquired in WGS84 datum.

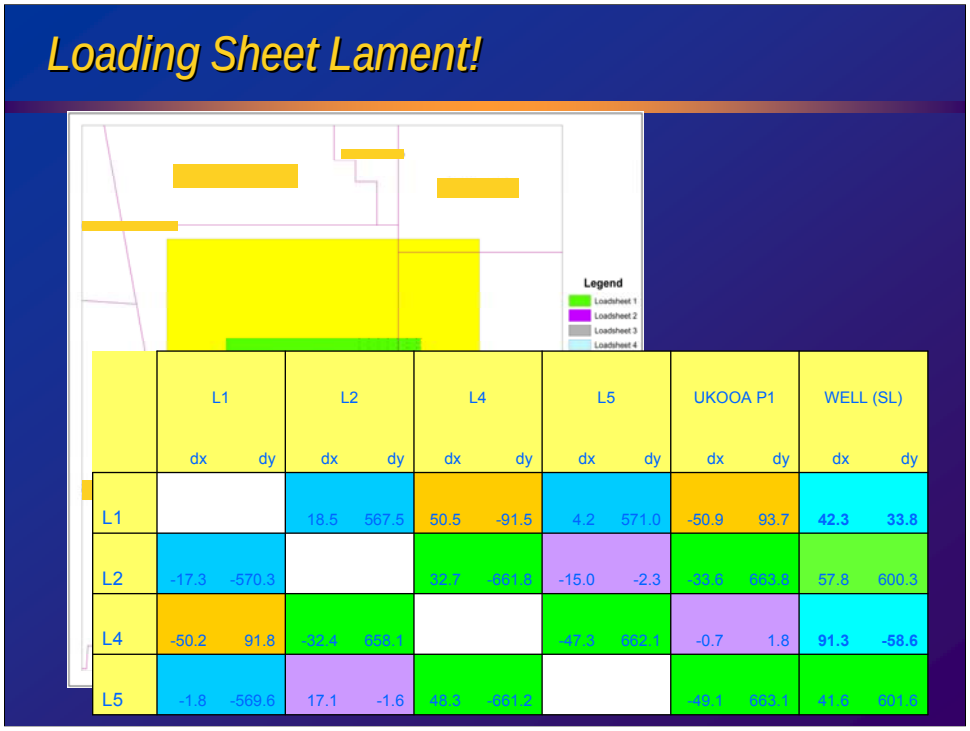
Data were transformed to local datum by the acquisition contractor.

After completing the processing, the processor called the acquisition company and asked which datum it was acquired in.

On being advised that is was WGS84, they executed the datum shift a second time.

Well was 350 meters misplaced and was a dry hole. It was re-drilled at a cost of $30MM.

Moral of the story – a little knowledge is even more dangerous than none at all – and you have to ask the right question.

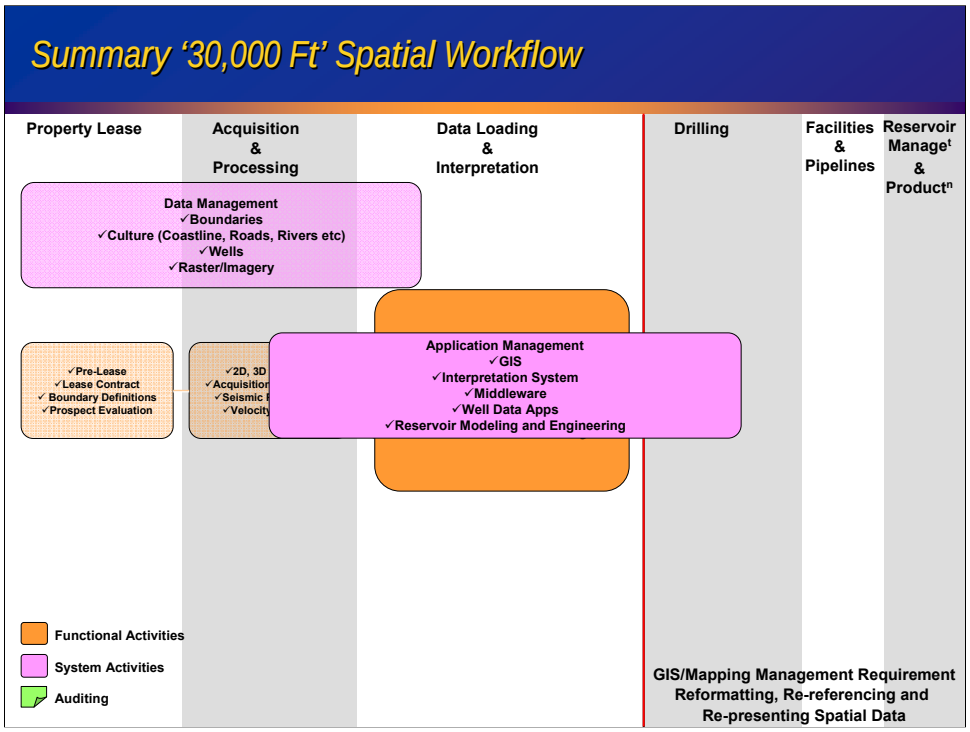


	L1		L2		L4		L5		UKOOA P1		WELL (SL)	
	dx	dy	dx	dy	dx	dy	dx	dy	dx	dy	dx	dy
L1			18.5	567.5	50.5	-91.5	4.2	571.0	-50.9	93.7	**42.3**	**33.8**
L2	-17.3	-570.3			32.7	-661.8	-15.0	-2.3	-33.6	663.8	57.8	600.3
L4	-50.2	91.8	-32.4	658.1			-47.3	662.1	-0.7	1.8	**91.3**	**-58.6**
L5	-1.8	-569.6	17.1	-1.6	48.3	-661.2			-49.1	663.1	41.6	601.6

Here is an example of multiple load sheets, most of which contain no geodetic information and 2 of which have no company of origin.

The project was loaded with Load Sheet 1 which was datum shifted incorrectly by changing the elliposid but leaving the datum shift parameters at zero.

The well was misplaced by about 90 feet in easting and 60 feet in northing, as a combination of the incorrect datum shift and the precision of the bin size when selecting the I,J reference.



