



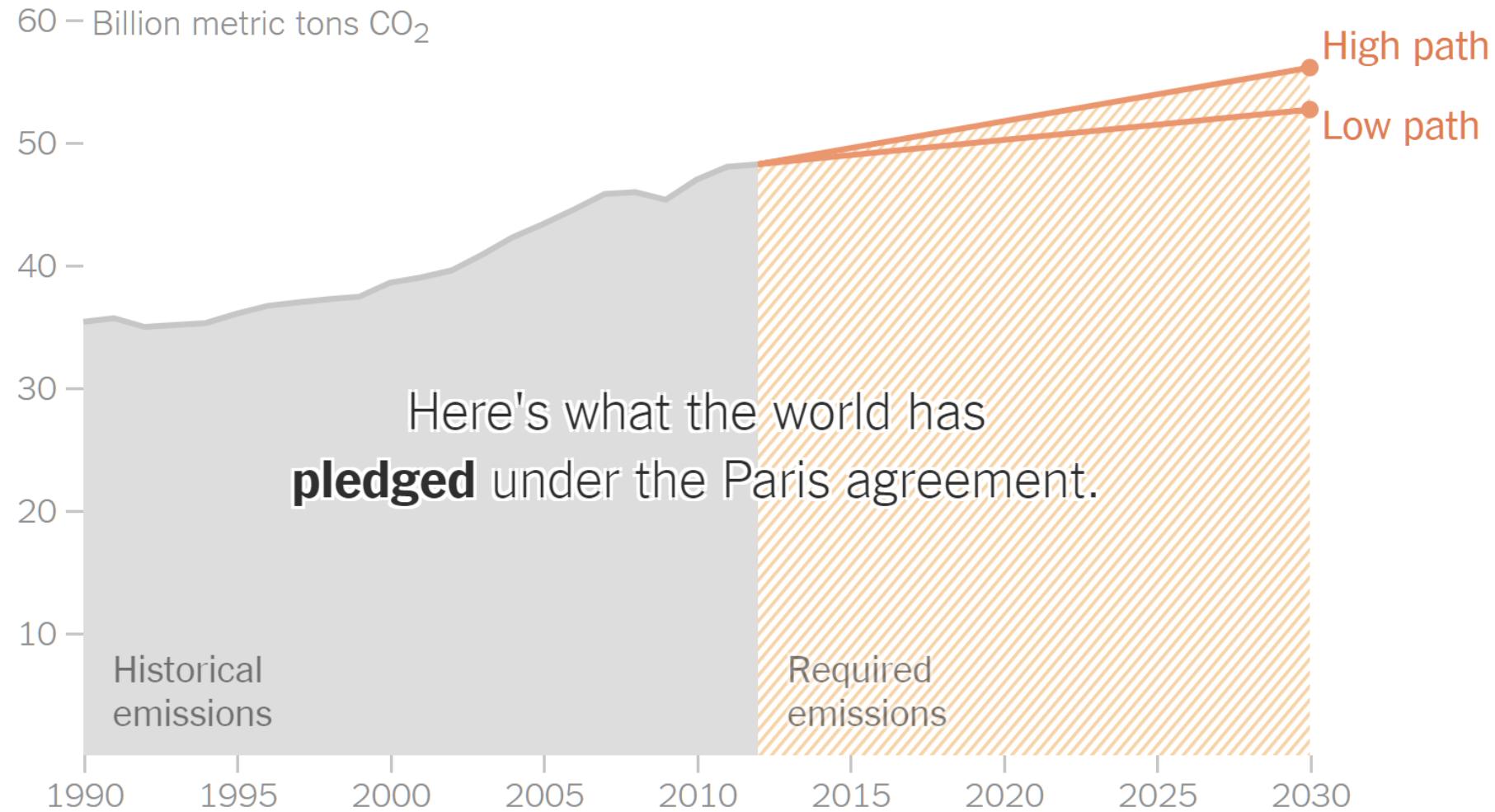
UNLOCKING FUSION ENERGY WITH

NEW TECHNOLOGIES

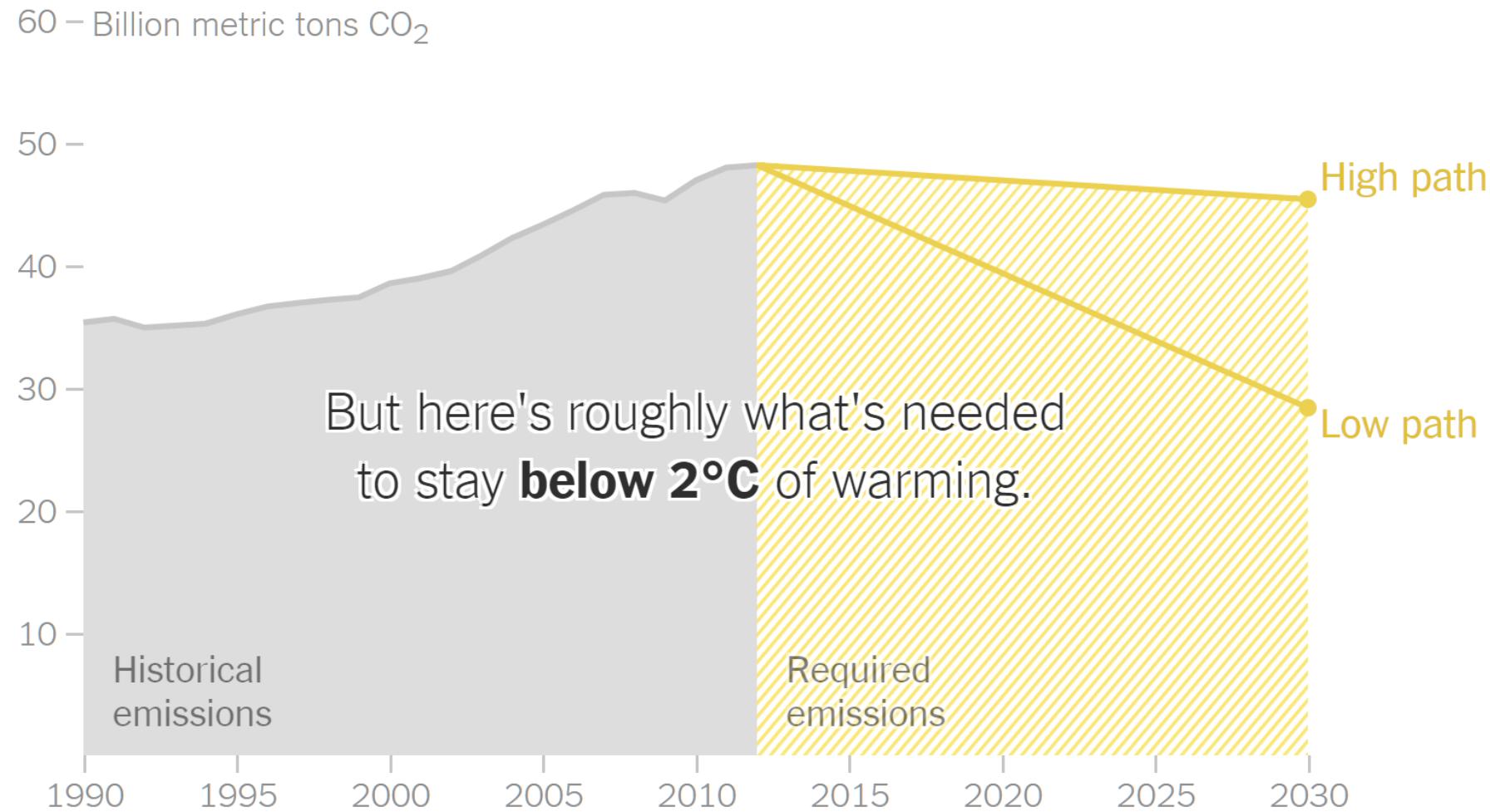
Jonathan Fraser

generalfusion®

Emissions continue to rise...



Emissions continue to rise...



