



Leveraging the PI System[®] to Build a Biologics Analytics Tool for Laboratory-Scale Bioreactor Data

Presented by **Sohan Patel**



Bristol-Myers Squibb

Agenda

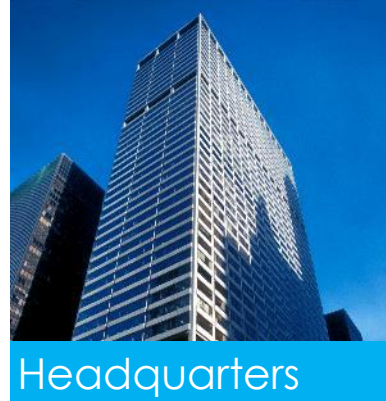
- Bristol-Myers Squibb Overview
- Business Challenge
- Step 1: Structure Data
 - PI Web API
- Step 2: Leverage Structured Data
 - PI Integrator for Business Analytics
- Example Biologics Analytics Tool Visualizations
- Next Steps
- Summary

Bristol-Myers Squibb is a global biopharmaceutical company whose mission is to discover, develop and deliver innovative medicines that help patients prevail over serious diseases.

Bristol-Myers Squibb at a Glance



CEO
Giovanni Caforio, M.D.



Headquarters
New York City



Business
Biopharmaceuticals



Net Sales
2015

R&D Investment
IN 2015
\$5.92 BILLION
\$4.04 BILLION
on a
non-GAAP basis*

25,000
Employees

www.bms.com

Orencia	\$1.9 BILLION
Eliquis	\$1.9 BILLION
Sprycel	\$1.6 BILLION
Hepatitis C franchise	\$1.6 BILLION
Yervoy	\$1.1 BILLION
Opdivo	\$942 MILLION

Largest –Selling Products

2015

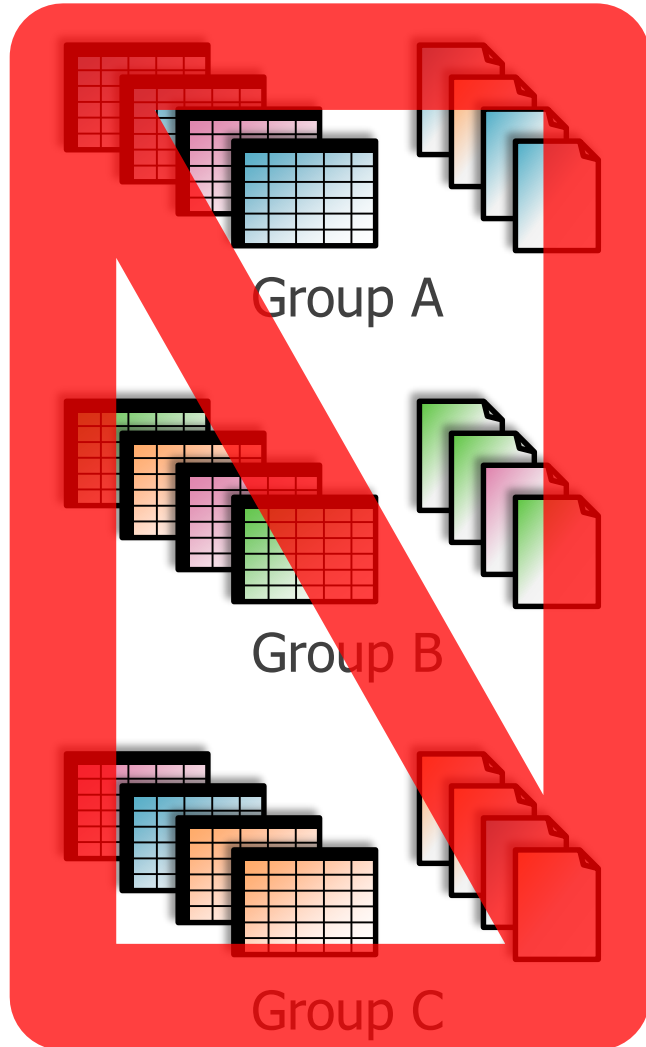
*This non-GAAP amount excludes significant upfront and milestone payments for business development transactions and other specified R&D items. A reconciliation of GAAP to non-GAAP measures can be found on our website at www.bms.com.

Business Challenge for Upstream Biologics Groups

- Inefficient process for managing, analyzing, and reviewing laboratory-scale bioreactor data
- Inconsistent workflow across sites and within groups
 - 100+ upstream scientists in BD and BMS&T departments
 - 6 groups in 5 locations:
 - Devens, MA
 - Bloomsbury/Hopewell, NJ
 - Syracuse, NY
 - Seattle, WA
 - Cruiserath, Ireland

BD = Biologics Development, BMS&T = Biologics Manufacturing Sciences & Technology

We Need a Strategy for Our Cell Culture Data



- **Goal:** Standardize cell culture data management & analysis
- **Benefits:**
 - Reduce time to gather data for analysis and reporting
 - Enable more in depth analysis by harmonizing data storage
 - Foster faster decision making by management and project leads
 - Facilitate cross-departmental collaboration
- **Approach:**
 - Utilize enterprise infrastructure to structure data
 - Leverage structured data to build an analytics tool

