HYSYS-based Operator Training Simulator for a new Cumene & Phenol plant

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Outline

- Piloting a process plant
- Project background
- Why OTS investment
- The OTS
- OTS value

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Piloting a process plant

If your process plant were the Saturn V,
your panel operators will be the astronauts

Now, think about the training hours of an astronaut

Process plant vs. Saturn V

	Ethylene plant	Saturn V
Throughput	800 kty ~ 90 t/h of Naphta	1st Stage burns 14200 t/h (Kerosene) with 32200 t/h Liquid Oxygen
Working time	~ 50 years	4 hours, 20 min
Instruments	~ 5000 AI/DI	Stage-1 about 900 instruments, Stages 2&3 ¿?
Cost	~ 1.5 Billion$	Per launch: $494 million in 1964–73 dollars (~$3 billion today)
PID loops	~ 800 loops in ICSS	~ 20 faceplates in Command Module
Training time before launch	3-9 months	Two years for Apollo missions (they are test pilots before)
OTS cost	0.8 – 1.2 Million$	All simulators > 50 million$

OTS is a multiplier of every hour invested in training

Source: https://www.hq.nasa.gov/alsj/NASATND7112.pdf

Project background

CEPSA Chemical Shanghai (“CCS”) is building the new Cumene and Phenol plants in the Shanghai Chemical Industry Park (SCIP), with a capacity to produce:
250kMt of phenol and
150kMt of acetone

CCS is using OTS to reinforce the training for all the operation staff, with plenty of scenarios, to improve the economical operation of the plant, such as normal operations, start-up and shutdown, equipment malfunction and emergency conditions.

Inprocess Technology and Consulting Group (“Inprocess”) has rich modeling and project experiences for OTS (Operator Training System).

www.youtube.com/watch?v=NJxIXR3ZAKs

Why OTS investment

The OTS overall objectives were:

- Train the chinese/spanish operation staff on the process and the DeltaV system in Shanghai and Huelva (Spain).
- Reduce the risk of major operational incidents
- Reduce start-up time
- Increase plant on-stream time and performance
- Verify Process Control & Safety Systems operation
- Avoid equipment damages
- Provide a test-bed system for engineering analysis

The OTS: Concept

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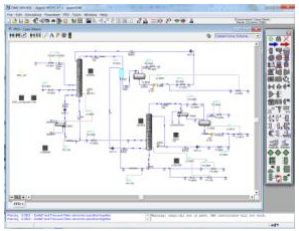
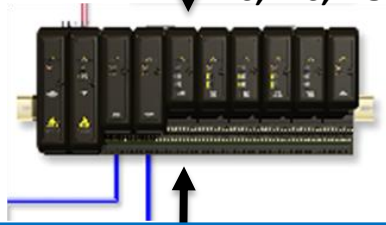
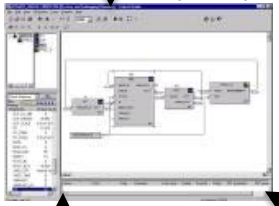
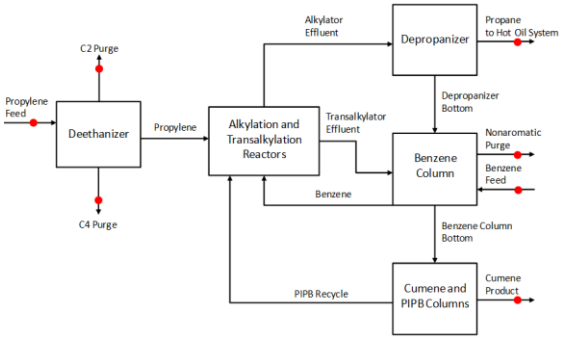
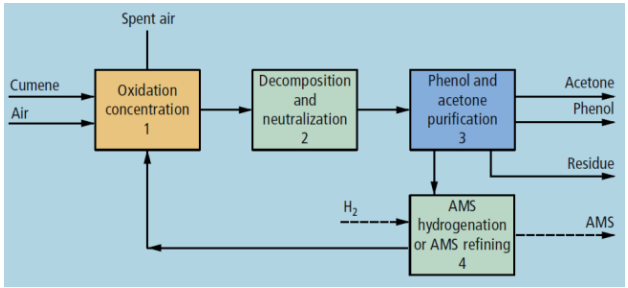
	Real World	Direct-Connect OTS
Process Plant	 Field Operator 	 Aspen HYSYS Dynamics Model
Control System & SIS	AIs, DIs, AOs, DOs  ICSS Hardware & Software	Download Database AIs, DIs, AOs, DOs  ICSS Emulation Software
Human Machine Interface	 Panel Operator	Graphics  Panel Operator ICSS Console as in Control Room  Instructor Station & Field Operator Devices

