Bridging ADO and EPICS for the Electron Ion Collider (EIC)

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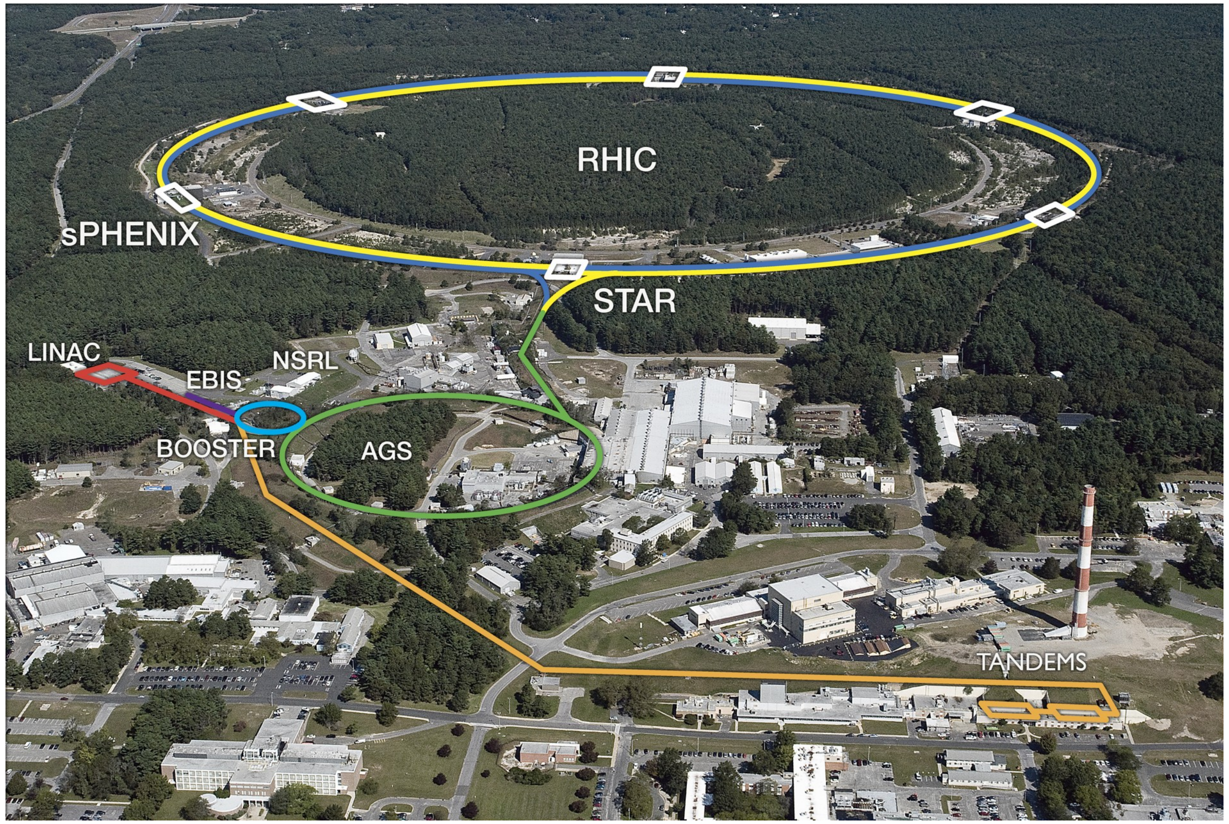
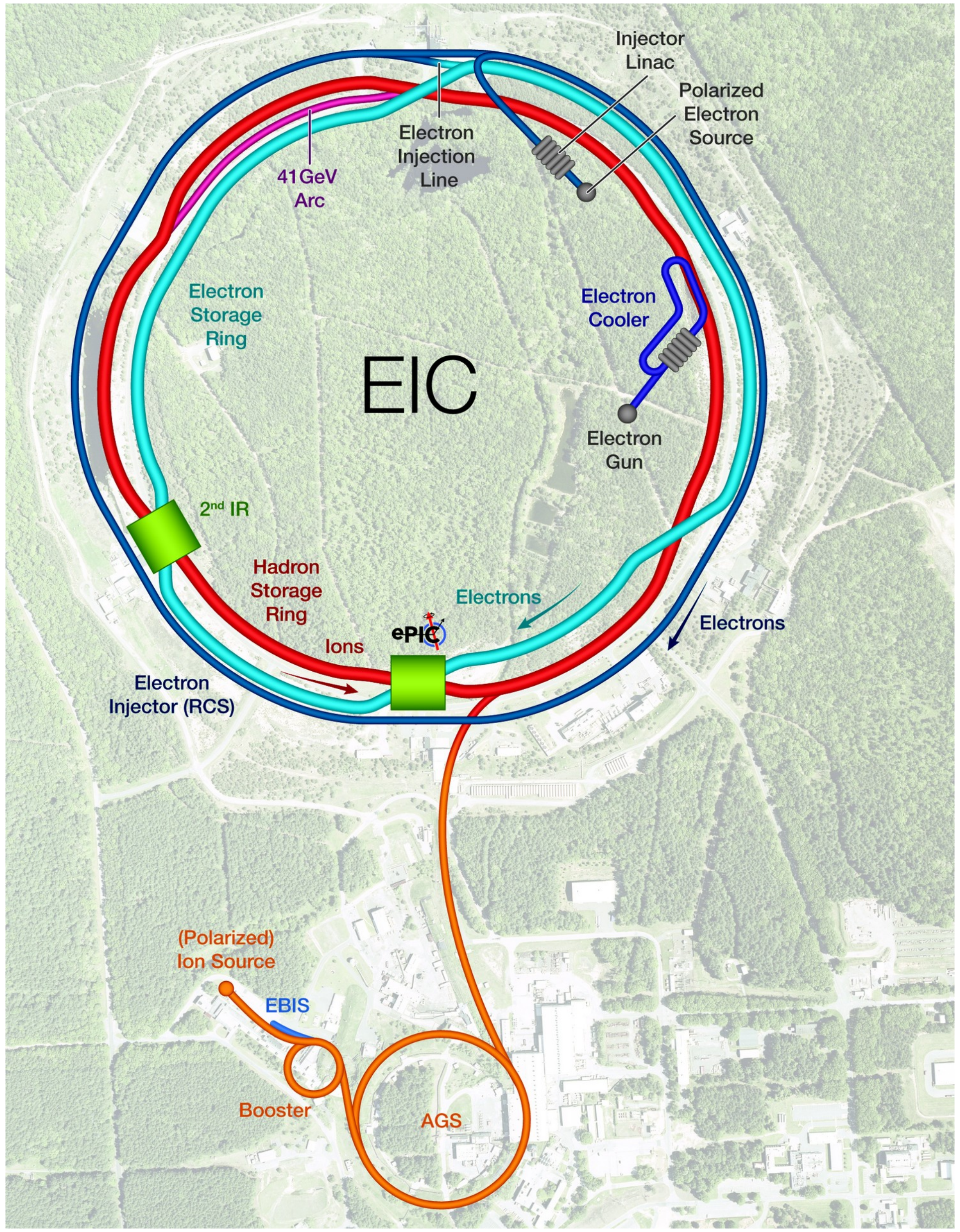
Outline

- Overview of the EIC and RHIC
- RHIC and EIC control system
- Overview of ADO
- Different approaches of the ADO-EPICS bridge
- Bridge using pvAccess/pvxs
- Pros and cons of different approaches
- Challenges and outlook

From RHIC to the EIC: Collider and Injectors





- Relativistic Heavy Ion Collider (RHIC) is the world's only polarized proton-proton collider
- RHIC will be replaced by a future Electron Ion Collider (EIC) to study the QCD structure of matter

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From RHIC to the EIC: Collider and Injectors

	RHIC	EIC
Operating Period	2000 - 2025	~2032 - 2050s
Machines	Blue & Yellow Rings (LEReC, CeC)	HSR, ESR, RCS, Linac, SHC
Spin Physics Program	Part-time (p^)	Most of the time
Collisions	Hadrons, same or mixed species	Hadrons / electrons
Beam Cooling	Add-ons for injection and store	At injection and store
Footprint / Circumference	RHIC tunnel, 2.4 miles	>RHIC tunnel, 2.4 miles
Beam Experiments (Initial)	4	1
Buildings (incl. Storage, Cooling)	44	62