STEP 1: Setting the Foundation

Structure Equipment Data and Automate Its Collection

- Historized data from bioreactor-related assets in PI Data Archive
- Structured data using PI Asset Framework (PI AF)
 - Element hierarchy: **department** » **site** » **lab number** » **equipment type**

200+ Bioreactors

- Finesse
- Sartorius
- Xcellerex
- Applikon

1 **universal**
element template

50+ Instruments

- Vi-CELL XR
- BioProfile pH0x
- BioProfile FLEX
- Cedex Bio HT

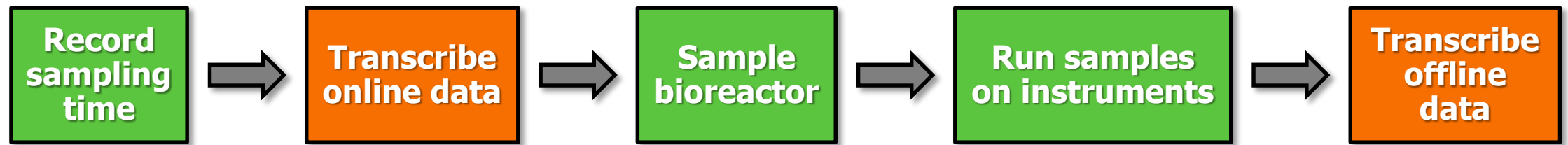
1 element template
per instrument

Interfaces

- PI Interface for OPC DA
- PI to PI Interface™
- PI Interface for Relational Database (RDBMS via ODBC)
- PI Interface for Universal File and Stream Loading (UFL)

Structure Experiment Data in Electronic Lab Notebook

- Created one experiment template per unit operation to structure raw and contextual data, such as experimental design
 - Bioreactor, Seed Train, Media Preparation



- Streamlined bioreactor sampling workflow through integration with PI System®
 - Eliminates manual transcription to save time and eliminate errors

Retrieve Our Data Directly into ELN Using PI Web API

- **Constraint:** Our enterprise ELN environment is a validated repository for both GxP and non-GxP data

One advantage of using Web Services is that as almost all the communication is in XML or JSON, which means that it is not tied to any operating system or programming language.

Concerning the client application that are consuming the web service, no local installation are required. What is important is that the application supports HTTP.

Finally their concepts are easier to learn when compared to other types of data access such as PI OLEDB Enterprise, PI ODBC, or PI AF SDK.

"Developing with PI Web API – PI Developers Club White Paper"
<https://pisquare.osisoft.com/docs/DOC-1940>

- **Solution:** We programmed data retrieval functionality in the ELN bioreactor template leveraging PI Web API 2016 SP1

Map Bioreactor Element Path for Data Retrieval

1 Navigate PI AF element hierarchy

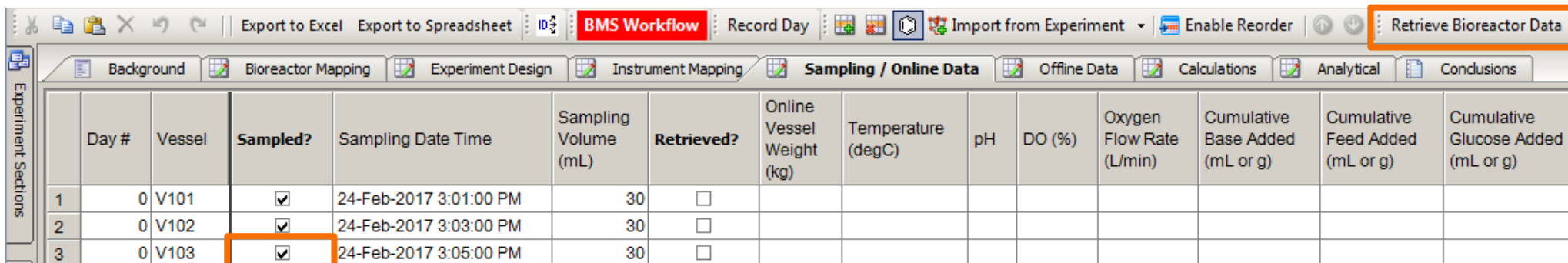
2 Select element

3 Click Select to map element name & path

Bioreactor	PI Path	PiTemplate
V101	\\...Satellite_Sites_PI_AF\BDO\PD\DVN\2315\Finesse G3Lab Universal\V101	BDO_Default Bio...
V102	\\...Satellite_Sites_PI_AF\BDO\PD\DVN\2315\Finesse G3Lab Universal\V102	BDO_Default Bio...
V103	\\...Satellite_Sites_PI_AF\BDO\PD\DVN\2315\Finesse G3Lab Universal\V103	BDO_Default Bio...