The OTS: Model Scope





Challenge

Multiple chemical reactions, many separation units (18 distillation columns) and large recycles

Simulation Scope Cumene

- Equipments: 60
- Isolation valves: 20
- Control valves: 91
- Relief valves: 20
- PID loops: 90
- I/O Count: 1000
- Component List 28

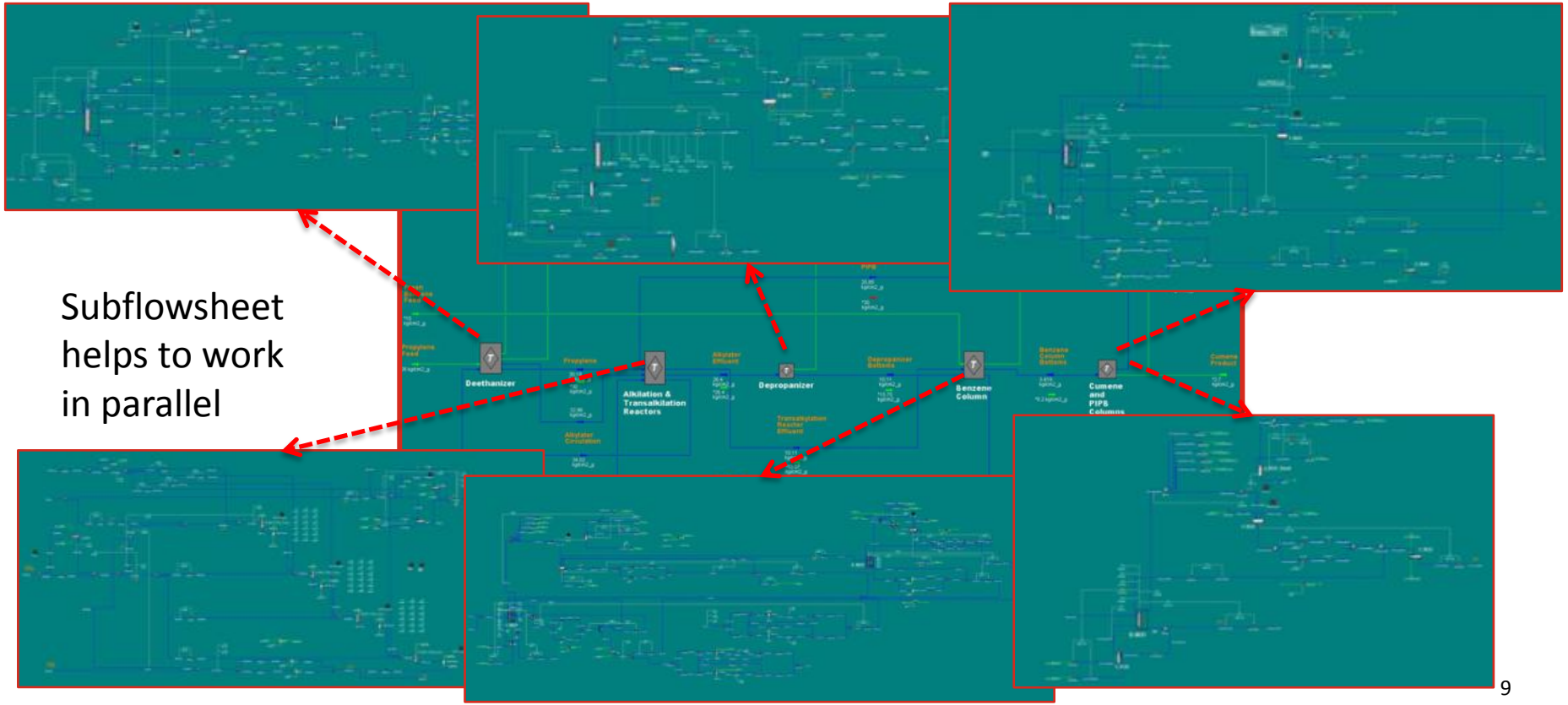
Component List-Cumene	
H2O	Benzene
Methane	Toluene
Ethylene	E-Benzene
Ethane	Cumene
Propene	n-Pbenzene
Propane	AMS
Cyclopropane	i-BBenzene
Propadiene	m-Cymene
M-Acetylene	p-Cymene
1-Butene	1-E-4-iP-BZ*
i-Butene	13-iP-BZ
i-Butane	n-Hexyl-BZ
13-Butadiene	135-iP-BZ*
n-Hexene	DiPhenylC3