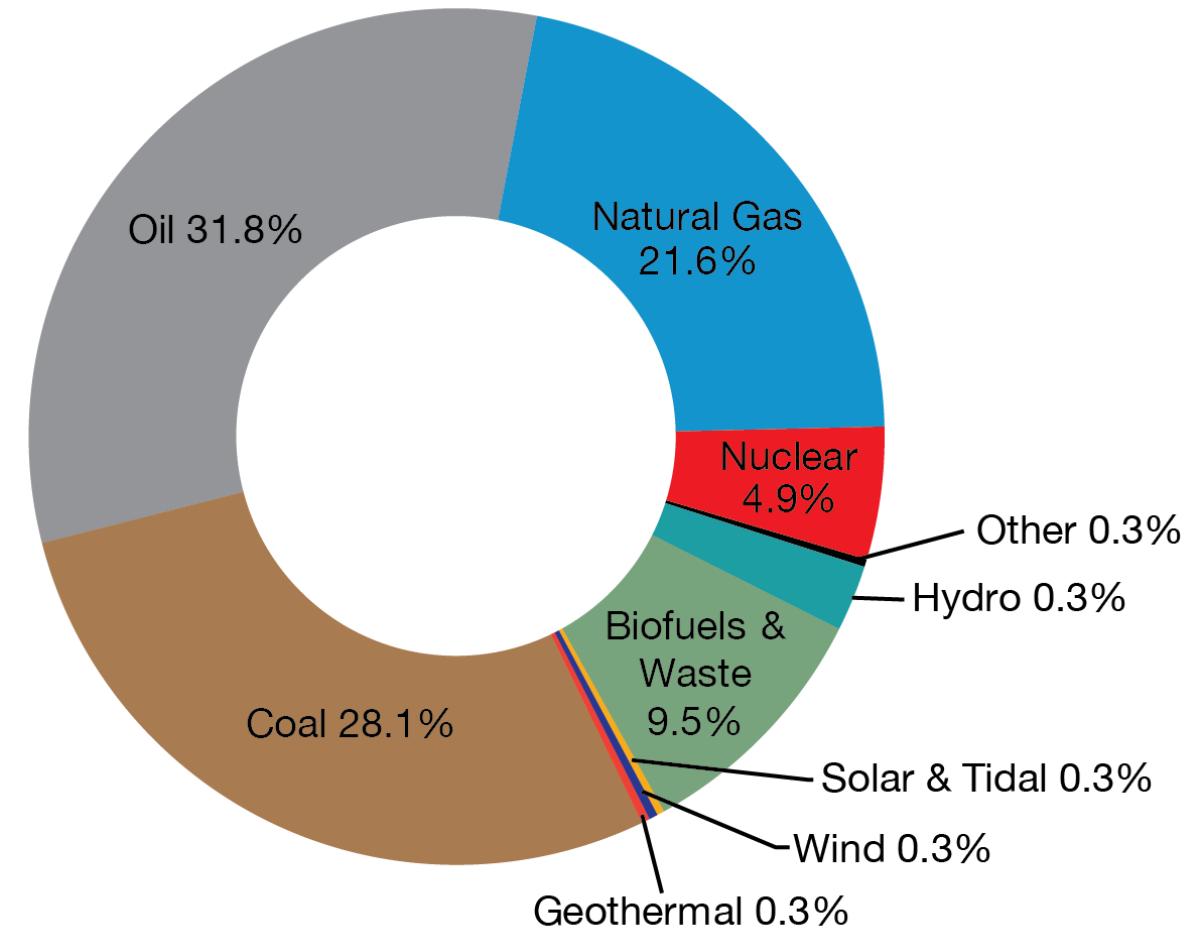
Why develop a new type of power plant?

Fuel shares in world total primary energy supply (2015)

80% of the world's energy still comes from fossil fuels.¹

Electricity is the world's fastest-growing form of end-use energy consumption.²

\$480 billion per year is invested in new power plants.³



Fusion is the future of energy...

Fossil Fuels



55,000 barrels of oil

and 23,500 tons of CO₂

Fusion Energy



... can be replaced by
1 liter of fusion fuel ...

(distilled from water)

Electricity



powering **10,000 homes** for 1 year

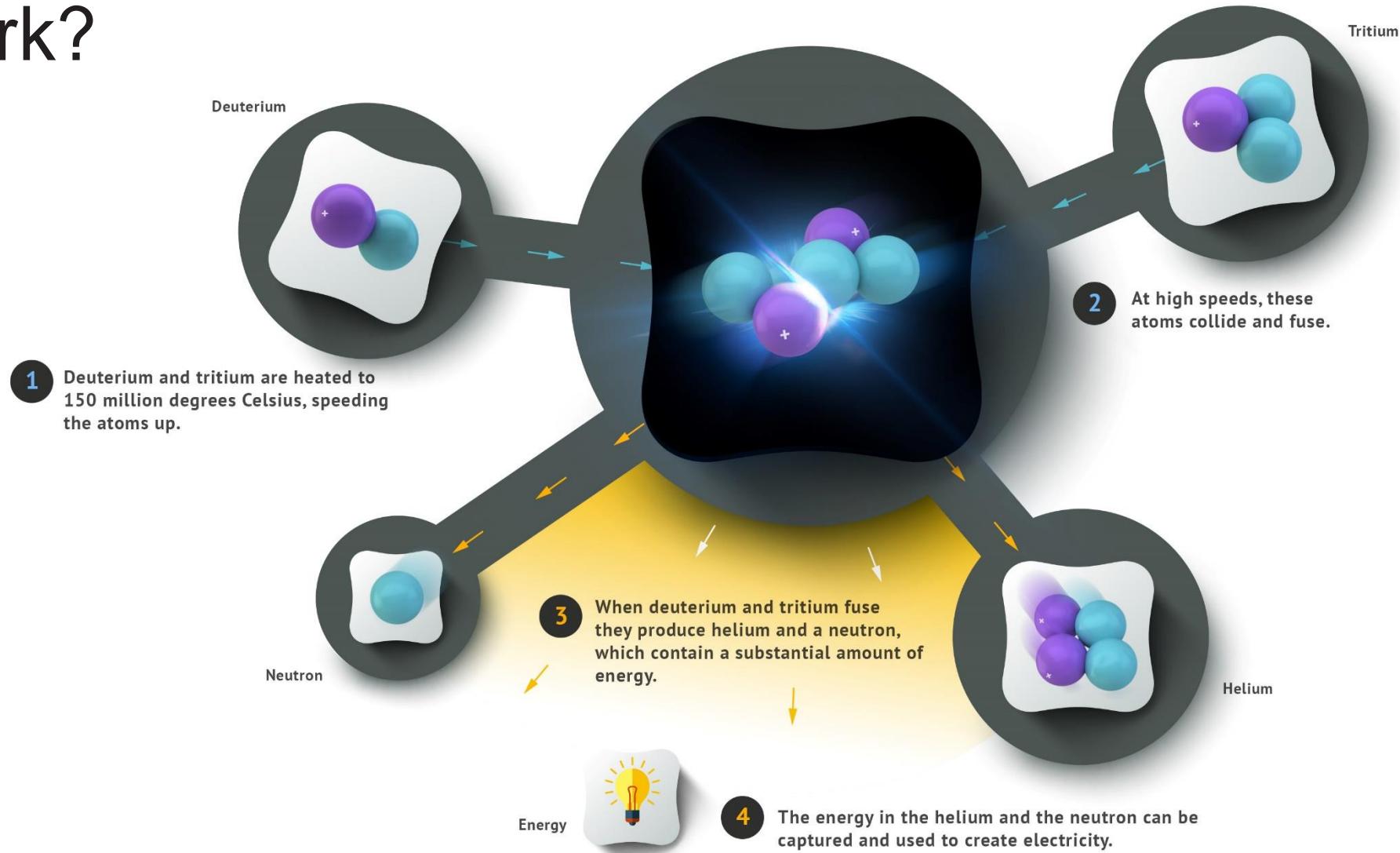
100,000 Megawatt-hours

Introduction to General Fusion

- Founded in 2002 by Michel Laberge
- Privately backed by investors including Jeff Bezos and Khazanah Nasional Berhad (Malaysian Sovereign Wealth Fund)
- 75+ employees, \$100M+ in funding
- Focused on building a practical, commercially viable fusion power plant



How does fusion work?

