DYNAMIC DATA RECONCILIATION AND OPTIMIZATION

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Overview

- PRISM Group Overview
- Monitoring / Intelli-Fields
  - Unmanned Aerial Vehicles
  - Oil and Gas Exploration and Production
- Uncertainty Analysis
  - Investment Planning Under Uncertainty
  - Energy Storage and the Smart Grid
- Next Generation Simulation with Optimization
  - Solid Oxide Fuel Cells
  - Systems Biology

PRISM Group Overview

- PRISM: Process Research and Intelligent Systems Modeling
- Methods
  - Mixed Integer Nonlinear Programming (MINLP)
  - Dynamic Planning and Optimization
  - Uncertain, Forecasted, Complex Systems
- Fit Systems into Standard Problem Formulation

$$\max \quad f(x)$$
$$\text{subject to } g\left(\frac{\partial x}{\partial t}, x, u, p\right) = 0$$
$$\text{h}\,(x, u, p) \leq 0$$

- Solver development: Large-scale MINLP (100,000+ variables)

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UAV Platform

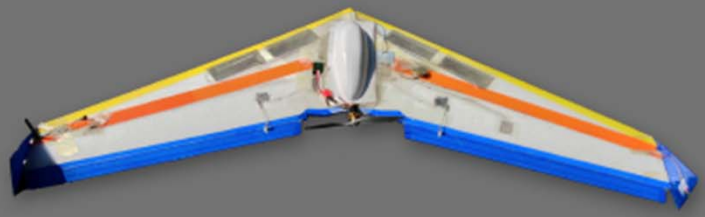
Platform One:

Ritewing 81″ ZXL

Sensor: GoPro Hero 3 Camera

Control: RC/FPV

Flight Time: 25 minutes



Platform Two:

