Todd Minehardt 6 November 2021

Q: If we're comparing your GIS & analytics experience, what do you consider as having spent most of your time on in your past projects? GIS stuff meaning spatial stuff; analytics meaning exploratory, diagnostic, or predictive/prescriptive stuff.

A: I'm going to break my timeline down over the past 30 years.

For the first 10-year period, which includes (roughly) my Master's, Ph.D., postdoctoral, and other academic experience, roughly half of it included a significant geospatial part: this includes my first exposure to ARC/INFO in 1992, when I was digitizing maps of oil plays as a research assistant at the Bureau of Economic Geology (BEG); my studies in Energy and Mineral Economics; and the entirety of my Master's thesis work. During this time, my work is fairly described as characterization of properties and extent of geospatial constituents.

At the BEG (1992-1993), I worked for Dr. Steve Seni on a piece of a larger project (Seni, S J, & Finley, R J. Atlas of Northern Gulf of Mexico Gas and Oil Reservoirs: Procedures and examples of resource distribution. United States.) for which I determined lateral and vertical extents of oil and gas plays from well logs and other sources. I recall laying out the well logs on long tables and matching producing zones by using colored string. The predicted size and shape of the play would then be digitized on a map using one of those digitizing tables with copper mesh. There was a heavy analysis part, as I had to be able to read and interpret well logs and infer the extent of the subsurface characteristics from limited sources of data.

Meanwhile, I was in the Energy and Mineral Economics Master's program (then, a subsection of Petroleum Engineering) where I was taking coursework in geology, economics, and the prevalence of mineral resources (specifically platinum-group metals and associated). While I ended up transferring in the Department of Geological Sciences to work for Dr. Phil Bennett for my Master's, I still had an interest in where things were (geospatially) and how those things were changing as a function of time.

My Master's theses – *Desorption of High Explosives from Soil: Thermodynamics and the Role of Soil Organic Carbon* (Minehardt, T. J. The University of Texas at Austin. 1995.) - was focused on playa recharge zones for the municipal water supply for Amarillo, Texas. The problem I was studying stemmed from a 50+ year environmental issue caused by the U.S. Army Corps of Engineers at PANTEX, a facility that was used to produce and later dismantle thermonuclear warheads. Massive amounts of high-explosive residues had been dumped into trenches that fed playa lakes, which in turn would fill with water that would then travel through the unsaturated zone to, eventually, the water table some 400 feet below the surface. Here, I was concerned with geospatial distribution of high explosive resides in core samples taken from the trenches; soil samples from the playa lakes; and water samples from the underlying aquifer unit. There was a great mix of geospatial, analysis, and prediction. I will emphasize that the prediction part was largely quantifying how high explosive residues moved with soil particulate to give time estimates for travel to the water table.

My doctoral, post-doctoral, and academic work was in large-scale scientific computing applications, from predicting energy flow at short timescales using quantum and classical mechanical formalisms (my Ph.D. dissertation is *Classical and Quantum Dynamics of Vibrational Energy Flow in Benzene: the CH(v=2) Overtone*); predicting structure-function relationships for how ATP is hydrolyzed by myosin and results in motive force; and predicting good candidates for drug leads.

Summary: A very good mix of spatial stuff, analytics, and predictive stuff for that period.

For the second decade, I was working in high-frequency algorithmic trading and other trading-related operations. I cannot recall any geospatial-related stuff, and it's fair to say that this decade was very heavy on analysis and prediction. Very specifically, it was intraday prediction of price and volume movement from historical data for asset classes including futures, equities, and interest rates. While not geospatial, it was very valuable experience in terms of signal processing, introduction to machine learning and AI circa 2005, and predictive analytics.

Summary: Heavy on analytics and predictive stuff, no geospatial components for decade #2.

The third decade began with my re-entry into geospatially relevant work, projects, and education. By this time, python was maturing, and AI/ML was in better shape than it had been. My first foray was as an Application/Software Engineer for Enthought. There, I worked with a lead developer and a client at BHP Billiton Petroleum as a technical liaison and developer for a python-based project to augment a commercially available product (Techlog, Schlumberger). Certain calculations were incorrectly handled and needed to be made faster; and certain functionality was not part of the product and needed to be implemented and usable via the Techlog API. It was on the latter that I contributed specific calculations for interpreting geophysical (seismic) logs. The geospatial component here was really in the Z dimension and most of the work was in applying known rock physics equations to available data to analyze for go/no-go on production.

