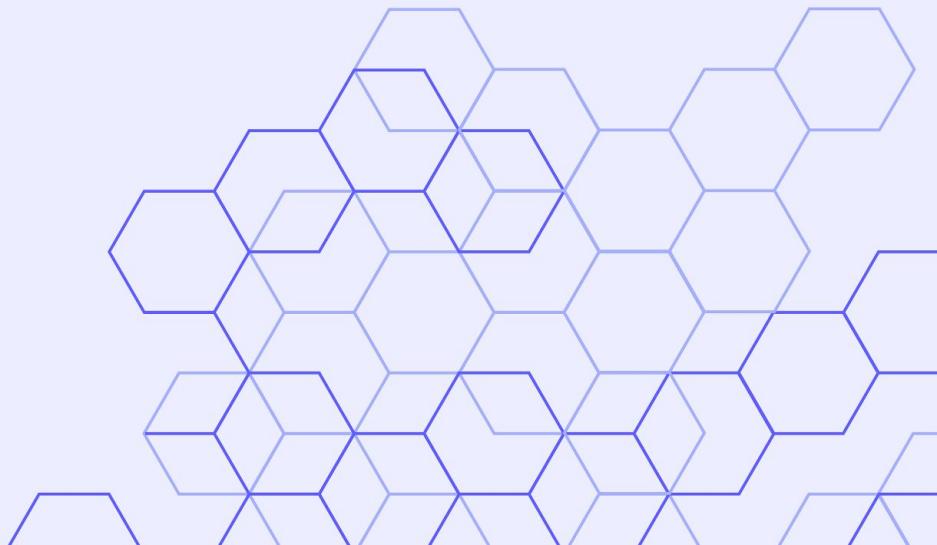


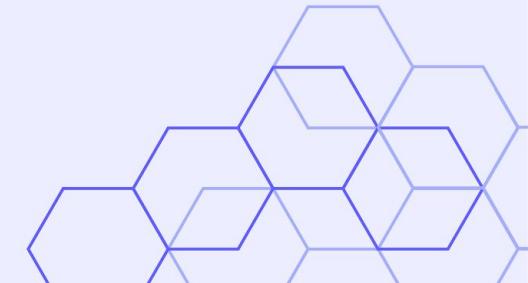
AI For Highway Maintenance



Who Am I



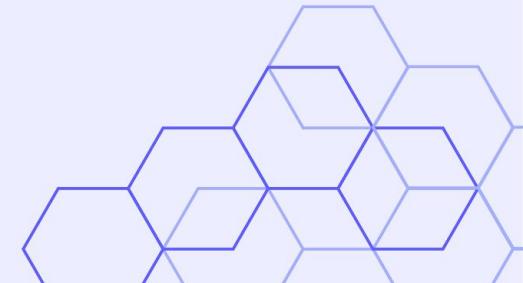
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Who Am I



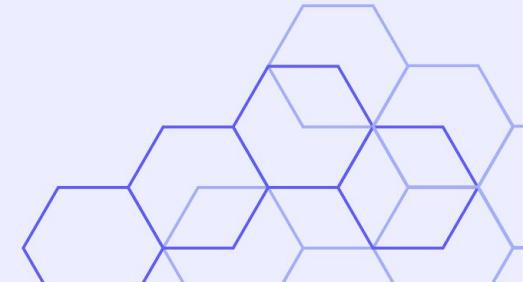
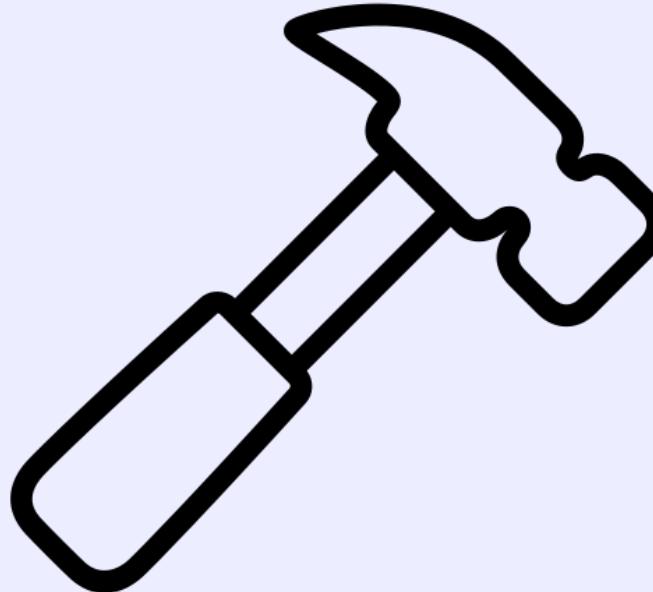
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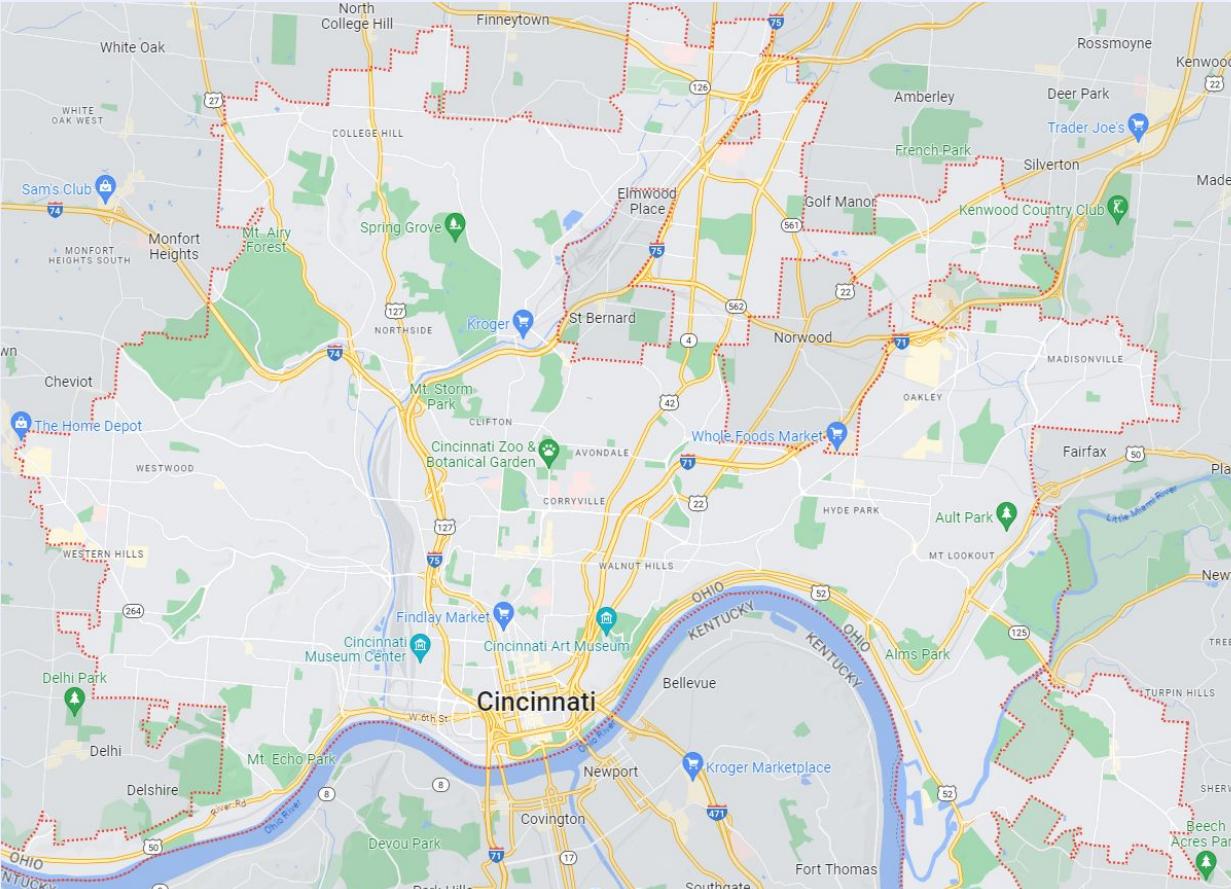
Who Am I



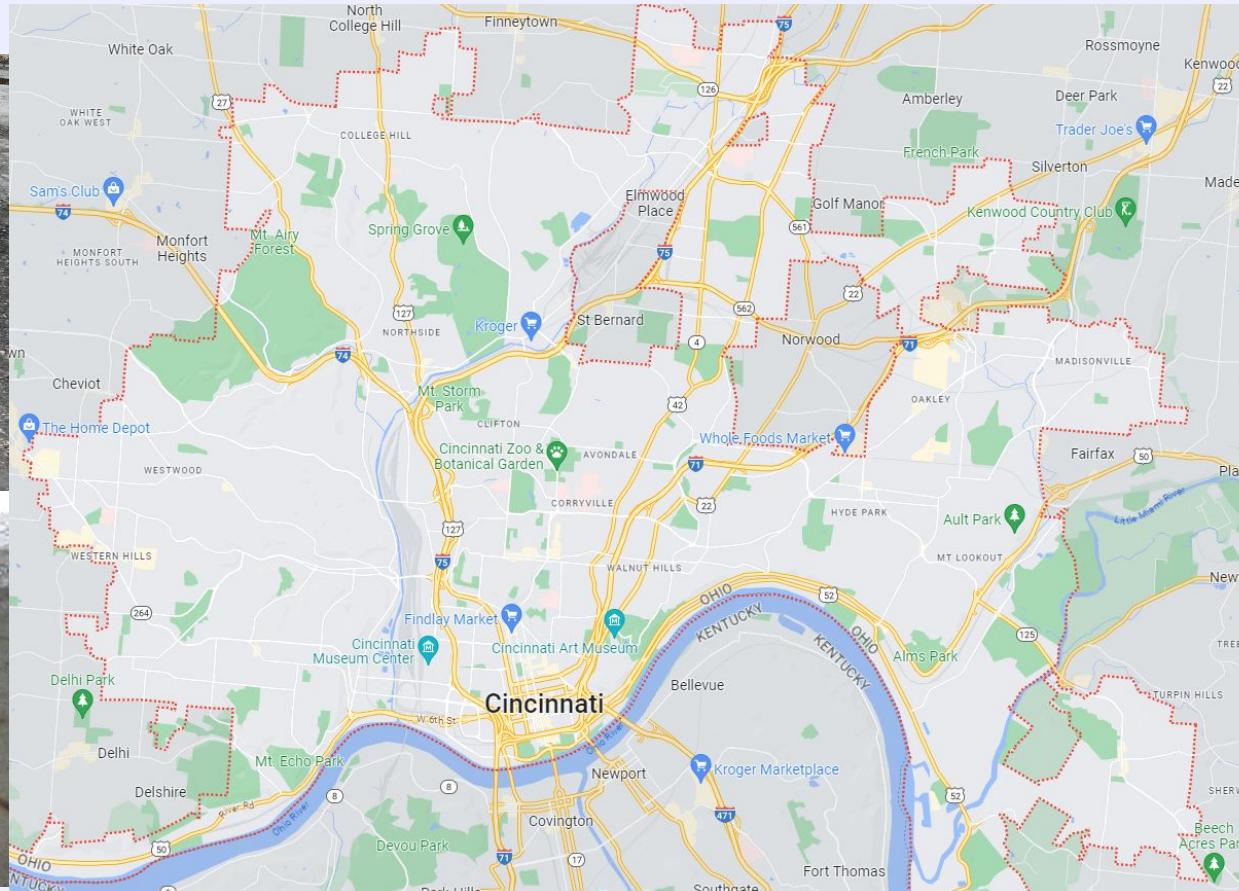
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How did we get here?

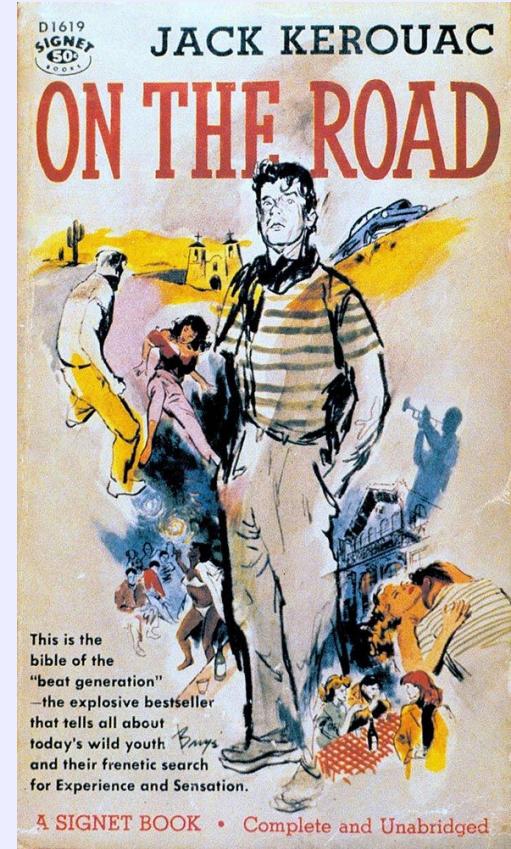


How did we get here?