#	Name	Value
1	Controller_Manufacturer	Finesse
2	Controller_Model	G3Lab Universal
3	Controller_Serial Number	...
4	Controller_Station ID	V104
5	Location_Group	PD
6	Location_Lab Number	2315
7	Location_Site	DVN
8	Vessel_Type	Stirred-Tank
9	Volume_Maximum Wor...	5.0
10	Volume_Total	6.5

Retrieve “Online” Bioreactor Data Directly into Table



The screenshot shows a software interface with a menu bar at the top containing options like 'Export to Excel', 'Export to Spreadsheet', 'BMS Workflow', 'Record Day', 'Import from Experiment', 'Enable Reorder', and 'Retrieve Bioreactor Data'. The 'Retrieve Bioreactor Data' button is highlighted with an orange box. Below the menu bar are several tabs: 'Background', 'Bioreactor Mapping', 'Experiment Design', 'Instrument Mapping', 'Sampling / Online Data', 'Offline Data', 'Calculations', 'Analytical', and 'Conclusions'. The 'Sampling / Online Data' tab is active, displaying a table with the following columns: Day #, Vessel, Sampled?, Sampling Date Time, Sampling Volume (mL), Retrieved?, Online Vessel Weight (kg), Temperature (degC), pH, DO (%), Oxygen Flow Rate (L/min), Cumulative Base Added (mL or g), Cumulative Feed Added (mL or g), and Cumulative Glucose Added (mL or g). The table contains three rows of data, with the 'Sampled?' checkbox in the third row highlighted by an orange box.

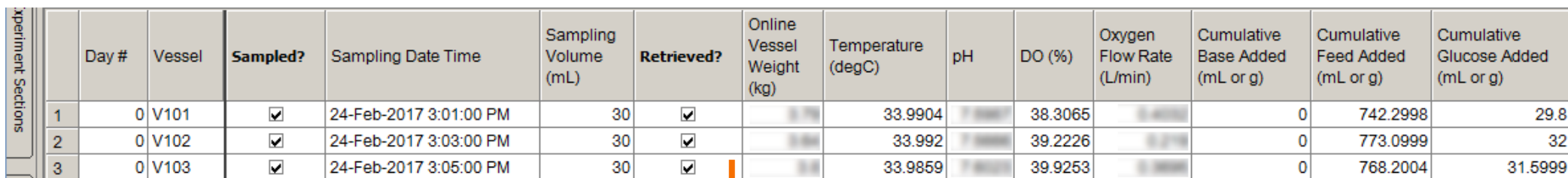
Day #	Vessel	Sampled?	Sampling Date Time	Sampling Volume (mL)	Retrieved?	Online Vessel Weight (kg)	Temperature (degC)	pH	DO (%)	Oxygen Flow Rate (L/min)	Cumulative Base Added (mL or g)	Cumulative Feed Added (mL or g)	Cumulative Glucose Added (mL or g)
1	0 V101	<input checked="" type="checkbox"/>	24-Feb-2017 3:01:00 PM	30	<input type="checkbox"/>								
2	0 V102	<input checked="" type="checkbox"/>	24-Feb-2017 3:03:00 PM	30	<input type="checkbox"/>								
3	0 V103	<input checked="" type="checkbox"/>	24-Feb-2017 3:05:00 PM	30	<input type="checkbox"/>								

2

Click Retrieve Bioreactor Data

1

Click Sampled? checkbox to populate timestamp



The screenshot shows the same software interface as above, but now the 'Retrieved?' checkboxes in the table are checked, and numerical data is populated in the remaining columns. An orange box highlights the bottom row of the table, and an orange arrow points from the 'Retrieve Bioreactor Data' button in the previous screenshot to this row.

Day #	Vessel	Sampled?	Sampling Date Time	Sampling Volume (mL)	Retrieved?	Online Vessel Weight (kg)	Temperature (degC)	pH	DO (%)	Oxygen Flow Rate (L/min)	Cumulative Base Added (mL or g)	Cumulative Feed Added (mL or g)	Cumulative Glucose Added (mL or g)
1	0 V101	<input checked="" type="checkbox"/>	24-Feb-2017 3:01:00 PM	30	<input checked="" type="checkbox"/>	3.78	33.9904	7.0007	38.3065	0.0000	0	742.2998	29.8
2	0 V102	<input checked="" type="checkbox"/>	24-Feb-2017 3:03:00 PM	30	<input checked="" type="checkbox"/>	3.88	33.992	7.0000	39.2226	0.0000	0	773.0999	32
3	0 V103	<input checked="" type="checkbox"/>	24-Feb-2017 3:05:00 PM	30	<input checked="" type="checkbox"/>	3.88	33.9859	7.0000	39.9253	0.0000	0	768.2004	31.5999







3 The button script sends HTTP requests to the PI Web API machine to retrieve “online” bioreactor data based on the sampling timestamp and the attribute mapped to each column

Note: Similar user interface and scripting developed to retrieve “offline” data and match with contextual data

STEP 2:

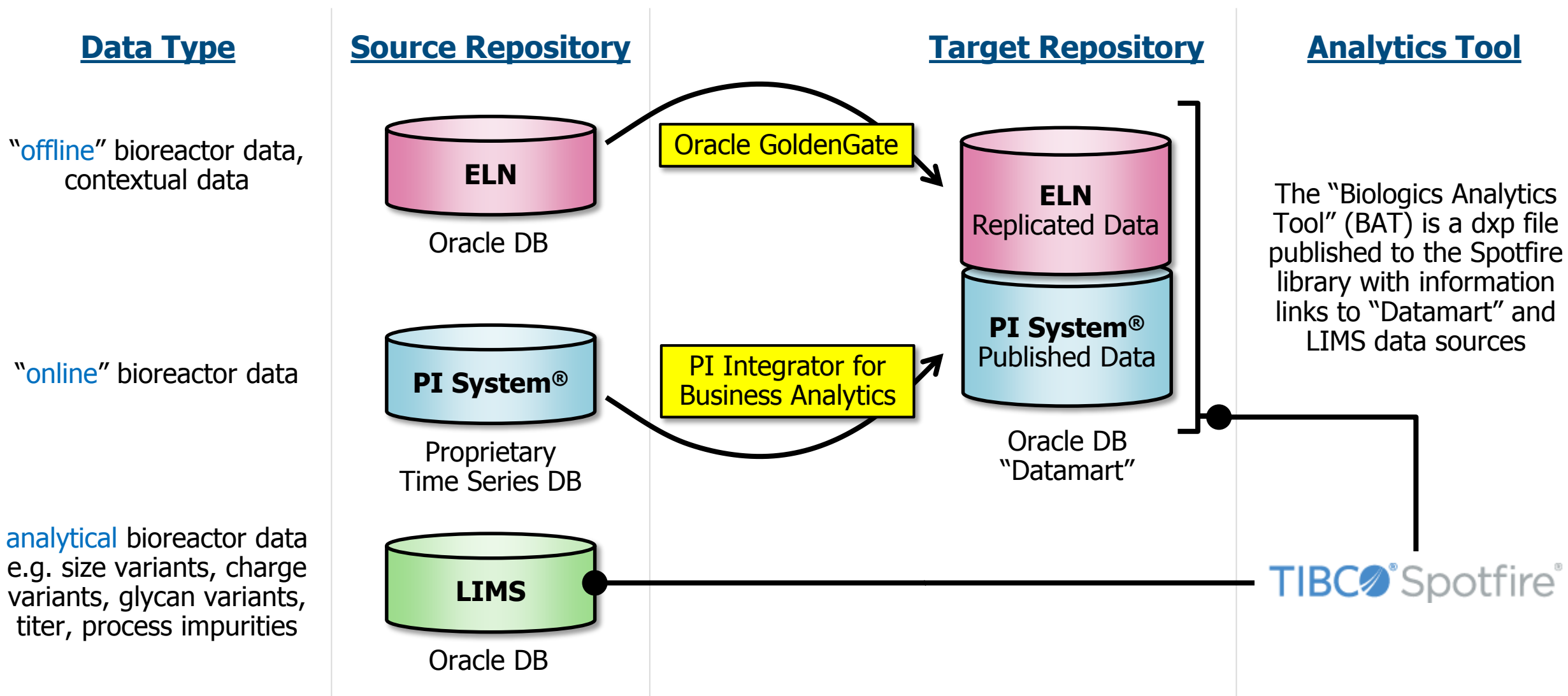
Building Improved Data Analysis Capabilities

An Analytics Tool Can Help Our Scientists...

-  Save Time **Gathering** Data! – automates data aggregation from ELN, LIMS, & PI System®
-  Save Time **Reformatting** Data! – automates data transformation to make compatible for visualization and reporting
-  Save Time **Reviewing** Data! – no need to log into ELN or LIMS to your data
-  Save Time **Interpreting, Preparing Reports, and Presentations!** – presents a set of standard upstream data visualizations useful for many applications
-  **Avoid Errors!** – sources data from the source; no more manual data transcription and potential errors
-  Focus on **Analyzing Data!** – allows scientists to focus their time on the value-added work, data analysis... transforming data into process knowledge

Our conservative estimate: an analytics tool can reduce data analysis time by at least 25%

Our Data Architecture Enabling Our Analytics Tool



PI Integrator for Business Analytics Made It Simpler

- **Requirements:**
 - Must be able to retrieve time-aligned data from multiple time ranges
 - Must be able to join with ELN data that provides batch context
- Explored other options including OSIsoft PI Field Connectivity Framework, a custom Spotfire extension
- Selected PI Integrator for Business Analytics 2016 R2 Data Warehouse Edition because it made it simpler:
 - No coding was necessary
 - Web-based user interface was easy-to-use
 - It was possible to publish to our “Datamart”, co-locating with ELN data

Create View on PI Integrator for Business Analytics

1 Select Data

Navigate element hierarchy
Select attributes
Adjust asset shape

2 Modify View

Add/remove columns
Change column names
Adjust sampling frequency
Adjust start/end times

3 Publish

Select target database
Select run mode
Select run frequency


The screenshot displays the 'My Views' interface in PI Integrator. At the top, there are four action buttons: 'Create Asset View' (Build a data view starting with your asset hierarchy), 'Create Event View' (Build a data view starting with your event frame hierarchy), 'Modify View' (Modify existing data view), and 'Remove View' (Remove selected view). Below these is a navigation bar with 'Overview', 'Log', and 'Security' tabs. The main content area is divided into four panels: 'Run Status' (View Name, PI AF Database, Publish Target, View Type, Run Mode, Run Frequency, Last Run Time, Your Start Time is, Your End Time is, Sample Frequency), 'Scheduled' (Status: Scheduled, View Name: [redacted], PI AF Database: Satellite_Sites_PI_AF, View Type: Asset, Run Mode: Continuous, Run Frequency: 4 Hours, Last Run Time: 2/25/17 10:00 AM, Your Start Time is: 10/1/16 12:00:00 AM, Your End Time is: *, Sample Frequency: 10 minutes), 'Publish Actions' (Resume, Stop, Update Data buttons), and 'Search Shape' (Asset Shape: BDO_Default Bioreactor Temp... with a list of attributes like Agitator PV, Dissolved Oxygen PV, Feed Scale Weight PV, MFCs, Pumps, Rotameters, Vessel Pressure PV, Vessel Temperature PV, Vessel Weight PV, and pH PV).

