APM Python / MATLAB Tutorial

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Outline

- Overview of Advanced Process Monitoring (APM)
- Recent Applications of APM
  - Solid Oxide Fuel Cells
  - Boundary Management of a Thermal Oxidizer
  - Virus and Biological Modeling
  - Unmanned Aerial Vehicles
- Tutorial Examples
  - Parameter estimation with PRBS data
  - Nonlinear control
  - Optimization
  - Parallel processing
- Getting Started with APM

Overview of APMonitor

APMonitor Modeling Language

The APMonitor Modeling Language is optimization software for differential and algebraic equations. It is coupled with large-scale nonlinear programming solvers for data reconciliation, real-time optimization, dynamic simulation, and nonlinear predictive control. It is available as a free web service or for commercial licensing.

Try Example Optimization Problems - Demo
Browse or modify example problems to start solving nonlinear programming problems with up to 10 million variables through a web-interface.

Documentation
APMonitor Documentation Wiki gives details of the modeling language and example applications. Compare to other popular modeling languages.

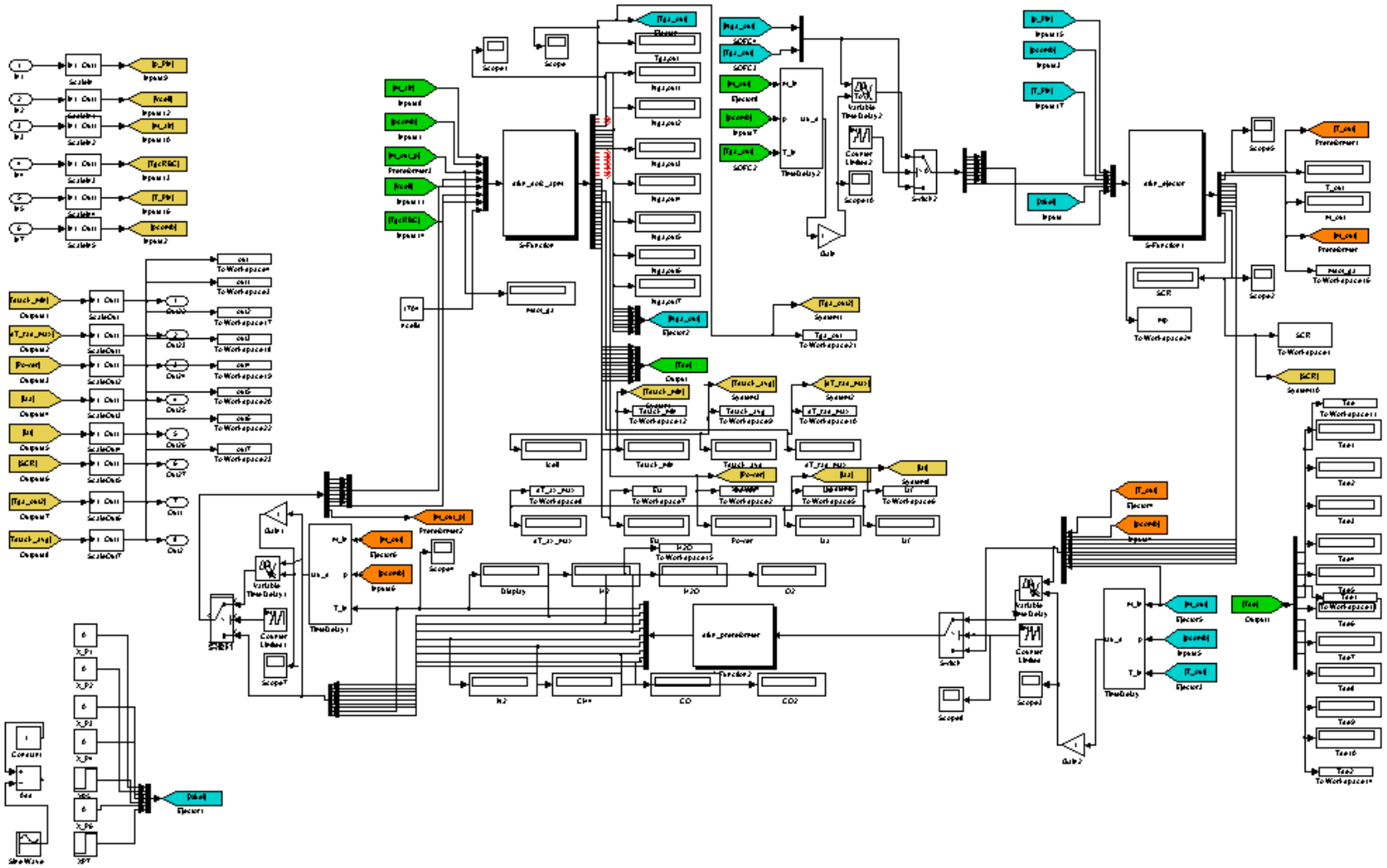
Discussion Forum and Webinars
Users share experiences and collaborate through an online discussion forum and regularly scheduled webinars.

