

Destroying Chemical Weapons with Splunk

Integration of the Industrial Internet to Optimize Plant Performance

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Session Presenters



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Chemical Demilitarization

History of U.S. chemical weapons disposal

- United States must safely manage and destroy legacy chemical weapon stockpiles
 - Chemical Weapons Convention (as of 1997)
- The Program Executive Office, Assembled Chemical Weapons Alternatives (PEO-ACWA) is responsible for the safe and environmentally sound destruction of the remaining U.S. chemical weapons stockpile

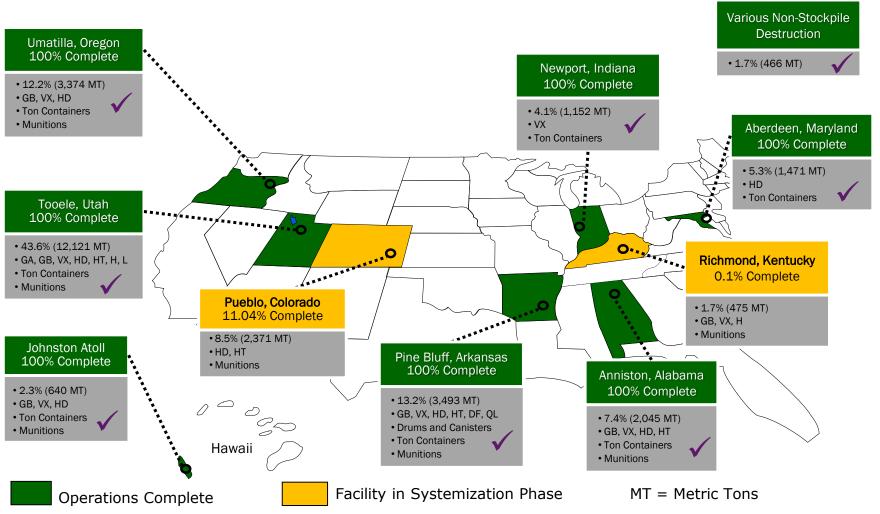
Historical disposal methods leave something to be desired...







U.S. Chemical Demilitarization Facilities



 As of July 27, 2018



Pueblo Chemical Agent-Destruction Pilot Plant



PEO ACWA, headquartered at Aberdeen Proving Ground, Maryland, is responsible for managing all aspects of the safe and environmentally sound destruction of the chemical weapons stockpiles in Colorado and Kentucky.



The Pueblo Chemical Agent-Destruction Pilot Plant (PCAPP) will safely destroy 2,613 tons of mustard agent in mortar rounds and artillery projectiles stored at the U.S. Army Pueblo Chemical Depot (PCD).

Neutralization followed by biotreatment is the technology selected by the Department of Defense to destroy the Pueblo chemical weapons stockpile.



The Bechtel Pueblo Team (BPT) is a partnership of Bechtel National, Inc., AECOM, and Battelle Memorial Institute. The BPT functions as the systems contractor selected to design, build, systemize, pilot test, operate, and close the PCAPP.

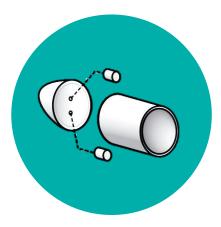




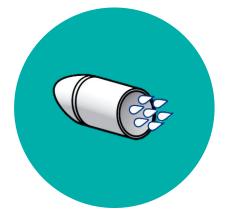


Chemical Demilitarization

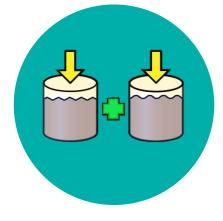
Modern method for destruction of chemical weapons



