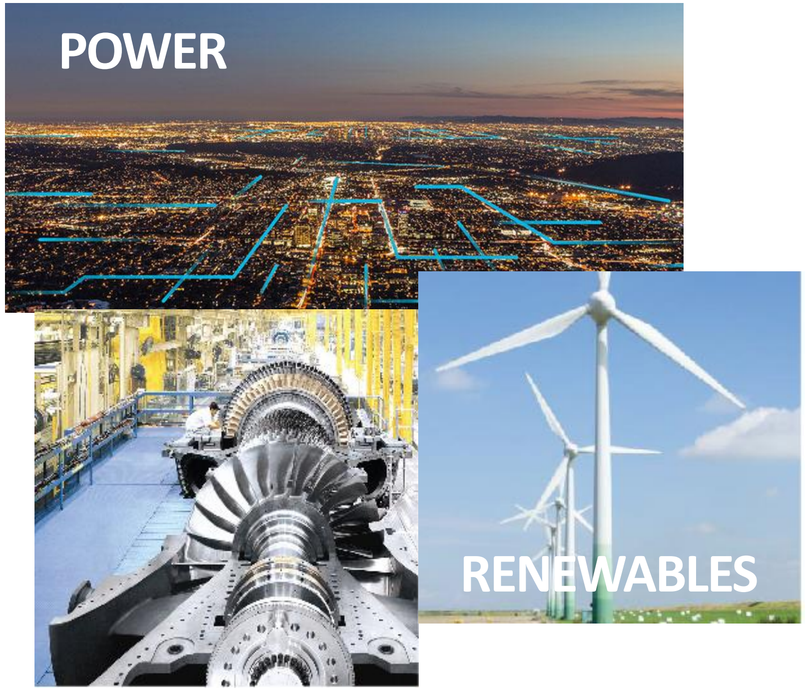
The role of simulation in contemporary Industrial Research – Sharing experiences

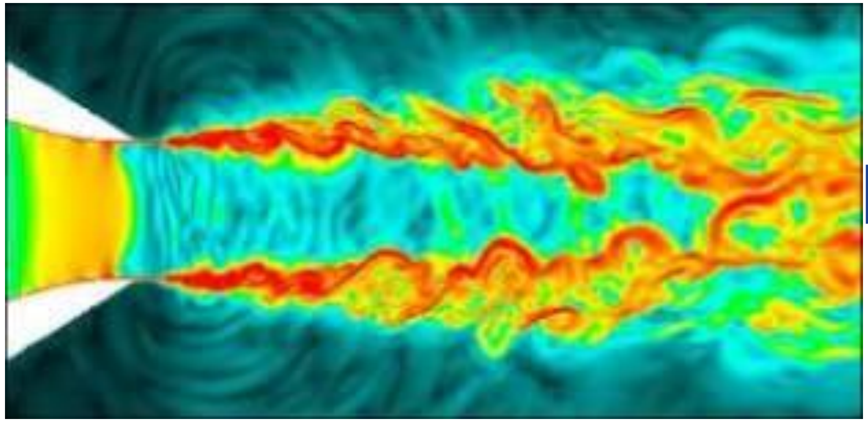
Rajendra Naik, PhD
Senior Principal, GE Global Research

May 15, 2018

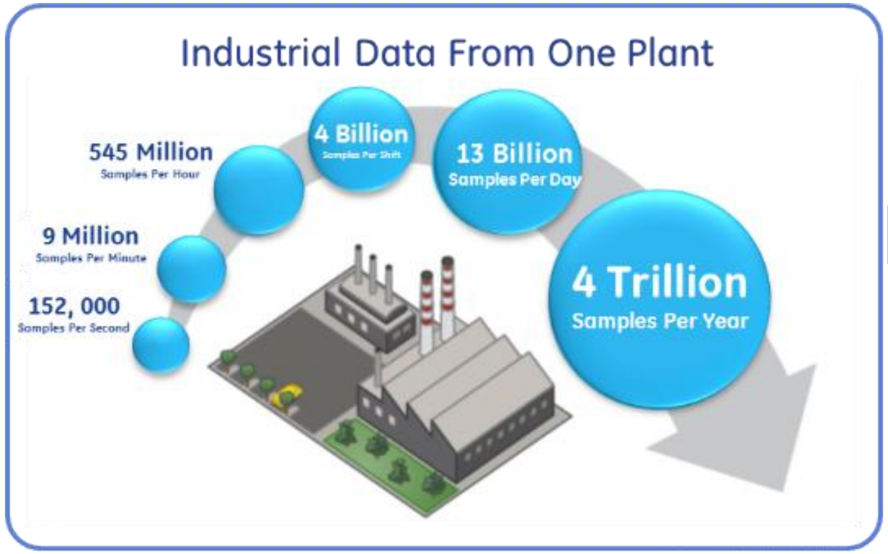
This is General Electric (GE)