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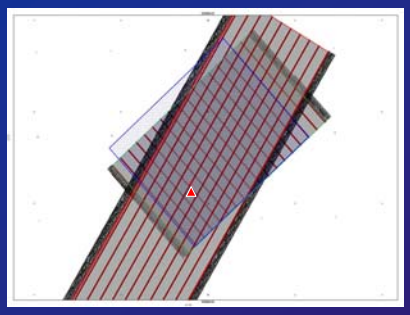
Proposed Drilling Location



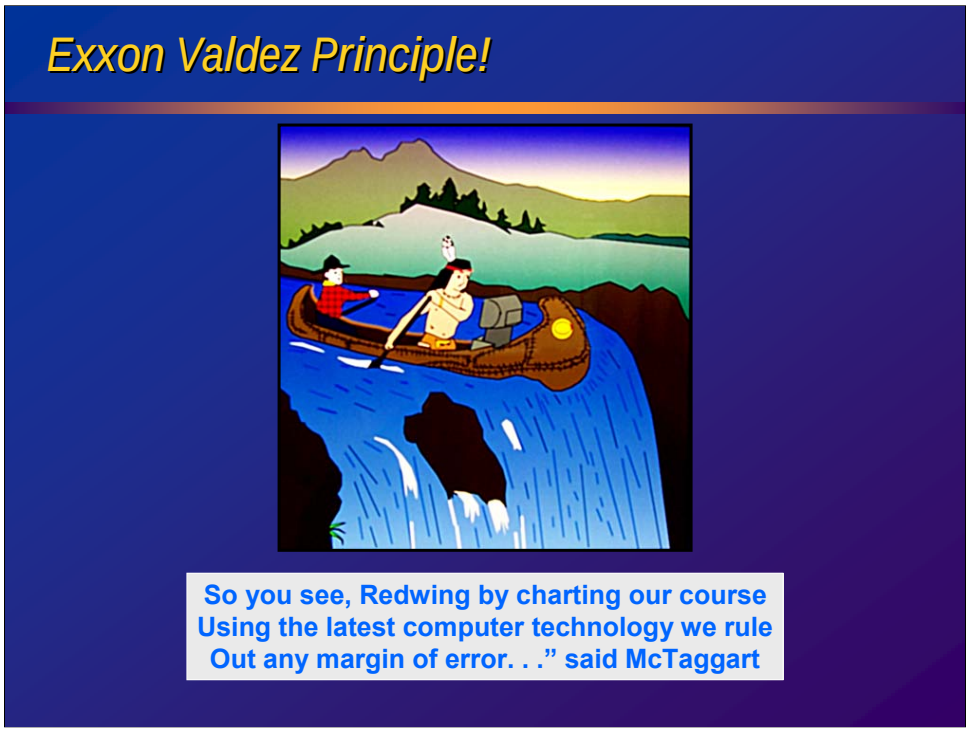
- **Two Surveys**
  - Interpreter complained that one was mismatched with the other
  - One survey loaded with new corners, but datum labeling not changed
  - Result – 250 meter error
- **Question – would we have found it if there was only one survey?**

First example is to show an area where there are two 3D surveys.

One of these disagreed ‘geophysically’ with the other one. On investigation it turned out that the load sheet corners had been changed to a different datum, but the label for the datum was not changed.

Error was ~250 meters.

Big question – how would you spot this if there was only one survey?



Exxon Valdez Principle – If it is color on the screen – “Must be True”

Or “Who moved that Rock over here!”

Overall Software Uncertainty

- Algorithm Errors
- Mapping Utility Afterthought
- Parameter Error/Parameter Limitation
- Default Datum Settings
- User Interface Uncertainty
- Lack of Error Trapping
- Lack of Audit Trail
- Poor user training and understanding

Software Uncertainty

- **Leading zeros in a geodetic package are ignored when converting DMS to Decimal Degrees.**
- **At least 2 major applications default to NAD27 in the absence of any reference data (doesn't matter where you are in the world) and the user is NOT notified or asked to confirm.**
- **Datum Shift information is 5 layers down in the menus. Datum shift parameters not accessible.**
- **There is no package, out of about 400 used at Devon, that gives a geodetic 'forensic' specialist an audit trail as to what a user may have done, to help trouble shoot mismatches.**