Publish PI System[®] Bioreactor Data to “Datamart”

VESEL	TIMESTAMP	PIPATH	AGITATORPV	DISSOLVEDOXYGENPV	VESSELTEMPERATUREPV
V301	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V301	289.6216...	40.3499717712402	36.5165176391602
V302	26-FEB-17 10.00.00.000000000 AM \V	I_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V302	290.0594...	41.8936920166016	36.5091514587402
V303	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V303	289.8567...	38.2834930419922	36.5096054077148
V304	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V304	290.0918...	39.5818481445313	36.5046081542969
V305	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V305	289.7216...	40.3643989562988	36.4742774963379
V306	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V306	290.4079...	40.9726486206055	36.4940414428711
V307	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V307	289.3432...	41.1560745239258	36.5127716064453
V308	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V308	290	40.8218154907227	36.5274505615234
V309	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V309	290.2443...	40.291820526123	36.5089454650879
V310	26-FEB-17 10.00.00.000000000 AM \V	I_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V310	289.9161...	40.9077453613281	36.5174293518066
V311	26-FEB-17 10.00.00.000000000 AM \V	I_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V311	290.3405...	40.1156463623047	36.5097808837891
V312	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V312	0	1.52690041065216	22.5855541229248
V313	26-FEB-17 10.00.00.000000000 AM \V	I_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V313	239.1621...	40.3530426025391	33.9920082092285
V314	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V314	239.0296...	40.1411056518555	34.0036697387695
V315	26-FEB-17 10.00.00.000000000 AM \V	I_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V315	240.0756...	40.1806755065918	33.9827041625977
V316	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V316	240.5621...	40.5206565856934	33.9982109069824
V317	26-FEB-17 10.00.00.000000000 AM \V	I_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V317	238.5676...	39.7007598876953	34.0094833374023
V318	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V318	240.2027...	40.3430938720703	33.9916610717773
V319	26-FEB-17 10.00.00.000000000 AM \V	_AF\BDO\PD\DVN\2550\Finesse G3Lab Universal\V319	240.5594...	40.1397247314453	33.9732627868652


5,500,000+ rows published so far with 32,000+ additional rows published per day

Visualizing PI System[®] Data in Biologics Analytics Tool



Biologics Analytics Tool (BAT)

Media Preparation Experiments	Seed Train Experiments	Bioreactor Experiments
<p>Background & Materials Sections</p> <ul style="list-style-type: none">Bioreactor Experiments: On Demand DataSeed Train Experiments: On Demand Data <p>Procedure Sections</p> <ul style="list-style-type: none">Batch, Heating & pH Adjustment InfoSample Analysis, Filtration & Procedure InfoComponents & Density Info	<p>Background & Data Table Sections</p> <ul style="list-style-type: none">Media Preparation Experiments: On Demand DataBioreactor Experiments: On Demand Data <p>Dynamic Calculations</p> <p>Plots and Table by Experiment</p>	<p>Background & Experiment Design Sections</p> <ul style="list-style-type: none">Seed Train Inoculum: On Demand DataMedia Preparation Materials: On Demand DataDevLIMS: On Demand Analytical Data <p>Online & Offline Data Sections</p> <p>Calculation & Analytical Sections</p> <p>Dynamic Calculations</p> <p>Offline Scatter Plots (ELN & DevLIMS)</p> <ul style="list-style-type: none">Parameters by Group vs. Elapsed TimeParameters by Run vs. Elapsed Time <p>Offline Bar Charts (ELN & DevLIMS)</p> <ul style="list-style-type: none">Parameters by Group vs. Elapsed TimeParameters by Run vs. Elapsed Time <p>Online Plots and Tables (PI)</p> <ul style="list-style-type: none">Plots by RunPlots by ParameterPlots by Group (Average + Standard Deviation)