Procerus 72″ Unicorn

Sensor: Gimbaled Camera

Control: Kestral Autopilot v2.2

Flight Time: 40 minutes

Sensors

GoPro Hero 3 Black Edition

Resolution: 1440x1990

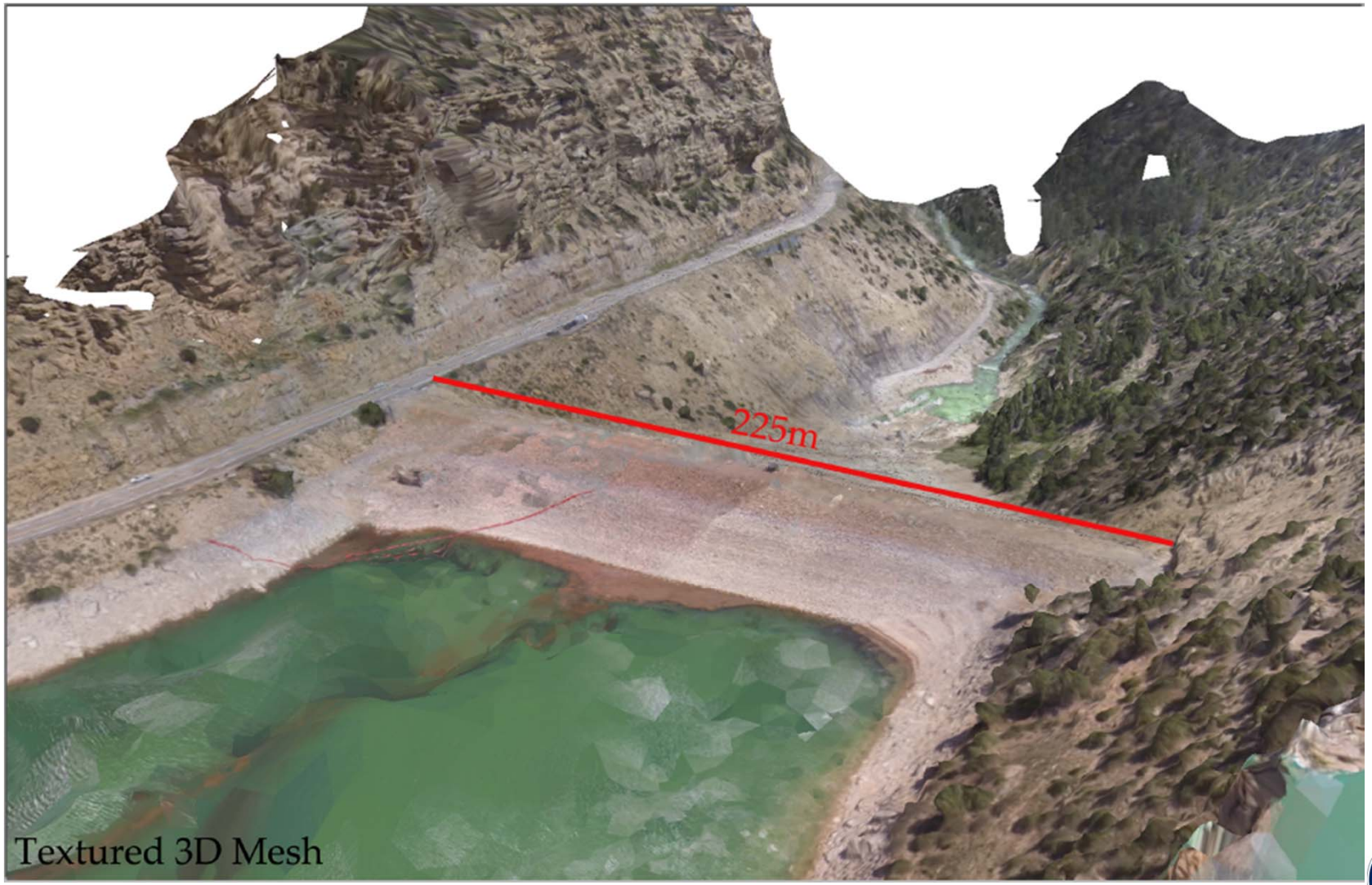
Frame Rate: 48 fps

Sony FCB IX11A Block Camera

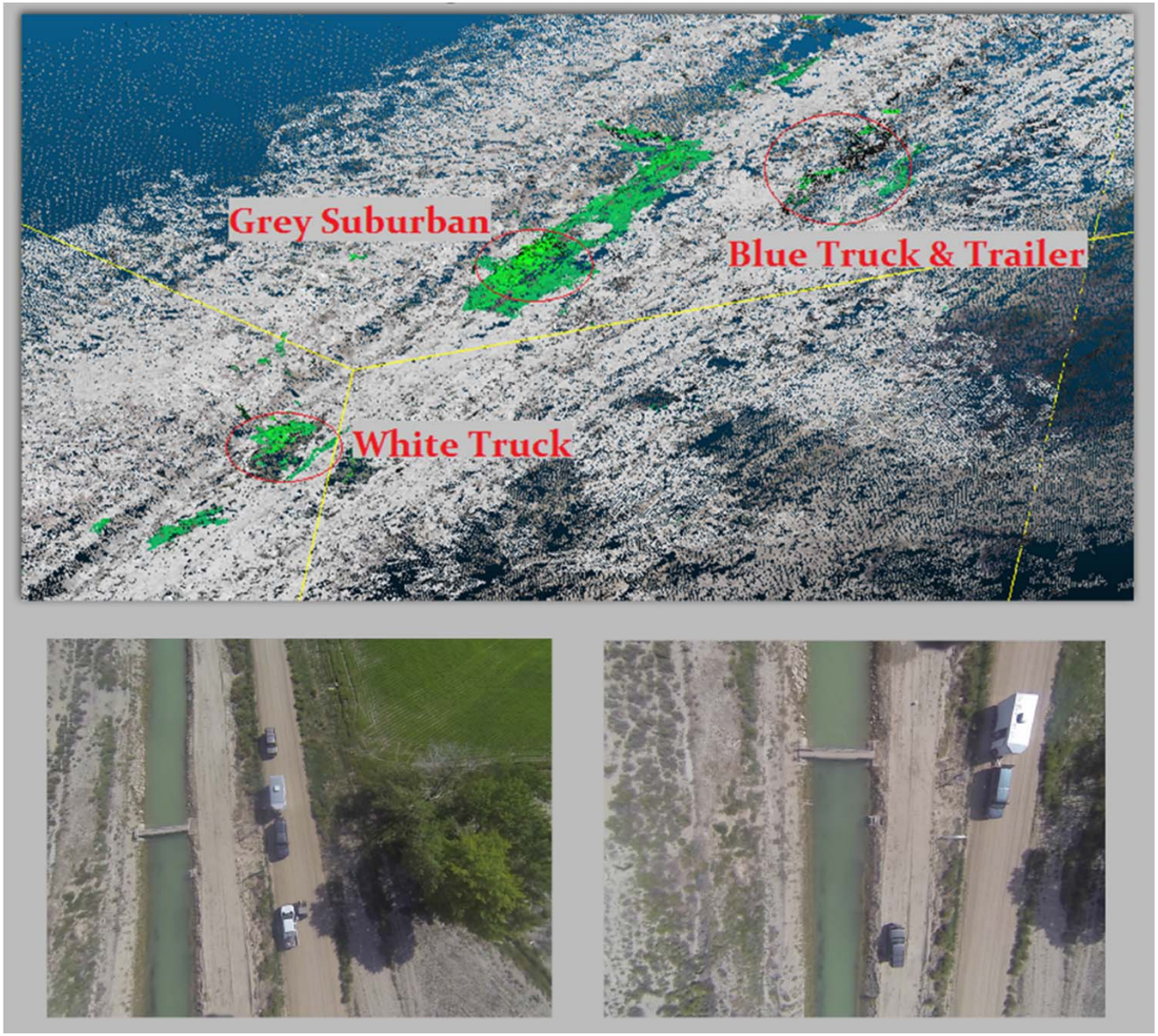
Resolution: 640x480

Frame Rate: 15 fps

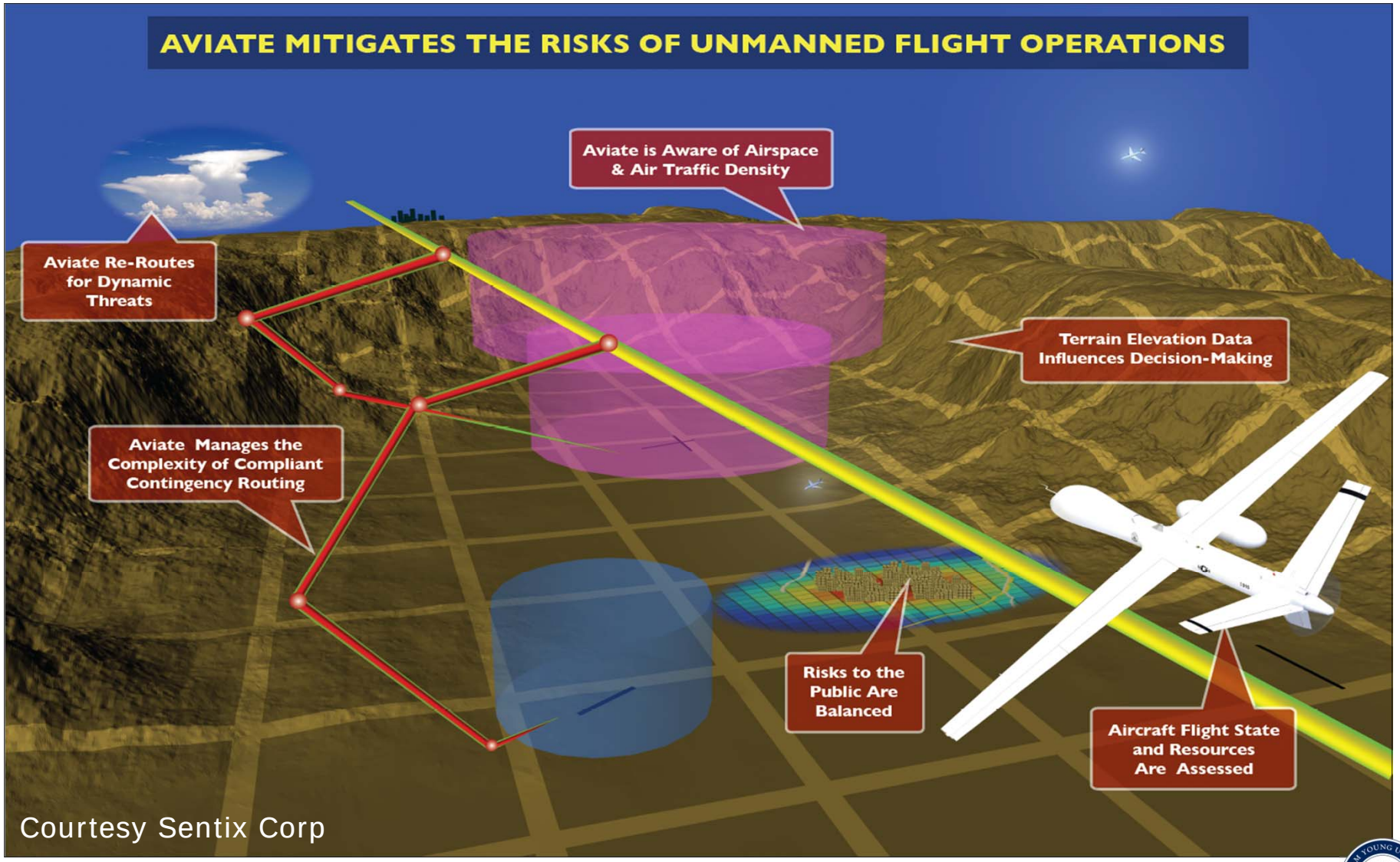
Monitor Infrastructure



Canal – Change Detection



Dynamic Optimization with UAVs



Information Sources

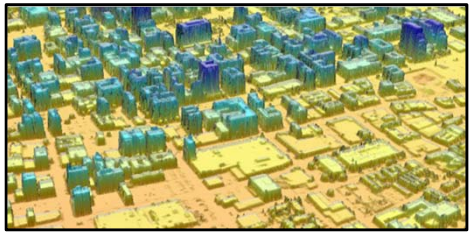
Multiple Sources of Information Can Be Utilized

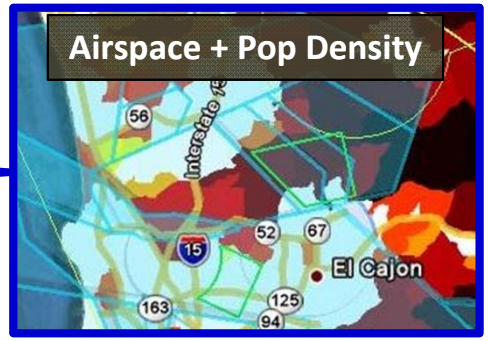
Population Density

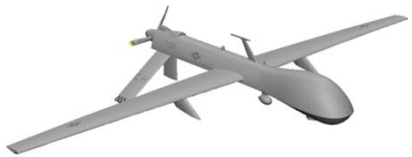
Controlled Airspace

Safety Thresholds

Geospatial / Urban Dev

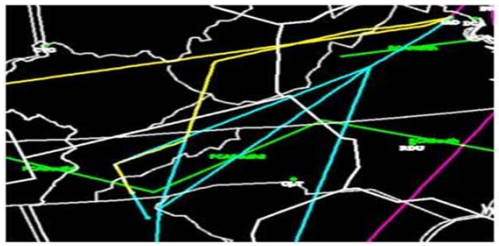


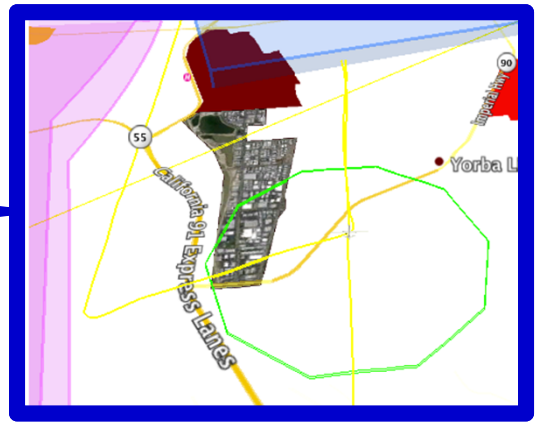


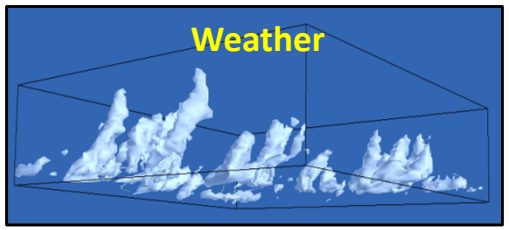


Aircraft Performance Model

Air Traffic Density







Functions

Define Risk

Compute Risk

Minimize Risk

Courtesy Sentix Corp

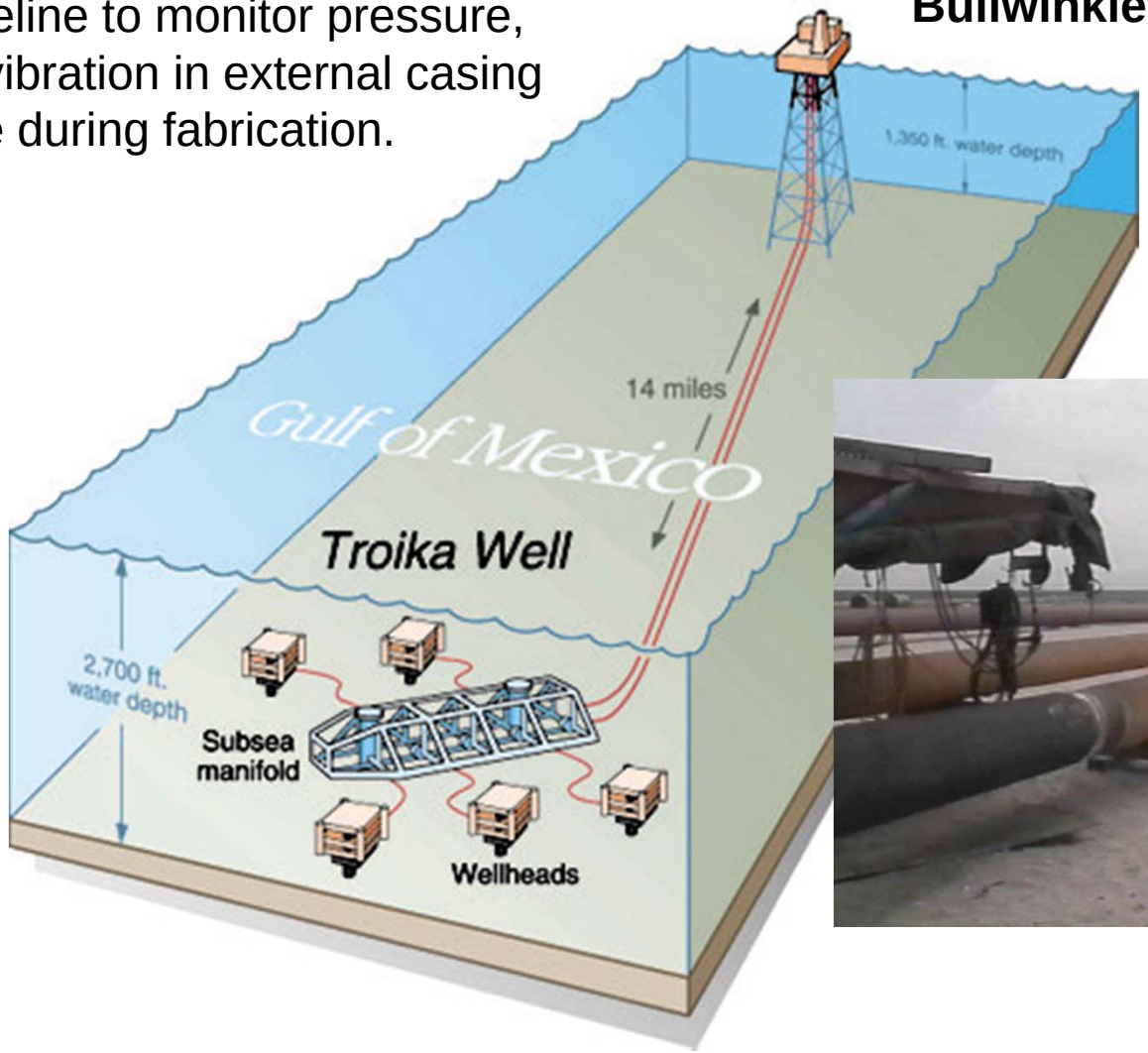
Failures to Monitor and Predict

- Detect early warning signs
- Automate monitoring of critical systems
- Give critical data to key decision makers

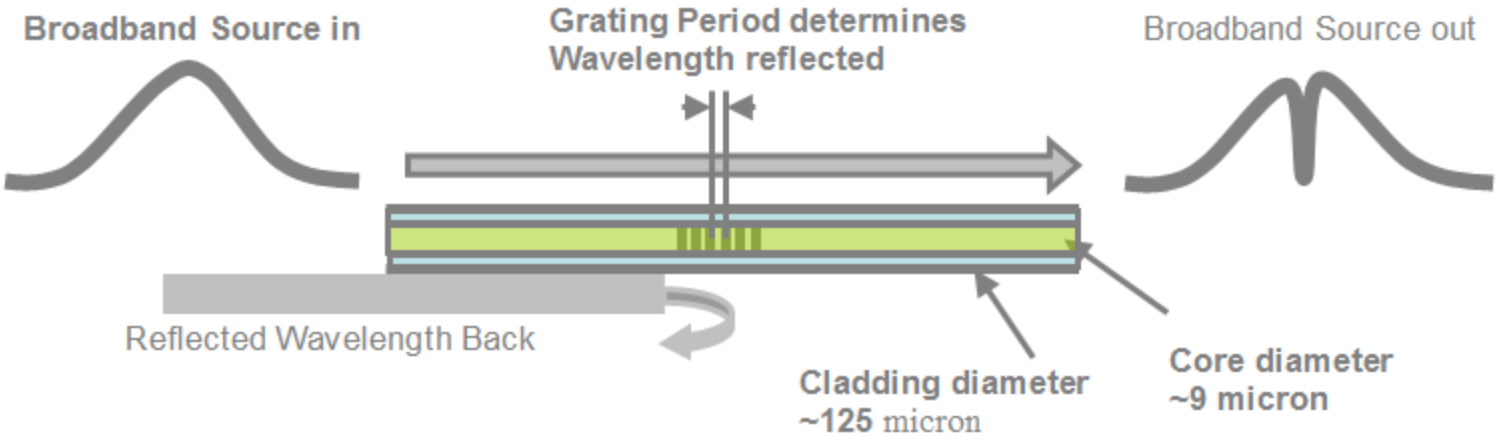
Troika - Gulf of Mexico

First use of fiber optic sensors on a subsea pipeline to monitor pressure, strain and vibration in external casing pipe bundle during fabrication.