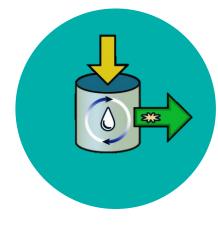
Removal of energetics



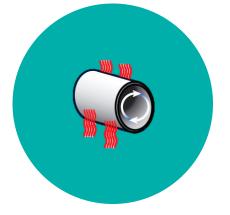
Removal of mustard agent



Neutralization of mustard agent



Biotreatment



Thermal treatment and disposal of metal parts

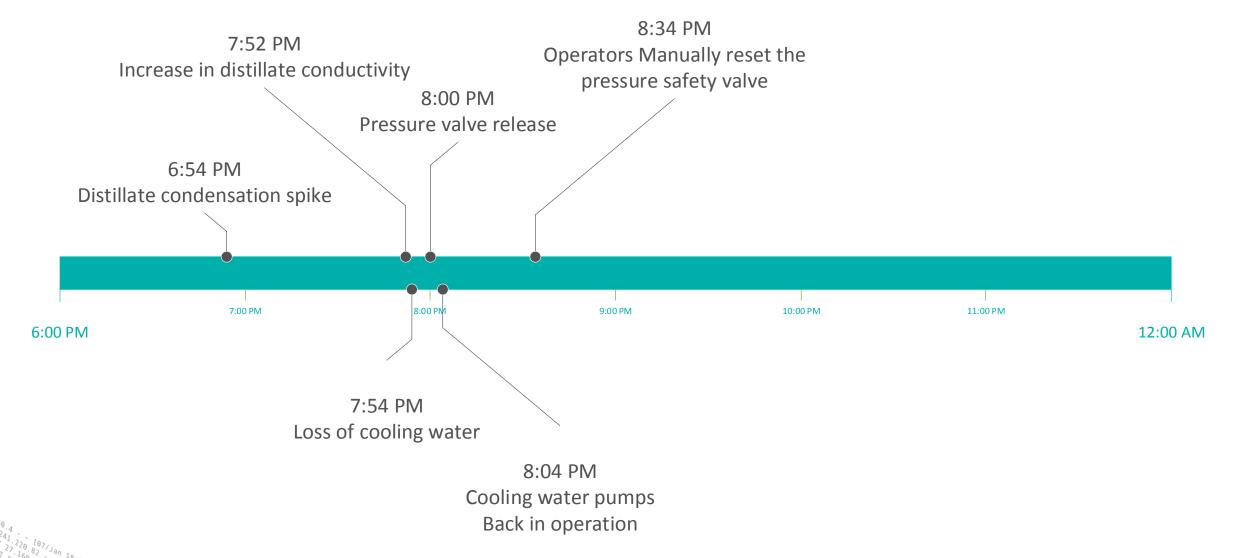
Early Splunk Implementation at PCAPP

- At the start of munition destruction operations, process data was available, but with limited capacity and access
 - Only two workstations with the ability to pull data
 - Air-gapped control and access systems made engineers and analysts develop charts in a control system software, paste screenshots into Word, print, and then scan the paper copy
- Splunk initiative was going on in the background
 - Two people used a small Splunk deployment daily
 - Five people had access to the Splunk instance

Manual Data Collection

- Splunk was proposed as a data collection and management system
- Many challenges to overcome
 - Facility Control System (FCS) security constraints require it to be stand-alone; a highly manual process was used to get usable information into Splunk
 - Started indexing 700 instruments at 1–2 GB per day
- Evaluation of historical process system upsets provided an opportunity for PCAPP's Splunk lead to show what data can do
 - Spill events in the water recycling system were analyzed in approximately 4 hours rather than the usual months (3-4)

Retrospective Analysis of Pressure Relief Valve Release



Condition Reports in the CAS system

Number	Title	Date Created
CR-06228	RCRA Deficiency: BRS Secondary Containment Spill near B12-PSV-1844/B12-PSV-1820	05/12/2017
CR-06395	Foaming in the B12 system caused erroneous indications resulting in a shutdown of the system	07/25/2017
CR-06406	RCRA Deficiency: Hazardous Distillate Spill in B12 Containment Area	07/29/2017