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From RHIC to the EIC: Control System

- **RHIC Blue and Yellow Rings and related eCooling system (CeC, LEReC) currently supports ~70k Accelerator Device Objects (ADOs)**
  - Proprietary controls system interface with functionalities similar to EPICS
  - Each ADO instance hosts several to > 1k number of I/O parameters, analogous to EPICS PV
  - Additional interfaces via CDEV objects for services
  - Total control points currently, ~29.5M, approximately ~5M are parameter values that may be of interest for logging purposes

- **Support for EIC will include**
  - The Hadron Storage Ring (HSR) will roughly be equivalent to RHIC Blue + Yellow Ring
  - New machines to be added for EIC: Electron Storage Ring (ESR), Rapid Cycling Synchrotron (RCS), eLinac and Strong Hadron Cooling (SHC)
  - Total device types: ~60
  - Total device instances: ~8000

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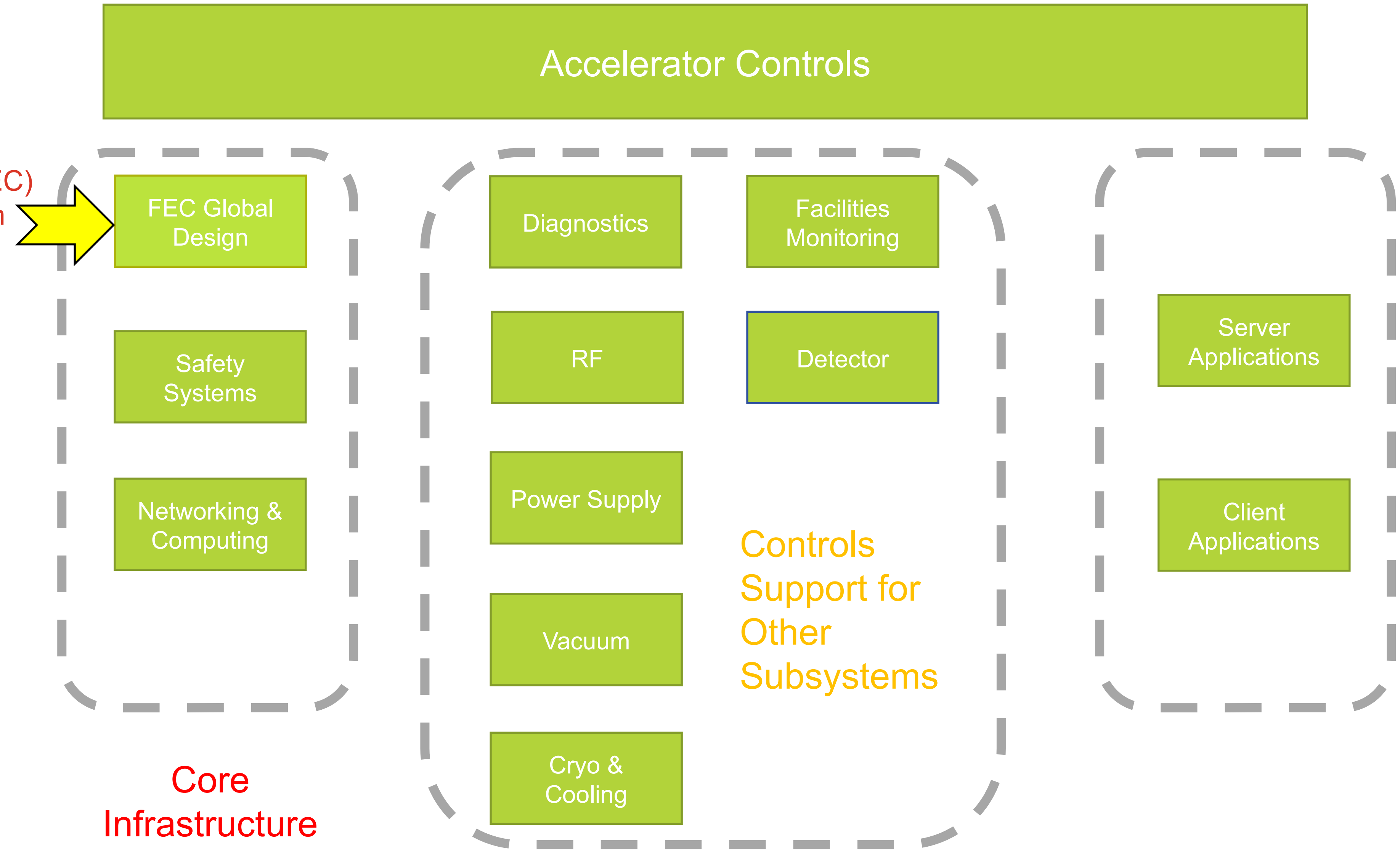
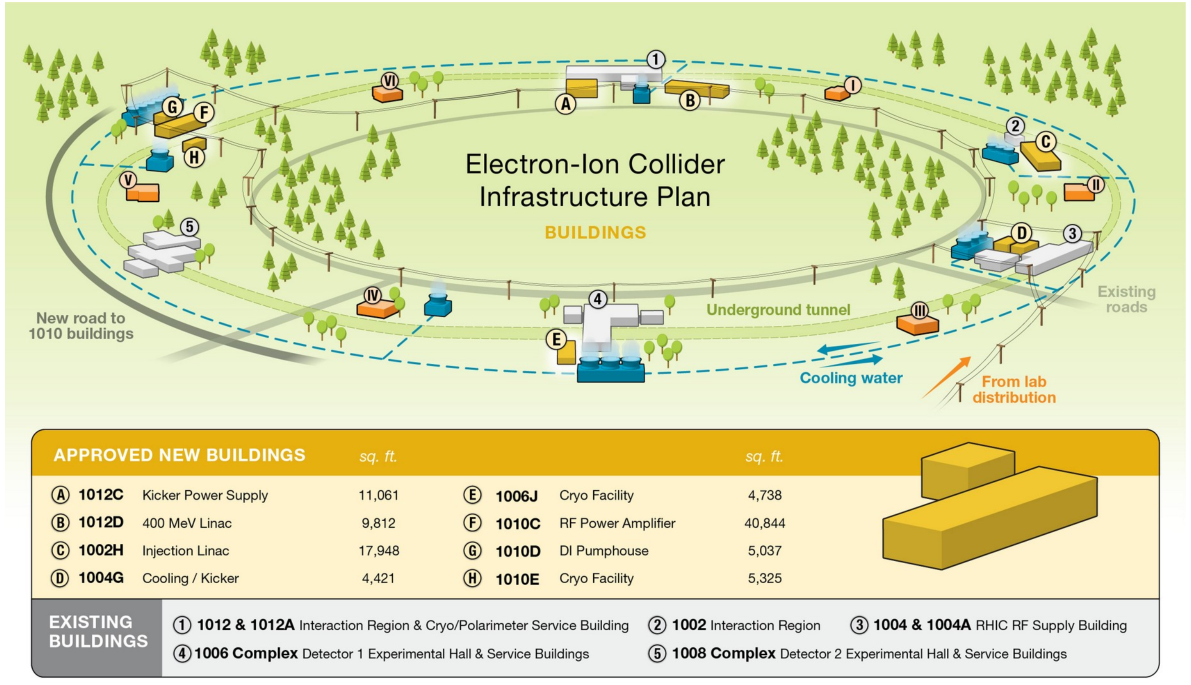
EIC Controls

- Front-End Computers (FEC)
- Timing & Data Distribution
- MPS Distribution
- FEC Remote Interface
- FEC Configuration



From RHIC to the EIC: Equipments

FEC Role	Count / %
Instrumentation	350 / 39%
RF	200 / 21%
Power Supplies°	130 /14%
Timing System°	120 / 13%
Miscellaneous°	50 / 6%
MPS°	40 / 4%
Vacuum°	20 / 2%
Total Chassis, Estimated*	910



APPROVED NEW BUILDINGS		sq. ft.			sq. ft.
Ⓐ 1012C	Kicker Power Supply	11,061	Ⓔ 1006J	Cryo Facility	4,738
Ⓑ 1012D	400 MeV Linac	9,812	Ⓕ 1010C	RF Power Amplifier	40,844
Ⓒ 1002H	Injection Linac	17,948	Ⓖ 1010D	DI Pumphouse	5,037
Ⓓ 1004G	Cooling / Kicker	4,421	Ⓗ 1010E	Cryo Facility	5,325

