Zero to One:
A Digital Transformation at Dominion Energy

Fall 2019 NASPI - Richmond, VA

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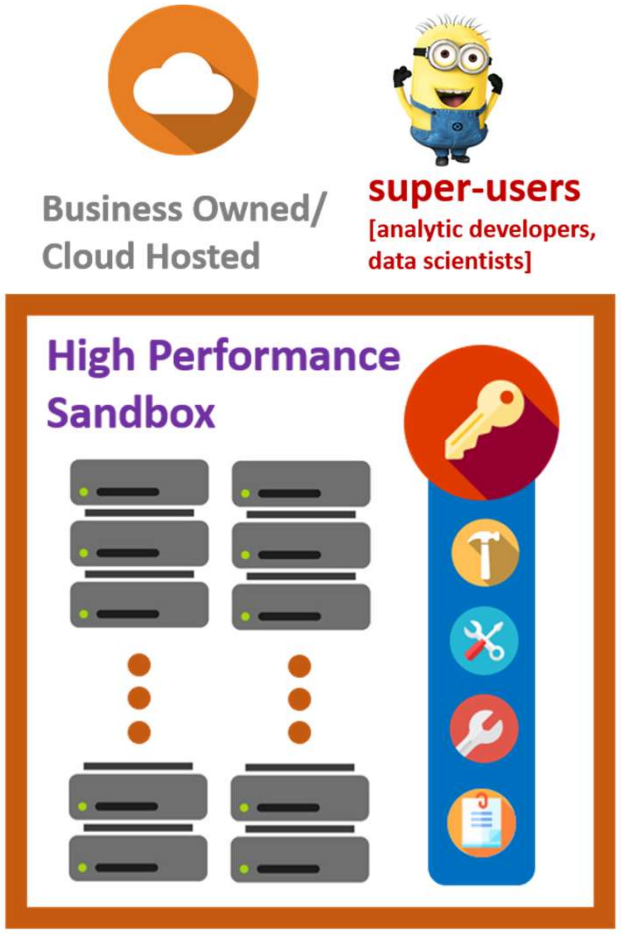
October 29, 2019

Recap:

Super Users and the High Performance Sandbox

- Focus on the "super-users"
- Focus Flexibility
- Focus on performance of users/workflows
- Don't try to be everything to everyone



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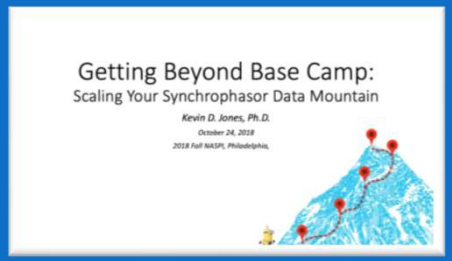
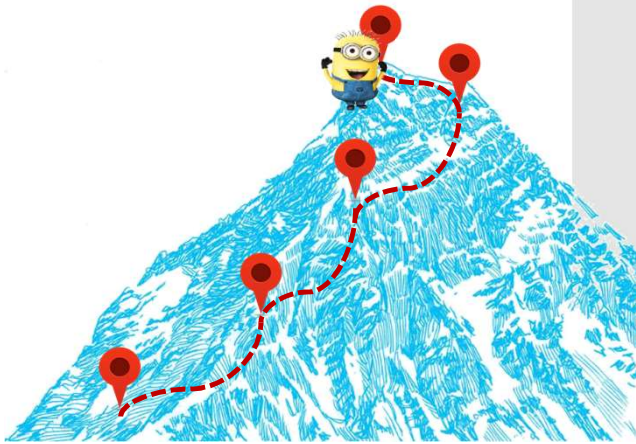


Minimize Cost of Experimentation

We explored:

What is the best metric to optimize to scale up our use of synchrophasor data??



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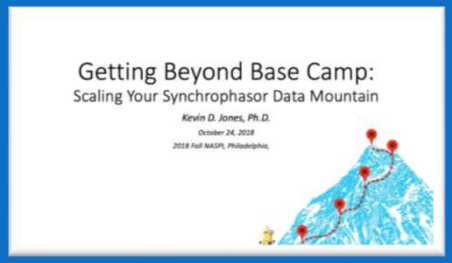
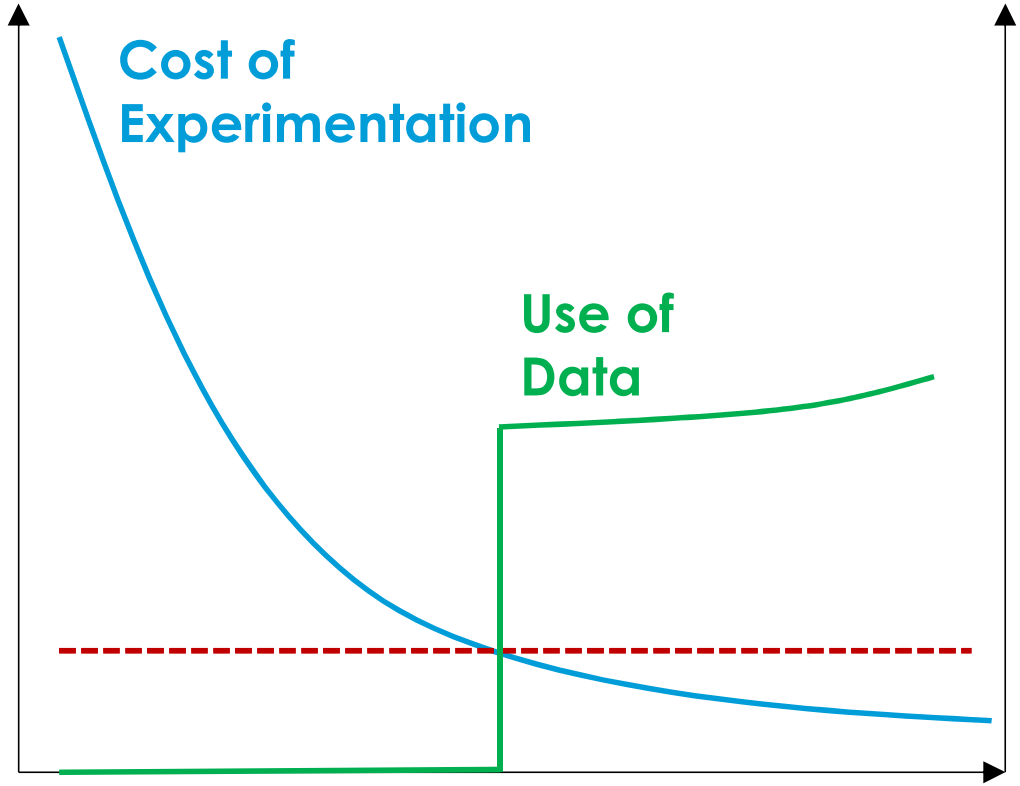
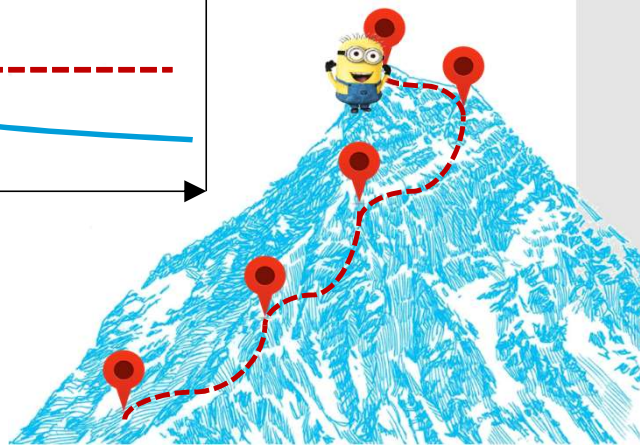


