

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

artdaq and otsdaq for SBN and DUNE

Kurt Biery, Scientific Computing Division SBN – DUNE DAQ Workshop 20 November 2015

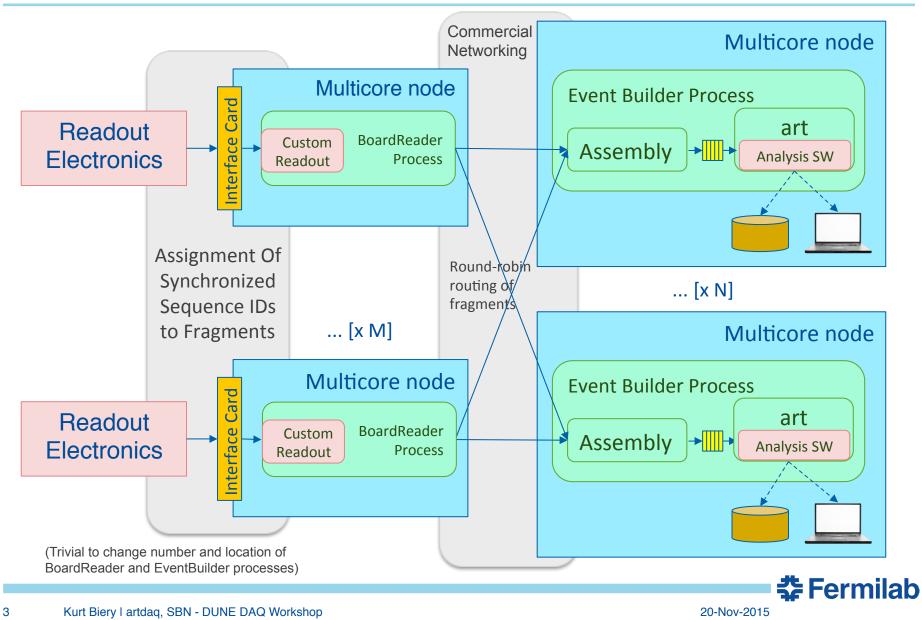
What is *artdaq*?

artdaq is a software toolkit for creating data acquisition systems

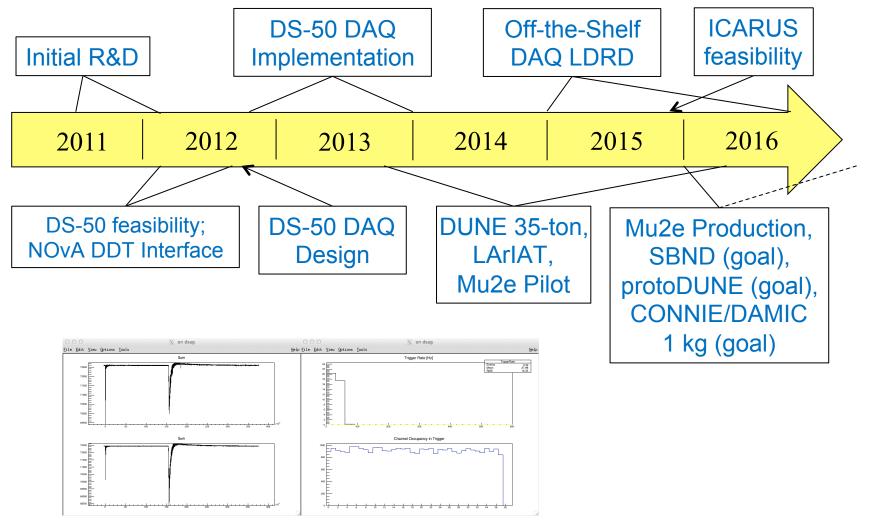
- Core DAQ software developed by Fermilab SCD
 - Provides common, reusable components
 - Based on a data-streaming architecture with software event filtering
- Integrated with the *art* framework
 - Same environment for development of online and offline algorithms
- It provides data transfer, event building, process management, system and process state behavior, control messaging, message logging, configuration infrastructure, DAQ monitoring, writing of data to disk, and infrastructure for online data quality monitoring.
- The goal is to provide the common, reusable components of a DAQ system and allow experimenters to focus on the experiment-specific parts of the system. These are the software that reads out and configures the experiment-specific front-end hardware, the analysis modules that run inside of *art*, and the data quality monitoring modules.