EXISTING BUILDINGS

① **1012 & 1012A** Interaction Region & Cryo/Polarimeter Service Building ② **1002** Interaction Region ③ **1004 & 1004A** RHIC RF Supply Building

④ **1006 Complex** Detector 1 Experimental Hall & Service Buildings ⑤ **1008 Complex** Detector 2 Experimental Hall & Service Buildings

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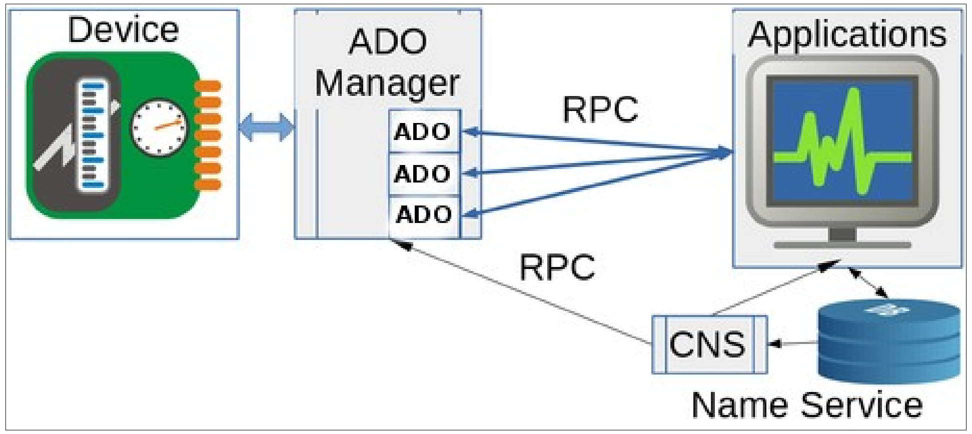
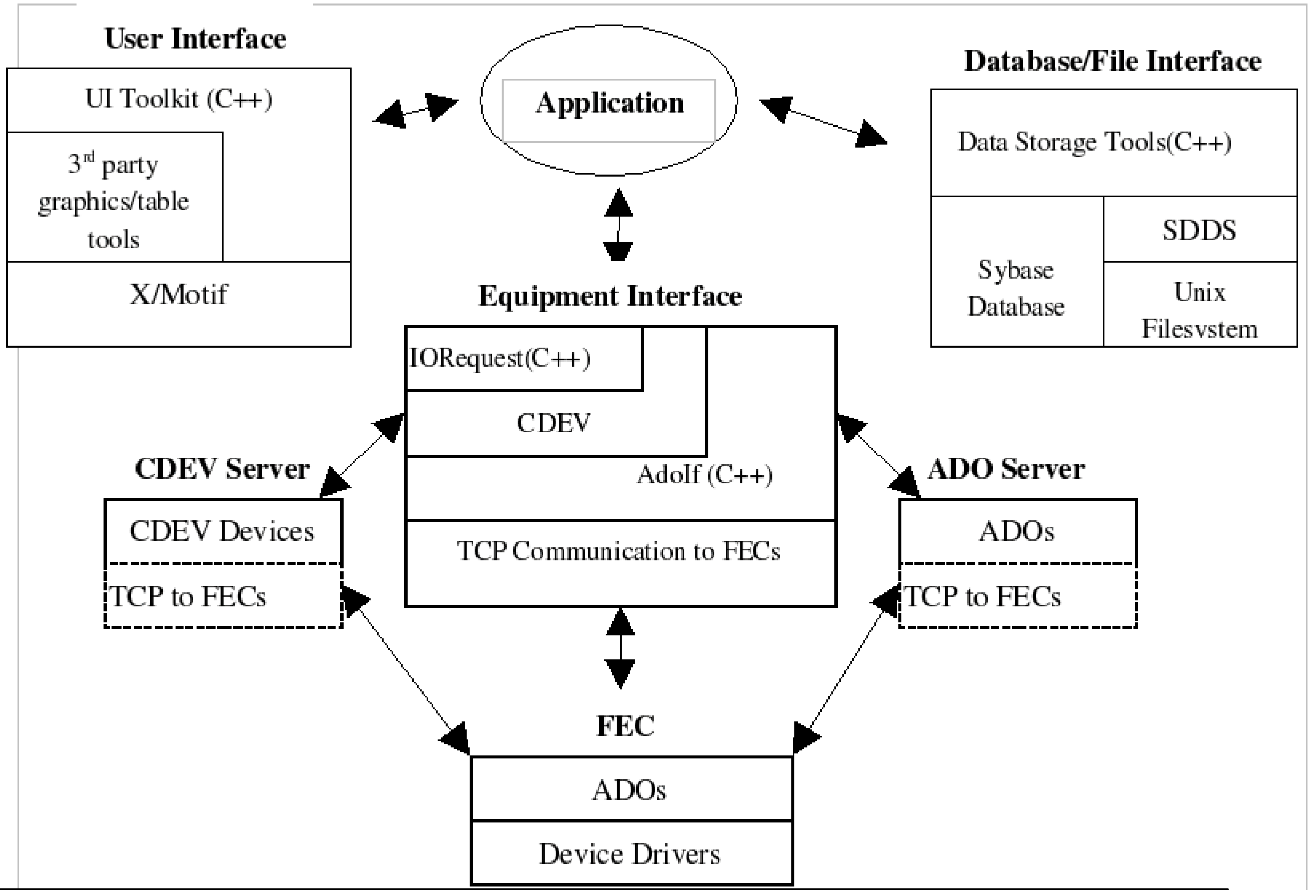
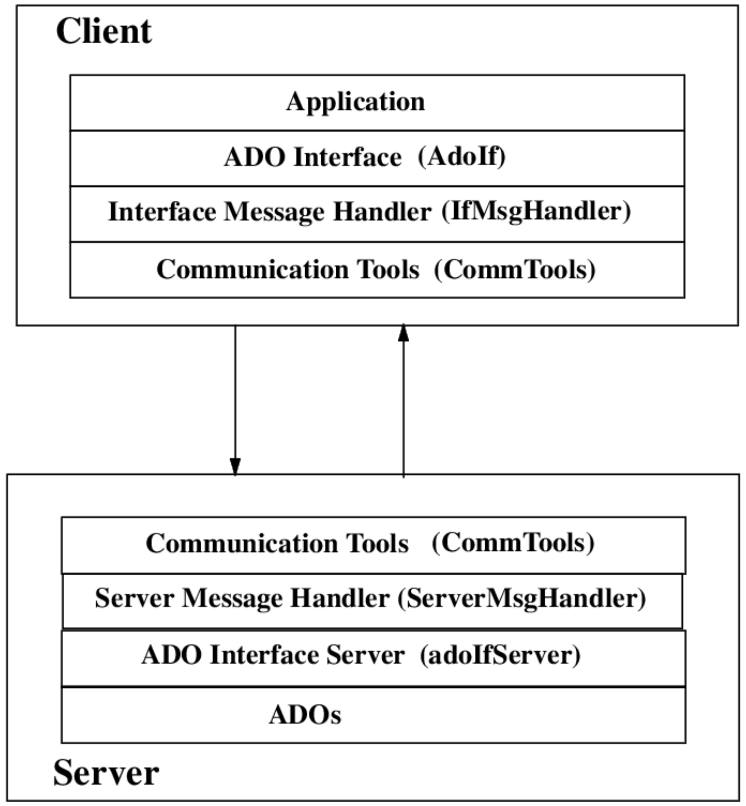
Accelerator Device Object (ADO)-Based Control System