Minimize Cost of Experimentation



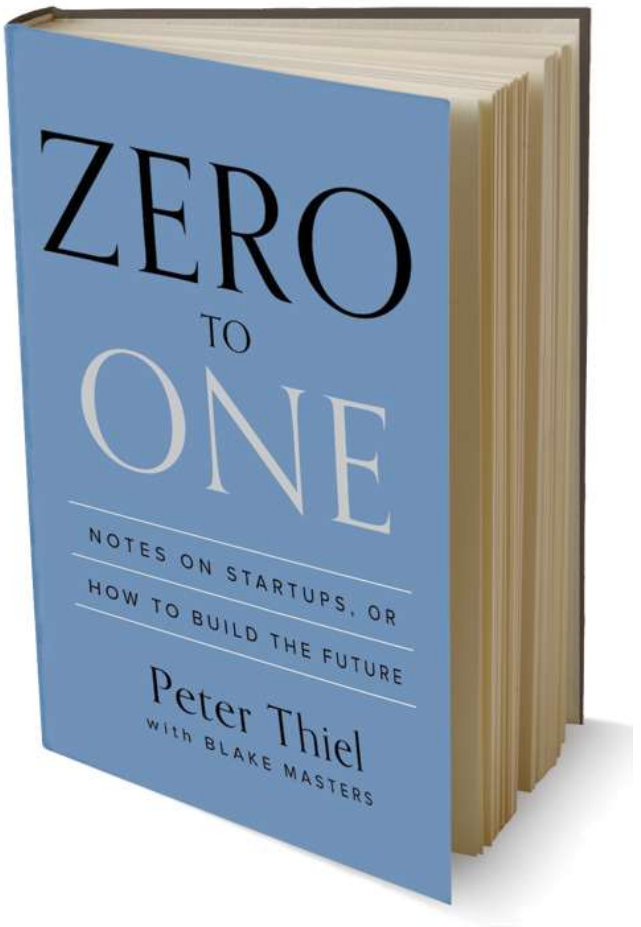


Recap:

PredictiveGrid Deployment

- **PredictiveGrid** *is a PaaS for ingesting, storing, analyzing, visualizing, and learning from high density telemetry from the grid.*
- Our instances is hosted in the AWS GovCloud
- **January 2019** - Capital project kickoff
- **February 2019** – Platform live with pre-loaded historical data
- **April 2019** – First PMUs streaming
- **May 2019** – 18,000 streams; Engineering analysis work begins

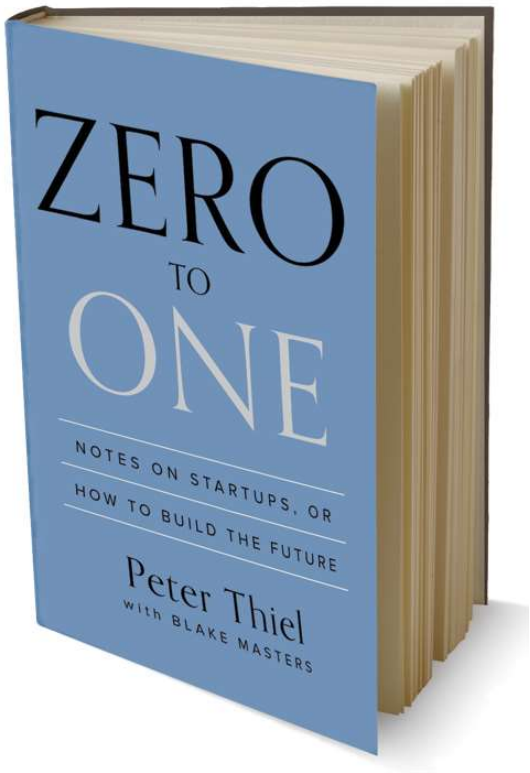
How to summarize our transformation?



Zero to One

- Two kinds of progress:
  - **Horizontal** – copying things that work (1 to n)
  - **Vertical** – doing something wholly new (0 to 1)

- Zero to One means:
  - Something from nothing
  - Greatest leap possible
  - Greater than 1 to 10 or even 1 to 100
  - **Conjure something into existence from the dark void of oblivion**
  - **Essence of true innovation**



What does "1" look like?

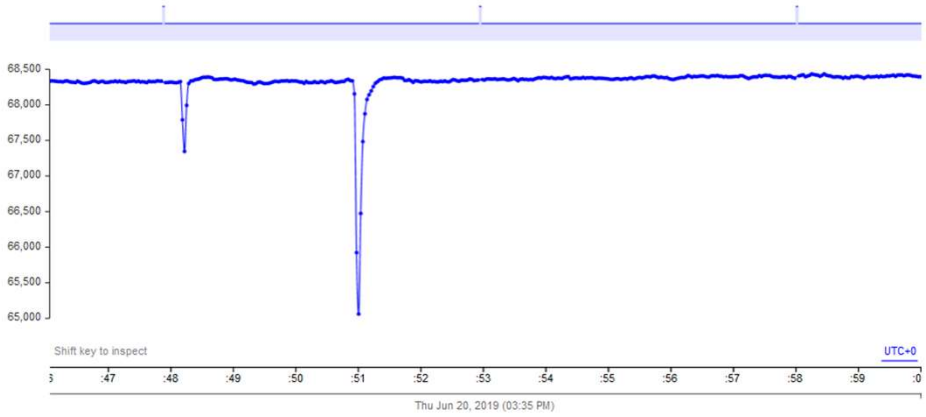
Use Case Exploration from **May 2019** until **October 2019**