Work Orders in Maximo

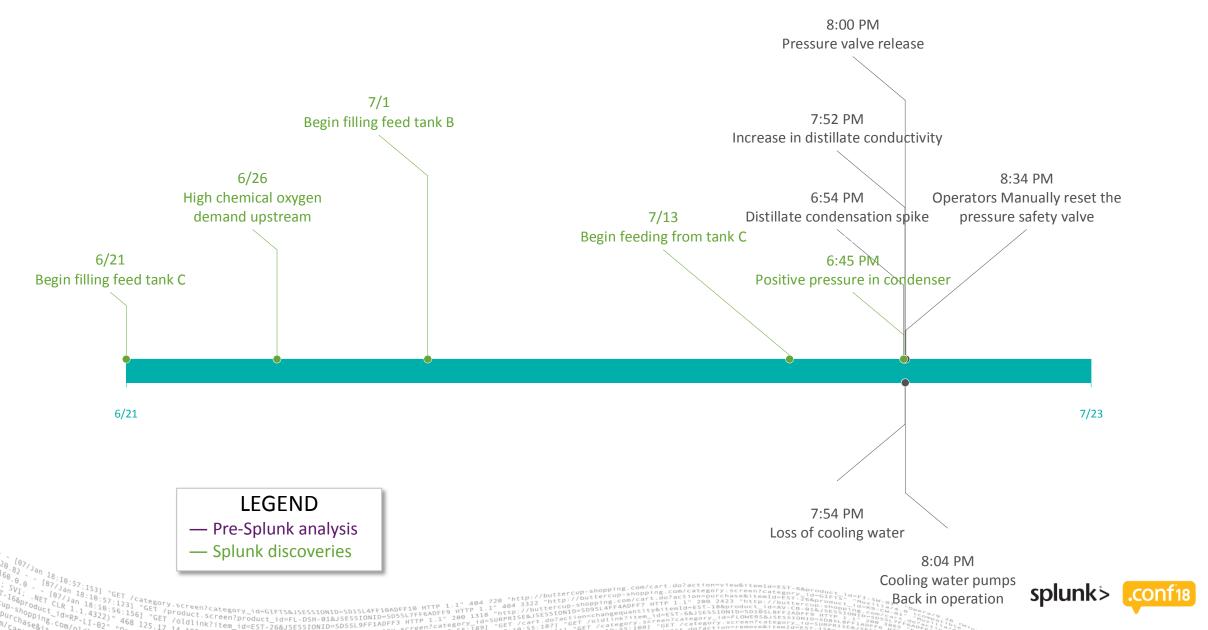
Work Order Number	Description	Asset Tag	Reported Date	Remarks
308869	B12-PSV-1820 lifted a little (M-03)	B12-PSV-1820	5/12/17 3:47 PM	CR06228 mentions PSV-1844 and PSV-1820
318174	B12-PSV-1844 lifting	B12-PSV-1844	6/22/17 10:56 PM	Cancelled to 323582
321711	Calibrate CIT-B121873	B12-CIT-1873	7/16/17 9:13 PM	See Environmental Database ID 8599
321712	Troubleshoot and Repair B12-LV-1880 (M-02)	B12-LV-1880	7/16/17 9:17 PM	See Environmental Database ID 8599
323582	Pressure relief valve PSV-1844 will not reset.	B12-PSV-1844	7/23/17 9:08 PM	

Entries in Environmental Database

ID	Description of Event	Spill Type	Start Date	Condition Report	Remarks
7747	Spill: Approximately 1 gallon of diluted hydrolysate was released from pressure safety valves B12-PSV-1844 and B12-PSV-1820 within the BRS Secondary containment near the pre-heaters, NW of the central sump.	Hydrolysate	5/12/2017	CR06228	
	Spill: 1 gallon of BRS distillate (B12 Recovered Water Preheater) was released onto coated concrete due to a pressure relief valve (B12-PSV-1844) on the N. side of the BRS containment area.	Water (Process) - M16	6/22/2017	No	
8599	Spill: 750 Gallons of Hazardous Distillate from the BRS BC Feed Pre-heater as a result of a pressure safety relief valve opening to relieve pressure from the M13 cooling tower pumps shutting down	Water (Industrial) - M11, M12, M13, M20, M30	7/16/2017		PSV- 1844
8710	Spill: 350 Gallons of Hazardous Distillate was released from the BRS BC Feed Pre-heater as a result of a pressure safety relief valve (B12-PSV-1844) opening to relieve pressure.	Other	7/23/2017	CR06406	