Premium Account Login
Registered users manage applications, view optimization results, and collaborate with other users.

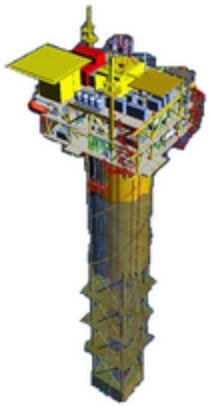
APM Python Interface
Python gives users an open-source option for solving nonlinear programming problems with a growing community of users.

APM MATLAB Interface - Demo
MATLAB provides a powerful mathematical scripting language to improve the capability of optimization solutions.

Comprehensive Model Capability (SOFC)



Remote Viewing and Control



Pressure Overview

All Pressures (psig) last 24 hrs

All Pressures (psig) last month

Temperature Overview

All Temperatures (°F) last 24 hrs

All Temperatures (°F) last month

FLMT #2 (18 miles)

T °F

Temperature (°F) last 24 hrs

Temperature (°F) last month

P psig

Pressure (psig) last 24 hrs

Pressure (psig) last month

FLMT #1 (36 miles)

T °F

Temperature (°F) last 24 hrs

Temperature (°F) last month

P psig

Pressure (psig) last 24 hrs

Pressure (psig) last month

FLET (57 miles)

T °F

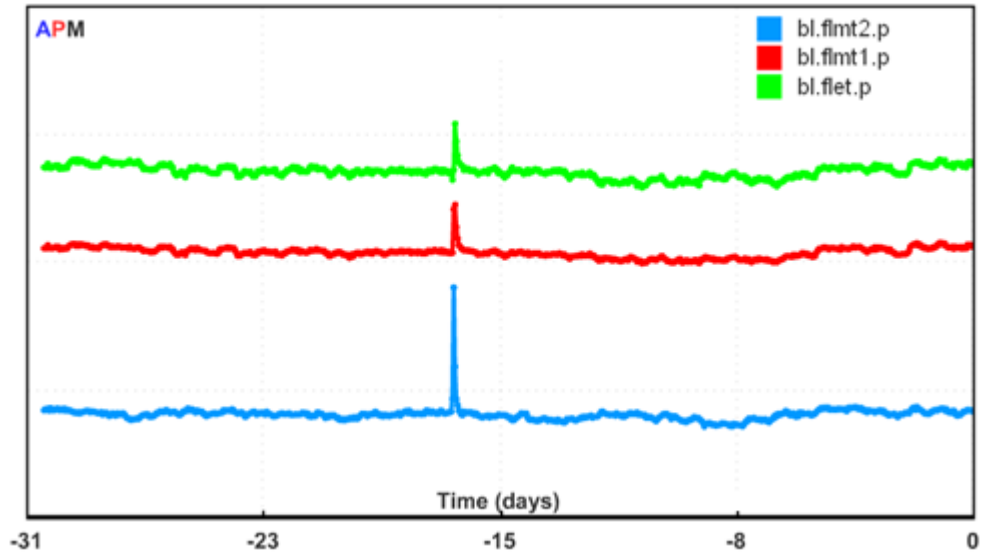
Temperature (°F) last 24 hrs

Temperature (°F) last month

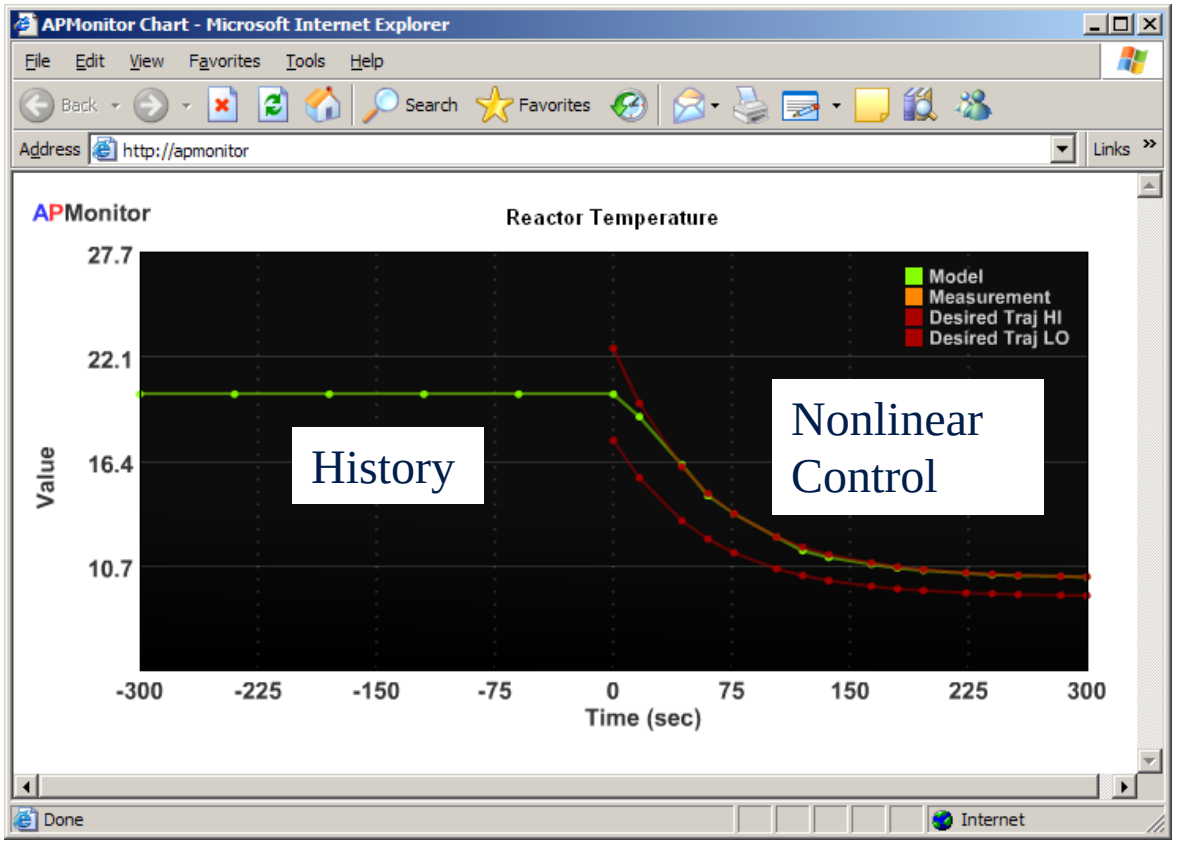
P psig

Pressure (psig) last 24 hrs

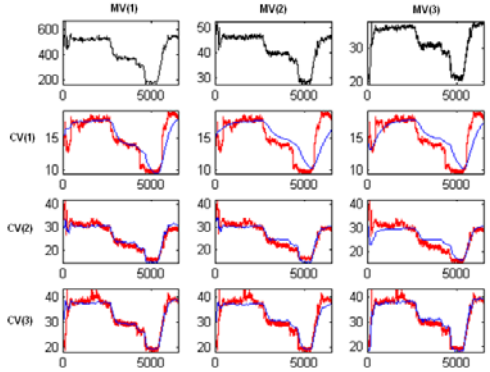
Pressure (psig) last month



Combine Empirical and Fundamental



Empirical Models



First Principles Models

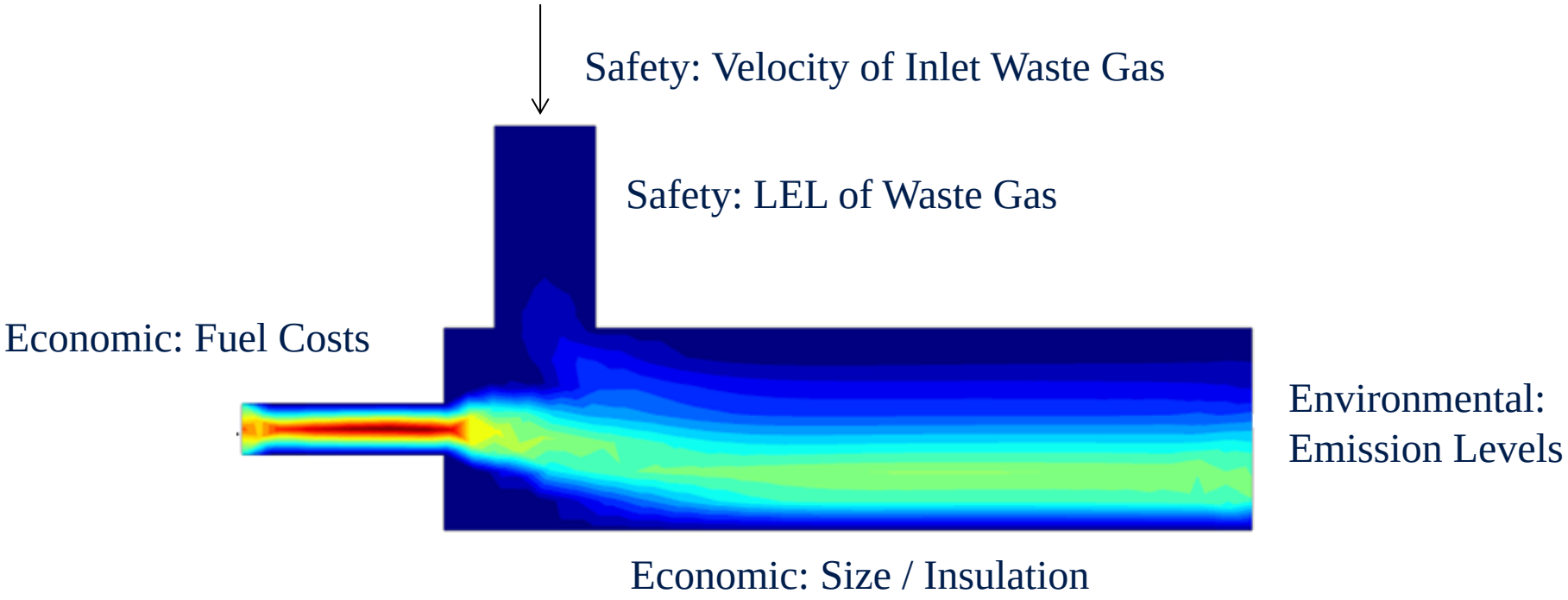
$$0 = f\left(\frac{\partial x}{\partial t}, x, u\right)$$