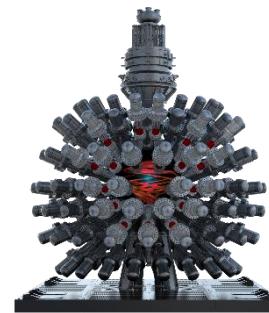




Approaches to fusion



**Magnetic
Confinement**



**Magnetized
Target Fusion**



**Inertial
Confinement**



All Confinement

Balanced

All Compression

Plasma confinement using
large magnetic coils

Combination of
compression and magnetic
confinement

Very fast compression using
high power lasers or ion
beams

Low density:

Medium density:

Extreme density:

$\sim 10^{14}$ ions/cm³

$\sim 10^{20}$ ions/cm³

$\sim 10^{26}$ ions/cm³

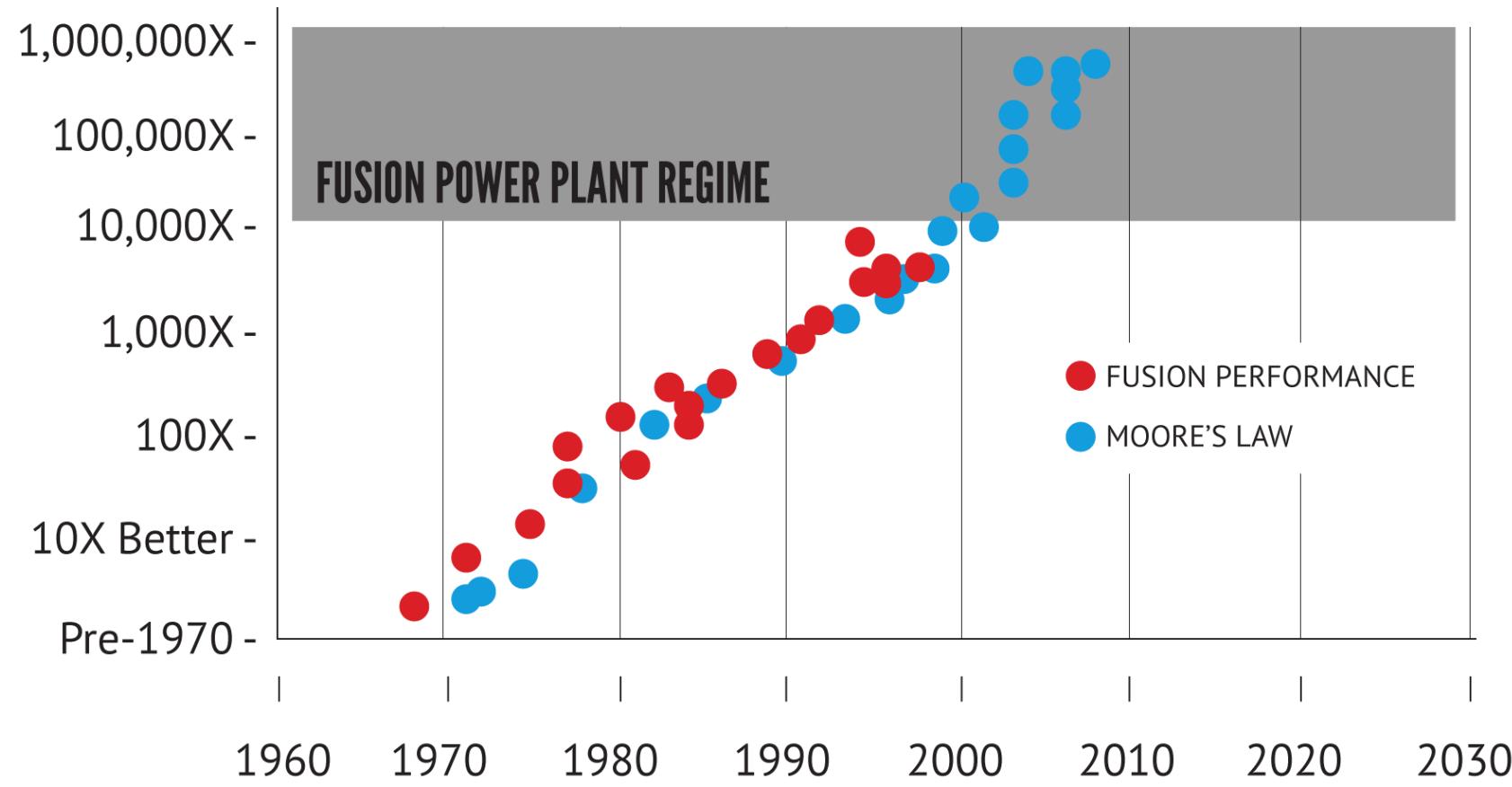
Continuous operation

Pulsed: ~10 µs

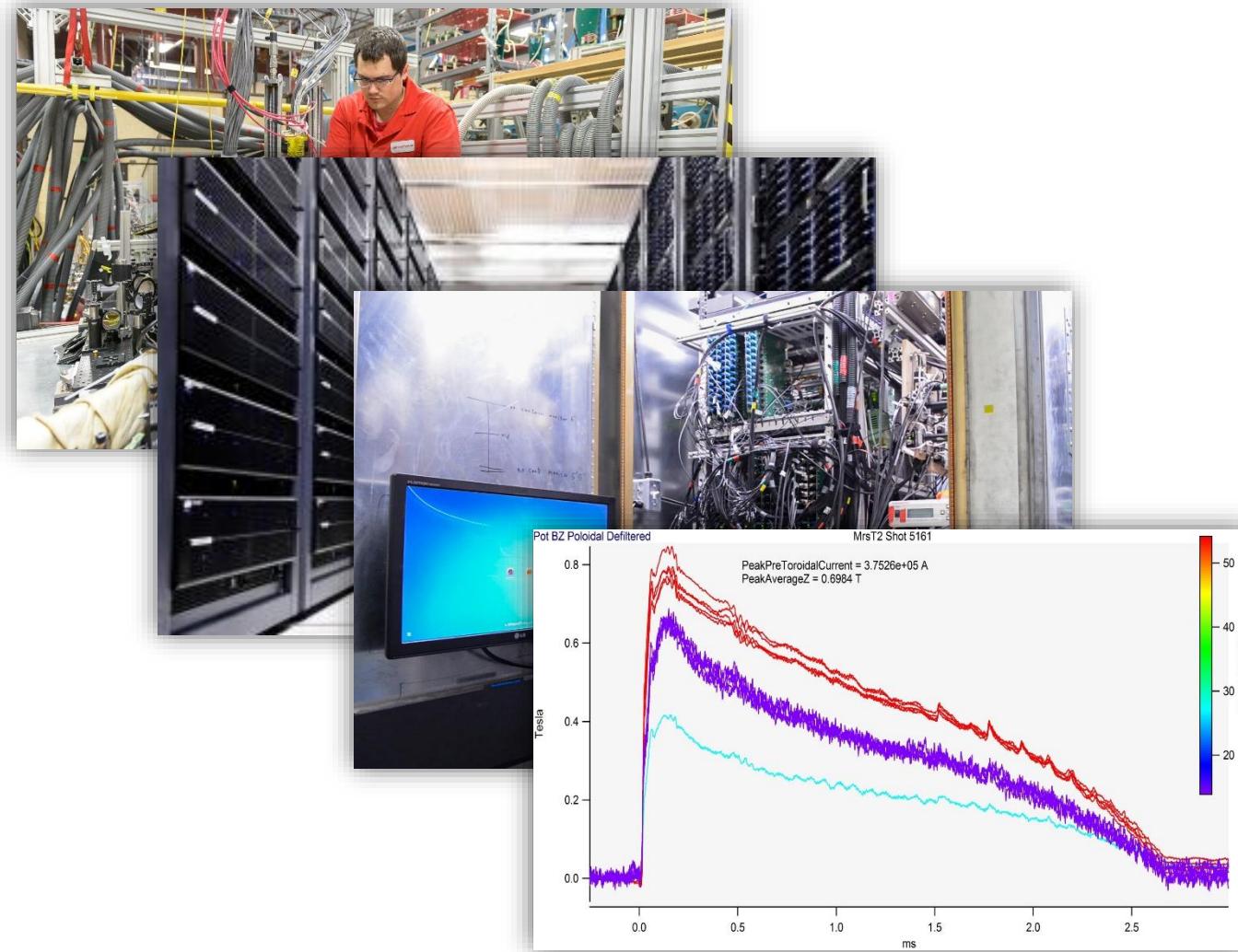
Pulsed: <1 ns

[Watch Video](#)

So why the heck am I here?