July 16th 2017								Q # / :
								A
:30	06:45	07 PM	07:15	07:30	07:45 i	08 PM	08:15	
B12CIT1873PV					R			1997.61
B12LIT1960PV								52.56
B12PIT1890APV		-						-0.08
B12PIT1962.PV	والمرابا إراجيا الشقائقا والمتاشور والمراج	and the state of t			the state of the s	14	and the second	0.62
B12TIT1893PV								207.35
B12TIT1961PV								213.50
B12TIT1987PV								101.02
:30	06:45	07 PM	07:15	07:30	07:45	08 PM	08:15	
July 23rd 2017								Q # / :
AM	10:15	10:30	10:45	11 AM	11:15	11:30	11:45 i	A
B12CIT1873PV								1997.34
B12LIT1960PV								35.87
B12PIT1890APV			A James and A					-0.05
B12PIT1962.PV								-0.14
B12TIT1893PV								207.30
B12TIT1961PV								210.90
B12TIT1987PV								82.56
АМ	10:15	10:30	10:45	11 AM	11:15	11:30	11:45	
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Timeline When Viewed With Splunk and ICS Data



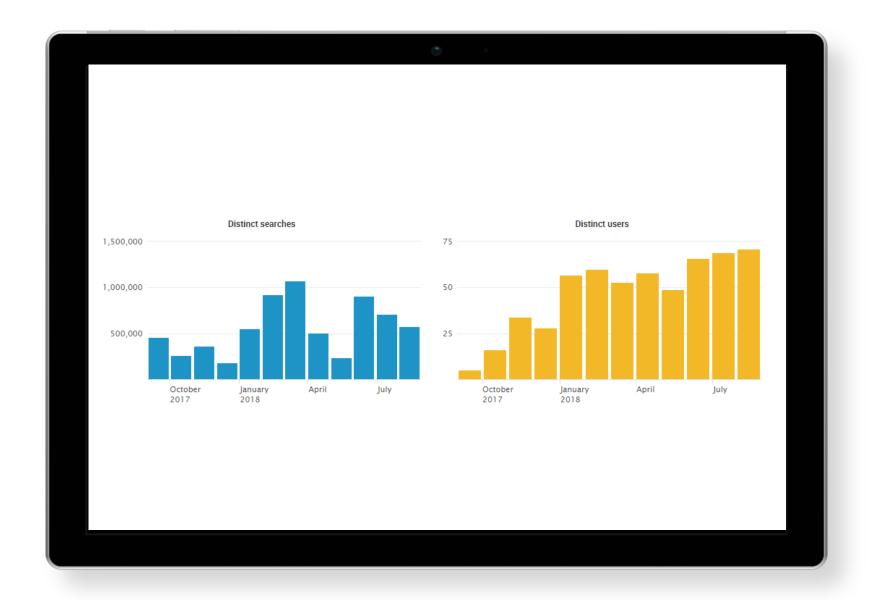
Retrospective Analysis Summary

- Quickly identified buried causes of a pressure safety valve release
- Set up alerts for predictive maintenance
 - When to expect high protein levels that will lead to foaming in the equipment
 - Install alarm indicating negative-to-positive pressure in the evaporator
- Forewarned operators of conditions that lead to foaming which allows for early mitigation
 - System operation now includes proactive addition anti-foaming agent

Proof of Concept Spurs Long-Term Strategy

- Transitioned from manual data loading to live data feed using a unidirectional security gateway (data diode)
 - Indexing 9,000 instruments at 7 GB per day
- Developed a team to build the new deployment
 - Information Systems and Technology architects
 - Data scientists
 - Engineers
 - Operations staff

Splunk is Integrated in Daily Decision Making



- Splunk dashboards are discussed at daily status meetings
- 400% increase in the number of daily users
 - Analytics team
 - Management
 - Engineering
 - Operations