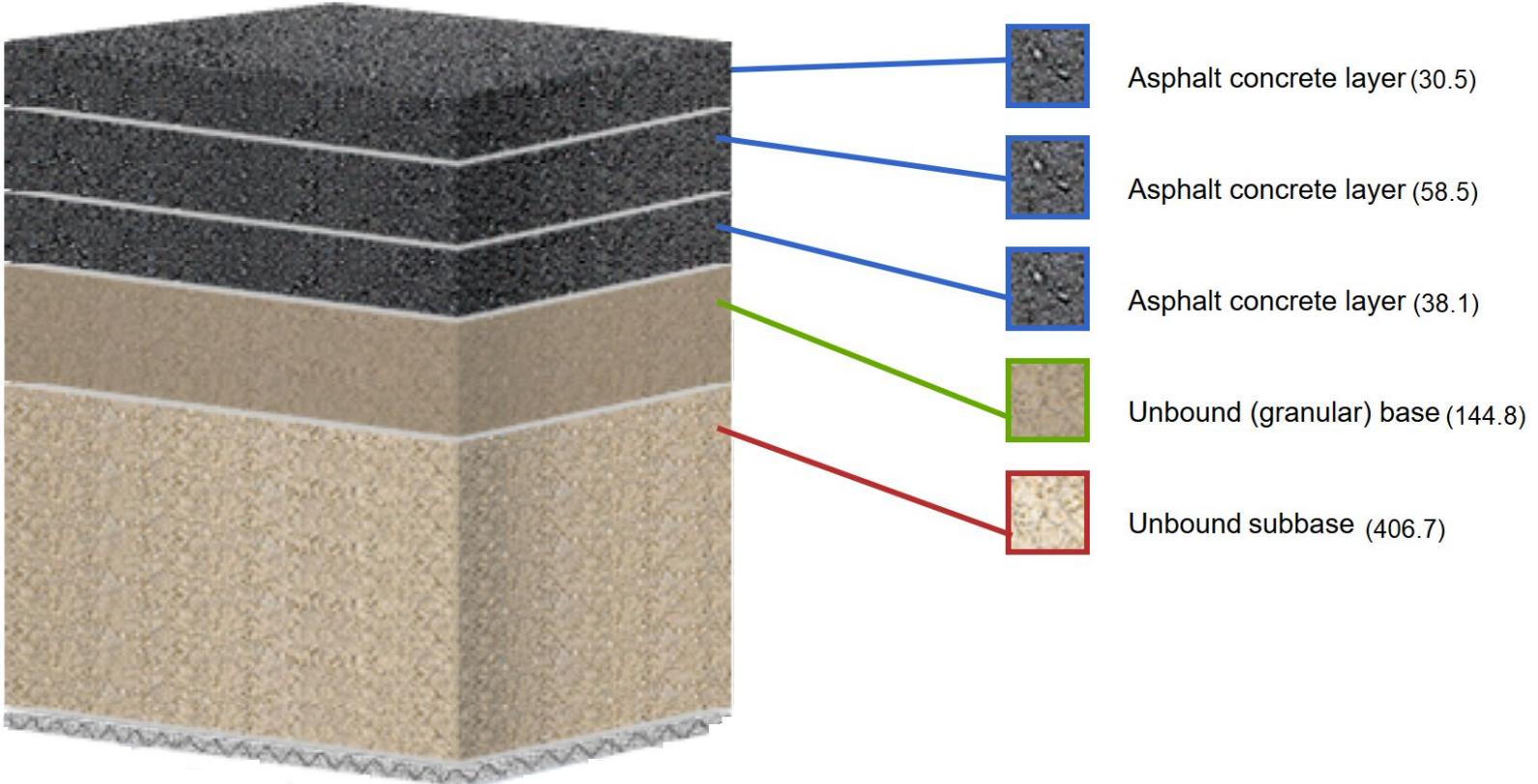


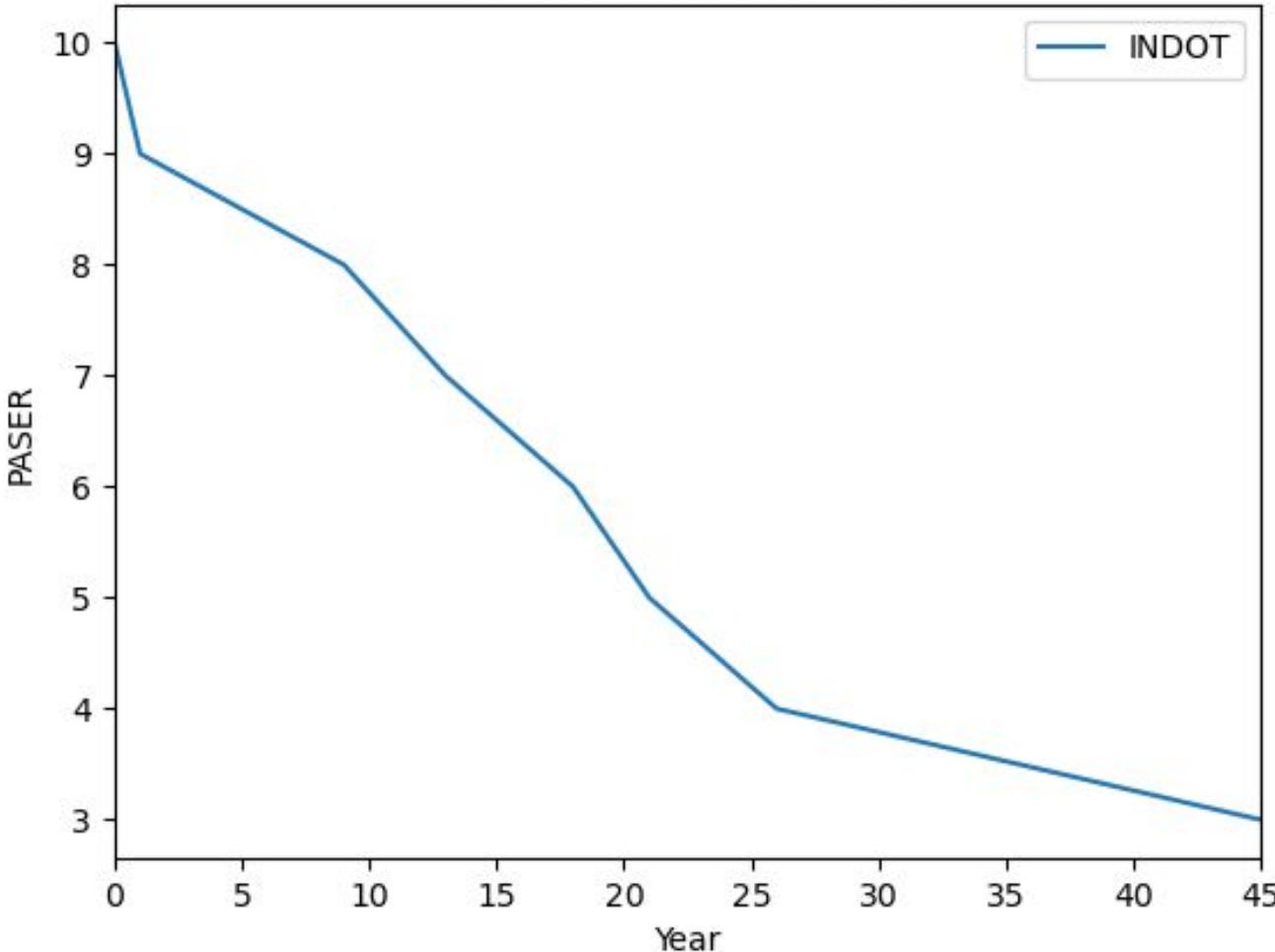
The Road Ahead

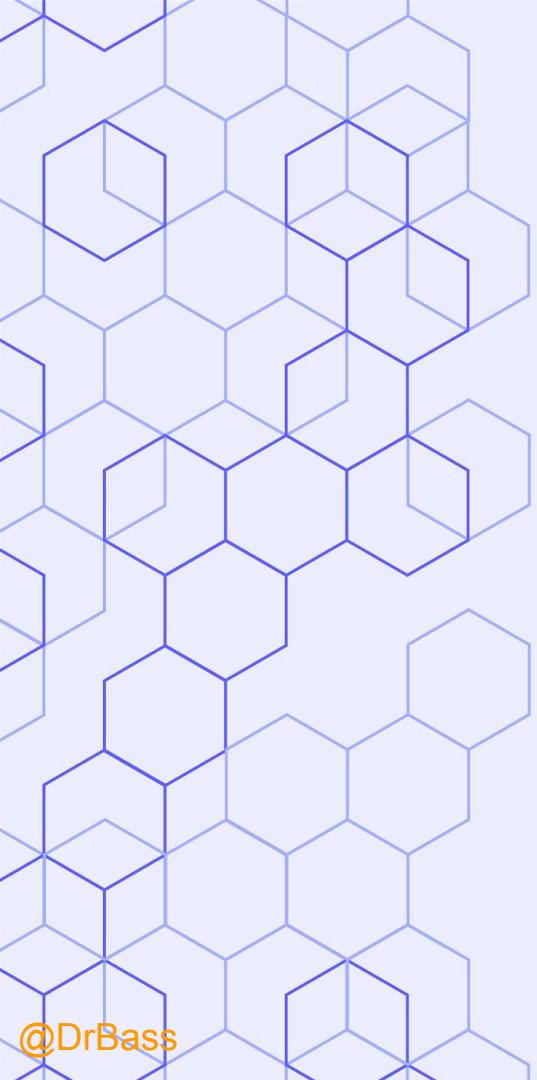
- The Problem Domain
- Using AI for Planning
- Some Initial Roadblocks
 - Understanding the domain
 - Problematic Models
 - Performance Hurdles
- Meeting the users where they are
 - Understanding needs
 - Adapting the solver





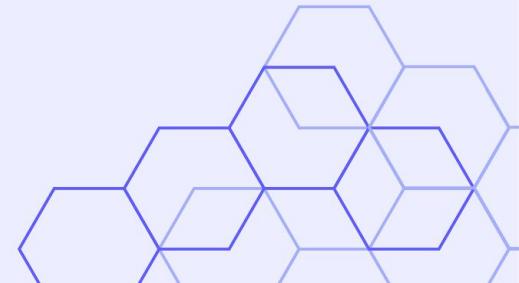


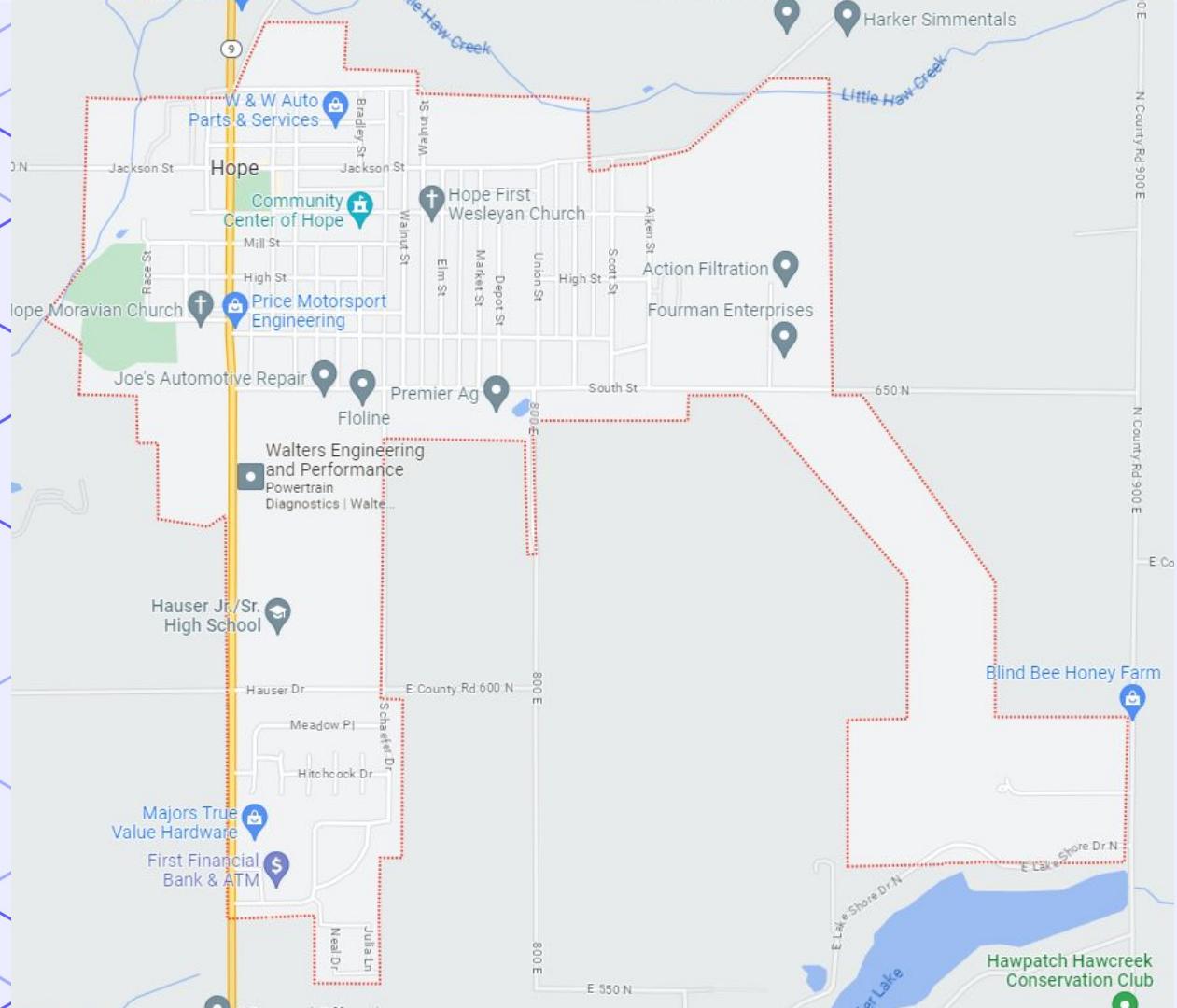




Some Terminology

- Segment - A section of road with a stop and end point
- Road Network - A collection of segments
- Agency - Some group charged with taking care of a road network
- PASER - the visual inspection scale for grading roads in Indiana
 - PAvement Surface Evaluation and Rating





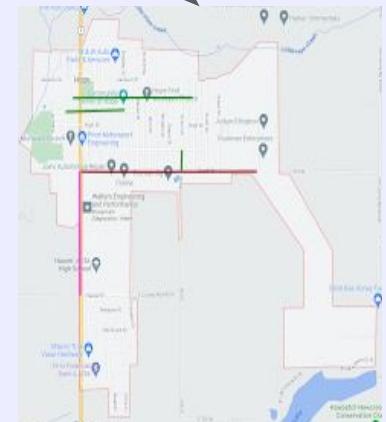
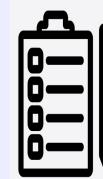
The Maintenance Process

@DrBass

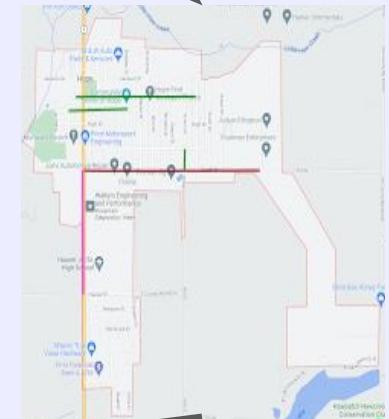
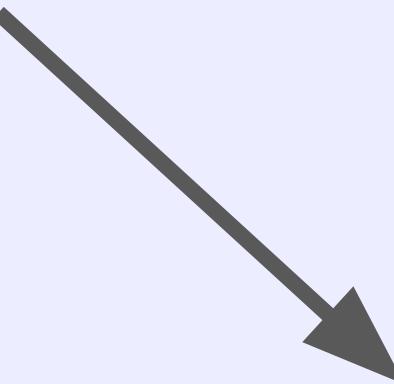


The Maintenance Process

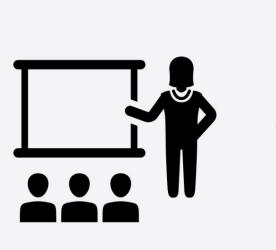
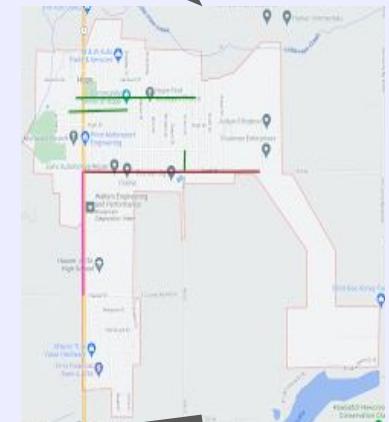
@DrBass



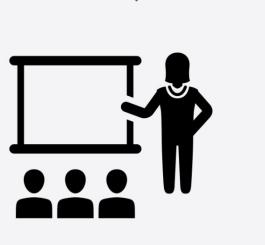
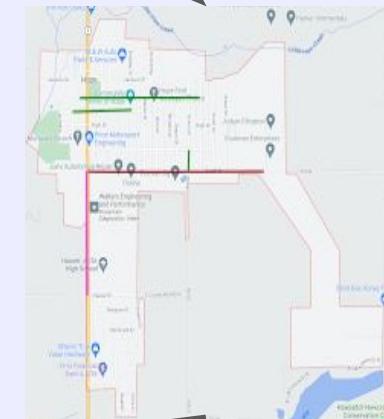
The Maintenance Process



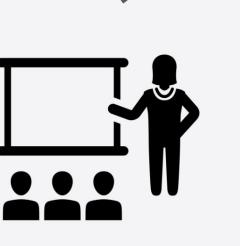
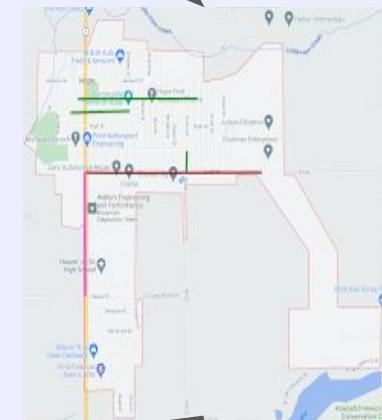
The Maintenance Process



The Maintenance Process

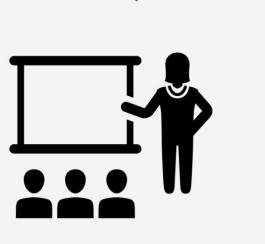


The Maintenance Process



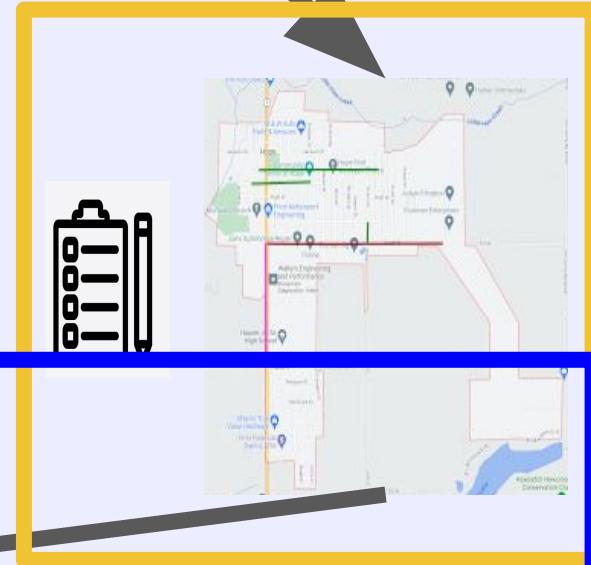
Where's Software?

@DrBass



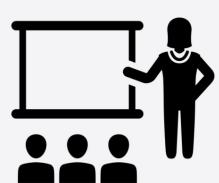
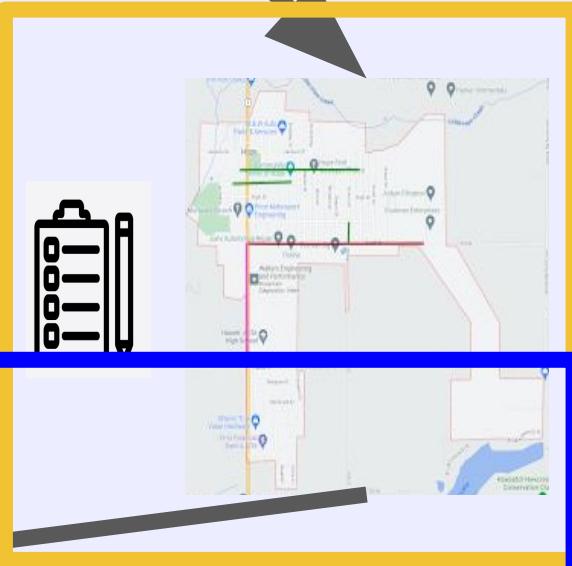
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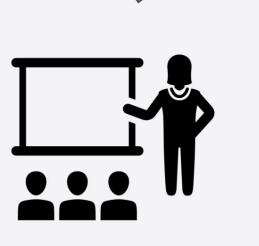
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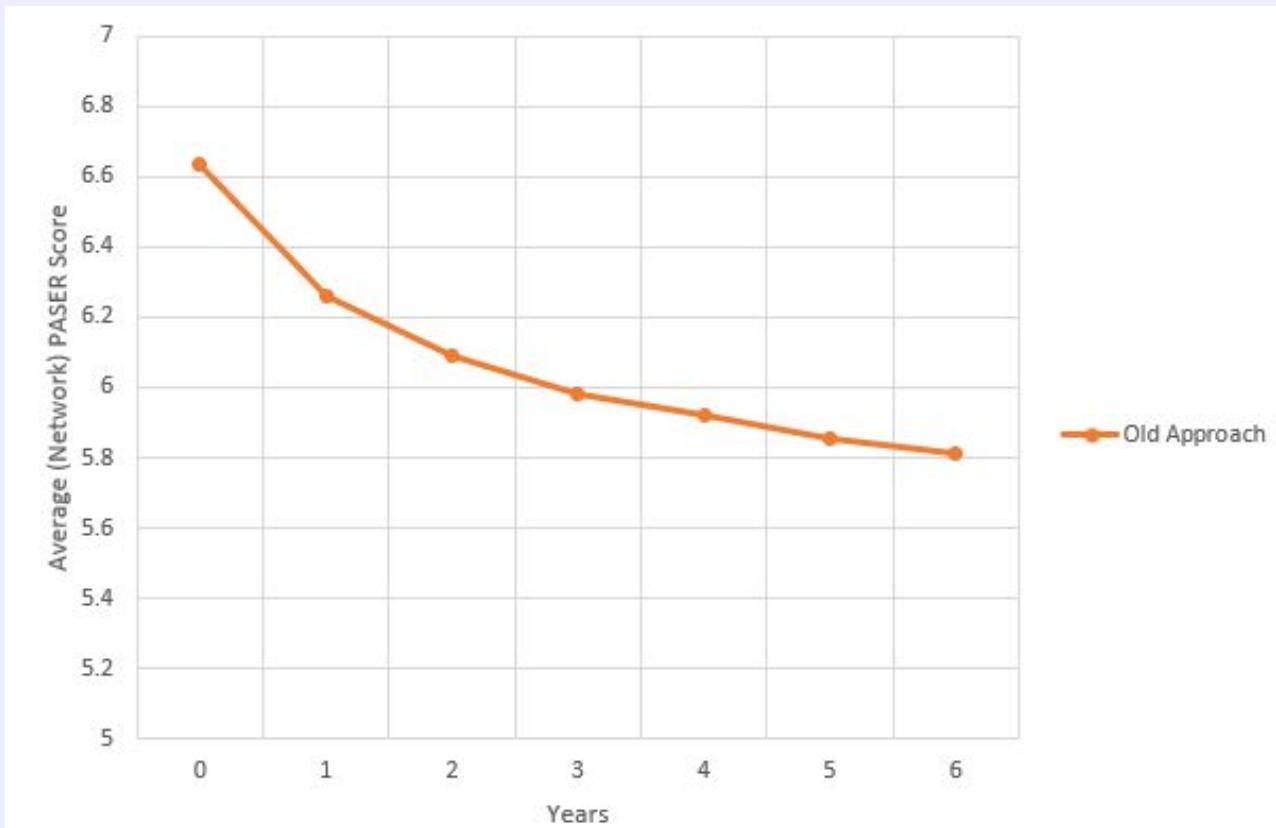


Today's Talk

@DrBass



There's a Problem Though



How Is It Done Today?