Intersection of Big data and physics



High Fidelity Models



Source: GE Intelligent Platforms

Artificial Intelligence, Learning Model

Hybrid Models

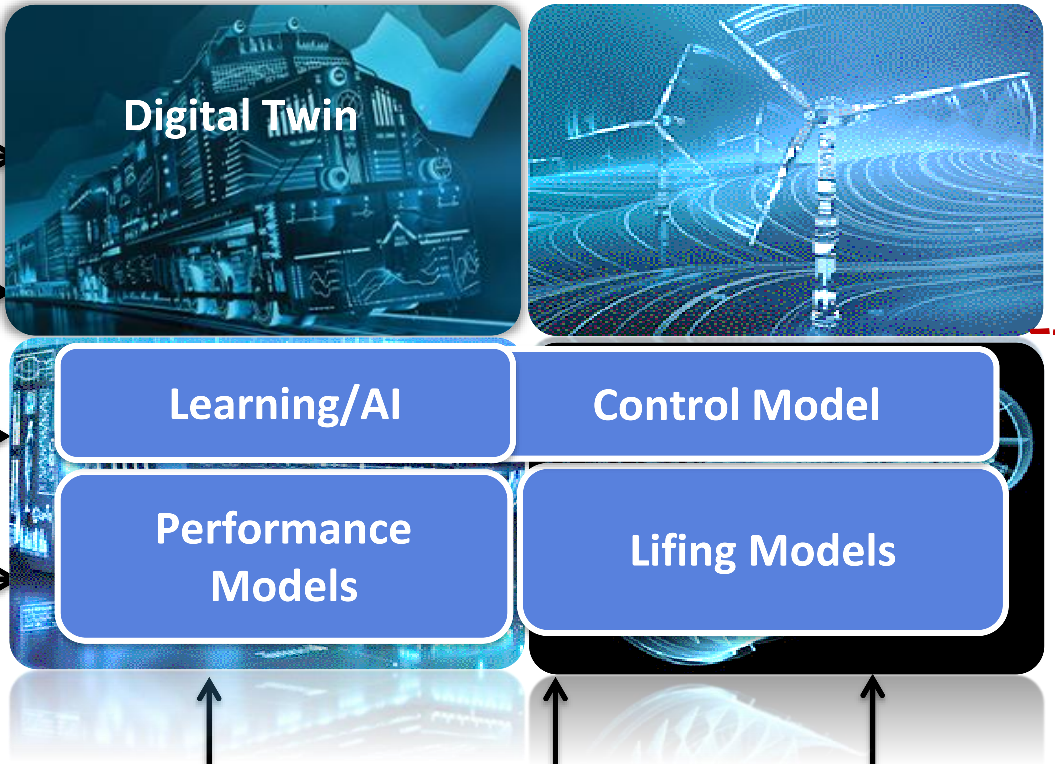
Physics Based
+
Data Adapted

Digital Twin – Engineering models with defined outcome

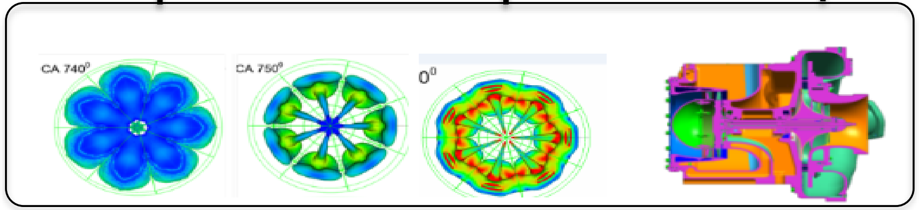
Data source

- Sensors
- Operational Data
- Inspection
- Maintenance Actions

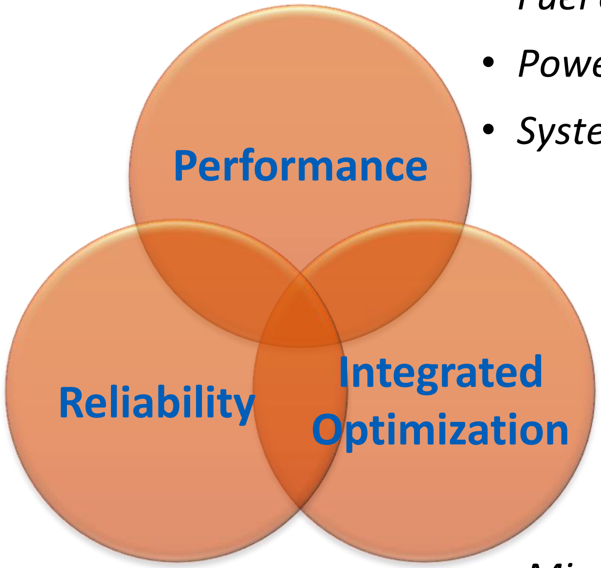
Asset



Domain knowledge



Business outcome



- *Fuel consumption* ↓
- *Power output* ↑
- *System efficiency* ↑

- *Mission Optimization*
- *Asset assignment*

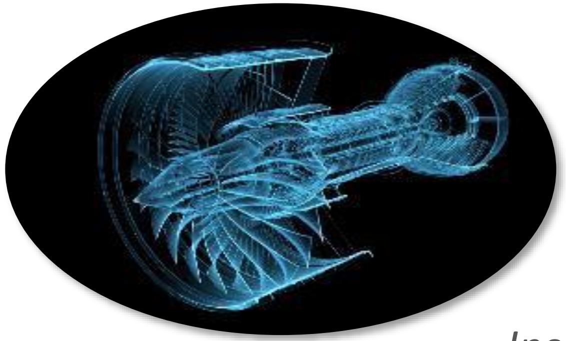
- *Remote Monitoring & Diagnostics*
- *Predict failure of components*
- *Condition based maintenance*
- *Life Optimizing controls*

Digital Twin – Aviation

Objective : *Maximum availability of an aircraft engine by intelligent workscoping*

