VisWeek 2011
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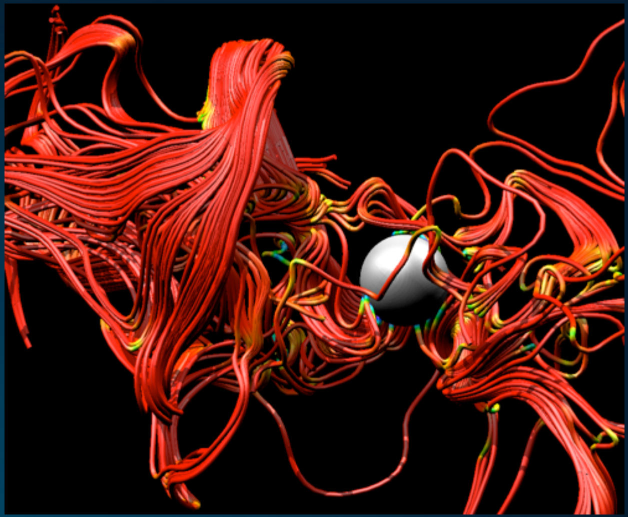


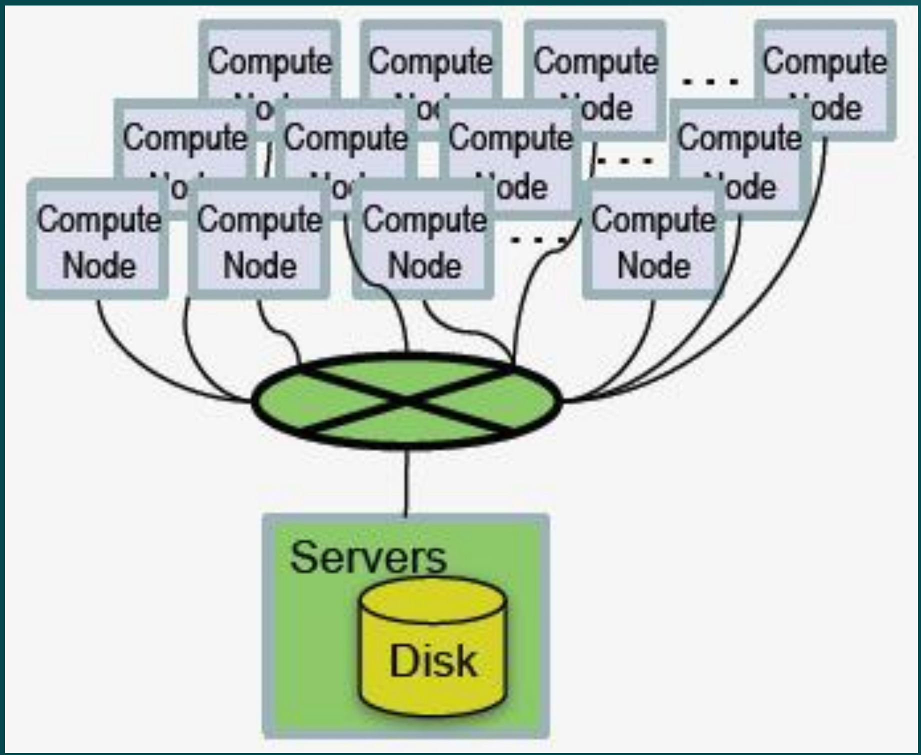
Evaluating the Benefits of An Extended Memory Hierarchy for Parallel Streamline Algorithms

David Camp (LBL, UC Davis), Hank Childs (LBL, UC Davis), Amit Chourasia (SDSC), Christoph Garth (UC Davis),
& Kenneth I. Joy (UC Davis)

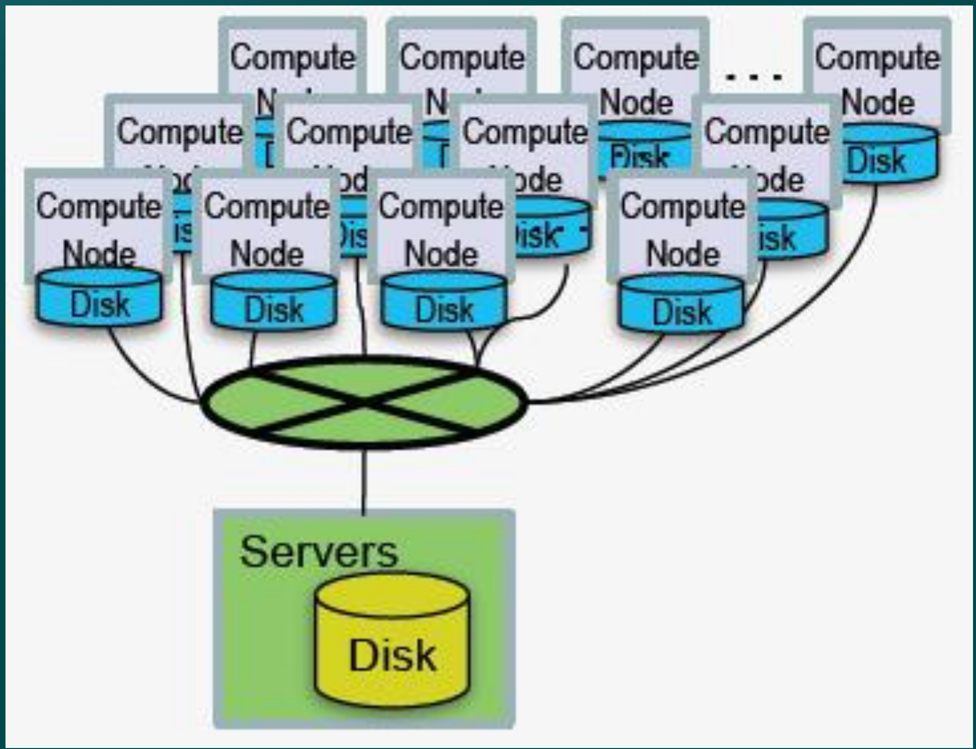
Outline

- New emerging I/O configuration for supercomputers
  - Can we use this new configuration to improve streamline performance.
- Streamline Algorithm
  - Parallelize-over-Seeds
- Results
  - Up to three times faster
  - Model that can determine benefit