1	Roadway	From	To	Rating	2020 Treatment
2	1ST ST	Park Avenue	Cross Street	8	Mill and Overlay - 1.5"
3	1ST ST	Cross Street	Dead End	8	Mill and Overlay - 1.5"
4	2ND ST	Park Avenue	Cross Street	8	
5	2ND ST	Cross Street	Dead End	8	Asphalt Full Depth Repairs
6	A ST	North Main Street	Graham Road	6	Cape Seal
7	ACORN RD	Galaxy Drive	Fairlane Court	8	Chip Seal
8	ACORN RD	Fairlane Court	Cobra Drive	4	Chip Seal - Double
9	ACORN RD	Cobra Drive	Torino Lane	5	Chip Seal - Double and Fog
10	ACORN RD	Torino Lane	Taurus Lane	5	Chip Seal - Triple
11	ACORN RD				Chip Seal and Fog
					Chip Seal and Microsurfacing

Instructions Road Asset Inventory

Surface Types

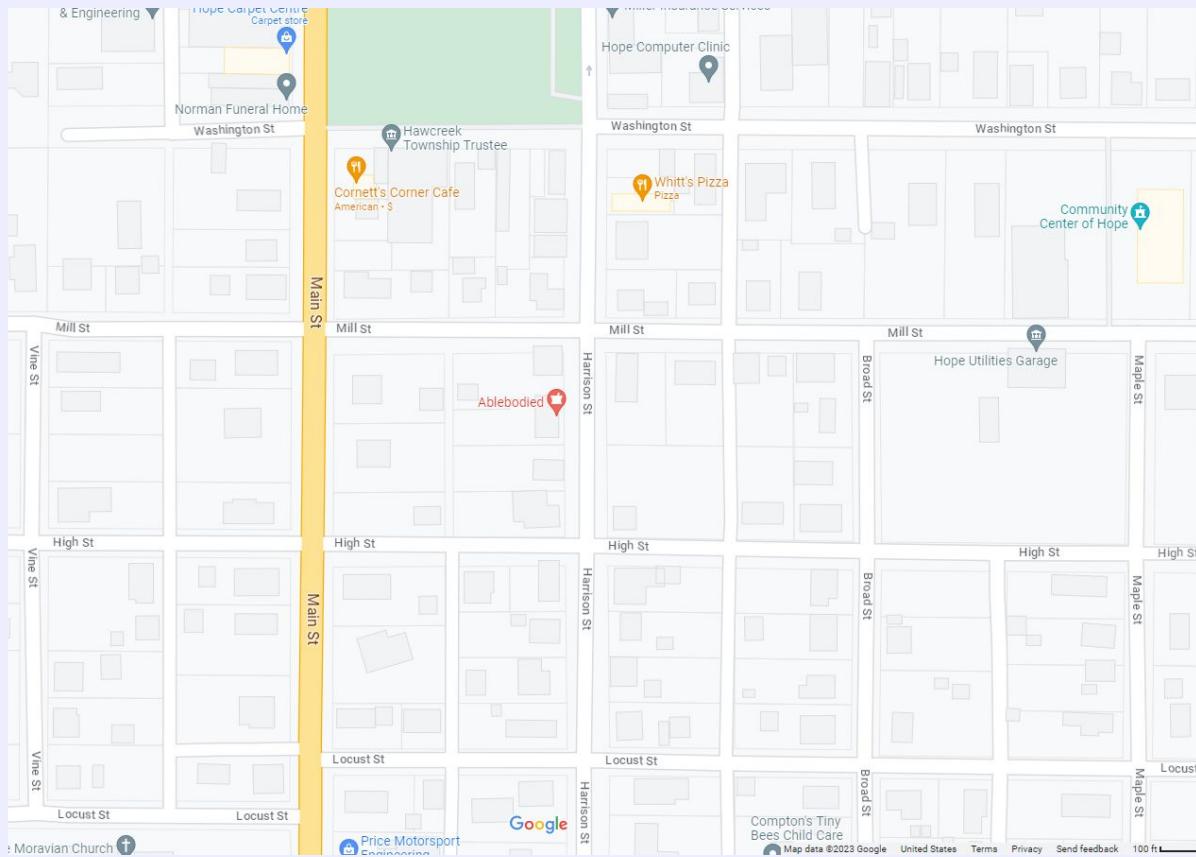
Rating System

Functional Classifications

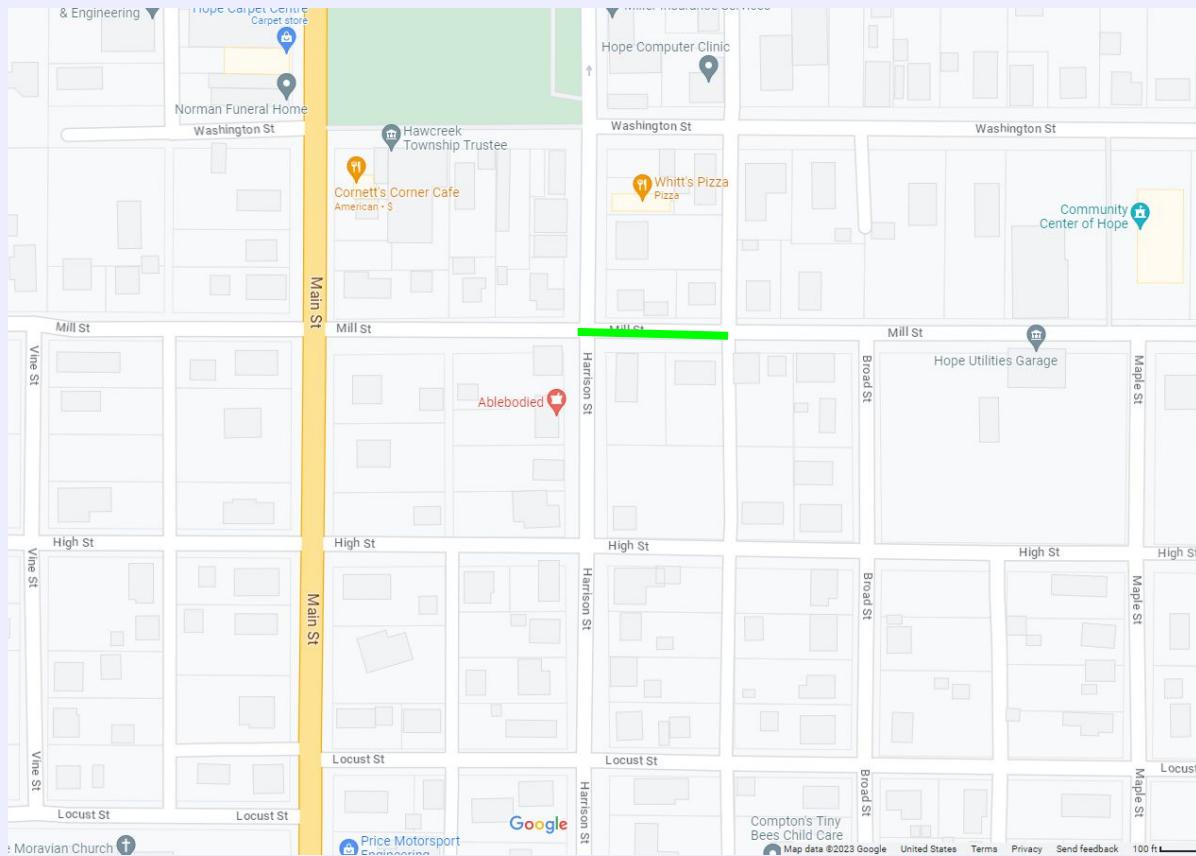
Treatr ...

Display Settings

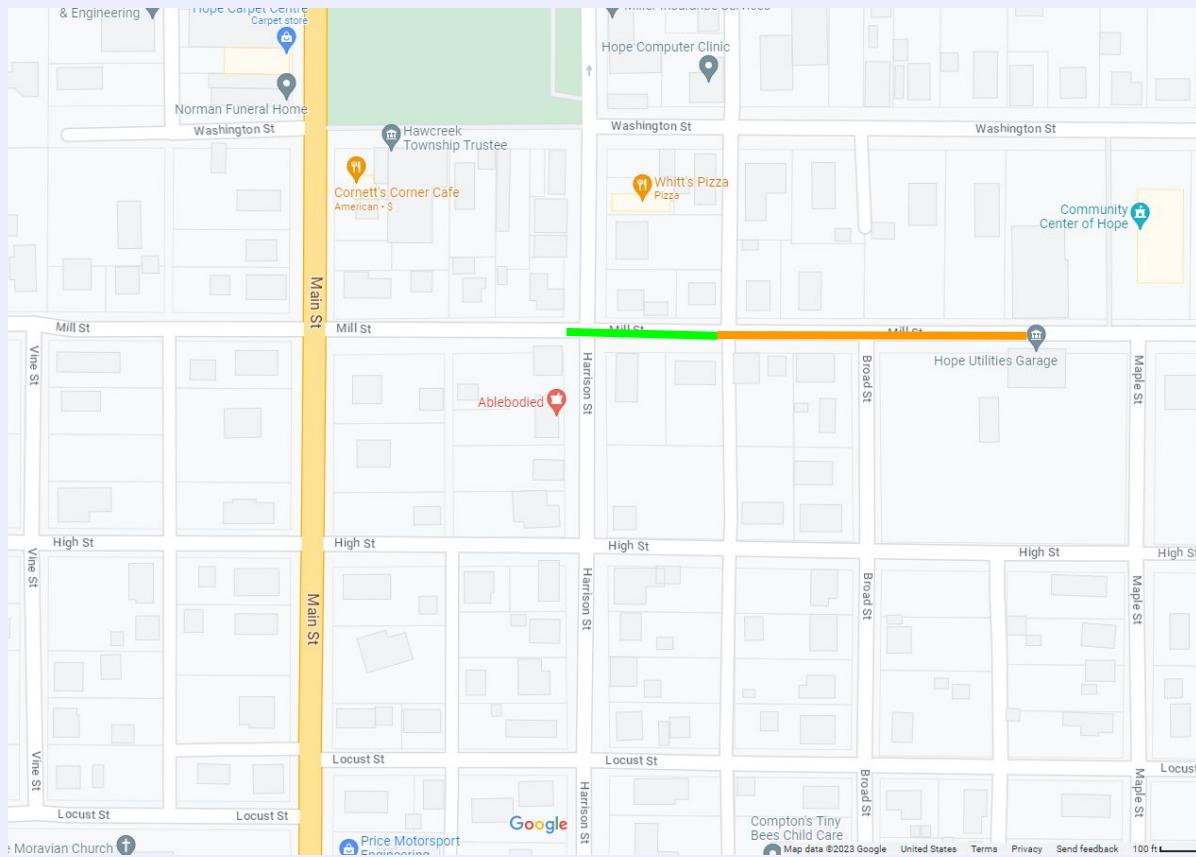
How Is It Done Today?



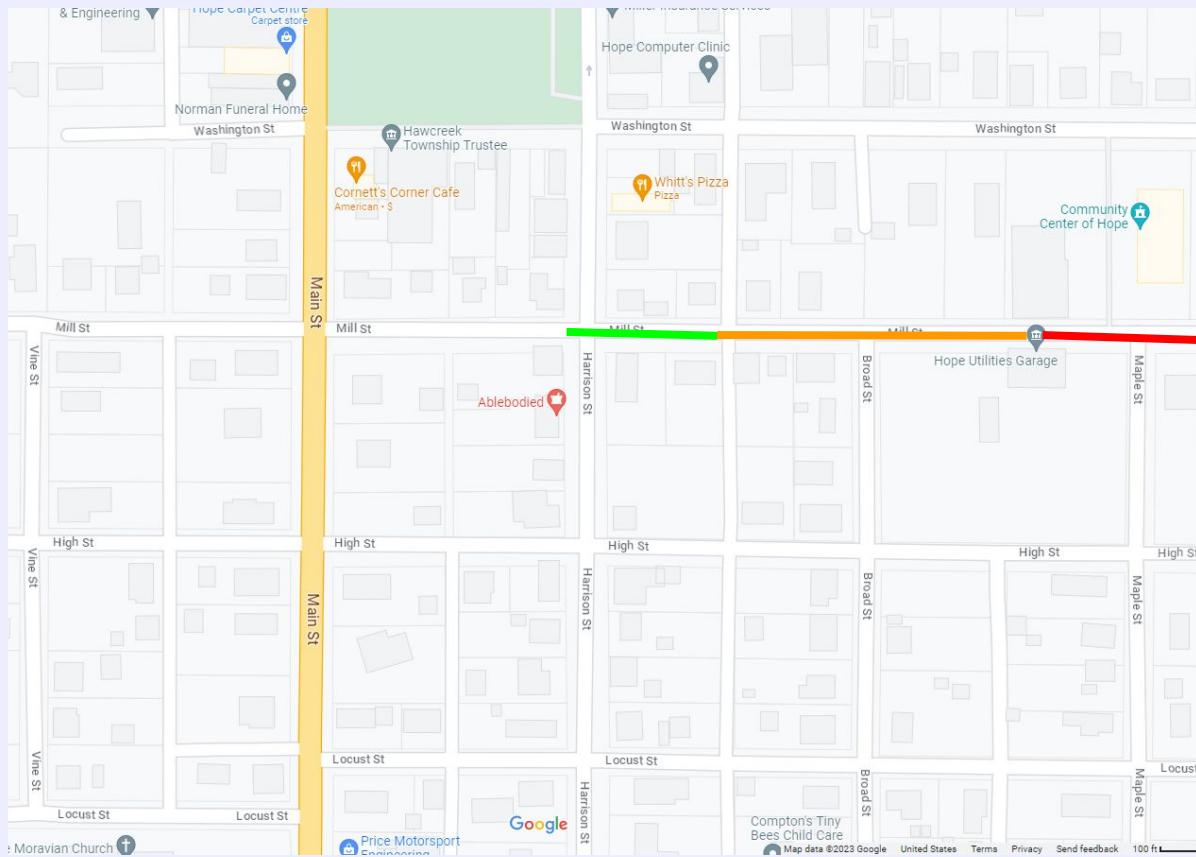
How Is It Done Today?



How Is It Done Today?



How Is It Done Today?