Environmental conditions;
Per-Flight data;

Prior damage;
Engine Operating Mode



Inspection time;
Optimized shop time

Reduce maintenance cost using **turbine blade cumulative damage** models – updated per flight

Increased availability, reduce unnecessary service overhauls

Digital Twin – Transportation

1 **Per asset model**

2 **Business outcomes**

3 **Continuously tuned** – new data / insights

4 **Scalable** – MMs assets

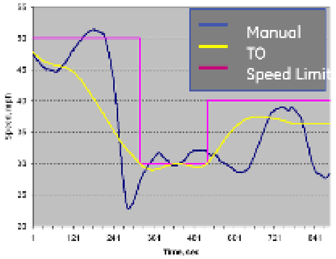
5 **Adaptable** – new …

Locomotive – Trip Optimizer

Locomotive data;
Track database;
Operating condition

Real time optimization :
Optimal speed & horse power

Objective : *Minimize fuel consumption & emissions – generated per trip*



Operator Cab

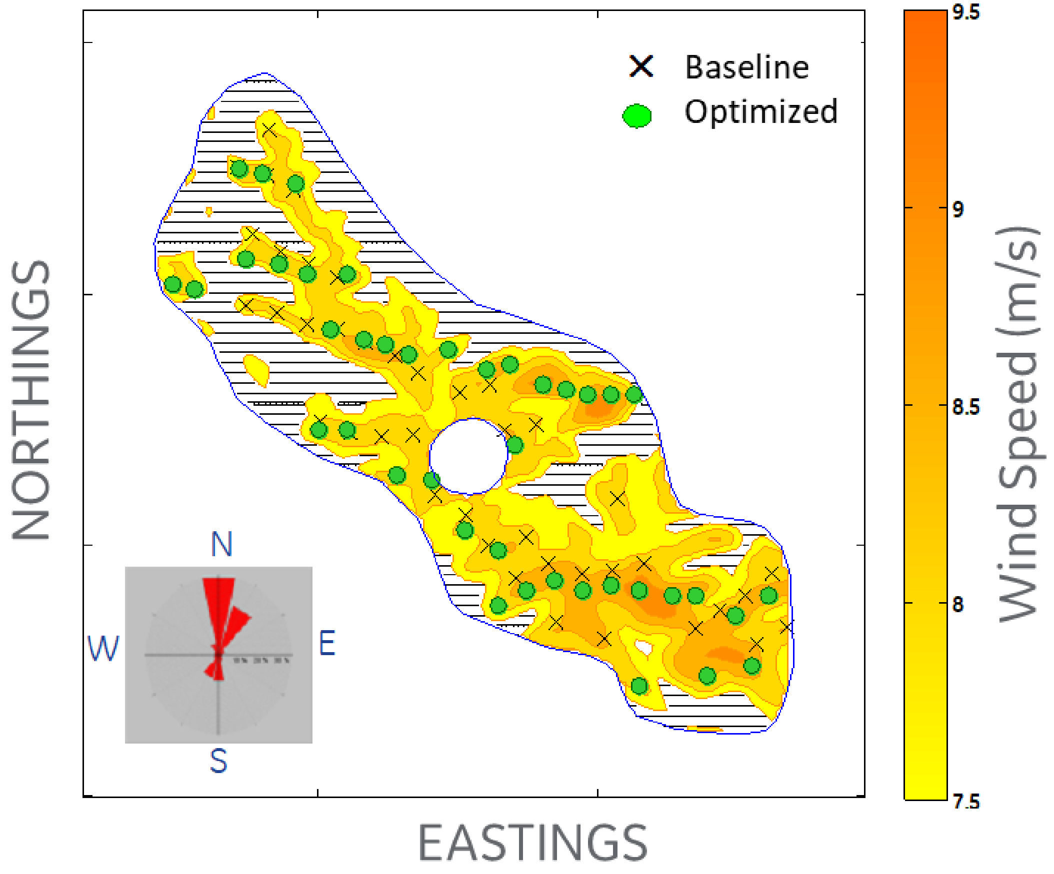
3-17% fuel savings
Enabled by system modeling, real time optimization & controls