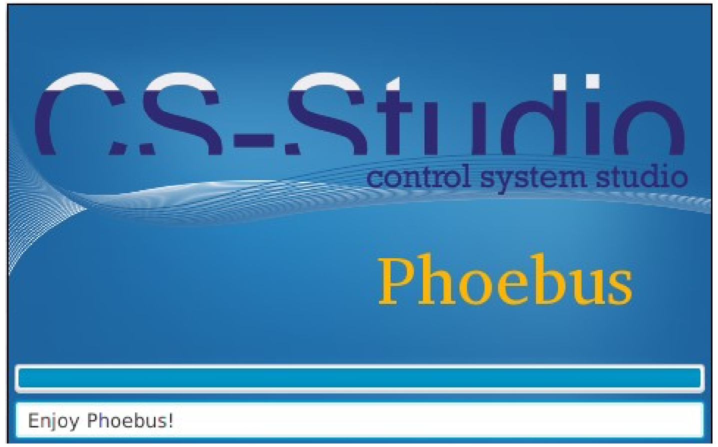


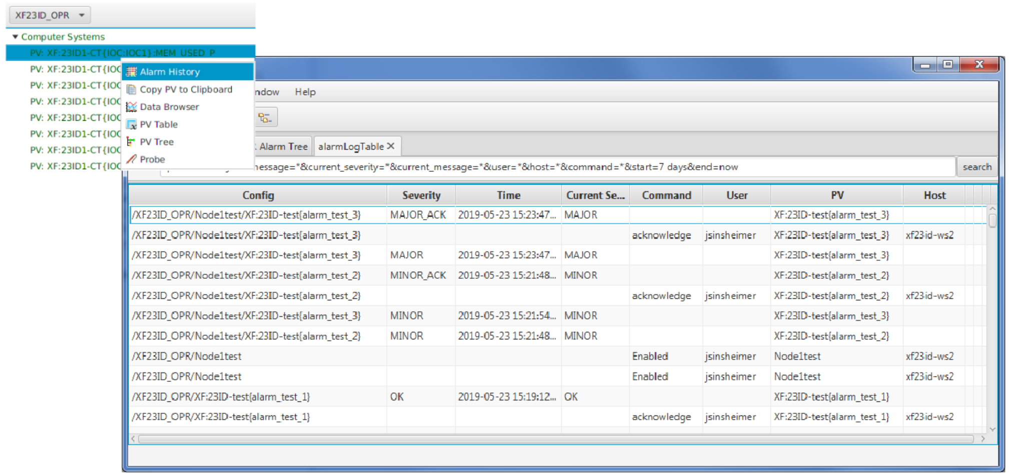

Client
Application
ADO Interface (AdoIf)
Interface Message Handler (IfMsgHandler)
Communication Tools (CommTools)
Communication Tools (CommTools)
Server Message Handler (ServerMsgHandler)
ADO Interface Server (adoIfServer)
ADOs
Server

ADO = C++ class or object representing a device with parameters
Manager = Server
Parameter = PV
FEC = Front-End Computer

Why Do We Need ADO-EPICS Bridge?

- The Electron Ion Collider (EIC) plans to transition to EPICS for its control software infrastructure.
- The source and injectors will likely continue relying on ADO infrastructure
- ADO-EPICS bridge is needed to access source/injector data from EIC
- If ADO parameters can be made available as EPICS PVs, we can take advantage of the whole suite of EPICS client-side tools e.g. display manager, channel finder, alarm service, archiver service etc.





```
essage=*&current_severity=*&current_message=*&user=*&host=*&command=*&start=7 days&end=now
```

Config	Severity	Time	Current Se...	Command	User	PV	Host
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_3}	MAJOR_ACK	2019-05-23 15:23:47...	MAJOR			XF:23ID-test{alarm_test_3}	
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_3}				acknowledge	jsinsheimer	XF:23ID-test{alarm_test_3}	xf23id-ws2
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_3}	MAJOR	2019-05-23 15:23:47...	MAJOR			XF:23ID-test{alarm_test_3}	
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_2}	MINOR_ACK	2019-05-23 15:21:48...	MINOR			XF:23ID-test{alarm_test_2}	
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_2}				acknowledge	jsinsheimer	XF:23ID-test{alarm_test_2}	xf23id-ws2
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_3}	MINOR	2019-05-23 15:21:54...	MINOR			XF:23ID-test{alarm_test_3}	
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_2}	MINOR	2019-05-23 15:21:48...	MINOR			XF:23ID-test{alarm_test_2}	
/XF23ID_OPR/Node1test				Enabled	jsinsheimer	Node1test	xf23id-ws2
/XF23ID_OPR/Node1test				Enabled	jsinsheimer	Node1test	xf23id-ws2
/XF23ID_OPR/XF:23ID-test{alarm_test_1}	OK	2019-05-23 15:19:12...	OK			XF:23ID-test{alarm_test_1}	
/XF23ID_OPR/XF:23ID-test{alarm_test_1}				acknowledge	jsinsheimer	XF:23ID-test{alarm_test_1}	xf23id-ws2

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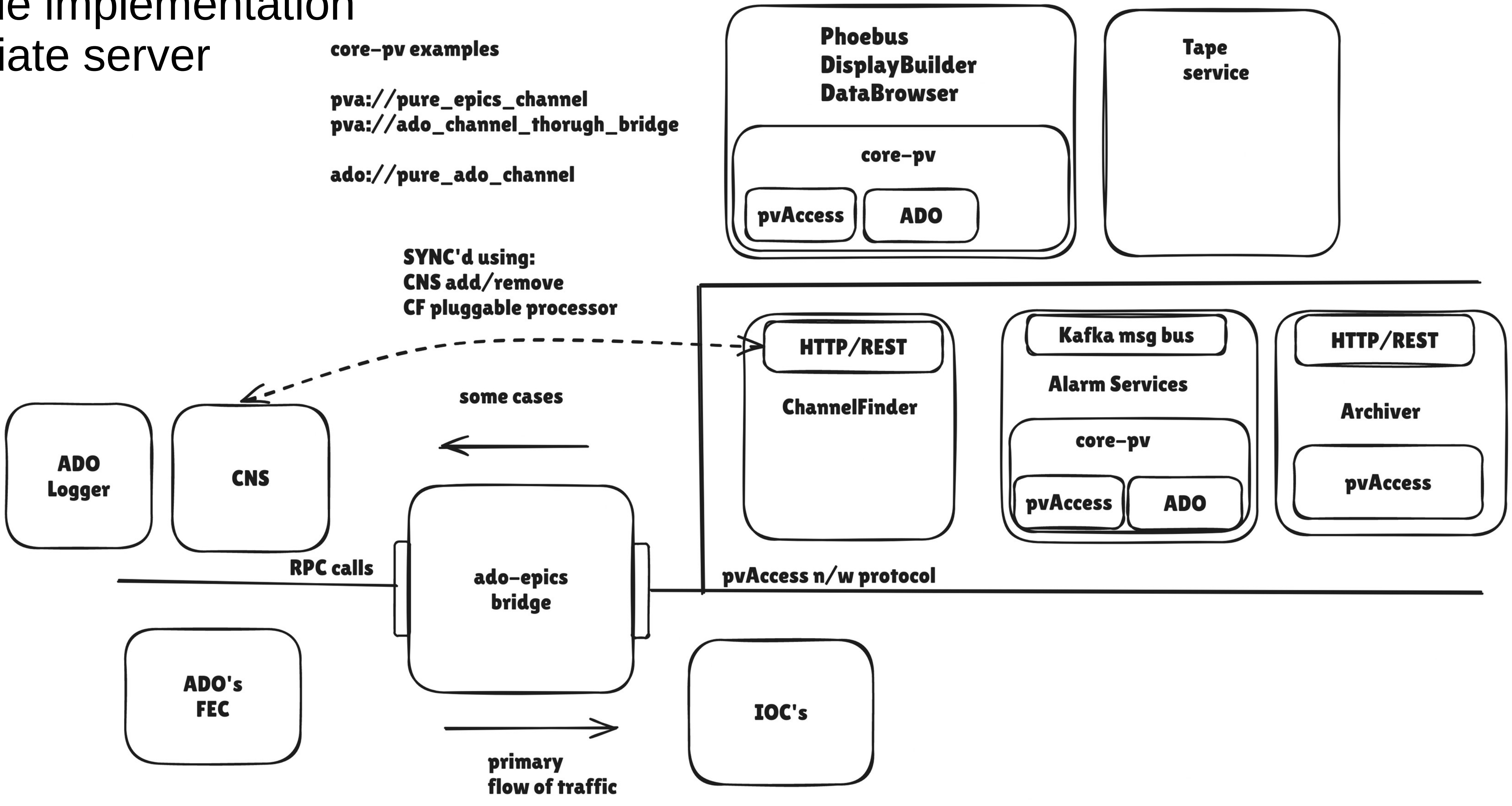
ADO-EPICS Bridge: Possible Approaches

1) **Server-side implementation**
2) Client-side implementation
3) Intermediate server



Accessing ADO Using pvAccess Protocol

- pvAccess is a (relatively) newer high-performance network communication protocol for EPICS.
- pvAccess is designed to support the structured data types of the EPICS7 data exchange system called pvData.
- pvxs is modern C++ implementation of pvAccess protocol by Michael Davidsaver for EPICS7
- adoSrv is a PVAccess protocol server based on pvxs providing remote access to local ADOs developed by Michael Davidsaver (Osprey) for BNL CAD Controls.