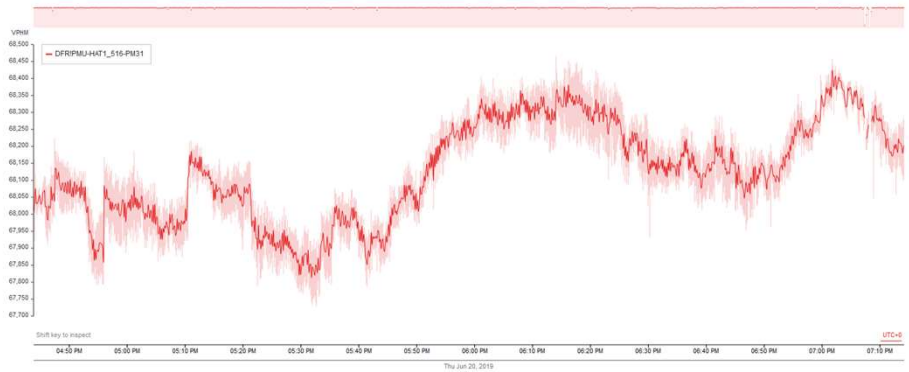
- **Graduate Interns**
- **Super Users**
- **Workshops**

- Data Exploration
- Templated Event Reporting
- Improved Fault Analysis Workflows
- Data Preprocessing
- Conduit Data Flow Library for Power Eng. Metrics
- Voltage Stability Metrics
- Critical Operating Points
- Angular Stability Metrics
- Inertial Estimation
- Transient Stability Metrics
- ZIP Load Model Tuning

Data Exploration

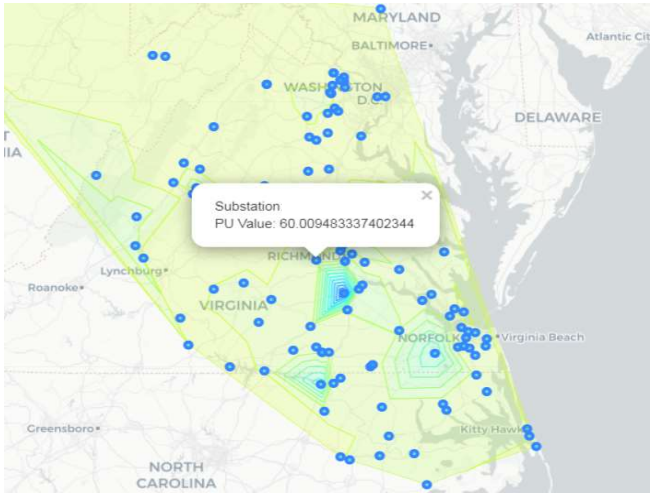
- All our data at our fingertips!
  - Instant visual access:
    - *Any stream*
    - *Any time period*
- Most popular and widespread use case
- Enables numerous workflows
- Worth the price of admission
- "Google Maps" for time series

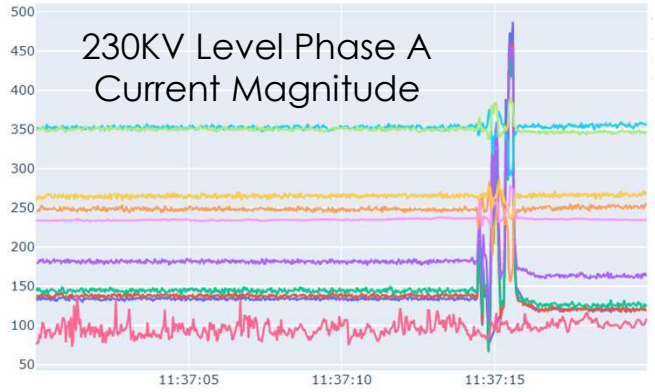




Templated Event Reporting

- Notebook-based templates for event reports
  - ***Event types:*** *faults, gen. trip, load trip, etc.*
  - ***Components:*** *Freq., System Freq., Local & System Voltages, Seq. Components, etc.*
  - ***Views:*** *Trends, heat-maps, etc.*
- Socialize synchrophasor data and analytic capabilities
- Minimizes time to generate reports





Improved Fault Analysis Workflows

- Reduced time on fault analysis workflows
  - *Data retrieval typically took 30-45 minutes*
  - *Now instantly accessible*
- Easily assess impact of faults and other transmission events on neighboring substations
  - *Tracing power plant swings to source*
  - *Visualize voltage during and after fault*
  - *Precise timestamp identification*
- Feedback into DFR configuration & data quality

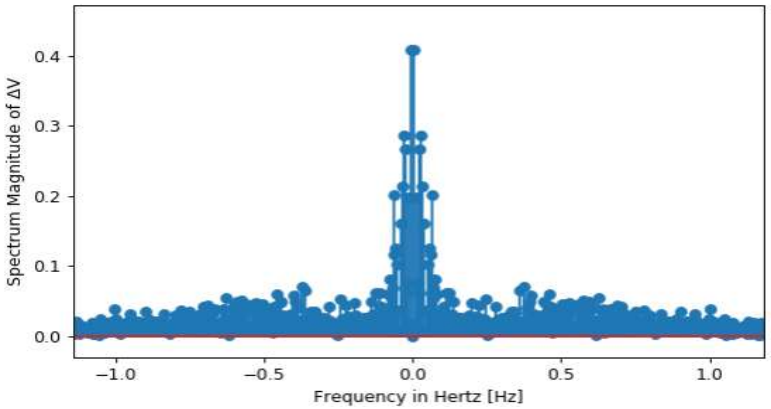
conduit: A Data-Flow Library for Common Power Eng. Metrics

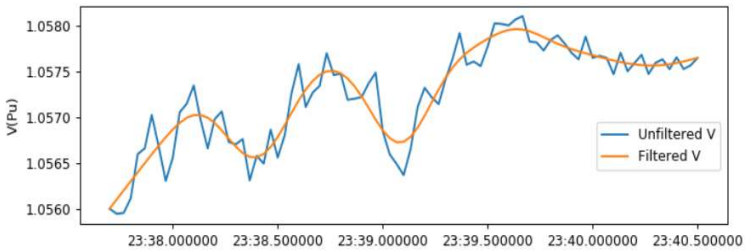
- Common power engineering computations includes:
  - Per-Unitization; L-L, L-N; Calibration; Wrap/Unwrap; Bit-Extraction, Power Calculations, Symmetrical Components,
- Stream composition: Allows user defined conversions/transformations on groups of related streams
- Optimizes for speed, correctness, & resource constraints
- Flows validated for provenance and metadata tracking

```
streams = db.streams_in_collection("dfr/DFR!PMU-MT3_200")
conduit = Conduit(streams)

vphm = conduit.subset(unit="VPHM")
vpha = conduit.subset(unit="VPHA")

vphm = vphm.line_to_neutral().calibrate(rcf=1.3)
vpha = vpha.radians().calibrate(pacf=0.3)

pg = PhasorGroup(vphm, vpha).per_unit(base_kv=500)

reactive = pg.reactive()
factor = pg.power_factor()

reactive.windows("2019-06-10 12:00:00.000", "2019-06-10 13:00:00.000",
width=ns_delta(minutes=5), depth=30).head()
factor.windows("2019-06-10 12:00:00.000", "2019-06-10 13:00:00.000",
width=ns_delta(minutes=5), depth=30).head()
```