$$0 = g(x,u)$$

$$a \le h(x,u) \le b$$

RTO: Dynamic Optimization

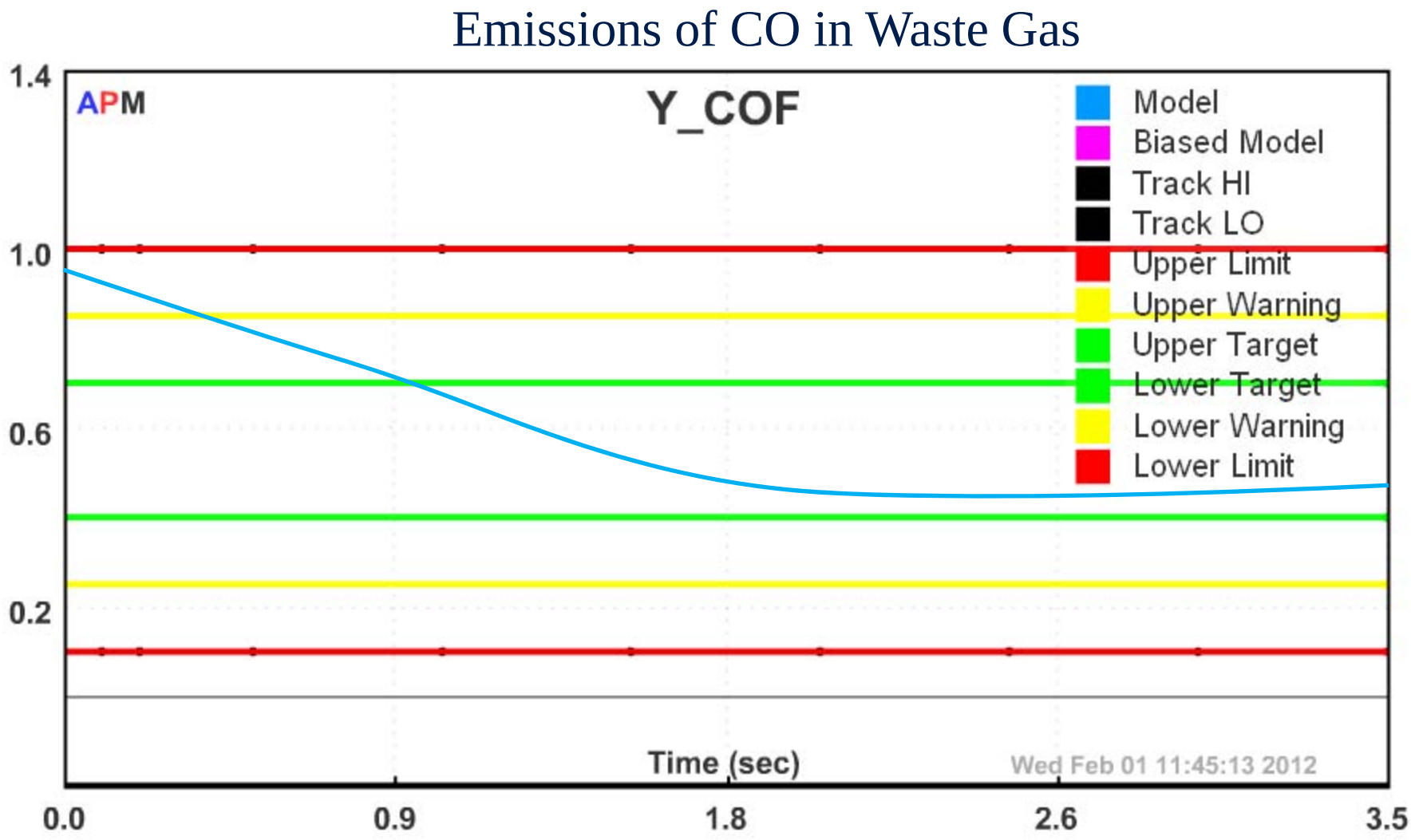
- Model predicts boundary values for safe, responsible, and economic operating conditions