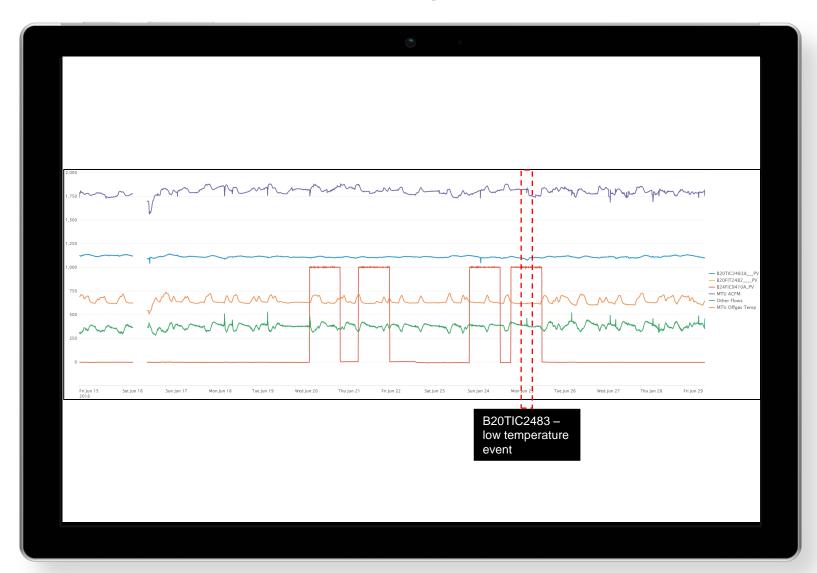
Big data initiative maturity

With great data comes great responsibility

- Accessible by the entire facility
- First goal is to provided simple trends to gain buy-in from daily users
- Analytics team continues to mature and has started to use the machine learning toolkit

Application of the Machine Learning Toolkit at PCAPP

Evaluation of low-temperature alarms in the Off Gas Treatment System



- Drop in temperature in the plant's Off Gas Treatment
 System triggered plant alarms
 - Management placed a hold on upstream system operations until the event was understood – processing stopped
- Complicated interactions make manual trend analysis difficult; too many variables to manually track interactions

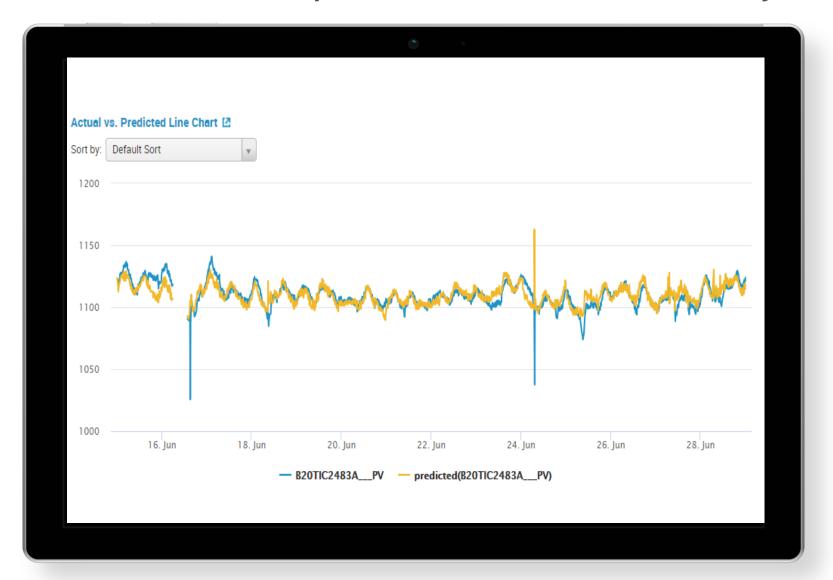


Manual Data Evaluation Feeds Machine Learning

- Off Gas Treatment System temperature is influenced by multiple system operations
 - Activity of a supposedly isolated system may be influencing temperature drop, but this doesn't fully behavior
 - Plant activities (waste treatment operations, munitions processing, chemical agent levels, etc.)
 overlap, making concise analysis impossible
- Leverage Splunk Machine Learning Toolkit (MLTK) to tease out relationships/impacts
- Multi-step process to troubleshoot system interactions, rather than strict machine learning approach
 - Build a first-pass model using a static dataset (includes data from before, after, and during the low-temp event)
 - Perform equipment maintenance, perform post-maintenance testing, and then apply model to operational and system test data (after event and testing period)
 - Model system using a post-maintenance data set and compare to previous model outputs