Simulation Scope Phenol

- Equipments: 132
- Isolation valves: 62
- Control valves: 210
- Relief valves: 41
- PID loops: 204
- I/O Count: 2000
- Component List 35

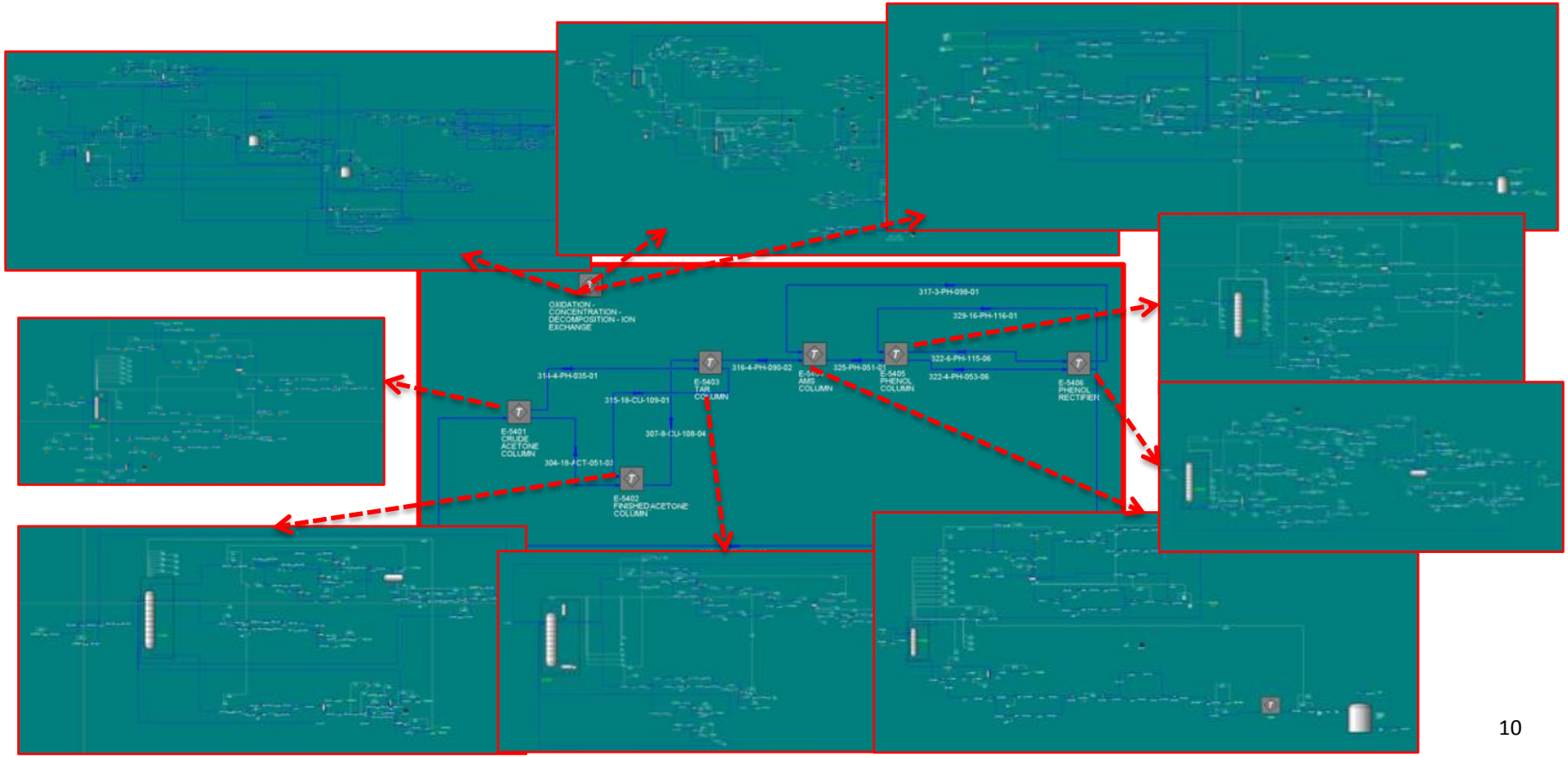
Component List-Phenol	
H2O	diAcetone-ol
Hydrogen	BZoicAcid
Nitrogen	o-Cresol
Oxygen	m-Cresol
Methane	p-Cresol
CO	M-PH-Ketone
Formaldehyde	2MBenzoFuran
FormicAcid	AMS
Methanol	Cumene
Oxalic_Acid	DMPHCarbinol
AceticAcid	CumHyPeroxid
Propanal	o-Cymene
Acetone	m-Cymene
Acetol	p-Cymene
Benzene	pCumylPhenol
Phenol	DCumPeroxide
Mesityloxide	H2SO4*
3Mcycpentene	

Cumene HYSYS model



Subflowsheet helps to work in parallel

Phenol HYSYS model



The OTS: modeling highlights

- **Reactor Dynamics**

  The HYSYS CSTR reactor was used with rigorous kinetics.
  Reactors parameters and kinetics constants were adjusted to obtain accurate dynamics.

