Annual Symposium: AI Accelerated Physics Based Modelling and its Role in Energy Industry
August 22, 2024

Overview of Hybrid Simulation and Data Science Models

NOV - Corporate Engineering Analysis & Data

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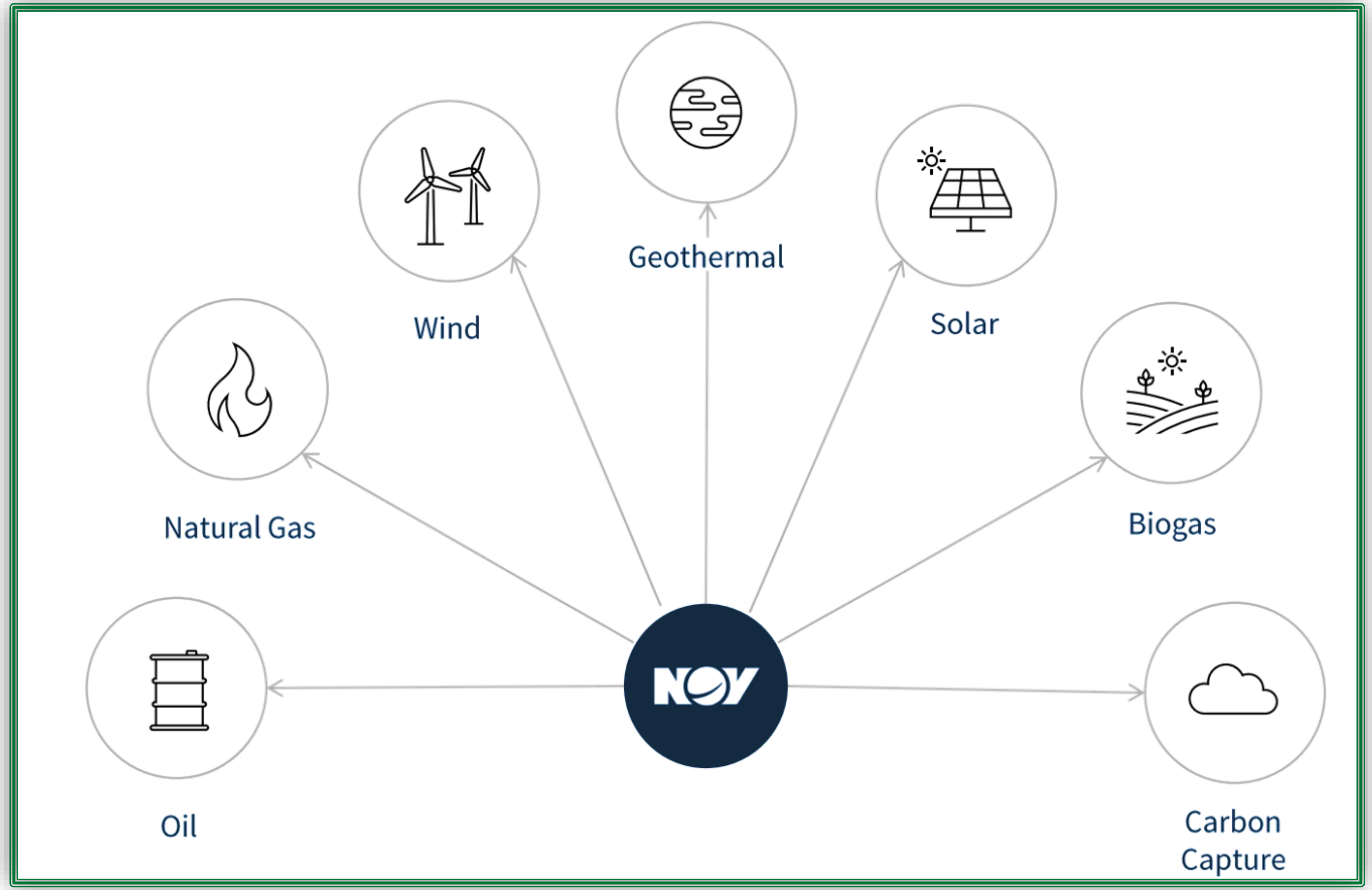
Overview – NOV



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Blender Pump: Digital Twin

- Hybrid Pump Degradation model
- Solid Concentration model

Role of Simulation
- Adding physics
- Virtual sensors
- Online Insight

Challenges
- Integrating different systems
- Validation of the simulations

Limitations
- Simulations are not feasible for some of the complex process

Fracking (Hydraulic Fracturing): injecting high-pressure fluid - solids into formations to create fractures to increase production