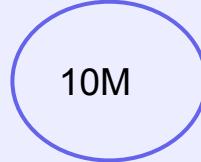
Let's Do That

1ST ST

2ND ST

3RD ST

4TH ST

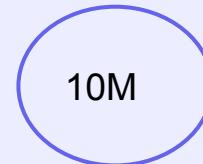


10M

Let's Do That

1ST ST

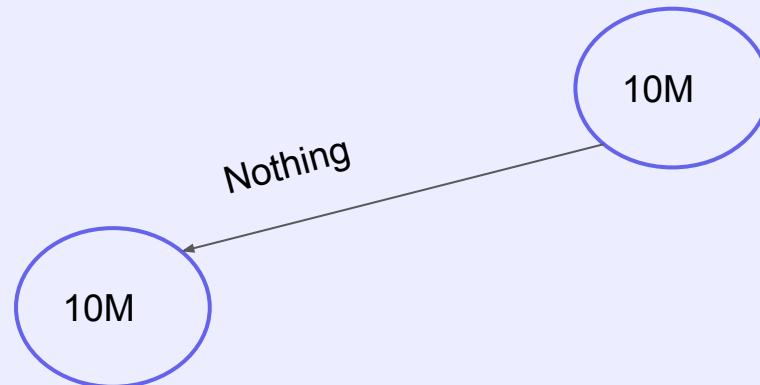
2ND ST
3RD ST
4TH ST



Let's Do That

1ST ST

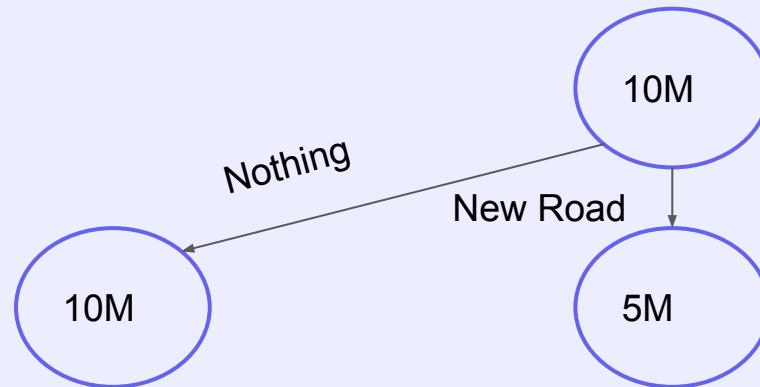
2ND ST
3RD ST
4TH ST



Let's Do That

1ST ST

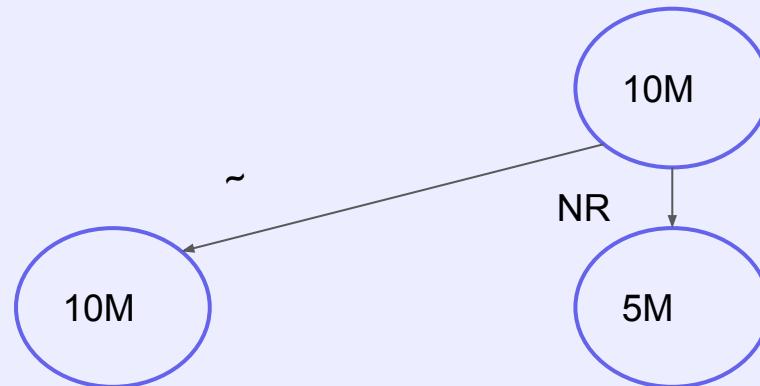
2ND ST
3RD ST
4TH ST



Let's Do That

1ST ST

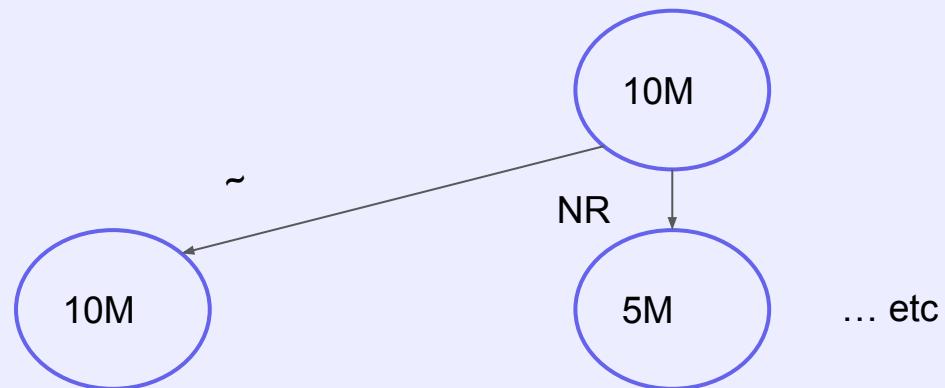
2ND ST
3RD ST
4TH ST



Let's Do That

1ST ST

2ND ST
3RD ST
4TH ST



... etc

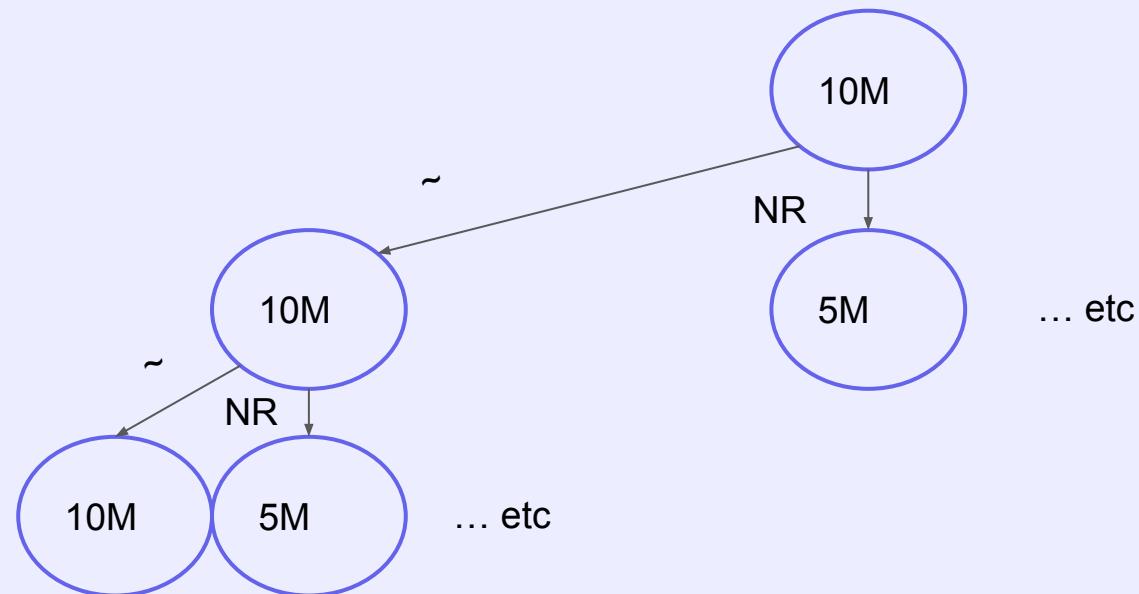
Let's Do That

1ST ST

2ND ST

3RD ST

4TH ST

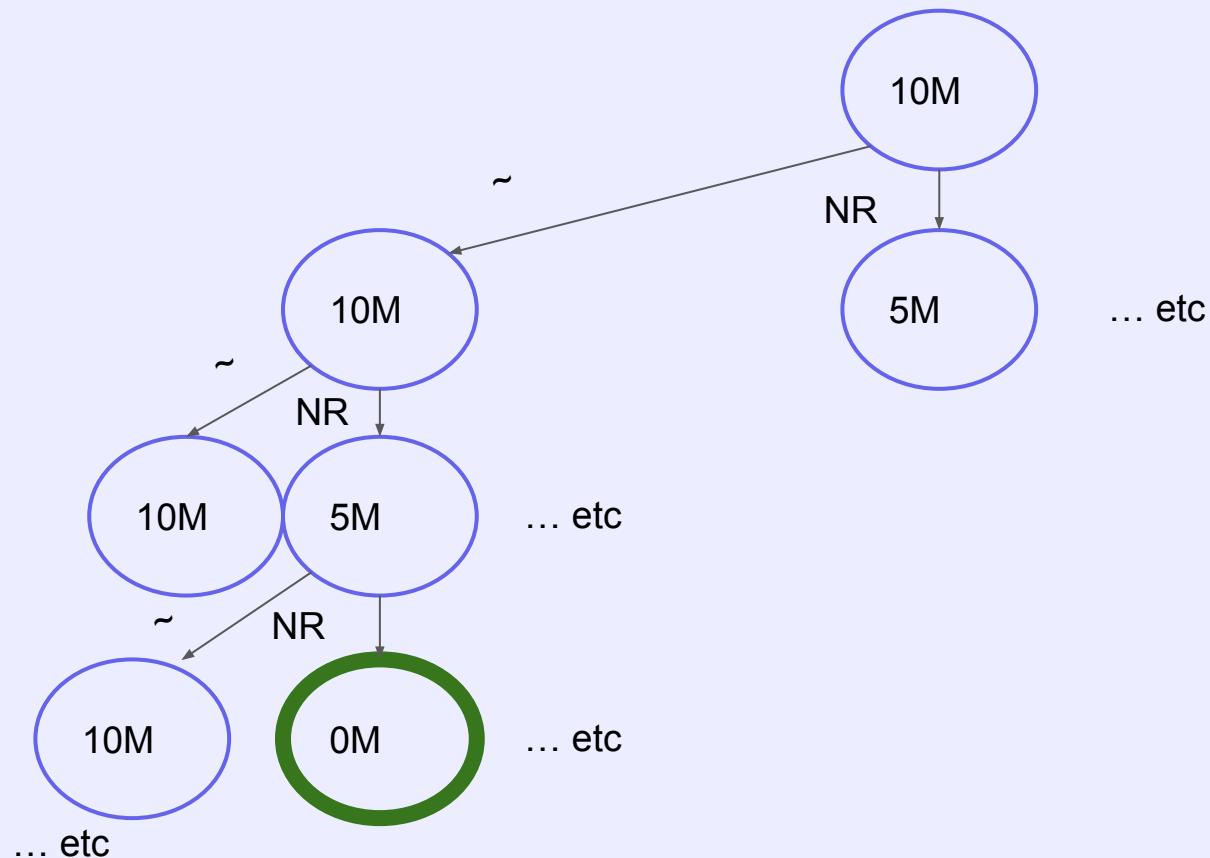


Let's Do That

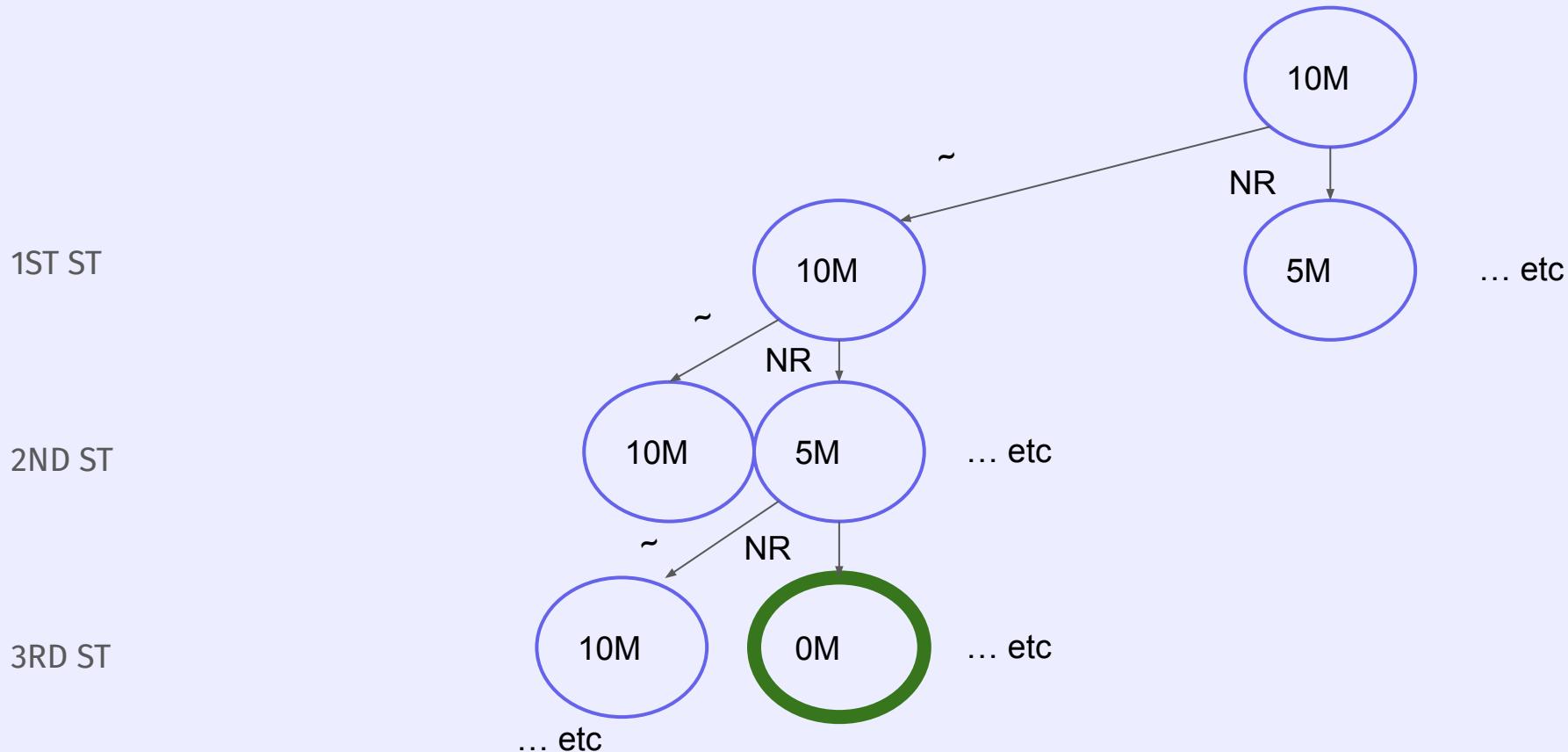
1ST ST

2ND ST

3RD ST

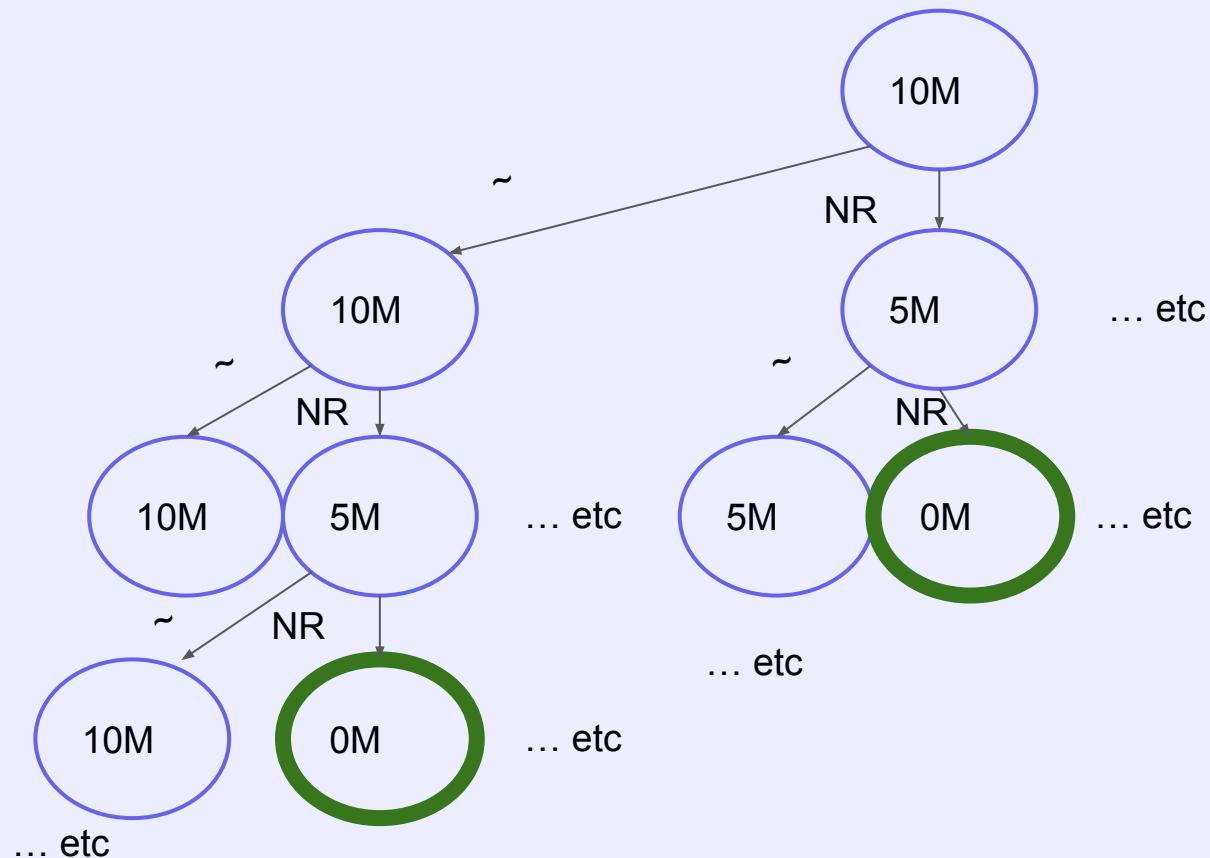


Let's Do Tree Search



Let's Do Tree Search

1ST ST



2ND ST

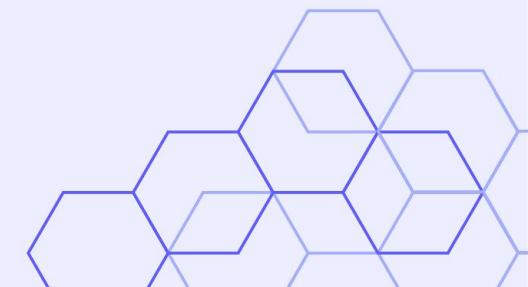
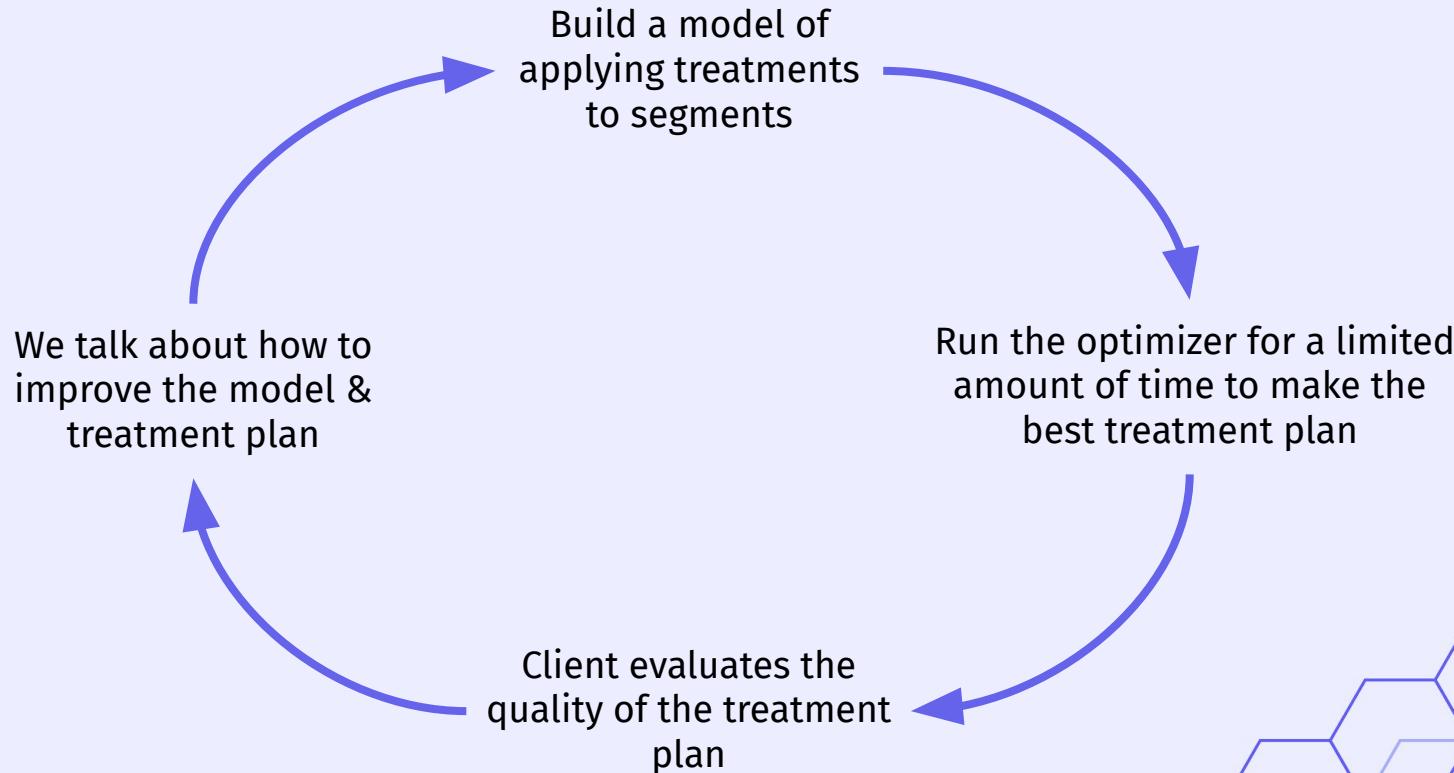
3RD ST

Why Is This So Hard?