Bullwinkle Platform



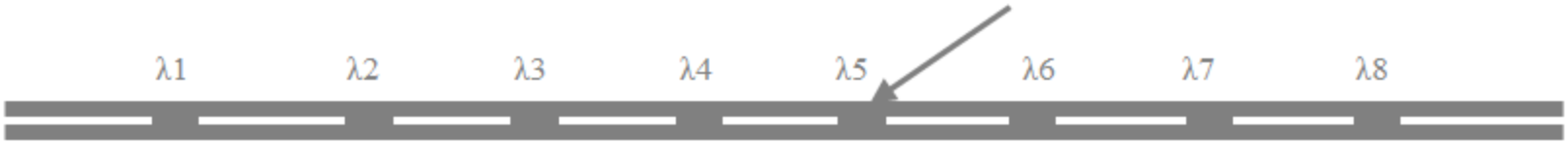
Fiber Bragg Gratings



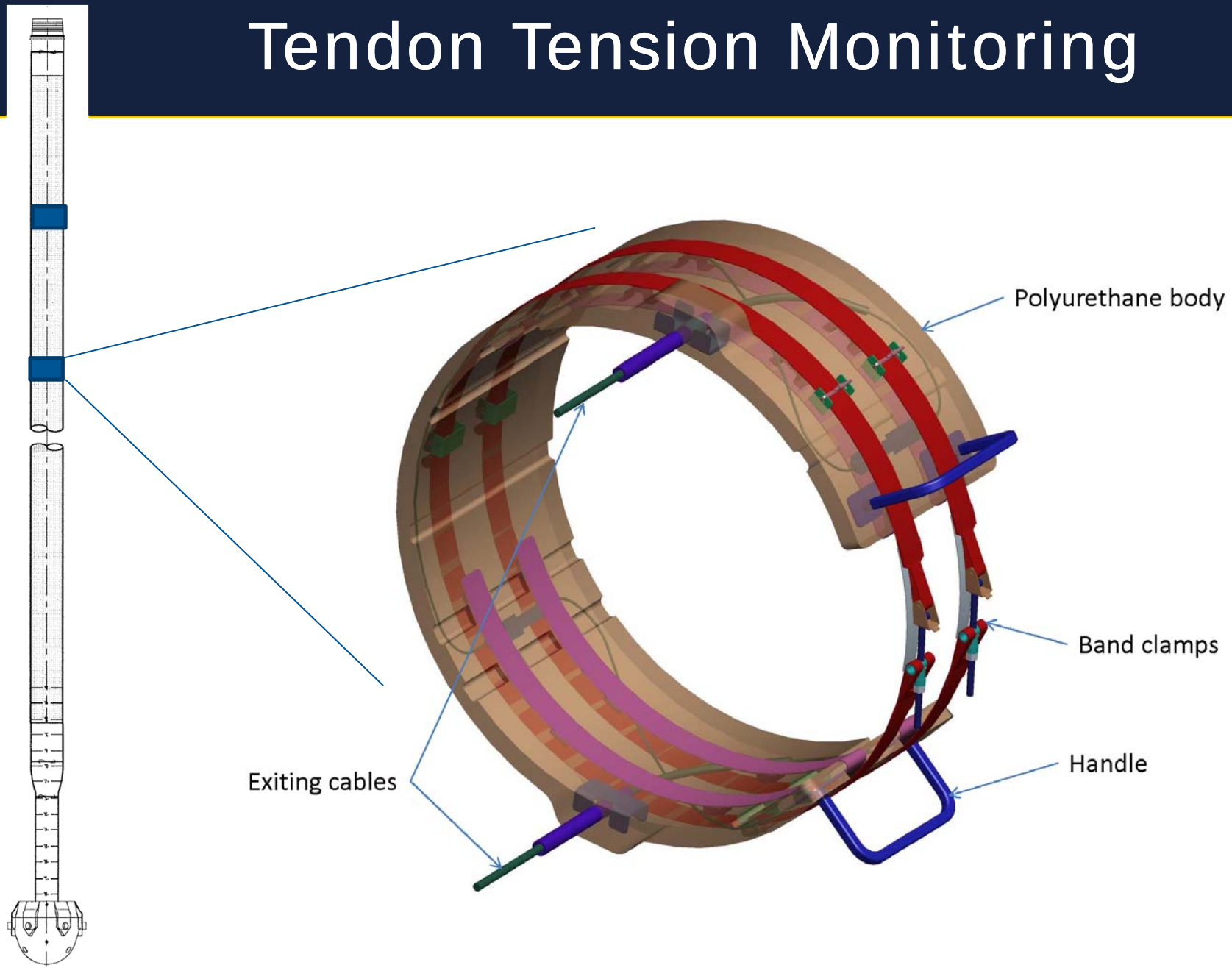
Relationship between Strain (ε) and Change in Wavelength ($\Delta\lambda_b$)

$\Delta\lambda_b / \lambda_b = (1-p_e)\varepsilon$, where p_e is the photoelastic constant for glass and λ_b is the base wavelength

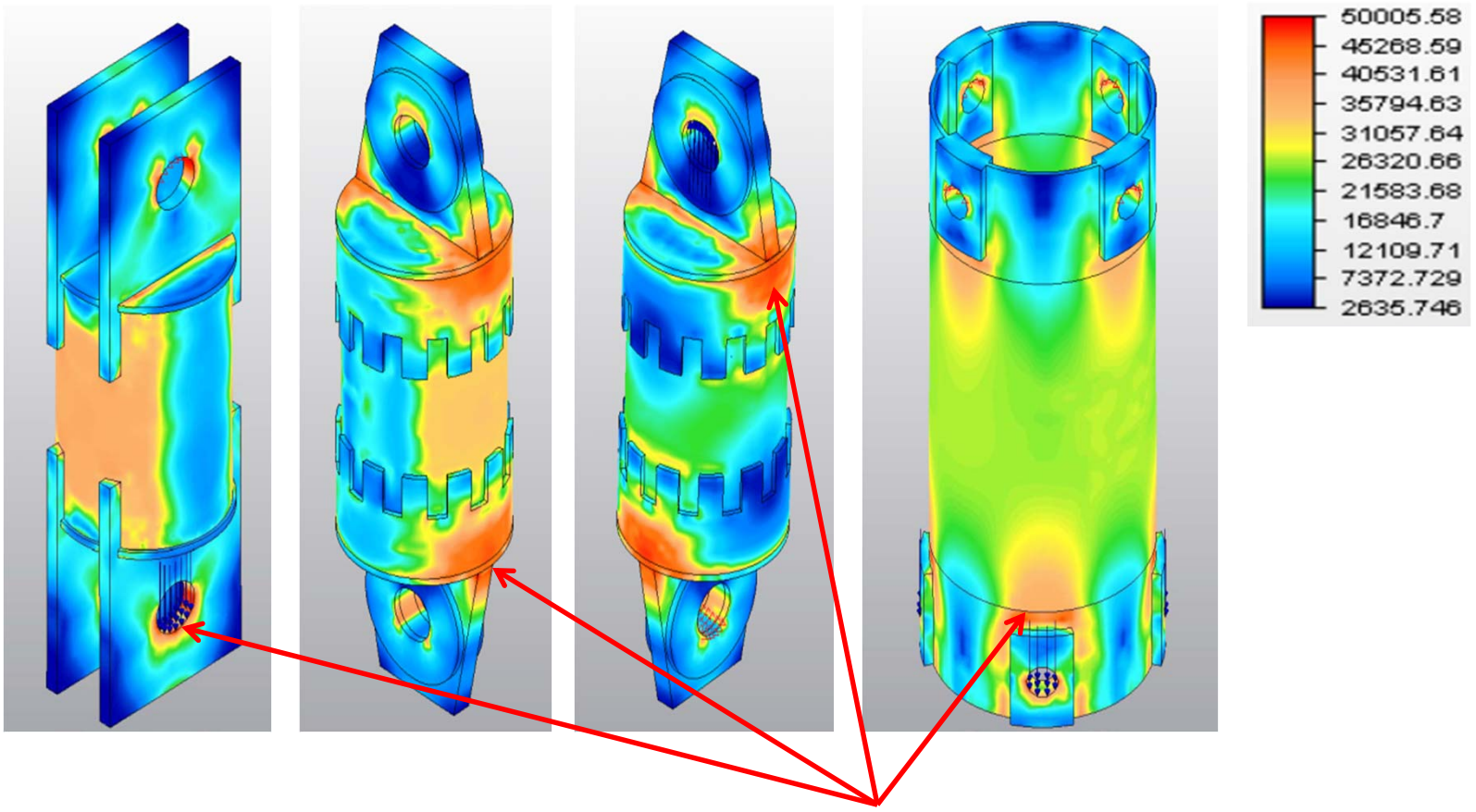
Multiple Gratings (sensors) can be placed on a single fiber, enabling high sensor count per fiber channel.



Tendon Tension Monitoring

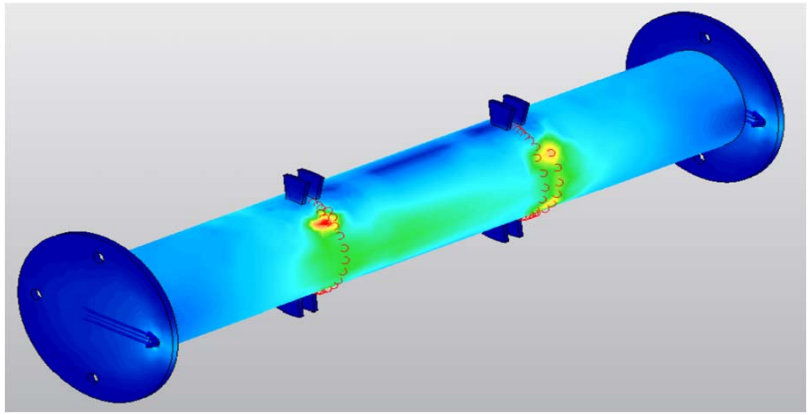


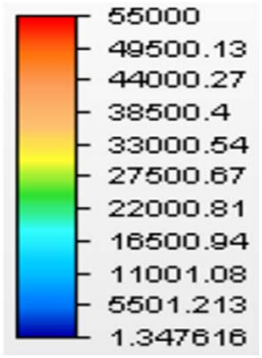
Adhesion Testing for Subsea Installation