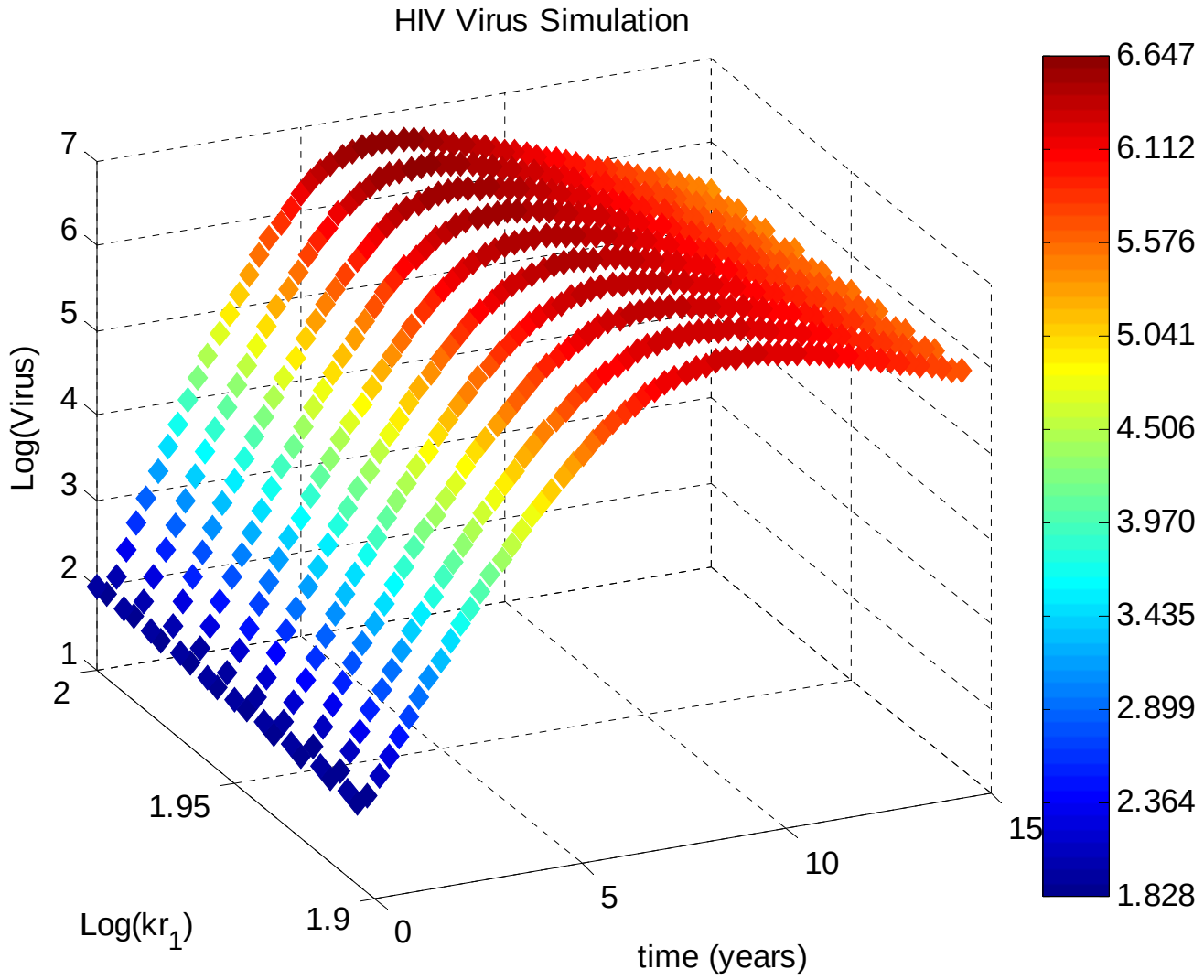
Safety Constraints

- LEL (lower Explosion Limit)
  - Inlet gas composition < 25% of LEL
- Minimum oxygen concentration
- Flashback Velocity
  - Inlet gas velocity > minimum safety limit
- Failure to observe safety constraints may lead to deflagration of waste gases back to operating units