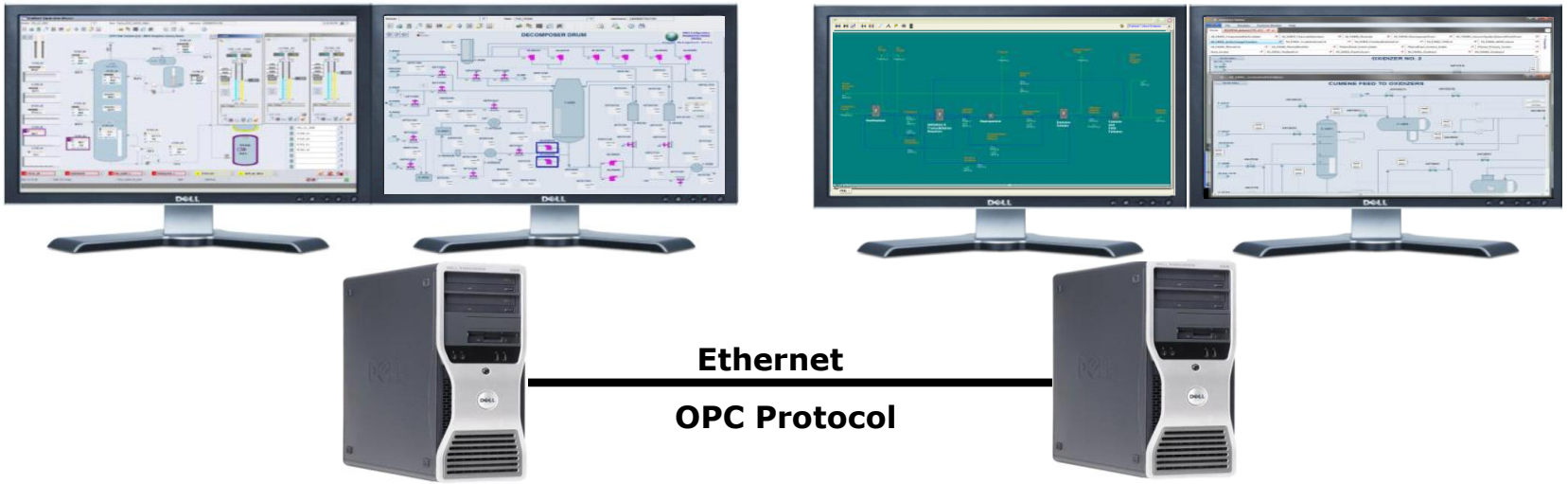
- **Hydraulics Effects in Reactor Dynamics**

  Compressors push air to the bottom of the Oxidizers and the liquid mass is in suspension, but HYSYS CSTR is an ideal homogenous reactor. These dynamics were modeled, therefore when compressor trips the Oxidizers levels are affected.

- **Calorimeters DeltaT**

  They are the sensors of the reaction. They were calibrated with the same dynamics that the existing Huelva (Spain) plant was providing.