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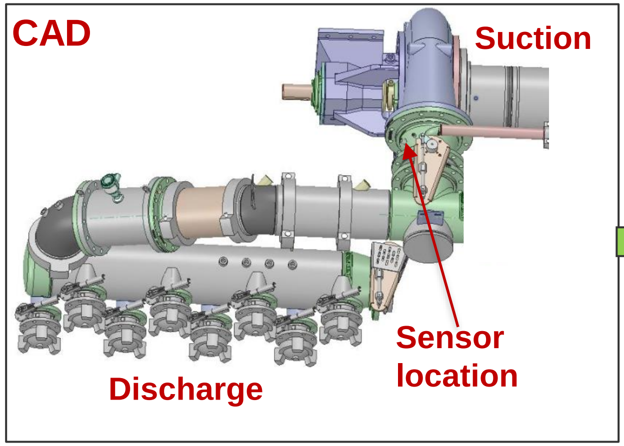
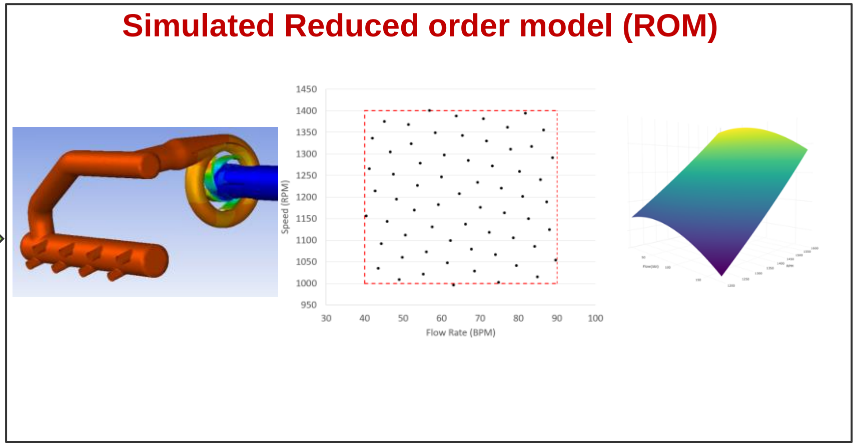
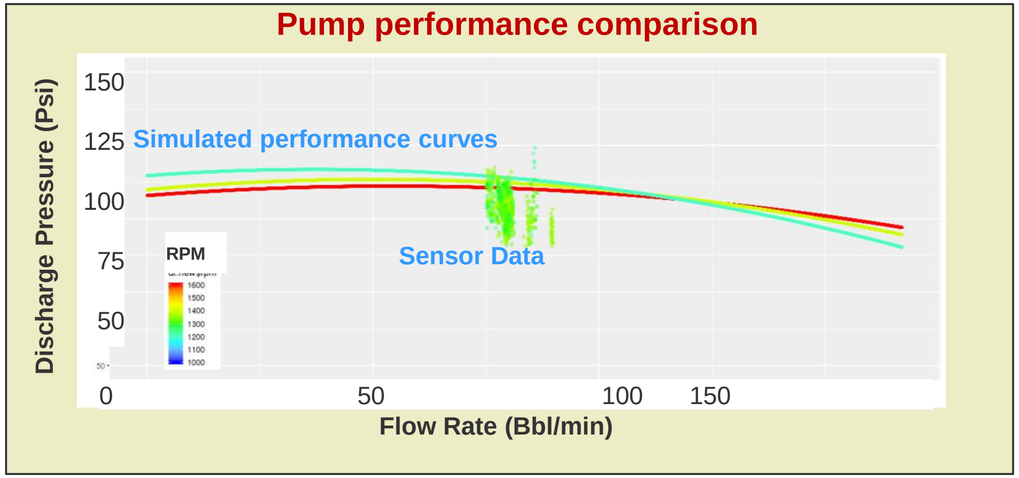
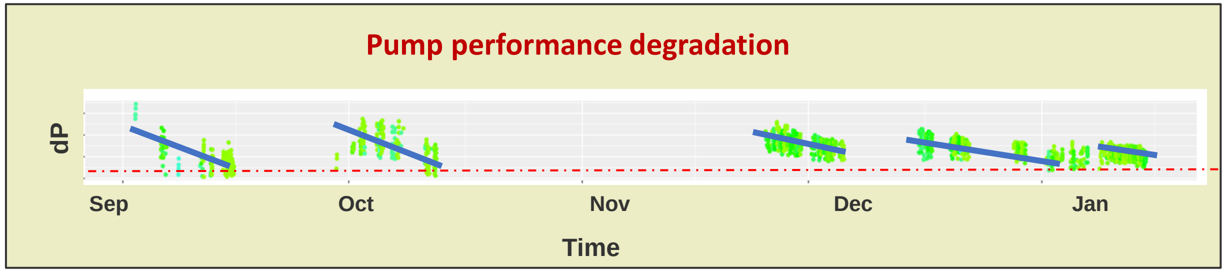
Simulation based Digital Twin : Blender Pump