Data Preprocessing

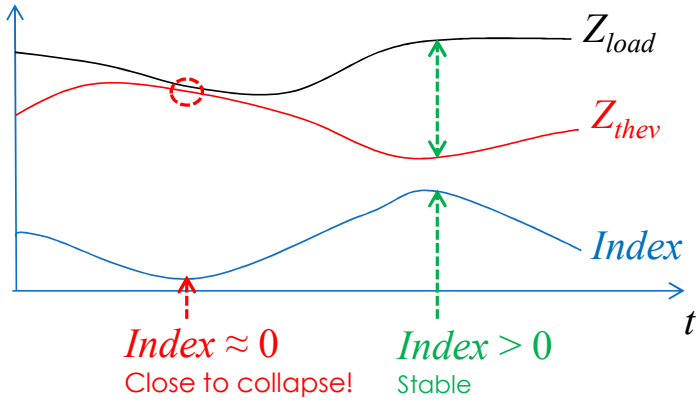
- Phenomena at different time scales (slow moving trends + oscillatory components)
- Need to isolate time scale / frequencies of interest
- Typically high pass filter for $f > 0.1\ Hz$ for detrending + low pass filter $f < 2.5\ Hz$ to denoise
- Highly reusable and extensible across use cases

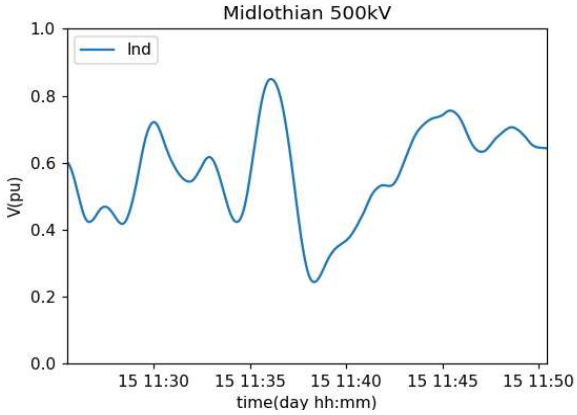


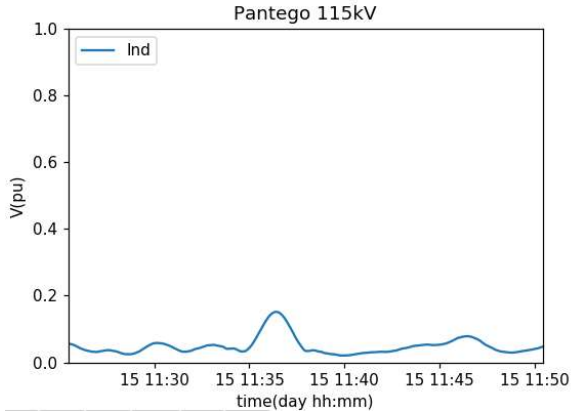


Voltage Stability Metrics: ***Thevenin Equivalent***

- Find load margin of each bus
- Equate external system by Thevenin circuit
- Voltage stability index based on maximum power transfer on equivalent system

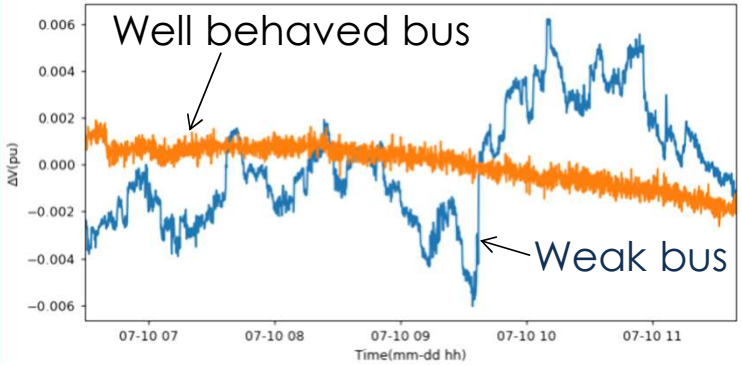






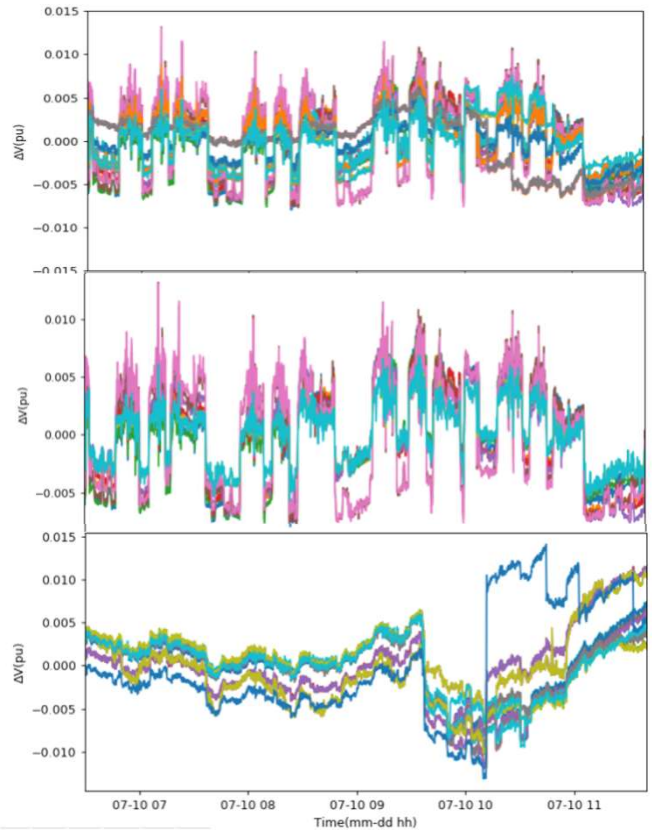
Voltage Stability Metrics: ***Voltage Variability & Coherency***