Wind Farm Layout Optimization

Objective : Determine optimal wind turbine positions to maximize Annual Energy Production (AEP) and reduce Balance of Plant costs

Constraints of geography, turbine loads, acoustic noise and mix of turbines

Heuristics + Best in class MINLP algorithms + multi threaded optimization code

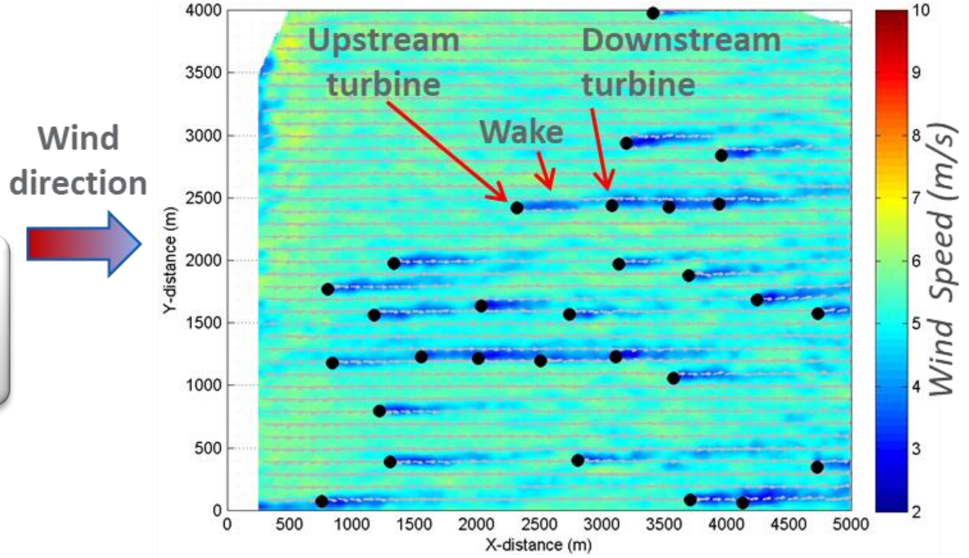


Novel approach to modeling, algorithms, software architecture

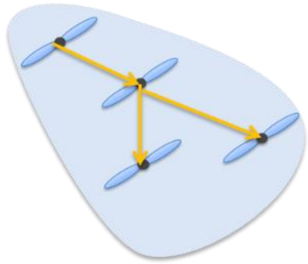
Wind Farm Operational Optimization

Objective : Maximize Annual Energy production (AEP) of a wind farm

Solution : Minimize inter turbine wake losses with coordinated controls



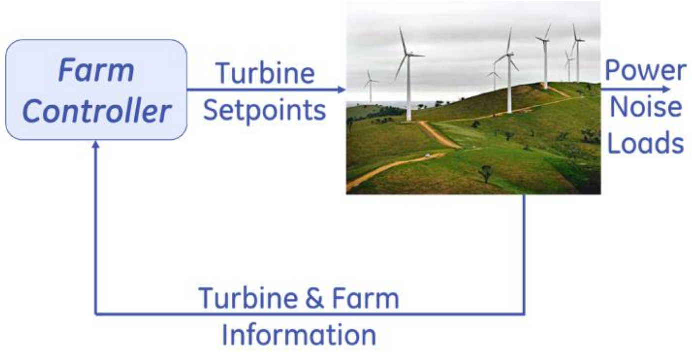
Networked Controls



Communications
Farm-wide awareness

Digital Twin of the wind farm

Co-ordinated turbine control



$$\max_{x} \sum_{i} \text{Power}_i(\text{Wind Speed}_i, x_i)$$