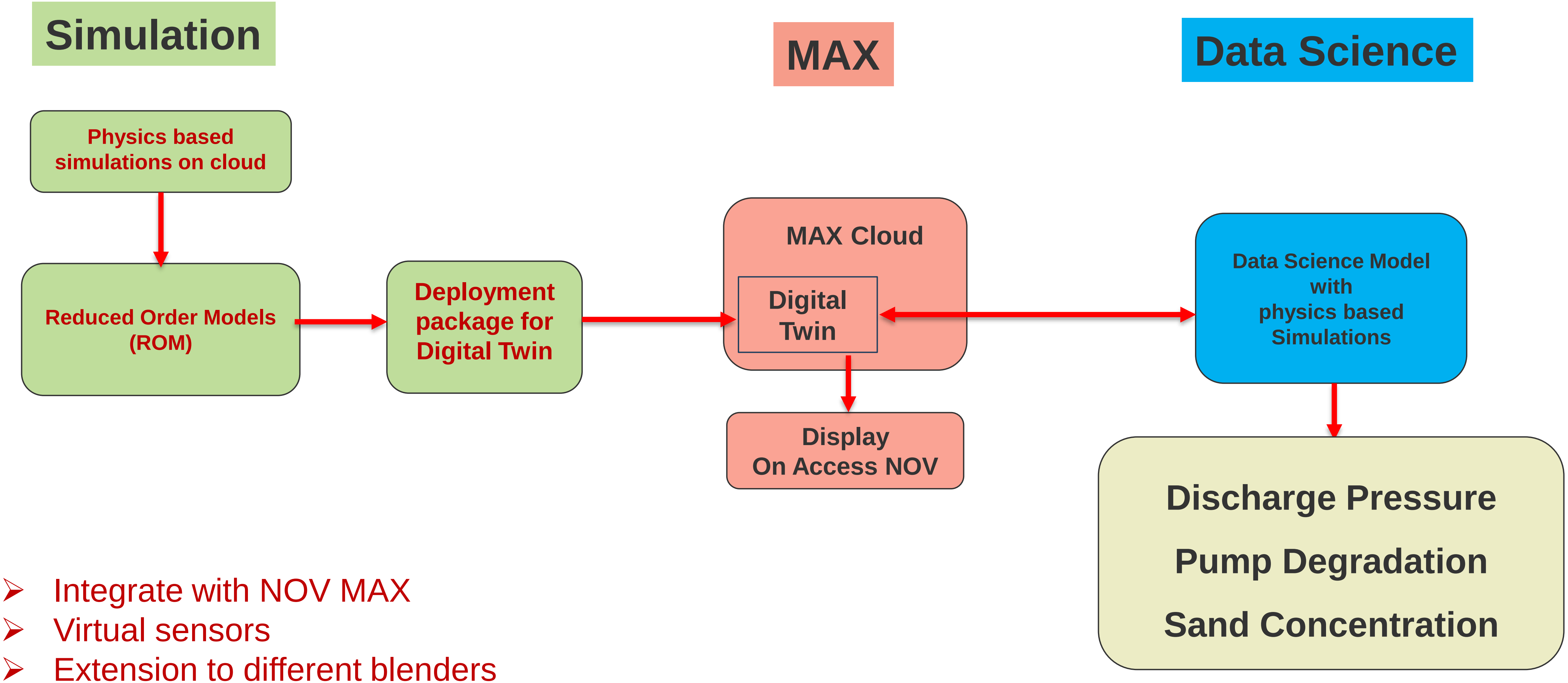






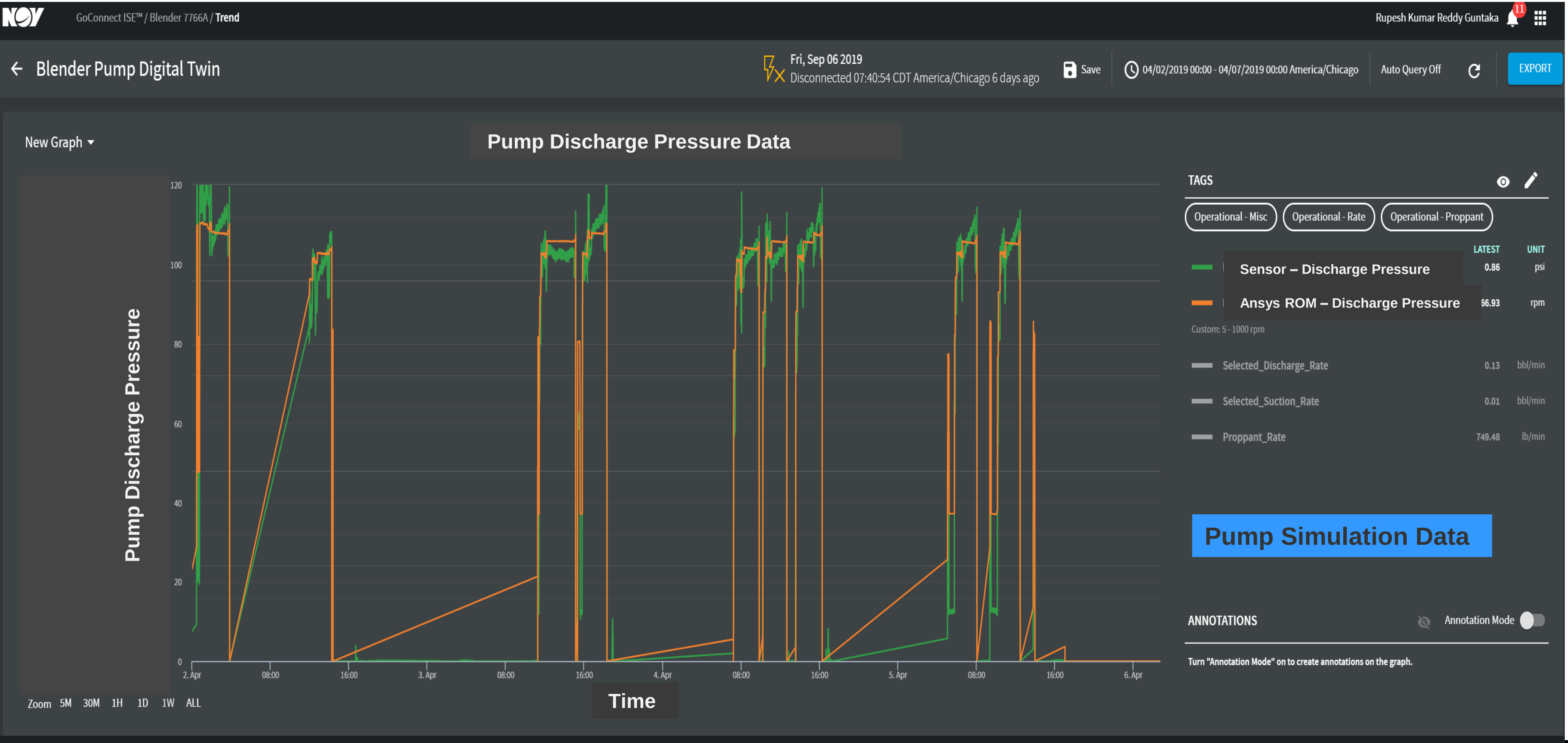


Simulation based Digital Twin : Blender Pump



- Integrate with NOV MAX
- Virtual sensors
- Extension to different blenders

NOV Access Portal : Blender Pump



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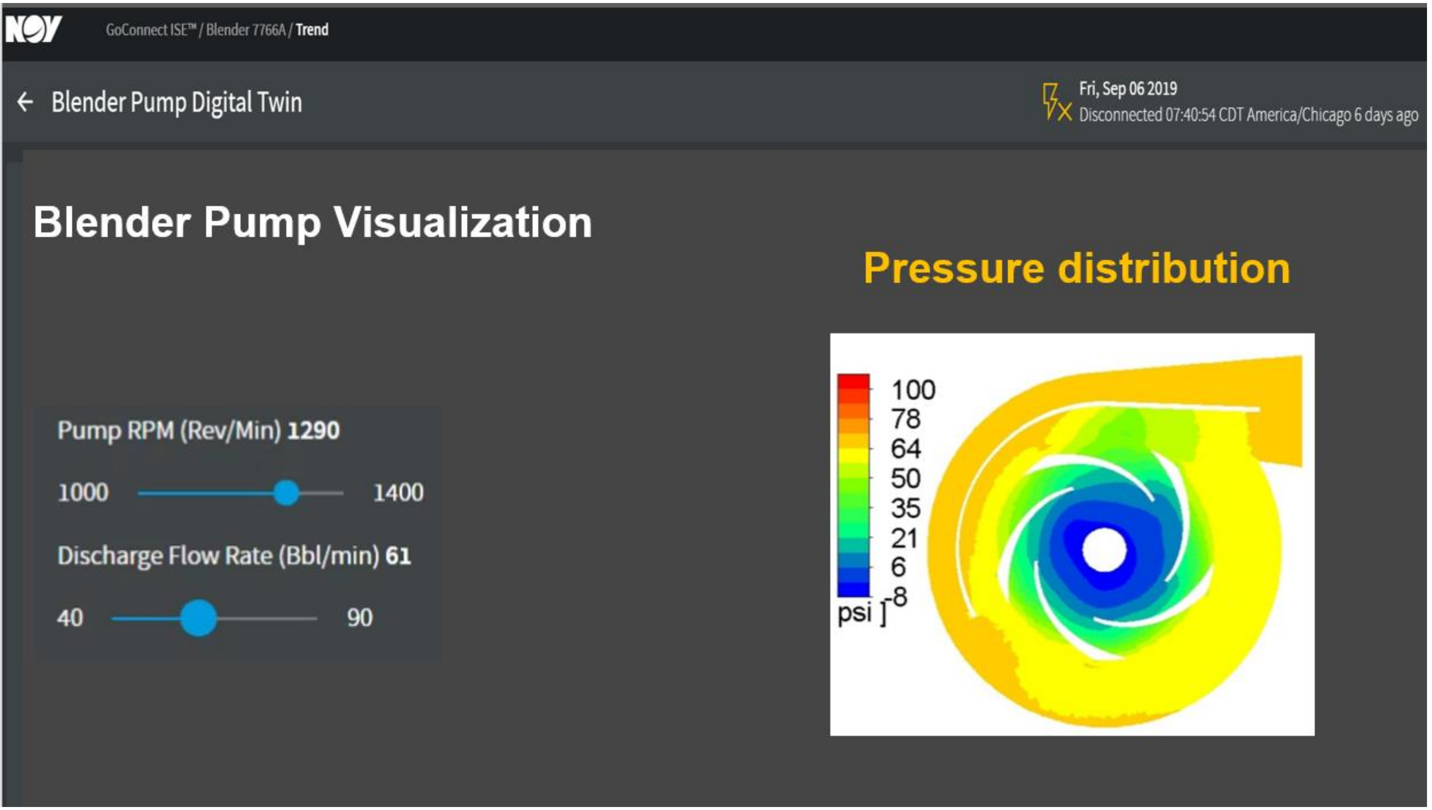
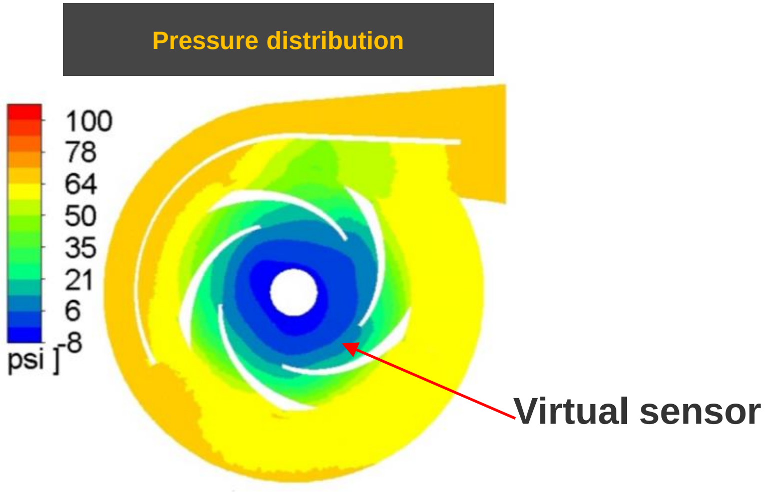
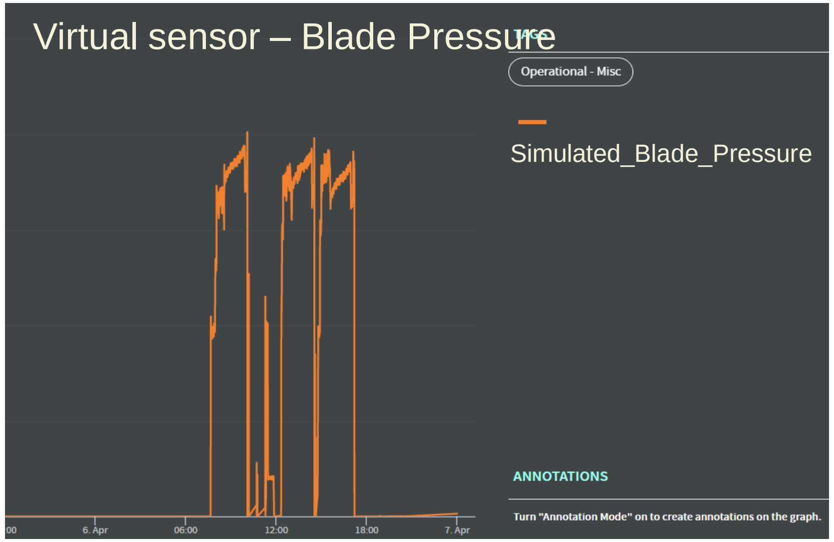
Blender Pump Digital Twin : Access NOV

Digital twin data as virtual sensor







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Blender Pump Digital Twin : Access NOV

Sand Concentration Model

- Physics-based model is developed to replace the sand concentration sensor when **tub level/suction rate is stable**.
- A data-driven model model is developed to complement the Physics-based model when **tub level/suction rate is not stable**.
- Physics-based or data-driven model will be **adaptively switched** to predict the sand concentration based on the **stability of suction rate and tub level**.
- When **suction/discharge rate are stable**, the prediction error of the hybrid model is **less than 10%.**
- The SC calculation model is currently deployed in both AWS and Databricks, but it can also be deployed in a **PLC**.