The OTS: Architecture



DCS Operator Workstation

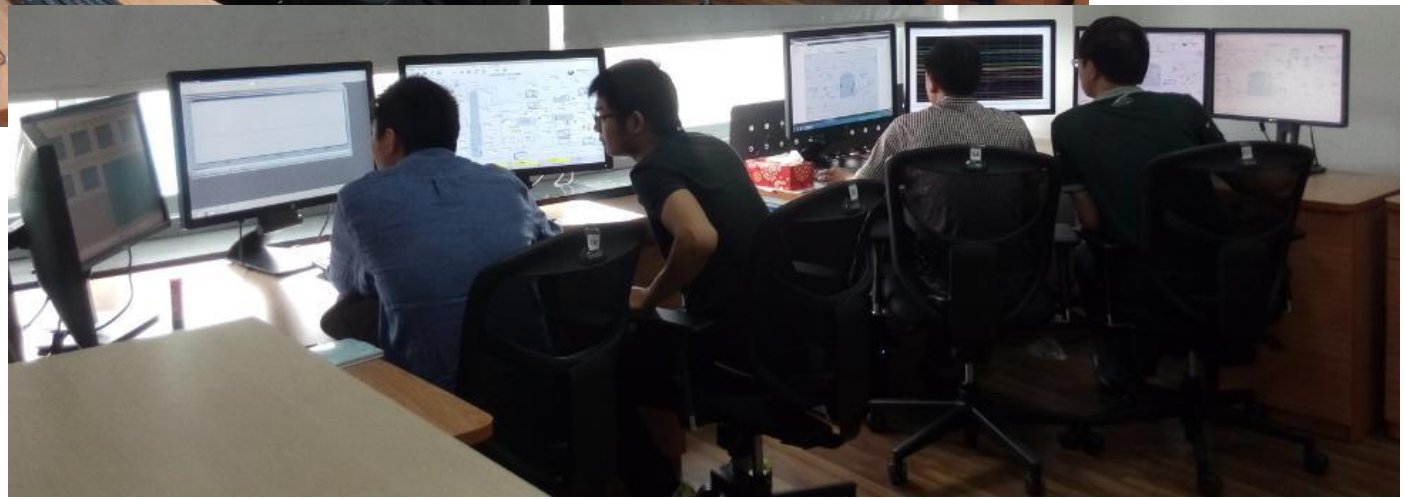
- Plant Control System Emulator DeltaV Simulate Pro
- Operator HMI, DCS DeltaV

Instructor Workstation

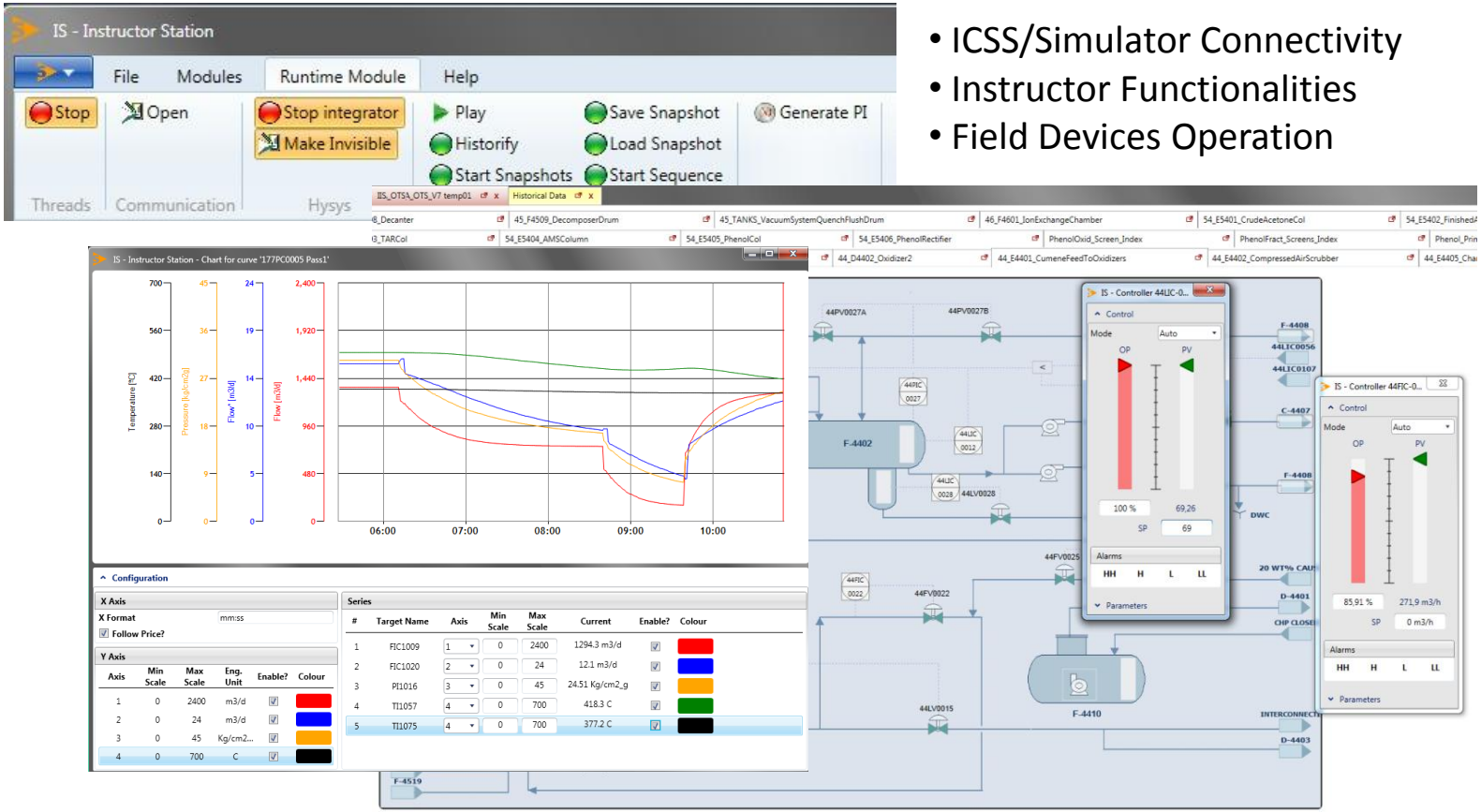
- Plant Dynamic Model (HYSYS Dynamic model)
- Inprocess Instructor Station
  - HMI for Field Operated Devices
  - Simulation Management
  - Communication