Example of Variability



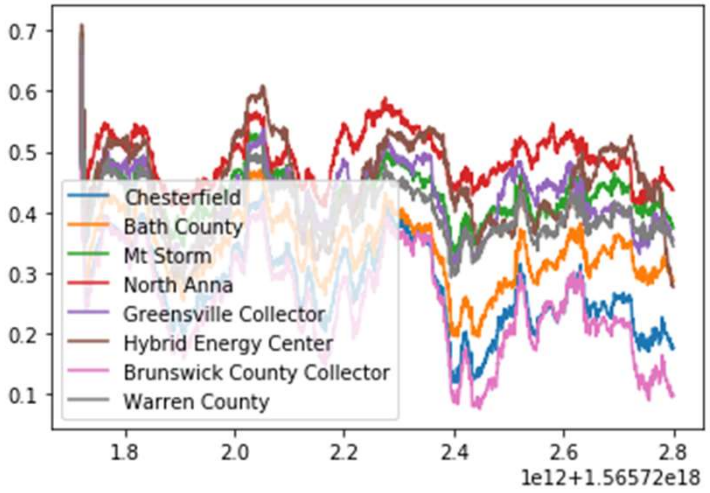
- Weakly controlled, coherent bus groups are candidates for future dynamic **VAR resource planning**
- Strongly controlled locations are candidates for **future renewable generation.**

Modes & Coherent Buses



Detecting Critical Operating Points

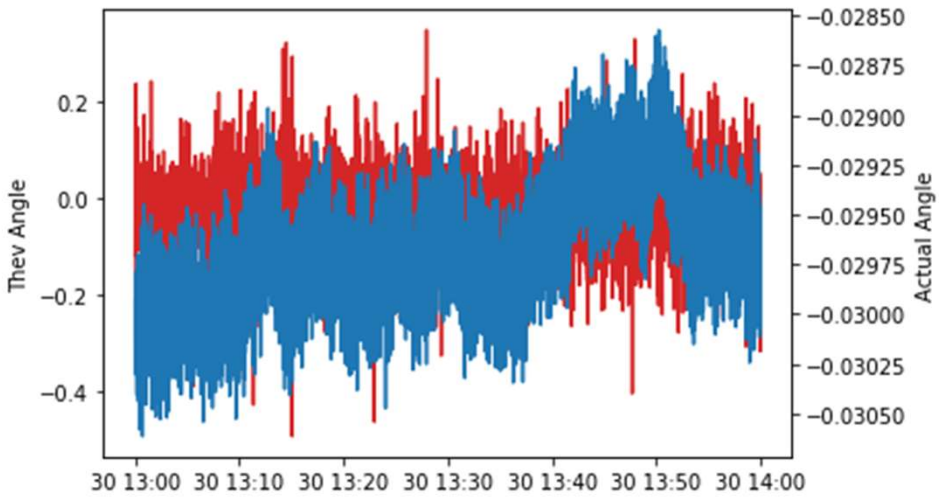
- Damping decreases at critical operating conditions
- Autocorrelation coefficient increases rapidly near critical point, used as a metric



$$\rho(t) = \frac{\sum_{\tau=t-2\,mins\,-:\,t} \hat{x}(\tau-1) \times \hat{x}(\tau)}{\sigma^2}$$

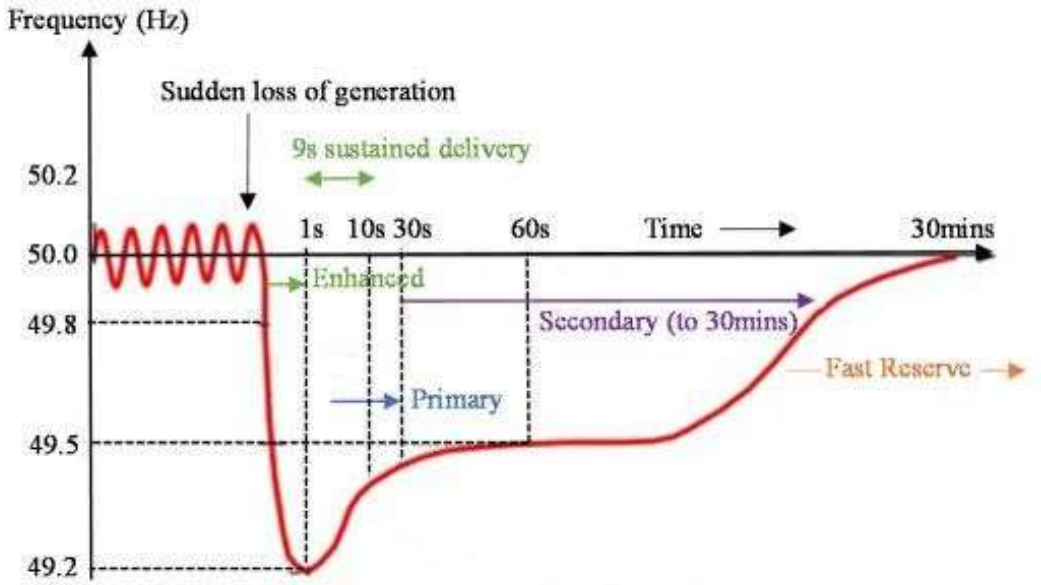
Angular Stability Metrics

- Assess steady-state angular ability with local line measurements
- Phase angle delta has limited information
- Thevenin voltage phase angle observes this well
  - Learn “normal” or baseline from heuristics



Inertial Estimation

- Ambient vs event-based approaches
- Challenges:
  - Ambient: Hard to discern governor response
  - Event: Little data, not good for overall monitoring



ZIP Load Model Tuning

- ZIP load model is widely used for load flow/steady state studies

$$P, Q = a_0 + a_1 V + a_2 V^2$$

- Aim is to tune the model parameters online with PMU data
- Linear regression,

$$\begin{bmatrix} P(t_1), \dots, P(t_n) \\ Q(t_1), \dots, Q(t_n) \end{bmatrix} = \begin{bmatrix} a_0^P, a_1^P, a_2^P \\ a_0^Q, a_1^Q, a_2^Q \end{bmatrix} \times \begin{bmatrix} 1, \dots, 1 \\ V(t_1), \dots, V(t_n) \\ V^2(t_1), \dots, V^2(t_n) \end{bmatrix}$$

- Challenge is that load is of the form,

$$(P, Q)_{scale} \times (a_0 + a_1 V + a_2 V^2)$$

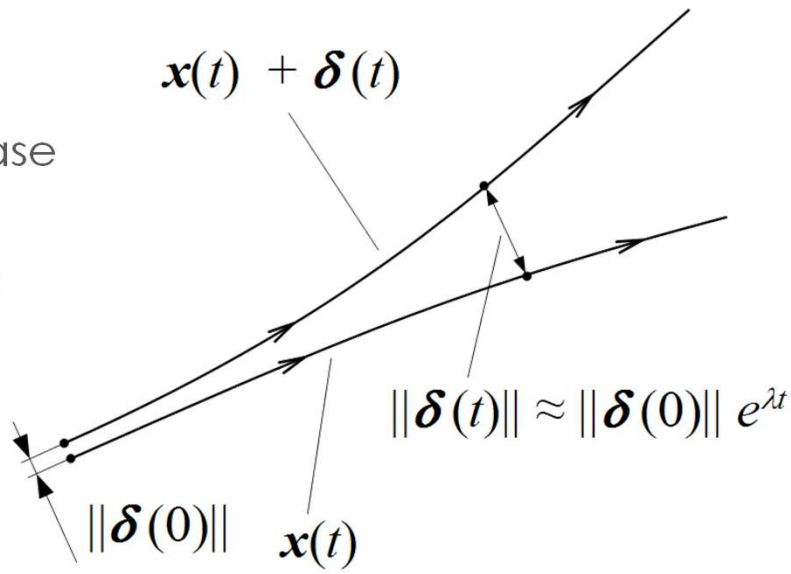
Where we don't have access to $(P, Q)_{scale}$ datag