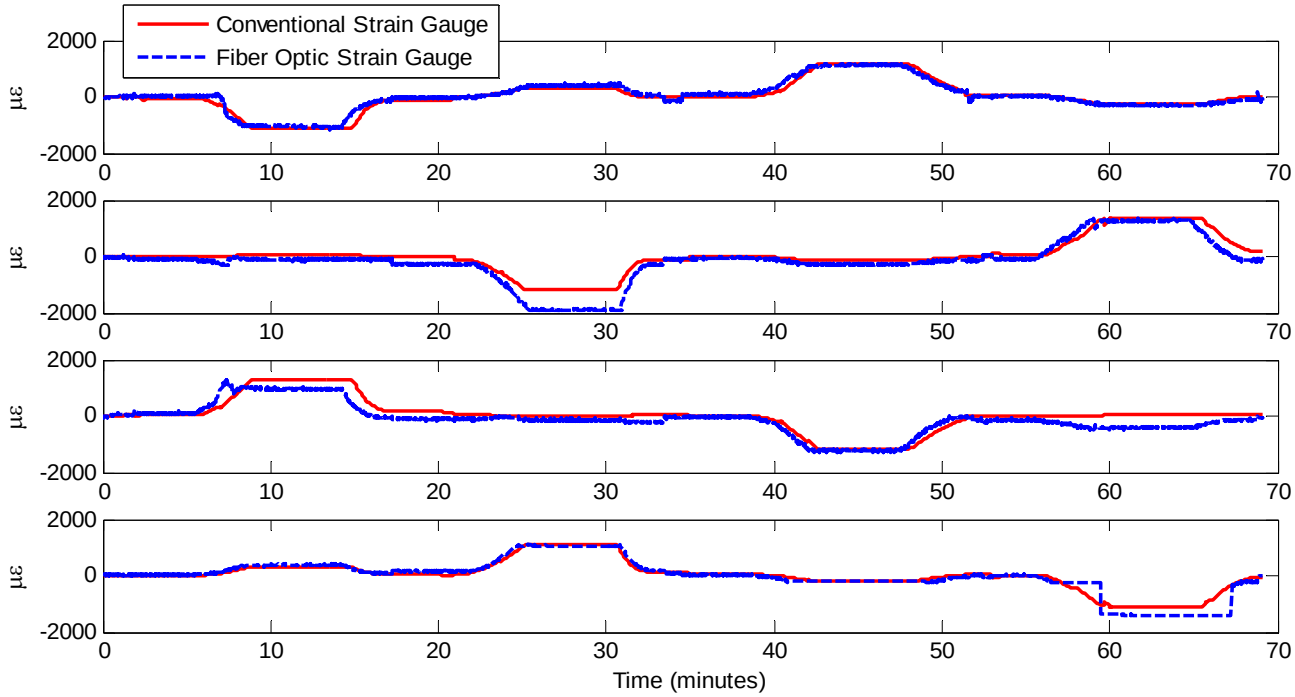


FEA Test Article Pipe for Tension Testing
Avoid Local Areas of Inelastic Deformation (>50 ksi)