An OTS replica was installed in Huelva complex (Spain)

The OTS: DeltaV Operate



The OTS: Instructor Station



- ICSS/Simulator Connectivity
- Instructor Functionalities
- Field Devices Operation

The OTS: Scenarios

50 scenarios were developed:

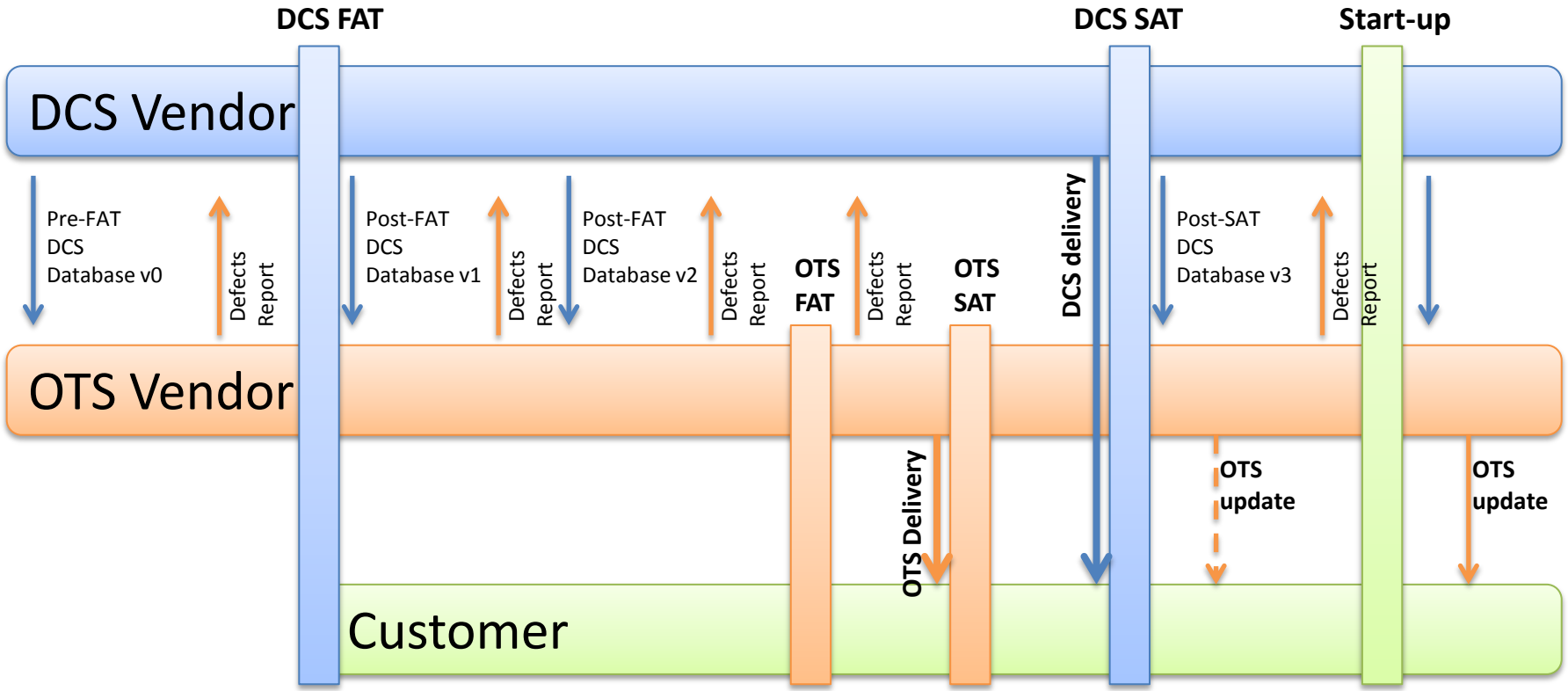
- Operational scenarios:
  - change utilities conditions
  - change in raw material quality
  - throughput changes

