



# Shaping Tomorrow's Engineers in Process Optimization and Control using Aspen DMC3

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# Today's Presenters

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# Today's Discussion

## AGENDA

**1.**

AspenTech Overview

**2.**

Introduction to  
AspenTech APC

**3.**

AspenTech DMC3  
in Academia

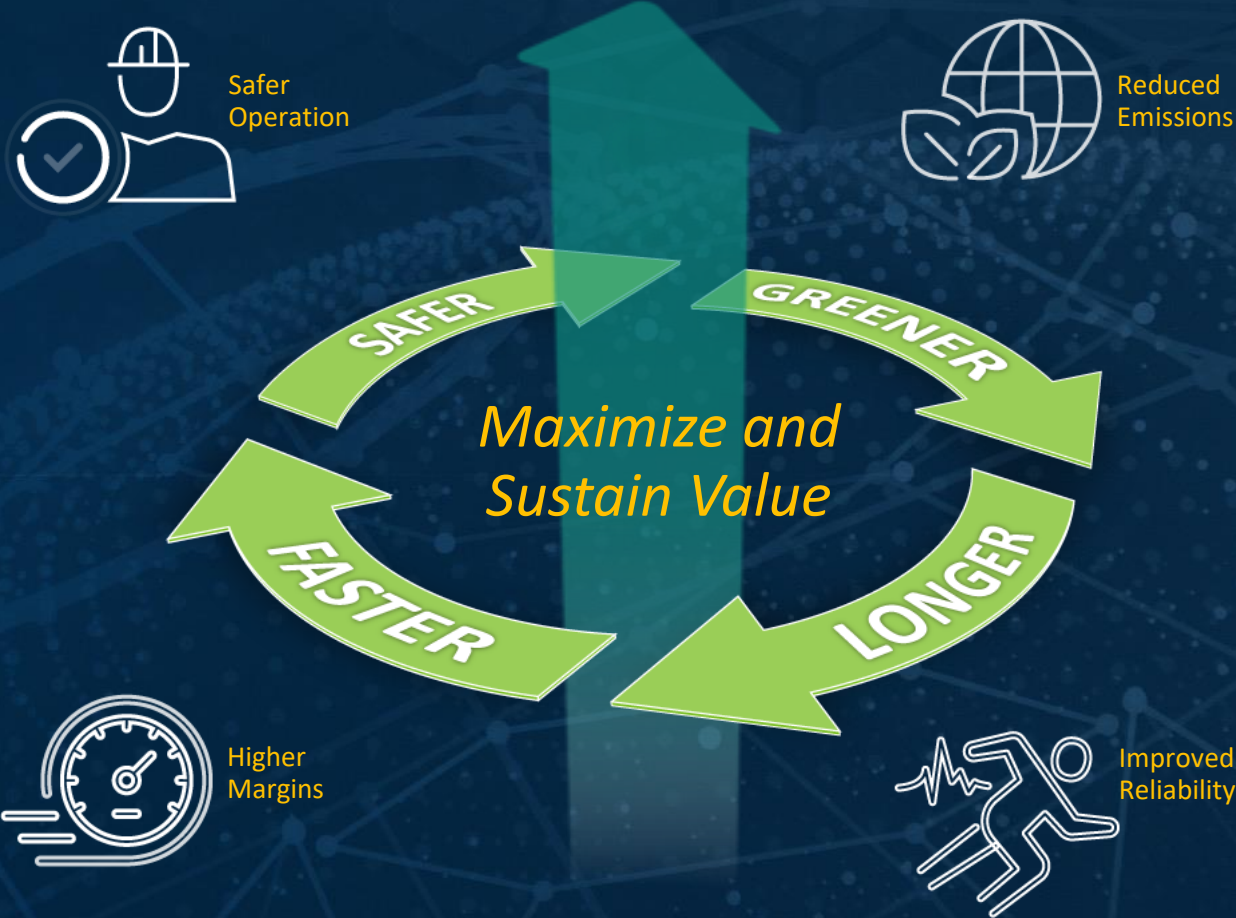
**4.**

Q & A

# AspenTech Overview

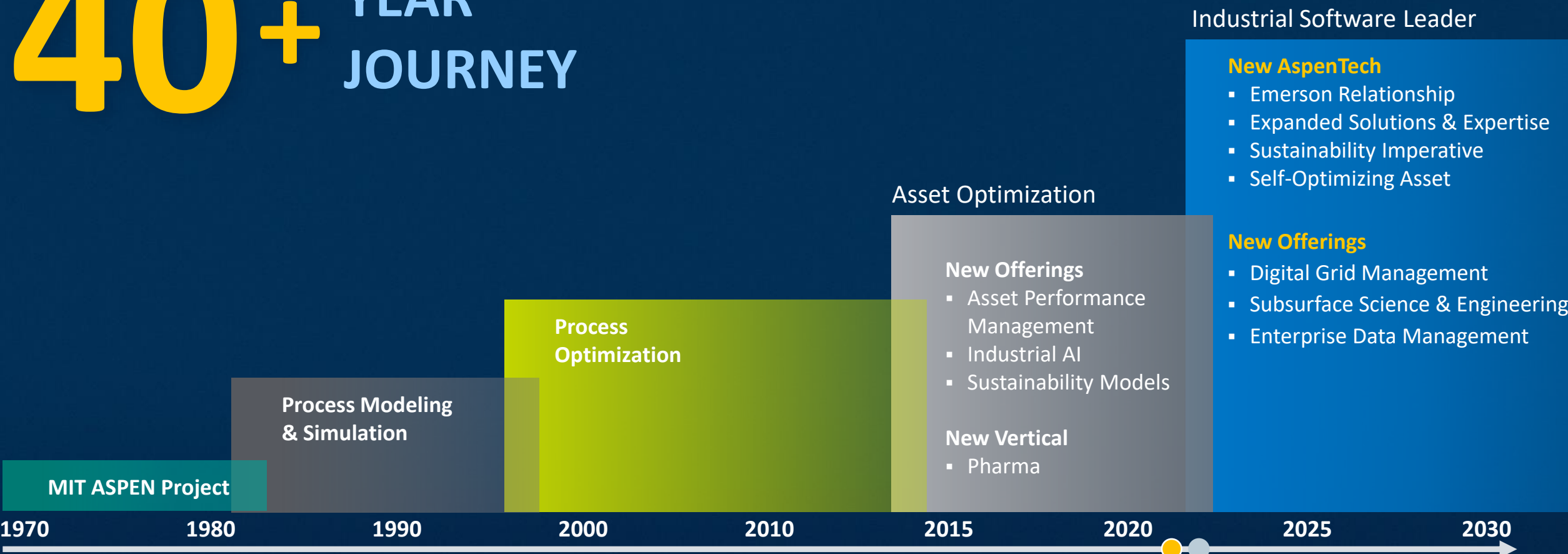
# AspenTech Mission

Accelerate the digital transformation of the industries we serve by optimizing their assets to run **safer, greener, longer** and **faster**