- Programmers Are Not Civil Engineers
- Our Input Data Wasn't Pristine
- Tree Search at These Scales is Inherently Difficult

Building Tree Search with SMEs

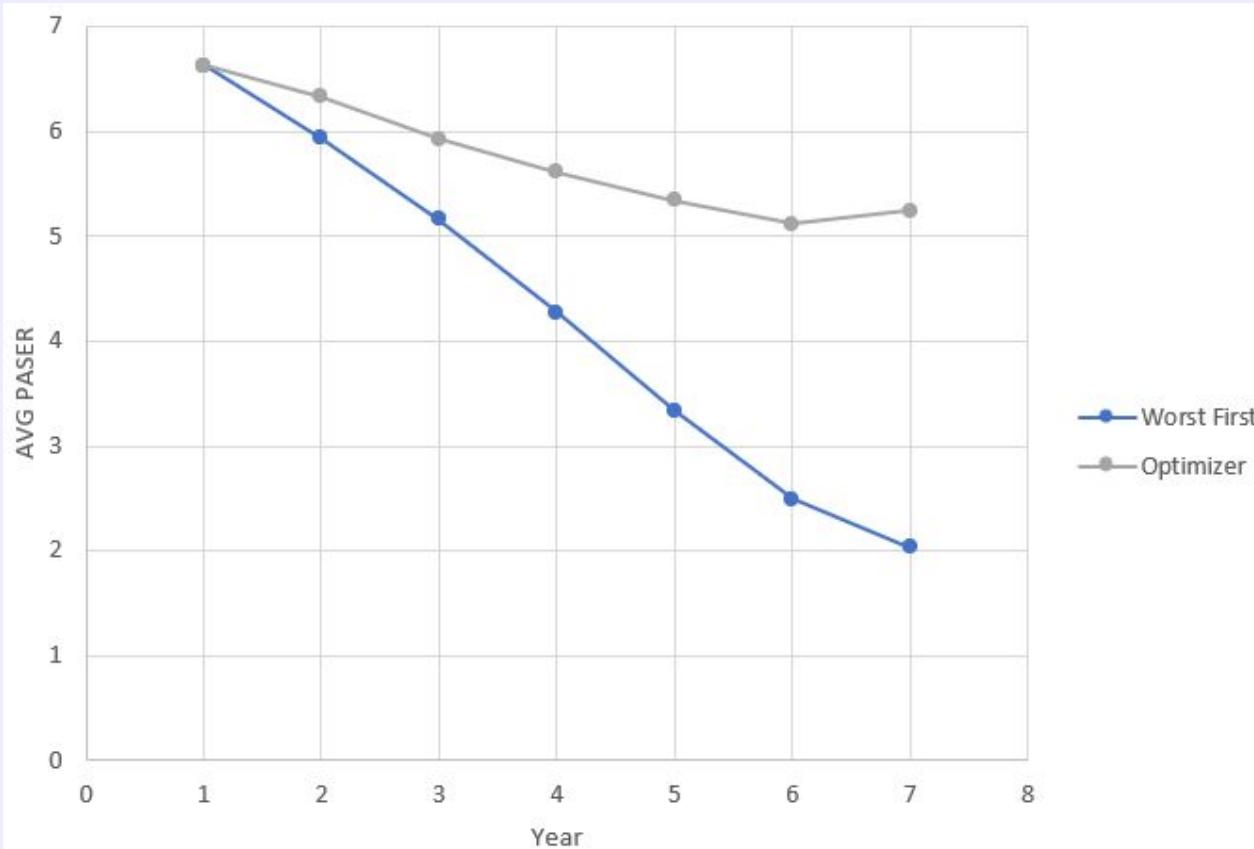


Building Tree Search with SMEs

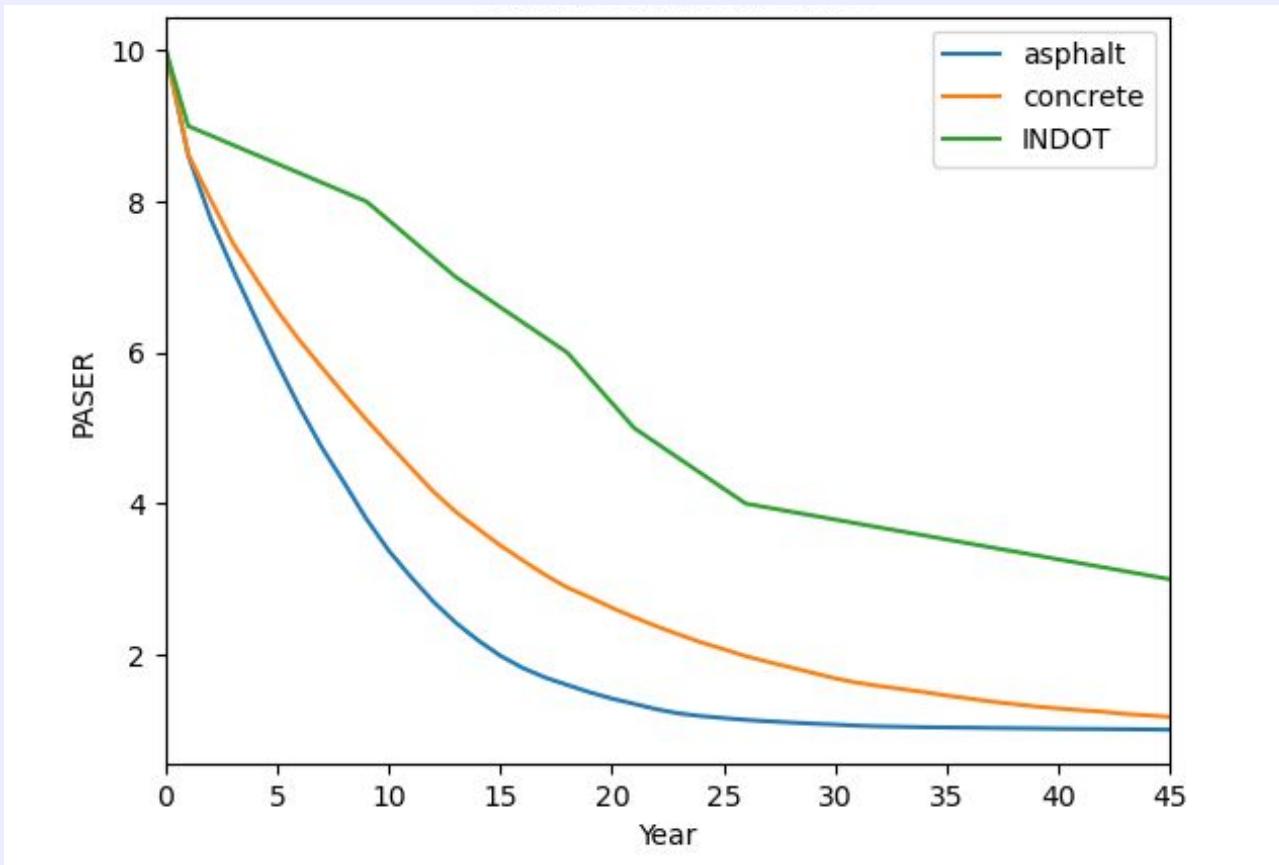
Google search results for "build measure learn loop":

- Microsoft Learn**: The build-measure-learn feedback loop ...
- Medium**: Build, Measure, Learn cycle
- Amplitude**: Product Management Lifecycle Loop ...
- Steve Blank**: Why Build, Measure, Learn
- YouTube**: The Build-Measure-Learn Feedback Loop ...
- Marmelab**: Lean Startup, day 10: Build-Measure-Learn
- Sameologic**: Build, Measure, Learn with Lean ...
- Kromatic**: Build Measure Learn - Why The Lean ...
- Inside Product**: Build Measure Learn
- thr**: Build-Measure-Learn Feedback Loop
- Praxie.com**: Build-Measure-Learn Feedback Loop ...
- Visualise Solutions**: Why the B-M-L Loop of Lean Startup is ...
- Steve Blank**: Steve Blank Why Build, ...
- Lean East**: Lean Startup Thinking - Lean East
- Learn**: BUILD MEASURE LEARN
- How the Build Measure Learn Cycle**: Build Measure Learn Cycle
- A more accurate depiction of the Build-Measure-Learn loop**: Build Measure Learn Cycle
- There's much more...**: Build Measure Learn Cycle
- Build**: BUILD MEASURE LEARN

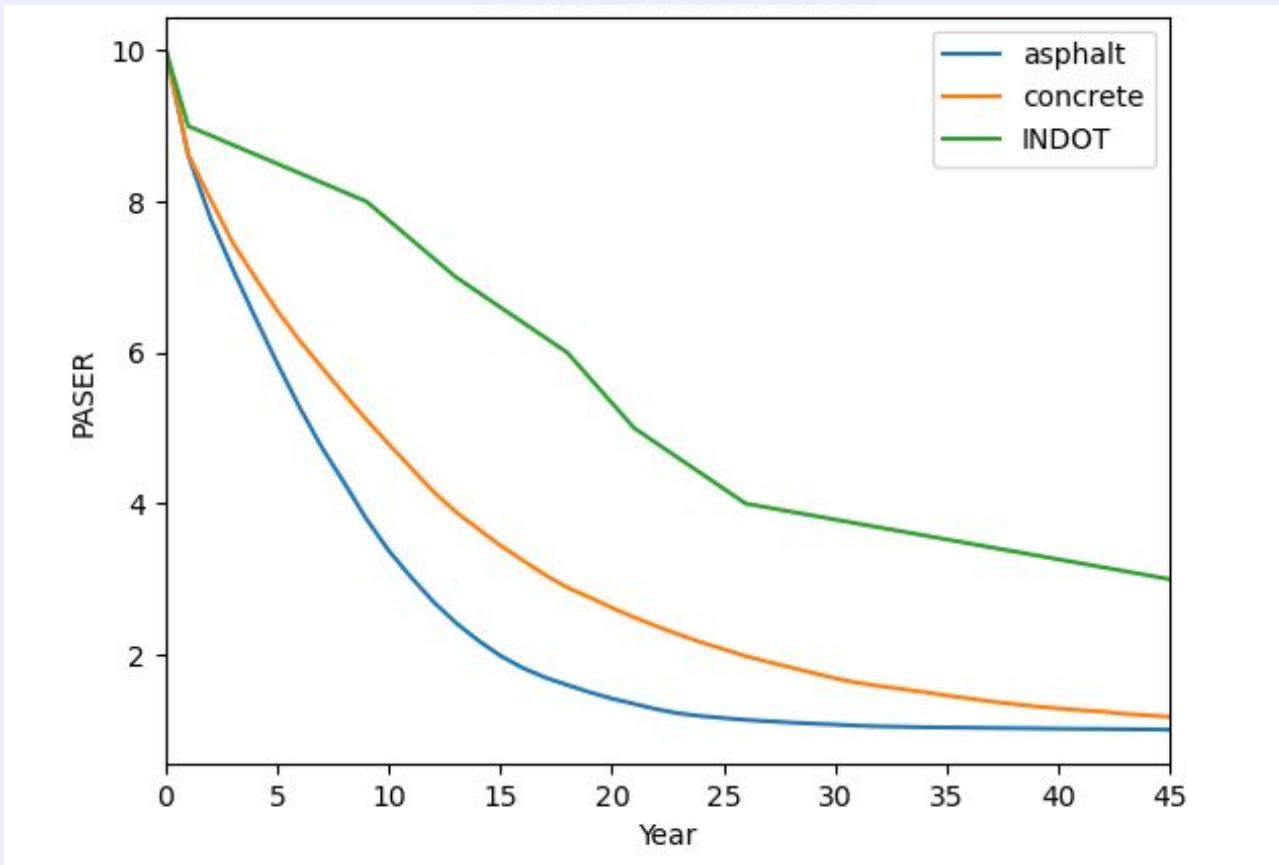
Our Plans Underperformed Expert Expectations



Real World Data and Official Model Don't Align



These Curves Were Made Using Other AI Techniques



Why Is Tree Search Hard?

"Space is big. Really big. You just won't believe how vastly hugely mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist, but that's just peanuts to space."

Hitchhiker's Guide to the Galaxy



So, Why Is Finding Good Goals Hard?

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Turns out, actual space is just peanuts to our search domain.



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30 treatments

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$$30^{(500 * 5)} = 30^{2500} = 6.35 * 10^{3692}$$



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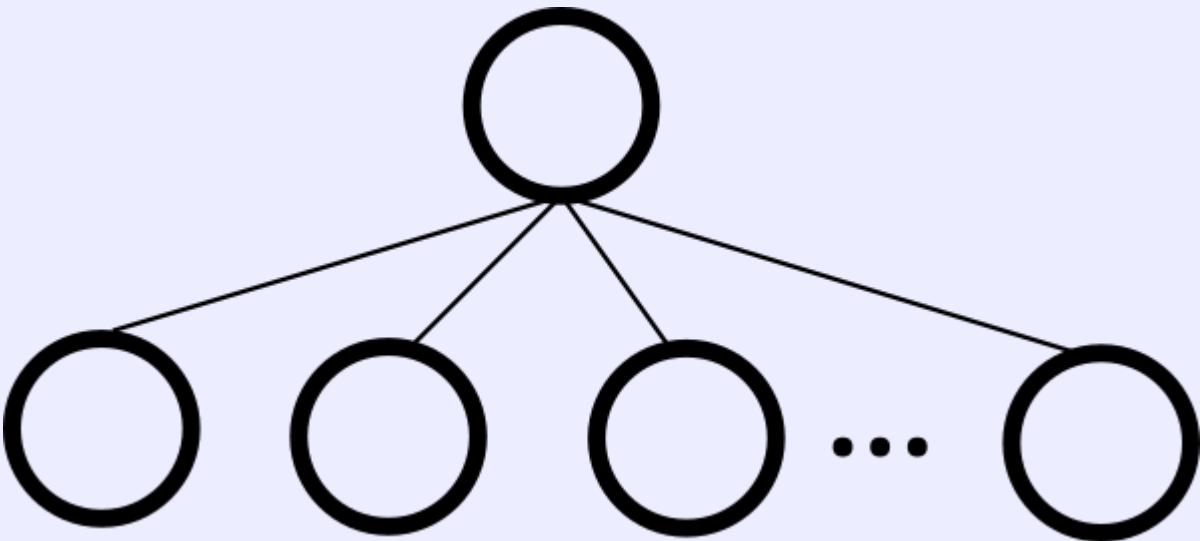
5 year planning horizon (dictated by Indiana)

$$30^{(500 * 5)} = 30^{2500} = 6.35 * 10^{3692}$$

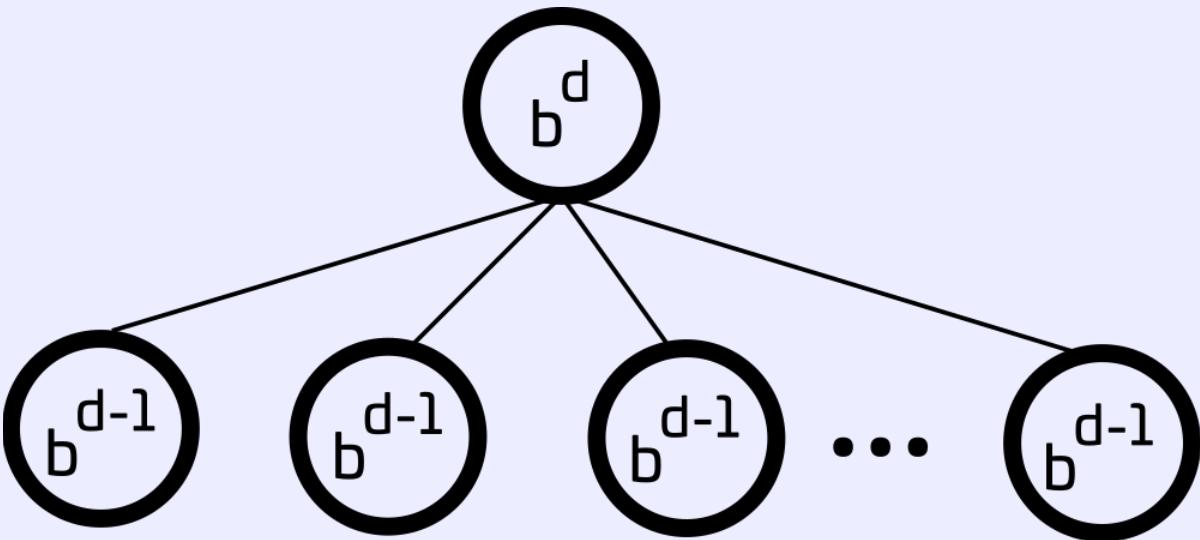
Atoms in the Observable Universe = 10^{82}