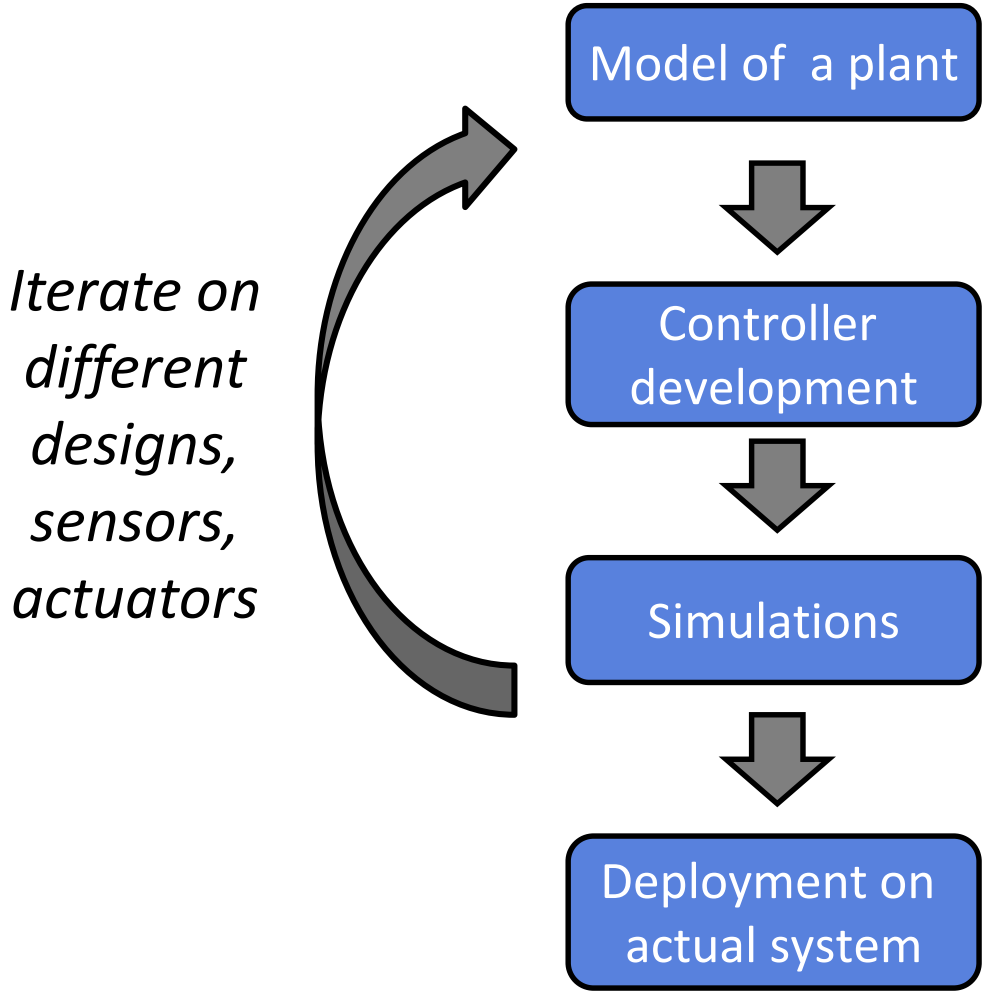
$$\text{Wind Speed}_i = f_{Wake}\left(\prod_{j}(\text{Wind Speed}_j, x_j)\right)$$

$$x_i \rightarrow \text{Control Setpoints for Turbine } i$$

0.5-2% AEP improvement

1% AEP improvement → $ 2MM value per year for 100 MW farm

Model Based Design Cycle



- *Plant : Process / system to be controlled*
- *Data driven and/or physics based*

- *Controller synthesis & analysis*
- *Choose appropriate type of controller*

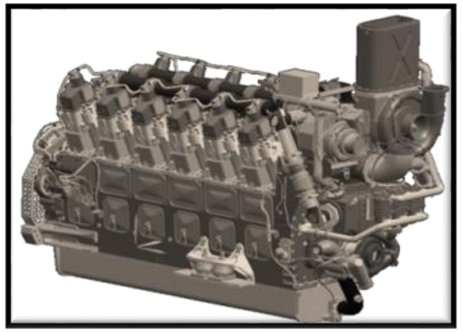
- *Offline or real time simulation*
- *Model in the loop/ Hardware in the loop*

Autocode generation

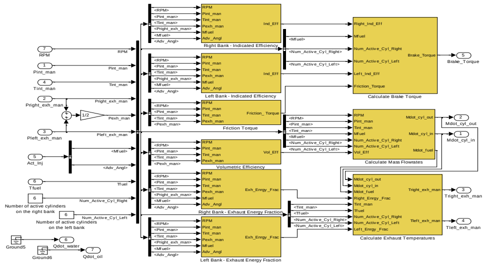
Reference : http://en.wikipedia.org/wiki/Model-based_design

Model Based Design Example – IC Engine

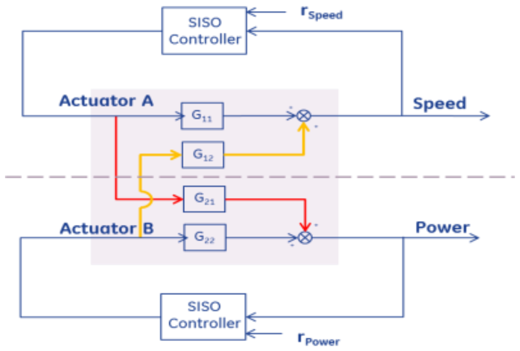
Design a controller for an IC engine to meet speed and power requirements across the operating range