# AspenTech – A History of Innovation

# 40+ YEAR JOURNEY



*Organic and Inorganic growth over the years.*



# Asset Optimization — Extending the Lifecycle

DESIGN

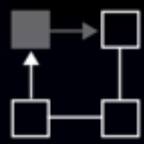
OPERATE

MAINTAIN

Pushing the Boundaries of What's Possible

Running to the Limits of Performance

Driving Uptime Through Actionable Insights



Performance  
Engineering



Manufacturing &  
Supply Chain



Asset Performance  
Management



Subsurface Science &  
Engineering



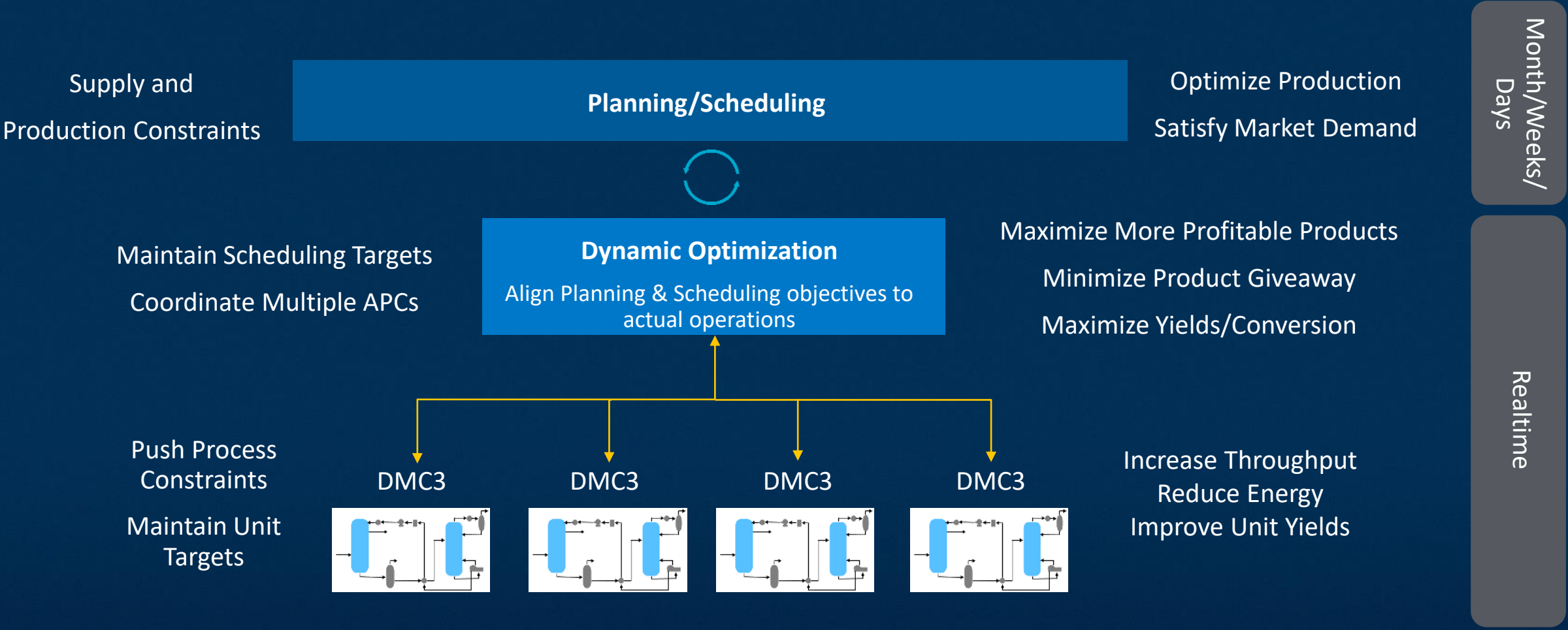
Digital Grid  
Management



Industrial Data Management

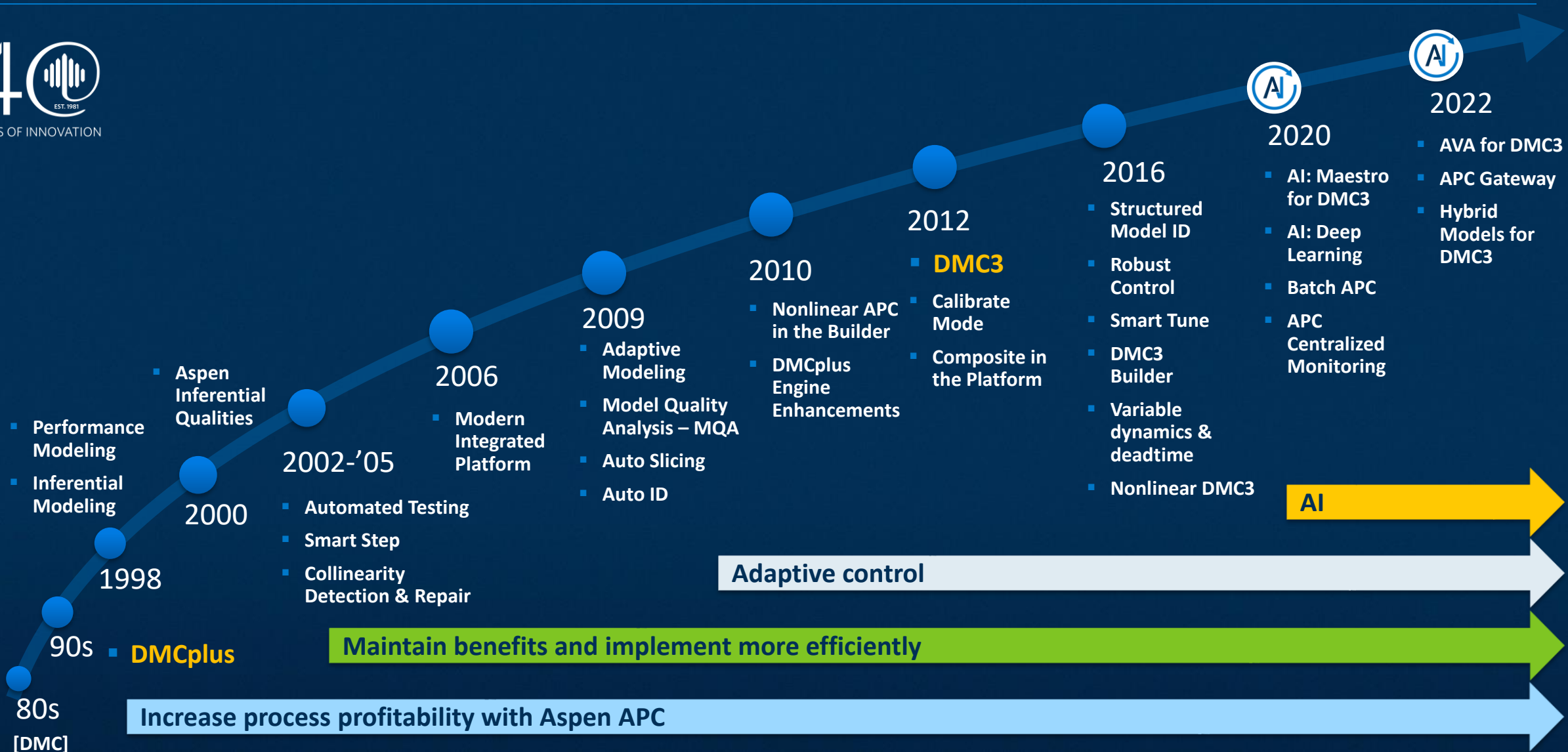
# Introduction to AspenTech APC

# Production Optimization: APC is the Foundation of Digital Transformation

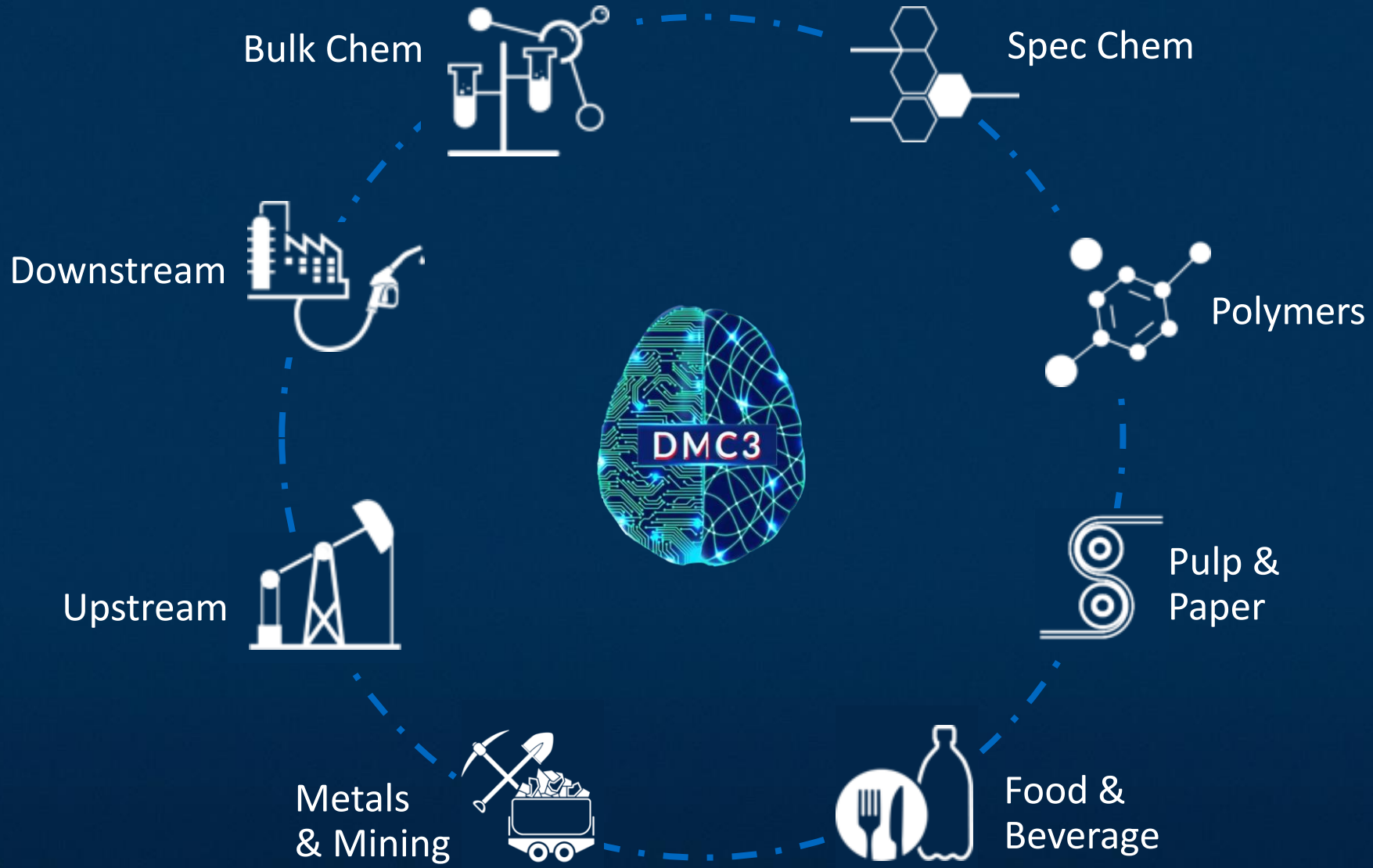


Running to the Limits of Performance – 24x7, minute-by-minute

# Aspen APC Innovation Timeline



# APC Versatility: Broad Industry Use Cases



## Examples of Customer Benefits – AspenTech APC



**\$45 Million in benefits over 5 years**

**Achieved \$3.8 Million/year Savings In high capacity FCCU APC application**



**\$1.5M benefits from increased yield on a single refinery unit**

**2-5% increase in reactor yield Using AspenTech APC**



**\$4M in operational benefits from APC in ethylene plant**

**€ 2.1 million/year benefits from reduced fuel gas usage and venting**



\* May not apply in VUCA environment. Still relevant during ramp-up.

# Viewer Poll

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What are the primary challenges you face when integrating process control concepts into your courses?

- a) Difficulty in finding relevant and up-to-date teaching materials
- b) Time constraints to adapt curriculum
- c) Insufficient training

# AspenTech DMC3 in Academia

# AspenTech APC Solution

## Definition of Terms

- Advanced Process Control (APC)
- Model Predictive Control (MPC)
- Dynamic Matrix Control (DMC)

## APC Goals: Improved Operations & Profitability

- Achieving stable control of the unit in the presence of disturbances
- Maximizing unit throughput (feed flow)
- Maximizing production of the most profitable products
- Minimizing the cost of utilities (fuel gas, steam, cooling water, electricity)
- Achieving the best possible product quality to meet specifications

## Examples of Process Units

- Crude Distillation unit in a refinery
- Ethylene furnaces (reactors) in a petrochemical plant