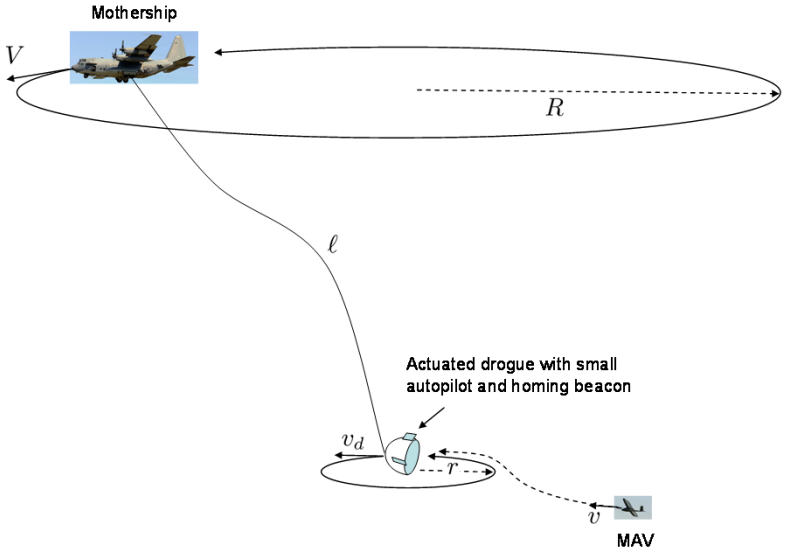
Monitor Critical Parameters

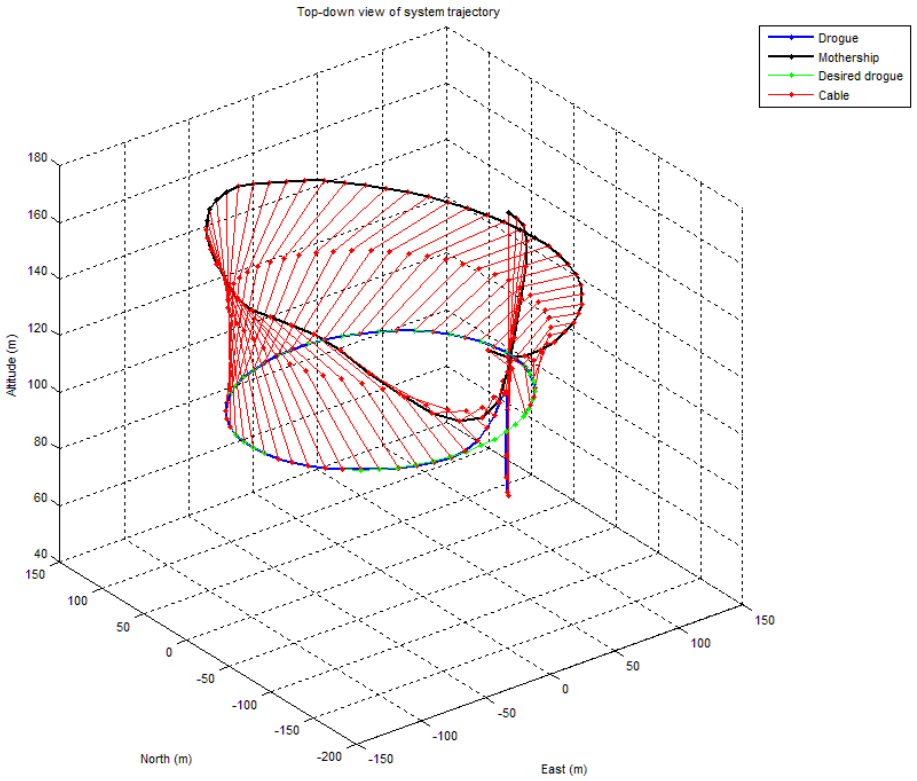


Parallel Processing with APM



Dynamic Optimization of UAV Flight





Tutorial Examples

- Tutorial Examples
  - Parameter estimation with PRBS generated data
  - Nonlinear control
  - Optimization
  - Parallel processing
- Download APM Python/MATLAB from APMonitor.com


APM MATLAB


APM Python

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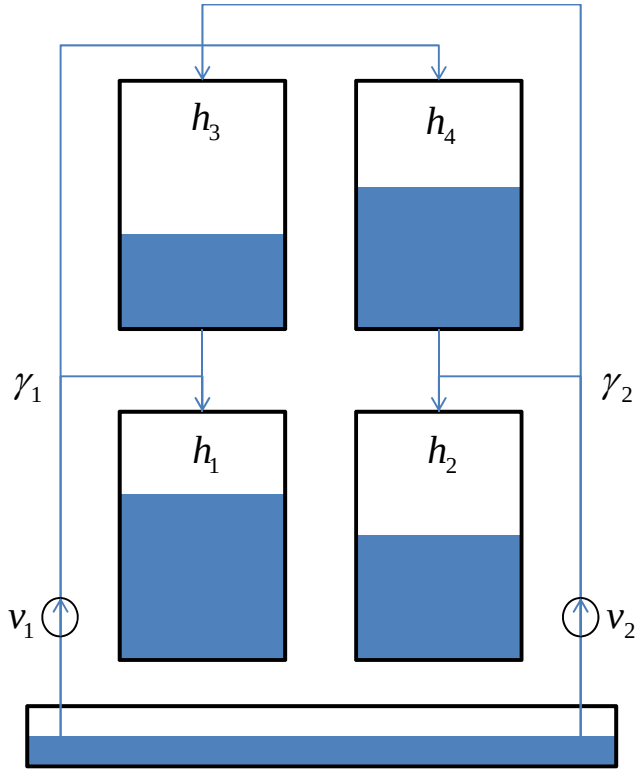