Algorithm Errors

Mapping Utility Afterthought

Parameter Error/Parameter Limitation

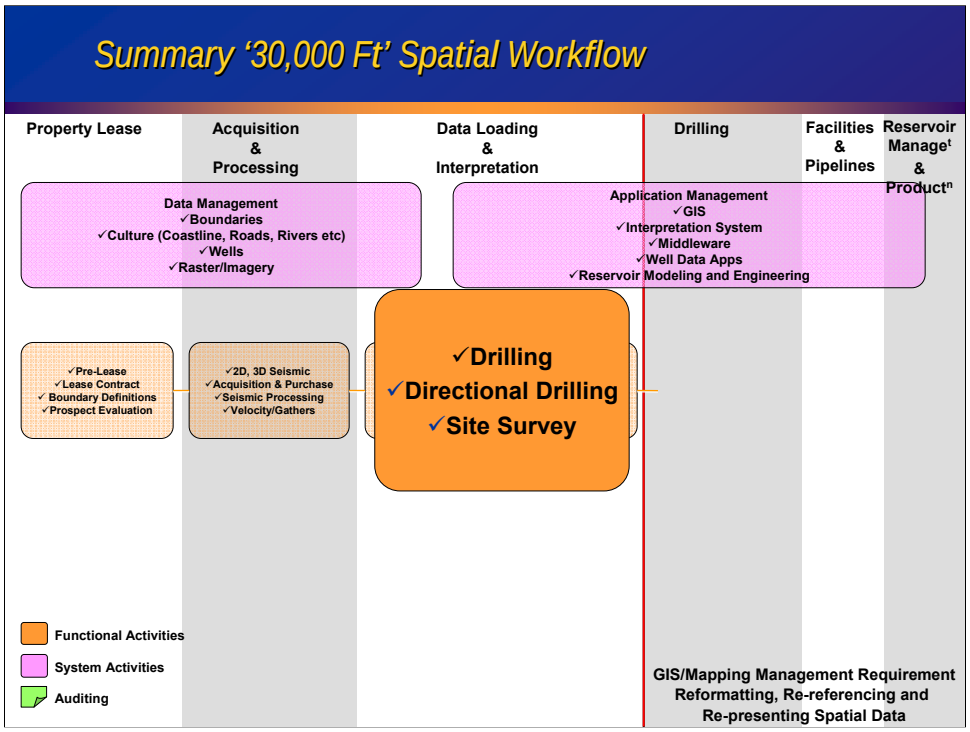
Default Datum Settings

User Interface Uncertainty

Lack of Error Trapping

Lack of Audit Trail

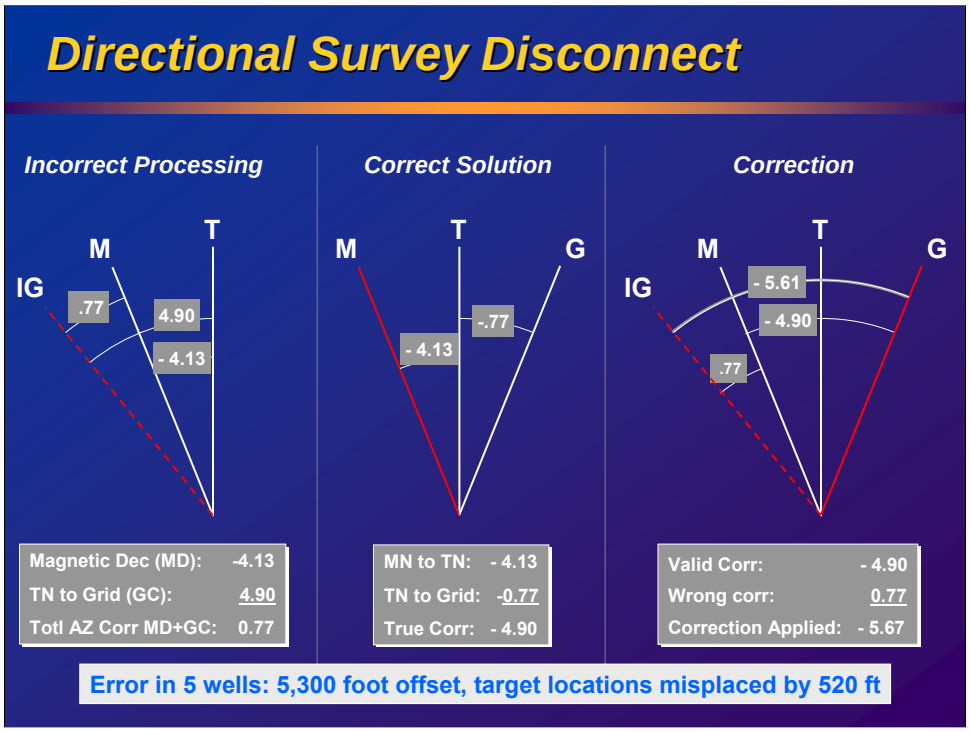
Poor user training and understanding



Fifth step – in the model – Drilling activities.

Note the red line – shows the cultural 'chasm' between earth science and engineering!!!

Two major functional components are drilling and directional drilling.



A directional drilling problem.

The diagram on the left shows the incorrect result – a mix up between the corrections for convergence and magnetic declination

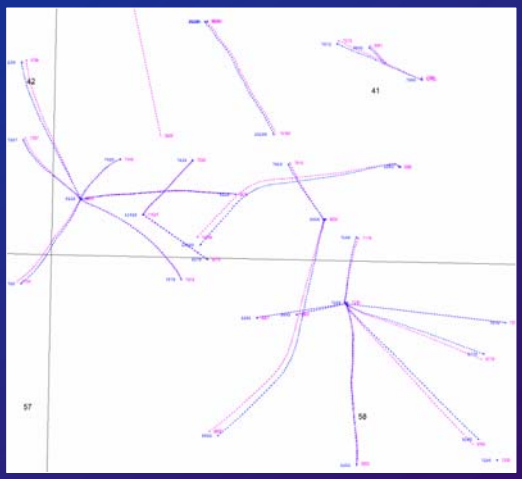
The middle diagram shows the correct solution.

The right hand diagram shows what was done to correct the initially incorrect solution.

This was spotted by comparison between two companies' solutions – previous slide (proposed well location), would we have seen it if there was nothing to compare?

Error was 520 ft rotation from target, for each of 5 wells!

Well Walkabout

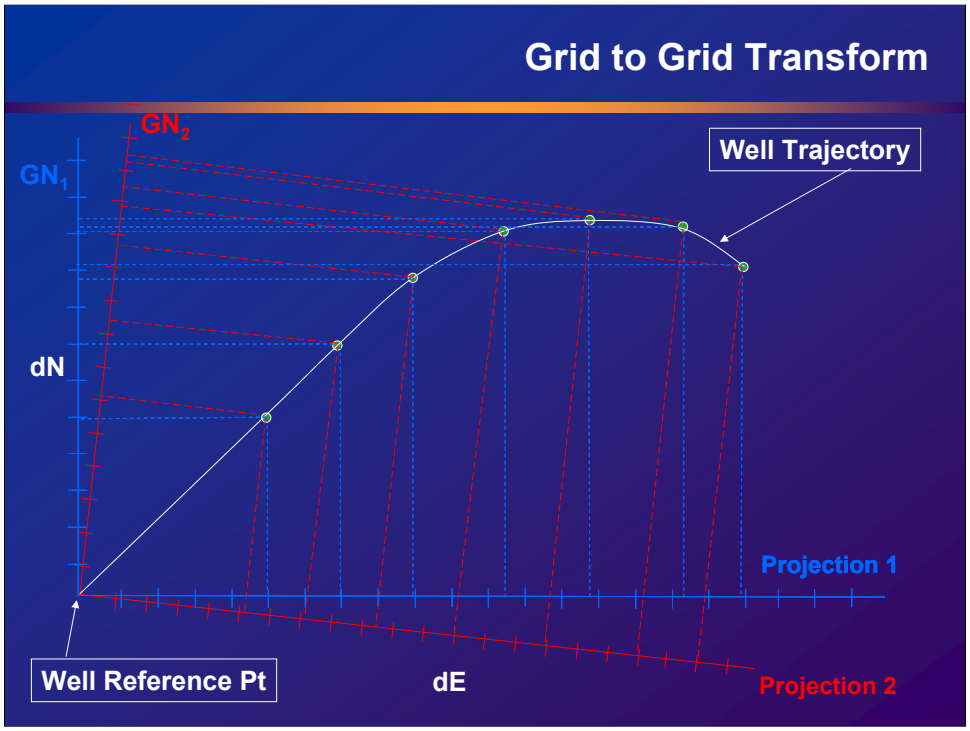


This slide shows 40 well tracks for 20 wells in 2 randomly selected concession blocks in the Gulf of Mexico. These data came from two different commercially available well databases.

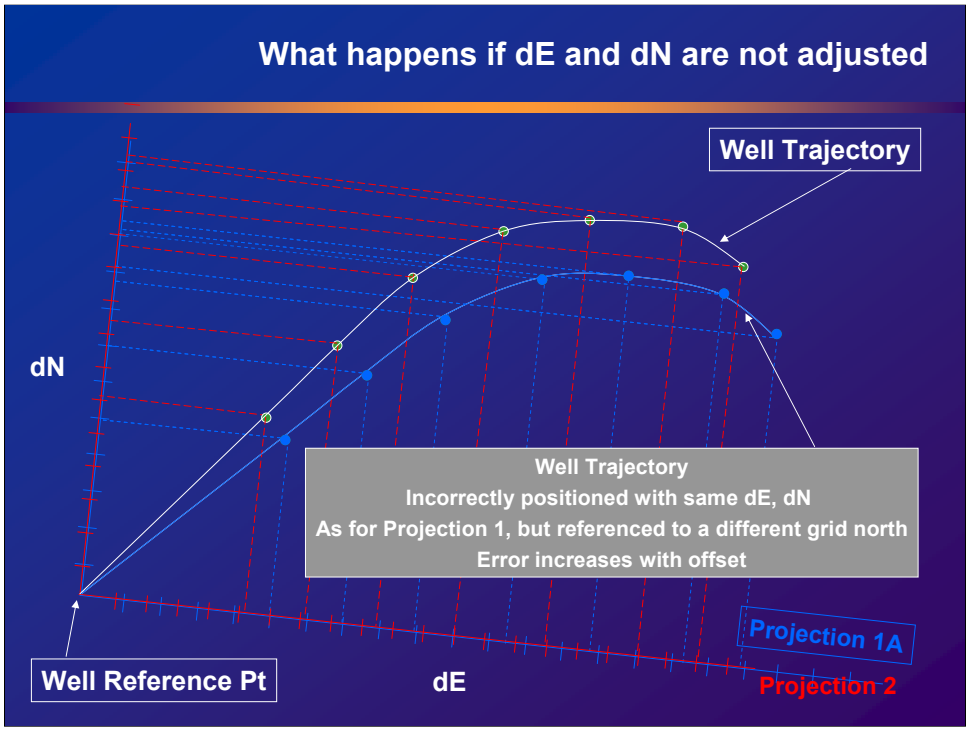
9 (~50%) of the tracks disagree because of convergence angle mismanagement.