Emerging I/O Configuration

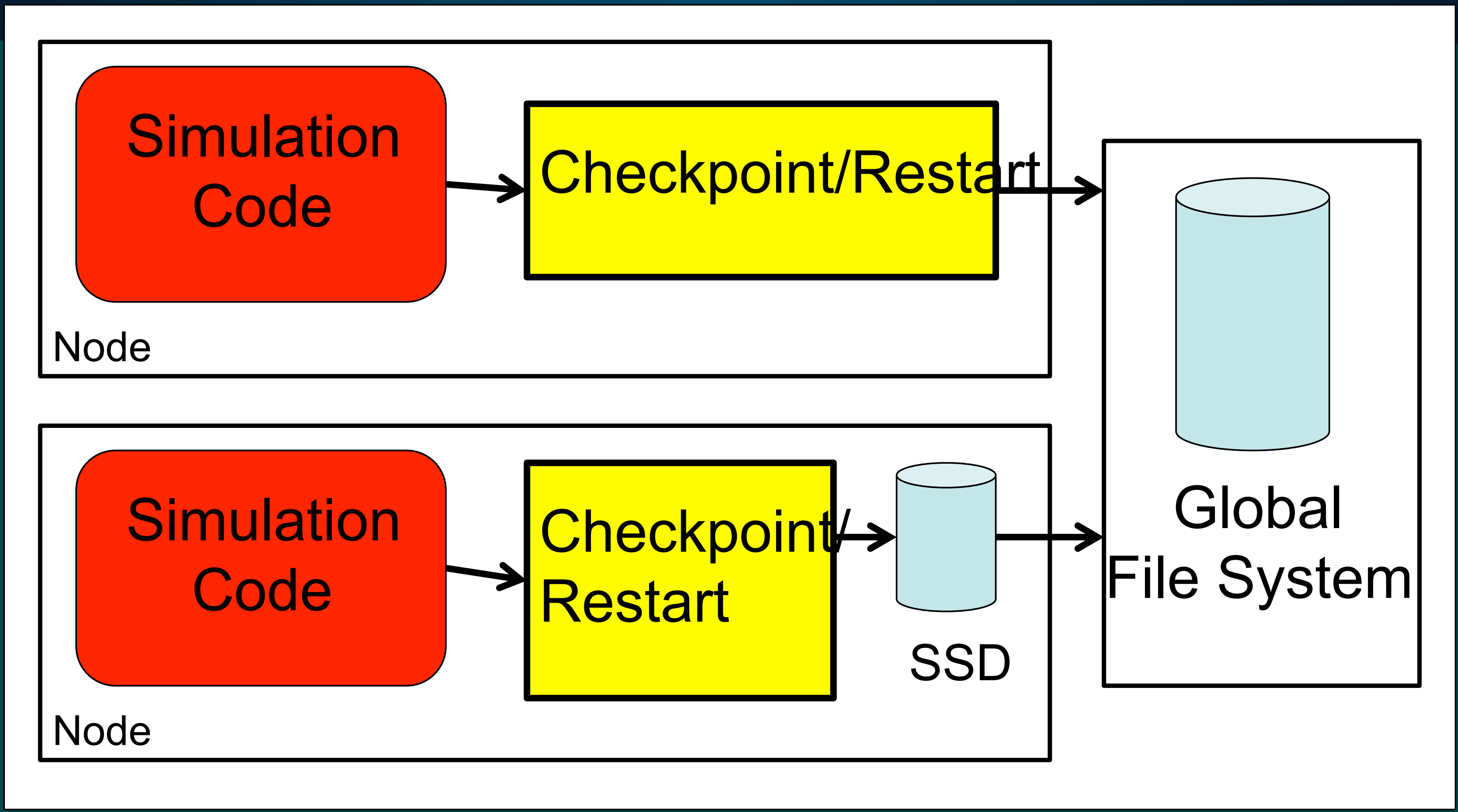


Common I/O Configuration



Emerging I/O Configuration

Simulation Codes

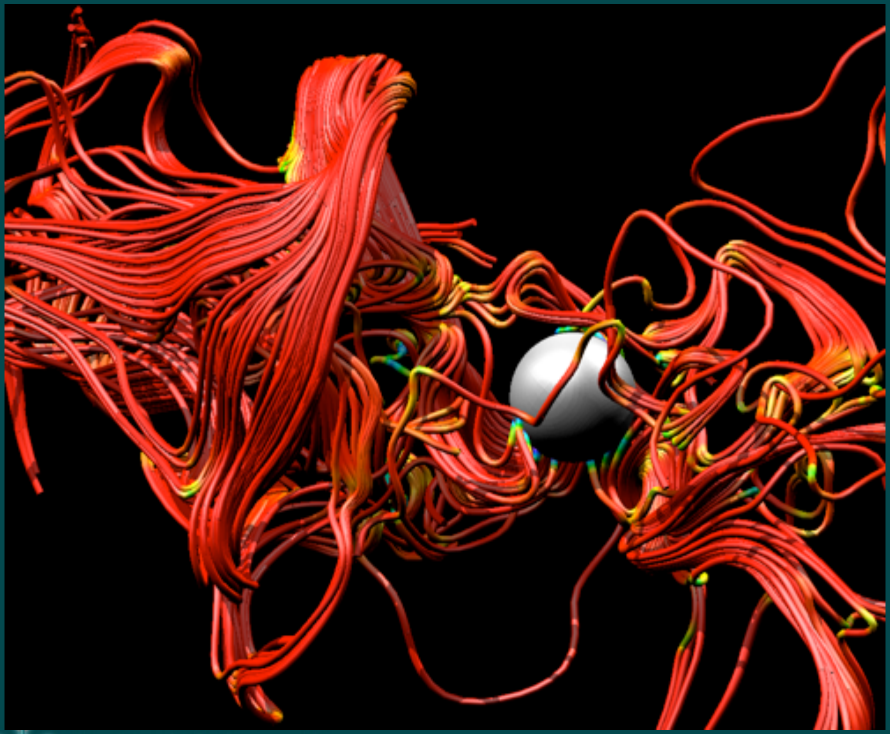


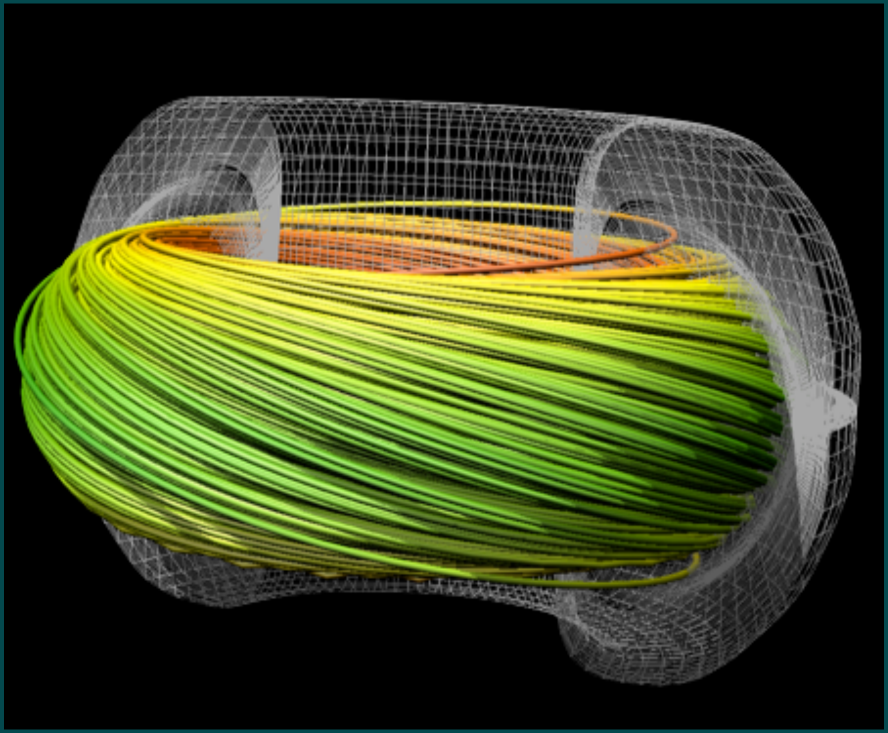
Research Questions

- New design is primarily made for data producers (those who store data), not data consumers (those who read data).
- But can we use the SSDs to benefit data consumers?
  - IDEA: use the SSDs to extend the memory hierarchy and reduce redundant reads. In effect increases local memory size.
- Research questions:
  - Can the extended memory hierarchy improve performance?
  - To what extent?

What Type of Vis Algorithm Can Benefit From an Extended Memory Hierarchy?