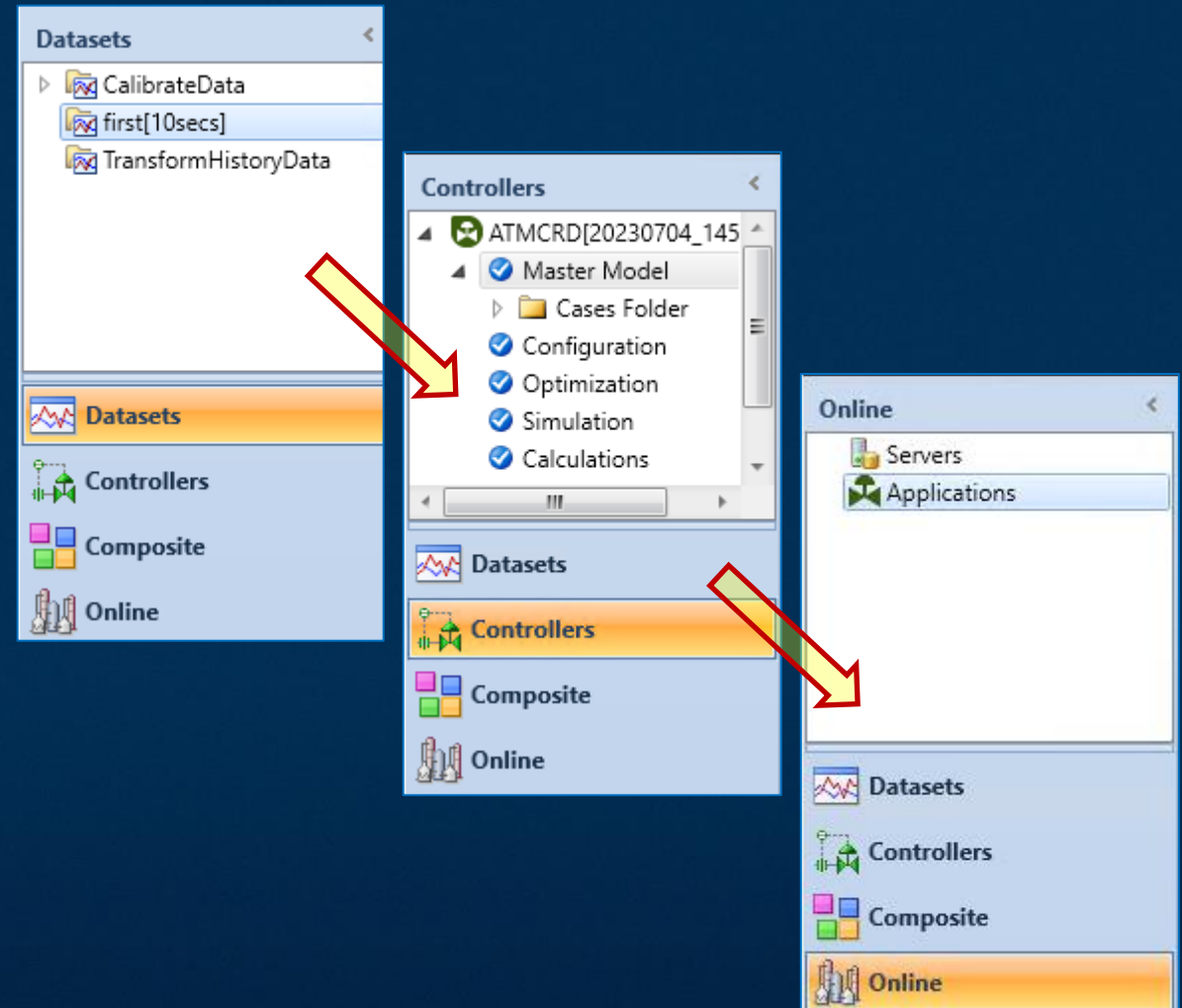
# APC Project Overview

- **Project Definition and Scope**
  - Project benefits, costs, schedule
- **Preliminary Design**
  - APC objectives, scope
  - Optionally create skeleton model and connections
- **Preliminary Plant Test**
  - Start collecting live data
  - Initial steps to check system (PID, Instrumentation, etc.)
  - Generate seed model
- **Plant Step Test**
  - Generate dynamic data
  - Collect steady-state data for property estimators
- **Detailed Design and Analysis**
  - Develop dynamic models
  - Develop property estimators
  - Develop online calculations
  - Offline simulation and tuning
- **Commissioning**
  - Install and evaluate property estimators
  - Operator and engineer training
  - Closed-loop commissioning
  - Final project documentation
- **Sustained Performance**
  - Controller monitoring and enhancement
  - Maintain on-going training

**DMC3 Builder is used for developing the DMC3 controller Model under the Detailed Design and Analysis step**

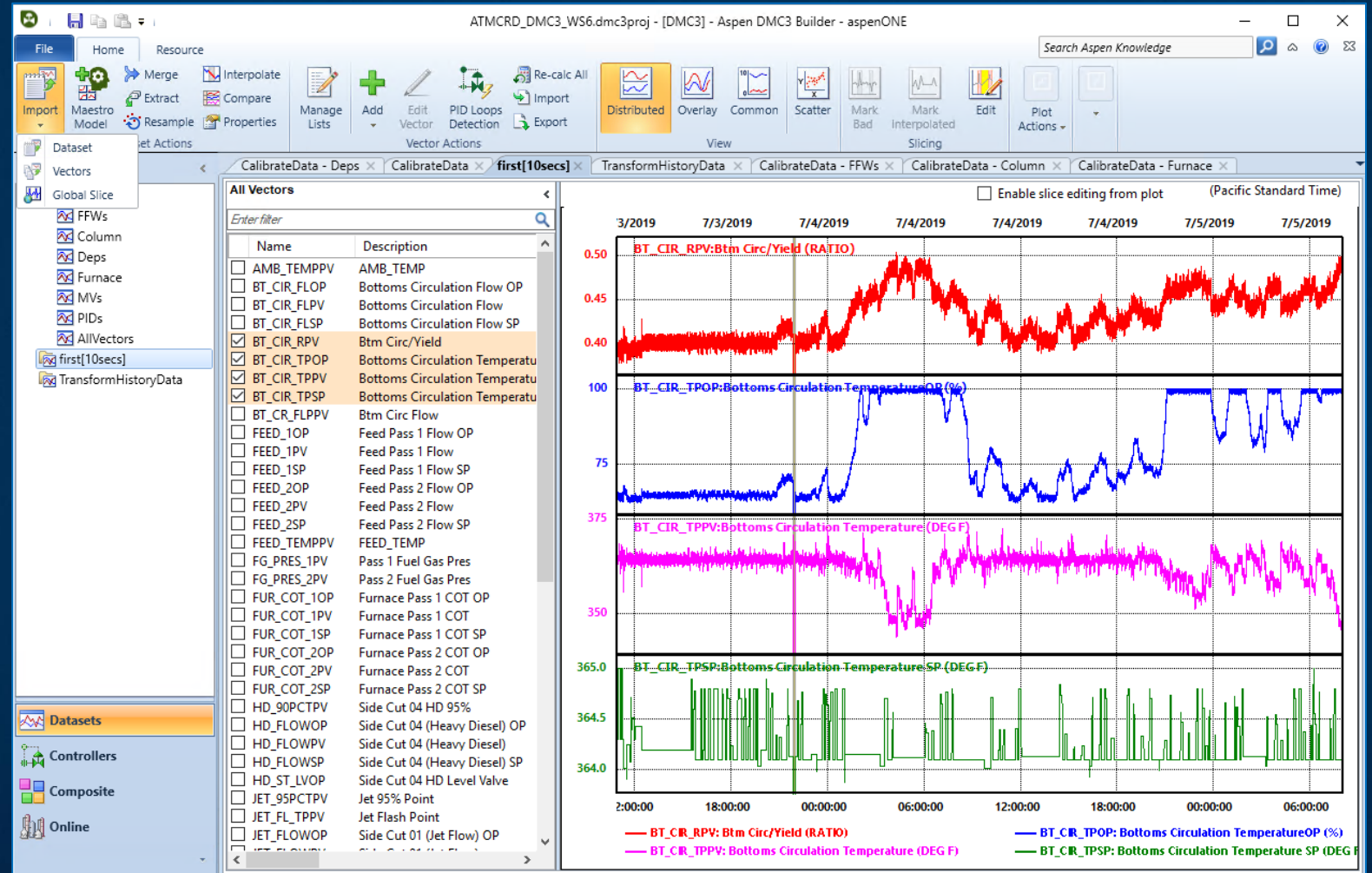
# Aspen DMC3 Builder - Overview

- The DMC3 controller application is developed in DMC3 Builder
  - Part of the Detailed Design step
- Step by step work process guides the user
  - **Datasets:** import and condition the process data
  - **Controllers:** DMC3 model identification, configuration and simulation without deploying the controller online
  - **Composite:** coordinates the optimization functions of multiple DMC3 controllers
  - **Online:** Configure and test DCS connections and deploy the controller online