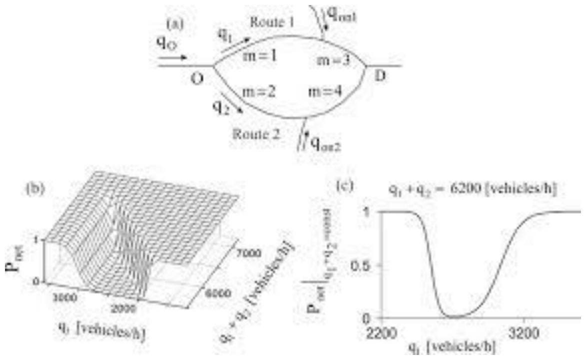
Plant to be controlled



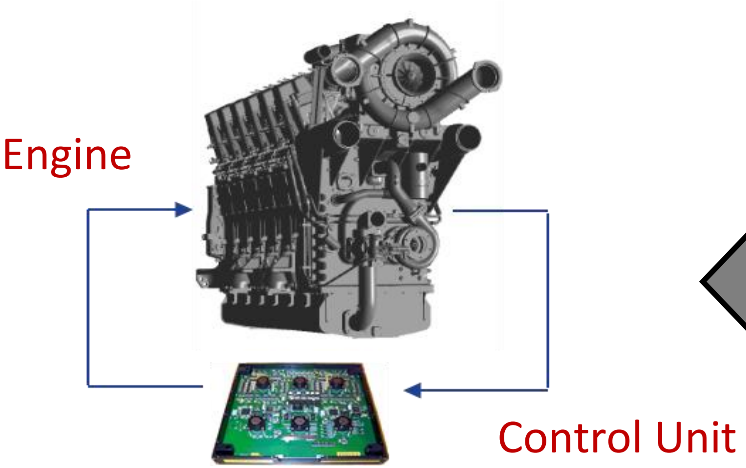
Model : Physics based and data driven (Grey box approach)