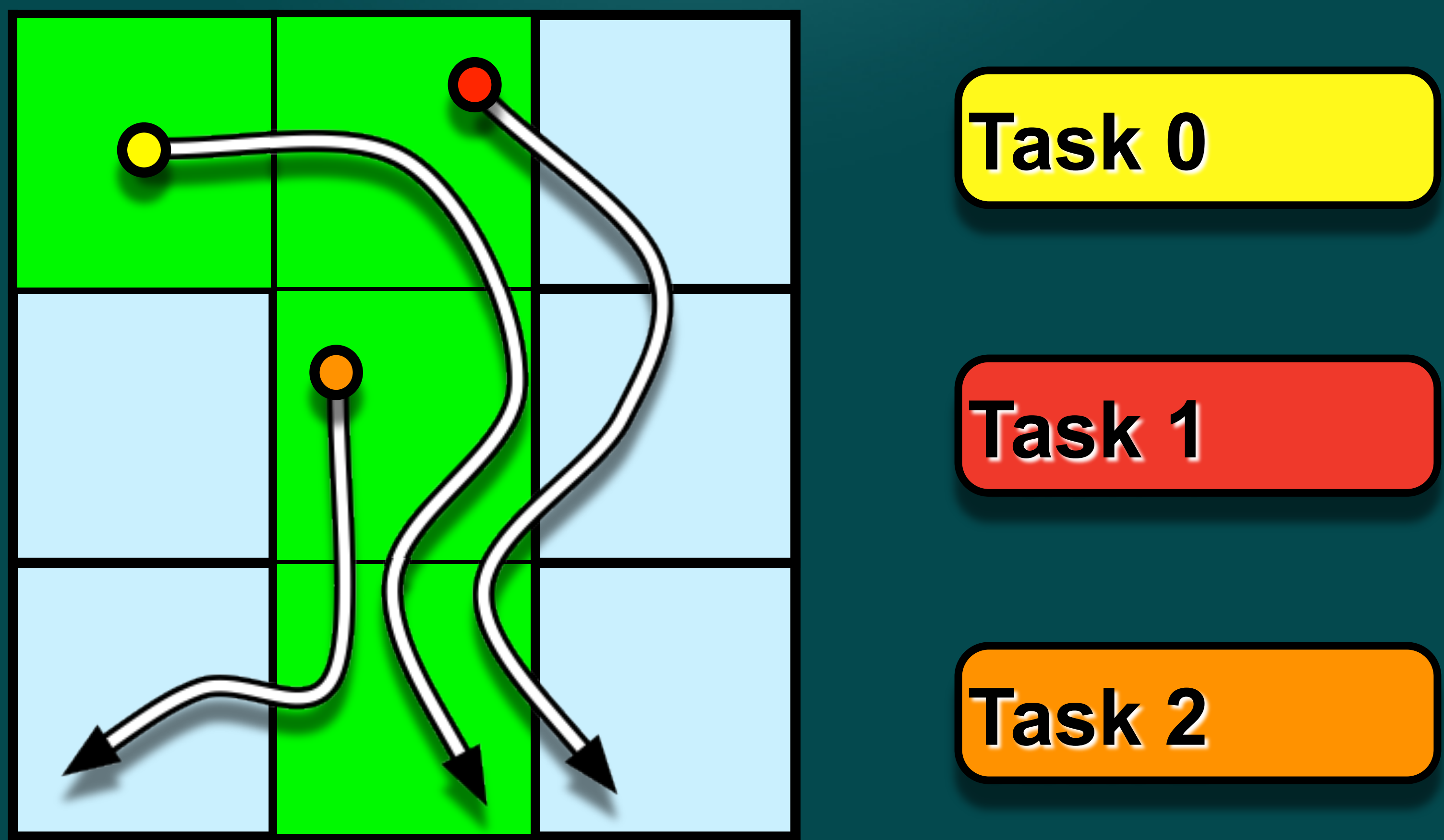
- Answer: Algorithms that repeatedly read data
  - Streamline algorithm - Parallelize-over-Seeds



