

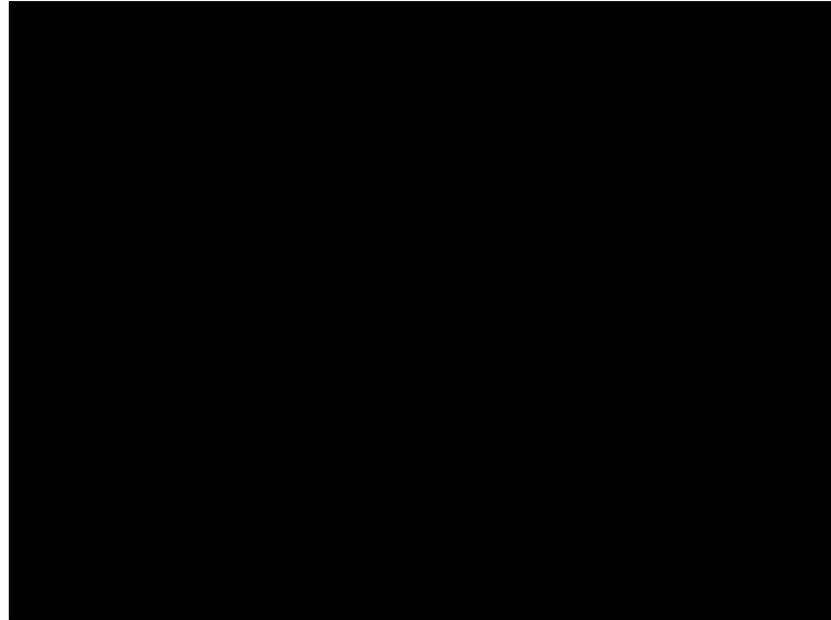
LCLS Data Movement

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Data Analytics for high repetition rate Free Electron Lasers

FEL data challenge:

- **Ultrafast X-ray pulses** from LCLS are used like flashes from a high-speed strobe light, producing stop-action movies of atoms and molecules
- Both **data processing** and **scientific interpretation** demand intensive computational analysis



LCLS-II will increase **data throughput by three orders of magnitude** by 2025, creating an exceptional scientific computing challenge

Computing Requirements for Data Analysis: a *Day in the Life of a User* Perspective

- During **data taking**:
 - Must be able to get real time (~ 1 s) **feedback** about the **quality of data taking**, e.g.
 - Are we getting all the required detector contributions for each event?
 - Is the hit rate for the pulse-sample interaction high enough?
 - Must be able to get **feedback** about the **quality of the acquired data** with a latency lower than the typical lifetime of a measurement (~ 10 min) in order to optimize the experimental setup for the next measurement, e.g.
 - Are we collecting enough statistics? Is the S/N ratio as expected?
 - Is the resolution of the reconstructed electron density what we expected?
- During **off shifts**: must be able to run **multiple passes** (> 10) of the full analysis on the data acquired during the previous shift to optimize analysis parameters and, possibly, code in preparation for the next shift

Offsite data movement critical
- During **4 months** after the experiment: must be able analyze the raw and intermediate data on **fast access storage** in preparation for publication
- **After 4 months**: if needed, must be able to **restore** the archived data to test new ideas, new code or new parameters

