

Parallel Applications Workshop, Alternatives to MPI+X

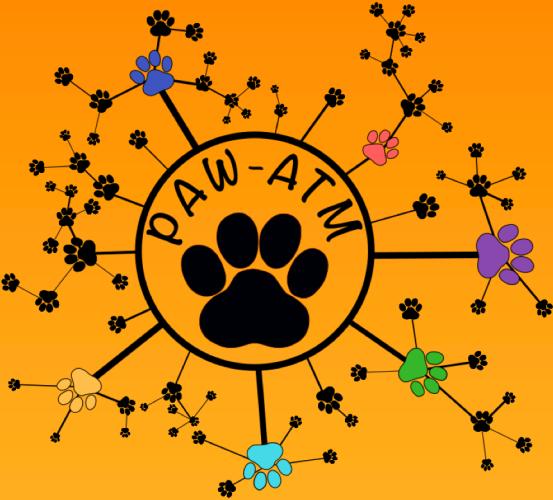
November 17th, 2019

Held in conjunction with SC19: The International Conference for
High Performance Computing, Networking, Storage, and Analysis



In cooperation with:





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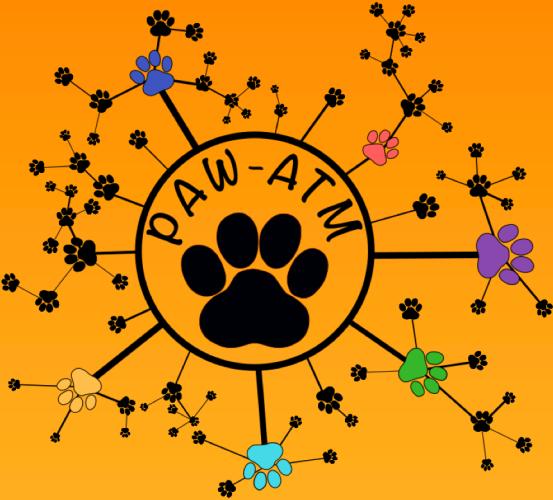
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MPI: HPC's de facto programming model

MPI (Message Passing Interface)

[MPI Forum, ~1992–]

- a library for inter-process communication and synchronization
- run a process per compute node, core, or NUMA domain
- call routines for point-to-point messaging, collectives, barriers, ...



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MPI+X: Adding inter-process parallelism

MPI+X

[various, ~2010–]

- X = something supporting finer-grain parallel programming
- intended to support multi-core or hybrid computing (e.g., GPUs)

X could be...

...**Pthreads**

[POSIX, ~1995–]

...**OpenMP**

[OpenMP ARB, ~1997–]

...**CUDA**

[Nvidia, ~2007–]

...**OpenCL**

[Khronos Group, ~2009–]

...**OpenACC**

[OpenACC.org, ~2012–]

...**Kokkos**

[Sandia, ~2012–]

...**RAJA**

[LLNL, ~2016–]



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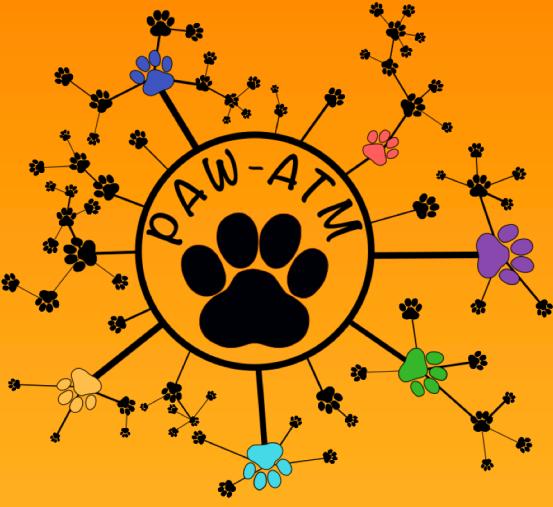
MPI+X: Pluses and Minuses

Pluses:

- general-purpose
- adopted / ubiquitous
 - MPI is, at least; some choices of X may not be
- explicit:
 - if the system can do something, you probably can too

Disadvantages:

- explicit:
 - detail-oriented
 - relatively low-level
 - not very insulated from architectural details



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A Historical Analogy with Fortran

In Fortran's early days, assembly programmers were concerned about switching to it, due to:

- loss of explicit control
- fear of performance impact

However, Fortran succeeded, providing many productivity benefits

- Its success led to other successful high-level languages:
 - e.g., C, C++, Java, Python, Go, Rust, Swift, ...
- Today, we rarely worry about things like register allocation
 - plus, can always drop down to assembly if required

In HPC, we've been less successful at creating—and broadly adopting—higher-level alternatives to MPI+X to reap similar benefits



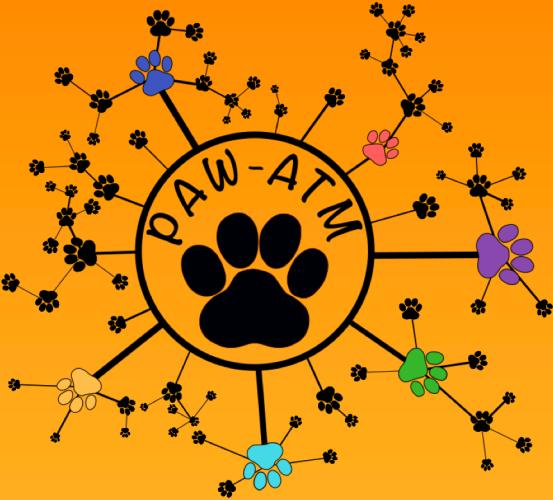
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PAW-ATM's Goals

- 1) To provide a forum to discuss **Alternatives to MPI+X**
 - capable of targeting HPC-scale **Parallel** systems
- 2) To highlight **Applications** from real users to keep things concrete and applied



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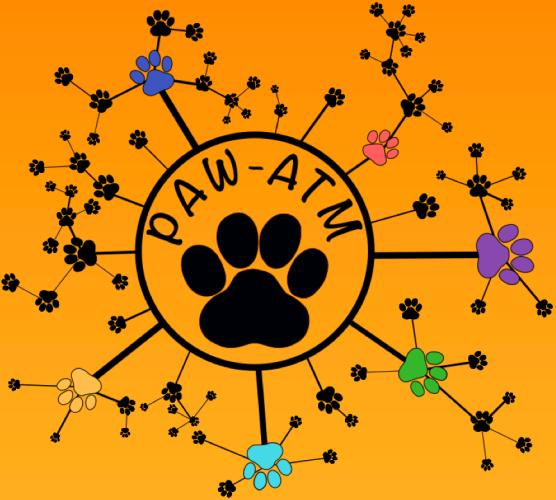
Goals and Disclaimers for this talk

Goals:

- ✓ Give context and motivation for PAW-ATM 2019
- Provide a mental framework for today's talks

Disclaimers:

- This will be a rapid summary of a complex topic
- Technologies will be dramatically oversimplified
- Others will be skipped altogether
- My apologies for any big mistakes or omissions



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Early Alternatives to MPI

- High Performance Fortran
- ZPL
- NESL
- Charm++
- ...

[HPF Forum, ~1991–2002]

[U. Washington, ~1992–2005]

[CMU, ~1993–1997]

[UIUC, ~1993–]



PGAS Programming Approaches

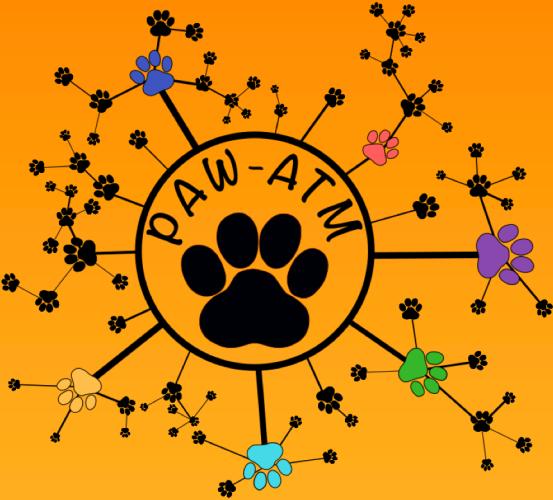
PGAS: Partitioned Global Address Space

- **unifying theme:** refer to remote values by naming them
- this “name” could be...
 - ...a remote address
 - ...the name of a variable stored remotely
 - ...a remote element of a distributed array
 - ...