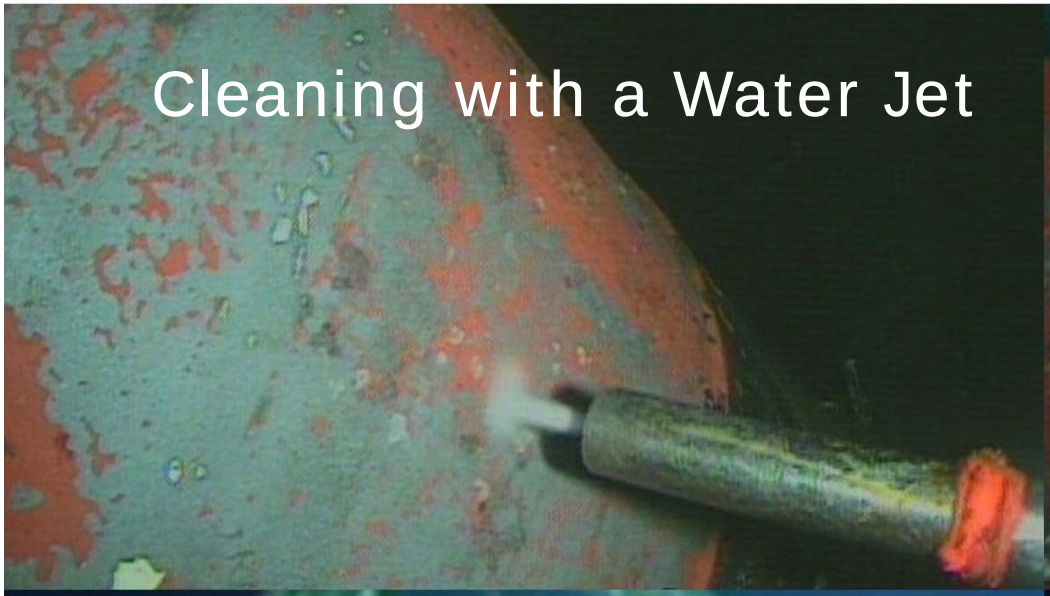
Uniform Loading in 4 Point Bending

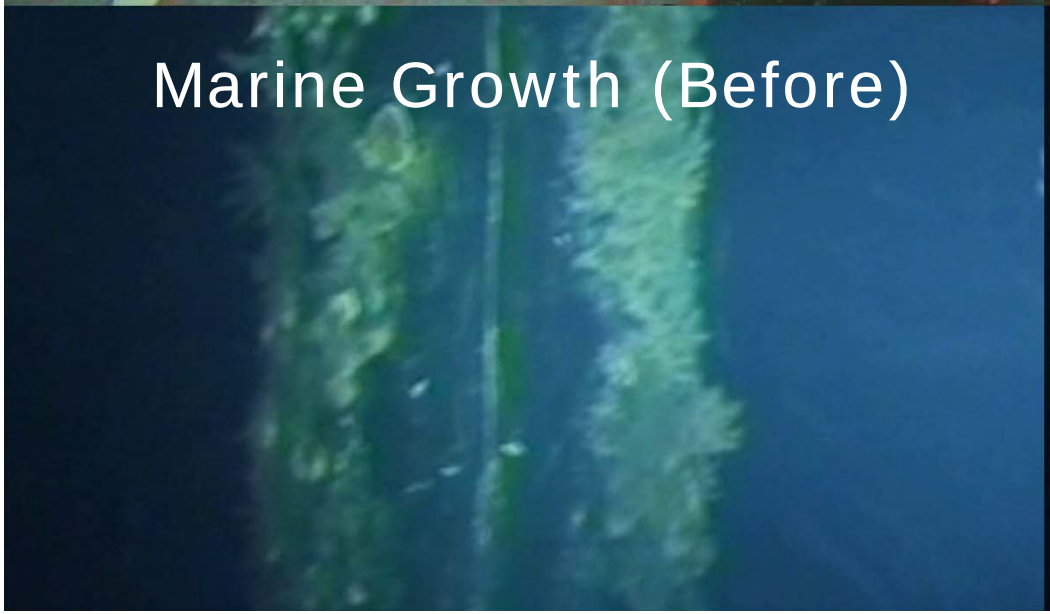




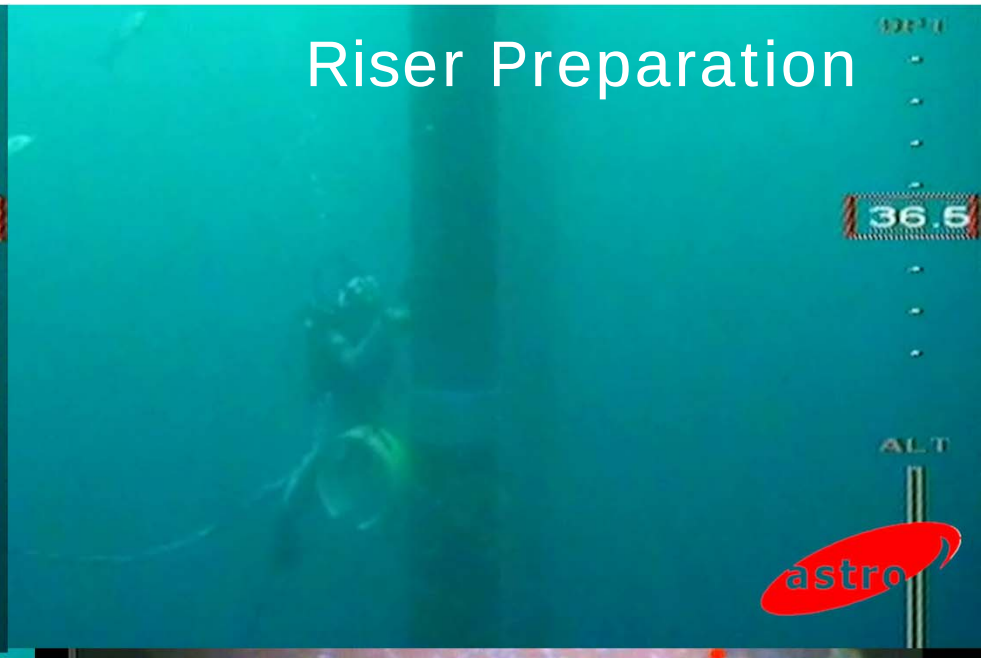


Tendon Band Preparation

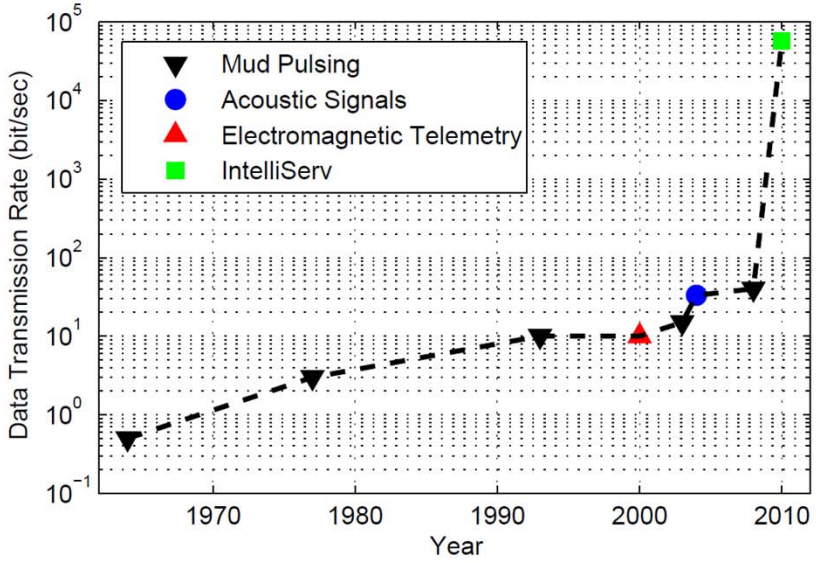


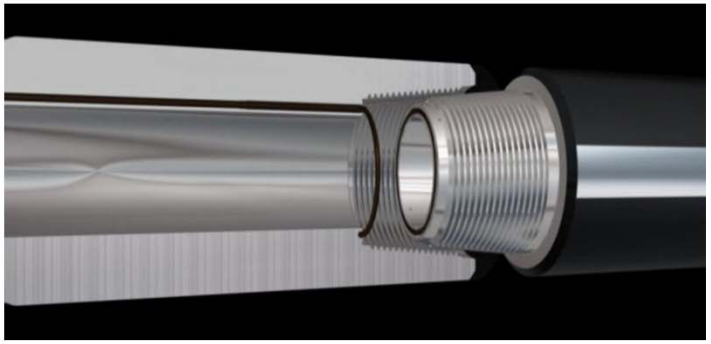


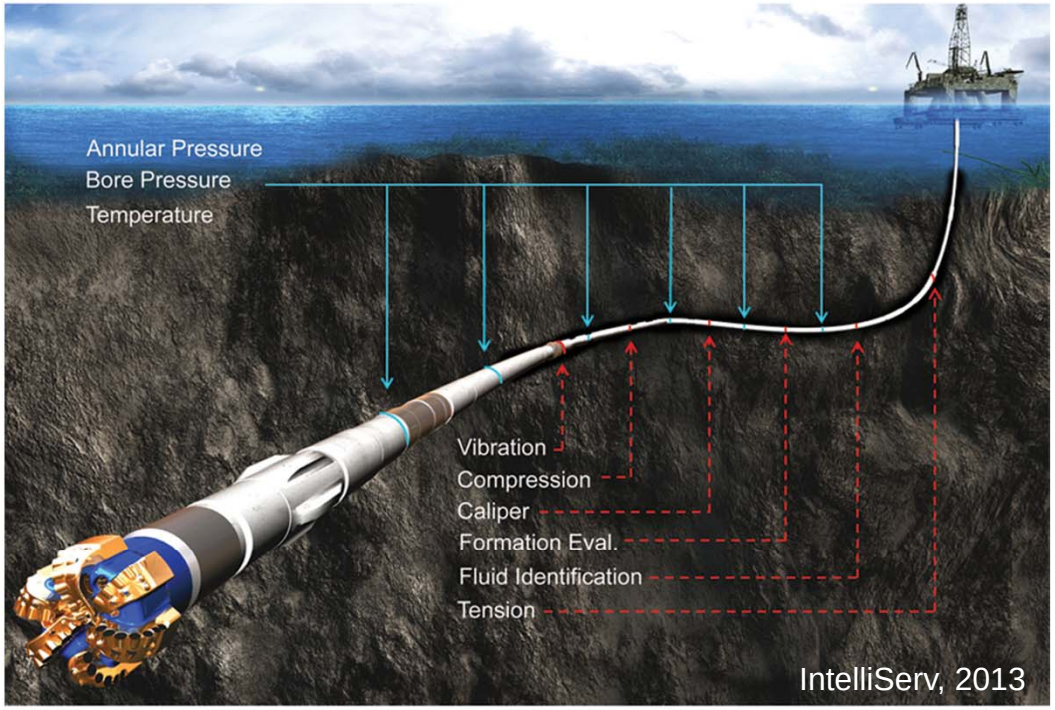
Diver Installation



Drilling and Production







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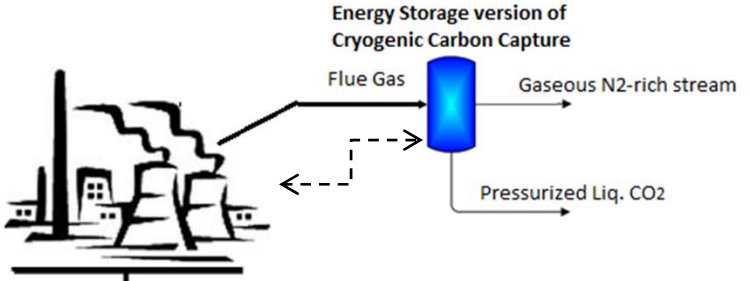
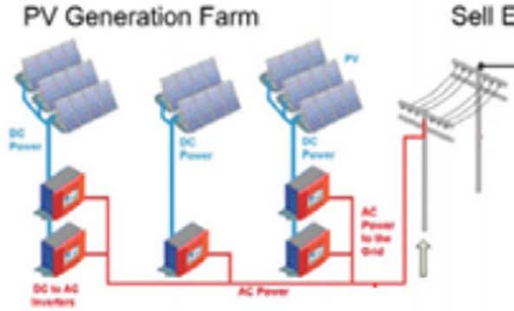