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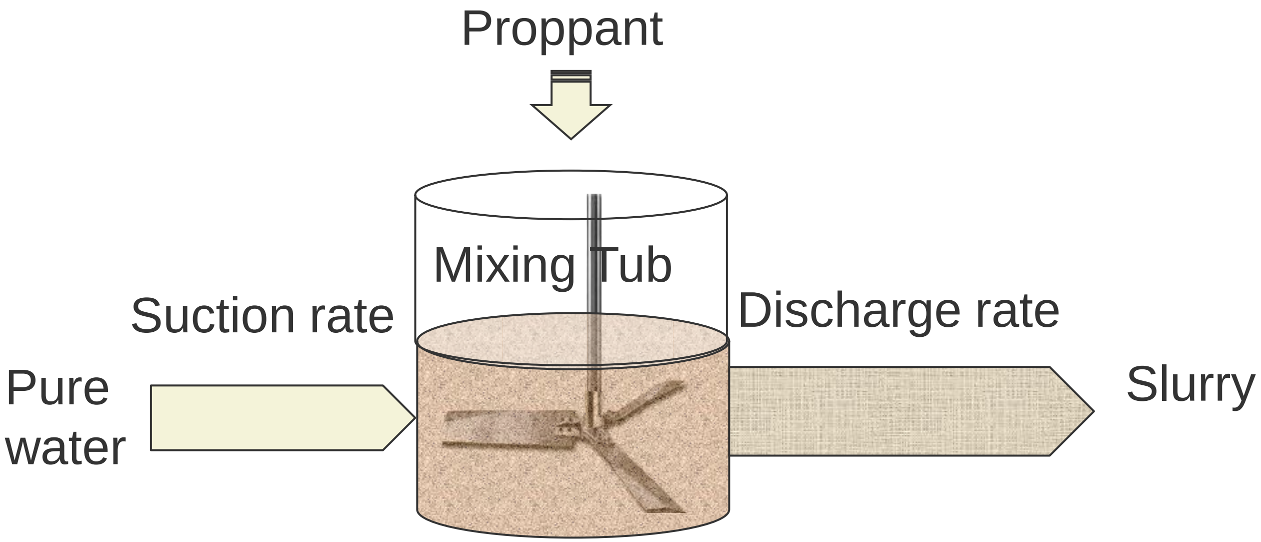
Assumptions on the Physics-based Sand Concentration Model

Frac Blender



Simplified schematic

Assumptions:

- The added chemicals are negligible compared to the amount of proppant.
- No loss of water and proppant in the tub (**Tub level is relatively constant**)
- The density is constant (**at least for a short time window**)

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Hybrid Sand Concentration Prediction Model

Physics-based and Data-driven models will be **adaptively switched** based on the stabilities of suction rate/tub level.

Overall flowchart of the hybrid sand concentration model

Flow sensors OK
AND
Suction rate stable?

$\Delta Q^{rel} < 10\%$

Yes → **Physics-based model**

↑ SC calculation

Proppant density

↓ Model selection

No → **Data Driven model**

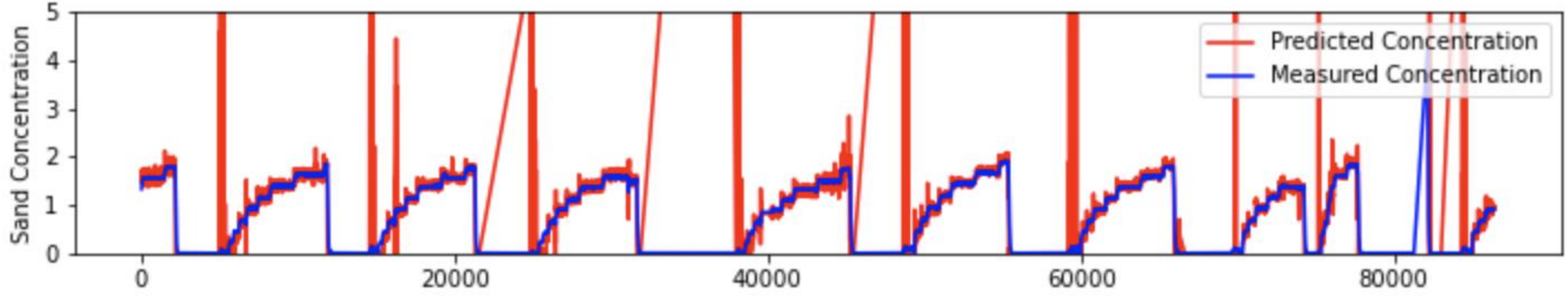
Train the Data-driven model at different proppant density levels

Proppant Type	Specific Gravity
Sand	2.65
Resin Coated Sand (RCS)	2.55
Intermediate Strength Proppant (ISP)	3.15
Bauxite	3.60

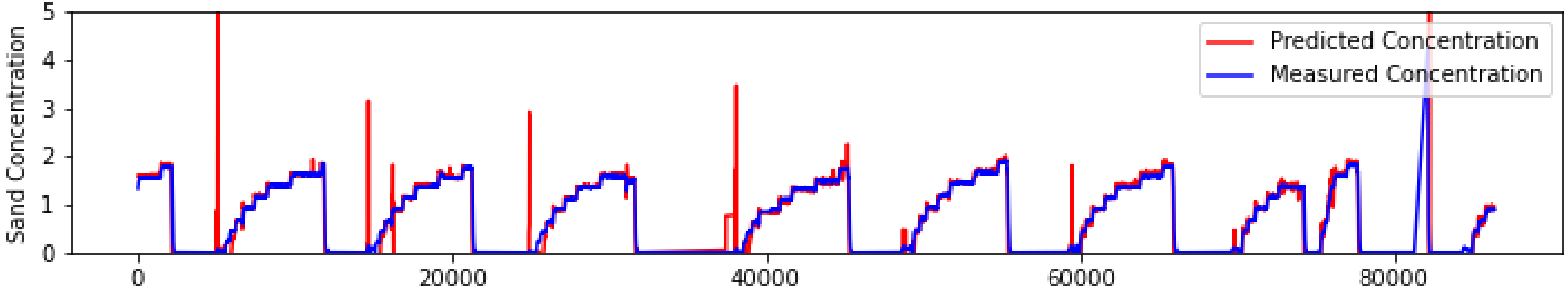
Validation of Sand Concentration Model

Before/After Smoothing on Cudd 7762A

Before



After



Feb. 16th to Feb. 17th, 2023

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Optimization and Emission Reduction for Gensets