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Original PGAS Approaches

PGAS-oriented Libraries:

- **[Open]SHMEM**
- **Global Arrays**
- **ARMCI**
- **GASNet[-EX]**

[OpenSHMEM project / Cray, ~1993–]

[PNNL, ~1994–]

[PNNL, ~1999–2010]

[LBL / UC Berkeley, ~2002–]

PGAS languages

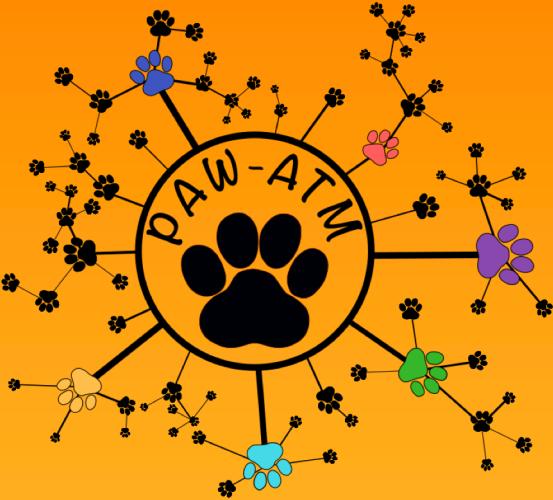
- **Fortran 2008 / 2018**
- (previously **Co-Array Fortran, F--**)
- **Titanium**
- **Unified Parallel C (UPC)**

[Fortran Working Group, ~1997–]

[Cray, et al.]

[UC Berkeley, ~1998–2005]

[UPC Consortium, ~1999–]



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Next-Generation PGAS Approaches

HPCS Languages

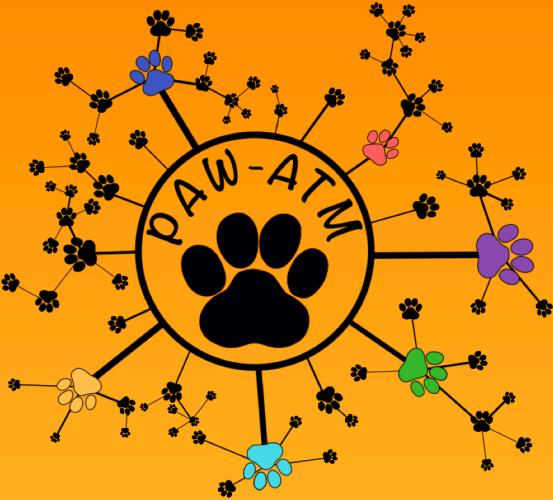
- **Chapel** [Cray, ~2003–]
- **X10** [IBM, ~2004–]
- **Fortress** [Sun/Oracle, ~2005–2012]

Others

- **XcalableMP** [XMP Working Group, ~2008–]
- **PCJ** [Nicolaus Copernicus U. / U. Warsaw, ~2012–]
- ...

C++ Template Libraries

- **Coarray C++** [Cray, ~2013–]
- **UPC++** [UC Berkeley, ~2014–]



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Task-based Alternatives to MPI

Runtime Systems

- **HPX**
- **Legion**
- ...

[Stellar Group, ~2012–]

[Stanford / SLAC / LANL / NVIDIA, ~2012–]

Programming Models / Languages

- **Charm++**
- **PaRSEC**
- **COMPSS**
- **PyCOMPSS**
- **Regent**
- **Pygion**
- ...

[UIUC, ~1993–]

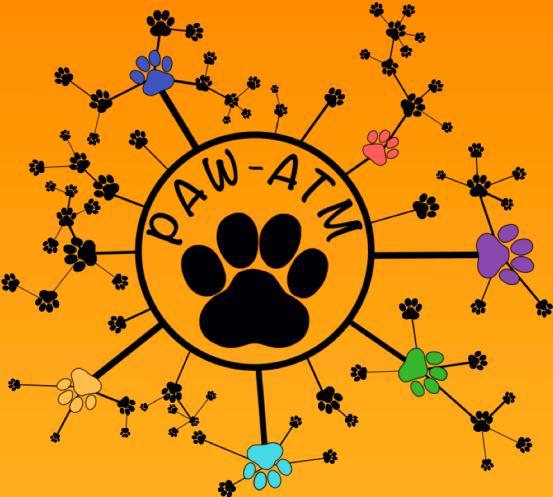
[U. Tenn. Knoxville, ~2009–]

[BSC, ~2011–]

[BSC, ~2015–]

[Stanford / SLAC, ~2015–]

[Stanford / SLAC, ~2019–]