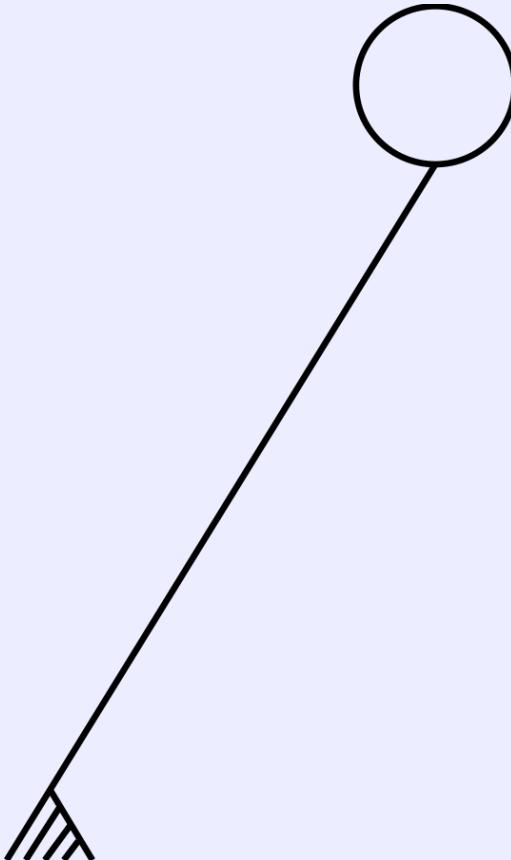
Work Smarter, Not Harder



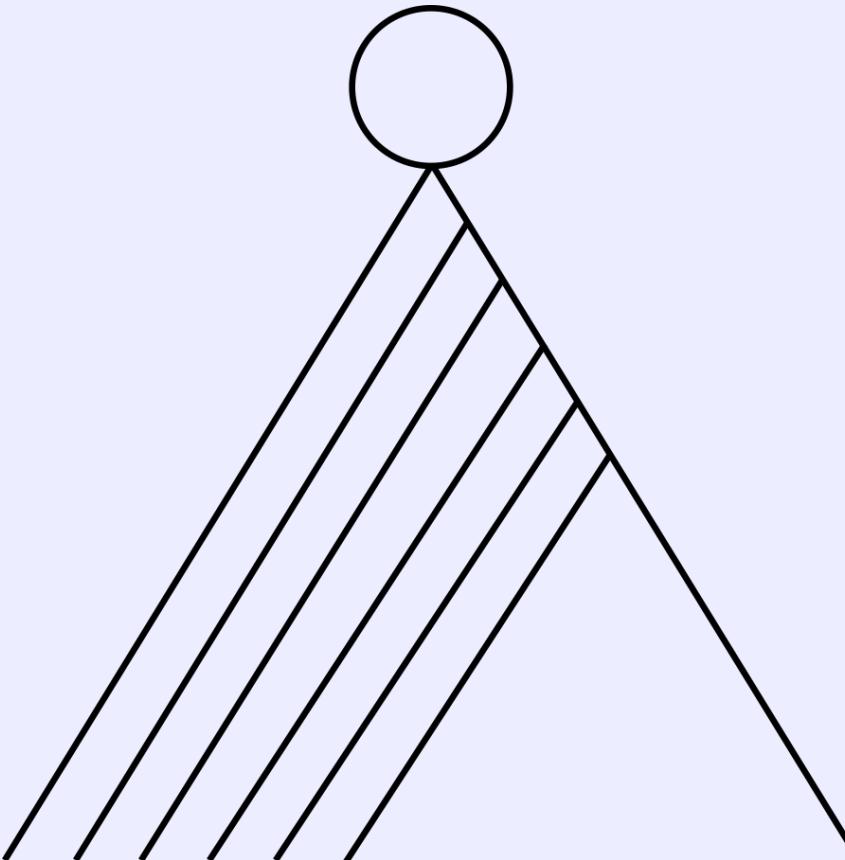
Work Smarter, Not Harder



Work Smarter, Not Harder



Work Smarter, Not Harder



Also, Work Faster

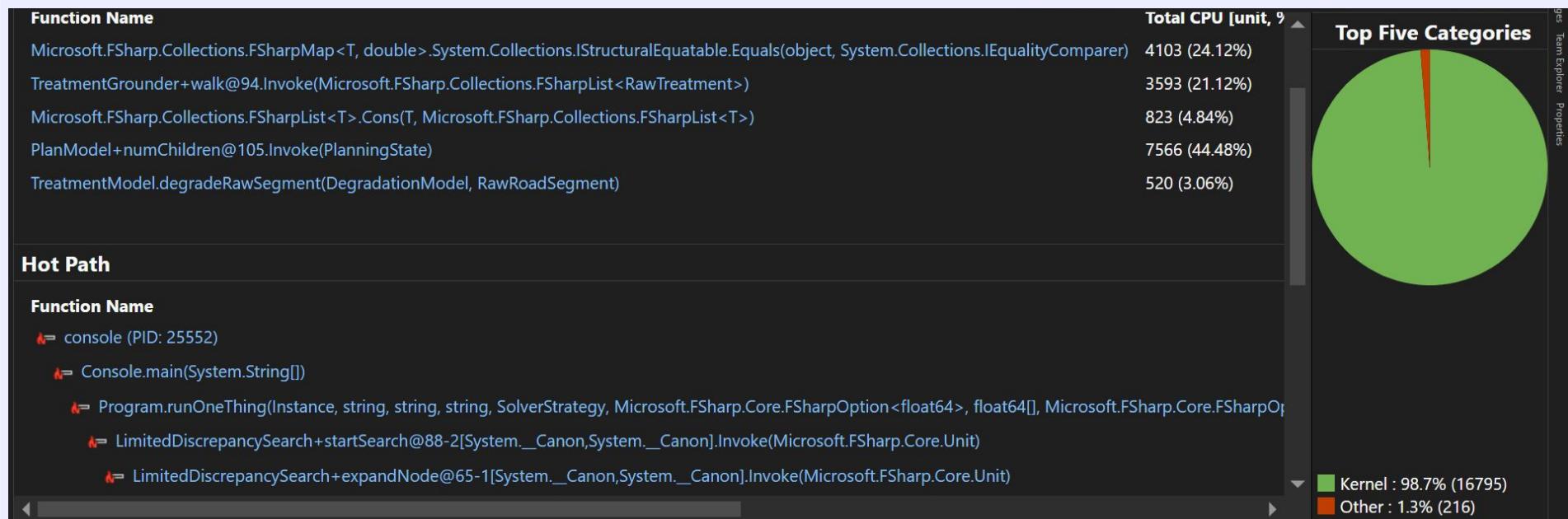


Also, Work Faster

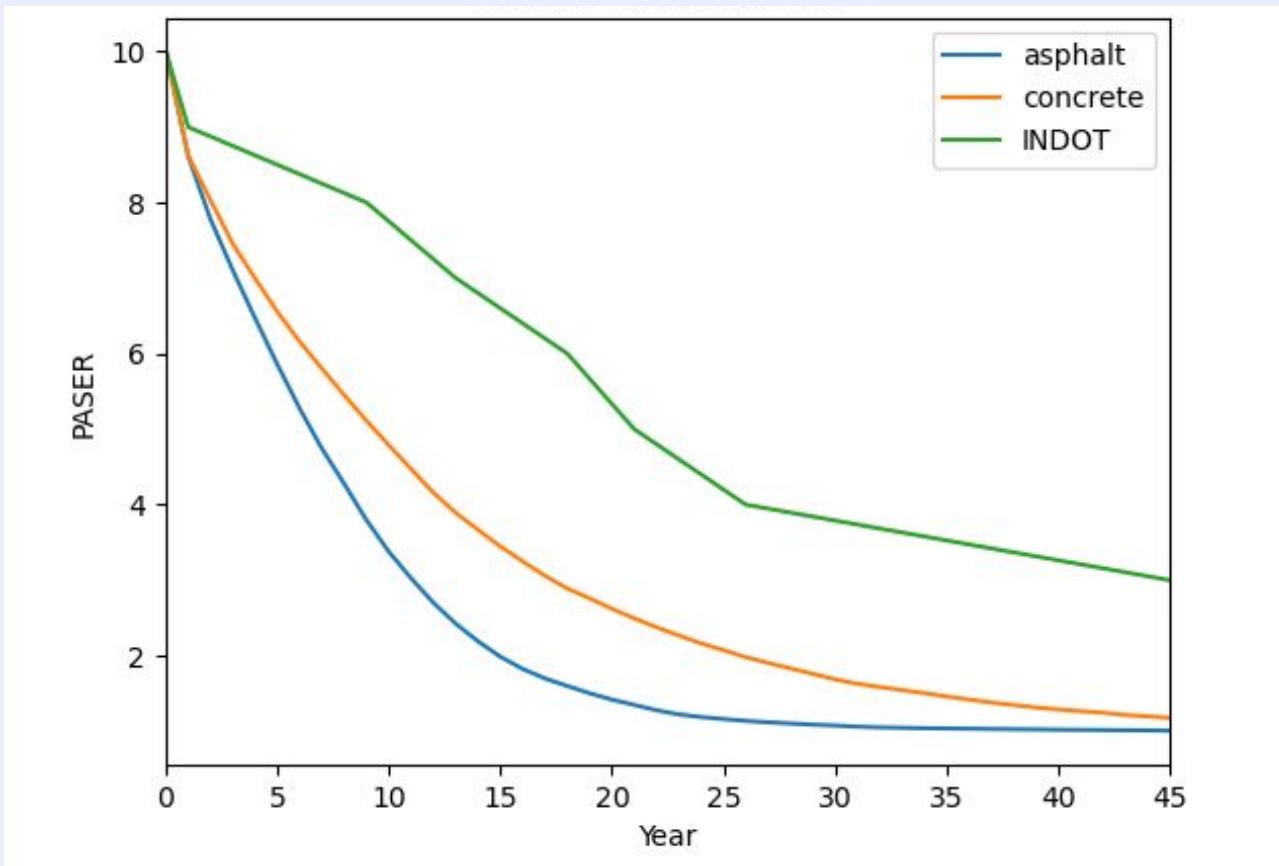
~ 1,000,000 nodes a second



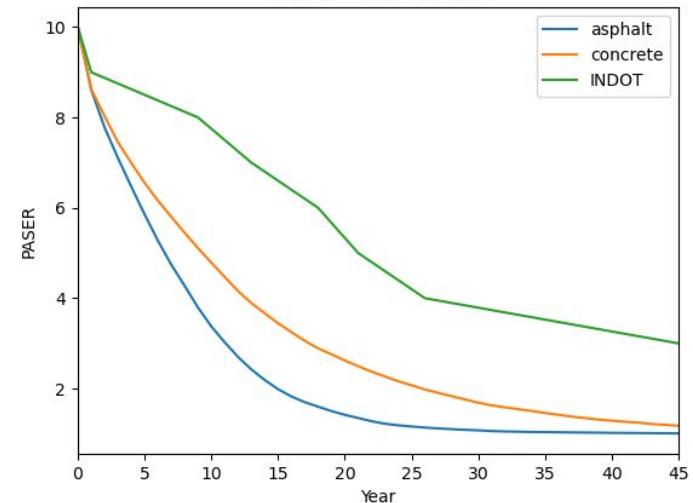
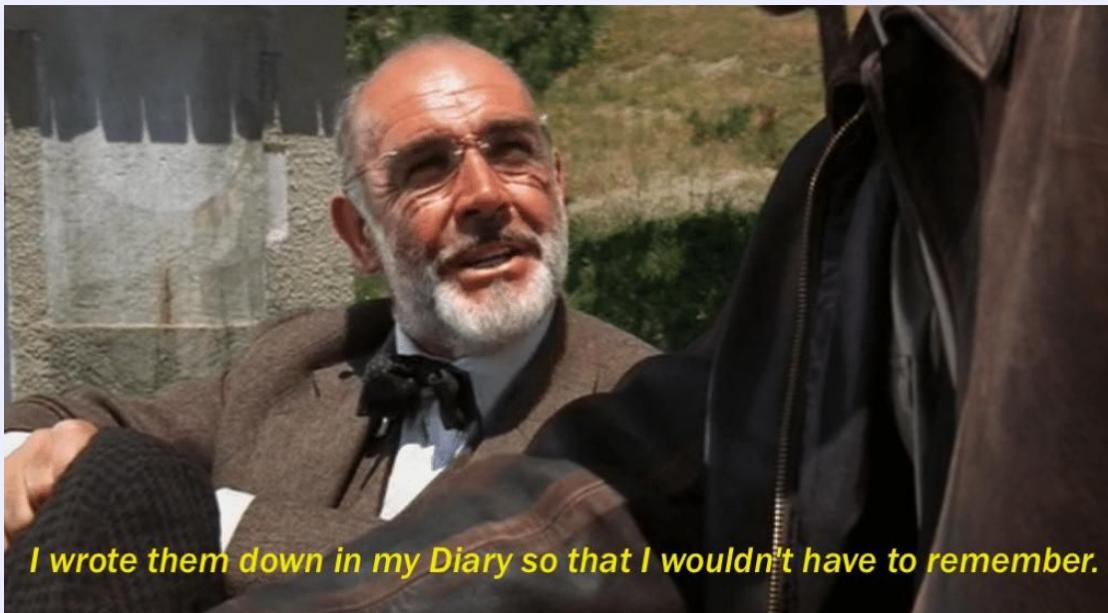
Use a Profiler



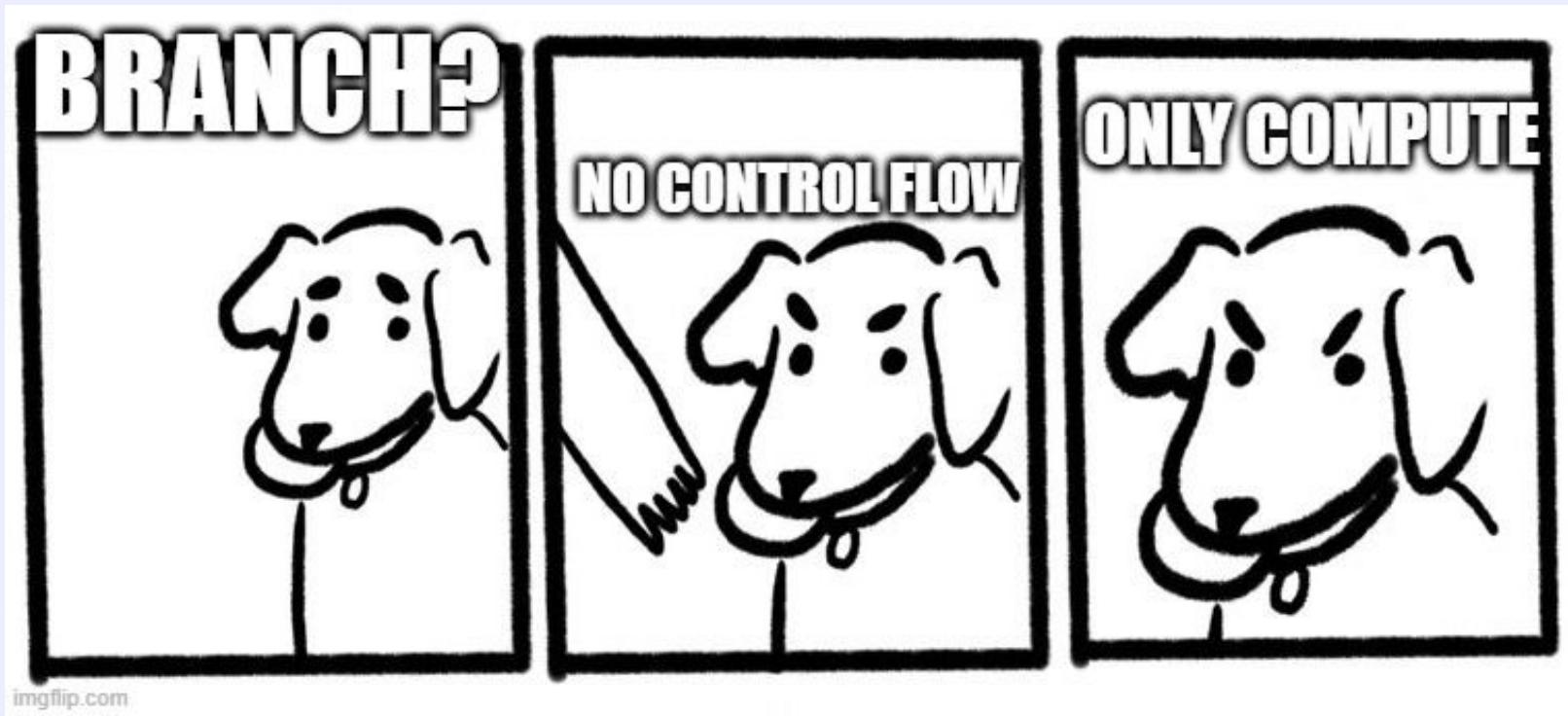
Also, Work Faster



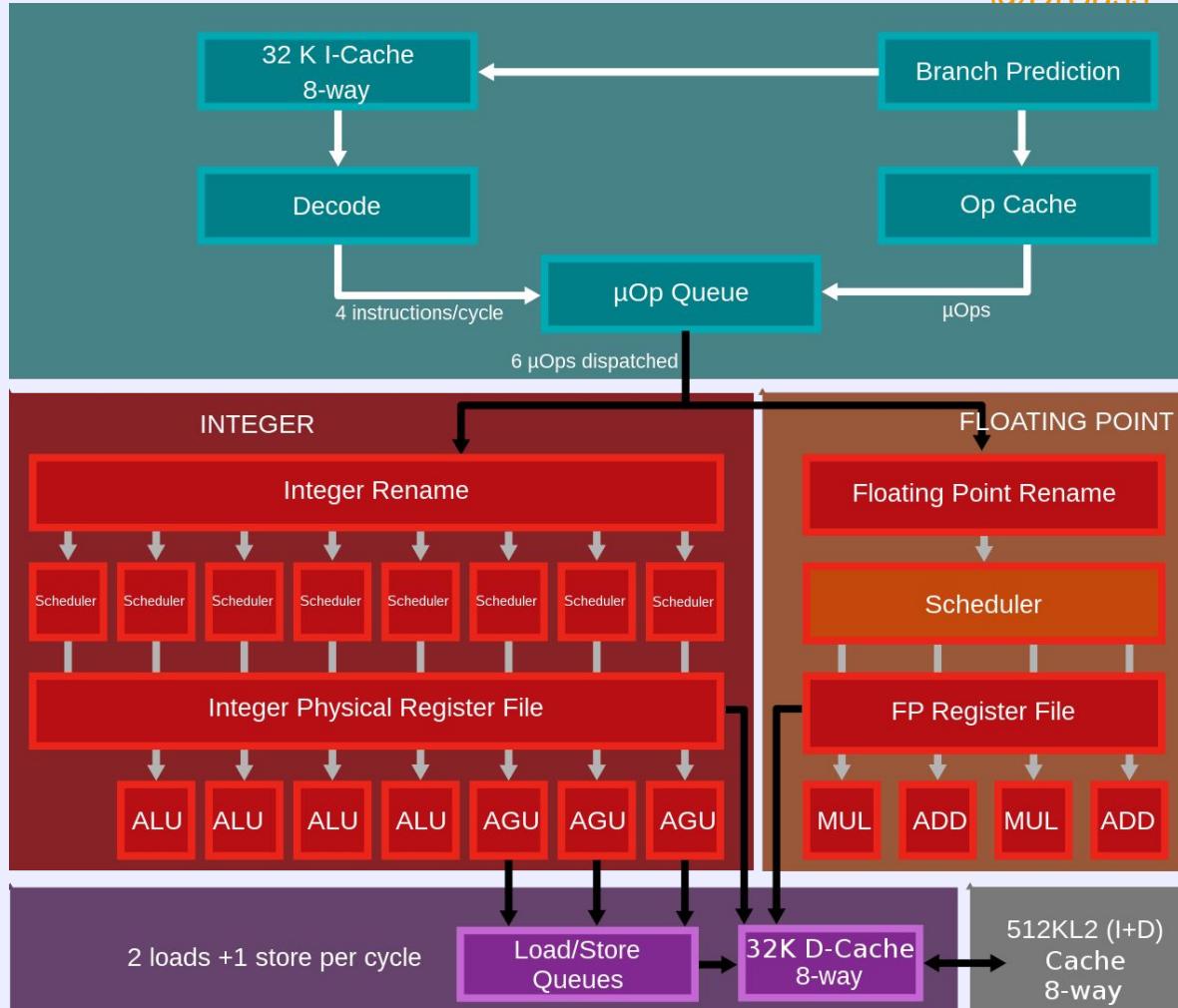
Write Down Expensive Computations in Tables