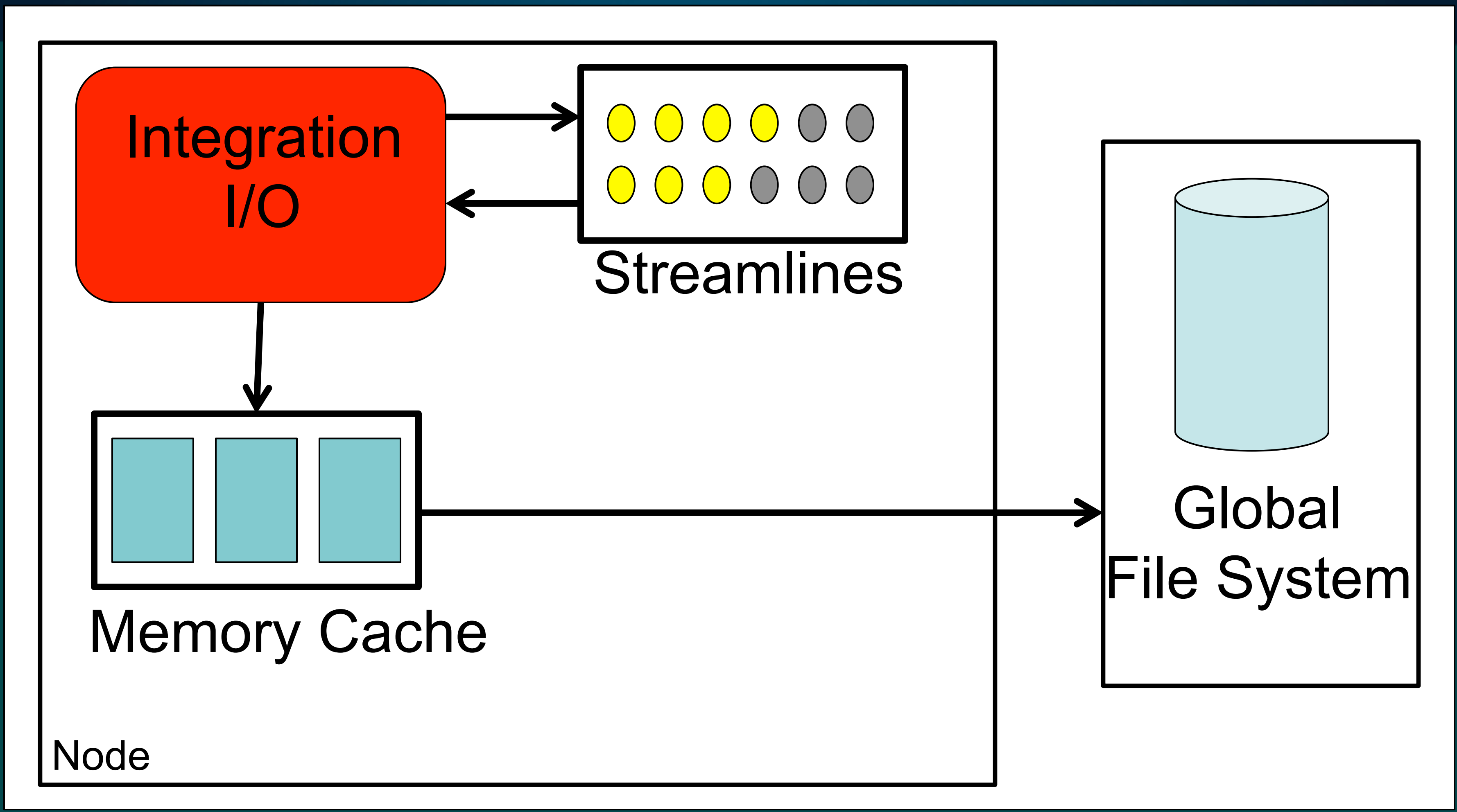


Streamline Algorithm - Parallelize-over-Seeds

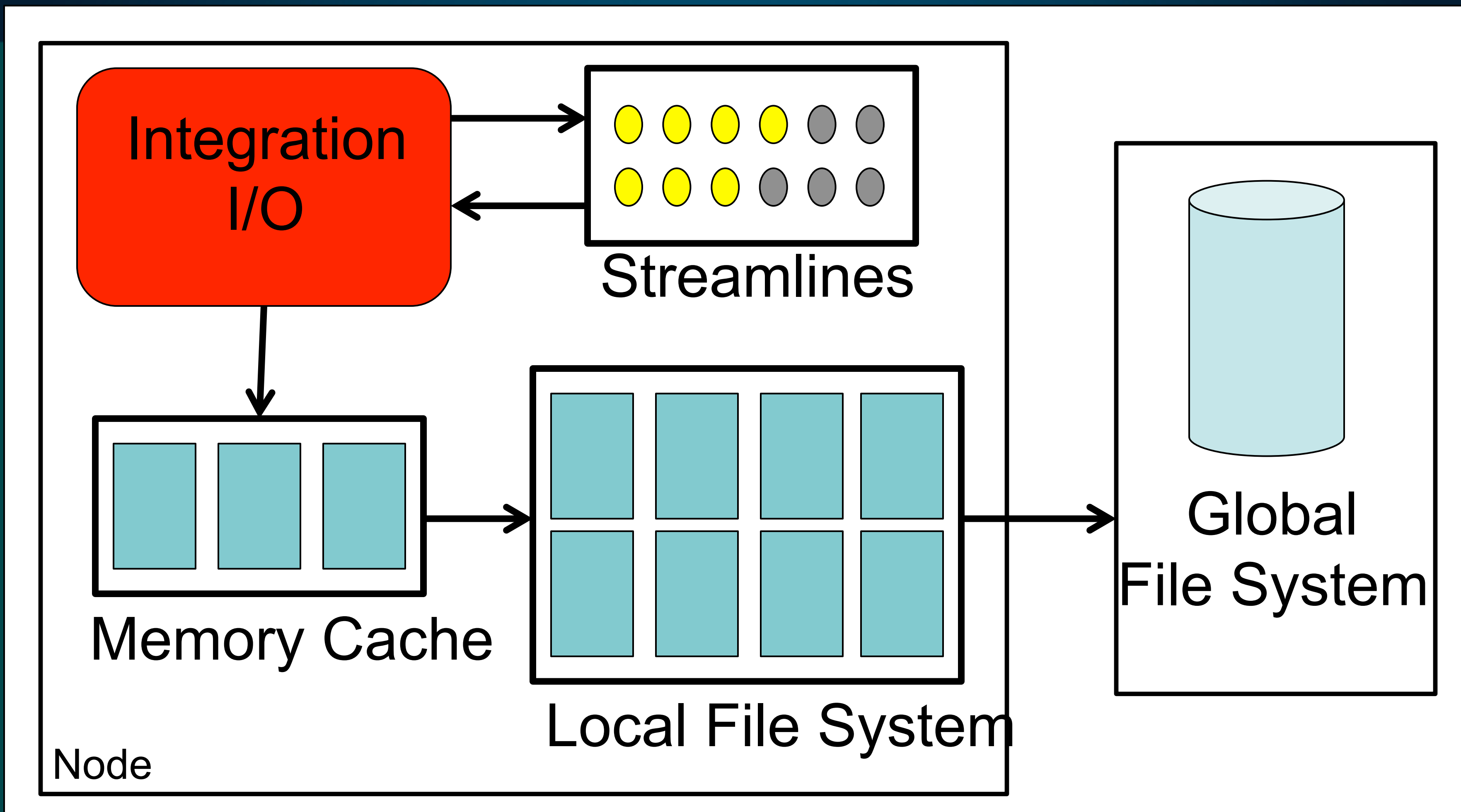
- Example: 2d data set with 9 data blocks and 3 seed points partitioned over 3 processors



Parallelize-over-Seeds Algorithm

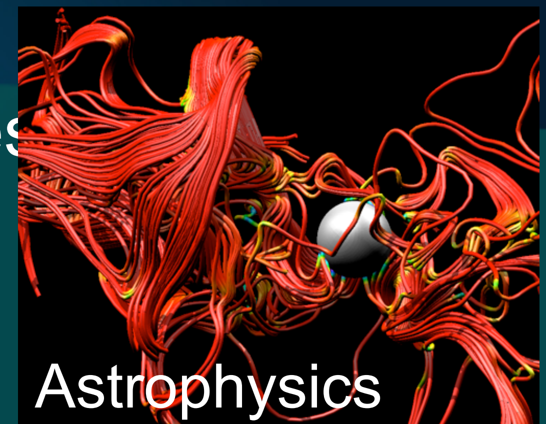


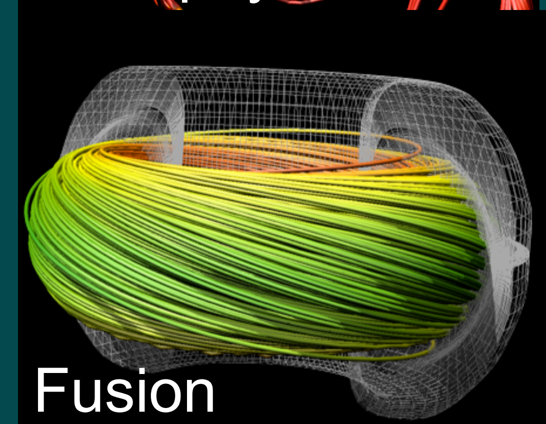
Parallelize-over-Seeds Algorithm with the Extended Memory Hierarchy

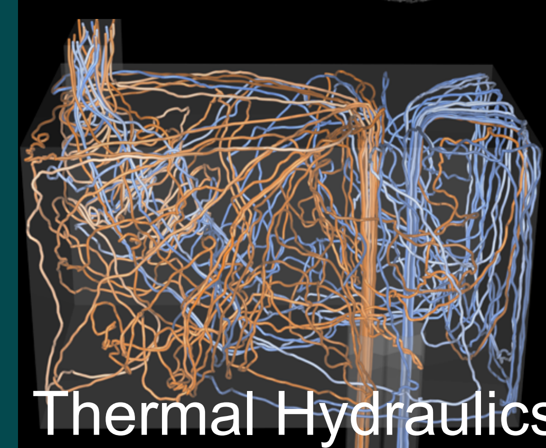


We designed experiments to illuminate the benefits of an extended memory hierarchy for streamlines.

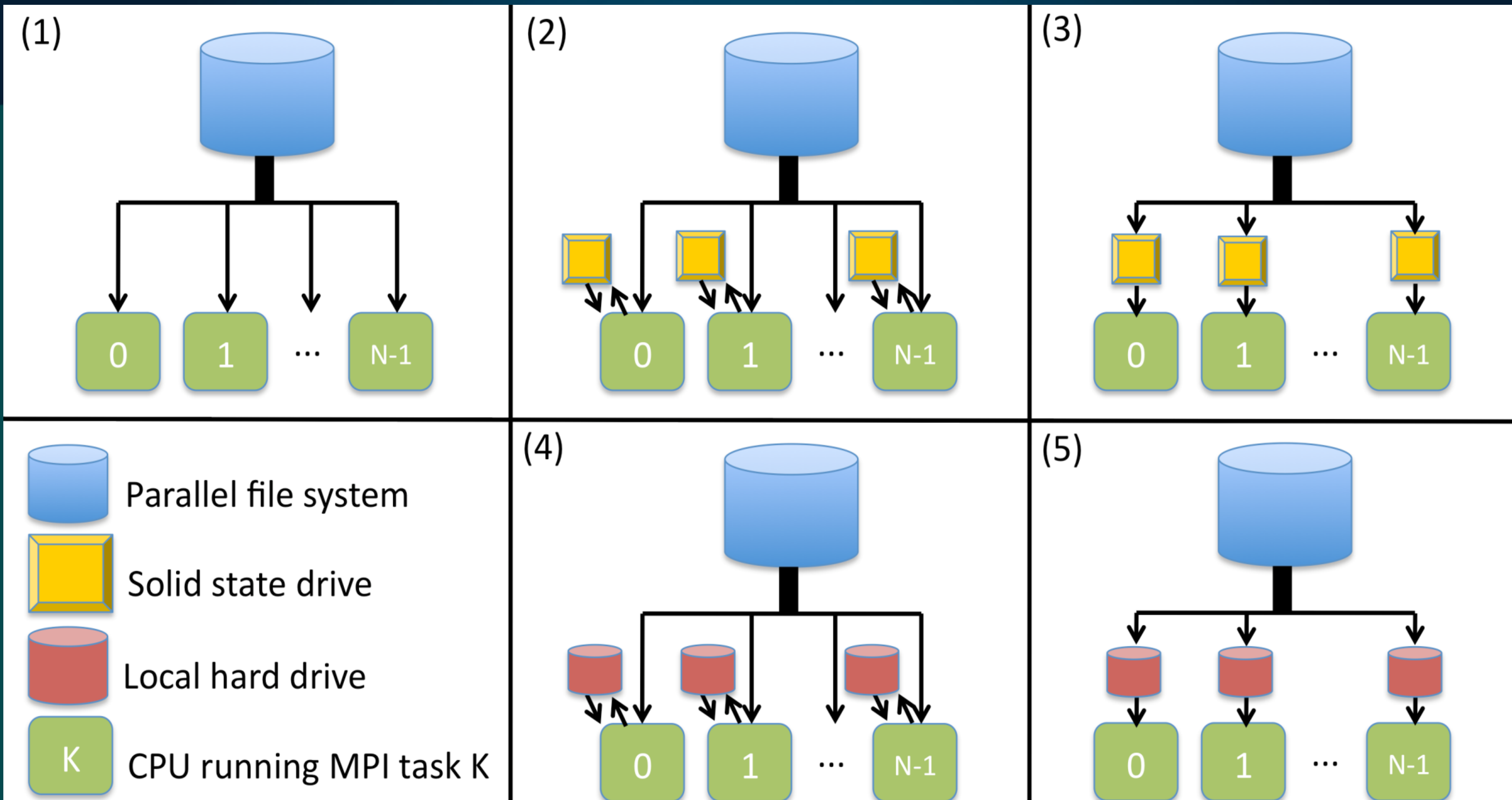
- Goal was to cover complexities of streamlines
  - Seed set size
  - Seed set distribution
  - Data set size
  - Vector field complexity
- 30 experiments varied over:
  - Five different I/O configurations
  - Three data sets
  - Two seed set sizes (2,500 and 10,000)