Transient Stability Metrics

- The **Lyapunov exponent (LE)** is the principal criteria of chaos and represents the growth or decline rate of small perturbation along each main axis of the phase space system.
- Positive value gives loss of synchronism

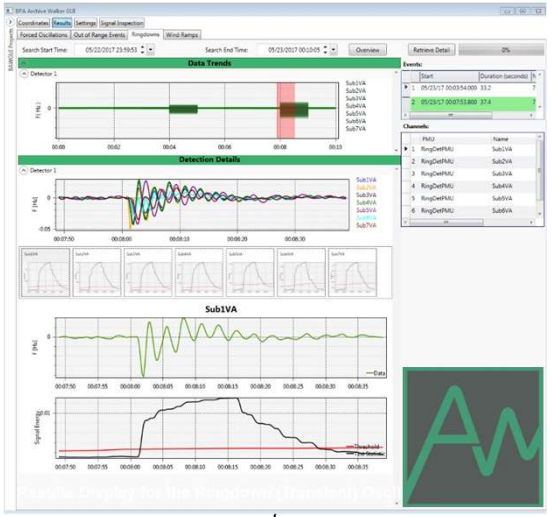
$$\lim_{t\to\infty}\frac{1}{t}\log\frac{\|\partial x(t)\|}{\|\partial x(0)\|}$$

- Computed on voltage phase angle at generator bus



(**ADAPT**) Accelerated Data Analytics for Power System Time-Series

- Supported by DOE Technology Commercialization Fund
- Signal processing and event detection
- Develop toolbox for PredictiveGrid that incorporates core capabilities of Archive Walker
  - AW initially developed by PNNL w/ support from BPA and DOE
- Participants: PNNL, PingThings, Dominion, BPA