1 disagrees because of a misplaced surface location.

How do we know which is right and which is wrong and perhaps more importantly, if we only have one dataset how would we know there was a problem?

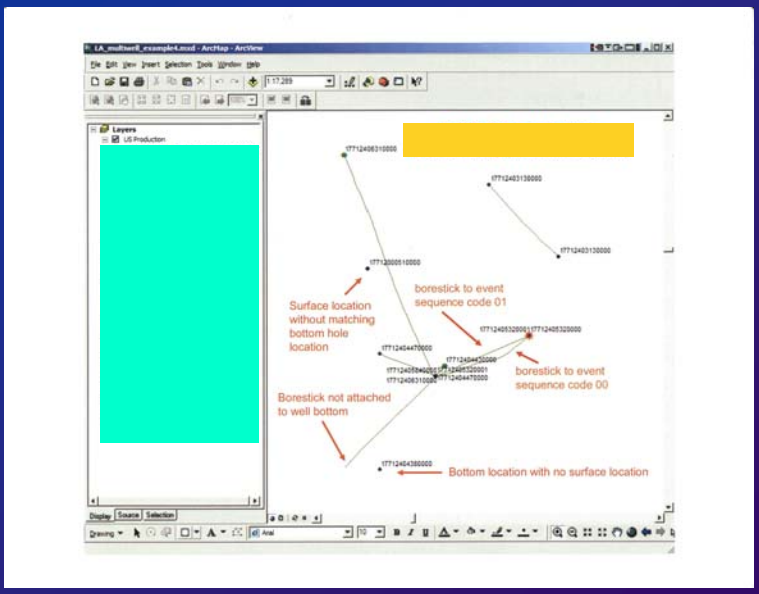


The Blue grid shows the first projection you are using. The red shows the projection you want to change to. The origin is the well reference (KB or Drill Floor or Ground Level). The blue lines show the dEasting and dNorthing for the black dots which define the well trajectory. Grid north is different, since the location of the well in one projection is different relative to the central meridian than the other.



Here is what happens if you use the blue dEasting and dNothing on the red projection. It rotates the well trajectory in space. Remember that the well trajectory doesn't move, we are changing the north reference, when we change the projection. As you can see the potential damage to the integrity of the well trajectory position could be severe (increase with offset from the well reference point.

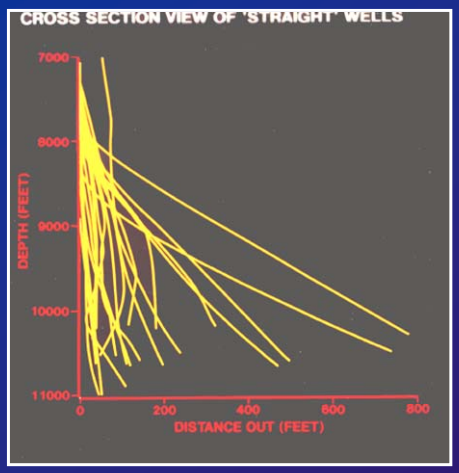
Commercial Well Location Data



Spatial Layer from a a leading data provider.

Note how poor the QC is on these data. This product was supposed to provide some sort of efficiency by reducing the time to load the data into SDE clearly this will not provide a good return for the time saved!

Angle of Dangle!!

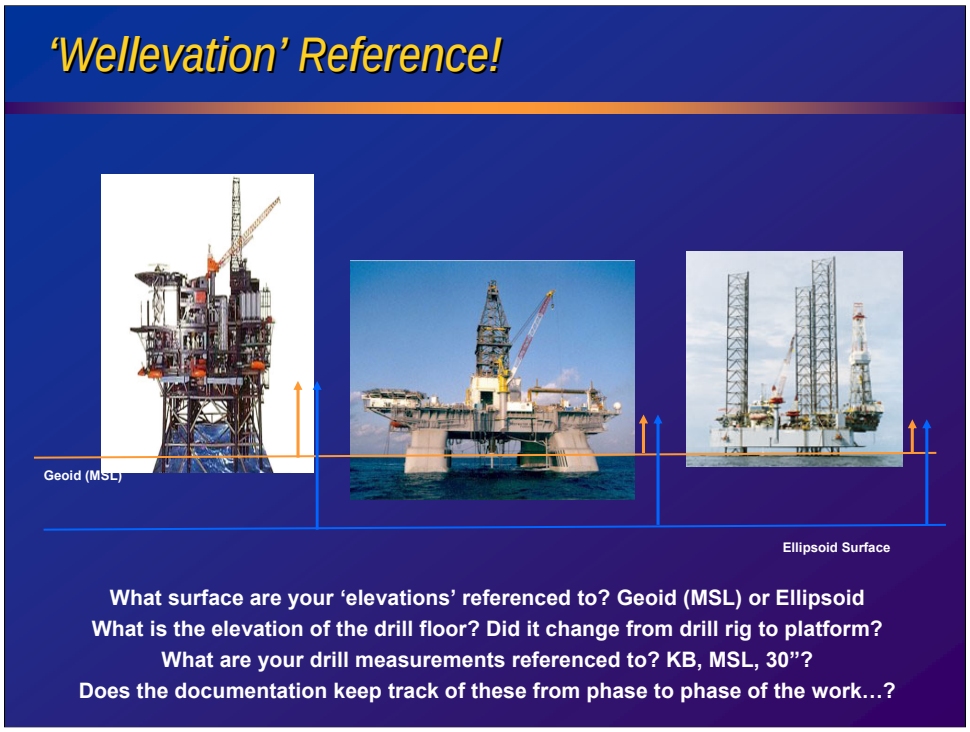


One manager estimated that his staff of 5 geologists spent 80% of their time figuring out where wells were and 20% interpreting the geological horizons!!

All posted as 'straight wells'!!!