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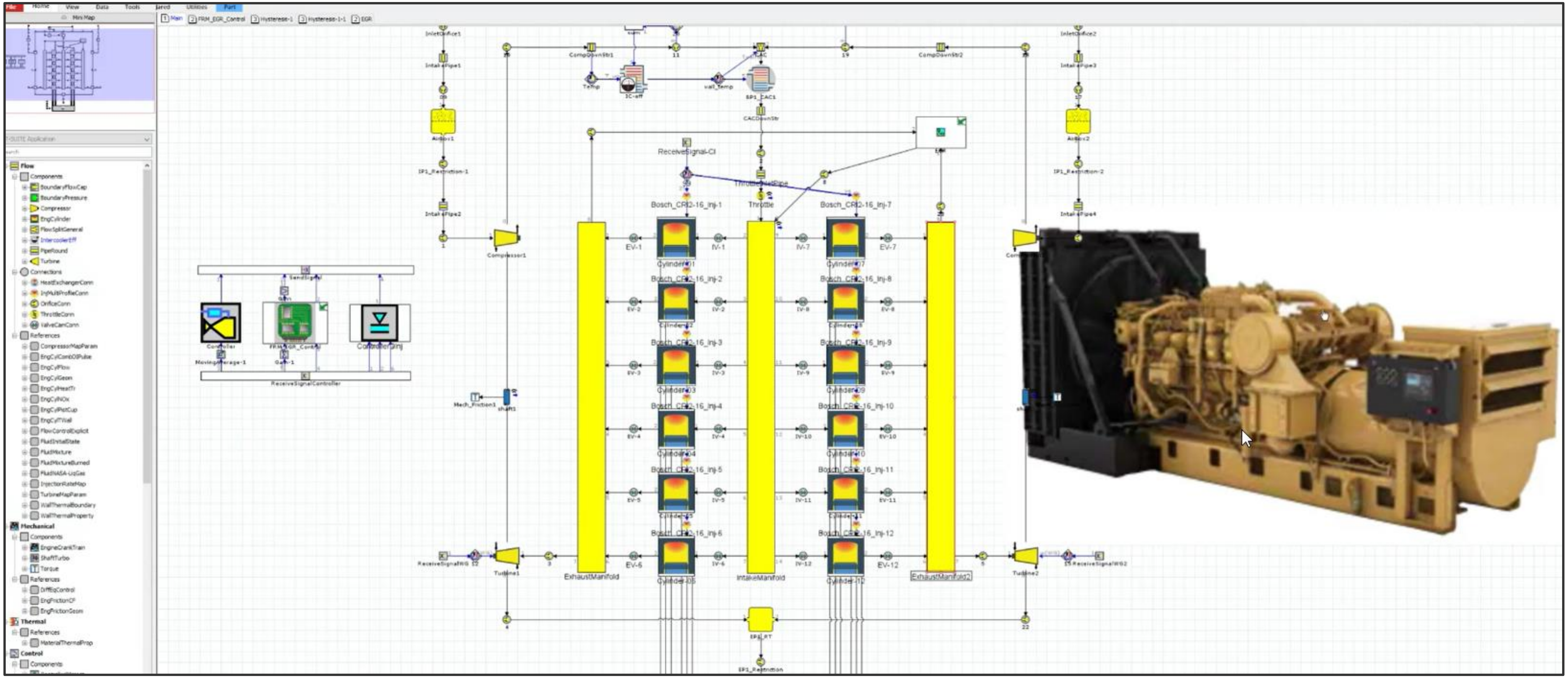
- 3 to 4 Gensets per Rig. Each having 1000 -1500 KW
- Fuel consumption is around 5000 to 7000 Gal/Day
- Fuel Cost per month is $ 0.5 million to $ 1 million

CO_2 emission per month

1500 tons

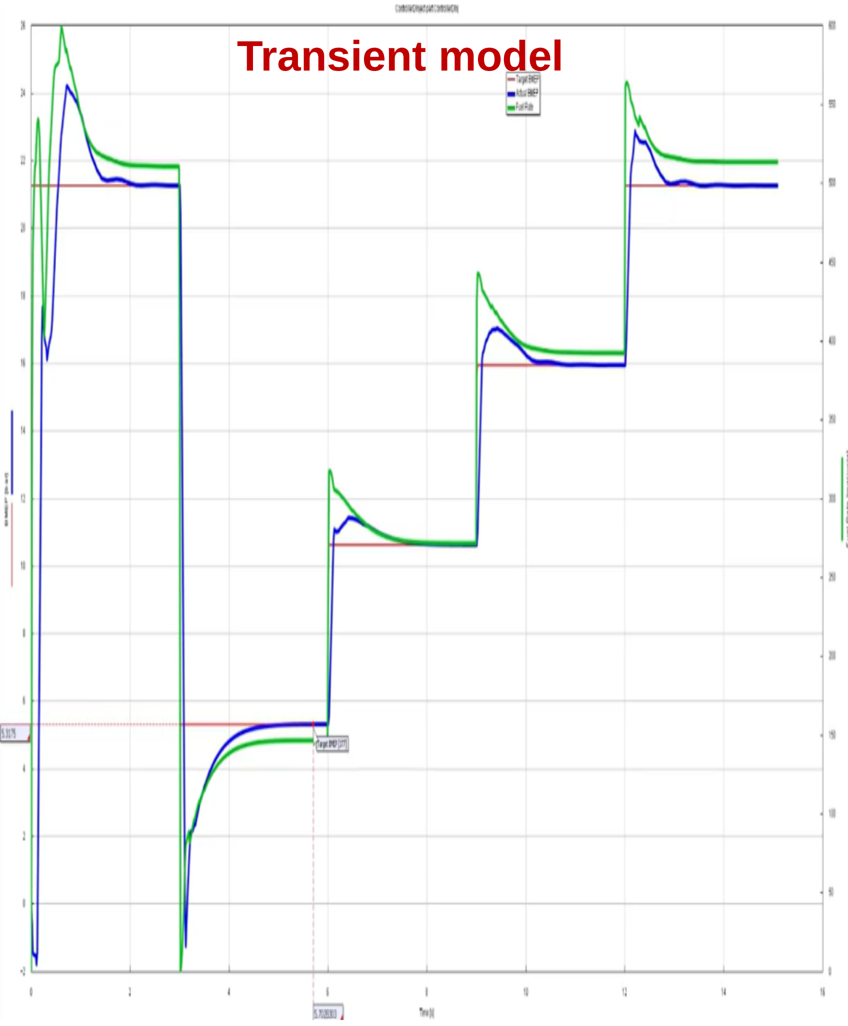
Optimization and Emission Reduction for Gensets