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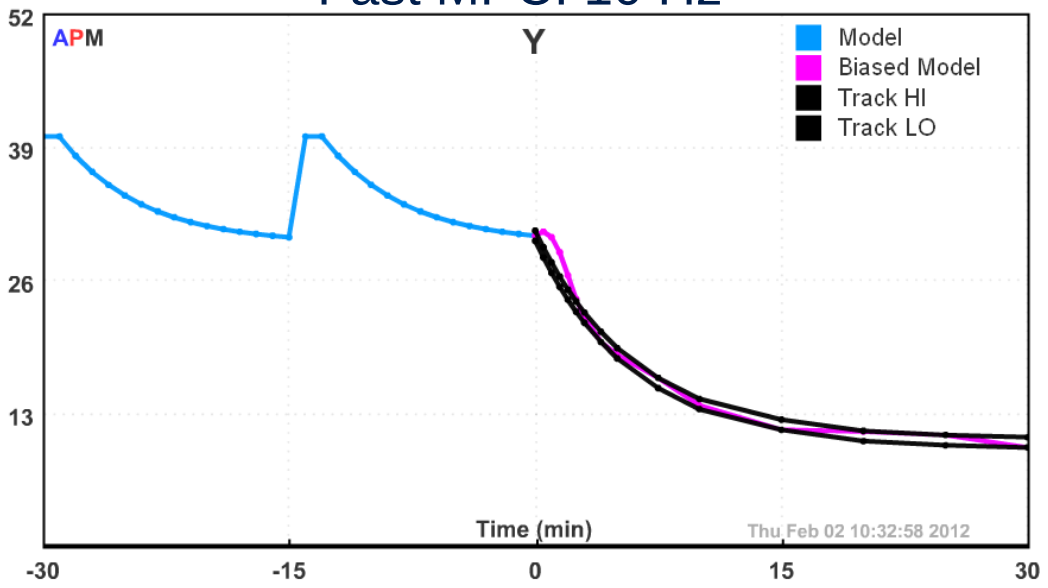
Fast MPC: 10 Hz



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$$
\begin{aligned}
\min \quad & x_1 x_4 (x_1 + x_2 + x_3) + x_3 \\
\text{s.t.} \quad & x_1 x_2 x_3 x_4 \geq 25 \\
& x_1^2 + x_2^2 + x_3^2 + x_4^2 = 40 \\
& 1 \leq x_1, x_2, x_3, x_4 \leq 5
\end{aligned}
$$

$$x_0 = (1, 5, 5, 1)$$

Name	Lower	Value	Upper
ss.x[1]	1.0000E+00	1.0000E+00	5.0000E+00
ss.x[2]	1.0000E+00	4.7430E+00	5.0000E+00
ss.x[3]	1.0000E+00	3.8212E+00	5.0000E+00
ss.x[4]	1.0000E+00	1.3794E+00	5.0000E+00
ss.slk_1	0.0000E+00	1.3237E-08	---

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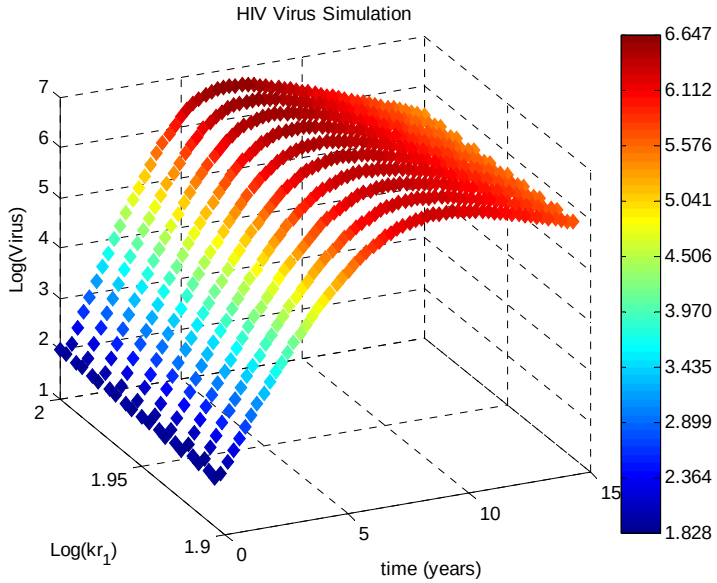

Getting Started with APM

- APM as a Free Web-Service
  - Academic or Industrial use
- APM User's Group
  - E-mail Group: groups.google.com/group/apmonitor
  - Bi-weekly Webinars
  - Support e-mail: support@apmonitor.com
- Corporate Licensing Options
  - Linux Cluster Version
  - Windows Server Version