Process for determining future projections

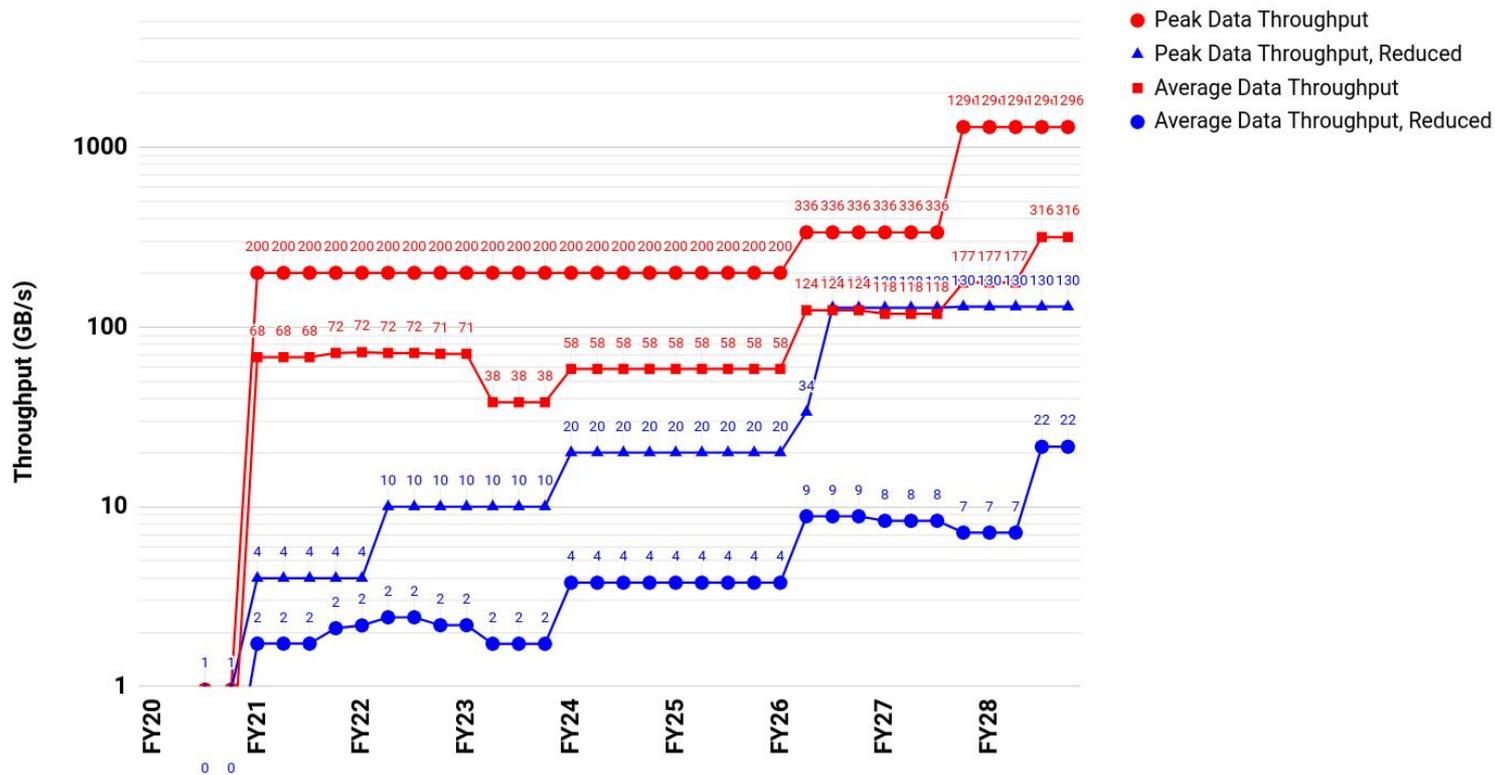
Includes:

1. **Detector rates** for each instrument
2. **Distribution of experiments** across instruments (as function of time, ie as more instruments are commissioned)
3. Typical **uptimes** (by instruments)
4. **Data reduction** capabilities based on the experimental techniques
5. Algorithm **processing times** for each experimental technique