I/O Configurations



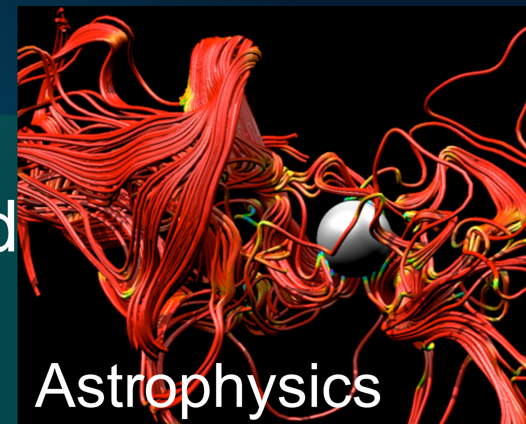
Runtime Environment

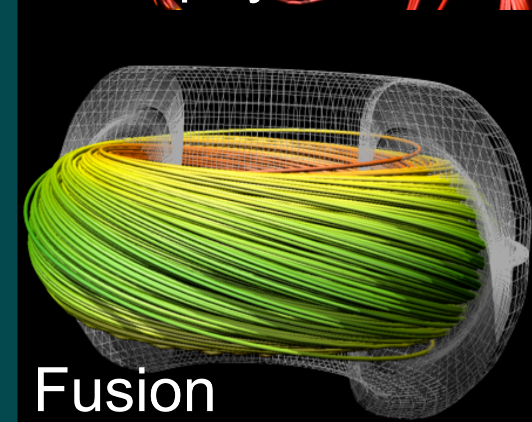
- Dash is a prototype system at San Diego Supercomputer Center
  - Each node has
    - Two quad Intel processors
    - GPFS, local SSD and local hard drive
- VisIt
  - End user visualization and analysis tool for large data sets
- Benchmarks were performed during production use
  - Each benchmark run was performed using 64 cores (8 nodes)

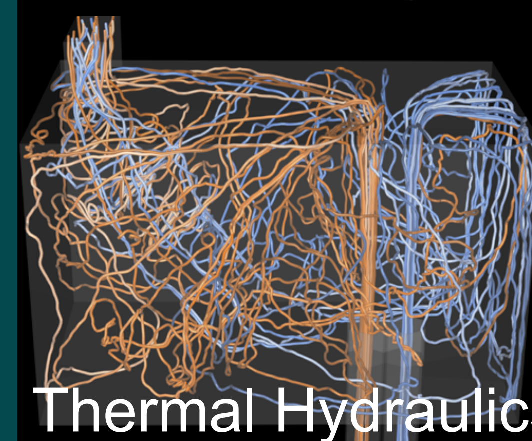
Measurements

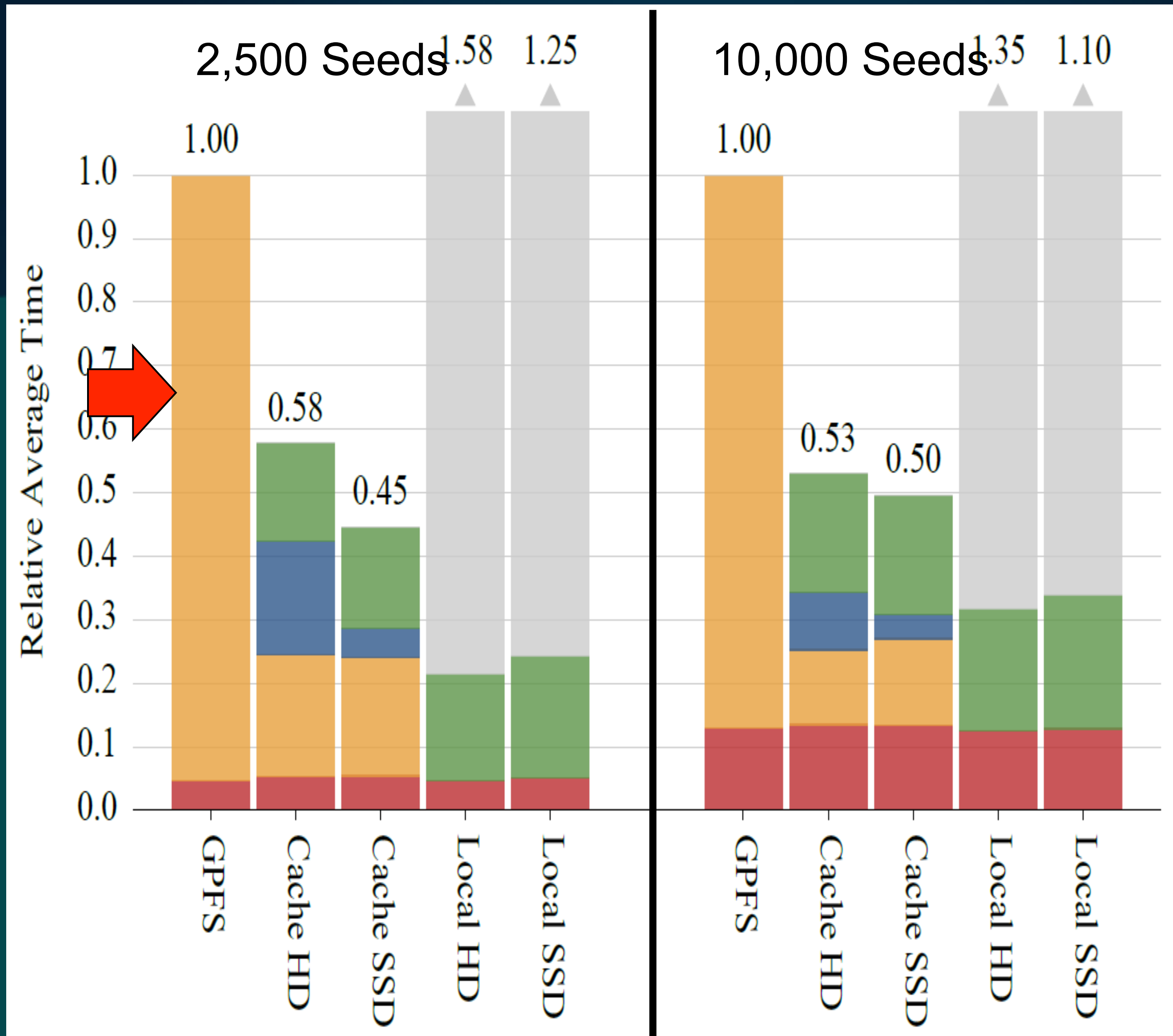
- Time to calculate streamlines
  - Total time = integration time + Data load
  - Integration time
  - I/O time
    - Data retrieval and storage time