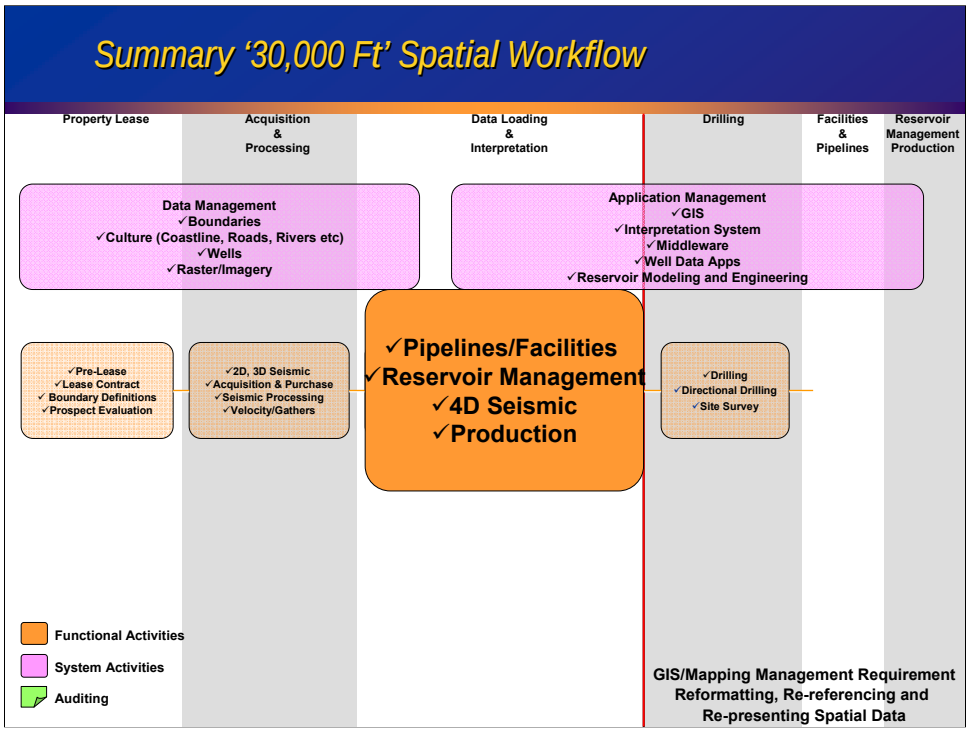
The above diagram shows the result of re-surveying all the 'straight' (un-deviated) wells on a prospect!

The price of this is huge – this represents a corporate hemorrhage!



Managing the vertical referencing can be a challenge as a project proceeds. Referencing everything to the KB or MSL in the drilling stage and not keeping track can lead to mis-referencing of elevation at a later stage when a platform is installed.

5-10 meters of difference in elevation can mean millions of barrels of missed production and millions of dollars of lost revenue if the directional target is hit high or low in the reservoir.



Sixth step in the model build – Pipeline and Facilities.

There is frequently a disconnect between construction and facilities management and the exploration groups. Geophysicists vs Engineers.

In addition many engineers did the 2 survey week course at college, and do not understand the problem.

This tends to lead to a trivialization of survey requirements and planning. A major area in this regard is the management of positioning for deepwater projects. Multiple contractors are used. It is best to plan to have a single positioning contract for all phases and make it a requirement that all contractors use it. This can save millions of dollars in lost time for expensive vessels standing by for complications in the availability of signals due to interference in the systems or incompatible operational activities.

The design of facilities and pipelines has to be linked to the anticipated volumes of hydrocarbons. These have to be accurately assayed prior to discovery if economies of scale are to be on target. Both under-designing and over-designing will create problems. Integrity in the spatial data management process, especially in the use of applications, is critical to these estimates.

And the seventh stage – Production/Reservoir

The last stage in the functional model is Production.

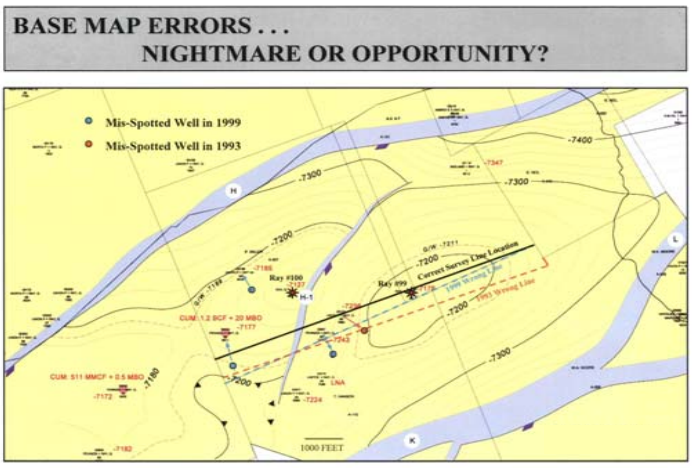
This is the second part of the "Finding and Producing hydrocarbons" definition of what we, mapping/GIS specialists are trying to support.

The primary function is production, the supporting functions are Reservoir management and 4D seismic projects.

Most reservoir visualization applications are based on a square world! The deeper we image and the further out we send our directional wells, the less true they are to real world space! Most packages the data have to be prepared before loading. This can lead to misplacement of datasets relative to each other.

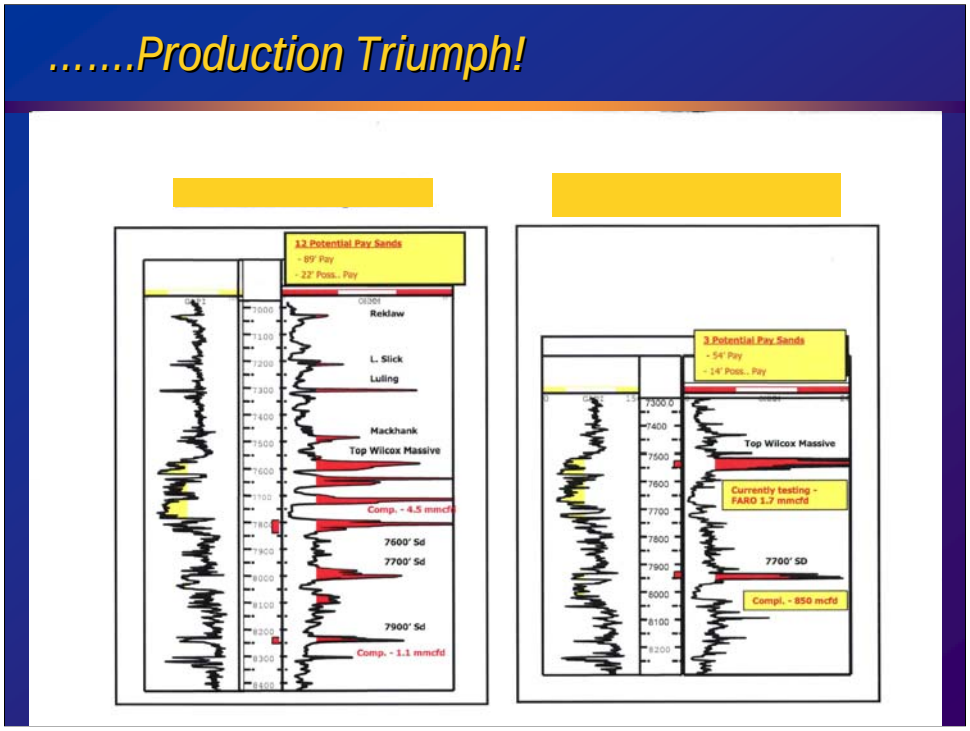
The issue of 4D surveys is important, as the best way to manage this is by much earlier planning than is culturally accepted. The capital cost of fixed installation of bottom cable or seismometers needs to be built into the funding model to be really effective, and the planning for the acquisition needs to be designed with the earlier acquisition to allow better matching of spatial data locations of the receivers and sources.