Controller design Multi-loop PID



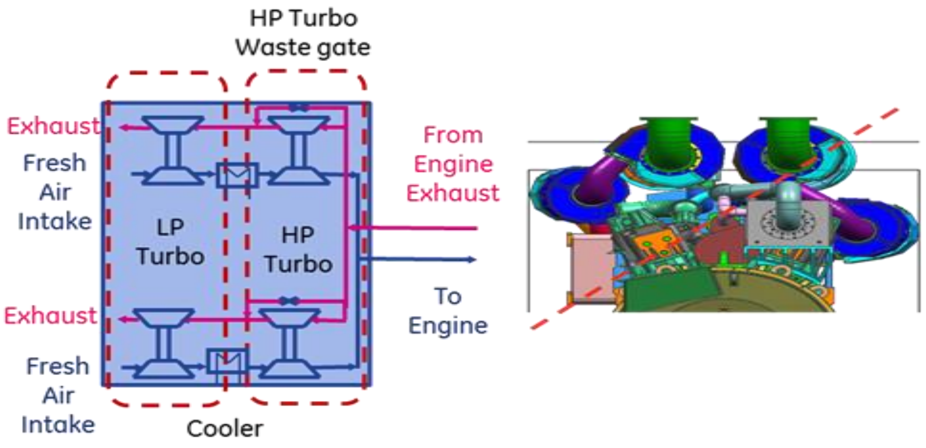
Simulation studies Desktop/ hardware



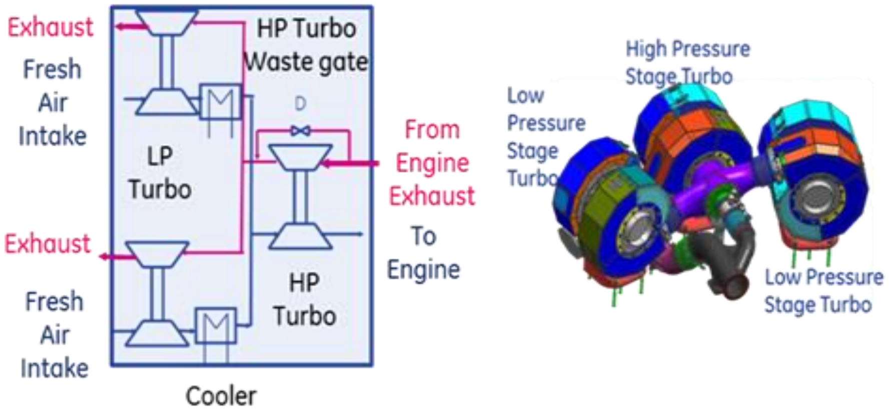
Actual engine testing

Marine Engine Turbocharger - Model Based Design

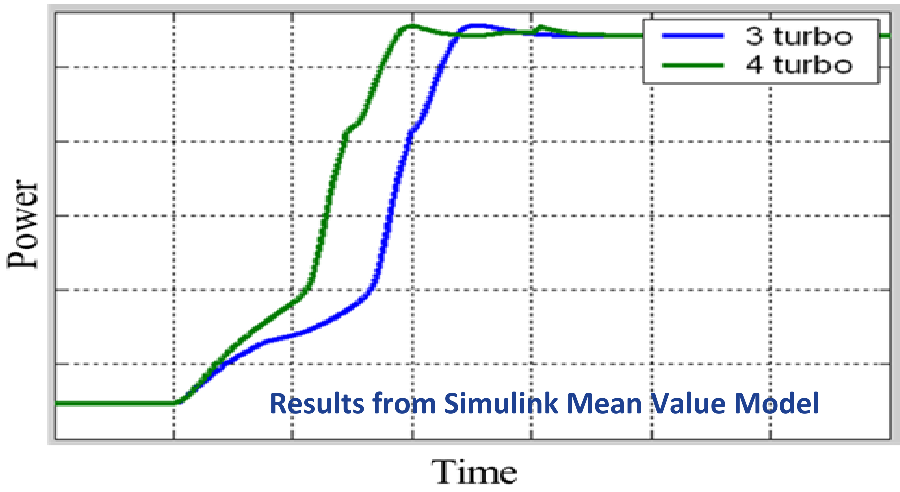
Four Turbo Configuration



Three Turbo Configuration

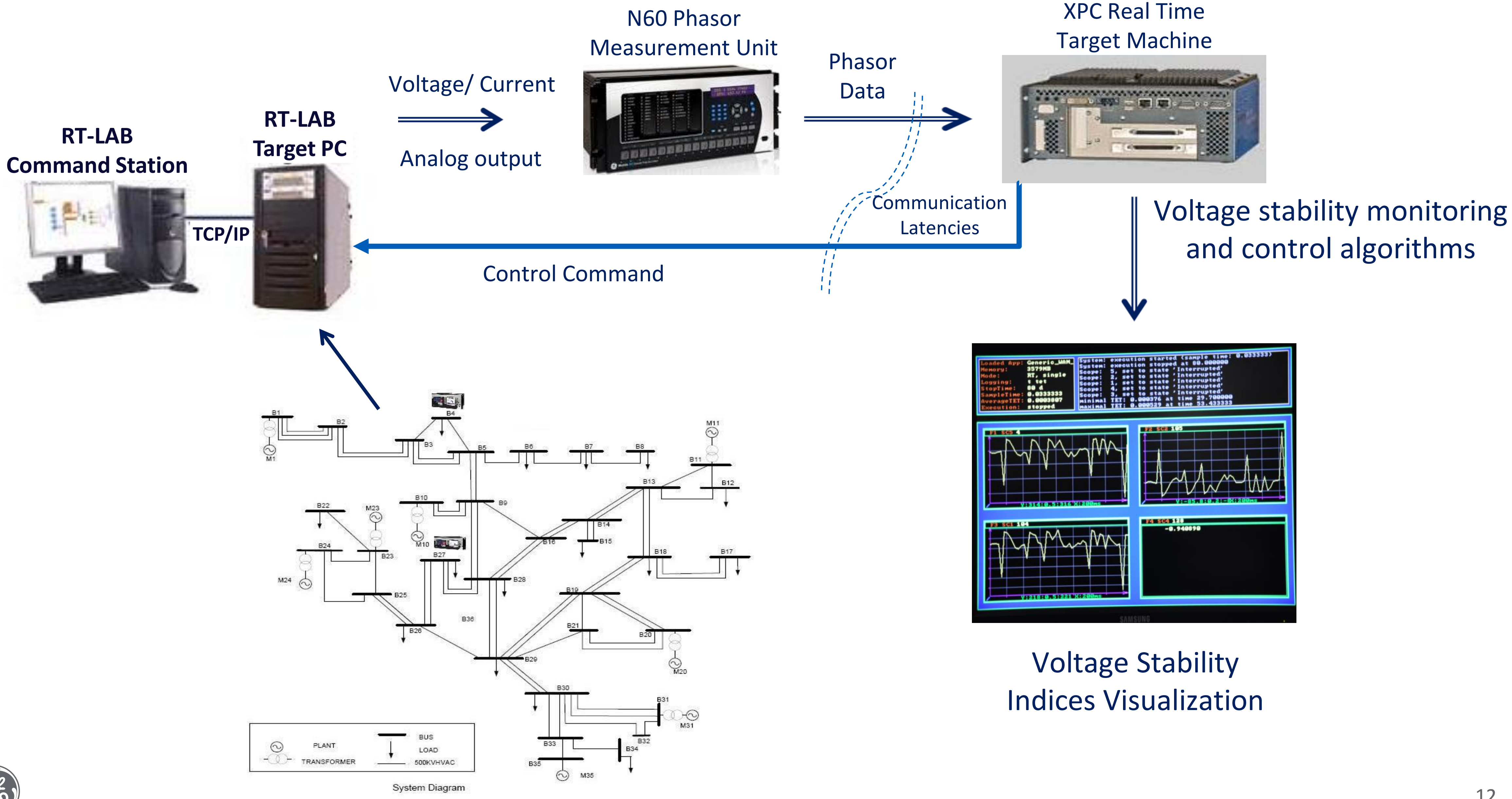