So why does it track so well?



- Large volumes of Data
- Simulation Requires Compute
- Control System Complexity & Performance
- Sharing & Collaboration

Big(ish) Data

Each shot generates ~1 GB of data

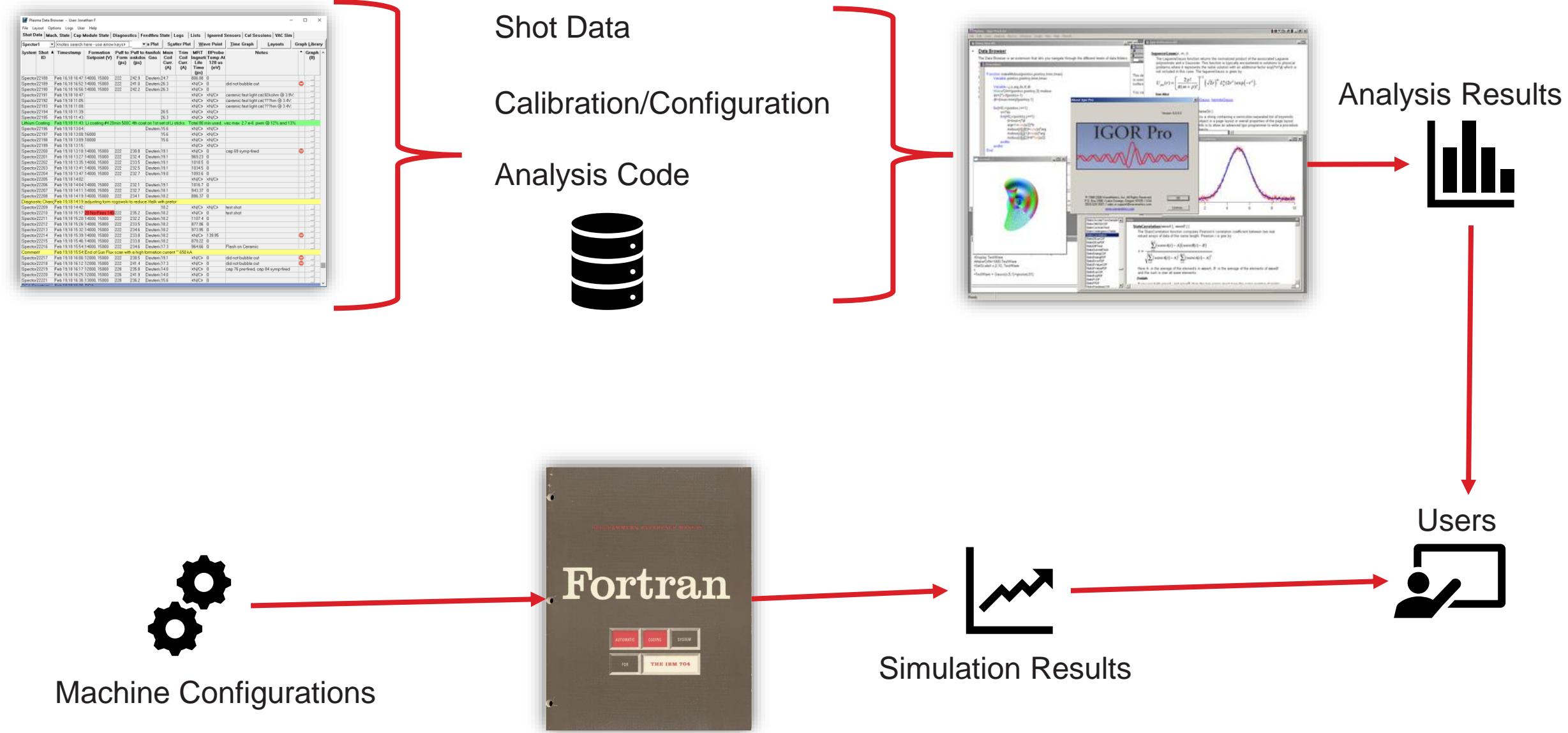
General Fusion has conducted >150,000 plasma shots to date

3D plasma simulations take 3 weeks to run....on a 128 CPU AWS cluster

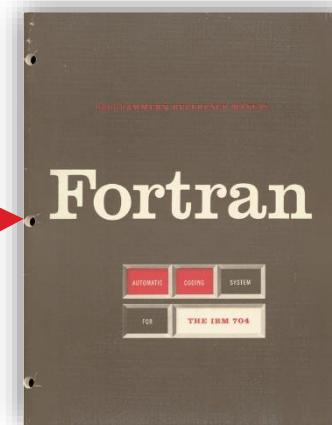
15 microseconds / day



Current State of the Art



Machine Configurations



Simulation Results



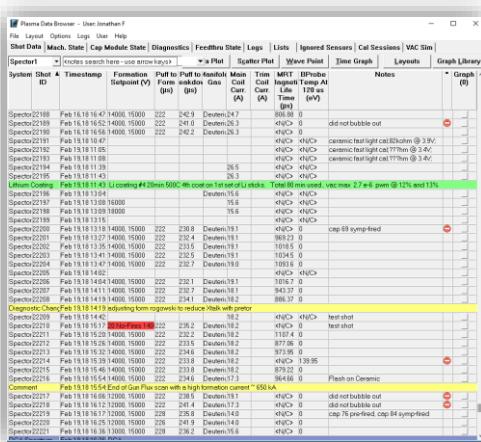
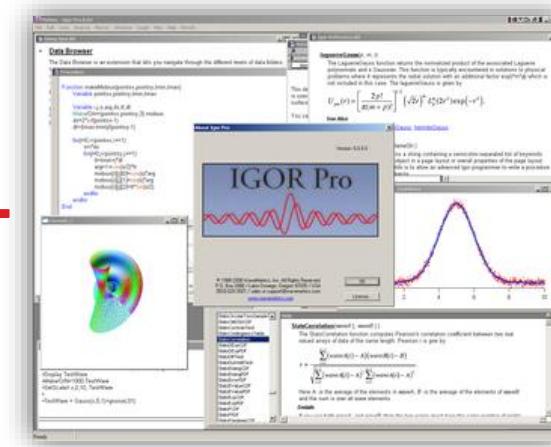
Analysis Results