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Components of pvAccess for ADO

EPICS Infrastructure

- EPICS 7 Base
- pvxs

ADO Infrastructure

All essential libraries
- ado
- adoIf
- adoIfServer
- async
- cns
- cdev

…

…

pvAccess Binding for ADOs

- **adoSrv**
- Target ADO's library
- Modified server for the target ADO

- **adoSrv** implements a modified/overloaded version of pvxs::server::Source
- The end result is a server executable that exposes ADO parameters as PVs through the pvAccess protocol

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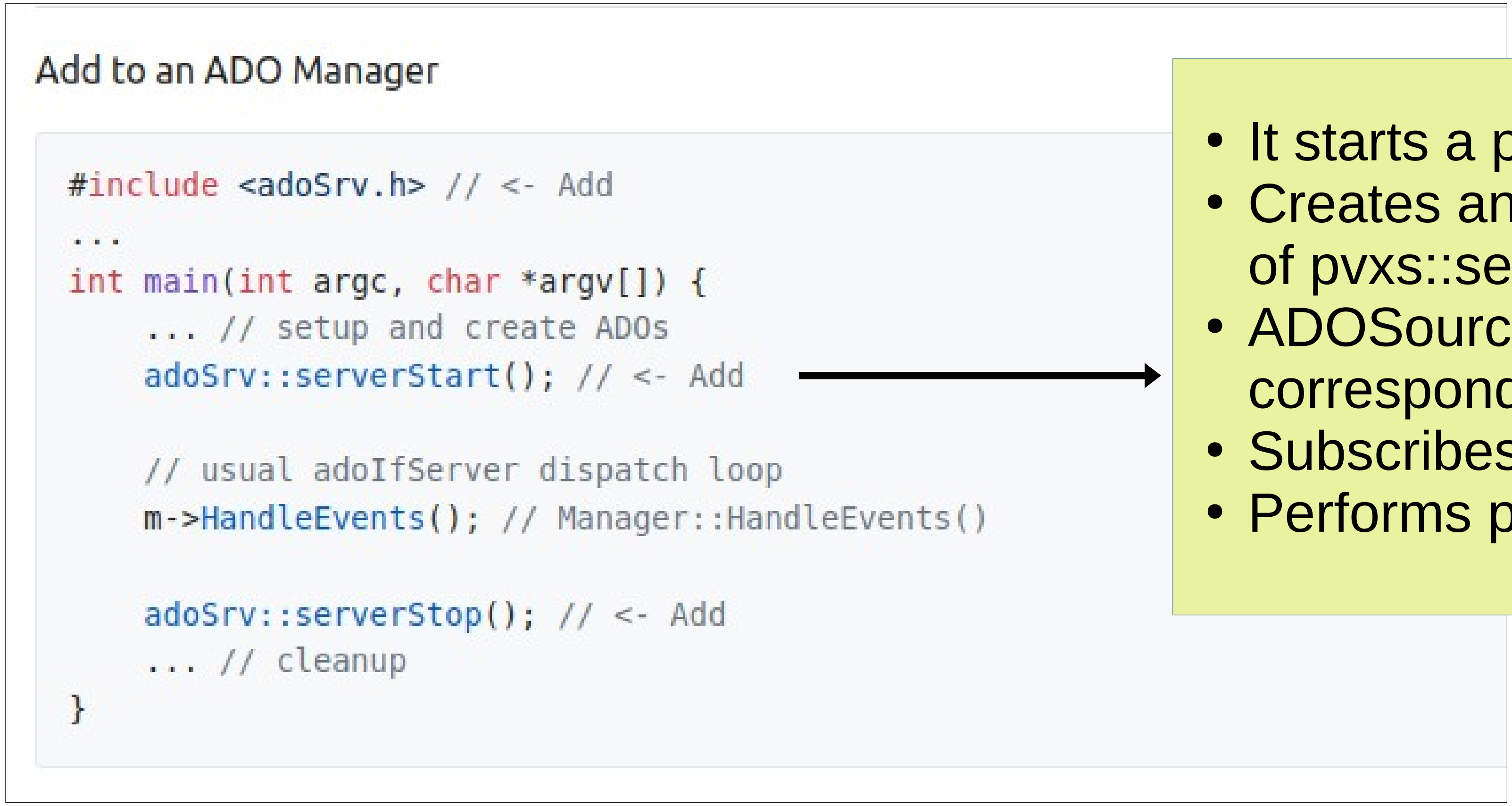
Changes to ADO Server Code


Add to an ADO Manager

```
#include <adoSrv.h> // <- Add
...
int main(int argc, char *argv[]) {
    ... // setup and create ADOs
    adoSrv::serverStart(); // <- Add

    // usual adoIfServer dispatch loop
    m->HandleEvents(); // Manager::HandleEvents()

    adoSrv::serverStop(); // <- Add
    ... // cleanup
}
```

- It starts a pvxs server
- Creates an instance of the modified version of pvxs::server::Source (i.e. ADOSource).
- ADOSource populates a list of PVs corresponding to all ADO parameters.
- Subscribes to asynchronous callback
- Performs pv2ado and ado2pv tasks

- The usual ADO/server functionality remains the same
- ADO parameters are accessible as PVs through the pvAccess protocol

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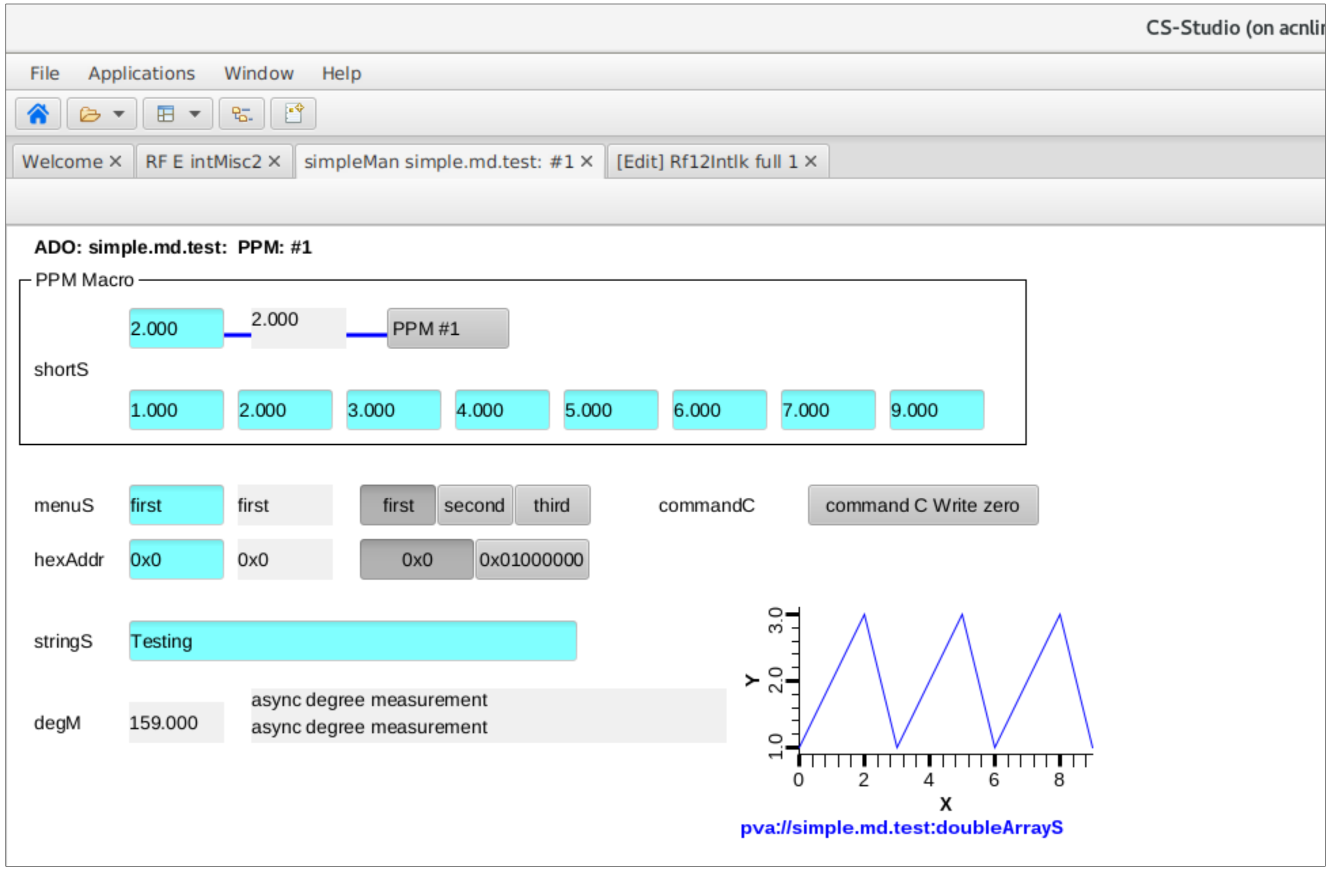
Demo Using a Test ADO