Undulator	Instrument	Endstation	Technique	Detector	Detector Size	Detector Rate (Hz)	Data Rate (aggregate) (GB/s)	Utilization Factor (0-1)	Data Reduction Type (1st Cut)	DR Factor (1st cut)	Data Reduction Type (Optimistic)	DR Factor (Optimistic)	FY20 Q1	FY20 Q2	FY20 Q3	FY20 Q4	FY21 Q1	FY21 Q2	FY21 Q3	FY21 Q4	
SXU	NEH 1.1	DREAM	COLTRIMS	Digitizer	800000	100000	160.0	0.75	Zero suppression	0.020	Peak Finding	0.0020		1.00	1.00		0.50	0.25	0.25	0.25	0.25
SXU	NEH 1.1	DREAM	Time of Flight	Digitizer	1000000	100000	200.0	0.75	Zero suppression	0.020	Peak Finding	0.0020					0.13	0.13	0.13	0.06	0.06
SXU	NEH 1.1	LAMP	Time of Flight	Digitizer	1000000	100000	200.0	0.75	Zero suppression	0.020	Peak Finding	0.0020					0.13	0.13	0.13	0.06	0.06
SXU	NEH 1.1	LAMP	Imaging	SXR Imag. + Digi.	4000000	10000	82.0	0.45	Veto	0.100	N.A.	0.1000								0.13	0.13
SXU	NEH 2.2	LJE	XAS / XES	TES	1000	100000	20.0	0.60	Zero suppression	0.100	Binning	0.0000									
SXU	NEH 2.2	LJE	XAS / XES	TES	10000	1000000	200.0	0.60	Zero suppression	0.100	Binning	0.0000									
SXU	NEH 2.2	LJE	XAS / XES	RIXS-ccd	4096	1000	0.0	0.60	N.A.	1.000	Accumulating	0.0010				0.25	0.50	0.25	0.25	0.25	0.25
SXU	NEH 2.2	RIXS	IXS / RIXS	RIXS-ccd	4096	1000	0.0	0.60	N.A.	1.000	Accumulating	0.0010						0.13	0.13	0.13	0.13
SXU	NEH 2.2	RIXS	XRD / RXRD	SXR Imaging	1000000	10000	20.0	0.60	ROI	0.100	Accumulating	0.0001						0.06	0.06	0.06	0.06
SXU	NEH 2.2	RIXS	XPCS	SXR Imaging	1000000	10000	20.0	0.60	Compression	0.500	Accumulating	0.1000						0.06	0.06	0.06	0.06
SXU	NEH 1.2	---	X-ray/X-ray	SXR Imaging	1000000	10000	20.0	0.30	ROI	0.100	Binning	0.0001									
SXU	NEH 1.2	---	Imaging	epix100-HR + Digi.	4000000	5000	42.0	0.45	Veto	0.100	N.A.	0.1000									
SXU	NEH 1.2	---	XAS / XES	RIXS-ccd	4096	1000	0.0	0.60	N.A.	1.000	Accumulating	0.0010									