Shot Data

Calibration/Configuration

Analysis Code

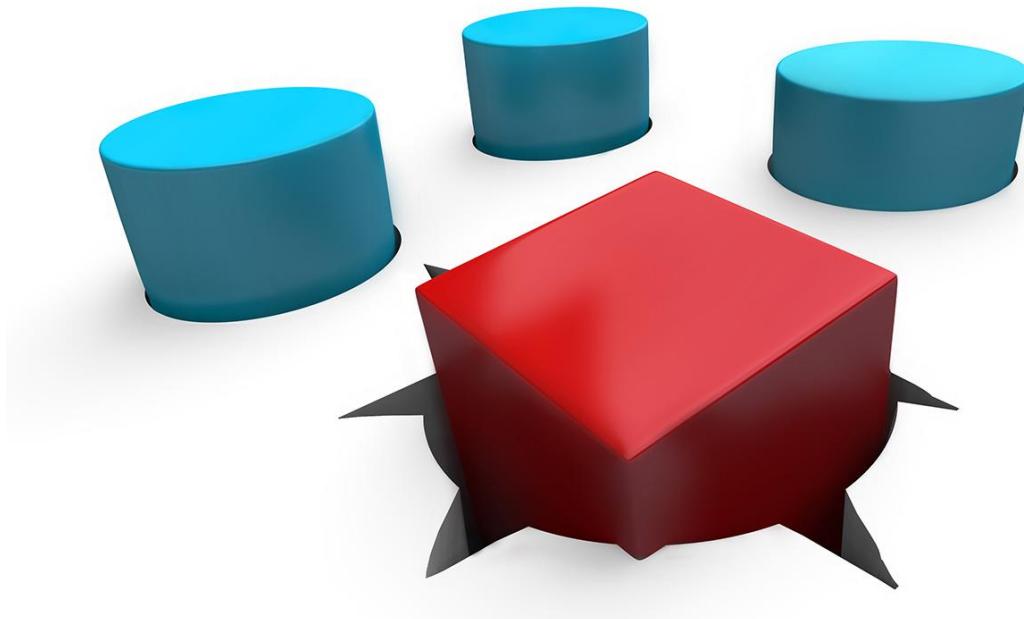


Sounds like a job for



right?

- Data shape is awkward



Sounds like a job for



right?

- Data shape is awkward
- Types of analysis

MHD in flux conservative form

$$\partial_t \rho + \nabla \cdot (\rho \mathbf{v}) = 0$$

$$\partial_t(\rho \mathbf{v}) + \nabla \cdot \left[\rho \mathbf{v} \otimes \mathbf{v} + \left(P + \frac{1}{8\pi} \mathbf{B}^2 \right) \mathbf{I} - \frac{1}{4\pi} \mathbf{B} \otimes \mathbf{B} \right] = 0$$

$$\partial_t \mathbf{B} + \nabla \cdot \left[\mathbf{v} \otimes \mathbf{B} - \mathbf{B} \otimes \mathbf{v} \right] = 0$$

$$\partial_t(\rho E) + \nabla \cdot \left[\left(\rho E + P + \frac{\mathbf{B}^2}{8\pi} \right) \mathbf{v} - \frac{1}{4\pi} (\mathbf{v} \cdot \mathbf{B}) \mathbf{B} \right] = 0$$

Sounds like a job for



right?

- Data shape is awkward
- Types of analysis
- Record size



Sounds like a job for



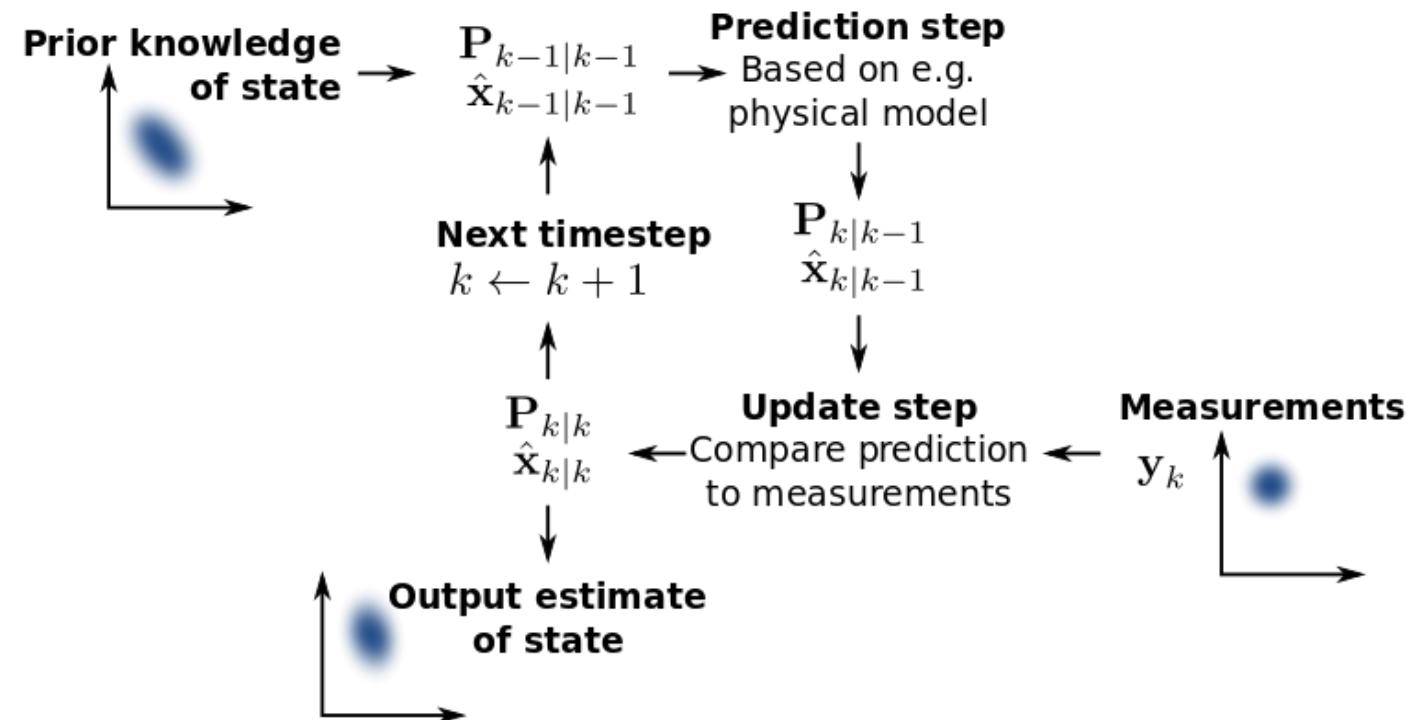
right?

- Data shape is awkward
- Types of analysis
- Record size
- We slice the data horizontally and vertically.**

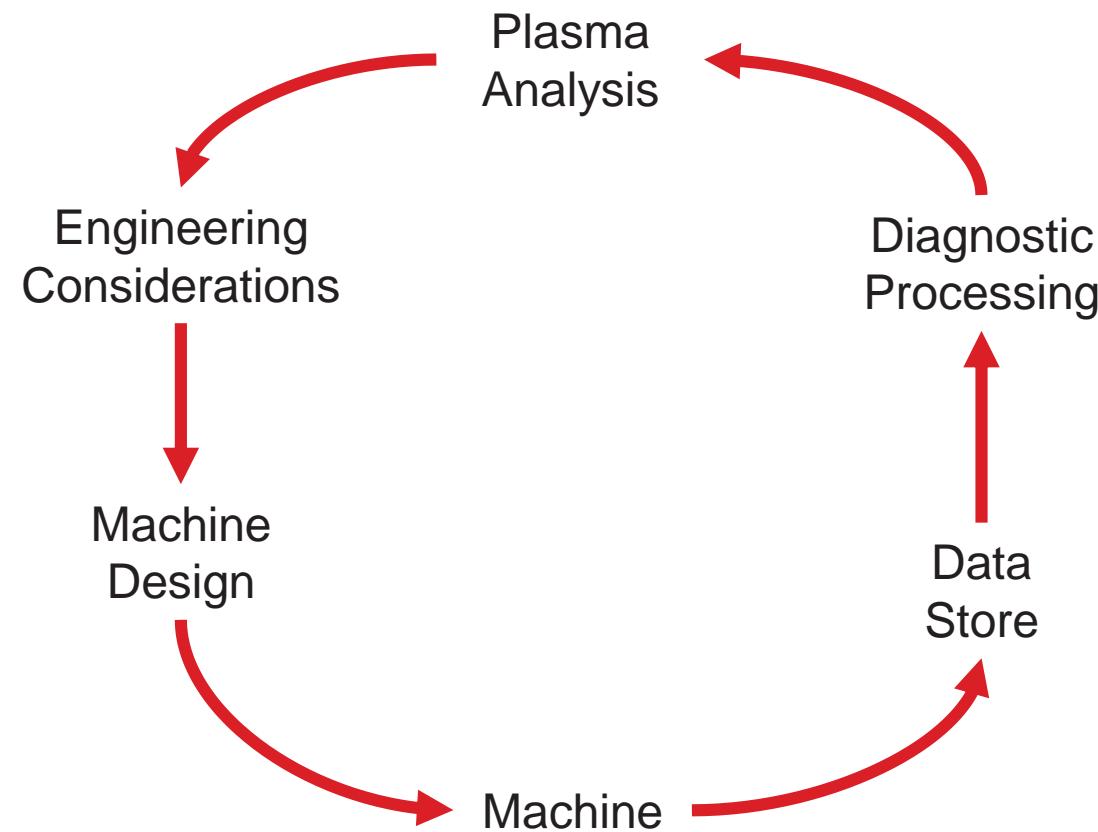


Sounds like a job for  right?