Contour Catastrophe……..!



4 wells repositioned ~500 ft, due to grid error discovered by geologist's field visit, allowed for re- contouring and subsequently discovery of 2 major gas fields.

Imagine how many of these have been missed because the geologist did not have the persistence to go to the field. A case of a direct relationship between possibly missing reserves directly due to mispositioned information.

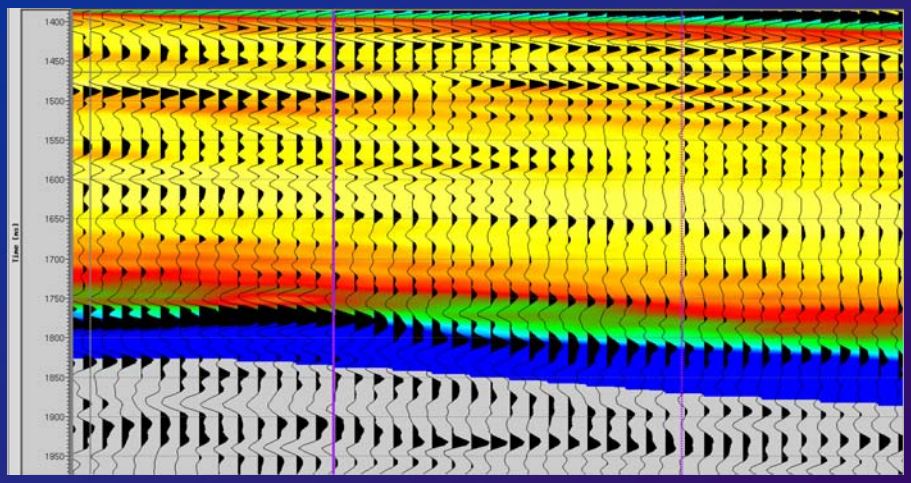


Producing horizons of the 2 wells.

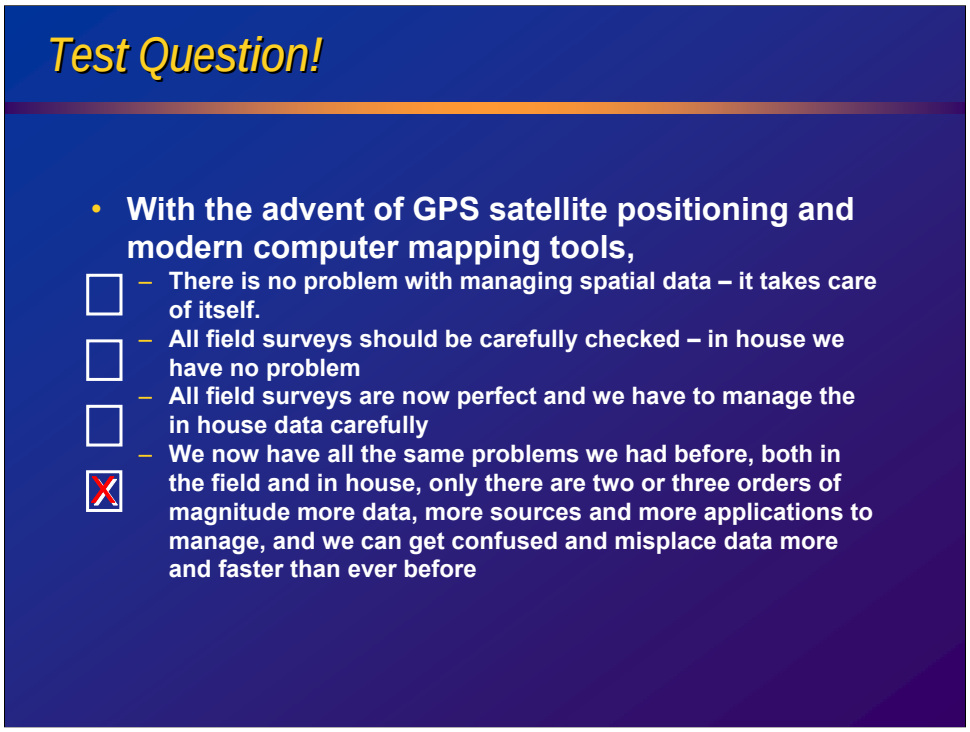
Volumetrics – CPS3

- dx, dy, dz is presented to user. Could be:
  - Delta Easting, Delta Northing, Delta Elevation or
  - Centroid offsets for a 3 parameter datum shift
- dx, dy, dz will change for different projections. No facility for transforming without exporting data to a geodetic program and back again.
- Initial screen input scrolls down out of sight. Buffers are not cleared. Second entry is additive with first.

Inversion Insanity!



Well data misplaced about 1800 meters – and used for inversion. While one well may not cause too much trouble, 75% of the wells in this field were misplaced. This will create major bias in the inversion and subsequent use of the data for follow on drilling decisions.



Second Test Question

The Environment

- Great workforce efficiency due to ….
  - Distributed computing – Multiple users
  - Multiple sources of data/Internet access
- Higher risk due to……
  - New data in satellite, legacy data in local datums
  - Low training budgets/poor understanding
  - Little internal and supplier oversight
  - Few procedures