- Procedure scenarios:
  - Start-up
  - Shutdown

- Safety Scenarios:
  - Equipment power loss
  - Instrument air failure
  - Critical utilities loss

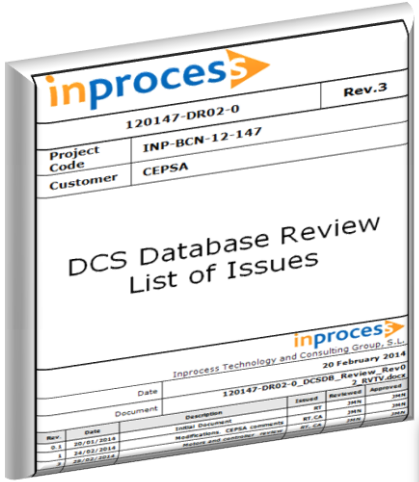
- Equipment failures and malfunctions:
  - Column steam failure
  - Exchangers fouling
  - Instrument failure

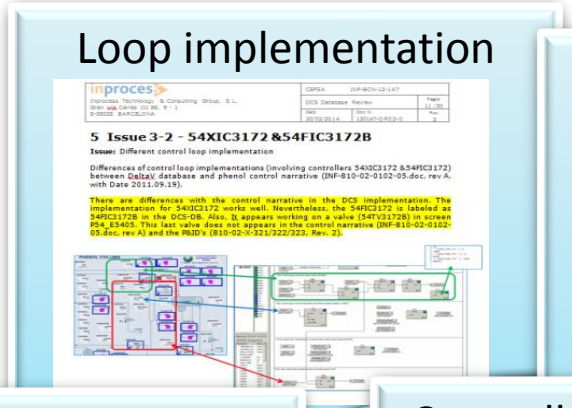
OTS value: Debug ICSS code

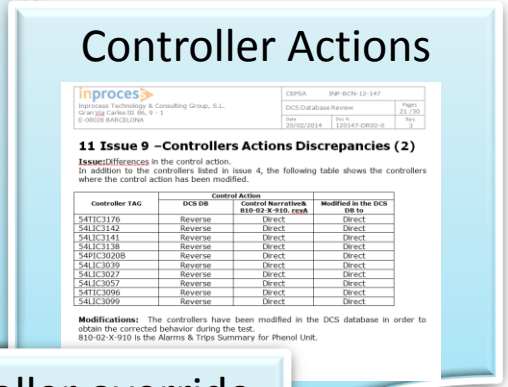


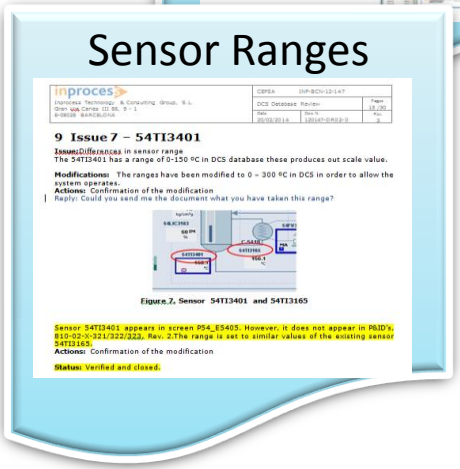
Important: OTS Vendor acts as an independent auditor of the ICSS functionality