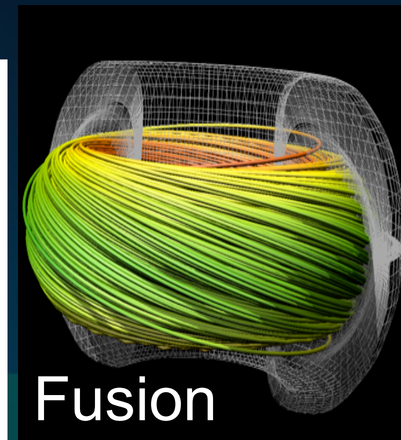
- For our 30 tests…
  - Three different data sets
  - Five I/O configurations
  - Two seeding sizes (2,500 and 10,000)











GPFS fetches

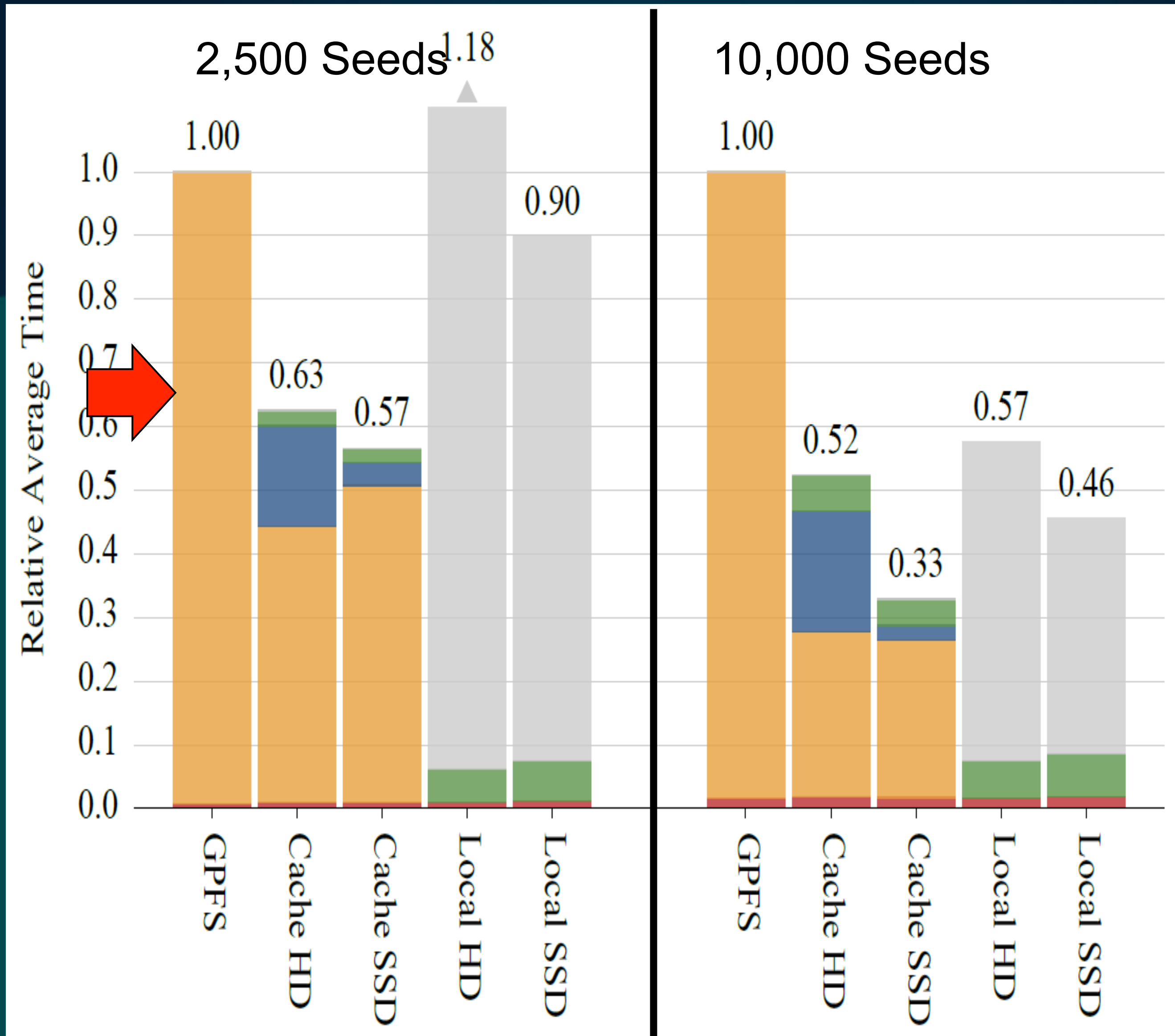
Integration time

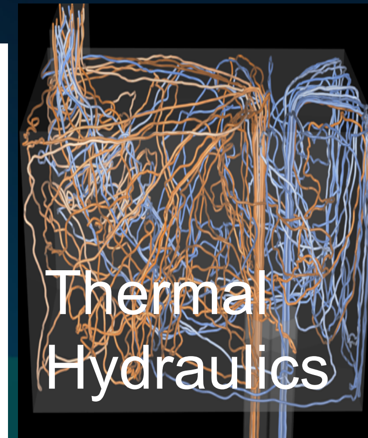
Local disk Stores

Local disk Fetches

Local copy time

Conf.	N_{GF}	N_{LF}	N_{LS}	% Accel	Conf.	N_{GF}	N_{LF}	N_{LS}	% Accel





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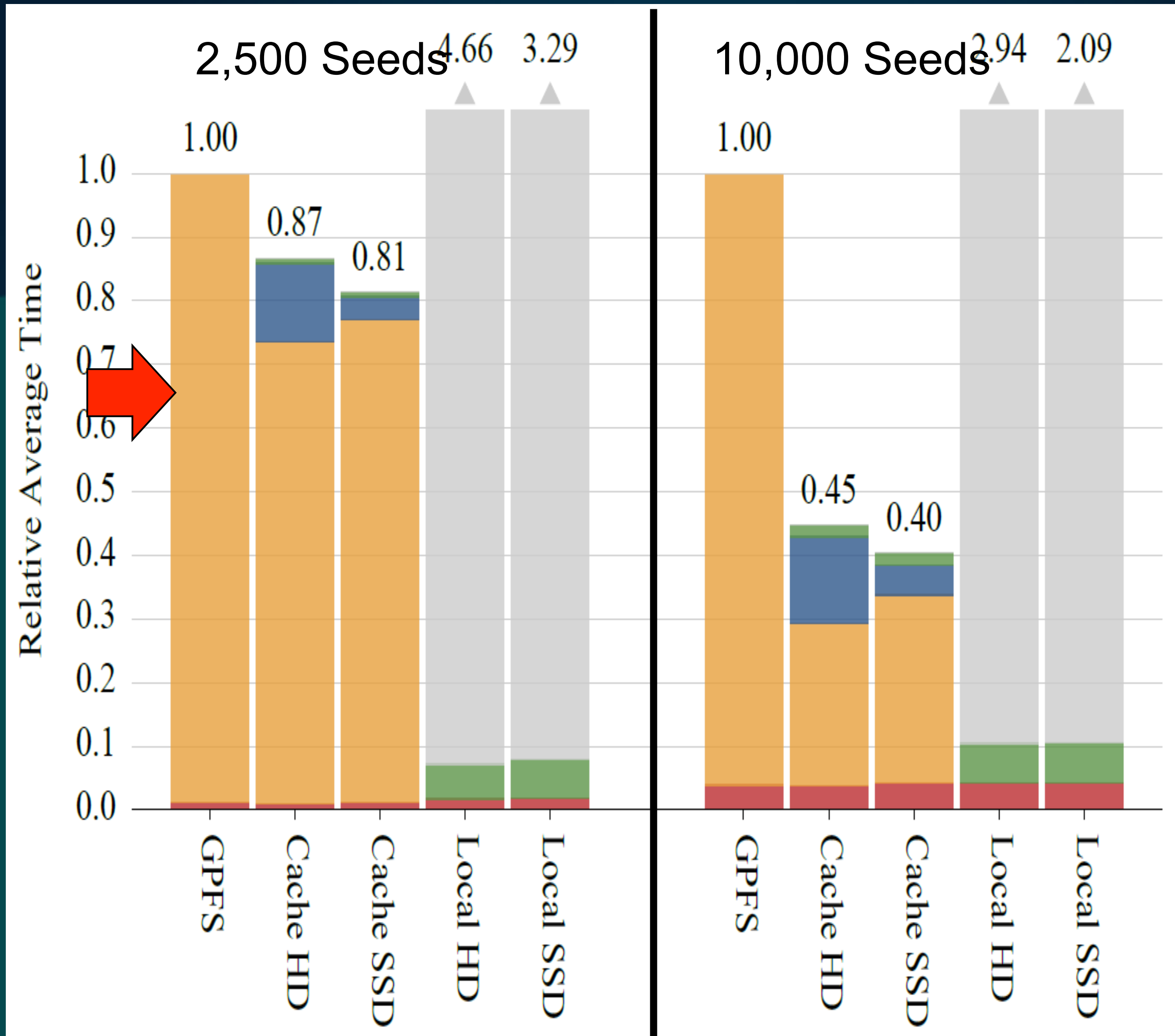