Application of the Machine Learning Toolkit at PCAPP

Evaluation of temperature in the Off Gas Treatment System using a static dataset



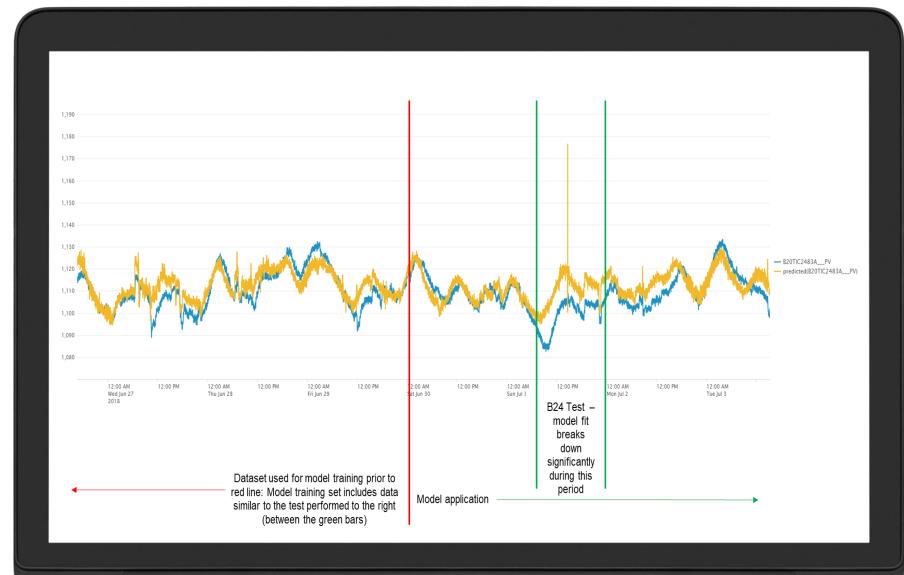
feature 0	coefficient 0 /				
B03FIC9308APV	-0.39139071301				
B03FIC9308BPV	-0.355793952622				
B03T19309APV	-0.0547925376965				
B03TI9309BPV	-0.0572103905425				
B04PIC7085APV	-0.598216013893				
B04PIC7085BPV	-8.95640971631				
B20FI2482PV	0.337116352596				
B20PDI2561PV	-69.1645913668				
B24FV9410APV	-0.323866600969				
_intercept	1172.39450154				
R ² Statistic 🛂 Root Mean Squared Error (RMSE) 🗵					
0.5615	6.17				



Equipment Evaluations and Maintenance Evolutions

- First-pass model suggests an "isolated" stream (B24FV9410A__PV) is impacting temperature
- System valves manually checked twice (between event and later testing)
 - Anecdotal report of ¼ to ½ turn on that valve before it reached a fully closed position
 - Leak-by past this valve may have been impacting downstream temperatures
- Heater system adjustments made based on model significance
 - Inlet flows (B03FIC9308A/B) adjusted
 - Average air temperature decreased by 100°F
 - Systems that showed difference in performance began to respond similarly

Low Temperature Event Model Application - Testing



Data Evaluation Conclusions and Recommendations

- Findings from this Analysis
 - A model fit using <u>pre-maintenance</u> data does not accurately predict post-maintenance performance
 - Maintenance matters!
 - Building MLTK models helps understand the system
 - Increased R² and RMSE (0.7791/4.32) more predictable performance
 - B24FV9410A___PV shows changed relationship (negative to positive)
- Conclusions
 - Maintenance matters! Temperature is no longer shifted by the activity of a single system
 - Resumption of system operations following Splunk team analysis and recommendation
 - More work needed to better predict performance, lots of model training and testing
- MLTK can be used to quickly evaluate plant performance and system interactions
 - More research and staff learning needed to develop truly predictive models
- PCAPP is just beginning to see how Splunk and the MLTK can help the project understand the process, find new efficiencies, and make chemical weapons destruction even more safe!

feature 0	coefficient © /
B03FIC9308APV	-0.344384043812
B03FIC9308BPV	-0.739204146256
B03T19309APV	-0.060210178991
B03TI9309BPV	-0.11373811217
B04PIC7085APV	-1.14502823174
B04PIC7085BPV	46.0269300319
B20FI2482PV	0.268796267008
B20PDI2561PV	-28.5830308087
B24FV9410APV	0.246779333526
_intercept	714.23689455

Key Takeaways

- Increased access to data drives informed decision making
- 2. Innovation requires collaboration
- 3. Machine learning tool kit is used to predict and analyze live data

Thank You

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