Smart Grid Optimization

Smart grid integration with solar, wind, coal, biomass, natural gas, and energy storage

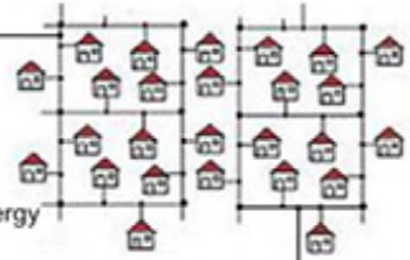




Sell Energy

Sell Energy | Buy Energy

Sell Energy



Sell Energy

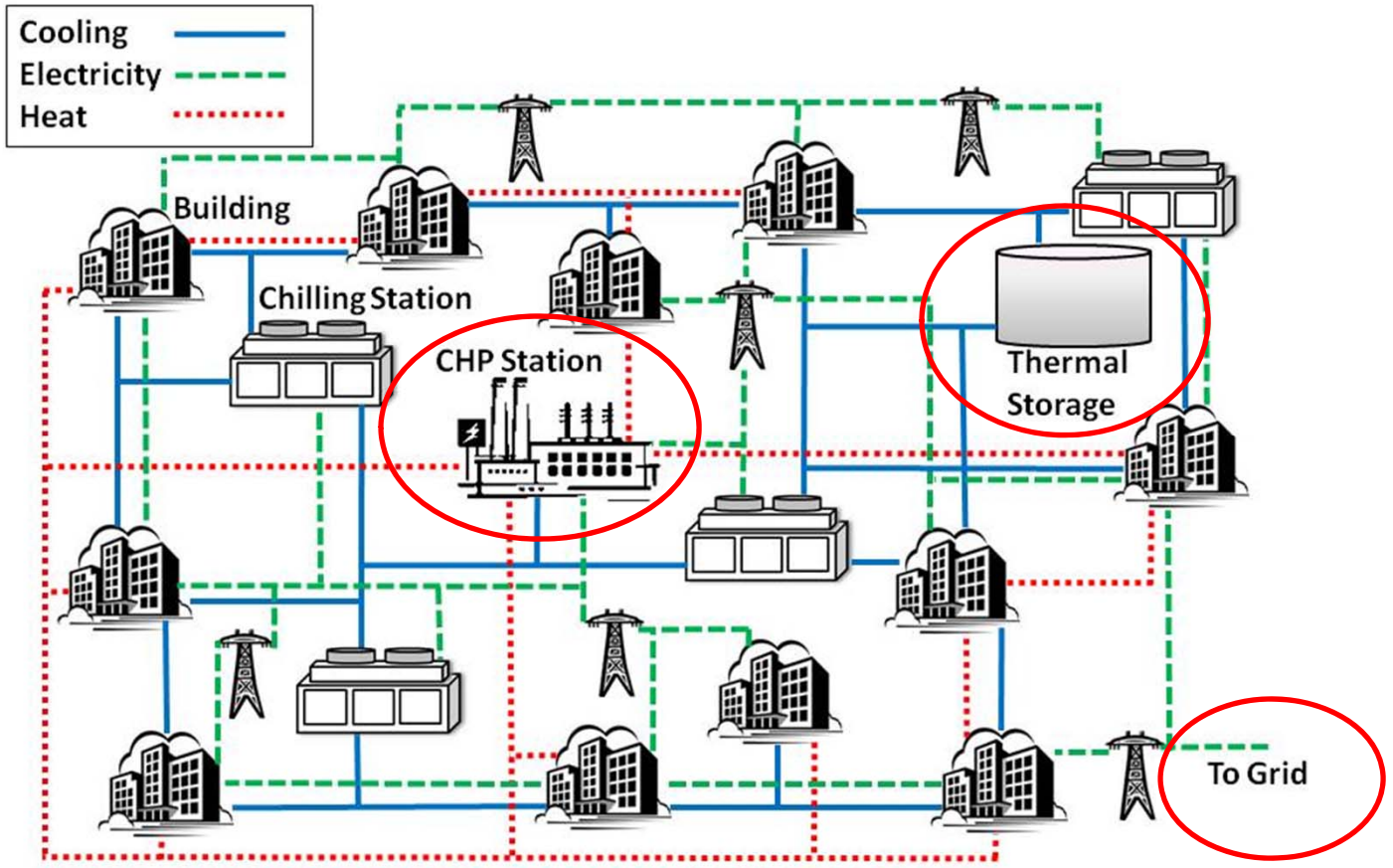
Local Transmission Grid

Residential Network

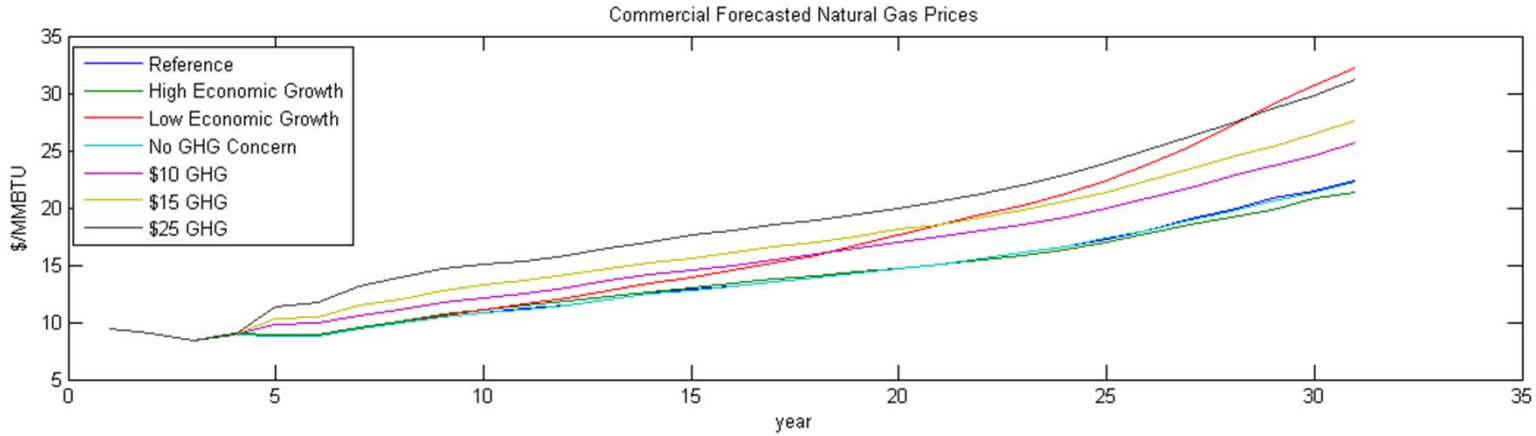
Sell Energy

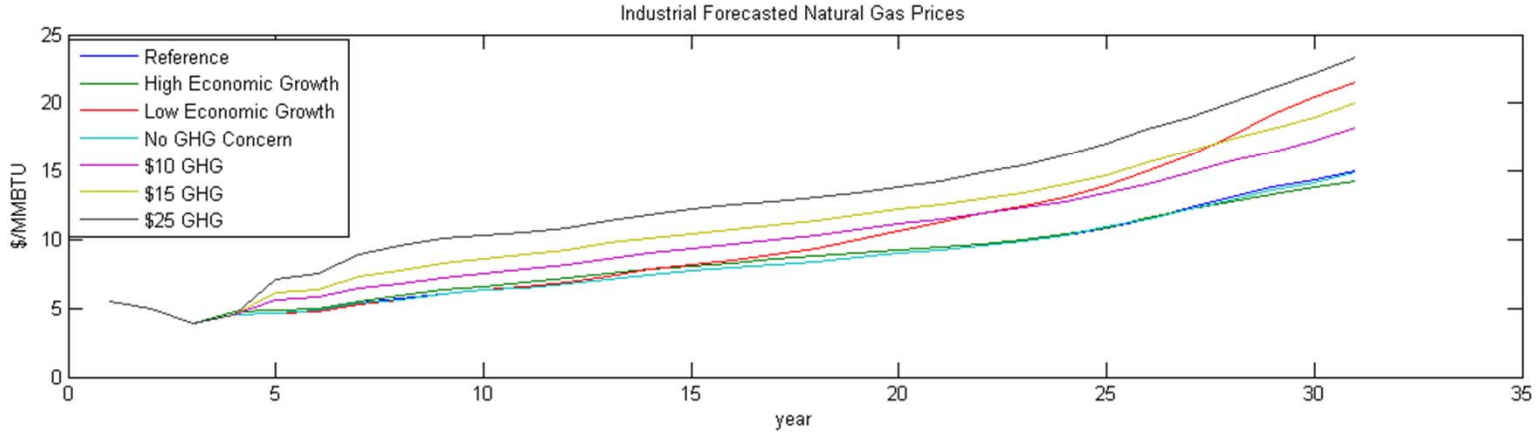
Nuclear integration with petrochemical production, processing, and distribution