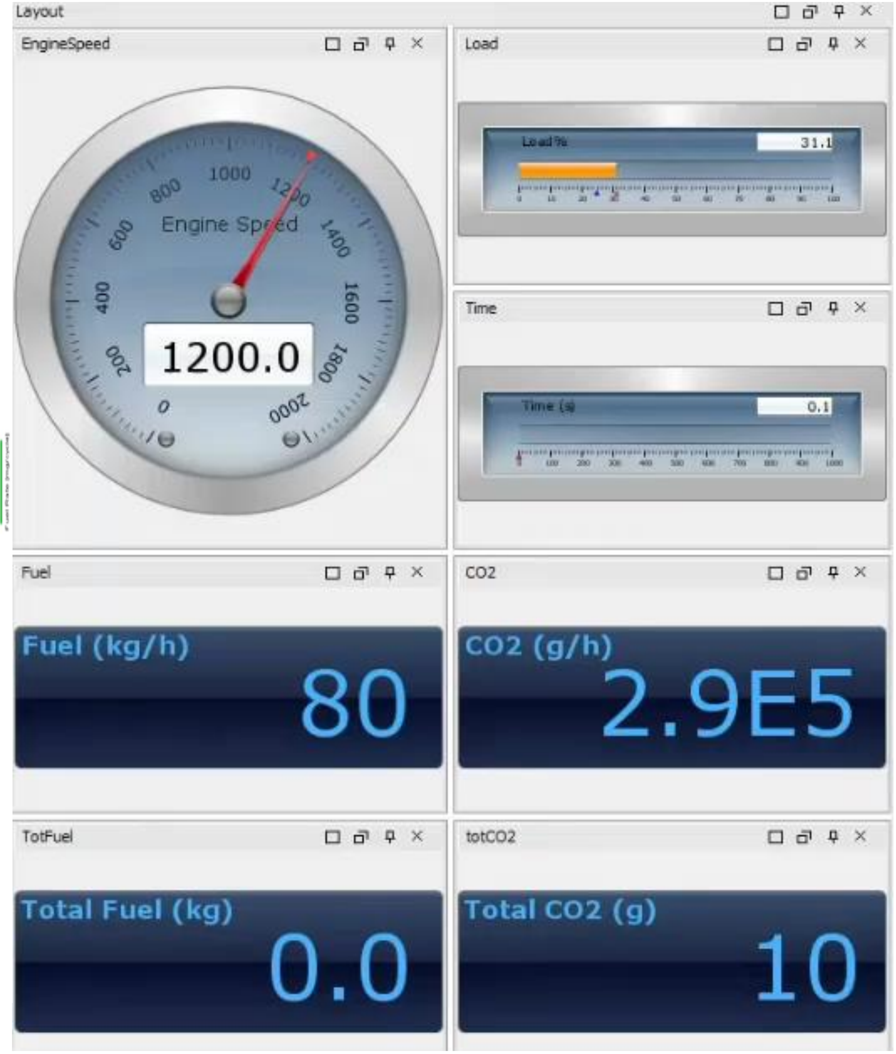
CAT3512C Engine model



Optimization and Emission Reduction for Gensets

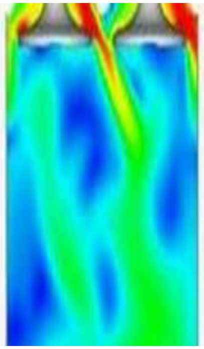
Transient model



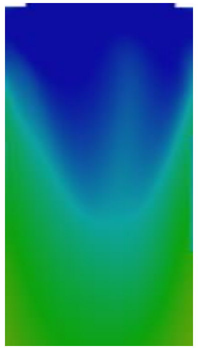


2D CFD Simulations

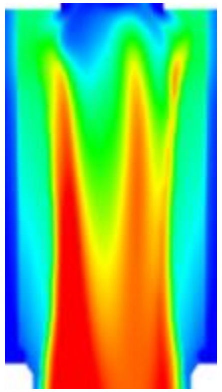
Velocity



CO_2

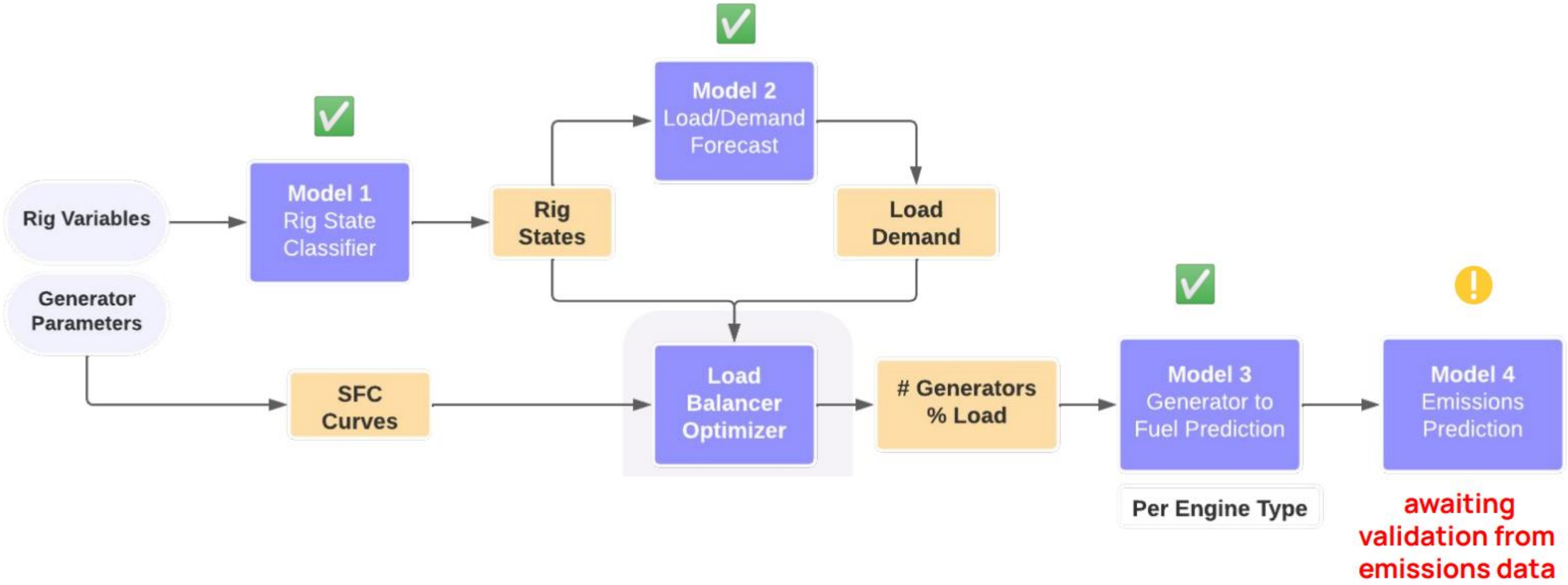


Temperature



Optimization and Emission Reduction for Gensets

Data Driven Model



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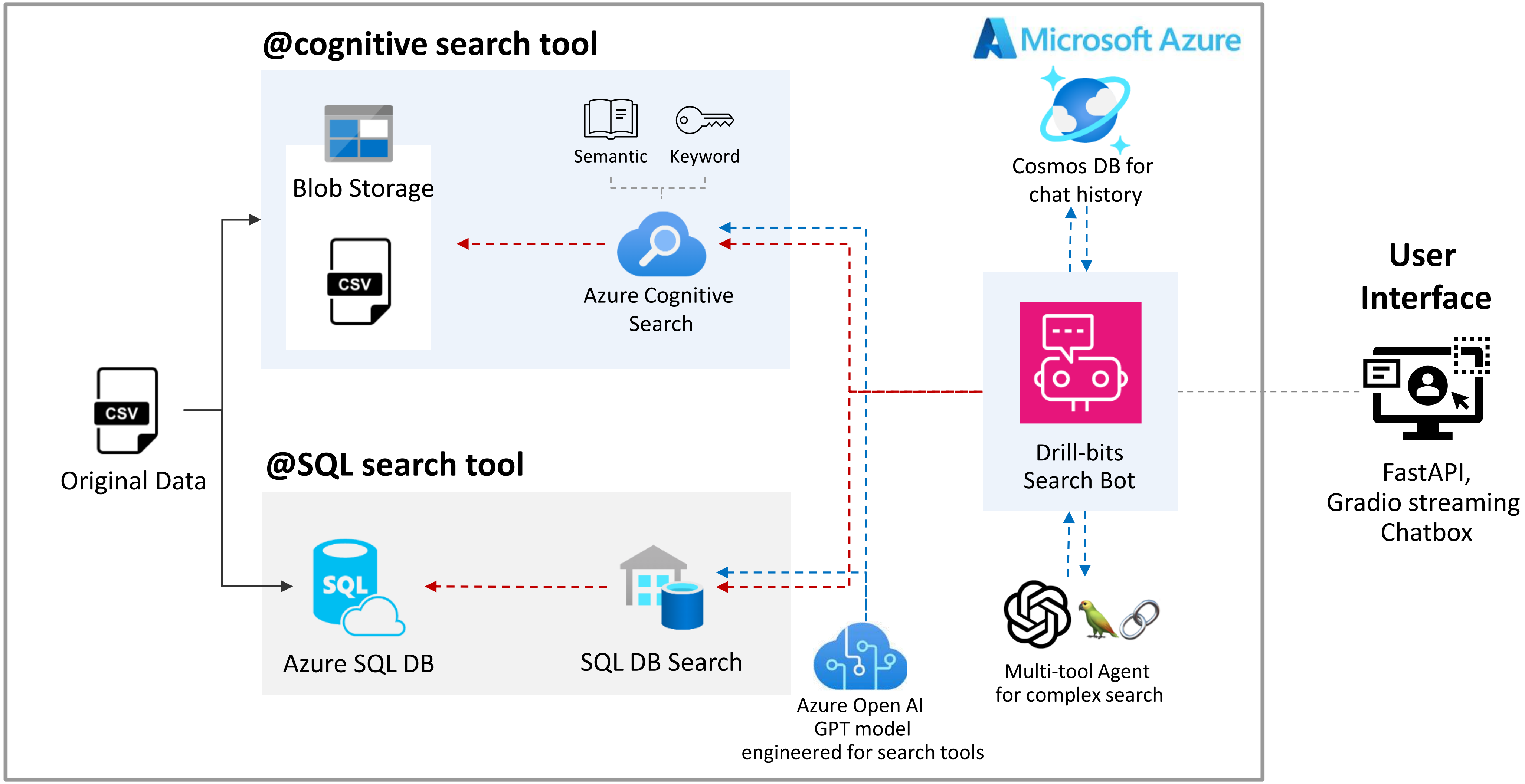
Architecture



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Governing Equations Used in GT-Power

The significant equations that govern the GT-Power are Continuity Equation (Conservation of mass), Momentum Equation, and Energy Equations.

Continuity Equation:

This equation signifies the law of conservation of mass. It states that the mass of fluid is conserved. Initially, the mass will change according to time, but after a certain point, the mass flow rate becomes constant.

$$\frac{dm}{dt} = \Sigma_{boundaries}\,\dot{m}$$

$$mdot = r * V * A$$

Where m is the mass and *m* is the mass flow rate.

Momentum Equation:

It is based on Newton's second law, which states that the rate of change of momentum of a fluid particle equals the sum of the forces on the particle.

$$\rho\frac{Du}{Dt} = \frac{\partial(-p+\tau_{xx})}{\partial x} + \frac{\partial\tau_{yx}}{\partial y} + \frac{\partial\tau_{yz}}{\partial z} + S_{Mx}$$

Where p denotes pressure on the surface, xx indicates various stress components in j direction on a surface normal to I direction, u is the velocity vector in the x-direction, SMx is the source term that accounts for body forces.

Note: The above equation is given for x-direction. Similarly, the equation can be written for y and z-direction.

Energy Equation:

The law of energy conservation states that the energy can neither be destroyed nor be created. It can only be transformed from one form to another,

$$\frac{\partial E}{\partial t} + \nabla . q = 0$$

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