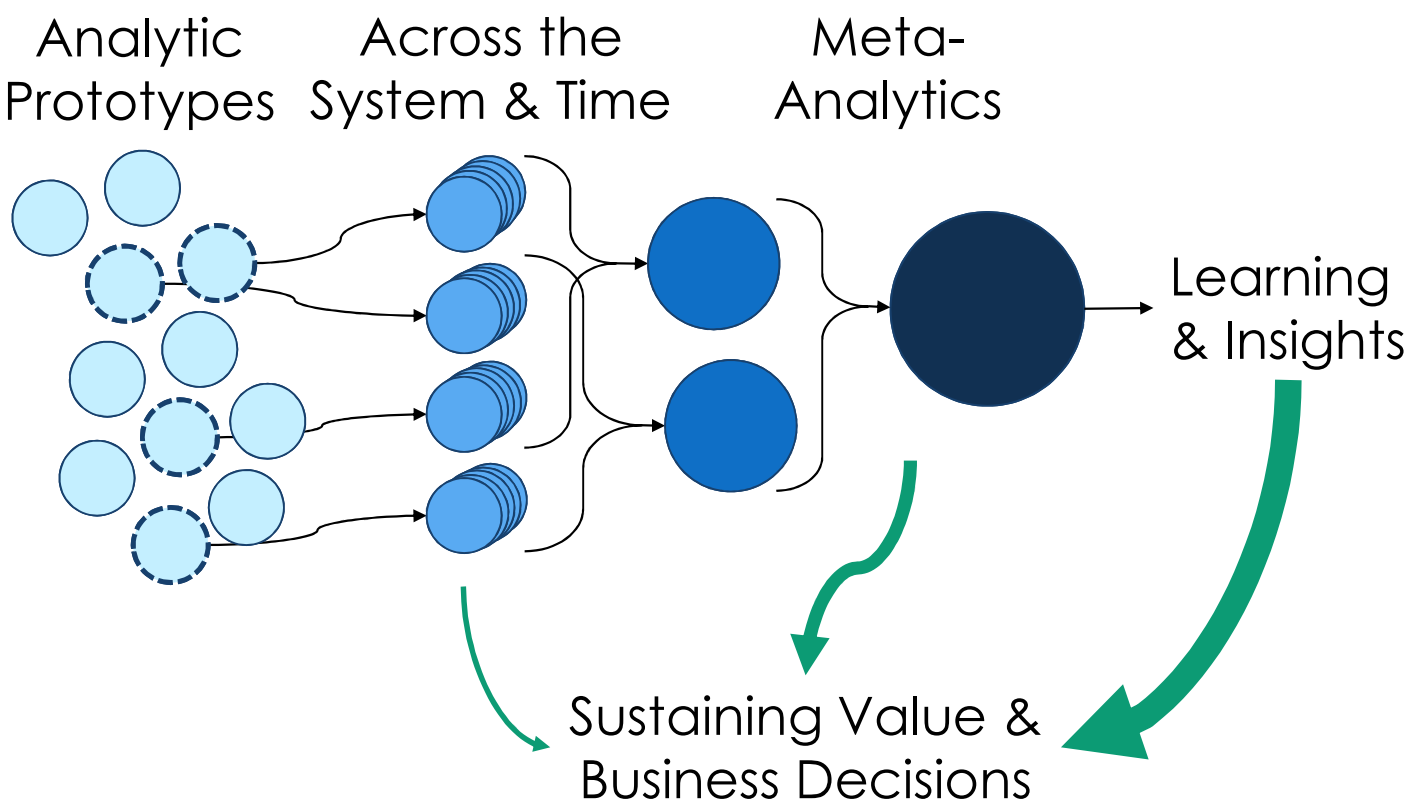


PingThings

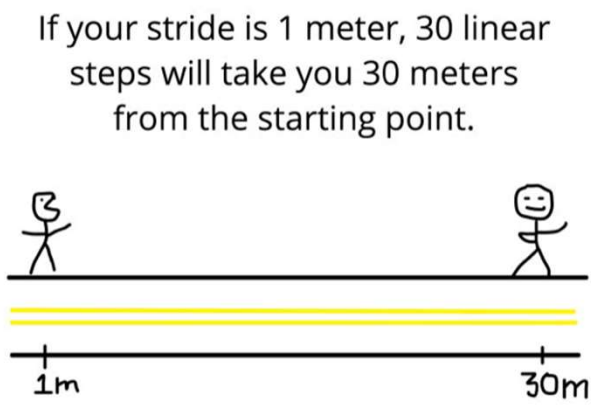
PredictiveGrid™ Platform

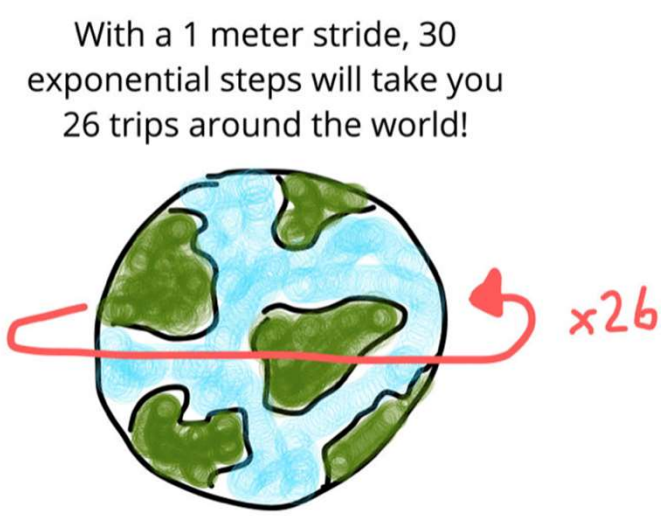
Please, go to the poster session ☺

Next Steps


Analytic Prototypes
Across the System & Time
Meta-Analytics
Learning & Insights
Sustaining Value & Business Decisions

1 to N Growth is Exponential

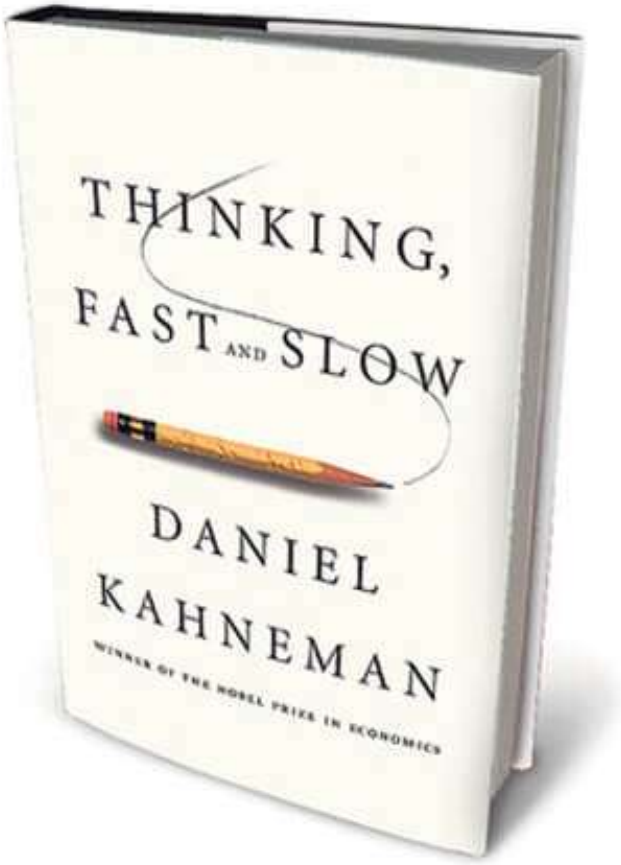




https://singularityhub.com/2016/04/05/how-to-think-exponentially-and-better-predict-the-future/

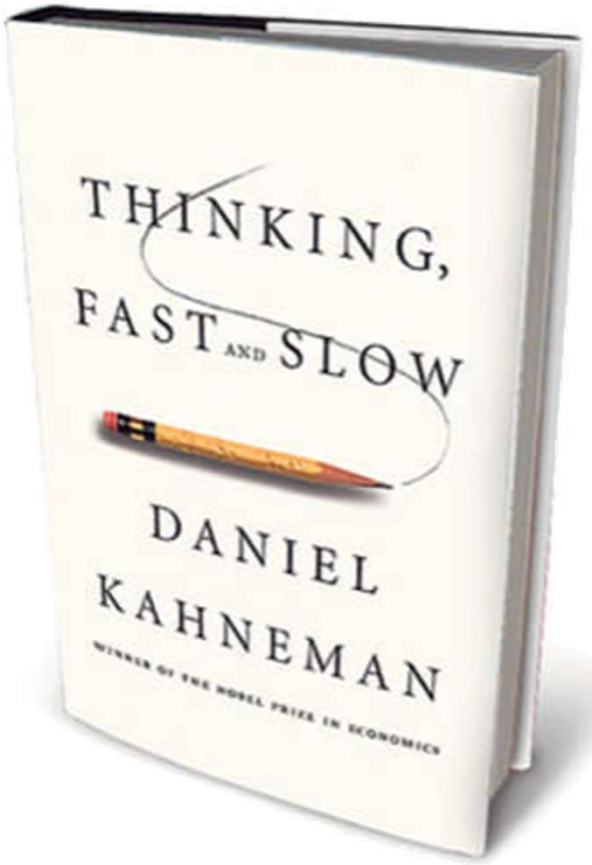
- First mover advantage is real!
- Can we accept our current pace of innovation as an industry?

What does "N" look like?