District Heating and Cooling

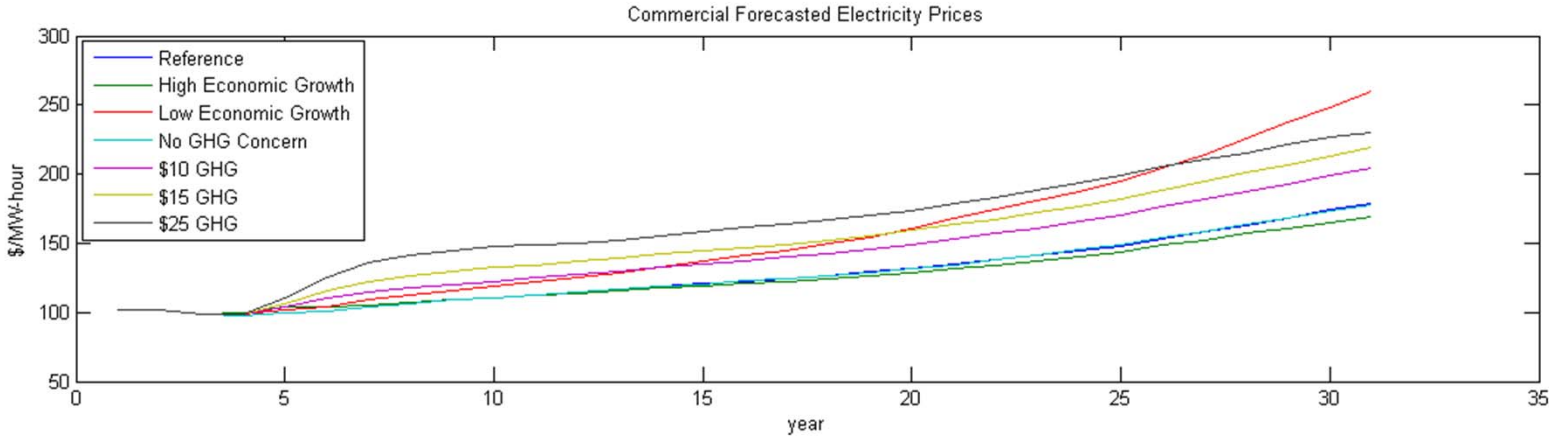


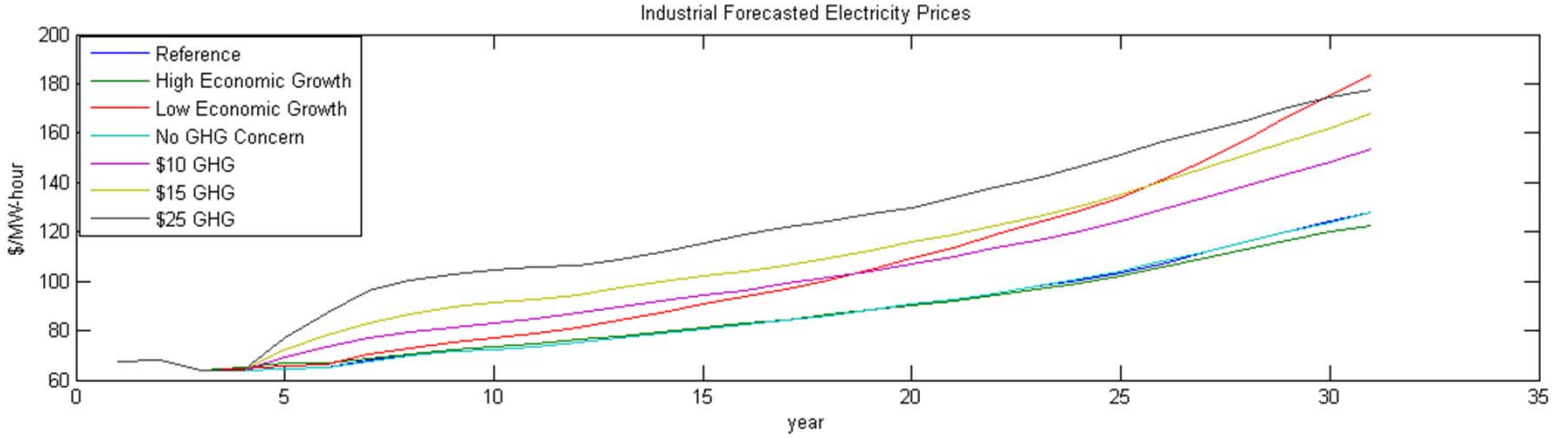
Uncertainty in Natural Gas Prices



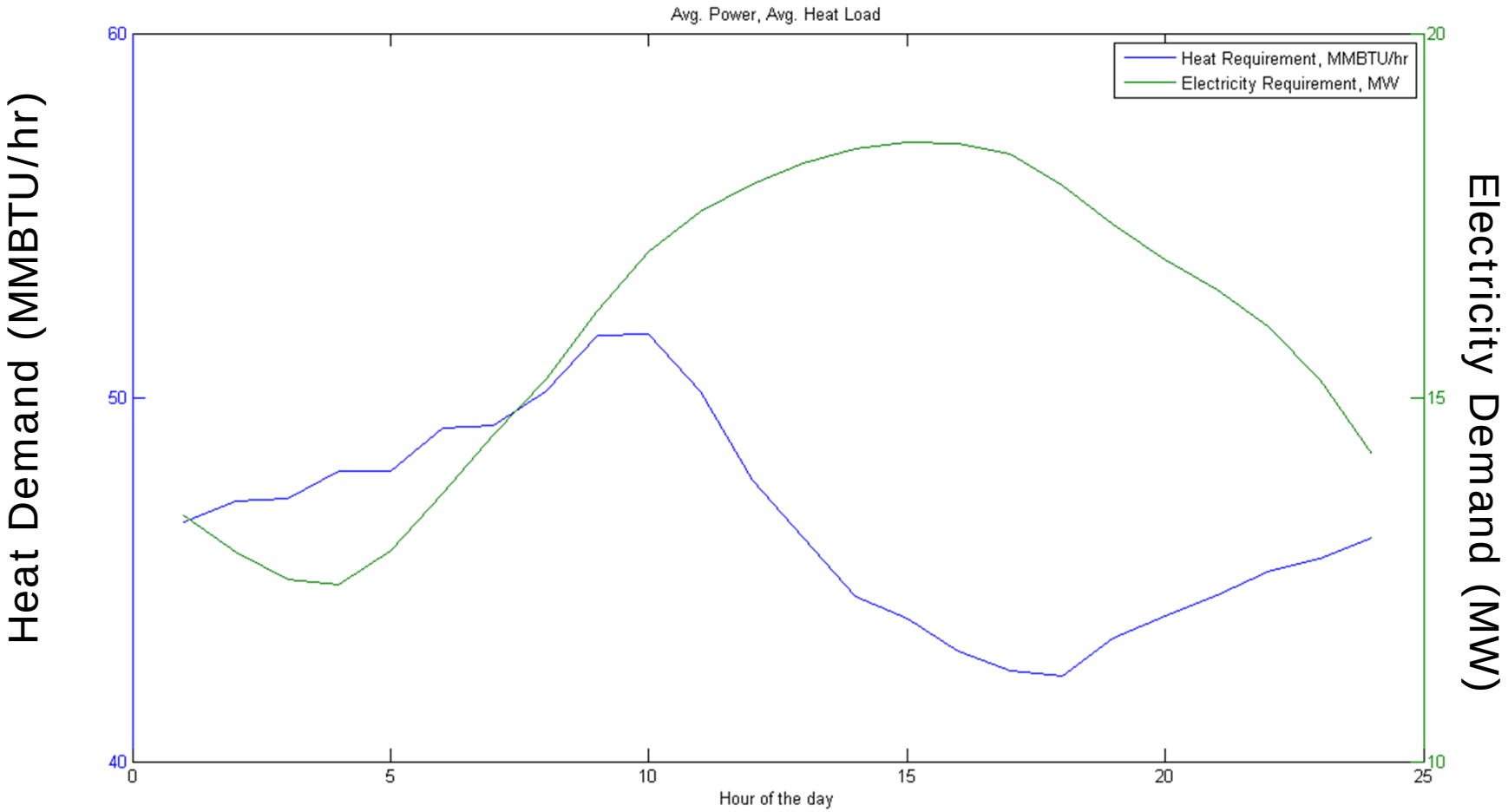


Uncertainty in Electricity Prices



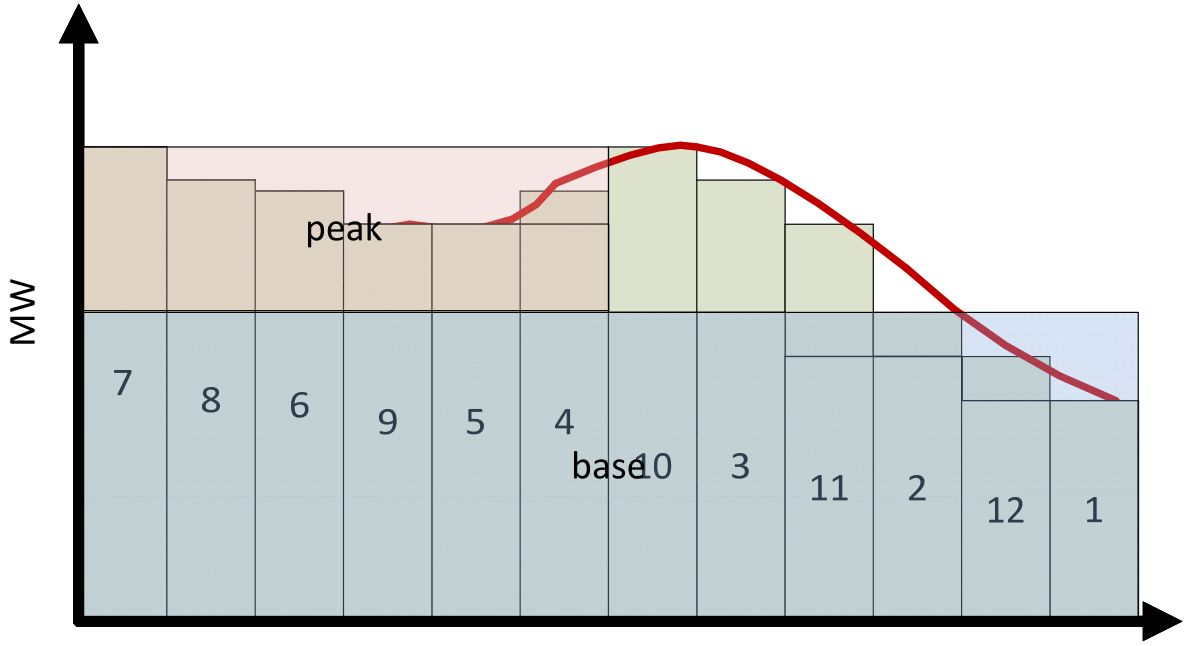


Dynamic Model for Dynamic System

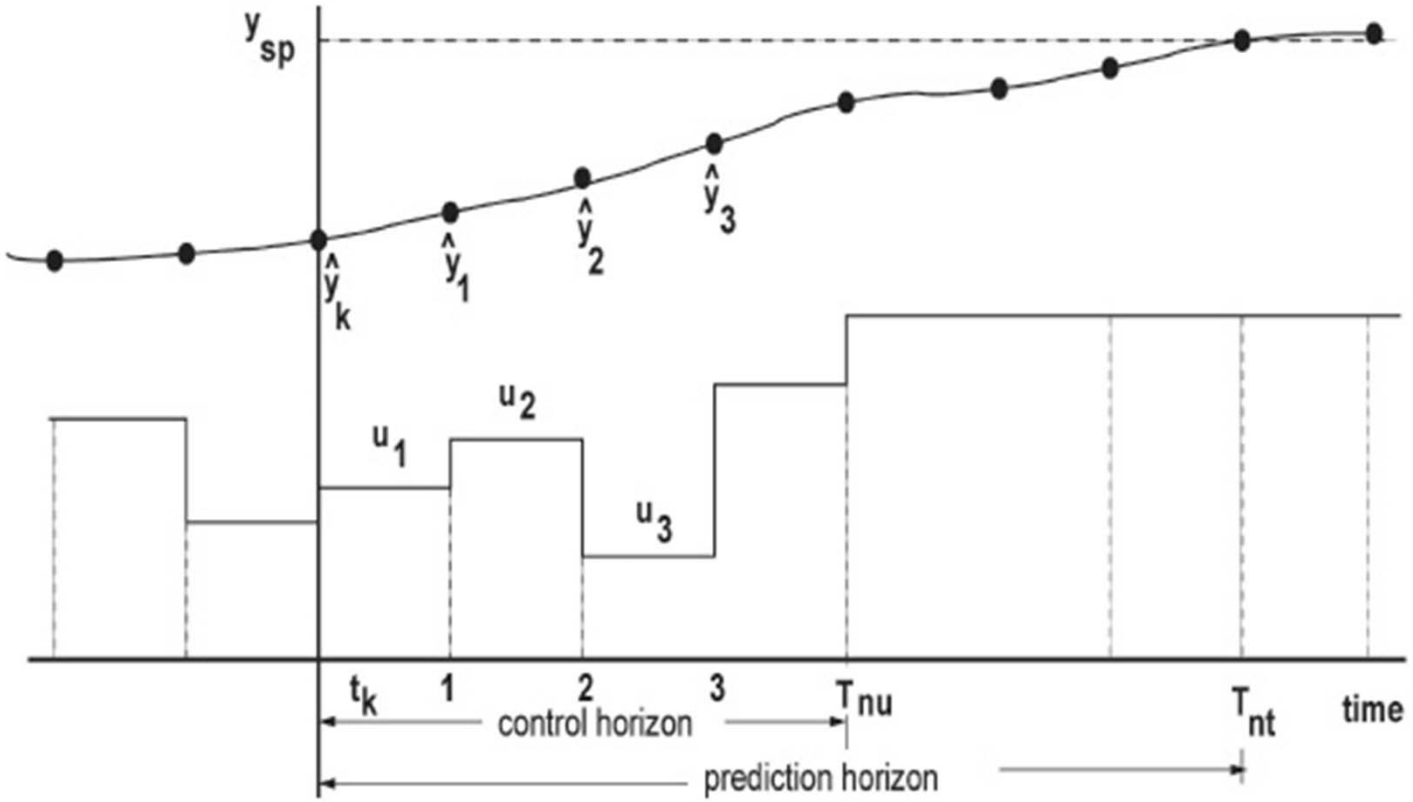


Simplifying System

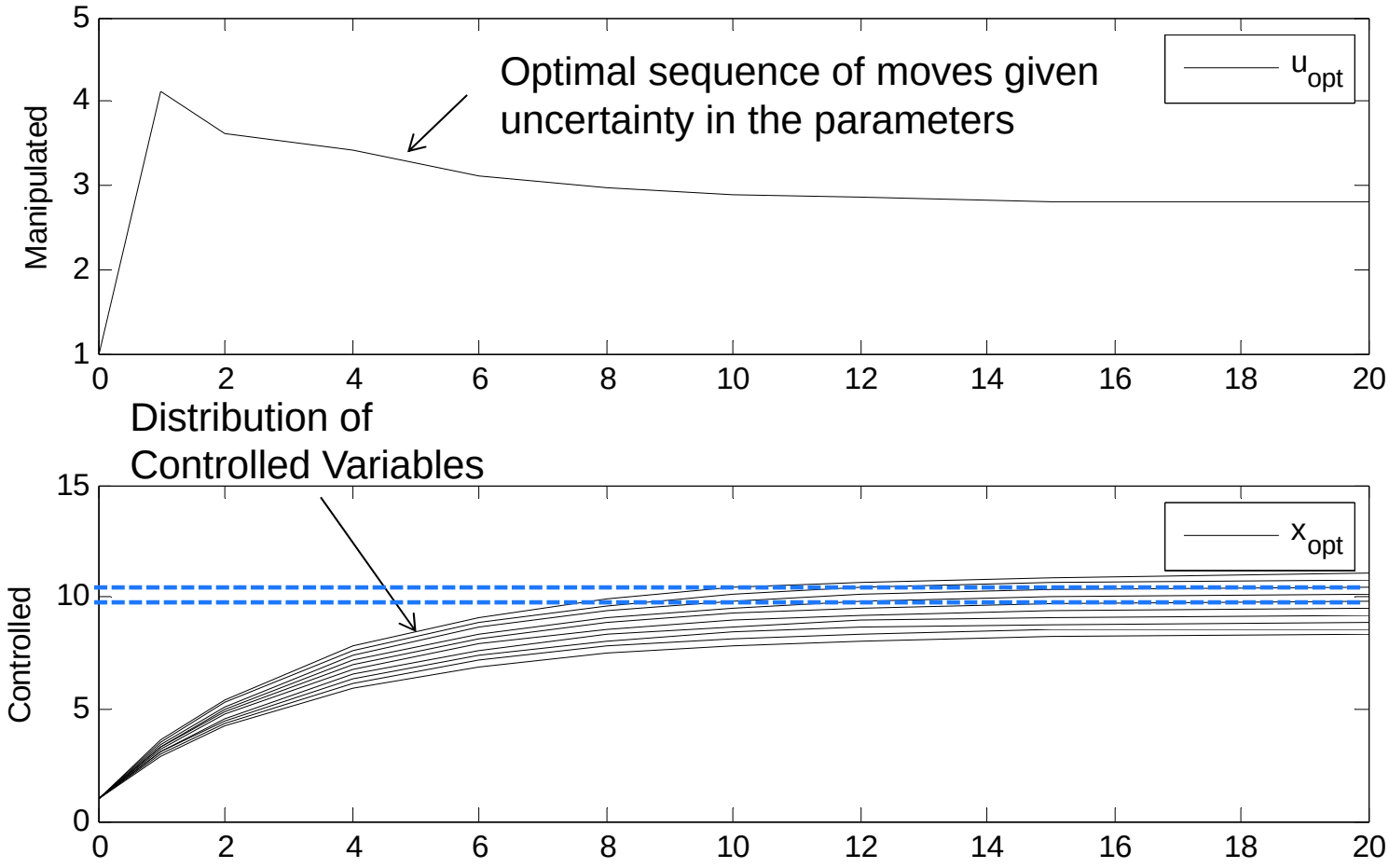
- Create Model:
- Electric and Heating Demand Model (winter and summer)