Simplified artdaq System



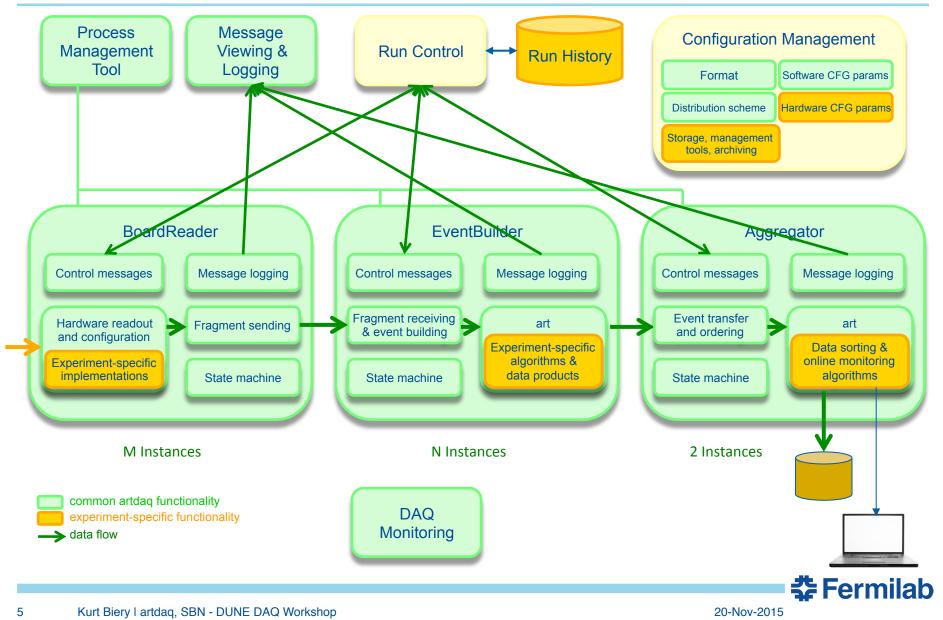
artdaq Timeline



Sample DS-50 online monitoring histograms



artdaq Software Components and Functions



Off-the-Shelf DAQ LDRD

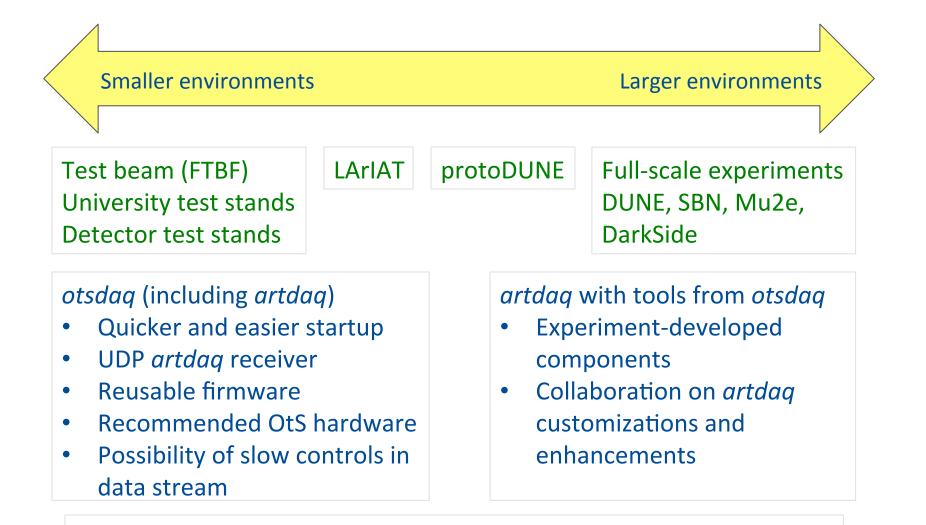
- 2 years of effort for *otsdaq* proof-of-concept:
 - Survey the market for candidate IoT boards.
 - Focus on 1 board in each range (Low, Mid, and High) to populate initial menu.
 - Develop a JavaScript GUI for control and readout using web browser.
 - Develop host and embedded APIs for socket based communication between *artdaq* and candidate boards.
 - Develop sample reusable firmware components.
 - Test and catalog available features and supported data rates.