I also went back to school at Austin Community College where I earned a Certificate in GIS and Cartography in 2014. As part of my final project and internship (Structure Development, LLC), I used U.S. census data (TIGER/Line shapefiles as well as actual census data) along with geospatial data (from TNRIS, mostly) to predict how changes in demographics were ongoing in areas that could secure federal funds for building low-income and need-based housing. This was an exercise in collating and interpreting geospatial data for the most part: the year-to-year trends were easily identifiable as a function of social demographics.

Prior to finishing-up at ACC, I did present a project to the City of Austin Transportation Department (concerning bicycle routes). I was able to illustrate (with the network optimization functionality of ArcGIS) that directional bicycle travel was in fact biased for north-south, thus underserving the eastside cycling community. While this conclusion was known, it was an exercise in quantifying something geospatial without my having to input prior knowledge.

After graduating from ACC, I went to work for the City of Austin Department of Watershed Protection as a GIS analyst. Here, I integrated python via the arcpy library for timesaving on otherwise manual-entry heavy tasks. However, the extent of the watersheds and their boundaries directly impact the City's tax base, budget, and allocations for zoning and the like. This was also an exercise in assimilation of data in various formats. Not all the orthography was current, nor were some of the Google image we used to try to rectify what had changed in certain areas. I repeatedly drove to the Hays County Tax Appraisal District to bring back GIS data on a USB stick. There was also data I had mailed-in, on a CD-ROM, from Williamson County. The hardest part by far was wrangling data formats – at least as hard as finding data.

I then took a position as a Python Software Developer for the Texas Water Development Board. The task I spent most of my time on was triaging an almost-finished software product used by scientists to analyze how quickly reservoir sediment rates change. This has serious implications for water storage and usage needs, and I was able to get the software to a usable point. The inputs were reflections from sones that were towed by surface craft. The output was an image of the floor of the reservoir. I did not do much analysis on this project, as my role was much more software development.

I was recruited by a startup in the athletic wearables space – BSX Athletics – where I did almost entirely analysis and data gathering. Again, as in most data science type jobs, getting data into usable formats was a large time commitment. This was a startup that unfortunately did not last.

There was an interlude – January 2017 through April 2021 – where I was working in the AI/ML space for applications in financial predictions. During this time (SparkCognition and AIM2, the later was spun-off by the former) I was an analyst, modeler, and had a role briefly as Head of Operations. The was no geospatial components here.

Most recently, I contracted for Zara Environmental on a project for forward and inverse modeling of groundwater evolution in a cave system in an area where impervious cover was recently introduced. It was/is a GIS, in that the data were for times and places. I was tasked with trying to model along a flow path using specialized software for that (PHREEQC) function.

Summary: Like first decade in terms of geospatial, predictive, and analytical components for decade #3.

Q: How do you describe your GIS work in terms of tools used and questions you helped the companies answer?

A: I'm going to be referencing the first set of answers for this and other questions.

Tools have evolved from SGI-based ARC/INFO and a Sun workstation along with 3- or 4-track (at most) conventional well logs and paper maps; to cloud-based Arc* tools, python, Mapbox, OpenStreetMap, numerous add-ons to the ESRI suite for predictive modeling, and so on. I do want to state here that I do consider anything with a geospatial component to be "a GIS:" simply using ArcGIS or other software is a great way to assimilate and represent conclusions, but any GIS project

does not necessarily have to be integrated with an ESRI or alternative open-source software. I want to make sure that I am communicating that I am not confined to only using ArcGIS software to approach a problem.

In that respect, I have used the above tools on platforms ranging from Solaris, IRIX, AIX, Windows, and Linux and made use of on-site or cloud-based resources for appropriately sizing tasks. I use a lot of bash shell scripting and python for data wrangling. I am agnostic about databases upstream from geodatabases, but I do like PostgreSQL's early support for geospatial information. Tools also include word processors, spreadsheets, printed media that I scan, KML files from Google Earth, census data, hydrological and weather data, you name it. I think what sets my previous work apart from that of a "regular" GIS Analyst is that I have used GIS software in conjunction with myriad other tools to arrive at a conclusion.

The questions answered came down to what you predict in (some time span), what can you do to alter/stop/restart/enhance something, how do you spend or allocate financial resources to certain areas and populations.