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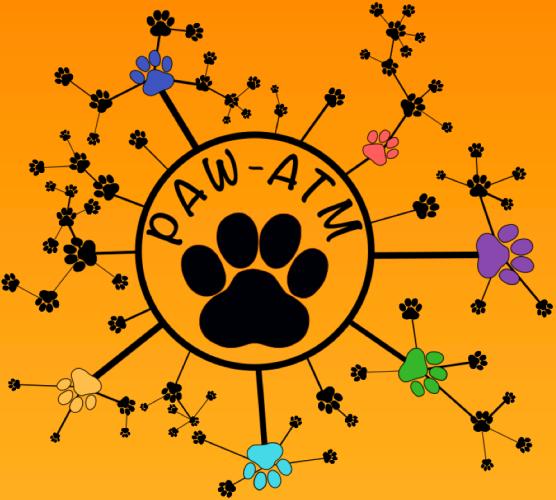
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Analytics- / NumPy-based Approaches

- Hadoop [Apache Software Foundation, ~2006–]
- Spark [UC Berkeley / ASF, ~2009–]
- Flink [Apache Flink Committee, ~2014–]
- Dask [Dask Dev. Community / NumFOCUS, ~2015–]
- **Arkouda** [DOD, ~2019–]
- Legate [NVIDIA, ~2019–]
- ...



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Which Alternatives to Consider?

Regent

Chapel

XcalableMP

X10

Fortran 2018

UPC

Legate

Dask

Arkouda

PaRSEC

COMPSS

Pygion

PyCOMPSS

Hadoop

Flink

Spark

Charm++

Coarray C++

UPC++

Global Arrays

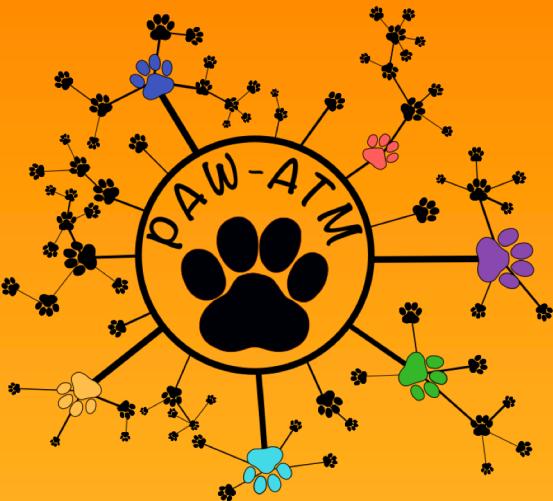
PCJ

HPX

Legion

GASNet-EX

OpenSHMEM



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Which Alternatives to Consider? And Why?

Regent

Chapel

XcalableMP

X10

Language vs. Language Extension vs. Library?

Fortran 2018

UPC

Compiled vs. Interpreted?

Legate

Dask

Arkouda

Type(s) of parallelism: SPMD vs. data- vs. task-parallel?

PARSEC

COIMPSS

PvISION

PVCOIMPSS

Explicit vs. Implicit Communication, Synchronization, Parallelism?

Hadoop

Flink

Spark

Support for distributed data structures? Local- or global-view?

Charm++

Coarray C++

UPC++

Global Arrays

PCJ

Compatible / Interoperable with Language of Choice?

HPX

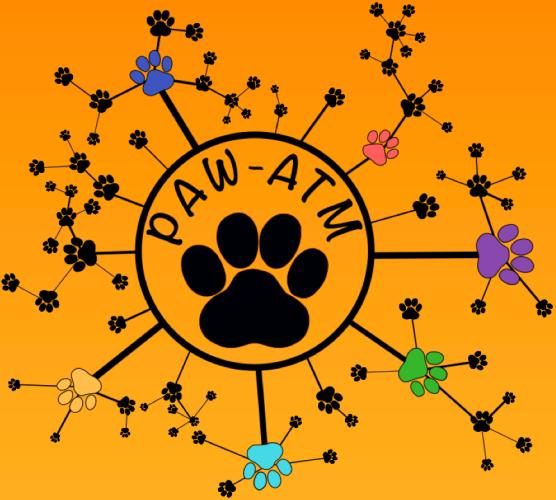
Legion

Portable? GPU Support?

GASNet-EX

OpenSHMEM

...?