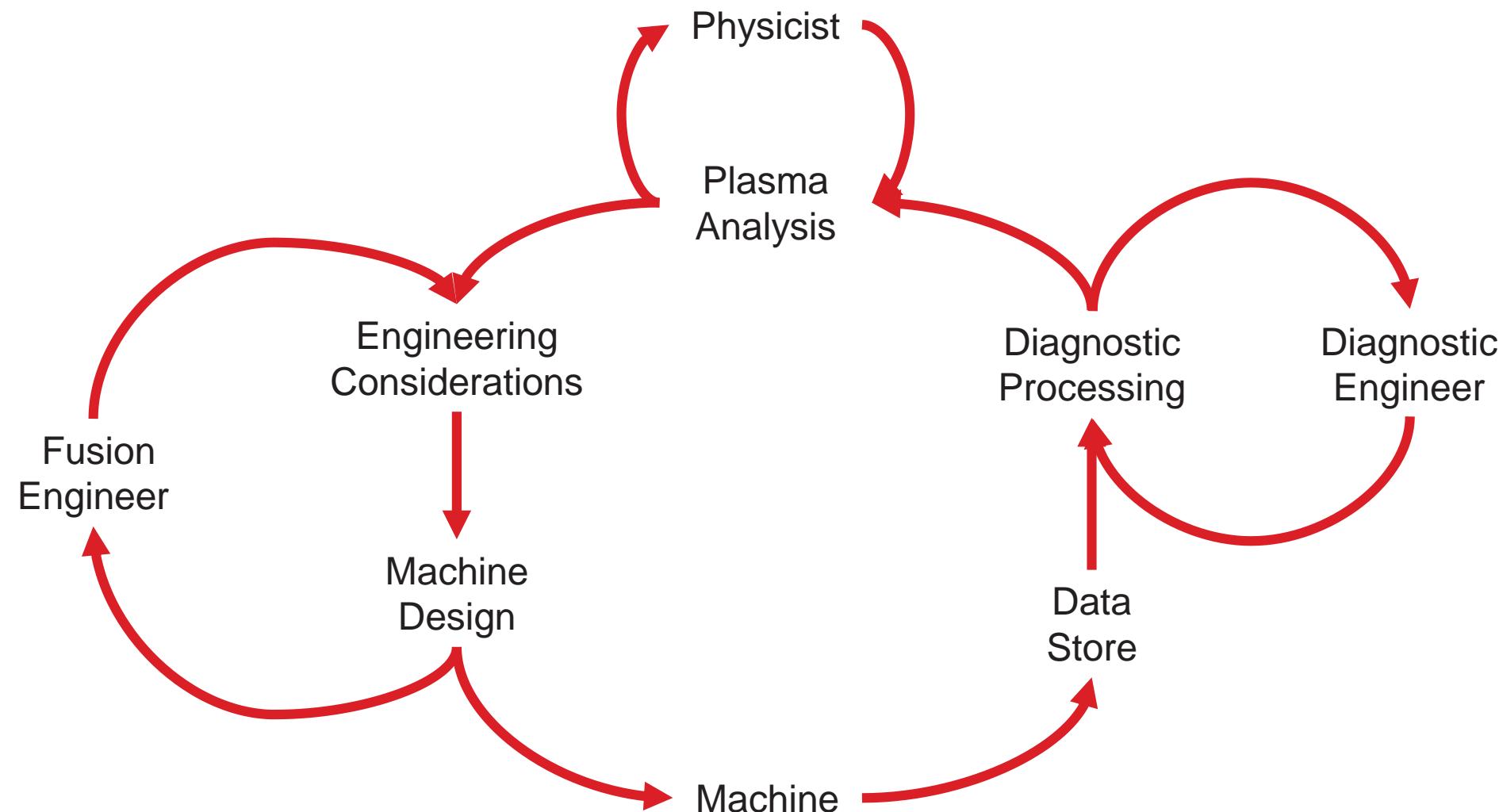
- Data shape is awkward
- Types of analysis
- Record size
- We slice the data horizontally and vertically.
- Data flow