娄 Fermilab

20-Nov-2015

 Beyond the LDRD, our goal is to build on the proof-ofconcept to build a fully functioned, easy-to-use, off-the-shelf DAQ system (bringing together HW, FW, SW).

Scaling Up and Scaling Down



Goal is smoother transition from test stands through full experiments

20-Nov-2015

🛟 Fermilab

Developing *artdaq*-based Experiment DAQ Systems (1)

Our model is to partner with experiments

- FNAL SCD: *artdaq* training and guidance; changes to *artdaq*, if needed; system integration, testing, and debugging; assistance with experiment-specific components, upon occasion.
- Experiment collaborators: software interface to detector electronics, online monitoring algorithms, compression or analysis software.

DUNE 35-ton experience

- SCD: initial setup of the lbne-raw-data and lbne-artdaq git repos; advice and contributions for development of RCE, SSP, and PTB interface software; development of RunControl-to-*artdaq* interface application; core *artdaq* changes; builds of lbne_raw_data for offline; system testing (e.g. max throughputs); lbneartdaq development (e.g. stats to RC).
- DUNE scientists: RCE, SSP, and PTB interface software; *art*-based analysis and filtering software; online monitoring software; RunControl; configuration management.



Developing *artdaq*-based Experiment DAQ Systems (2)

DarkSide experience

- SCD: core *artdaq* development; RunControl scripts; collaboration on hardware interface and compression software; commissioning effort; assistance with builds and deployments.
- DarkSide scientists: CAEN V1720, V1724, V1190, and trigger board interface software; graphical RunControl application, online monitoring software, primary responsibility for testing and updates to new versions of the software.

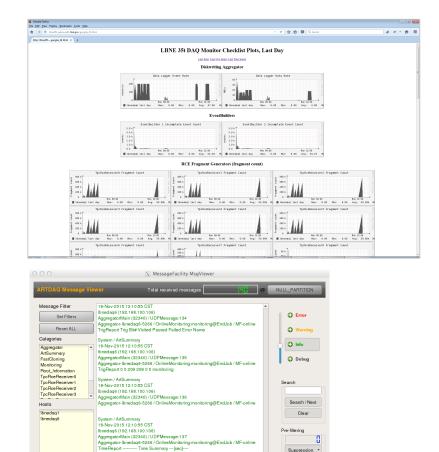
Working model for SBND (Wes' talk on 09-Nov)

- Reuse of hardware interface libraries from uBooNE.
- *artdaq* infrastructure.
- PMT, trigger, and laser readout in parallel with TPC a critical piece of this will be a common sequence ID.
- Update CRT (cosmic ray tagger) teststand at Bern to use artdaq.
 - Build partial events consisting of just CRT data sequence ID important here, too.
- Path forward includes artdaq teststands, core artdaq enhancements, Run Control



Sample Enhancements to artdaq for DUNE 35-ton

- DAQ performance monitoring using Ganglia
- Graphical viewer for log messages
- Fragment synchronization to prevent readout of some parts of the detector running far ahead
- Error state for *artdaq* processes to indicate a fatal error in one part of the DAQ system
- All of these have been on the *artdaq* todo list for a while, and their implementation was motivated by the needs of the 35-ton DAQ.