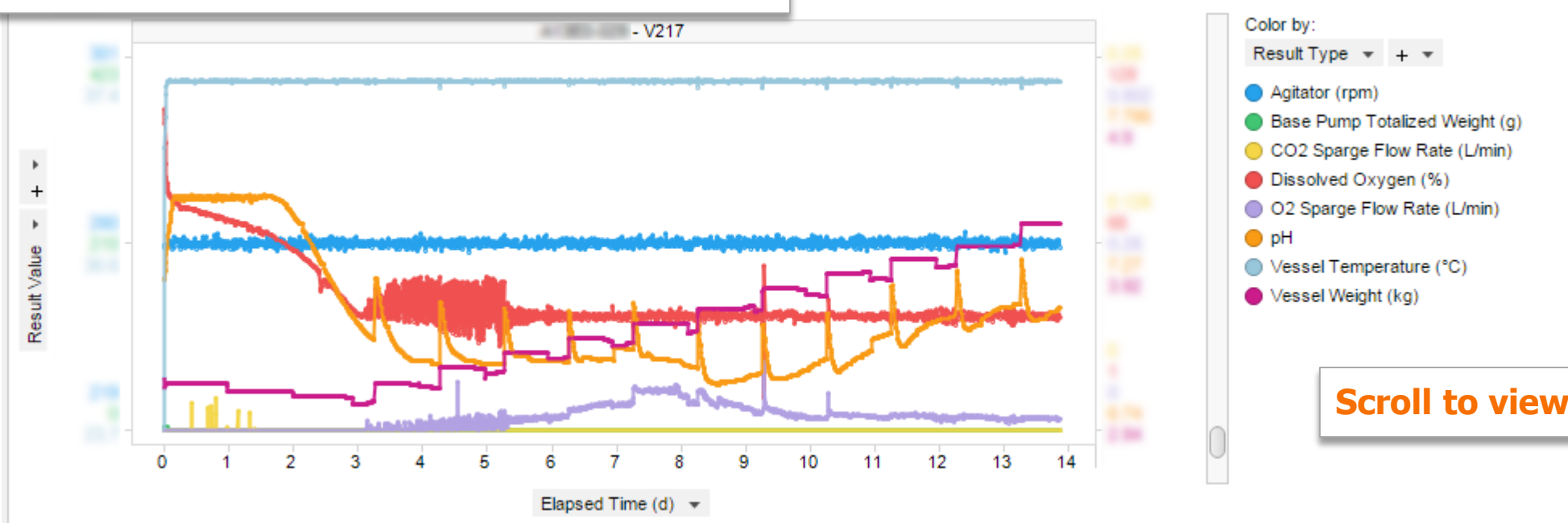


Visualizing PI System[®] Data in Biologics Analytics Tool

Experiment Design

Experiment ID	Vessel	Group	Start Date Time	End Date Time	PI Path
...	V214	Control	11/8/2016 10:40:00 AM	11/22/2016 7:00:00 AM	...
...	V214	Control	11/8/2016 10:14:00 AM
...	V214	Control	11/8/2016 10:13:00 AM
...	V205	Control	1/4/2017 10:32:00 AM
...	V206	Control	1/4/2017 10:32:00 AM
...	V217	Control	1/27/2017 10:44:00 AM	2/10/2017 7:24:04 AM	...
...	V221	Control	1/27/2017 10:39:00 AM	2/10/2017 7:29:00 AM	...

Online data from PI System[®] trellised by run



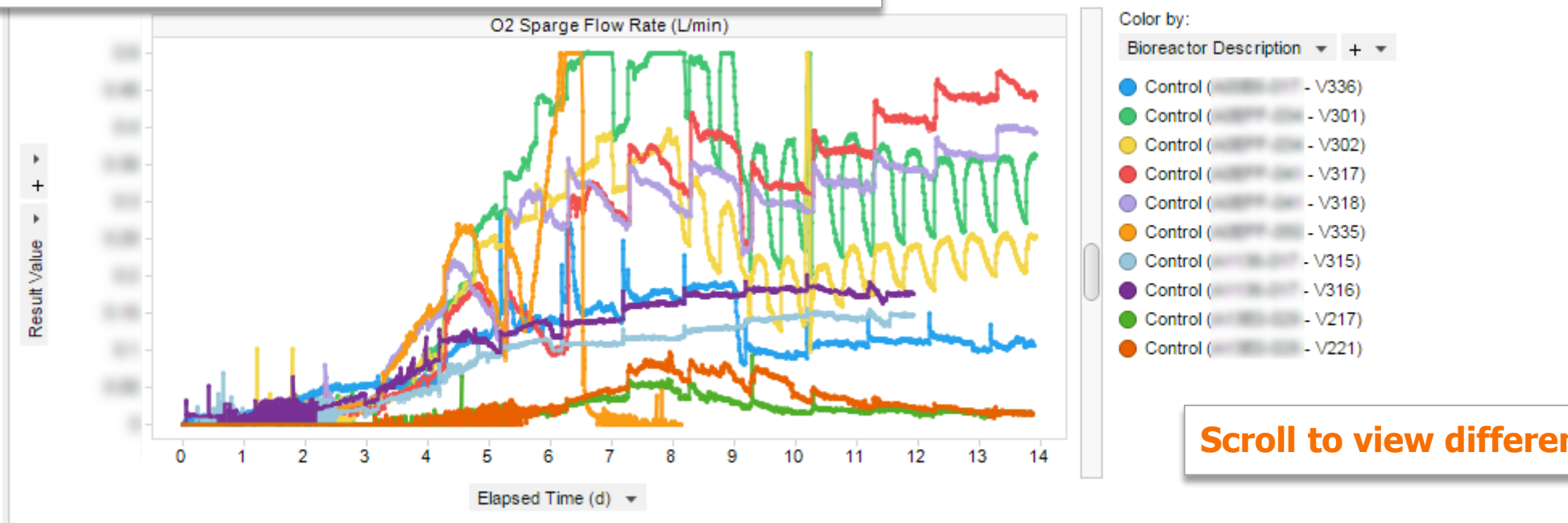
Scroll to view different runs

Visualizing PI System® Data in Biologics Analytics Tool

Experiment Design

Experiment ID	Vessel	Group	Start Date Time	End Date Time	PI Path
	V336	Control	1/9/2017 12:00:00 PM		\\Satellite_Sites_PI_AF
	V301	Control	2/13/2017 11:34:00 AM		\\Satellite_Sites_PI_AF
	V301	Control	1/4/2017 12:00:00 PM		\\Satellite_Sites_PI_AF
	V302	Control	1/4/2017 12:00:00 PM		\\Satellite_Sites_PI_AF
	V317	Control	1/25/2017 11:30:00 AM		\\Satellite_Sites_PI_AF
	V318	Control	1/25/2017 11:30:00 AM		\\Satellite_Sites_PI_AF
	V335	Control	2/15/2017 12:00:00 PM		\\Satellite_Sites_PI_AF
			1/9/2017 10:15:00 AM		\\Satellite_Sites_PI_AF