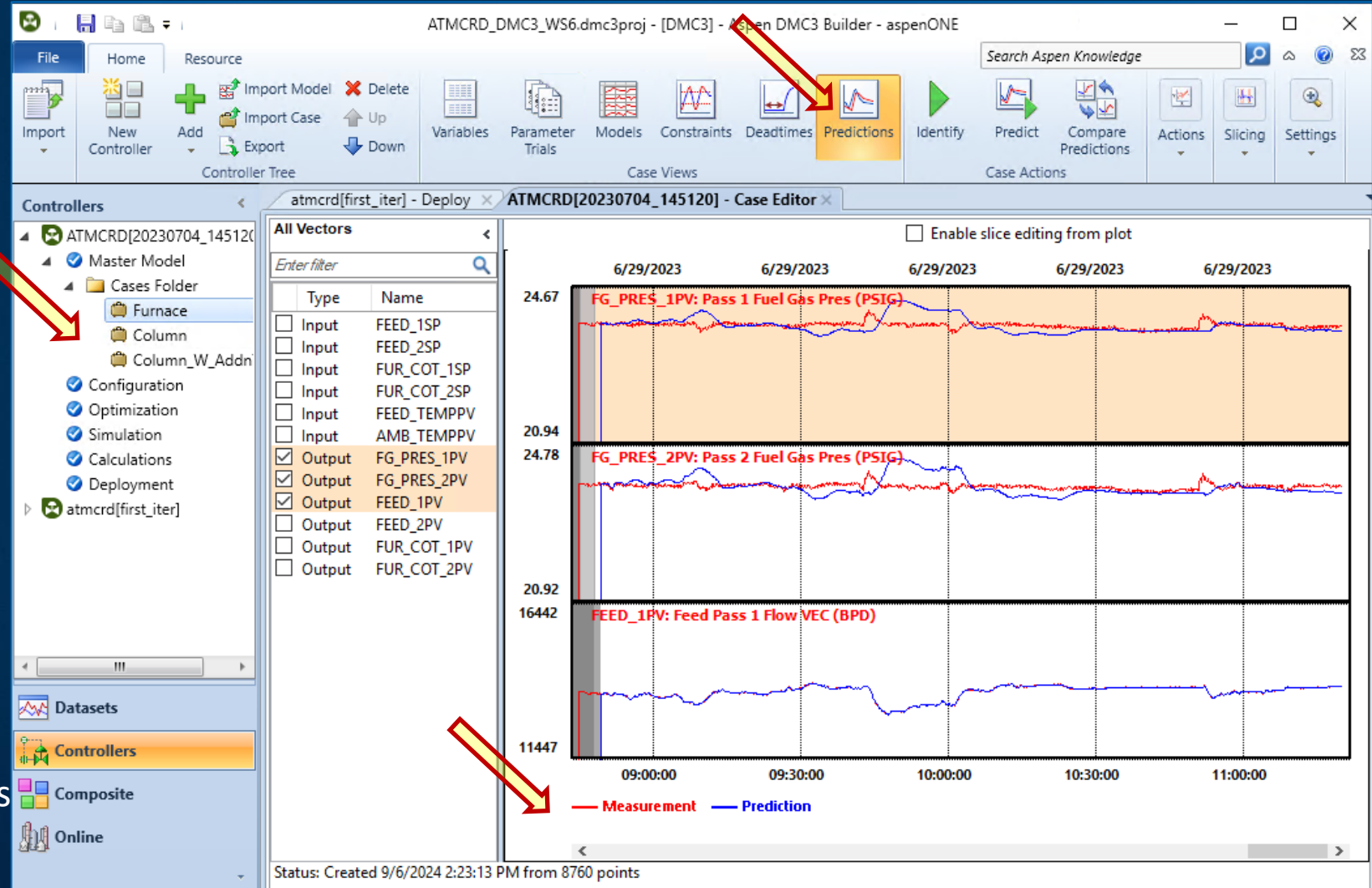
# Aspen DMC3 Builder - Datasets

- Use the Import function to bring process data into DMC3 Builder
- View the data information and plots
- Use the top ribbon to condition the data and remove (slice) inappropriate data
  - For example, data spikes, flat lines, valve saturation are not suitable for model identification



# Aspen DMC3 Builder – Controllers (1)

- **Model identification:**
  - Run subset of the total model in cases, assemble the cases to build the final (master) model
- **Algorithms available:**
  - FIR and Sub-Space for linear processes
  - Deep Learning for non-linear
- **Model evaluation:**
  - View model predictions
  - View frequency uncertainty plots



# Aspen DMC3 Builder – Controllers (2)

- Master Model graph shows:
  - Controlled Variables (CVs)
  - Manipulated Variables (MVs)
  - Deviation Variables (DVs)
  - Steady state gain for each one
  - Settling time (Time to Steady State, or TTSS)



# Aspen DMC3 Builder – Controllers (3)

- Configuration:

- Set controller-wide settings
- Feedback filters
- Define intermittent variables
- Sub-controllers
- Test groups

The screenshot displays the Aspen DMC3 Builder software interface. The title bar indicates the project is 'ATMCRD[20230704\_145120] - Configure'. The ribbon menu includes 'File', 'Home', and 'Resource' tabs. The 'Resource' tab is active, showing options like 'Import Model', 'Delete', 'Import Case', 'Up', 'Down', 'Summary', 'Feedback Filters', 'Subcontrollers', 'Test Groups', and 'Fine Tune'. A red arrow points to the 'Feedback Filters' icon. The left-hand 'Controllers' pane shows a tree view with 'Configuration' selected. The main area contains a table of feedback filter configurations.

Output	Description	Units	<input type="checkbox"/> Full Feedback	<input type="checkbox"/> First Order	<input type="checkbox"/> Moving Avera	<input type="checkbox"/> Intermittent	Pred. Error Lag
DELTA_TEMP	Delta Temperature	DEG F	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
DELTA_FLOW	Delta Flow	BPD	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
FEED_TARGET	Feed Target	BPD	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
FG_PRES_1PV	Pass 1 Fuel Gas Pres	PSIG	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	00:00:30
FG_PRES_2PV	Pass 2 Fuel Gas Pres	PSIG	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	00:01:00
REFLUX_FLPV	ATM Reflux Flow	BPD	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
NAPH_90PV	Naphtha 90%	DEG F	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
JET_FL_TPPV	Jet Flash Point	DEG F	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
JET_95PCTPV	Jet 95% Point	DEG F	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
JET_ST_LVOP	Side Cut 01 Jet Level %	%	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
LD_95PCTPV	Side Cut 02 LD 95%	DEG F	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
LD_ST_LVOP	Side Cut 02 LD Level %	%	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
TP_CIR_RPV	Top Circ/Btms	BPD/BPD	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
HD_ST_LVOP	Side Cut 04 HD Level %	%	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
HD_90PCTPV	Side Cut 04 HD 90%	EG F	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
BT_CIR_RPV	Btm Circ/Yield	BPD/BPD	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
STM_PRESSPV	Steam Pressure	PSIG	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
TP_CIR_TPOP	Top Circulation Tempe %	%	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
BT_CIR_TPOP	Bottoms Circulation Te %	%	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

# Aspen DMC3 Builder – Controllers (4)

- Optimization objectives:
  - Stepwise workflow guides through the optimization steps
  - Defines the optimization requirements, such as
    - Variables to maximize (+)
    - Variables to minimize (-)
    - Priorities of each
    - Criteria for relaxing constraints

**Smart Tune Workflow**

1. Define Structure
2. Select CV Ranks
3. Select Preferences
4. Prioritize Variables
5. Evaluate Strategy
6. Initialize Tuning

**Optimizer**

LP Strategy shows the order and direction in which MVs will be moved when a new CV constraint becomes active. You can change MV, CV, and subcontroller priorities to evaluate the impact on CV constraint handling. View the costs calculated by the Smart Tune engine using the Calculate Costs button. Save changes using the Apply button.

Subcontroller: All Variables  Show Costs

Variables	Priorities		DELTA_TEMP	DELTA_FLOW	FEED_TARGET	FG_PRES_1PV	FG_PRES_2PV	REFLUX_FLPV	NAPH_90PV
	Original	New	*Lo*Hi	*Lo*Hi	Lo Hi	Lo Hi	Lo Hi	Lo Hi	Lo Hi
HEATER	1	1						11 11	3 3
COLUMN	1	1							
OVH_PRESSSP	9	9							2 2
OVH_TEMPSP	10	10						3 2	1 1
JET_FLOWSP	7	7							
LD_FLOWSP	8	8							
TP_CIR_FLSP								4 1	

Buttons: Apply, Reset, Recalculate Costs, Previous, Next

# Aspen DMC3 Builder – Controllers (5)

- Steady State Simulation:
  - Optimization workflow step
  - Simulator tests controller behavior
  - Computes optimization targets
  - Is used for finalizing optimization tuning parameters
  - Various process conditions are tested to check the controller response prior to deploying it online

The screenshot shows the Aspen DMC3 Builder interface. The 'Steady-State Simulator' icon is highlighted in the top ribbon. The 'Controllers' tree on the left shows the 'Optimization' step selected. The main window displays a table of optimization results for the 'ATMCRD[20230704\_145120] - Optimizer'.