m / ArtS

System / ArtSummary 18-Nov-2015 12:10:55 CST Ibnedaq6 (192.168.100.106

Applications

Aggregator-Ibne

Aggregator-Ibnedag6-5

oardReader-Ibnedaq1 oardReader-Ibnedaq1 oardReader-Ibnedaq1

er-lbnedagt

-Nov-2015 12:10:55 CS

nedaq6 (192.168.100.106) ggregatorMain (32340) / UDPMessage:138

tor-Ibnedag6-5266 / OnlineMo

imeReport CPU = 15.387823 Real = 15.450643

Throttling

Pause

Evit

20-Nov-2015

Core artdaq **Development**

- Team of 6 software professionals with backgrounds in HEP and engineering working on DAQ software
 - Core *artdaq*, experiment-specific customizations, driver software, hardware interface libraries, system design and testing
 - With hardware and firmware engineers, developing off-the-shelf DAQ software, firmware, software, and recommended OtS HW
- Releases of *artdaq* scheduled based on needs of experiments, and needs of projects such as *otsdaq*
 - Release notes: https://cdcvs.fnal.gov/redmine/projects/ artdaq/wiki
 - Issue tracking: https://cdcvs.fnal.gov/redmine/projects/ artdaq/issues
- artdaq-demo for education and starting point for experiment-specific software packages
 - Wiki documentation: https://cdcvs.fnal.gov/redmine/ projects/artdaq-demo/wiki

1 (https://cdcvs.fnal.gov/red	mine/projec	ts/artdaq/wiki/	Rek 🔻 🛛 😋	☆ [🗎 💟 🔍 Search 🛛 📣	# - Ø	=				
Release Notes 11213 - artd × +											
ome My page Projects Help					Logged in as biery My	account Sign	out 🔺				
artdag				Search:							
	Issues	New issu	e Gantt	Calend	far News Documents <mark>Wiki</mark> Files	Repository	5				
Wiki >									_	1	-
artdaq Release Notes 1.		By Target Versio View Higtor			dmine - Mozilla Firefox						×
Introduction		· · · ·			uop s/projects/artdag/issues?p ⊽ C ☆ 自 S	Q Search		4			=
This version of artdag introduces sev		- Indexi	/ cuci sa naugi			- Contra		-44		2	-
Through artdag core v1 04 20, this	🗾 🚭 lss	ues By Target \	/ersion - a 1	: <i>\</i> +	boardkeaders as a way to trigger readout						
(s11) or v1_13_02 (s8). It can also b		12_13 10			boardiveabers as a way to digger readout						*
The initial builds on SciSoft include e Also, artdag can be built with the Inf		24 Support	Resolved	Normal	Add TRACE_NAME and MPI rank debug		v1,				
Also, artdag can be built with the Inf ib and eth.	107	23 Support	Resolved	Normal	logging to RHandles and SHandles Remove unnecessary socket bind() call in EventStore		v1,				
The default set of qualifiers for this v	107	22 Feature	Resolved	Normal	Add Binary output modules for disk writing and sending fragments between artdag		v1,				
Previous version's release not	m 107	21 Bug	Resolved	Normal	processes Change where we start the data collection	Kurt Bierv	v1				
 Previous version's release not Downloads:					thread in TriggerdFragmentGenerator to avoid race conditions						
 Nodes where this release has 		20 Support			Add Boost program options library to CMakeLists.txt file in Application/MPI2	Kurt Biery	v1,				
External Package Changes	101	46 Feature	Resolved	Normal	Provide moderate synchronization when sending fragments from multiple BoardReaders	Kurt Biery	v1.				
• @ art v1_15_02 • @ art dag_utilities v1_00_03	724	15 Idea	Resolved	Normal	Investigate whether we can use an MPI_Barrier to synchronize BoardReaders with a newer version of MPI	Kurt Biery	v1,				
artdag v1_12_13	724	4 Idea	Resolved	Normal	Create a reusable UDP FragmentGenerator	Eric Flumerfelt	v1,				E
aready ri_i2_i5	F 598	3 Idea	Resolved	Normal	Provide centralized message logging		v1,				
 New features: Issue #10146: Provide moder. 	<u> </u>	18 Idea	Resolved	Normal	Investigate the buffering that MPI provides and update the system to minimize any hidden buffering	Kurt Biery	v1,				
 BoardReaders (also fulfills Issu Issue #10722; Add Binary out 	= Fall	2015 Relea	se A 🔽								
 Issue #10/22. Add Binary dd processes NetMonOutput has beer 	834			Normal	Investigate new warnings since we started		Fall 201				
v neuronousucitids beer	38 0	57 Bug	Resolved	Normal	using art v1_13_01 Unnecessarily complicated code in NetMonTransportService	Eric Flumerfelt	Fall 201				
	a Kno	wnIssues E			recorder randporcase vice	riamericit					
	III 889		New	Normal	Reduce the data-dependence of our		Knov				
	640		New	Normal	metrics reporting Investigate whether FragmentGenerator		Knov				
					state change methods should return a status code						
	598	-	New		The Aggregator runs slower when event grouping is enabled		Knov				
	593		New	Normal	Incorporate control of the Linux system fsync calls into the system		Knov				
	595	59 Feature	New	Normal	Make full use of the file renaming feature(s) in art		Knov				12