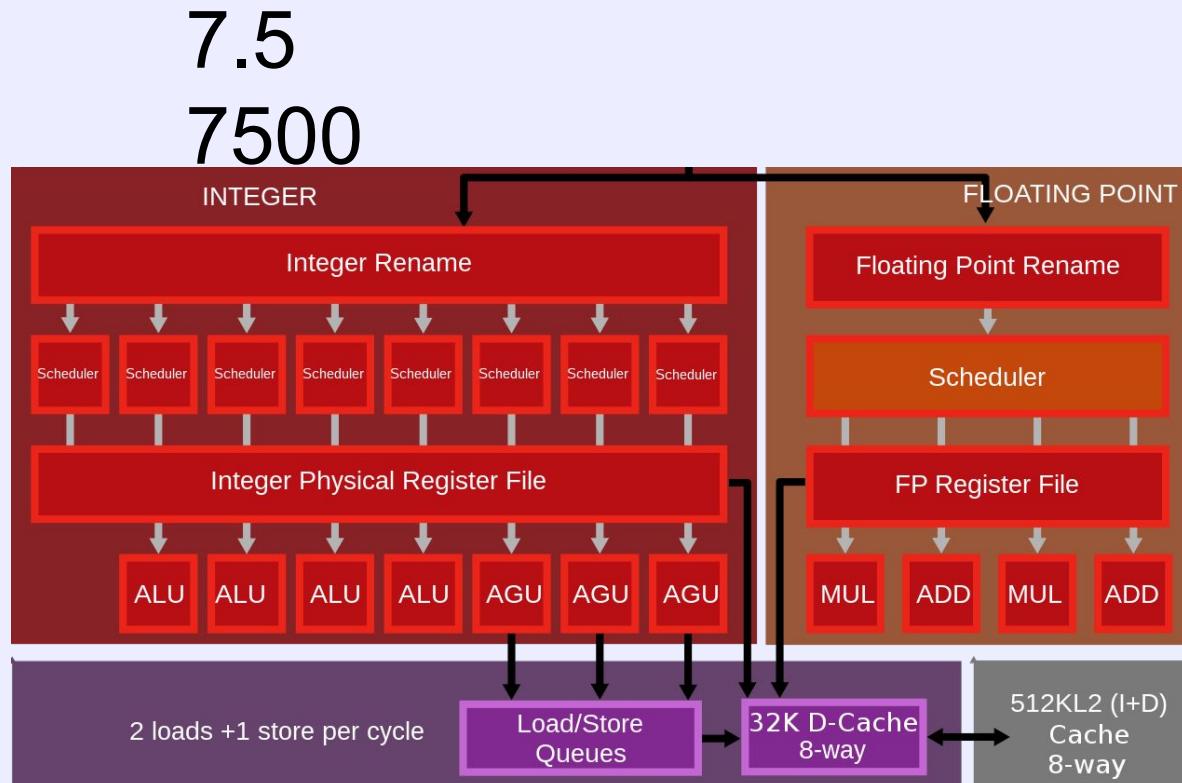
Trick 2: Gotta Go Fast Avoid Conditionals Where Possible



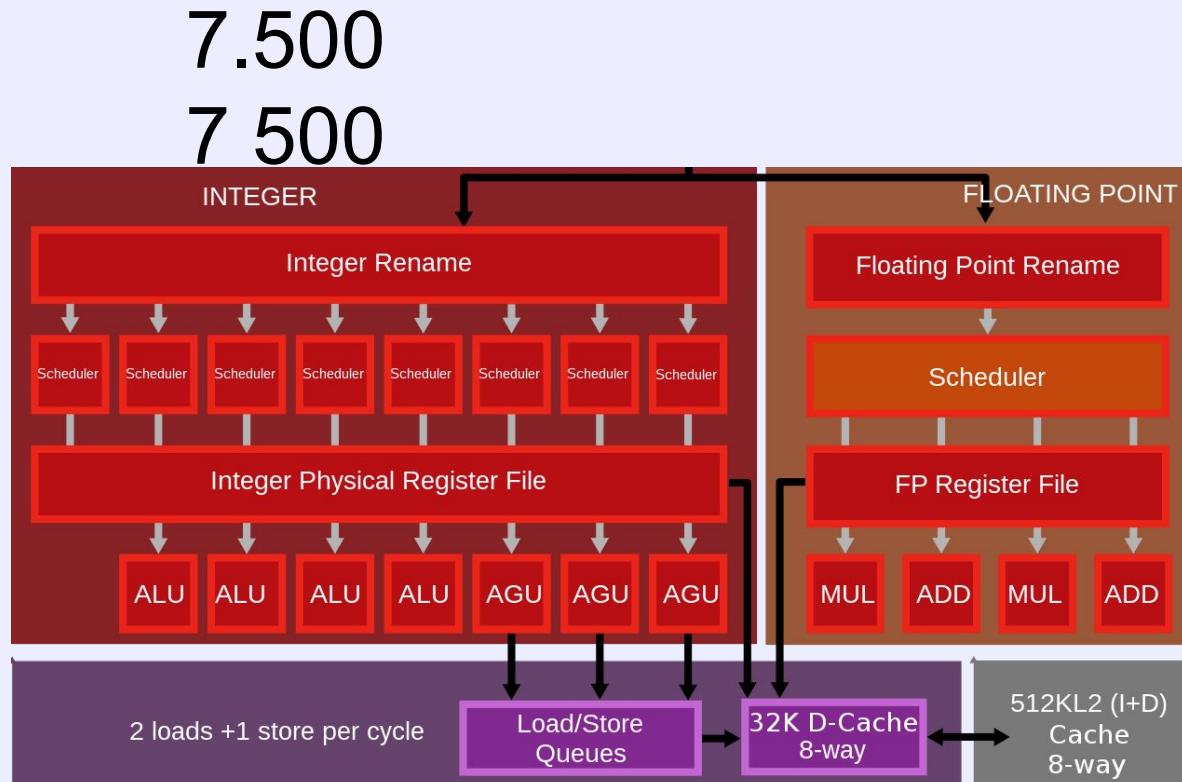
Trick 2: Gotta Go Fast



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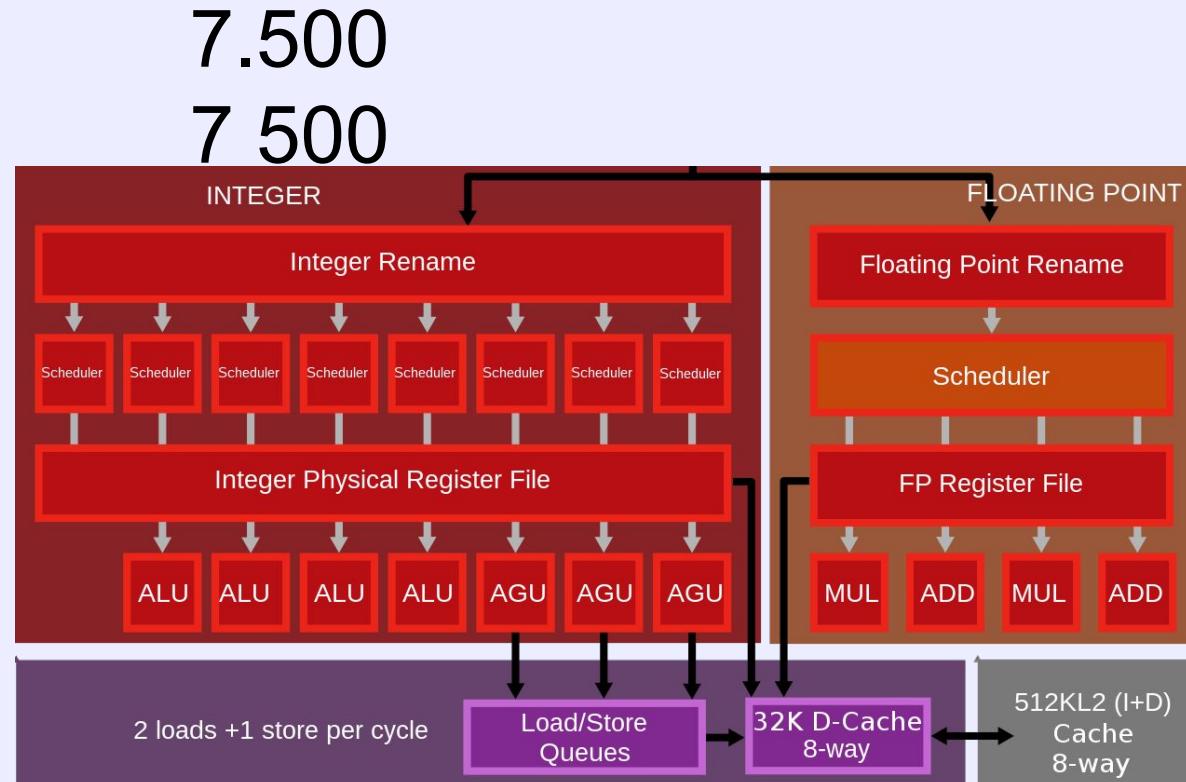
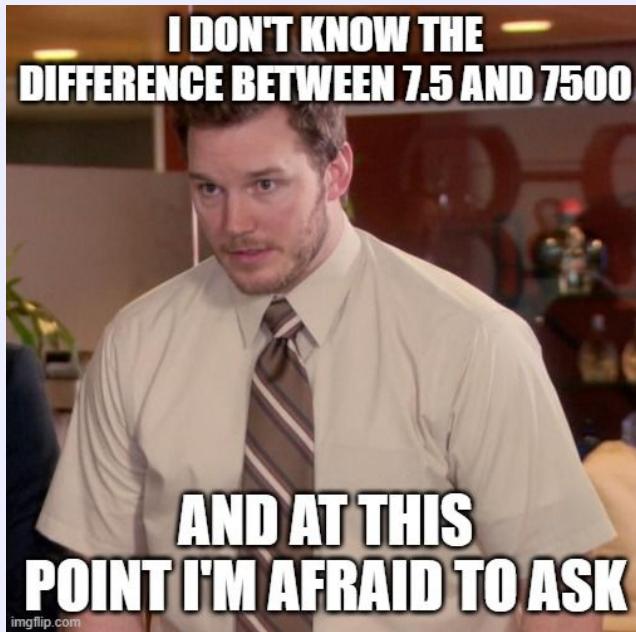


Trick 2: Gotta Go Fast

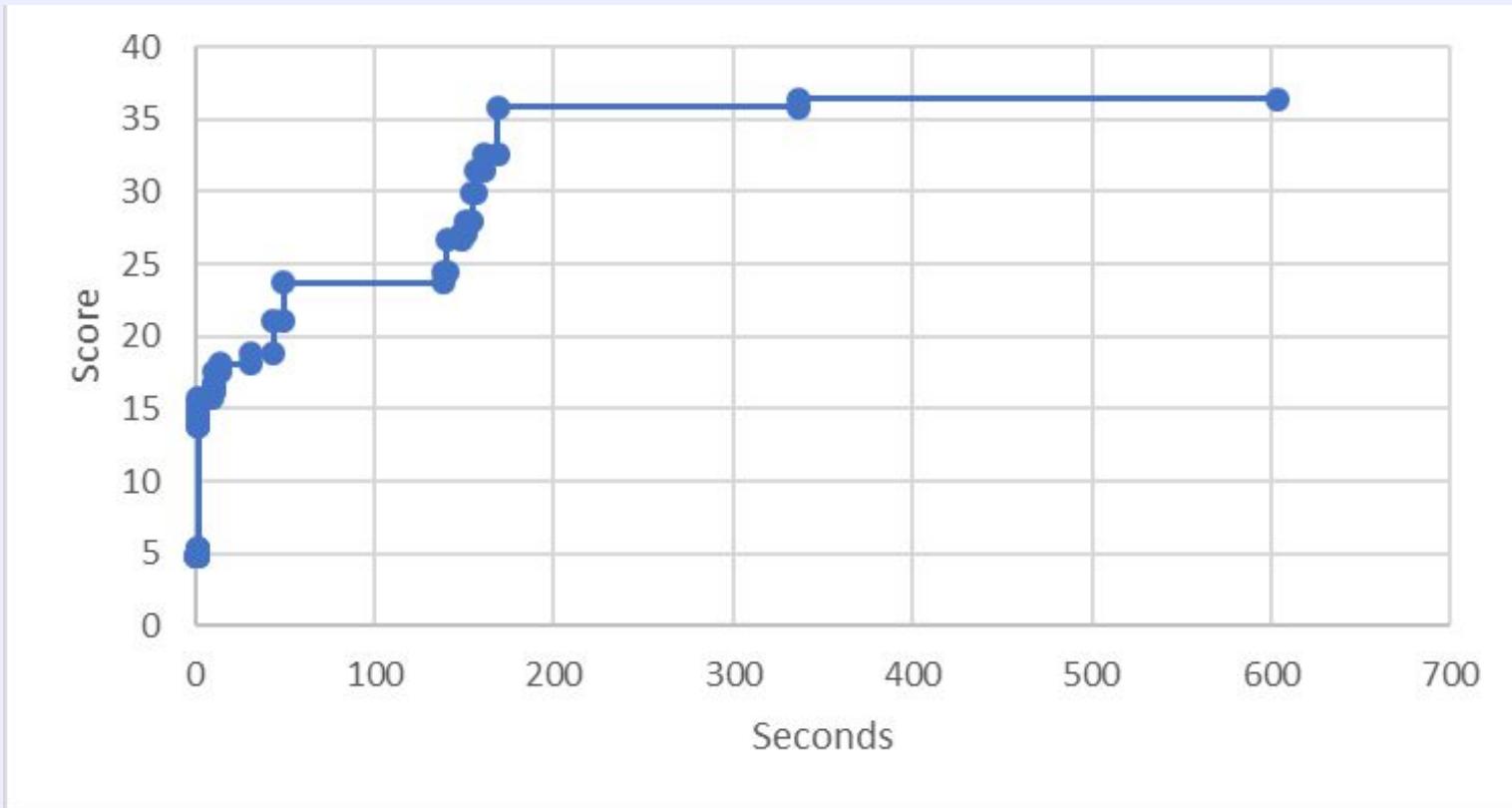


Trick 2: Gotta Go Fast

Integer Math is Often Faster Than Floating Point



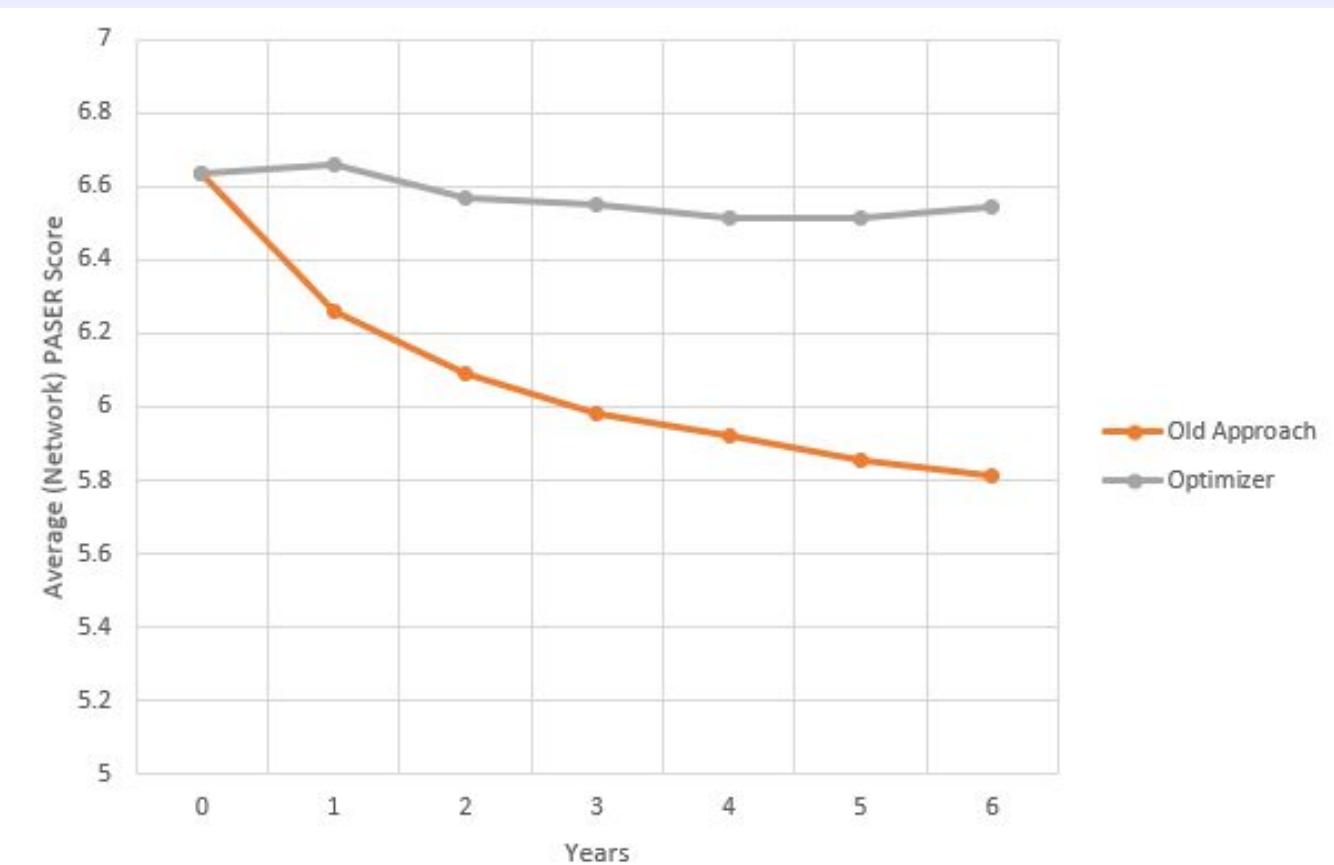
How Much Did Tuning Matter?