Inputs	Operator Low Limit	Steady State Value	SS Current Move	Operator High Limit	Engineering High Limit	Validity High Limit	LP Cost	Critical	Use Limit Tracking	Anti Windup Status	Reverse Acting	Engineer Request	SS Move Limit
FEED_1SP	9000	9595	▼ -1500	15500	20000	25000	-5	No	No	Free	No	On	1500
FEED_2SP	9000	14405.3	▼ -1500	15500	20000	25000	-5	No	No	Free	No	On	1500
FUR_COT_1SP	665	714.8	▼ -10	715	725	900	-300	No	No	Free	No	On	10
FUR_COT_2SP	665	715	▼ -10	715	725	900	-300	No	No	Free	No	On	10
OVH_PRESSSP	12.5	27	▼ -0.4223	27	36	50	4000	No	No	Free	No	On	5
OVH_TEMPSP	240	268.8	▲ 4	275	360	500	750	No	No	Free	No	On	4
JET_FLOWSP	17000	19584.2	▼ -1191	29500	30000	32000	-8	No	No	Free	No	On	3000
LD_FLOWSP	12000	14360.9	0	22000	28250	32000	-7	No	No	Free	No	On	3000

Outputs	Operator Low Limit	Steady State Value	SS Current Move	Operator High Limit	Engineering High Limit	Validity High Limit	LP Cost	SS Low Concern	SS Low Rank	SS High Concern	SS High Rank	Critical	Use Limit Tracking
DELTA_TEMP	-24	-0.1606	0	24	25	100	0	4	1000	4	1000	No	No
DELTA_FLOW	-5400	-4811	0	5450	5500	20000	0	10	1000	10	1000	No	No
FEED_TARGET	18000	24000	▼ -3000	24000	42000	45000	0	100	100	100	100	No	No
FG_PRES_1PV	18	21.17	▼ -4.968	24	24	100	0	5	100	5	20	No	No
FG_PRES_2PV	18	23.17	▼ -4.968	24	24	100	0	5	9999	5	20	No	No
REFLUX_FLPV	25000	39109.5	▼ -3650	46000	50000	60000	0.9999	1200	100	1200	80	Yes	No
NAPH_90PV	269	275	▲ 12.76	275	360	400	-0.2074	3	40	3	40	No	No
JET_P_TDRV	108	129.2	▲ 1.462	113	177.5	210	0	3	41	3	9999	Yes	No

# Aspen DMC3 Builder – Controllers (6)

- **Dynamic Simulation:**
  - Optimization workflow step
  - Simulator tests controller behavior in the dynamic sense
  - Predicts the controller dynamic response for achieving the steady state optimization targets
  - Is used for finalizing the dynamic tuning: response aggressiveness, constraint violations and similar
  - Various process conditions are tested to check the controller response prior to deploying it online

The screenshot shows the Aspen DMC3 Builder interface. The left sidebar contains a tree view with the following items: ATMCRD[20230704], Master Model, Cases Folder, Configuration, Optimization, Simulation (highlighted with a red arrow), Calculations, Deployment, atmcrd[first\_iter], Master Model, Configuration, Optimization, Simulation, Calculations, and Deployment. The main window is titled 'Preview Plots' and shows a table of process variables. The table has columns for Inputs, Combined Status, Service Request, Service Status, Measurement, Operator Low Limit, Steady State Value, and Ideal Steady State. The table is divided into two sections: Inputs and Outputs.

Inputs	Combined Status	Service Request	Service Status	Measurement	Operator Low Limit	Steady State Value	Ideal Steady State
FEED_1SP	Normal	On	On	9563	9000	9593	9585
FEED_2SP	Normal	On	On	14389.6	9000	14407.2	14414
FUR_COT_1SP	Normal	On	On	714.4	665	714.4	715
FUR_COT_2SP	Normal	On	On	714.4	665	714.4	715
OVH_PRESSSP	High Limit	On	On	27	12.5	27	27
OVH_TEMPSP	Normal	On	On	268.9	240	268.8	268.8
JET_FLOWSP	Normal	On	On	19437.9	17000	19437.9	19437

Outputs	Combined Status	Service Request	Service Status	Measurement	Operator Low Limit	Steady State Value	Ideal Steady State
DELTA_TEMP	Normal	On	On	0	-24	0	-3.297E-12
DELTA_FLOW	Normal	On	On	-4827	-5400	-4814	-4830
FEED_TARGET	High Limit	On	On	23952.4	18000	24000	24000
FG_PRES_1PV	Normal	On	On	21.02	18	21.03	21.09
FG_PRES_2PV	Normal	On	On	22.25	18	22.29	22.39
REFLUX_FLPV	Normal	On	On	39172.1	25000	39161.7	39161.7
NAPH_90PV	Set Point	On	On	275.1	269	275	275

# Aspen DMC3 Builder – Controllers (7)

## ■ Custom Calculations:

- Tool for addressing special needs
- Calculating controller variables from other process inputs
- Modifying controller parameters under certain process conditions
- For example, when feed makeup changes, disable a CV and enable another
- Can be tested offline prior to deployment
- Defined for controller inputs (MVs) and outputs (CVs)

The screenshot displays the Aspen DMC3 Builder interface for configuring a controller. The main window is titled 'ATMCRD[20230704] - Calculations'. The ribbon at the top contains tabs for File, Home, Resource, and Actions, with various icons for file operations, model management, and execution. The left-hand navigation pane shows a tree structure for the controller 'atmcrd[first\_iter]', with 'Calculations' selected. The central 'Calculations List' table shows three entries:

	Name	Description
1	InCalculation_1	From DMCplus CCF file
2	InCalculation_2	From DMCplus CCF file
3	InCalculation_3	{DEP:DELTA_FLOW DEP} = {IND:FEED_1SP VIND} - {IND:FEED_2SP VIND}

The right-hand pane, titled 'Enter Calculation', contains the formula:  $\{DEP:DELTA\_FLOW|DEP\} = \{IND:FEED\_1SP|VIND\} - \{IND:FEED\_2SP|VIND\}$ . Below this, the 'Map Calculation Variables' table is shown:

Name	Mode	Binding	Entry	Value
DEP_DELTA_FLOW_DEP	Output	Entry	/Dependent/DELTA_FLOW/Measurement	
IND_FEED_1SP_VIND	Input	Entry	/Independent/FEED_1SP/Measurement	
IND_FEED_2SP_VIND	Input	Entry	/Independent/FEED_2SP/Measurement	

At the bottom, the 'User Entries' section is visible, with a tree structure showing 'Dependent', 'General', 'Independent', 'Subcontroller', and 'Test Group'.

# Aspen DMC3 Builder – Controllers (8)

- Deployment:
  - Define connections to the control system (DCS)
  - Test the connections to ensure the controller can read process values
  - Press the Deploy button to begin the deployment process for online operation

The screenshot displays the Aspen DMC3 Builder interface. The top ribbon includes tabs for File, Home, and Resource, with various tool icons. The left sidebar shows a tree view of the project structure, with 'Controllers' selected. The main workspace is divided into several panes:

- Tag Browser:** Shows a list of variables with columns for Variable Name, Type, Generate Tags, Measurement Prefix, Measurement Suffix, and Interface Point.
- Variable Detail:** Shows a table of parameters for the selected variable, including Parameter, IO Source, IO Tag, IO Datatype, String Length, and Test Value.

Red arrows highlight the 'Test Connections' button in the top ribbon and the 'Deploy' button in the left sidebar. The 'Variable Detail' table is also highlighted with a red arrow pointing to the 'Test Value' column.