Online data from PI System® trellised by attribute



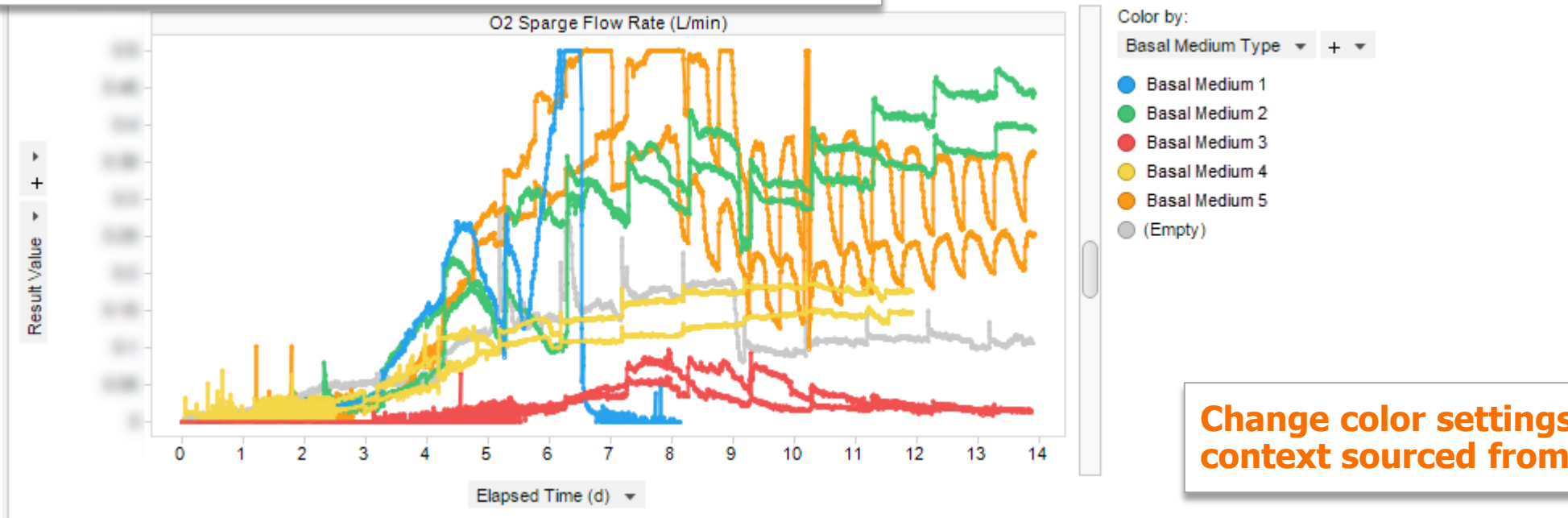
Scroll to view different attributes

Visualizing PI System® Data in Biologics Analytics Tool

Experiment Design

Experiment ID	Vessel	Group	Start Date Time	End Date Time	PI Path
	V336	Control	1/9/2017 12:00:00 PM		\\Satellite_Sites_PI_AF
	V301	Control	2/13/2017 11:34:00 AM		\\Satellite_Sites_PI_AF
	V301	Control	1/4/2017 12:00:00 PM		\\Satellite_Sites_PI_AF
	V302	Control	1/4/2017 12:00:00 PM		\\Satellite_Sites_PI_AF
	V317	Control	1/25/2017 11:30:00 AM		\\Satellite_Sites_PI_AF
	V318	Control	1/25/2017 11:30:00 AM		\\Satellite_Sites_PI_AF
	V335	Control	2/15/2017 12:00:00 PM		\\Satellite_Sites_PI_AF
			1/9/2017 10:15:00 AM		\\Satellite_Sites_PI_AF