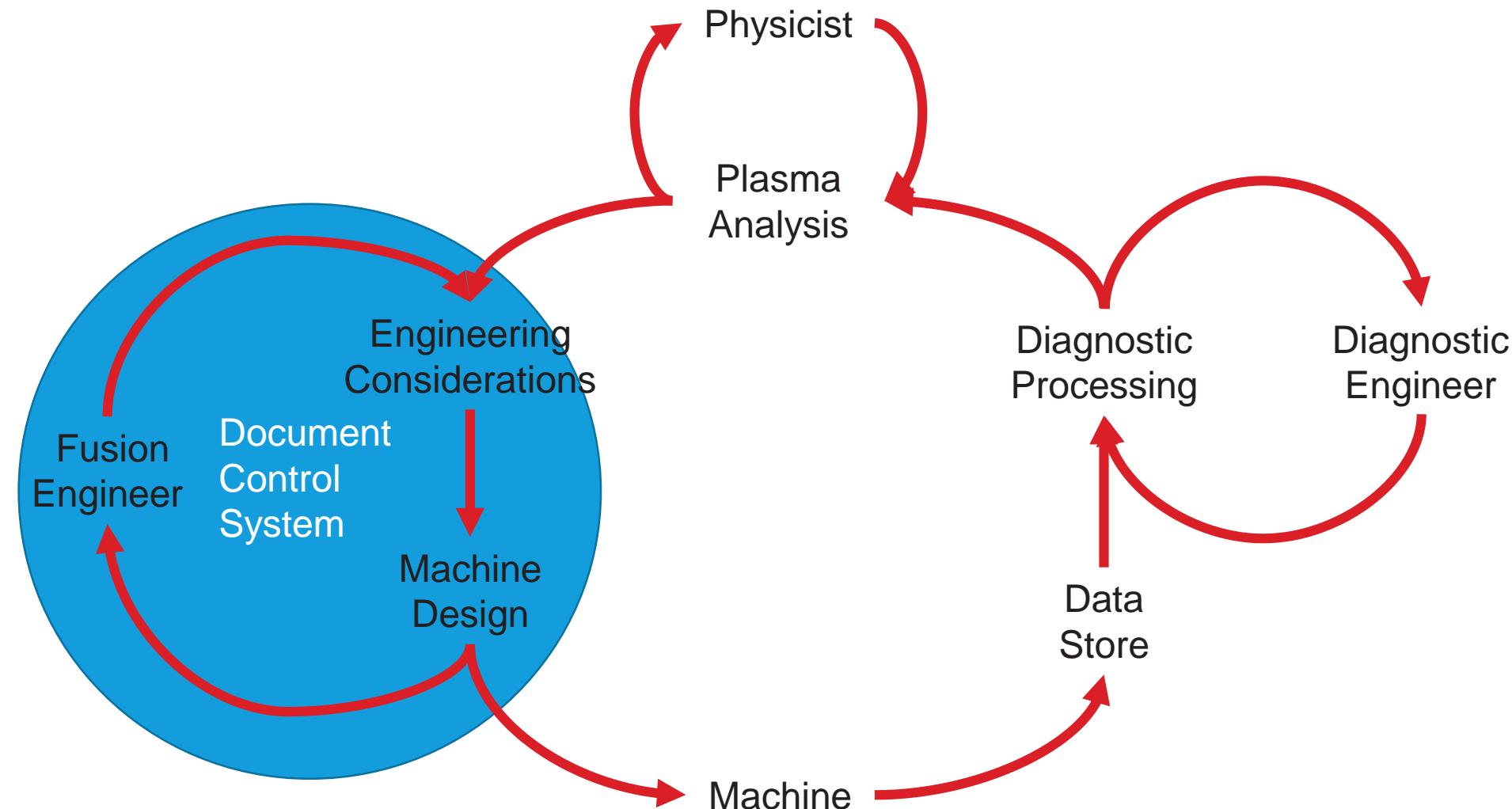
Data Flow is not Hadoop like



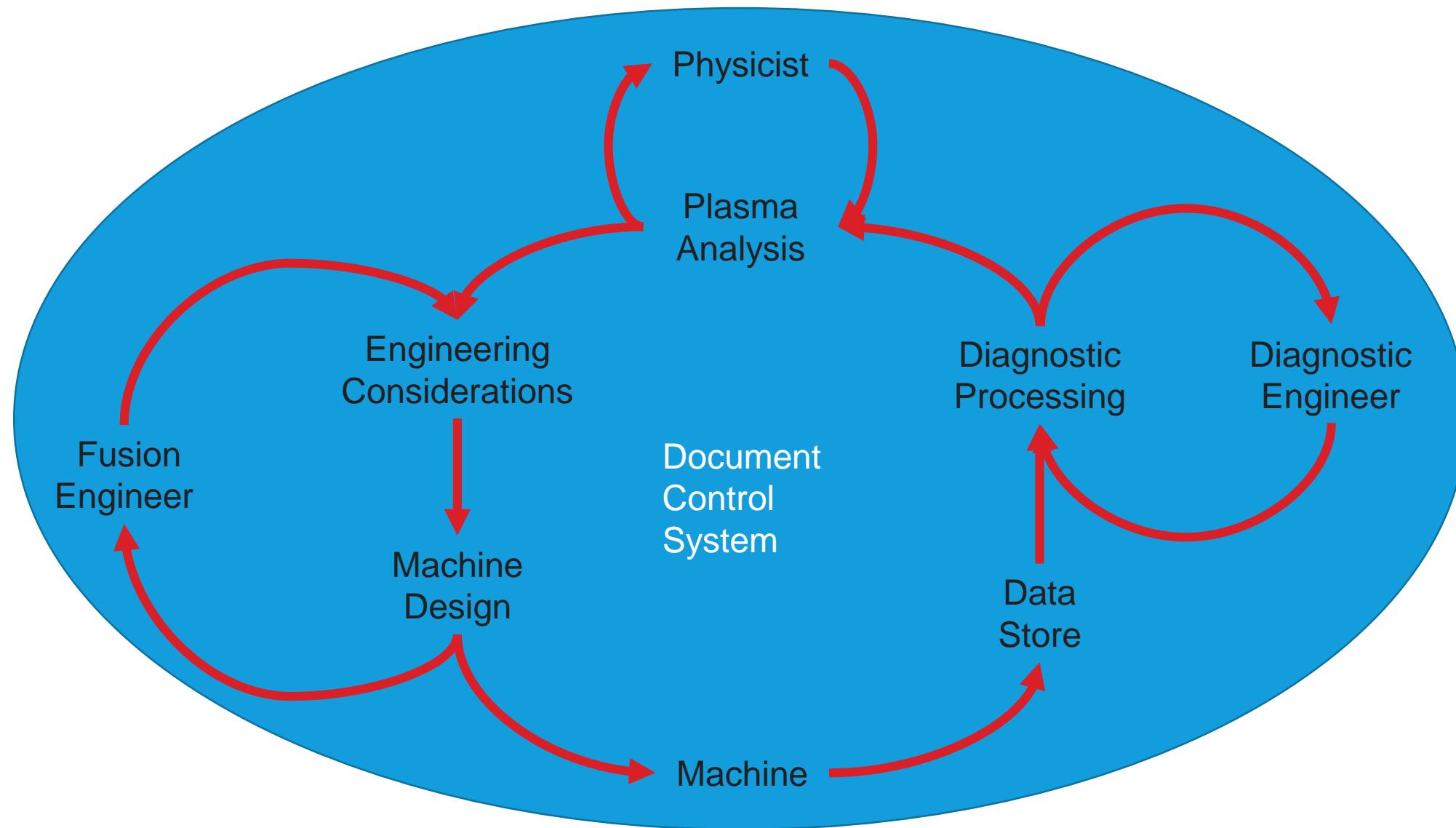
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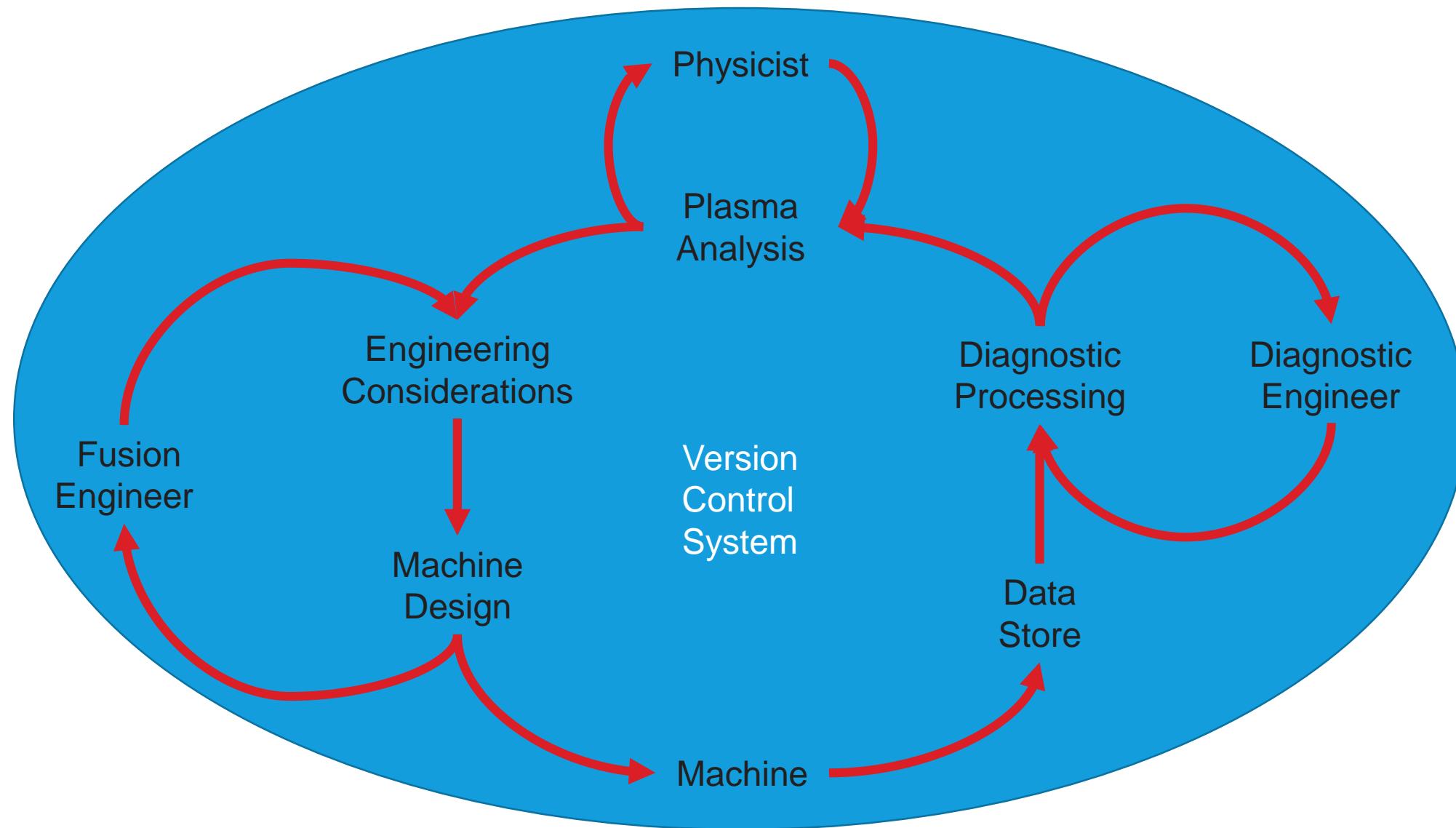
Data Flow is not Hadoop like