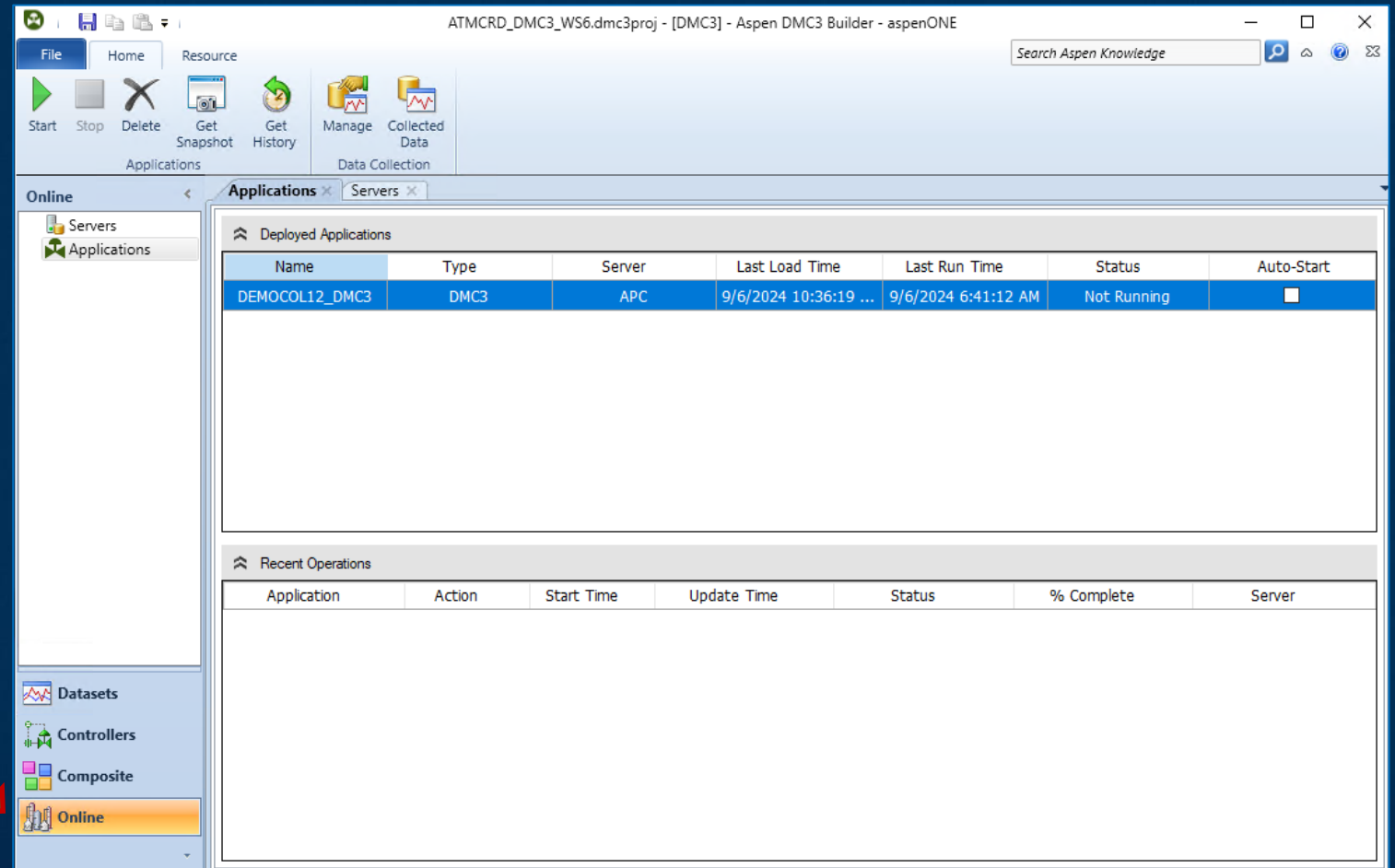
Variable Name	Type	Generate Tags	Measurement Prefix	Measurement Suffix	Interface Point
ATMCRD[20230704_...	General	<input checked="" type="checkbox"/>			
FEED_1SP	Input	<input checked="" type="checkbox"/>			
FEED_2SP	Input	<input checked="" type="checkbox"/>			
FUR_COT_1SP	Input	<input checked="" type="checkbox"/>			
FUR_COT_2SP	Input	<input checked="" type="checkbox"/>			
OVH_PRESSSP	Input	<input checked="" type="checkbox"/>			
OVH_TEMPSP	Input	<input checked="" type="checkbox"/>			

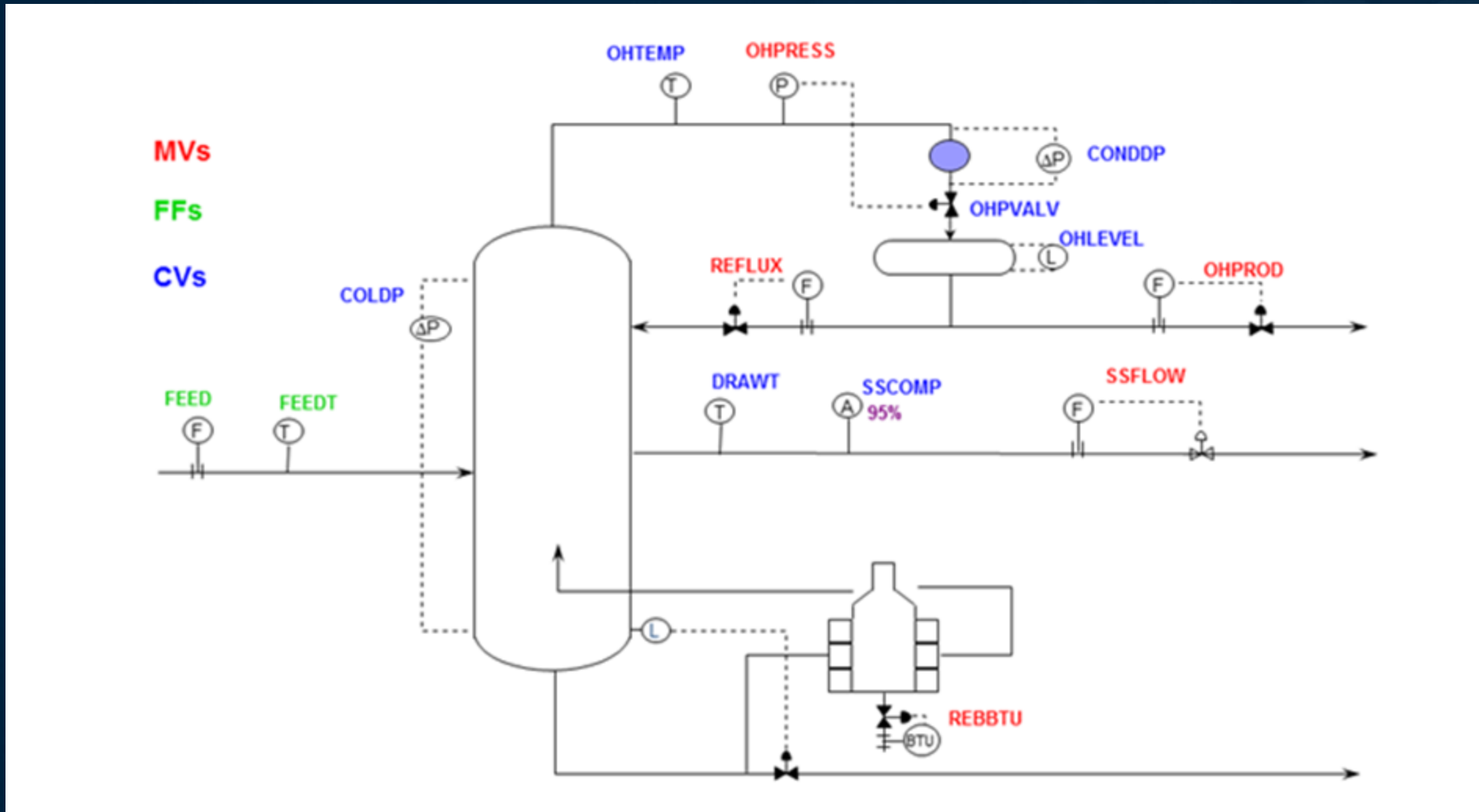
Parameter	IO Source	IO Tag	IO Datatype	String Length	Test Value
Anti Windup Status					
DMCplus Service...					
Loop Status					
Measurement	IOIP21	FEED_1.SP	Double		11912.70605468...
Operator High Li...	IOIP21	FEED_1.SP IP_HIGH_LIMIT	Double		15500
Operator Low Limit	IOIP21	FEED_1.SP IP_LOW_LIMIT	Double		9000
Setpoint	IOIP21	FEED_1.SP	Double		11912.70605468...