- For quantifying hydrocarbon plays, that has a direct impact in estimating reserves and where companies might invest exploration and production dollars. Where is the money best spent – new enhanced technology for secondary recovery, extending production, or something else?
- For a niche role at Structure Development, the issue is being able to underbid other players in the affordable housing space, which is a service the developers pay for and profit from.
- For the City of Austin, something as mundane as redrawing watershed boundaries has consequences in the tens of millions of dollars range. Do newly redrawn boundaries change wastewater permitting or zoning restrictions? At what cost and to whom?
- For BHP Billiton Petroleum, adding custom functionality to Techlog expands their capabilities (potentially) ahead of their competitors who use an unenhanced version of Techlog – faster results, more information, better informed decisions about future development, and this comes back to ROI.
- For environmental studies of the impact of introducing impervious cover near an ecologically and environmentally sensitive area, what are the tradeoffs, how much does it cost, and what are the expected returns which can be measured in dollars in terms of traffic easement, better infrastructure, and other metrics?

Summary: How to deploy capital efficiently while minimizing negative impacts on several fronts, GIS software is only one part of the suite of tools.

Q: What kind of challenges do you think a telecom/technology company could solve using GIS ?

A: I'm going to use the fiber optic run from that terminates in Kerrville, Texas here as an example. I've made some assumptions.

In general, a telecom/technology company that relies on the transmission of data from one point to another has two categories of problems when determining where to expand their presence and how much money to invest: (1) those that pertain to local, state, and federal laws and regulations; and (2) those that pertain to minimizing the problem of how to maximize network traffic flow volume and speed given constraints not in section (1), and those are mostly geographic constraints. The general problem comes down to do you (1) buy; (2) build; or (3) lease?

The State of Texas comprises only 5% federally owned, public land. This is an important piece of information for Lumen because you will be dealing almost exclusively with state and municipal governments and regulations. This means that Lumen will need to purchase ROW from the State of Texas, a city or town, or an individual. This is not the case in other areas, where federal laws do not apply to the small amount of land that might be available with fewer conditions and/or for less money.

In some regard, the dominance of the State of Texas over land use might play to Lumen's advantage. This must be evaluated – and likely has been – relative to other states in the U.S. The proximity of Texas to Mexico and the Gulf of Mexico is a critical positive for having a strong presence in the state: in one case you have an international border crossing, and in another you have subsea fanout to the rest of the Gulf of Mexico coast as well as the Caribbean. Lumen owns the westward Pan-American Crossing (PAC) but it is leasing bandwidth on the eastward ARCOS ring (as it is to service the Cayman Islands on Maya-1).

The challenges for an expansion in the Gulf of Mexico and Caribbean Sea are expensive and complex, as you are dealing with the laws of many nation states as well as high subsea fiber density. It probably doesn't make sense for Lumen to light their own cable in that region because other have done so, leasing terms are probably favorable, and the areas served are not predicted to require significant capacity upgrades for some time.

Back in Texas, Lumen has coverage along I-10 from San Antonio to Kerrville via a lease on FiberLight's Ring 2, Segment 4 backbone. The nearest data centers – 3 total - are in San Antonio. Coverage in West Texas is good now. Activity in the Austin – San Antonio – Dallas – Houston housing markets and technology boom is increasing. COVID-19 has changed the in-office to remote dynamic. Cost of living for people in the metro areas is increasing and the exurbs are becoming more populated. Lumen might have an opportunity to invest in the infrastructure to bridge the area where there is no preexisting fiber cable presence. However, the I-10 to I-20 to I-35 region is well-covered and the area contained in that triangle is largely farmland and oilfields.

The challenges I see here are at several levels. Does Lumen have a compelling need to own their infrastructure in the area? This opens the door to a high upfront cost but potential passive income from leasing revenue in the future. If the decision is made to deploy capital, how do you build out in the short-, medium-, and long-term time windows? This is where demographic trends or plans for building new roads (for example) comes into play as a challenge. You wait for the supporting infrastructure to be built but the opportunity cost might be very high. Probably your highest expense is securing ROW from private entities and dealing with railroad crossings, military installations, and unforgiving terrain. The former takes time and money and is not always coordinated in a timeframe. Railroads and military installations can be avoided. Unforgiving terrain is what I call mountains, large expanses of off-road land, large bodies of water, and the like.