20-Nov-2015

🛠 Fermilab

Coordinating with Other Groups at Fermilab

- We're working with SCD/ECF/SLAM group (Rennie Scott et al) to define standard patterns for DAQ teststand and pilot system clusters. (Rennie's group has already developed a robust model for production DAQ clusters.)
- We work closely with the *art* development team to prepare new versions of *artdaq* coupled with new versions of *art*, request and develop changes to either package based on the needs of the other, and get advice on best ways to modify parts of *artdaq* that are closely related to art.
- We work with the Neutrino Division Online Support Group to build and configure DAQ clusters and share information regarding support of experiment DAQ systems.



Enhancements and Additions

- Multi-layer *artdaq* systems motivated by needs of DUNE, SBND, upgraded uBooNE, Mu2e.
- Run Control ability to control/monitor multiple "experiments" has come up in discussions with both SBN and DUNE; prototype graphical interface developed as part of *otsdaq*.
- Configuration Management managing *artdaq* system and detector electronics configurations; *otsdaq* work; discussions with 35t folks.
- Run-level data products storing configuration information in the data file.
- Multiple Linux variants working with Wes now on Ubuntu.
- Integration or interfacing with slow controls.
- Publish/subscribe messaging system for data transfer and control messages; better separation of online monitoring from primary data flow; load balancing of events into the event builder farm.
- System-wide coordination of back-pressure maybe best left to hardware, but could be worth investigating.

🛟 Fermilab

Multi-layer artdaq Systems

SBND and Upgraded uBooNE:

- Writing of local supernova streams.
- Aggregation of cosmic ray tracker data into sub-events.

DUNE:

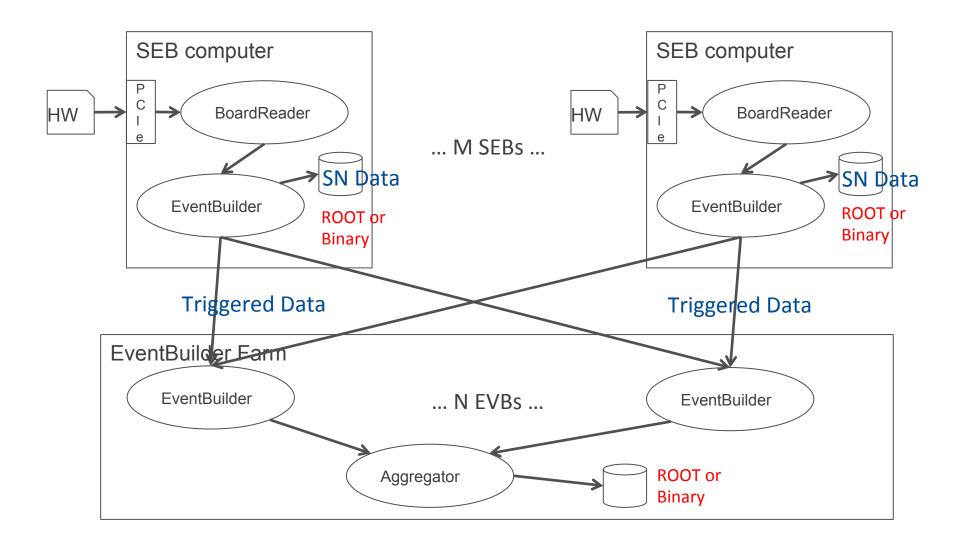
- Readout of zero-suppressed event data into a software trigger farm (first layer).
- For accepted events, the system would request the non-zero-suppressed data (second layer).

Mu2e:

- Readout of tracker and calorimeter into the software trigger farm (1st layer)
- Subsequent readout of cosmic ray veto data only for events which are accepted by the software trigger in the 1st layer (2nd layer)



Multi-Layer artdaq for uBooNE-Like System



15 Kurt Biery I artdaq, SBN - DUNE DAQ Workshop

20-Nov-2015

‡Fermilab

Run Control and Configuration Management

- Opportunities here for common effort and solutions.
- Similar themes have been heard in SBN and DUNE discussions.
- Common tool(s) for use in *artdaq* would likely benefit SBN, DUNE, *artdaq* itself, and future users of *artdaq*.

Configuration Management:

• We've had some preliminary discussions between DUNE 35t and *artdaq/otsdaq* folks about common needs and ideas.

Run Control:

• Maybe a workshop with wide participation?



Collaboration on *artdaq*

- *artdaq* is a toolkit, and adding new tools to the toolkit is beneficial to everyone.
- *artdaq* is an open project contributions from collaborators are welcome, and these are a natural extension of the collaborative work that we do on experiment-specific DAQ systems.



Backup Slides

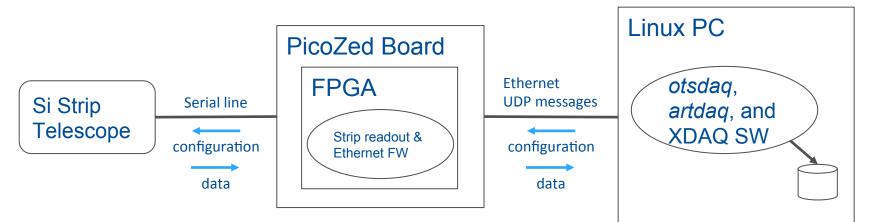


18 Kurt Biery I artdaq, SBN - DUNE DAQ Workshop

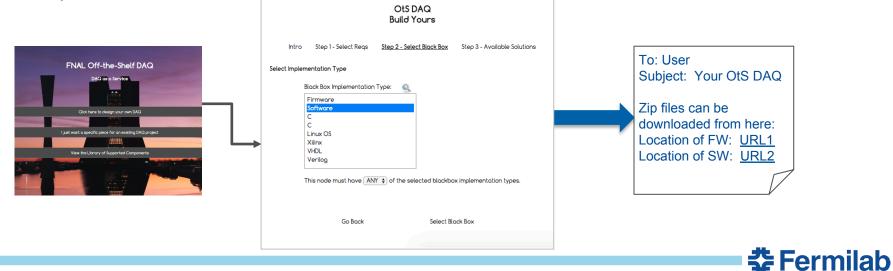
20-Nov-2015

Off-the-Shelf DAQ Status/Plans

Demonstration of detector readout (at FTBF)