CS-Studio (on acnli
File Applications Window Help
Welcome ✕ | RF E intMisc2 ✕ | simpleMan simple.md.test: #1 ✕ | [Edit] Rf12Intlk full 1 ✕

ADO: simple.md.test: PPM: #1

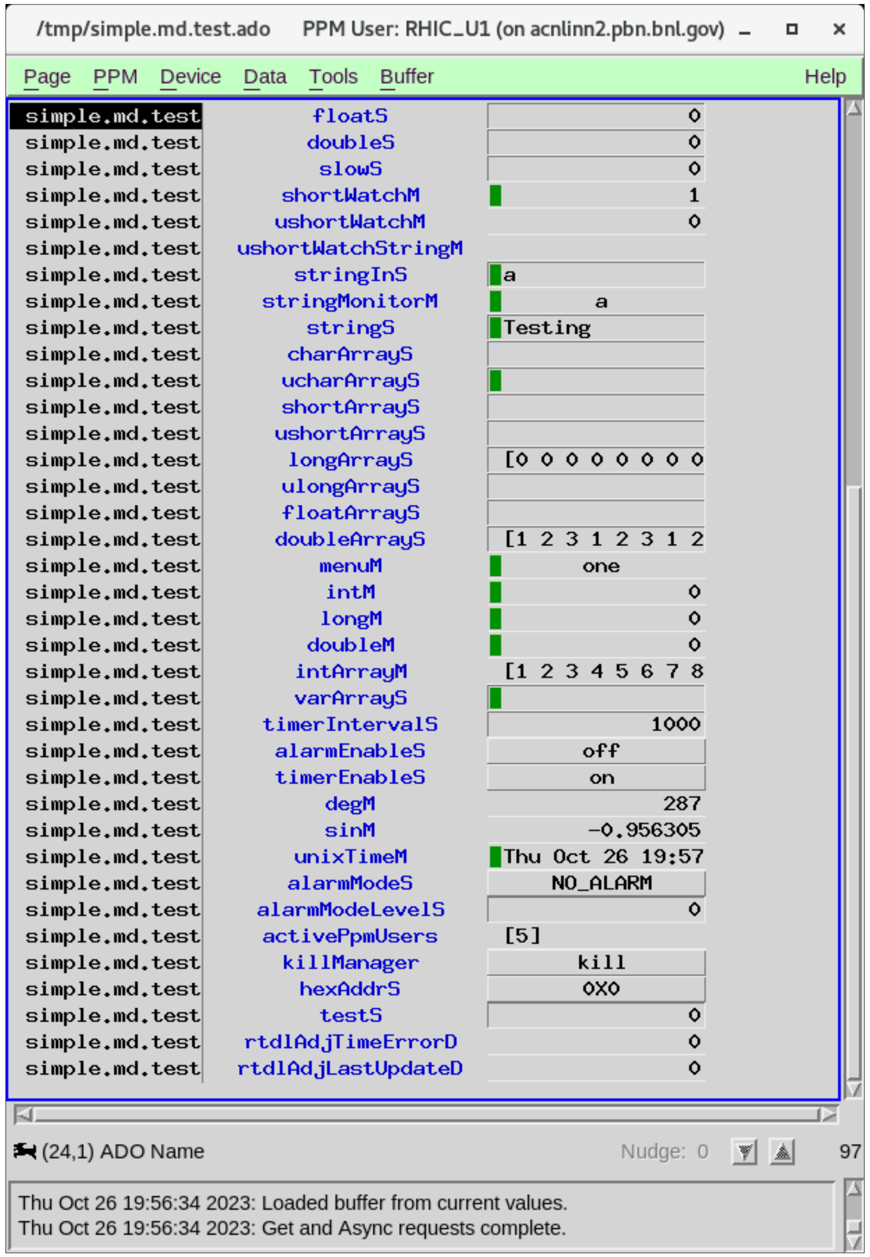
PPM Macro

shortS	2.000	2.000	PPM #1					
	1.000	2.000	3.000	4.000	5.000	6.000	7.000	9.000

menuS	first	first	first / second / third	commandC: command C Write zero
hexAddr	0x0	0x0	0x0 / 0x01000000	
stringS	Testing			
degM	159.000	async degree measurement async degree measurement		

Y
3.0
2.0
1.0
0
2
4
6
8
X
pva://simple.md.test:doubleArrayS

CSS Phoebus


/tmp/simple.md.test.ado PPM User: RHIC_U1 (on acnlinn2.pbn.bnl.gov)
Page PPM Device Data Tools Buffer Help

simple.md.test	floatS	0
simple.md.test	doubleS	0
simple.md.test	slowS	0
simple.md.test	shortWatchM	1
simple.md.test	ushortWatchM	0
simple.md.test	ushortWatchStringM	
simple.md.test	stringInS	a
simple.md.test	stringMonitorM	a
simple.md.test	stringS	Testing
simple.md.test	charArrayS	
simple.md.test	ucharArrayS	
simple.md.test	shortArrayS	
simple.md.test	ushortArrayS	
simple.md.test	longArrayS	[0 0 0 0 0 0 0 0
simple.md.test	ulongArrayS	
simple.md.test	floatArrayS	
simple.md.test	doubleArrayS	[1 2 3 1 2 3 1 2
simple.md.test	menuM	one
simple.md.test	intM	0
simple.md.test	longM	0
simple.md.test	doubleM	0
simple.md.test	intArrayM	[1 2 3 4 5 6 7 8
simple.md.test	varArrayS	
simple.md.test	timerIntervalS	1000
simple.md.test	alarmEnableS	off
simple.md.test	timerEnableS	on
simple.md.test	degM	287
simple.md.test	sinM	-0.956305
simple.md.test	unixTimeM	Thu Oct 26 19:57
simple.md.test	alarmModeS	NO_ALARM
simple.md.test	alarmModeLevelS	0
simple.md.test	activePpmUsers	[5]
simple.md.test	killManager	kill
simple.md.test	hexAddrS	0X0
simple.md.test	testS	0
simple.md.test	rtdlAdjTimeErrorD	0
simple.md.test	rtdlAdjLastUpdateD	0

(24,1) ADO Name Nudge: 0 97

```
Thu Oct 26 19:56:34 2023: Loaded buffer from current values.
Thu Oct 26 19:56:34 2023: Get and Async requests complete.
```