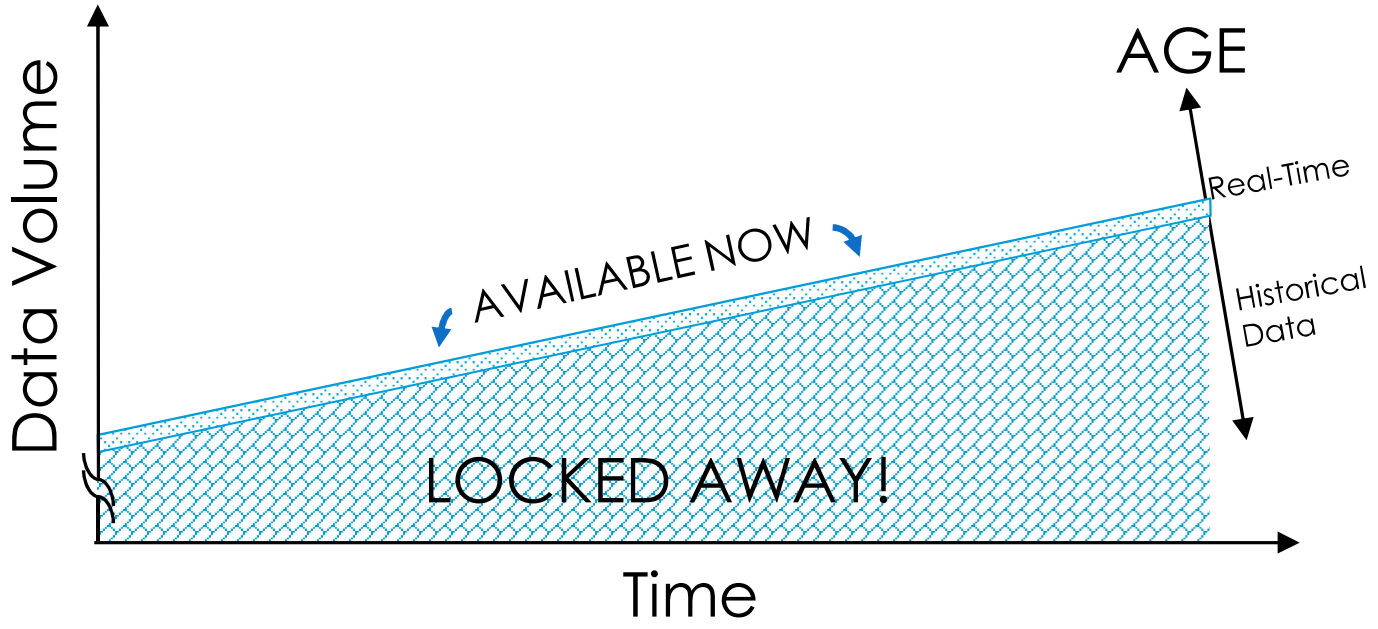


Thinking Slow

- Two modes of thought:
  - **System 1** – fast, instinctive, emotional, automatic
  - **System 2** – slower, more deliberative, more logical, complex, mentally draining
- System 2 is better at problem solving and intense analysis
- System 1 is likely to make predictions without having all of the evidence



Using Data for "Thinking Slow"



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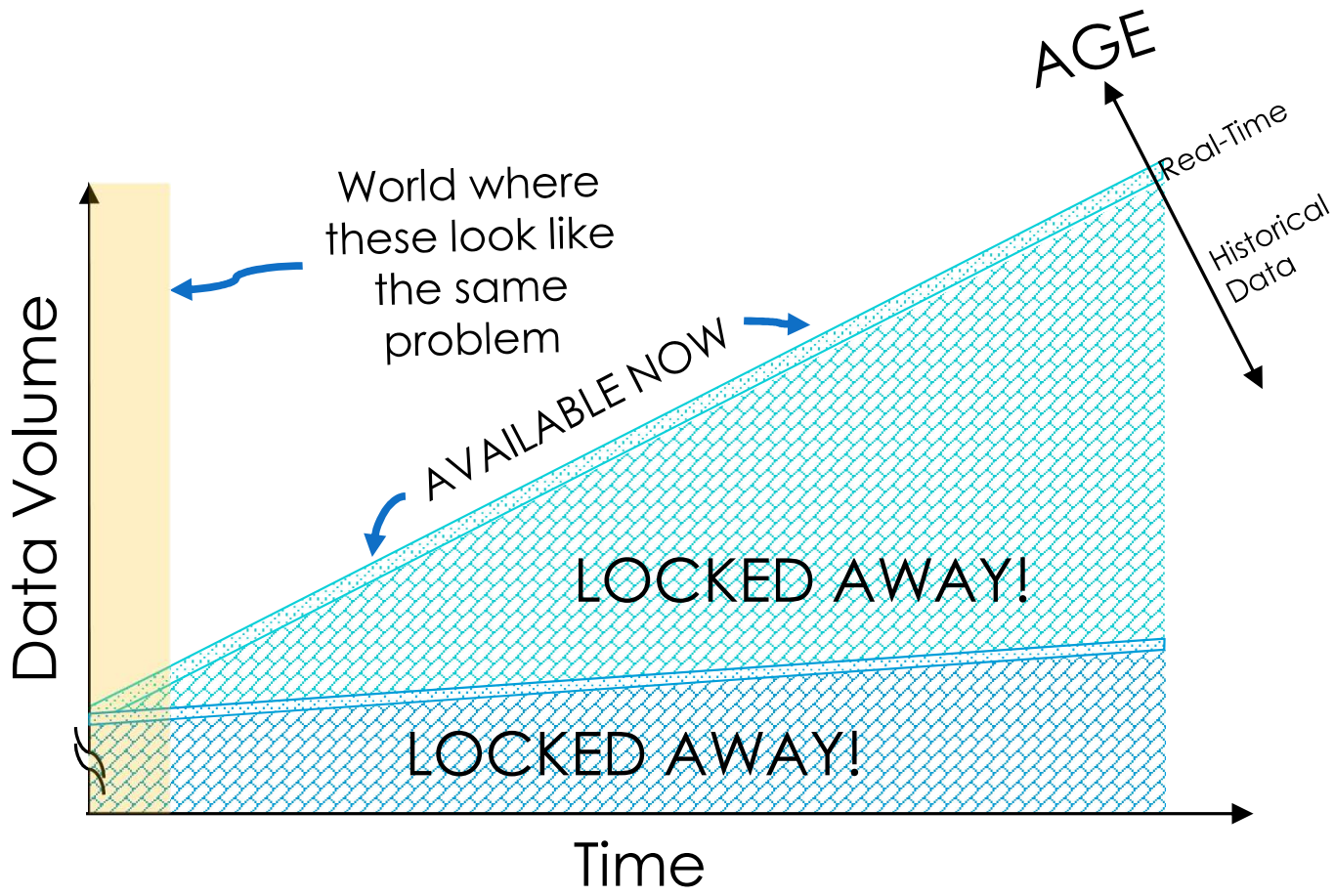
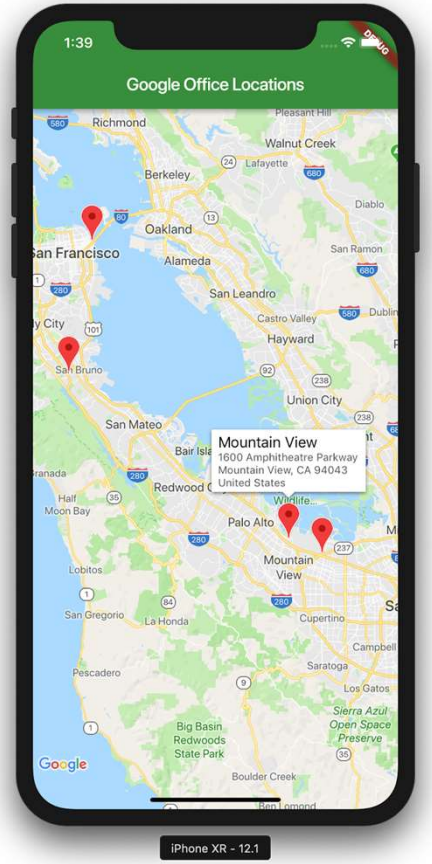


“Slow” Can Be Made Fast

Lengthy and tedious trip planning is now virtually instantaneous from anywhere!



Questions?

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