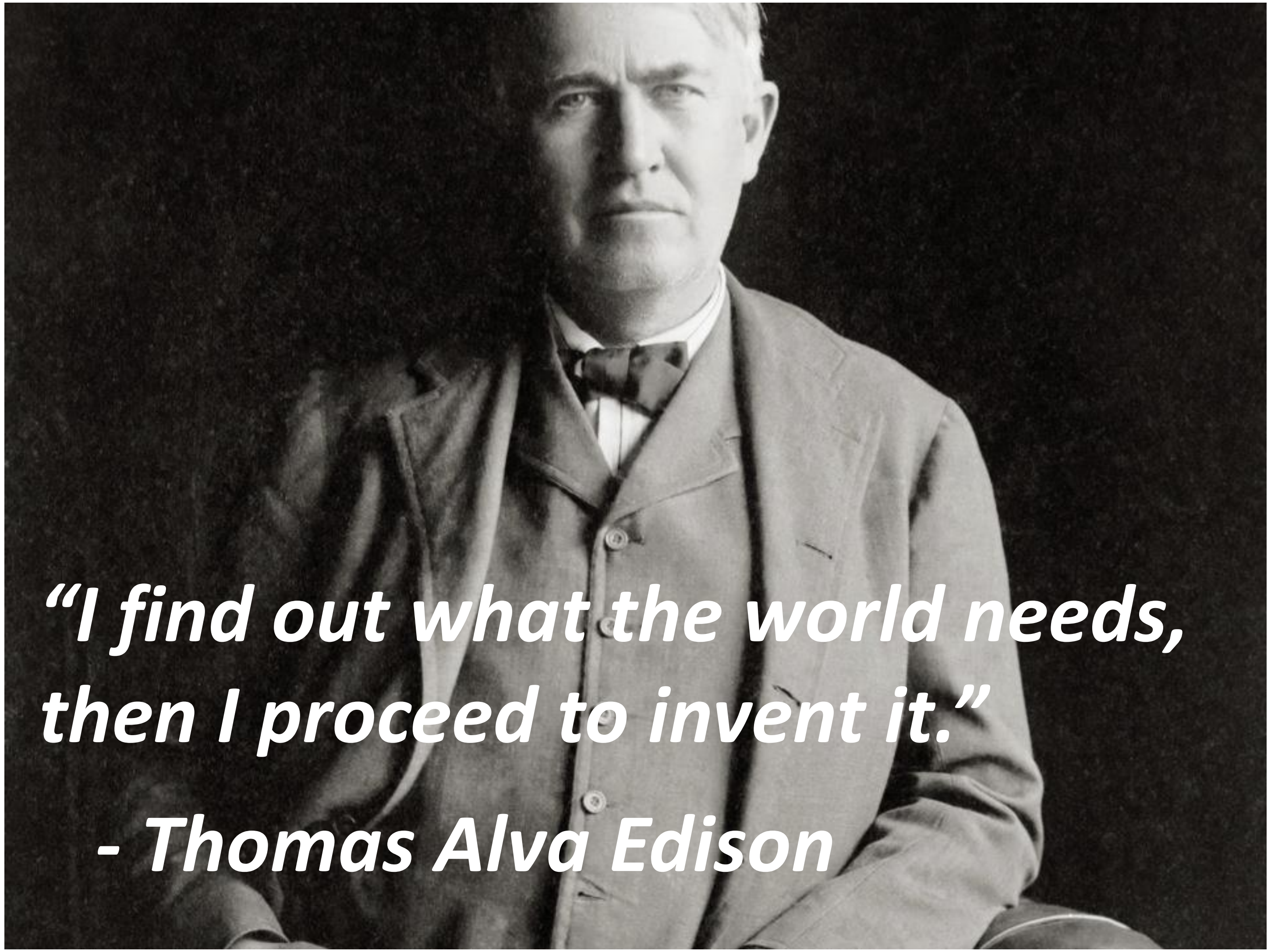
Trade off matrix	Three turbo	Four turbo
Cost, packaging & system complexity	Lower	Higher
Transient response	Slower but well within CTQ	Faster & well within CTQ



Model based design helped business take a decision to go for 3-Turbo configuration

Transmission and Distribution – Voltage Stability





And he didn't have the tools that we have today……….