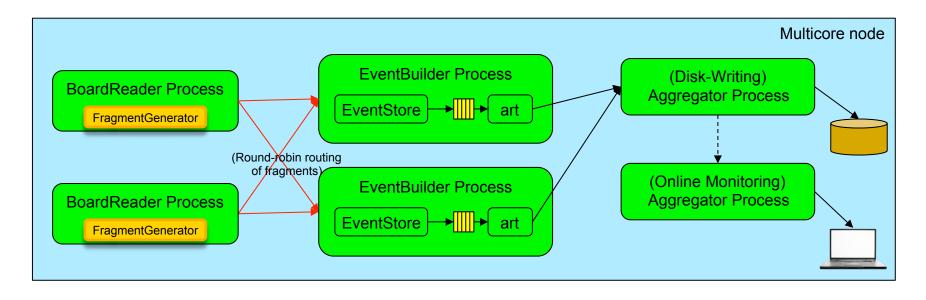
Development of the *otsdag* web site



The artdaq-demo

Demo package to illustrate artdaq use

- Instructions for downloading, building, and running a sample system
- More information here:
 - <u>https://cdcvs.fnal.gov/redmine/projects/artdaq-demo/wiki</u>
- An easy way to try out *artdaq* and learn more about it
- Currently targeted for Scientific Linux



😤 Fermilab

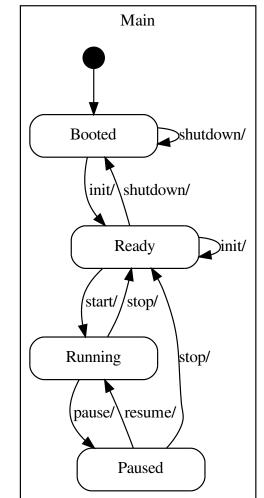
State Behavior & Control Messaging

State behavior part of artdaq core

- Standard states:
 - Booted, Ready (configured), Running, Paused, Error
- Standard transitions:
 - Init(cfgString), start(runNum), stop, pause, resume, shutdown
- State Machine Compiler tools
- Overall system state managed by Run Control

Control messaging infrastructure also included

- Standard commands:
 - State transitions & status queries
- XMLRPC
- Command-line Run Control scripts provided





Configuration Documents

Configuration infrastructure part of core *artdaq*

- Structured text string sent at "init" transition
 - hardware, software, system, art configuration
- Interpretation of software and system parameters provided in core artdaq
- Hardware parameters handled by experiment-specific code
- Archiving and management of configuration data – not yet part of core artdaq – but may be in the future

```
dag: { # red = group identifiers
 max fragment size words: 2097152
 fragment receiver: {
   mpi buffer count: 40
   generator ds50: {
      fragment id: 2
         # green = software params
    generator: V1495Driver
    first event builder rank: 3
    event builder count: 5
    rt priority: 2 # system params
    link type: PCIE
    link number: 0 # hardware params
   vme base: 0x01000000
   pulser frequency: 0.0
    laser frequency: 0.0
    random triggers: false
    acquisition gate us: 400.0
    low threshold: 5
```



Performance

- *artdaq* overheads are small networking, disk writing, and algorithm performance are bigger effects.
- Some sample numbers from DarkSide:
 - 6-12 BoardReaders on 4 computers, 16 EventBuilders on 4 computers, 40 Gbps Infiniband network.
 - Loss-less compression in software (*art* in EventBuilders) reduces ADC data size by approximately a factor of 5.
 - Up to 500 MB/s from BoardReaders to EventBuilders
 - 1.5+ kHz event rate for laser runs (200 MB/s)
- Initial artdaq performance studies showed 3.5+ GB/s overall throughput with 4+ EB nodes and 40 Gbps Infiniband.
- We'll continue to document performance results as we have opportunities to run tests in new DAQ environments (e.g. Mu2e Pilot system).