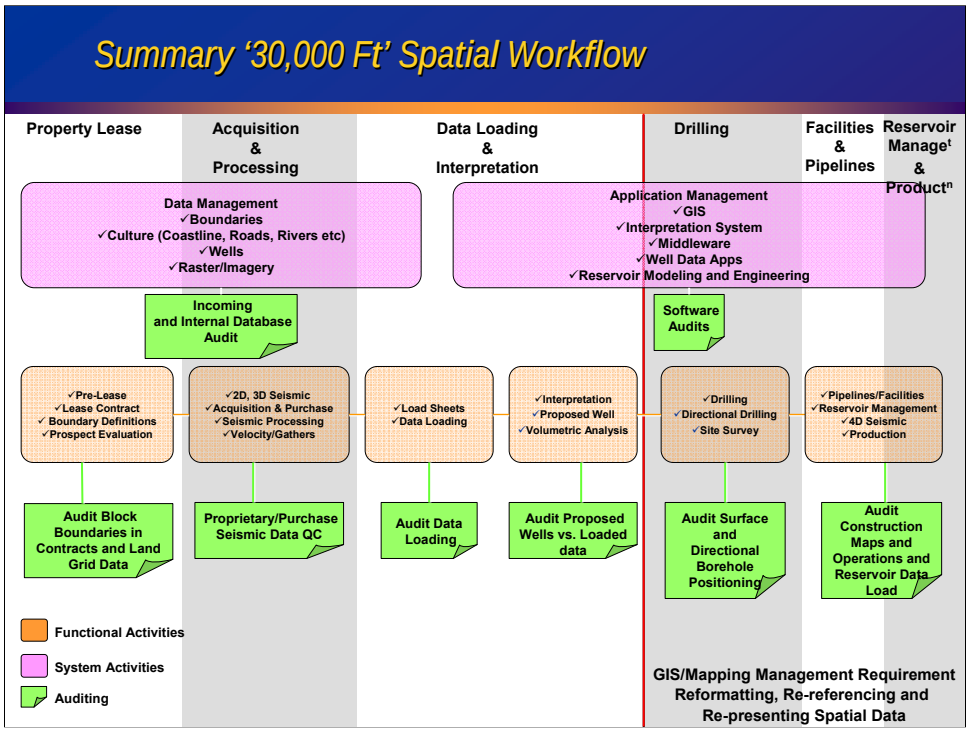
So who is minding the spatial data 'store'?

Users of spatial data maybe as varied as lawyers, IT support, interpreters, drillers and management

All have different issues and purpose for the mapping

But all should share a common goal, successful discovery and production

So who is responsible?



Here is the completed functional model. I have shown a 'serial process up to now.

What needs to happen to bring some integrity to this flow? This process is happening at one stage or another on a multiplicity of projects across the corporation.

We need to look at key critical functions in the work flow and provide audits and data reviews where we are most vulnerable.

These are:

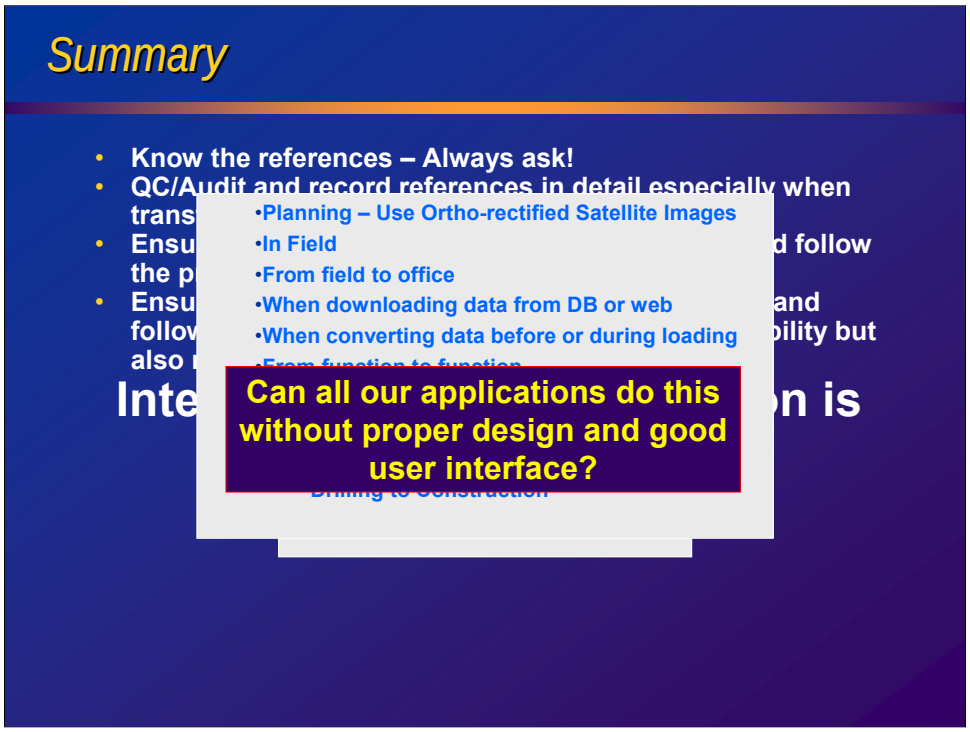
Bringing in data

Auditing field data acquisition for proprietary and multi-client datasets, as well as satellite, well and boundary data.

Audit proposed drilling locations to ensure they match the seismic data and offset wells

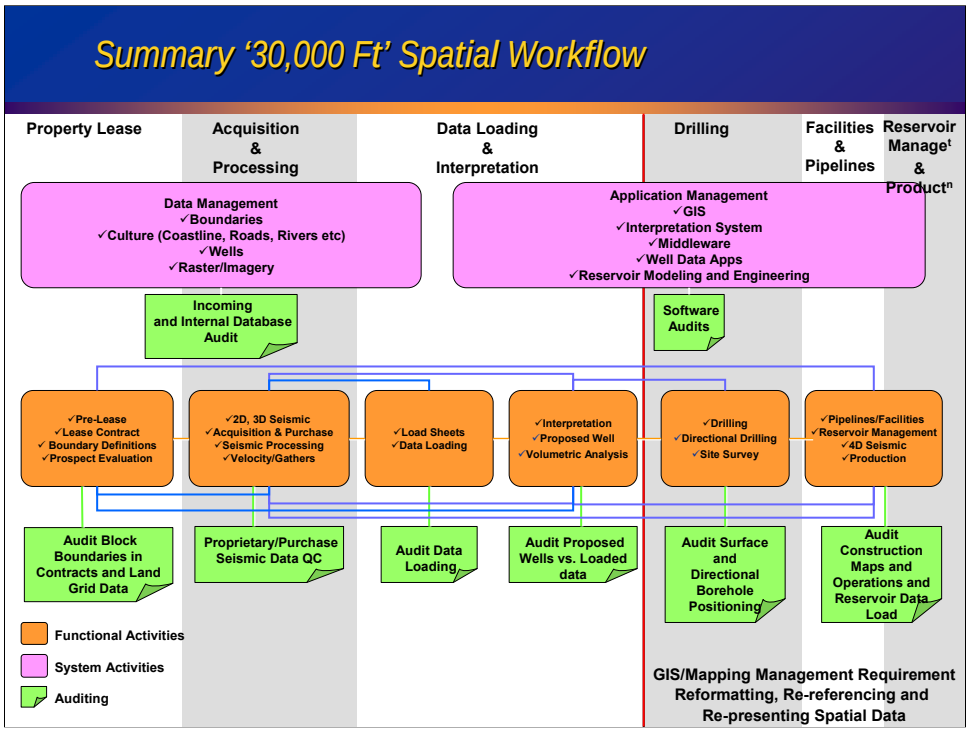
Audit of directional wells – bringing in the data by satellite to the office.

Audit of Spatial Data aspects of software used for Interpretation, Reservoir analysis, Coordinate conversion.



A summary of what we need to be doing.

Policies and Procedures need to specify who is responsible from loading tech to senior management.



Now to connect the dots….! And finalize the model

Most of these functions need to be connected with other functions sometimes across the complete timeline for the project.