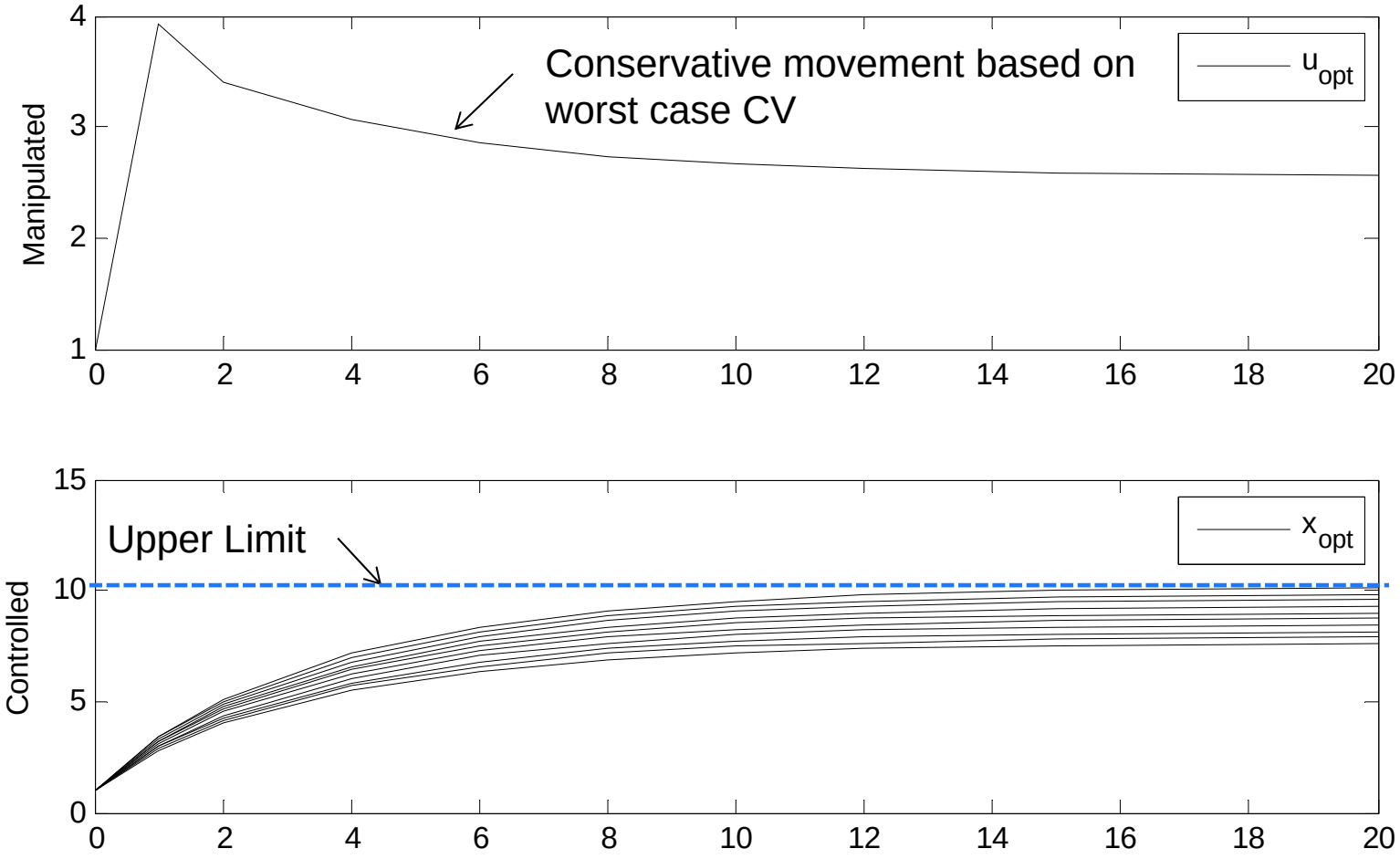
Model Predictive Control Approach



Optimize to a Target Range



Optimize to a Limit



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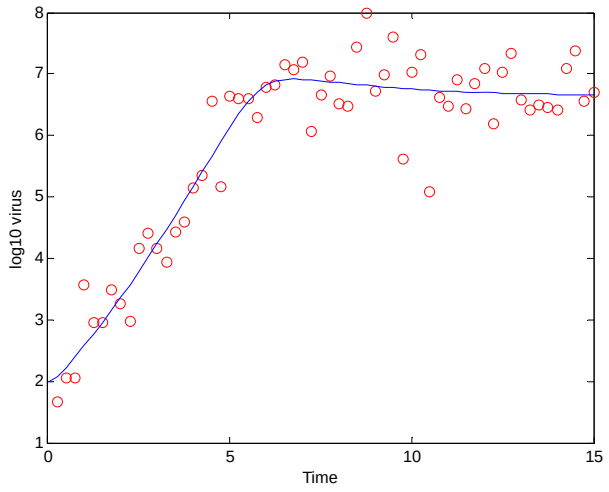
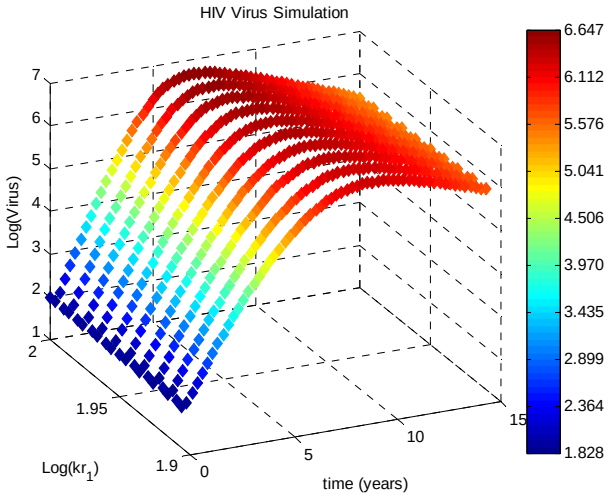
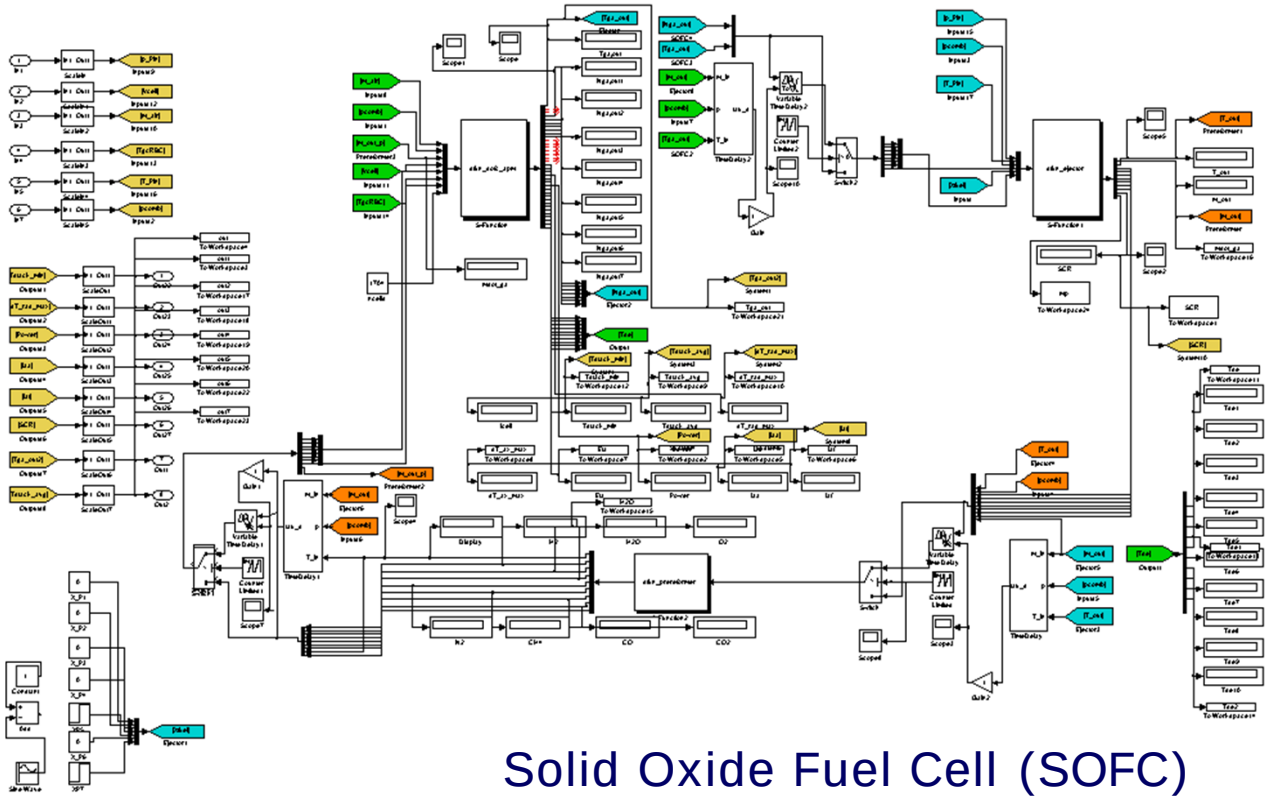
Systems Biology

- Objective: Improve extraction of information from clinical trial data
- Dynamic data reconciliation
  - Dynamic pharmacokinetic models (large-scale)
  - Data sets over many patients (distributed)
  - Uncertain parameters (stochastic)





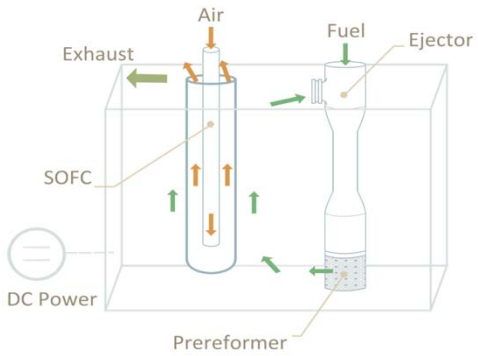
Dynamic Energy System Tools

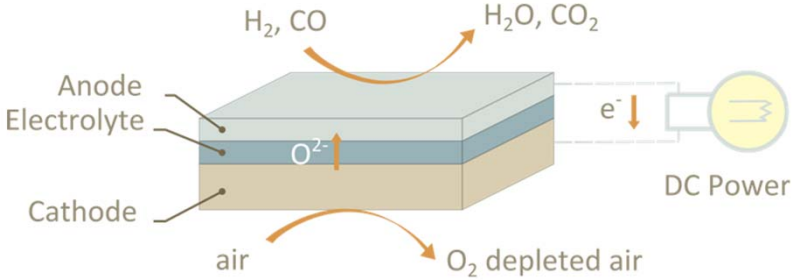


Toolbox for Object Oriented Modeling in MATLAB, Simulink, and Python

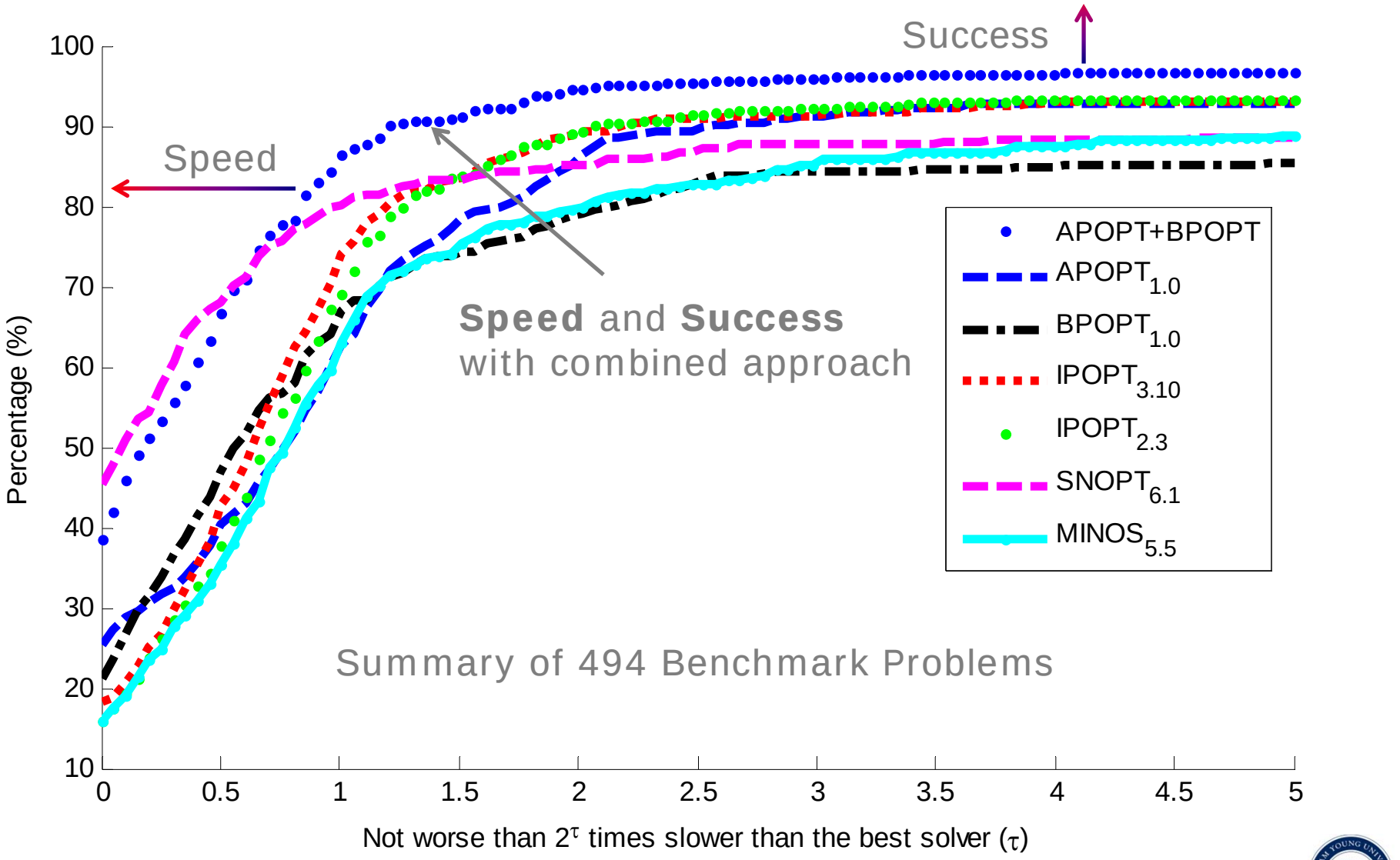
Advanced tools are required for collaborative modeling and high performance computing

Solid Oxide Fuel Cell (SOFC)





Optimization Benchmark



Survey of DAE Solvers

Software Package	Max DAE Index	Form	Adaptive Time Step	Sparse	Partial-DAEs	Simultaneous Estimation / Optimization
APMonitor	3+	Open	No	Yes	Yes	Yes
DASPK / CVODE / Jacobian	2	Open	Yes	No	No	No
gProms	1 (3+ with transforms)	Open	Yes	Yes	Yes	No
MATLAB	1	Semi-explicit	Yes	No	No	No
Modelica	1	Open	Yes	Yes	No	No

DAE = Differential and Algebraic Equation

Conclusions

- Powerful insights can be gained from modeling and data reconciliation over long periods of historical data
- When data, modeling, and optimization are combined, hidden savings are discovered through dynamic optimization
- Simulation and optimization can give realistic options to evaluate risks and rewards
- Simulation results can then be directly applied in practice to continuously monitor and optimize

Acknowledgments














Extra Slides