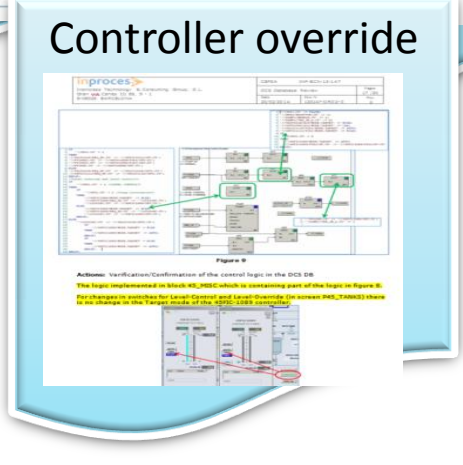
Examples ICSS database review











OTS value: Operator Training

46 operators have been trained: 1998 hours in total, training table sample

			Tue	Wed	Thu	Fri	Mon	
			10-Jun	11-Jun	12-Jun	13-Jun	16-Jun	17-J
1	Han Chunxing	韩春星	0800-1000					0800
2	Zhao Xu	赵旭	0800-1000					0800
3	Zhan Meng	詹猛	1000-1200					1000
4	Zhao Feng	赵峰	1000-1200					1000
5	Wu Weiwei	吴伟伟	1230-1430					1230
6	Wang Yan	王燕	1230-1430					1230
7	Lu Jian	陆建	1430-1630					1430
8	Wang Haiyang	王海阳	1430-1630					1430
9	Yang Chaolong	杨超龙		0800-1000				
10	Yang Yiyong	杨熠勇		0800-1000				
11	Bao Jianghong	鲍江鸿		1000-1200				
12	Bai Xusheng	白旭升		1000-1200				
13	Chen Xihui	陈新辉		1230-1430				
14	Fei Ping	费平		1230-1430				
15	Chen Huiwen	陈会文		1430-1630				
16	Kang Weitang	康为塘		1430-1630				
17	Wang Changping	汪长平			0800-1000			
18	Zhang Hailong	张海龙			0800-1000			
19	Wang Chengcheng	王诚诚			1000-1200			
20	Zhou Ruiqi	周瑞琪			1000-1200			
21	Yang Yihao	杨亦豪			1230-1430			
22	Xu Zhonghao	徐忠豪			1230-1430			
23	Shen Sitao	沈思涛			1430-1630			
24	Bao Yue	包越			1430-1630			
25	Wang Meiling	王美玲				0800-1000		
26	Yang Qiangqiang	杨强强				0800-1000		
27	Luo Haiping	骆海平				1000-1200		
28	Zhang Jiaqi	张嘉琪				1000-1200		
29	Zhang Ling	张玲				1230-1430		
30	Yao Chaoyi	姚超亿				1230-1430		
31	Ye Qinmei	叶琴梅				1430-1630		
32	Liu Erlong	刘二龙				1430-1630		
33	Yao Yazhou	姚叶舟					0800-1000	
34	Chu Yuan	褚渊					0800-1000	
35	Jin Yihui	金怡辉					1000-1200	
36	Mo Zijie	莫梓杰					1000-1200	
37	Zhou Ziyun	周子筠					1230-1430	
38	Wu Qiaowei	吴桥伟					1230-1430	
39	Yang Zili	杨自立					1430-1630	
40	Yu Chun	余淳					1430-1630	

1. GET FAMILIAR:

With the process
With the procedures
With HMI navigation and controls

2. IMPROVE:

Operation and safety procedures
Uniform skills levels in all operators
Rational thinking
Time to react

3. RESULTS:

Increased Safety
Reduce Start-up time
Off-spec reduction

OTS value: Operating range

In the Shanghai petrochemical area, there were several alternative providers of feed propylene, each with different grades and other distributions of Lights and Heavies components.

OTHER FEEDS

CEPSA Operations requested to investigate the process operating constraints (valve saturation, duty limits, impurities accumulations) with different streams compositions of propylene feed.

The model proved that, making certain SetPoint adjust, other propylene grades were able to be handled by the plant.

OTS ownership

There is one important aspect when Operating Companies decide to invest in OTS:

The OTS itself does not do the training and knowledge transfer

The Operating Company needs to design the operator competency program making use of the OTS as an integral tool of the training programs.

Like NASA does with astronauts

Like Airlines do with pilots

Like Mercedes does with Hamilton

Inprocess helps to design and complement those training programs with the use of the OTS. Resources and workflows need to be defined and budgeted.
Ongoing operator training programs in CEPSA:

- Petrochemical complex San Roque
- Refining business unit

HYSYS as OTS engine

Using HYSYS Dynamics as OTS simulation engine has some advantages:

1.- It is a known software inside CEPSA and most of the engineers are familiar with it

2.- It can increase the rigor as needed, depending on training objectives

3.- It is flexible enough to develop custom items (spreadsheet, UserVar, Extensions)

4.- It is powerful enough to handle >5000 I/O tags/sec in realtime in one PC.

5.- Models can be taken from the OTS to run other operations/eng. studies

6.- It is easy to maintain for typical changes (new instrument, new valves, loop changes, etc)

Conclusions

- OTS improves the ICSS testing and debugging
- OTS could reduce the major operational incidents
- OTS is a good platform to evaluate operator's skills and to uniforms them
- HYSYS-based OTS is a suitable tool to validate raw material planning decisions
- HYSYS-based OTS secures reusability of the process model for analysis
- OTS was executed within time and budget; OTS team was adaptive to the EPC and ICSS schedules.
- This was the first high fidelity HYSYS-based OTS in CEPSA; as a result CEPSA is considering OTS for new and existing plants. CEPSA is executing the 3rd training simulator with Inprocess.

Q&A,

Thank you

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