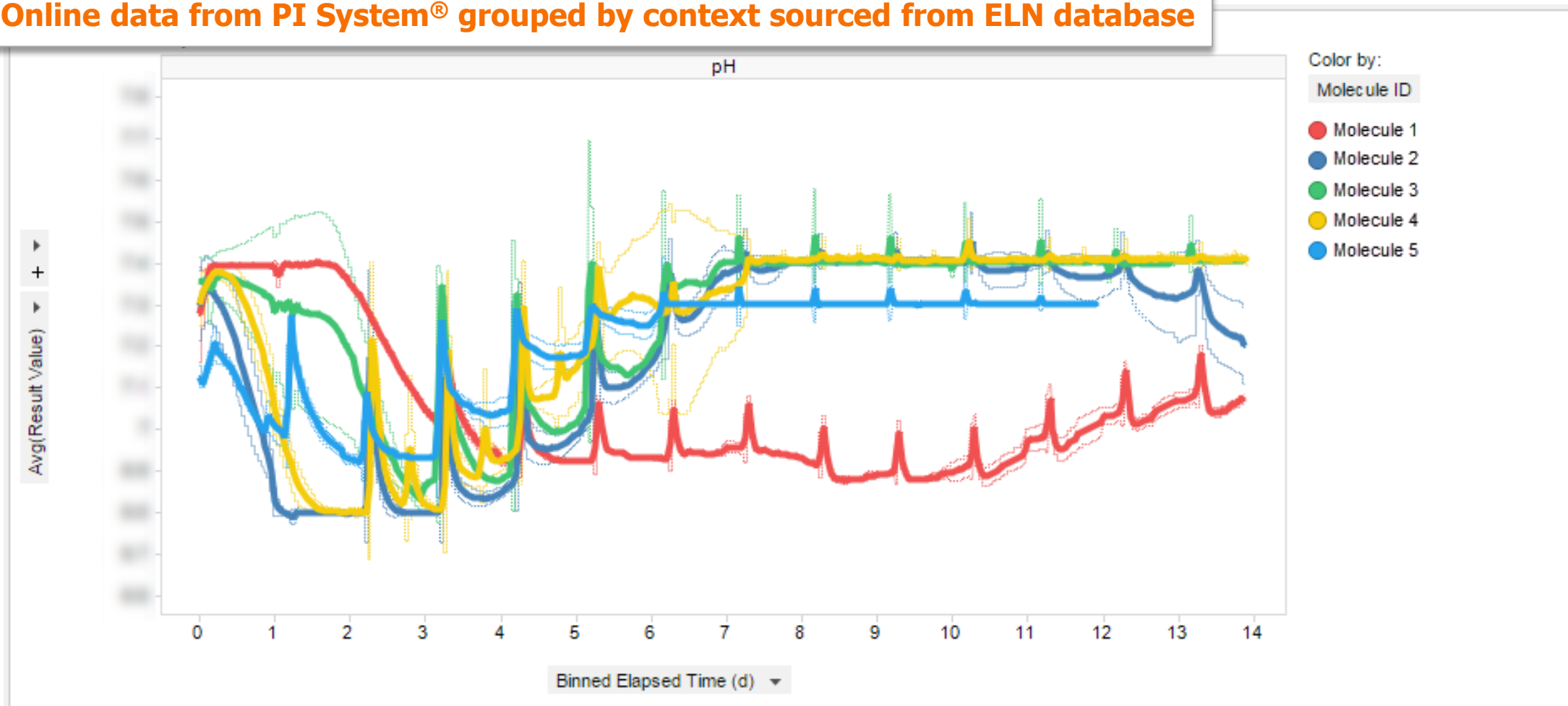
Online data from PI System® trellised by attribute



Change color settings based on context sourced from ELN database

Visualizing PI System[®] Data in Biologics Analytics Tool

Online data from PI System[®] grouped by context sourced from ELN database

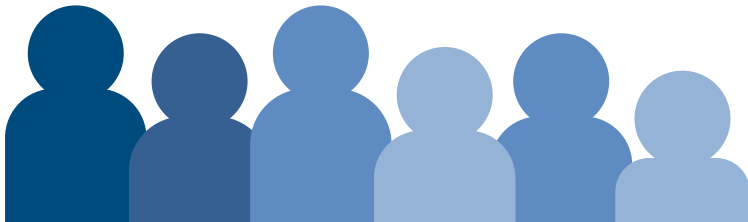


Next Steps

I'm going to save so much time when visualizing data across multiple sets of experiments!

I'm excited about being able to overlay online trends with just a few clicks!

This tool is going to help me dive deeper into the data and discover overarching trends!



- Provided multiple demos to both scientists and management to promote tool and build excitement
- Released for use in early March 2017
- Drive adoption:
 - Provide training and guidance
 - Address any unforeseen issues
 - Collect feedback for improvement
- Will survey scientists to assess reduction in data analysis time
- Explore using batch context data captured in ELN to generate Event Frames

Leveraging PI System® to Build a Biologics Analytics Tool

COMPANY and GOAL

With a growing biologics portfolio, **Bristol-Myers Squibb** sought to **standardize laboratory-scale cell culture data management & analysis**



CHALLENGE

Inefficient and inconsistent process for managing and analyzing bioreactor data across groups and sites

- 100+ upstream scientists
- 2 departments
- 6 groups in 5 locations across United States and Ireland

SOLUTION

Leveraged PI System® to build an analytics tool for laboratory-scale bioreactor data using Spotfire

- PI Web API used to retrieve bioreactor data directly in ELN
- PI Integrator for Business Analytics used to publish bioreactor data for consumption by analytics tool

RESULTS

Released for use in early March 2017; highly anticipated by upstream scientists

- Estimate at least a 25% reduction in data analysis time
- Will survey scientists to assess reduction

Contact Information

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Bristol-Myers Squibb



With special thanks to...

Bristol-Myers Squibb: Kenneth Yuen, Anthony Valbrun, Jeffrey Dzedzic, Matthew Morrow, Lori Harmon

OSIsoft: Edith Monino, Laura Posner, Alassane Seck, Matei Butnarusu, Weikang Sun, Scott Zimmerman

Questions

Please wait for the **microphone** before asking your questions



State your **name & company**

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감사합니다

谢谢

Danke

Merci

Gracias

Thank You

ありがとう

Спасибо

Obrigado