Pet

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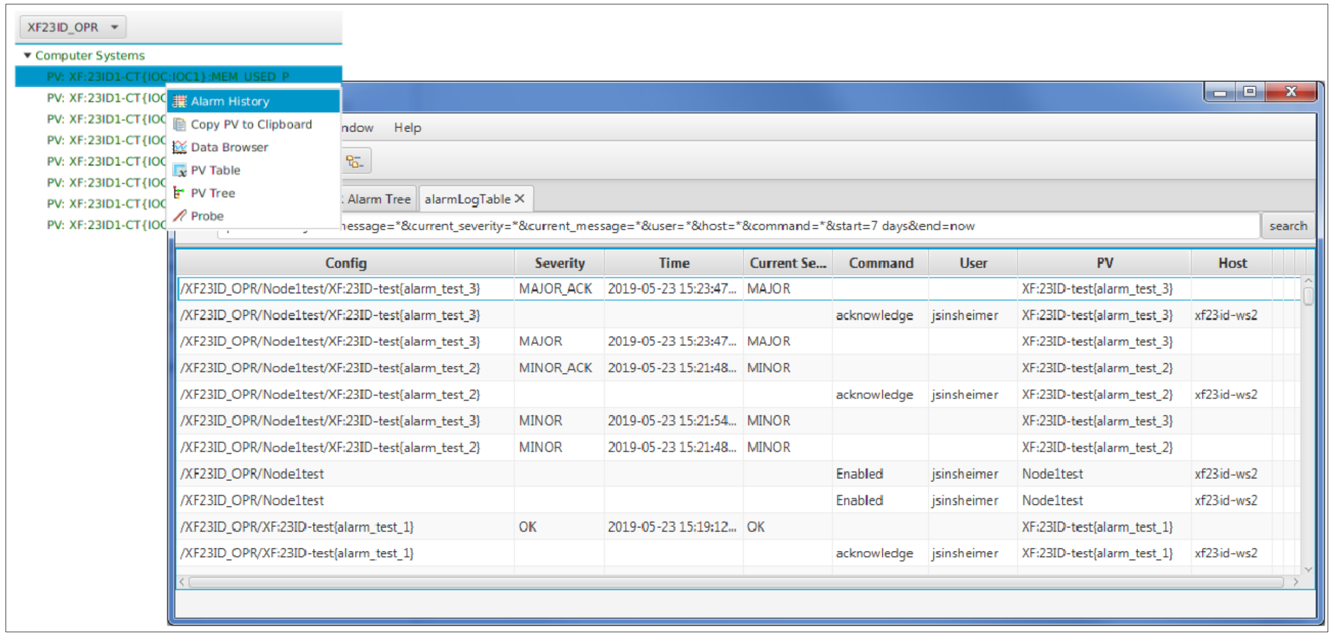
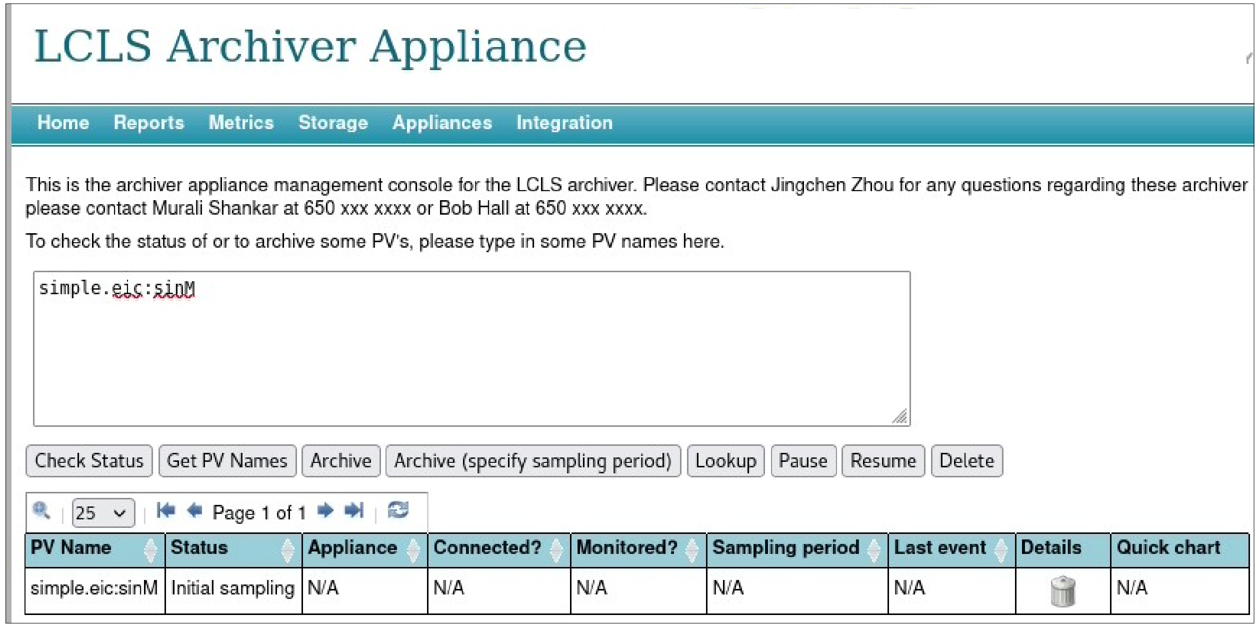
Using EPICS Services for ADOs

- Alarm properties are also mapped from ADO to PV
- EPICS archiver service can handle ADO parameters as PVs



nessage=*&current_severity=*&current_message=*&user=*&host=*&command=*&start=7 days&end=now

Config	Severity	Time	Current Se...	Command	User	PV	Host
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_3}	MAJOR_ACK	2019-05-23 15:23:47...	MAJOR			XF:23ID-test{alarm_test_3}	
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_3}				acknowledge	jsinsheimer	XF:23ID-test{alarm_test_3}	xf23id-ws2
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_3}	MAJOR	2019-05-23 15:23:47...	MAJOR			XF:23ID-test{alarm_test_3}	
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_2}	MINOR_ACK	2019-05-23 15:21:48...	MINOR			XF:23ID-test{alarm_test_2}	
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_2}				acknowledge	jsinsheimer	XF:23ID-test{alarm_test_2}	xf23id-ws2
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_3}	MINOR	2019-05-23 15:21:54...	MINOR			XF:23ID-test{alarm_test_3}	
/XF23ID_OPR/Node1test/XF:23ID-test{alarm_test_2}	MINOR	2019-05-23 15:21:48...	MINOR			XF:23ID-test{alarm_test_2}	
/XF23ID_OPR/Node1test				Enabled	jsinsheimer	Node1test	xf23id-ws2
/XF23ID_OPR/Node1test				Enabled	jsinsheimer	Node1test	xf23id-ws2
/XF23ID_OPR/XF:23ID-test{alarm_test_1}	OK	2019-05-23 15:19:12...	OK			XF:23ID-test{alarm_test_1}	
/XF23ID_OPR/XF:23ID-test{alarm_test_1}				acknowledge	jsinsheimer	XF:23ID-test{alarm_test_1}	xf23id-ws2



This is the archiver appliance management console for the LCLS archiver. Please contact Jingchen Zhou for any questions regarding these archiver please contact Murali Shankar at 650 xxx xxxx or Bob Hall at 650 xxx xxxx.

To check the status of or to archive some PV's, please type in some PV names here.

simple.eic:sinM

PV Name	Status	Appliance	Connected?	Monitored?	Sampling period	Last event	Details	Quick chart
simple.eic:sinM	Initial sampling	N/A	N/A	N/A	N/A	N/A		N/A