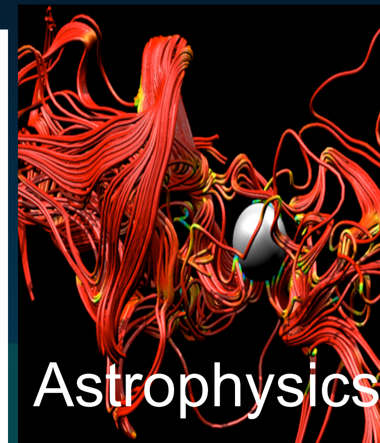

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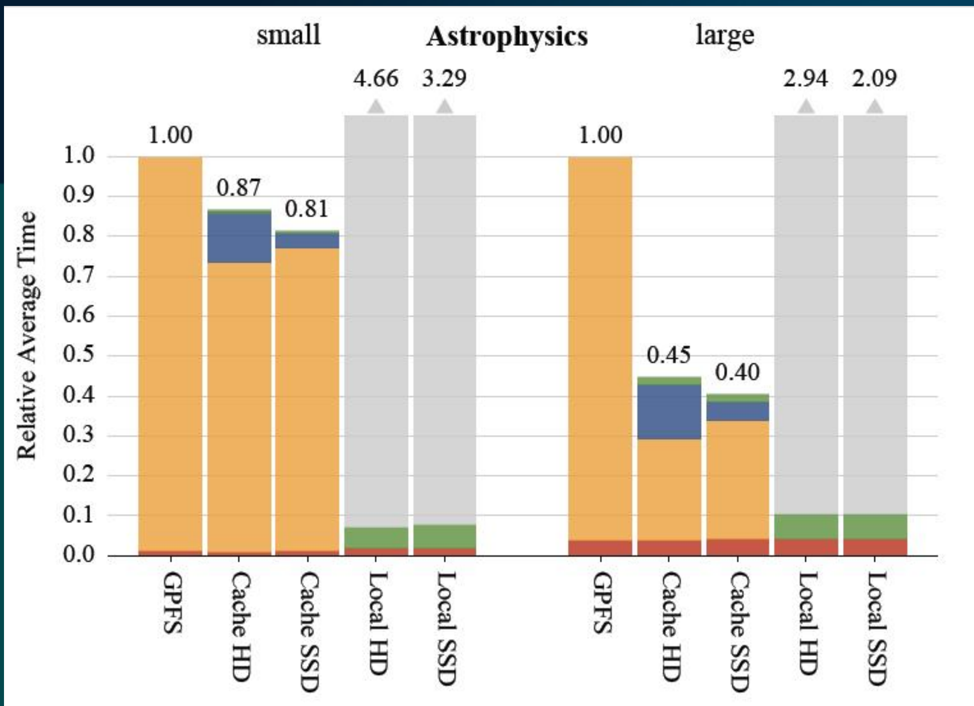
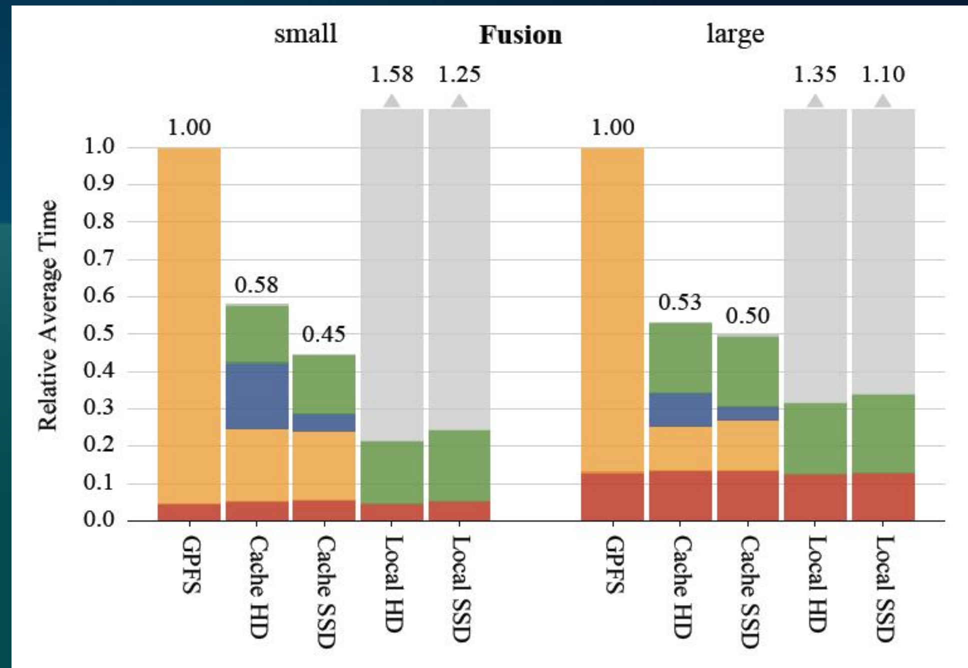
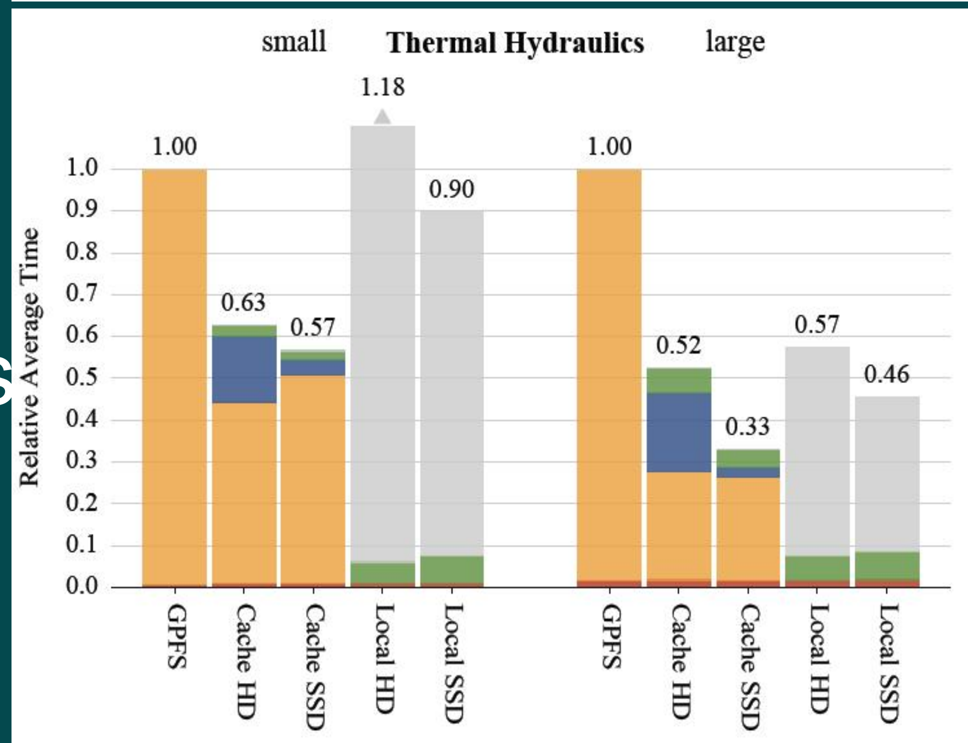
Results