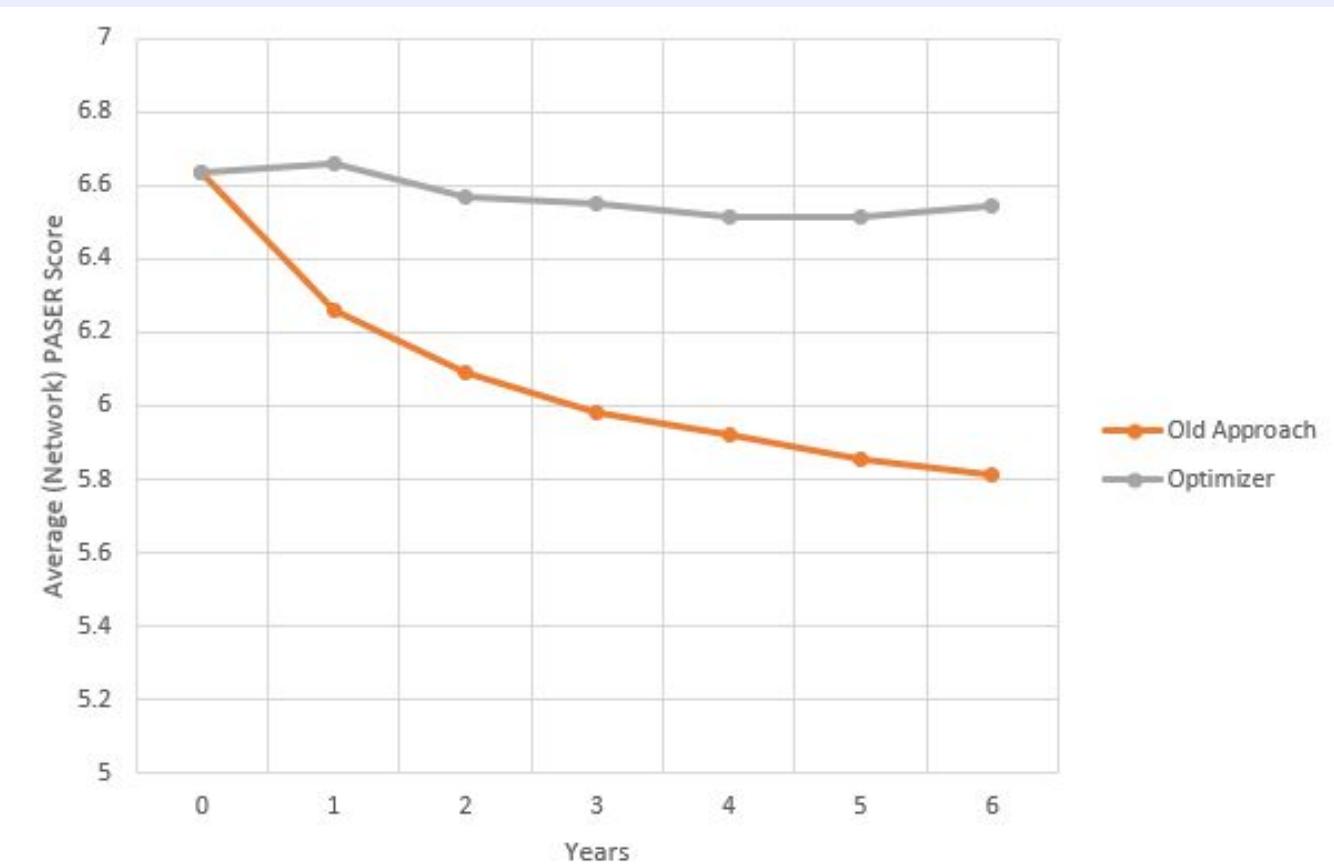
How Much Did Tuning Matter?



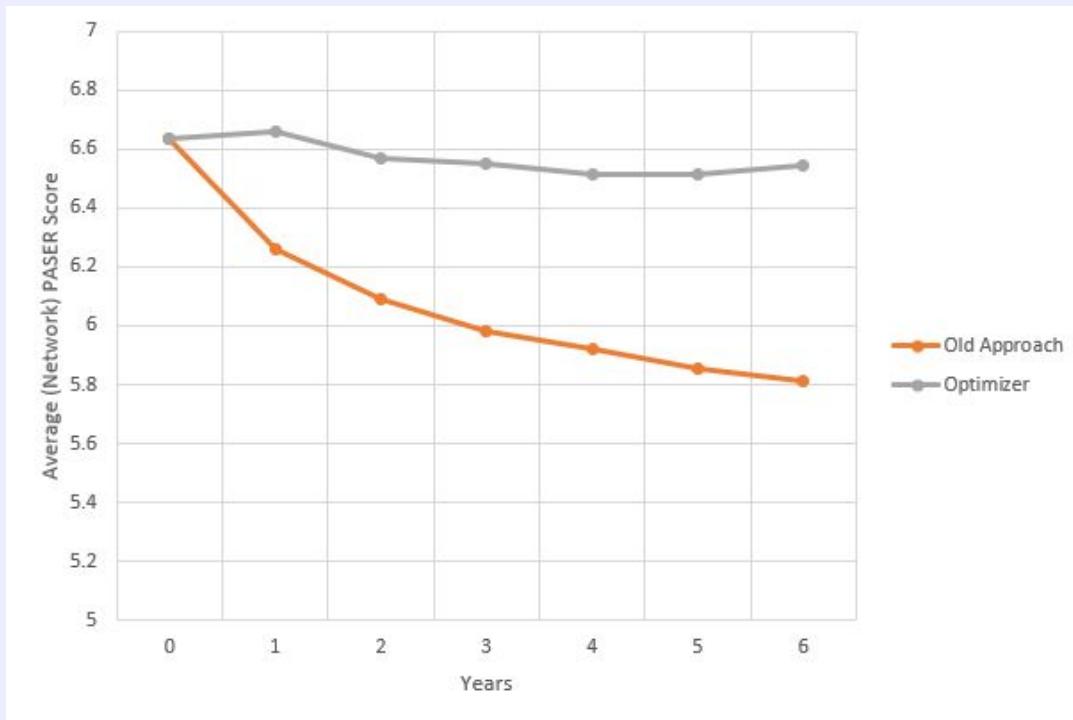
How Were The Solutions Over All?



How Do You Win Hearts and Minds?



The Maintenance Process Is Iterative, Not Comparative



The Users Iterated in Two Major Ways

- Don't do this part, and use the money on something else
- Do this, and find budget for it

The Users Iterated in Two Major Ways

- **Don't do this part, and use the money on something else**
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Roadway	From	To	Rating	2020 Treatment
1ST ST	Park Avenue	Cross Street	8	Mill and Overlay - 1.5"
1ST ST	Cross Street	Dead End	8	Mill and Overlay - 1.5"
2ND ST	Park Avenue	Cross Street	8	
2ND ST	Cross Street	Dead End	8	
A ST	North Main Street	Graham Road	6	
ACORN RD	Galaxy Drive	Fairlane Court	8	
ACORN RD	Fairlane Court	Cobra Drive	4	
ACORN RD	Cobra Drive	Torino Lane	5	Mill and Overlay - 1.5"
ACORN RD	Torino Lane	Taurus Lane	5	
ACORN RD	Taurus Lane	Ebony Lane	7	

The Users Iterated in Two Major Ways

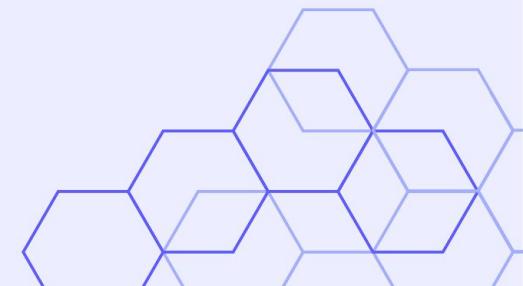
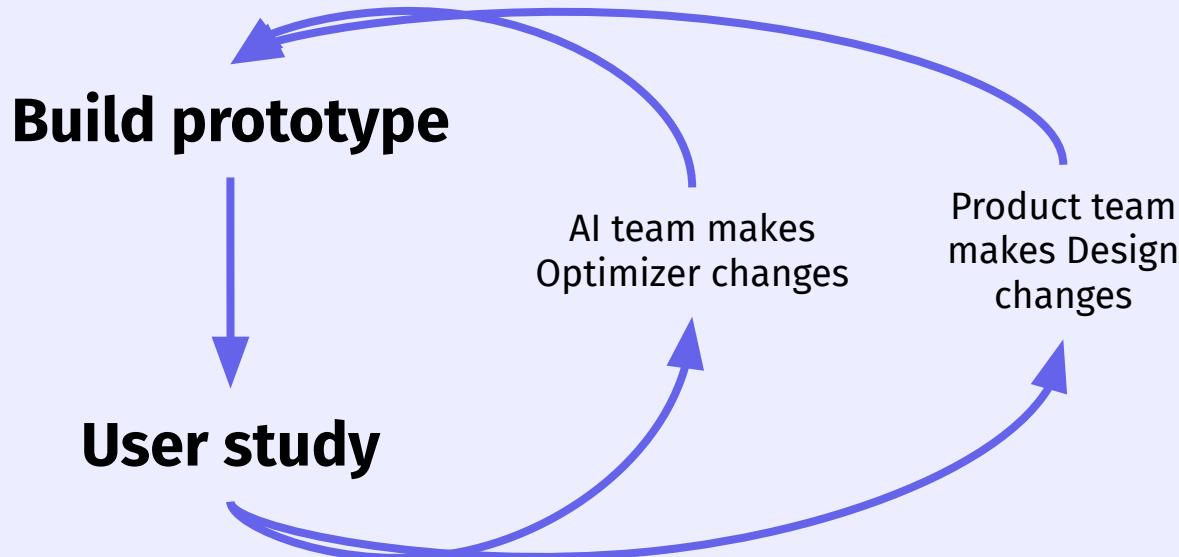
- Don't do this part, and use the money on something else
- **Do this, and find budget for it**

Roadway	From	To	Rating	2020 Treatment
1ST ST	Park Avenue	Cross Street	8	Mill and Overlay - 1.5"
1ST ST	Cross Street	Dead End	8	Mill and Overlay - 1.5"
2ND ST	Park Avenue	Cross Street	8	
2ND ST	Cross Street	Dead End	8	

Roadway	From	To	Rating	2020 Treatment
1ST ST	Park Avenue	Cross Street	8	Mill and Overlay - 1.5"
1ST ST	Cross Street	Dead End	8	Mill and Overlay - 1.5"
2ND ST	Park Avenue	Cross Street	8	Chip Seal
2ND ST	Cross Street	Dead End	8	Chip Seal - Triple

The Development Process Is Iterative Too!

@DrBass



The Development Process Is Iterative Too!

Google search results for "build measure learn loop":

Search bar: build measure learn loop

Filter: All, Images

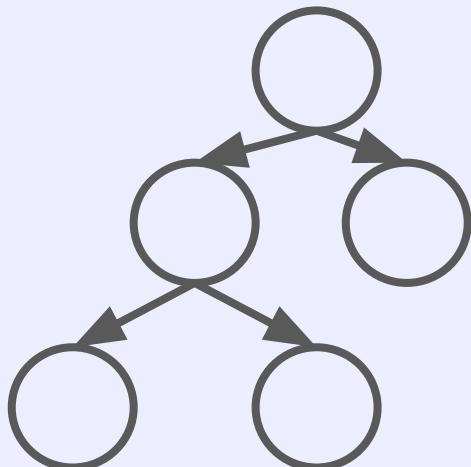
Tools: SafeSearch

Results:

- Microsoft Learn**: The build-measure-learn feedback loop ...
- Medium**: Build, Measure, Learn cycle ...
- Amplitude**: Product Management Lifecycle Loop ...
- Steve Blank**: Why Build, Measure, Learn ...
- YouTube**: The Build-Measure-Learn Feedback Loop ...
- Marmelab**: Lean Startup, day 10: Build-Measure-Learn ...
- Sameologic**: Build, Measure, Learn with Lean ...
- Kromatic**: Build Measure Learn - Why The Lean ...
- Inside Product**: Build Measure Learn
- thrv.com**: Build-Measure-Learn Feedback Loop
- Praxie**: Build-Measure-Learn Feedback Loop
- Visualise Solutions**: Why the B-M-L Loop of Lean Startup is ...
- Steve Blank**: Why Build, Measure, Learn ...
- Lean East**: Lean Startup Thinking - Lean East
- Bento and Beyond**: Validated Learning Loop
- How the Build Measure Learn Cycle**:
- A more accurate depiction of the Build-Measure-Learn loop**:
- There's much more...**:
- Build**:
- LEARN**:

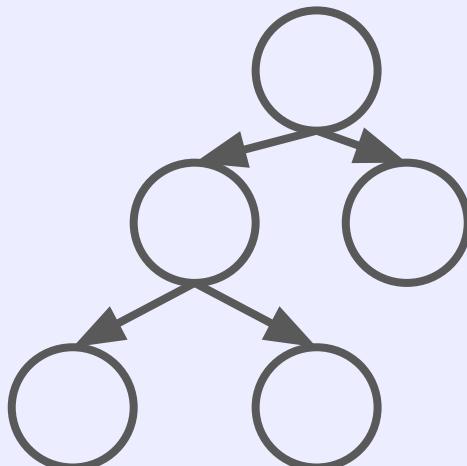
If I Knew Then What I Know Now

- Don't do this part, and use the money on something else
- Do this, and find budget for it



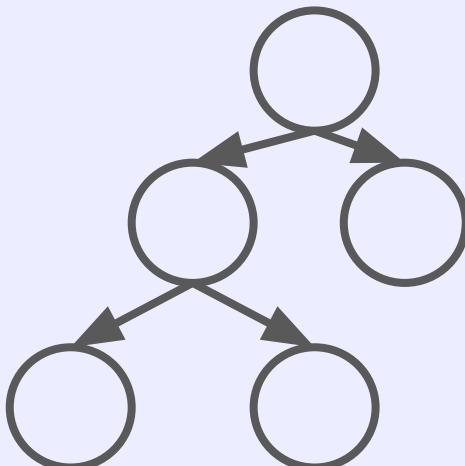
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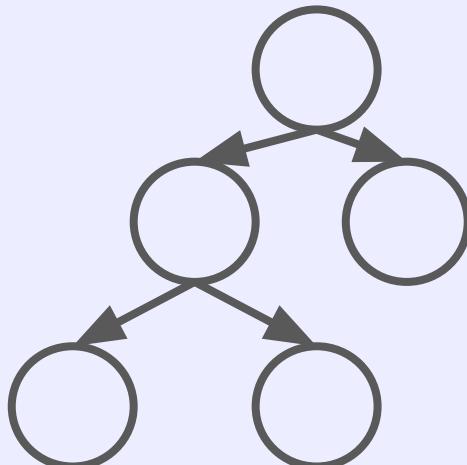
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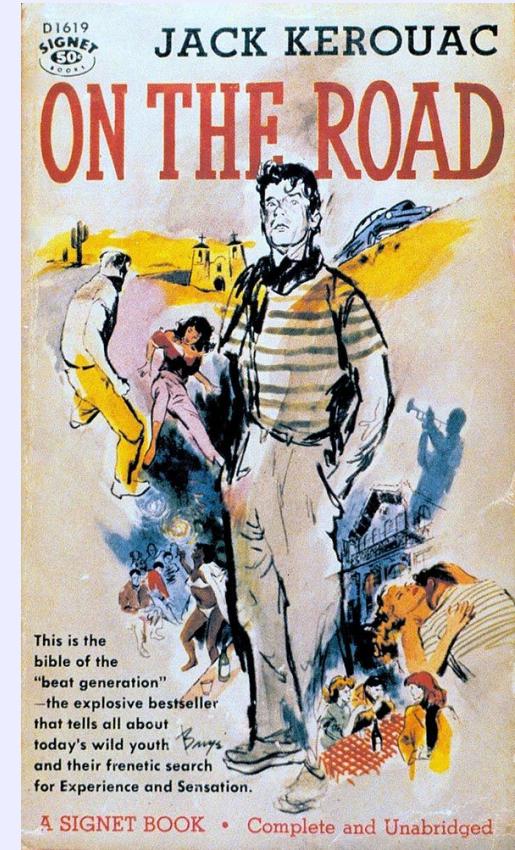
If I Knew Then What I Know Now

- Don't do this part, and use the money on something else
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The Road Ahead

- The Problem Domain
- Using AI for Planning
- Some Initial Roadblocks
 - Understanding the domain
 - Problematic Models
 - Performance Hurdles
- Meeting the users where they are
 - Understanding needs
 - Adapting the solver



Takeaways

- AI crops up in unexpected places
 - It can (and must) be built using the same sorts of agile techniques that are best practice everywhere
 - What users will accept is more important than finding the best solution
-
- Friday, 8:30 AM in Salon D
 - Can We Learn to Manage Uncertainty? Probably!
 - Robert Herbig, AI Practice Lead
 - Friday, 9:45 AM in Cypress
 - How to answer "When will it be done?" using probabilistic forecasting.
 - Chris Shinkle, Director of Innovation