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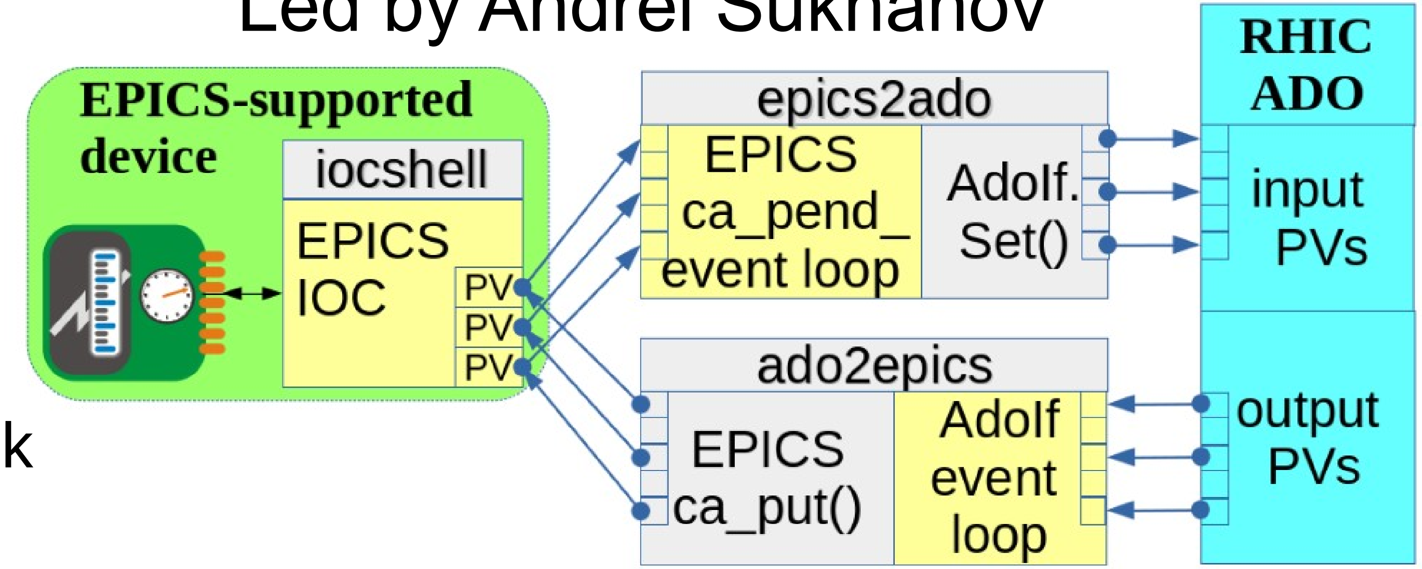
Bridge Using Intermediate Server

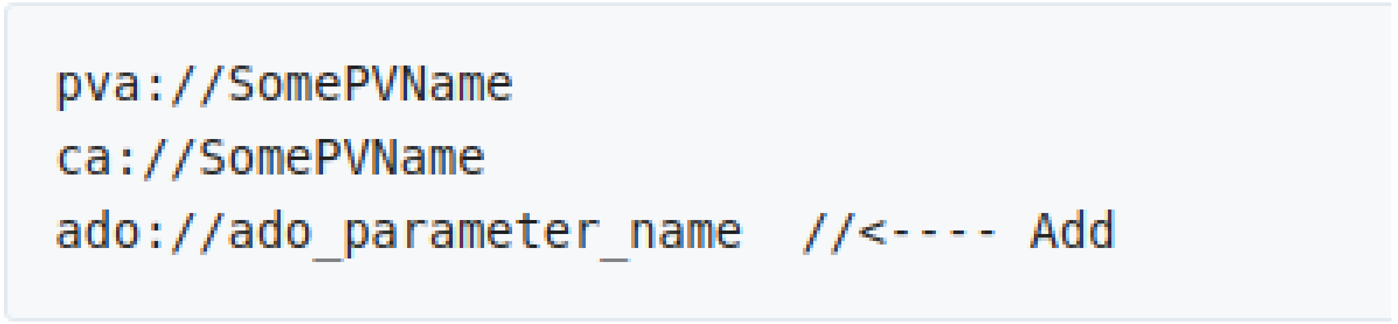
Led by Andrei Sukhanov

- Intermediate server to handle the bridge
- Subscribes to asynchronous callback for EPICS PV and/or ADO parameters
- Update or set them on any callback
- Pros: Simplest implementation
- Cons: Maintaining additional server



Bridge Using Client-side Implementation

- Make EPICS clients compatible with ADO communication protocol
- Cons:
  - Need to work with each client
  - Maintaining separate forks for the clients



```
pva://SomePVName
ca://SomePVName
ado://ado_parameter_name  //<---- Add
```

Challenges and Current Status

- Implementation for pulse-to-pulse modulation (PPM)
- Consistency for timestamp
- Addressing FEC-based ADO
- Data format for archived data
- EPICS directory service
- Scaling and stress testing

Summary

- For the EIC, we are actively exploring various options for the ADO-EPICS bridge
- Accessing ADO using pvAccess seems to be more promising
- We are working to incorporate other features
- Benchmarking of the ADO-EPICS bridge is in progress
- We would like to know the experience of other facilities for similar situations

Thanks to ….

Michael Davidsaver, Chanaka De Silva, James Jamilkowski, Seth Nemesure, John Morris, Jennefer Maldonado, Robert Olsen, Kunal Shroff and Andrei Sukhanov

Thank You!

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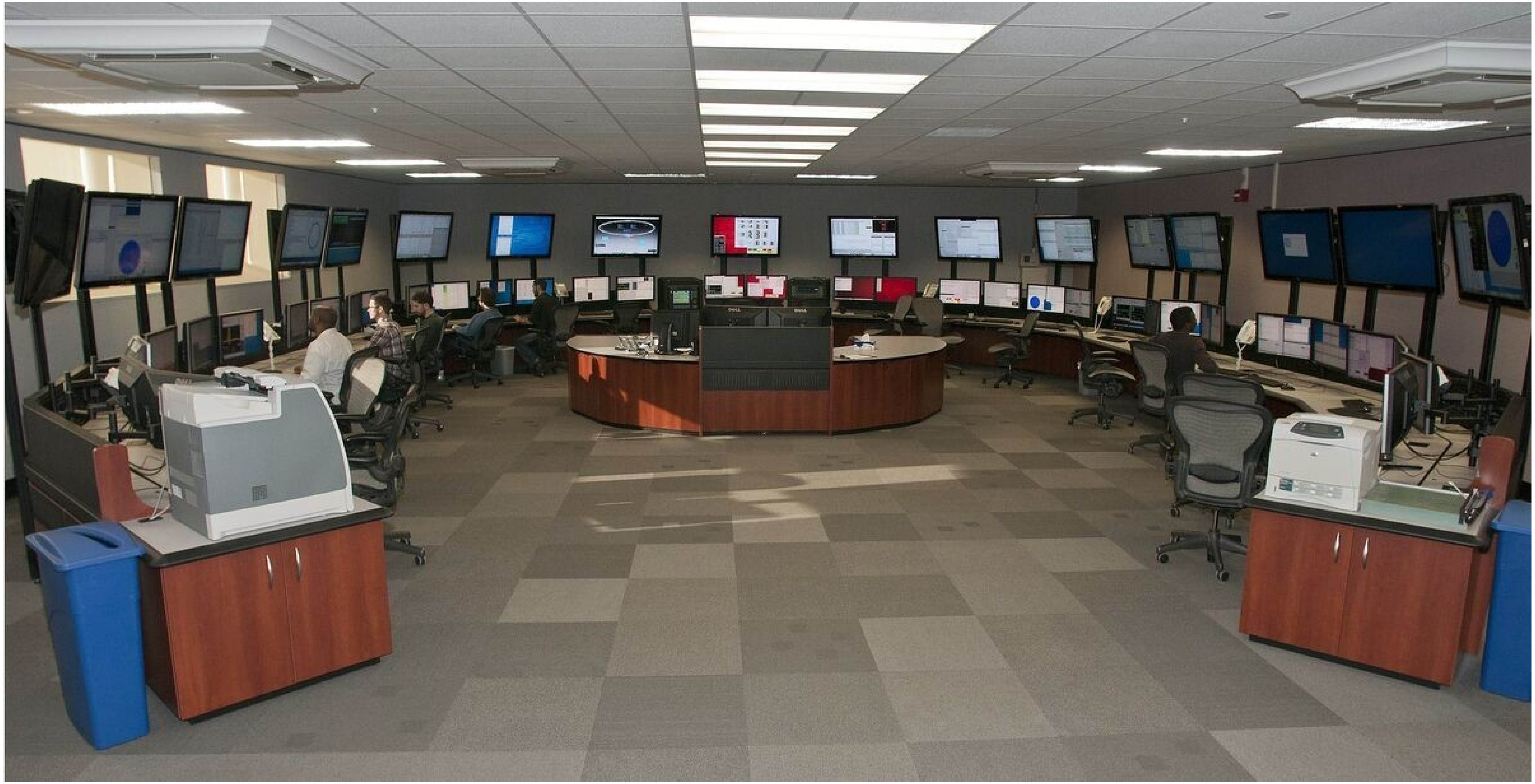

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