Cache SSD won all tests

		I/O Conf.	T_{Total}	T_{Total*}	T_{IO}	N_{GF}	T_{GF}	N_{LF}	T_{LF}	N_{LS}	T_{LS}	$\%_{Accel}$
Astro	small	GPFS	25.17s	25.17s	24.89s (98%)	5275	24.89s	–	–	–	–	0%
		Cache HD	21.81s	21.81s	21.60s (99%)	4456	18.31s	819	0.20s	3275	3.10s	16%
		Cache SSD	20.47s	20.47s	20.20s (98%)	4456	19.14s	819	0.18s	3275	0.88s	16%
		Local HD	117.37s	1.80s	1.37s (76%)	–	–	5275	1.37s	–	–	100%
		Local SSD	82.85s	1.97s	1.53s (77%)	–	–	5275	1.53s	–	–	100%
	large	GPFS	40.80s	49.80s	39.21s (96%)	9994	39.21s	–	–	–	–	0%
		Cache HD	18.26s	18.26s	16.71s (91%)	7059	10.40s	2935	0.77s	5890	5.55s	29%
		Cache SSD	16.48s	16.48s	14.75s (89%)	7059	12.03s	2935	0.78s	5890	1.95s	29%
		Local HD	119.83s	4.26s	2.54s (59%)	–	–	9994	2.54s	–	–	100%
		Local SSD	85.16s	4.28s	2.57s (59%)	–	–	9994	2.57s	–	–	100%
Fusion	small	GPFS	80.90s	80.90s	77.20s (95%)	51251	77.20s	–	–	–	–	0%
		Cache HD	46.79s	46.79s	42.48s (90%)	8642	15.55s	42609	12.55s	8453	14.38s	83%
		Cache SSD	36.07s	36.07s	31.68s (87%)	8642	15.05s	42609	12.85s	8453	3.78s	83%
		Local HD	128.07s	17.31s	13.61s (78%)	–	–	51251	13.61s	–	–	100%
		Local SSD	101.13s	19.68s	15.53s (78%)	–	–	51251	15.53s	–	–	100%
	large	GPFS	107.04s	107.04s	93.16s (87%)	79467	93.16s	–	–	–	–	0%
		Cache HD	56.79s	56.79s	42.39s (74%)	9907	12.59s	69560	20.16s	9714	9.64s	87%
		Cache SSD	53.07s	53.07s	38.78s (73%)	9907	14.57s	69560	20.14s	9714	4.07s	87%
		Local HD	144.65s	33.89s	20.60s (60%)	–	–	79467	20.60s	–	–	100%
		Local SSD	117.75s	36.30s	22.62s (62%)	–	–	79467	22.62s	–	–	100%
Thermal Hydraulics	small	GPFS	98.88s	98.88s	98.22s (99%)	19085	98.22s	–	–	–	–	0%
		Cache HD	61.81s	61.81s	60.85s (98%)	10278	42.88s	8807	2.39s	9888	15.58s	46%
		Cache SSD	55.92s	55.92s	54.95s (98%)	10278	49.20s	8807	2.16s	9888	3.59s	46%
		Local HD	116.48s	6.04s	5.13s (84%)	–	–	19085	5.13s	–	–	100%
		Local SSD	88.85s	7.38s	6.29s (85%)	–	–	19085	6.29s	–	–	100%
	large	GPFS	220.68s	220.68s	217.23s (98%)	48188	217.23s	–	–	–	–	0%
		Cache HD	115.39s	115.39s	111.47s (96%)	14099	57.38s	34089	12.54s	13717	41.54s	71%
		Cache SSD	72.56s	72.56s	68.80s (94%)	14099	54.56s	34089	9.13s	13717	5.10s	71%
		Local HD	126.84s	16.40s	12.93s (78%)	–	–	48188	12.93s	–	–	100%
		Local SSD	100.44s	18.97s	15.14s (79%)	–	–	48188	15.14s	–	–	100%

Model To Determine How Much The Extended Memory Hierarchy Can Benefit

- Baseline (GPFS)
  - Total Time = (Integration Time) + (Number of Blocks) * (Time to Fetch Data)
  - $T_{total} = T_{Int} + N_{GF} * A_{GF}$
- Extended Memory Hierarchy
  - $T_{total} = T_{int} + N_{\underline{A}} * T_{GF} + N_{\underline{A}} * T_{LS} + N_{A} * T_{LF}$

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(Number of Data Blocks) * (Time to Fetch Data from Global File S

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  - $T_{total} = T_{int} + N_{\underline{A}} * T_{GF} + N_{\underline{A}} * T_{LS} + N_{A} * T_{LF}$

(Number of Data Blocks) * (Time to Store Data to Local Dri

Model To Determine How Much The Extended Memory Hierarchy Can Benefit

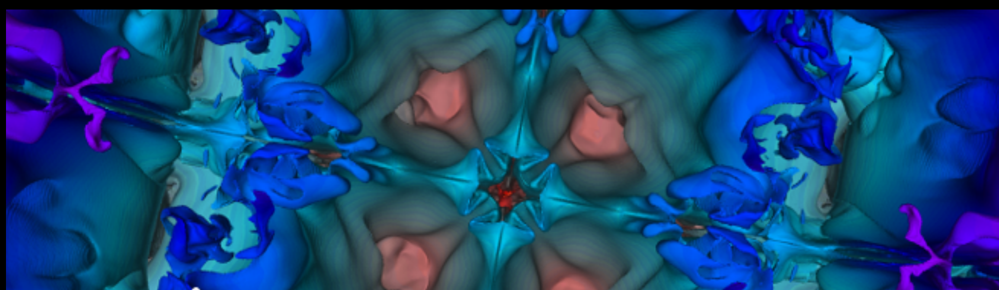
- Baseline (GPFS)
  - Total Time = (Integration Time) + (Number of Blocks) * (Time to Fetch Data)
  - $T_{total} = T_{Int} + N_{GF} * A_{GF}$
- Extended Memory Hierarchy
  - $T_{total} = T_{int} + N_{\underline{A}} * T_{GF} + N_{\underline{A}} * T_{LS} + N_{A} * T_{LF}$

(Number of Reused Data Blocks) * (Time to Load Data from Loca

Summary

- The I/O architecture of supercomputers is evolving.
- We designed and implemented a streamline algorithm that made use of an extended memory hierarchy.
- We found that the performance of a common visualization algorithm (streamline) can be improved by up to a factor of three.

EGPGV 2012 in Cagliari, Italy
Co-located with EuroGraphics 2012

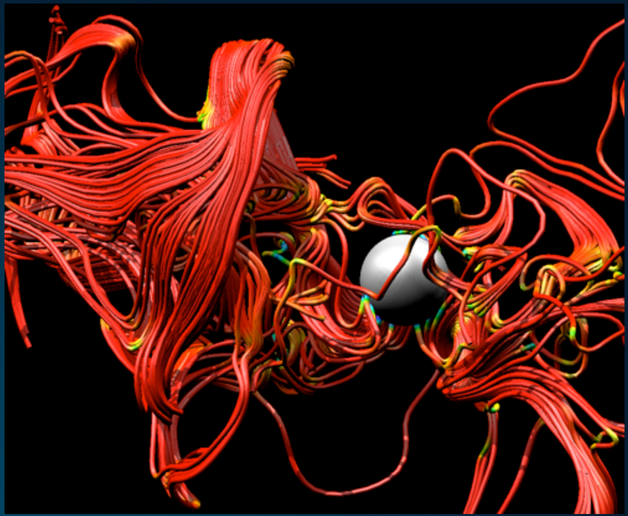


- Dates:
- February, 12, 2011: tentative data for paper submission
- Symposium: May 13-14
- Important:
- Best papers (up to 3) invited for TVCG submissions

Conference Chair:
Fabio Marton,
Visual Computing Group, CRS4, Italy

Papers Co-Chairs:
Torsten Kuhlen
RWTH, Aachen University

Thank you for your attention!!!



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