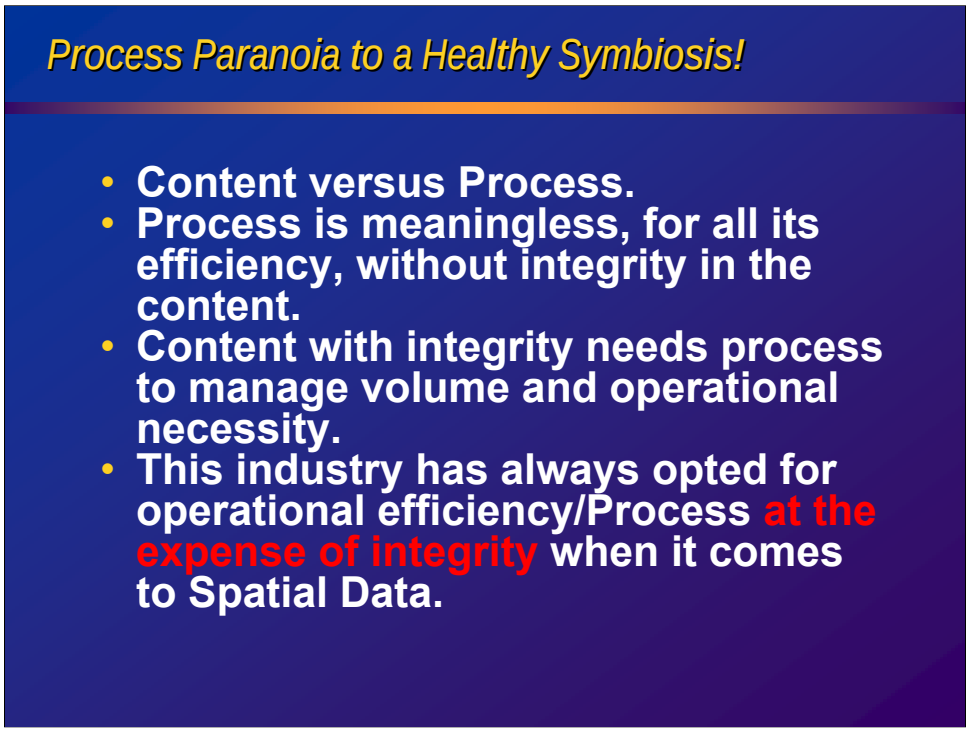
This process is often overlooked in the 'serial' approach to project management.

This results in much duplication of effort at best, and in wasted resources at worst.

For instance purchase of satellite map data needs to be coordinated
Planning for facilities capacity is a function of initial estimates of volumes etc.

This makes the process less serial and links areas that are often not very well linked.

Spatial data is a major and often the only common thread in these links.
The redline represents the cultural divide between Engineers and G&G!



No further comment

Name and Address

- **E.G. Greater Houston**
  - 2005 estimate 5.23 MM people
- **First thing we would consider in populating a database would be accurate**
  - Name
  - Address
- **Why is it that in populating well, boundary and seismic databases in our industry we ignore identity and location data in deference to the operational necessity of implementing the database into our operations?**

Identity and Location

Used according to good mapping and data management principles, GPS for content and GIS for Process provide the 'Glue' or the 'Foundation' that holds everything together throughout a project/asset life cycle.

How……?

Endocrine functions are those functions that under gird more than one 'line' function. In the human body these are primary organs – such as the heart, liver, kidney, pancreas etc.

Spatial Data Management falls into this category

Typically these are activities that a business unit will NOT DO well (or even at all) without some corporate 'incentive'!!

They are usually activities that need to be applied uniformly, strategically or both across the corporation.

The risk of financial loss due to Spatial data mis-management is every bit as high as the losses due to Health and Safety disasters, embezzlement, poor planning and bad IT and communications. An added risk is that it may also never be seen or discovered.

Benefits of Good Spatial Data Management

- **Lease costs – Ownership**
- **Value in geophysical data**
- **Correct Loading of processed data**
- **Better drilling decisions**
- **Properly placed wells**
- **Better appraisals**
- **Pipelines and facilities properly planned and placed**
- **Lower legal liability for damage and trespass**
- **Staff time spent on core competencies**
- **Improved reserve replacement**
- **Lower finding cost**
- **Increased value of the asset**

All these benefits together, I believe, can tangibly, demonstrably and significantly improve a large oil company's bottom line

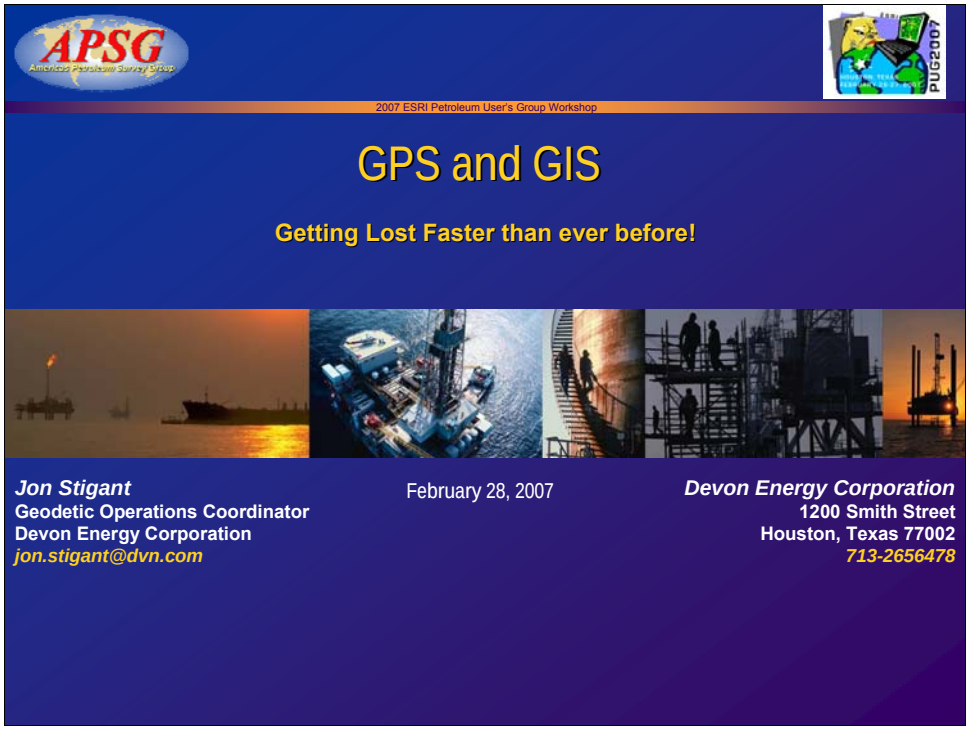
Here are some characteristic numbers for the investment in an exploration well.

There are Some Things Money Can't Buy….!

For Everything Else, there's

Poor POSITIONING is a HIGH RISK activity!!!

To summarize…!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