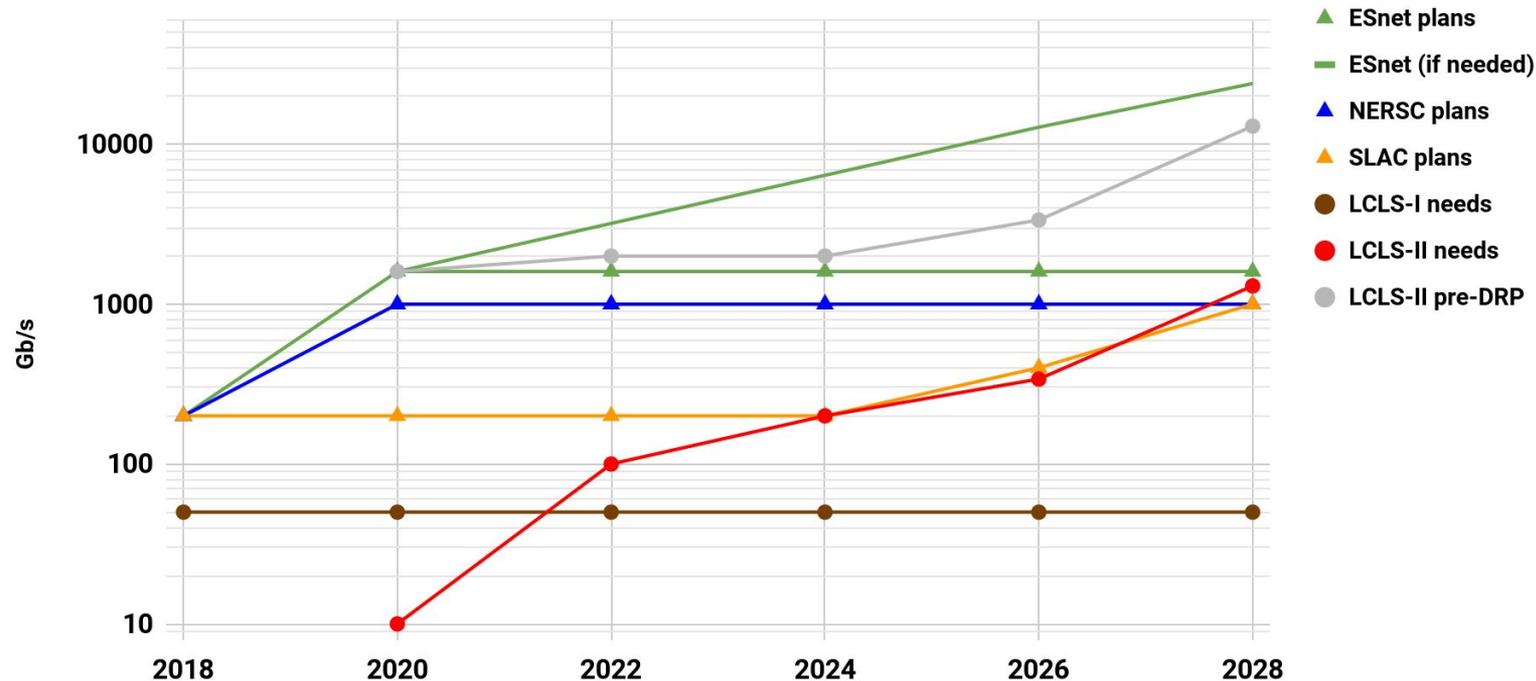
Data Throughput Projections

LCLS Data Throughput

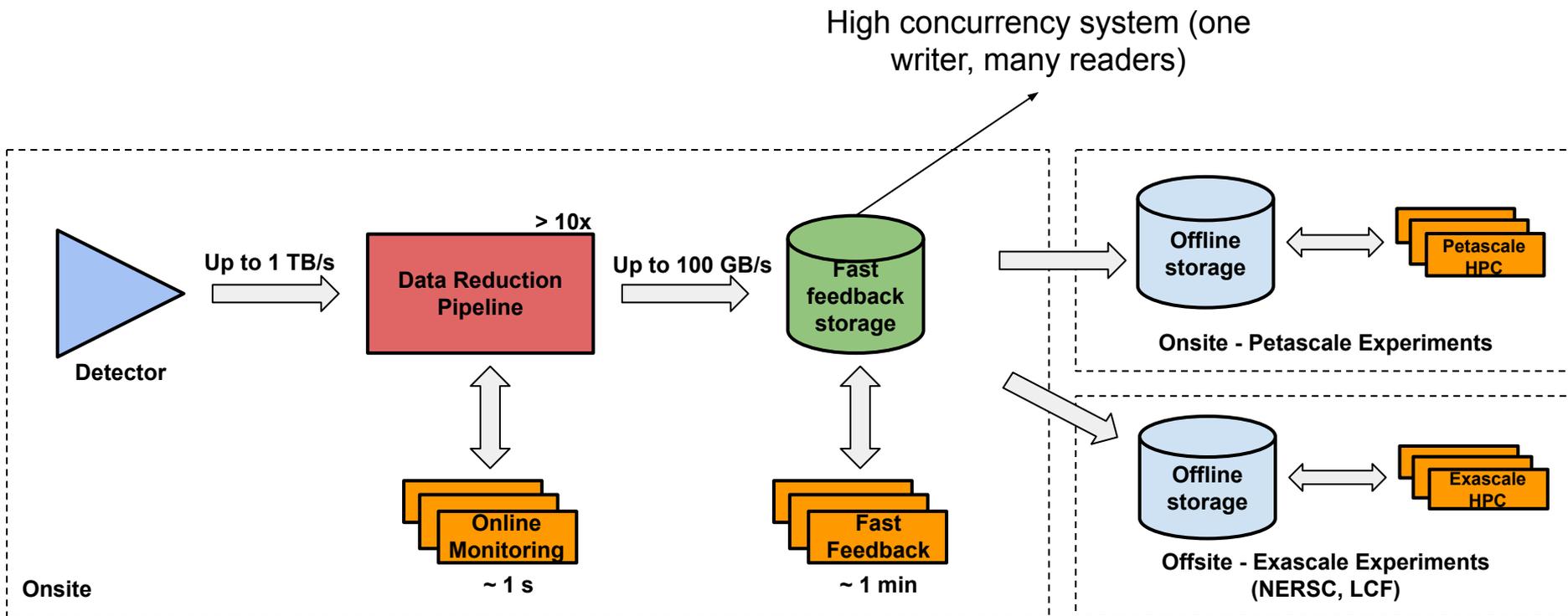


Offsite Data Transfer: Needs and Plans

Border Network: Needs and Plans



LCLS-II Data Flow

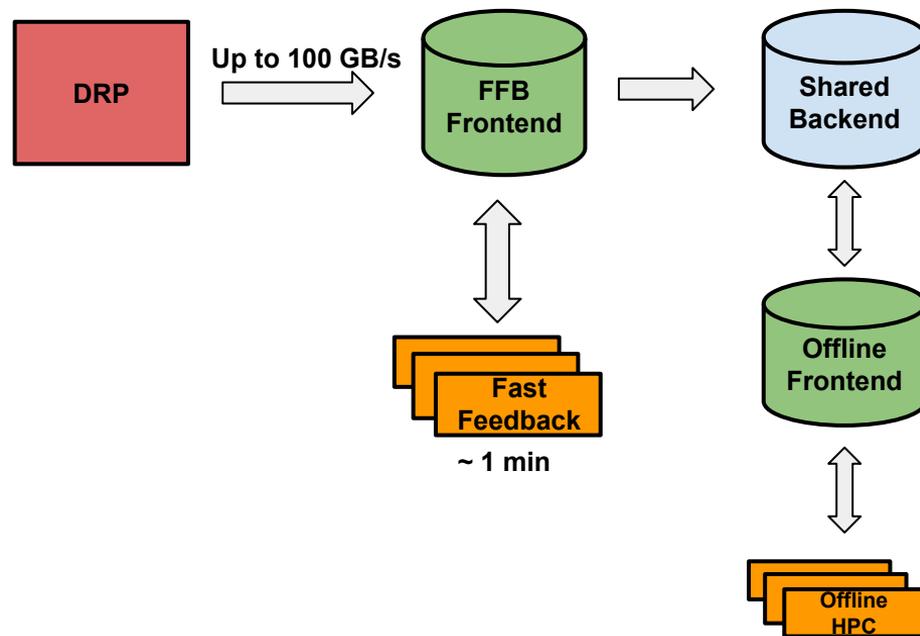


Shared backend between fast feedback (FFB) and offline storage layers

Potential of simplifying the data management system, improve robustness and performance

Key ingredients:

- Offline compute must **not affect FFB** performance
- File system transparently handles **data movement** and coherency between different frontends (cache) and the shared storage (as opposed to the data management system handling the data flow)

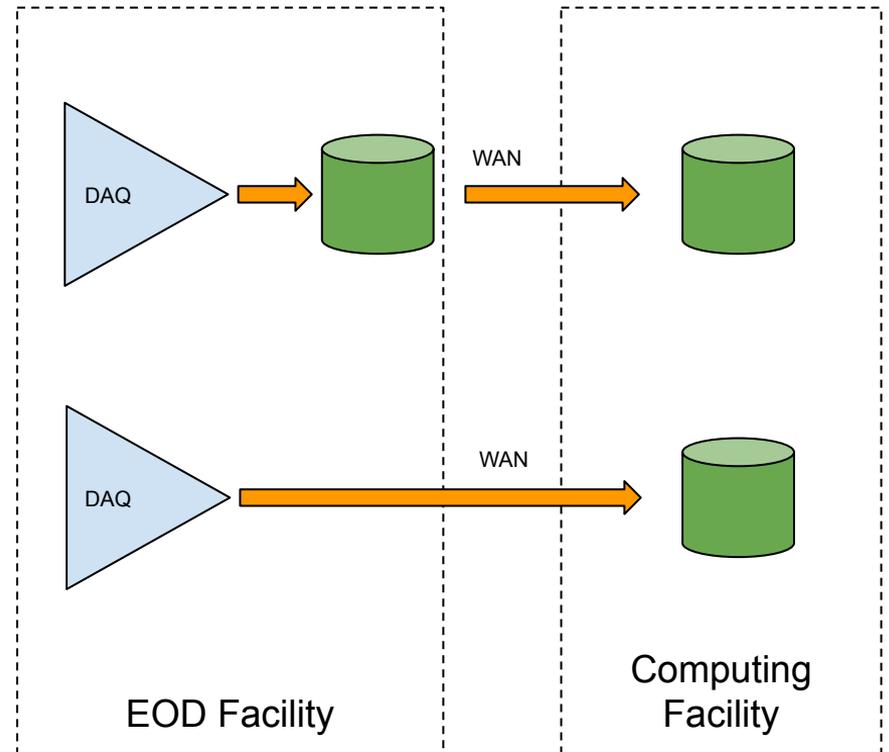


Remote mount over WAN

Ability to write directly from the data reduction pipeline to the remote computing facility

Potential of simplifying data management and reduce latency

Must handle throughput, network latency and network glitches



Zero-copy data streaming from front end electronics to computer memory

While data are being transferred to be analyzed, a copy of the same data must be made persistent for later analysis and archiving

This requires either:

- Persistent storage layer in the data path or
- the ability to send the data directly to the computer where it will be analyzed while replicating the data to persistent storage, without the need for an additional transfer ⇨ potential of significantly reducing latency