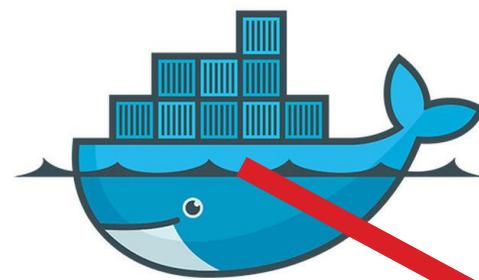
Data Flow is not Hadoop like



Data Flow is not Hadoop like



What's in the toolbox?



docker



kubernetes

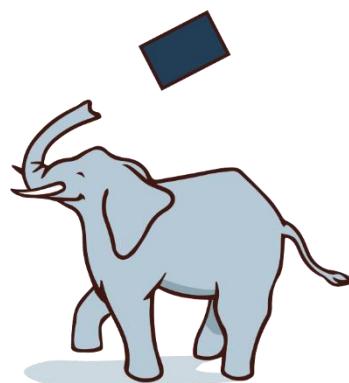


There are technologies out there



- Extension to regular git
- Makes heavy abuse of smudge and clean to version your data
- Extension is backed by the large git hosting providers

Git LFS

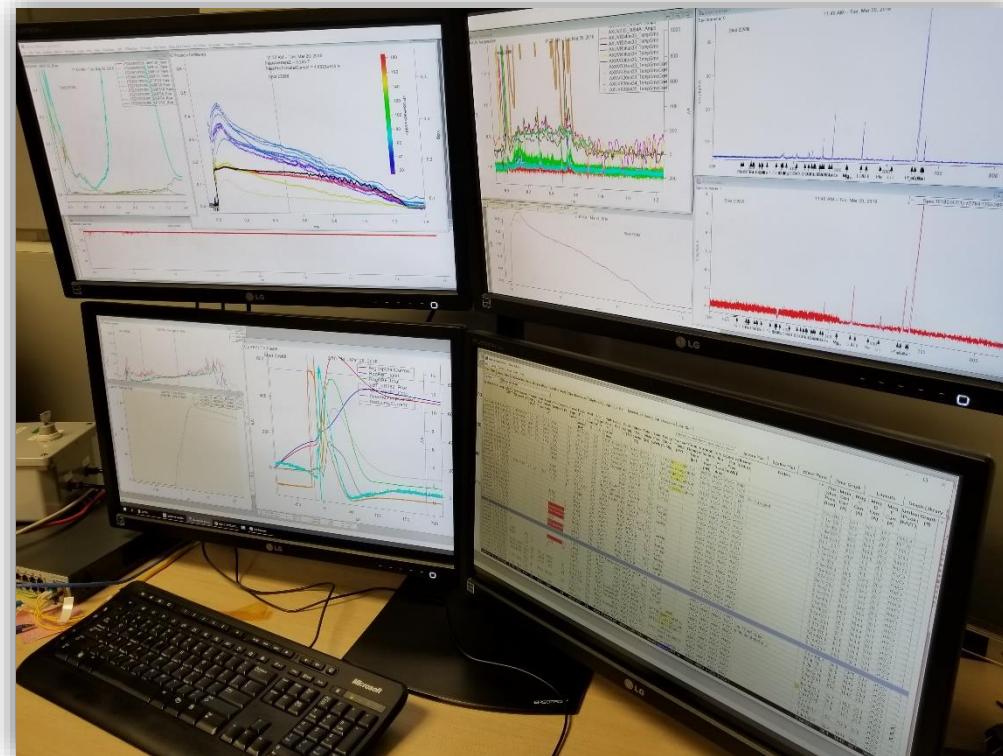


- Styles itself as a Git for data
- Uses Kubernetes as a execution cluster
- Enables incremental reprocessing and version control
- Collaboration with Microsoft to deploy on to Azure

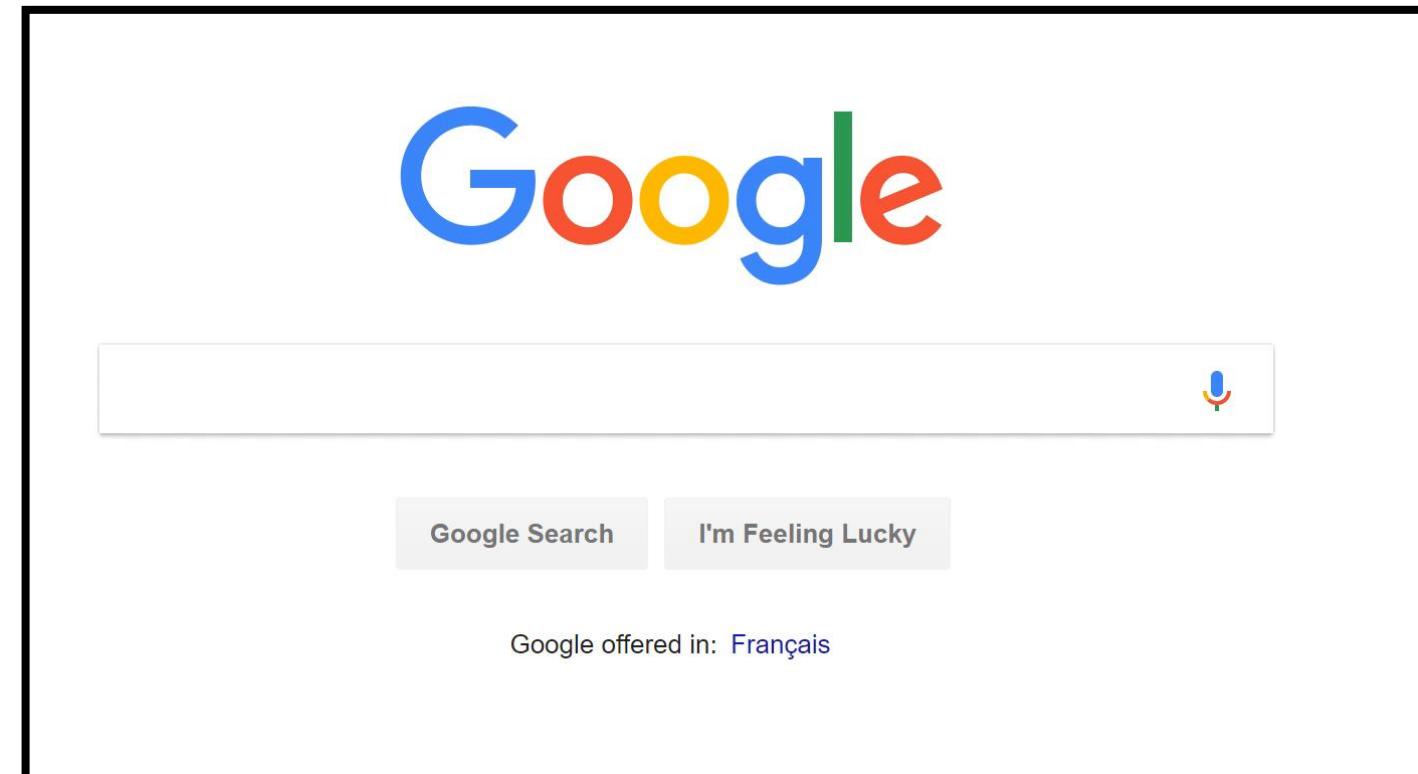
Pachyderm

There are still unanswered questions

How do you even display all that data



Not everyone is a programmer.
High level users require high level interfaces.



Google offered in: [Français](#)



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