In the end, the actual prediction and analysis comprises the geospatial constraints, legal and regulatory considerations, and what the projected ROI is for Lumen to expand in a certain area. For Kerrville, it might not make sense to light fiber north to San Angelo. But if there is a growing demand for commercial and residential land and infrastructure that closes the gap, first-mover advantage could offset high upfront costs.

Summary: Buy/build/lease with respect to (1) laws and regulations; and (2) geographic and infrastructure constraints.

Q: What kinds of questions do you think a telecom/technology company could answer using predictive or prescriptive analytics

A: Referring to what I have previously written here.

Predictive analytics that are relevant in the case of Lumen are going to be mostly infrastructure and demand. Realistically, Lumen can and has bought/built/leased in areas to improve their coverage and diversity of service offerings. Decisions made moving forward are going to look a lot like historical growth, where dendritic patterns of networks followed population and business growth. We want to be leading or concurrent with growth and not lagging.

Specific questions:

- What is the timeframe that Lumen can recoup some percentage of upfront costs for building-out service in a certain area?
- Are there any geospatial constraints that might change that materially affect the continued operation of the service and expansion thereof?
- Are there any rules or regulations that pertain to any change that might affect Lumen's proposed build-out currently being discussed by lawmakers; when could those changes go into effect; and is there a positive/negative/neutral effect predicted for Lumen?
- Given limited data for emerging technologies such as satellite networks, 5G, and other ways to communicate, can we identify areas where we need to deploy capital now with a high confidence level?
- Given long-term historical data for change in capacity and speed as a function of time and place, what are the minimal requirements the characterize deployments ranked by population, business types, accessibility to major infrastructure, and so on?

Summary: Largely the same as previous with specific attention paid to first-mover advantage from predictions using historical data.

Q: What data sources that you have used in your previous jobs do you think could be used in telecom/technology company as well?

A: Referring to what I have previously written here.

A partial list:

- Right-of-way, road, and railroad maps
- Maps of preexisting networks of pipelines and cables
- Aquifers, surface waters, rivers, reservoirs, lakes
- Hydrocarbon recovery activity or presence
- U.S. Census data and related demographics
- Permitted building applications that are in progress or about to be started
- News (including EDGAR/SEC) about business expansions into certain geographic areas or business areas that need certain geography (closer to raw materials for building batteries, for example)
- In short, all of it and more

Summary: I can see all the sources I have used as being worth looking at, some more closely than others.

Q: I understand you have vast experience in a variety of fields. What sort of work are you expecting to be doing on our team if we decide to hire you? I know you can do anything, but what would you consider as appropriate tasks for you; what would you consider as challenging tasks that you'd like to work on?

A: See below.

I expect the work to be a combination of locating data, assimilating it, and evaluating it in terms of the business cases being examined. I have no illusions about multiple data sources, formats, missing data, and so on. I would think that my experience and generalist-leaning background would mean that my tasks would change somewhat frequently: I can work on the GIS part, or clean data, or evaluate some data sets for predictive power, and so on.

Appropriate tasks for me are ones that generally are NOT specific to one person but require foundational knowledge. For example, I am not a so-called full-stack software engineer, so writing the codebase for supporting new software features is not a good fit for me (or my employer). Knowing that there are supervised and unsupervised learning algorithms that are more useful than others for answering certain types of questions and being able to gather the data, execute the predictive power and analytical part, and summarize the results IS a good fit for me.

Telecom is new to me, and I have a lot of interest in all kinds of questions in the industry that will be challenging for me and interesting. I suspect that getting into AI/ML for Lumen's specific use cases will be challenging for me, as I have not yet crossed that bridge. I also enjoy

the opportunity of examining a nice intersection of my education and skills with something that brings me closer to geography.

I like to work with an organized lead. Good management is essential. I like tasks that are generally time-gated, however I realize that some speculative assignments are open-ended, and I am fine with that if management is aware.

Summary: Day-to-day data gathering, assessment for inclusion in a model, model scoring and assessment, other needs that I can assist with.

Q: When will you be available to start if we decide to hire you?
A: I am presently finishing up 2 classes at ACC and can be available full time starting Monday December 13, 2021.

Q: Do you currently have active offers on hand?
A: I have a verbal offer from one large (FAANG) company and am in various stages with 2 other potential employers.

Q: Do you have other interviews in your pipeline in this month?
A:Yes, I am actively looking for an opportunity where I have a contract inked for no later than January 1, 2022 as a start date.