# Aspen DMC3 Builder – Online

- Complete the deployment:
  - Complete the connection definitions
  - Deploy and start the controller
  - Once this step is complete the controller will be displayed on the operator web screens
  - At this point, the controller is visible but has not been started
  - It will be started once the operators are confident it is ready to begin controlling
- DMC3 Controller Demo



# Simulated Distillation Column - Demo



**DEMO**



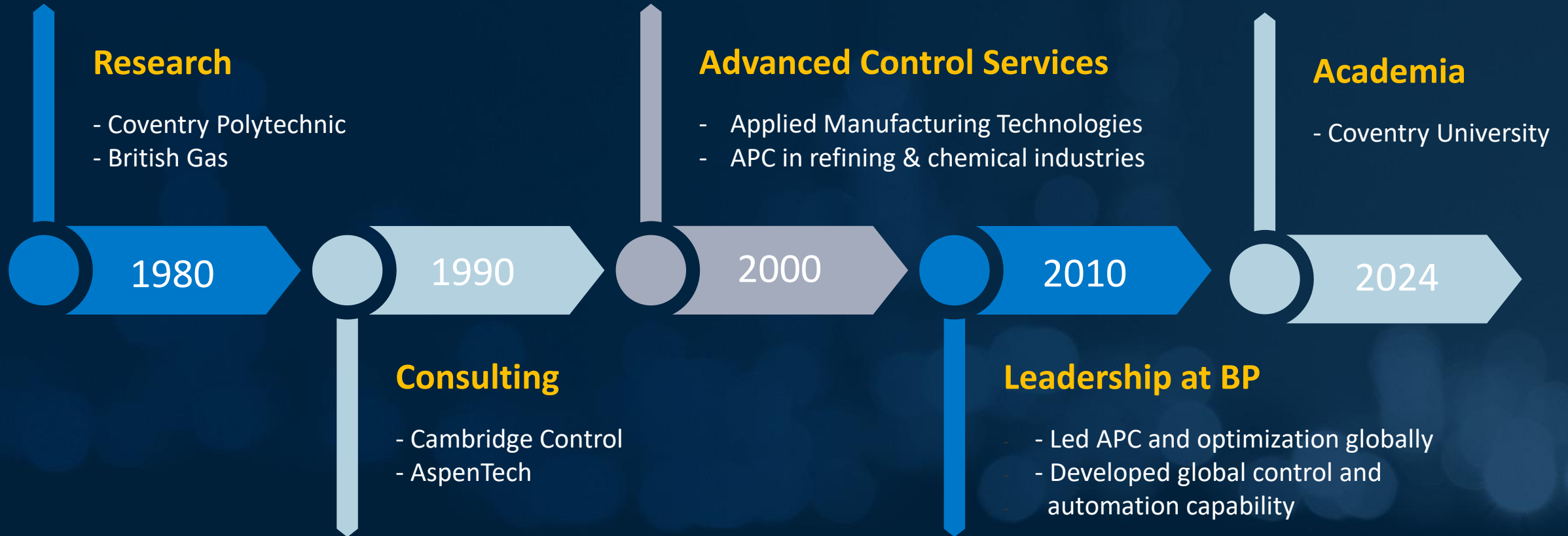
# Viewer Poll



Which of the following topics do you currently teach in your process control classes?

- a) Optimization
- b) Modeling for Control
- c) Automation Technology
- d) Feedback control
- e) Model Predictive Control
- f) Control System Programming
- g) Adaptive Control
- h) Stability

# From Research to Industry: *A Career in Control Engineering*



# An Industry Perspective

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- Acute shortage of APC engineers
- Difficulty for graduates to link control with process and operations
- Lack of appreciation for the depth required in control engineering
  - Systems hardware and networks
  - Human machine interfaces
  - Instrumentation and valves
  - Designing and debugging control strategies
  - Tuning
  - Commissioning

# The Value of DMC3 in Process Control Curriculum

- **Industry- standard:** DMC3 is well-established and widely used industrial tool
- **Comprehensive Functionality:** Incorporates key control theory concepts, including:
  - System identification and modeling
  - State-space analysis and uncertainty management
  - Deep Learning
  - Inferential soft sensors
  - Optimization using linear and quadratic programming
  - Non-linear control strategies
- **Integration Expertise:** Requires a solid understanding of system integration:
  - IT vs OT, digital security
  - Safe communication with PAS control blocks
  - Human machine interface, interacting with complex automation

# The Value of DMC3 in Process Control Curriculum

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- **Extensive Experience:** DMC3 methodology is based on decades of real-world engineering experience
- **Broader Perspective:** Understanding this methodology helps students grasp the broader context of control problems:
  - Integrating operations, human factors, and safety considerations
  - Appreciating the role of instrumentation and process actuation
  - Understanding the development of control schemes and strategies
  - Recognizing the exciting and rewarding nature of control engineering

# Leveraging DMC3 in Academia

## Teaching

- Bridging Theory and Practice
  - Use DMC3 to illustrate the hands-on application of control theory in practice.
- Real-World Examples:
  - Developing models by fitting plant test data
  - Addressing non-linear control challenges

## Research

- Identifying Research Gaps
- Enhancing MPC Usability and Operability
  - Focus on:
    - Improving visualization and interaction with complex MPC applications
    - Using clear language to enhance situational awareness
    - Strengthening the connection between the MPC layer and the PID layer for better system adaptability

# Questions & Answers



# Next Steps: Access to Relevant Resources

## Get started with key resources

**DMC3 Builder:** This video series offers a comprehensive introduction to the Aspen DMC3 Builder interface. Learn how to efficiently manage datasets and deployments in a streamlined environment.

- [How-to Video Series Part 1](#)
- [How-To Video Series Part 2](#)

## Learn more about AspenTech Academic Program

Visit our website: [AspenTech Academic Program](#)

AspenTech Academic Order: [Form to submit your new order or renewal](#)

Questions: If you have any questions email [Cecilia.singh@aspentech.com](mailto:Cecilia.singh@aspentech.com)

A person is silhouetted against a bright sun, with their arms raised in a gesture of achievement or gratitude. In front of them is a large, glowing digital globe composed of a network of white lines and dots. The background is a soft, hazy sky. Scattered throughout the scene are various white icons within hexagonal frames, including a cloud, a laboratory flask, a globe with a leaf, a chemical structure, a laptop, a leaf, a CO2 molecule, and a leaf with a drop. The overall theme is one of innovation, science, and environmental technology.

Thank You!