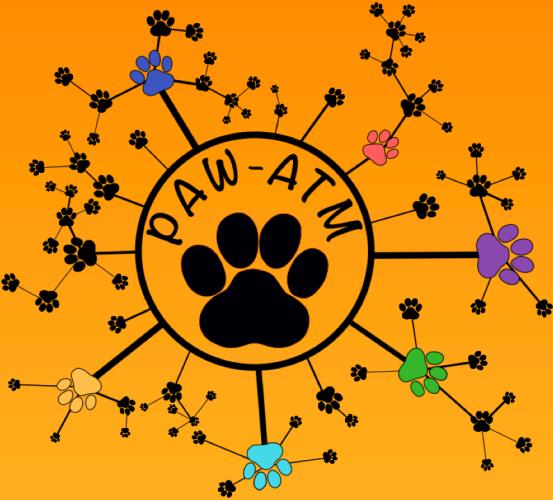
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Program

- 9:00: Welcome and Introduction
- 9:10: **Keynote:** *Computer Science Challenges to Imaging the Universe with the SKA Radio-Telescope*
Peter J. Braam, *University of Oxford*
- 10:00: **Break (catered)**
- 10:30: **Session 1:** Scientific Simulations
- 11:30: **Session 2:** Applying MPI+X Alternatives: from Shallow Water to Deep Learning
- 12:30: **Lunch (on your own)**
- 2:00: **Session 3:** Communication Libraries and APIs
- 3:00: **Break (catered)**
- 3:30: **Session 4:** Integrating Python into HPC
- 4:10: **Panel Discussion:** Applications in Alternatives to MPI+X
- 5:30: **Wrap-up**



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Regent

Legion **Kokkos**

Chapel

UPC++

PaRSEC **Charm++**

OpenSHMEM

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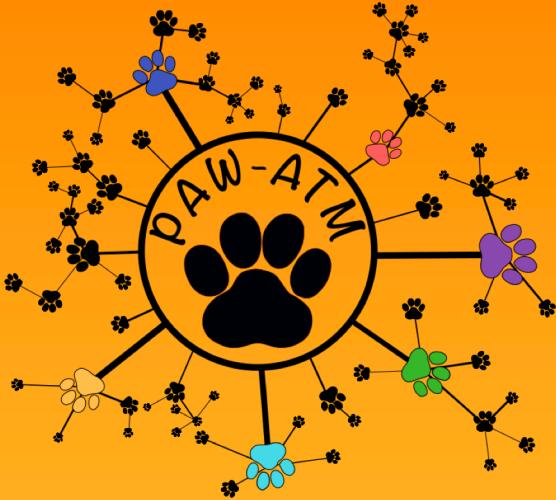
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4:10: **Panel Discussion:** Applications in Alternatives to MPI+X

Pygion **Legion** **Regent**

Chapel **[Py]COMPSS** **Fortran 2018**

5:30: **Wrap-up**



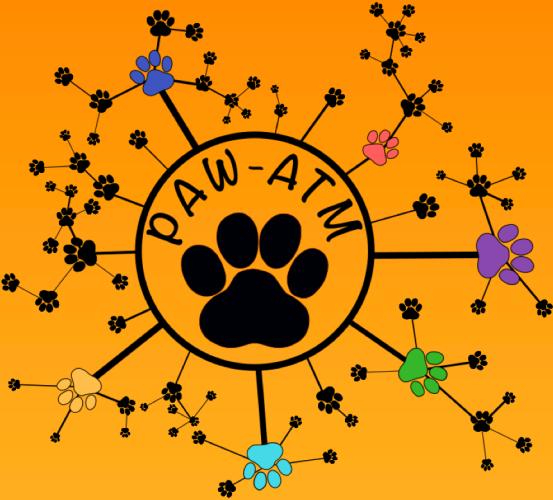
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PAW-ATM 2019: Program Committee

- Olivier Aumage - Inria
- Vicenç Beltran - Barcelona Supercomputing Center
- John Biddiscombe - CSCS Swiss National Supercomputing Centre
- Salvatore Filippone - Cranfield University
- Marta G. Gasulla - Barcelona Supercomputing Center
- Magne Haveraaen - University of Bergen
- Costin Iancu - Lawrence Berkeley National Laboratory
- Laxmikant Kale - University of Illinois
- Bill Long - Cray, a Hewlett Packard Enterprise company
- Swaroop S. Pophale - Oak Ridge National Laboratory
- Jason Riedy - Georgia Institute of Technology
- Francesco Rizzi - NexGen Analytics
- Mitsuhsia Sato - RIKEN Advanced Institute for Computational Science
- Elliott Slaughter - SLAC National Accelerator Laboratory



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SC19
Denver, CO | hpc is now.

TCHPC

PAW-ATM 2019: Organization

Workshop Chair

- Karla Morris
- Sandia National Laboratories

Organizing Committee

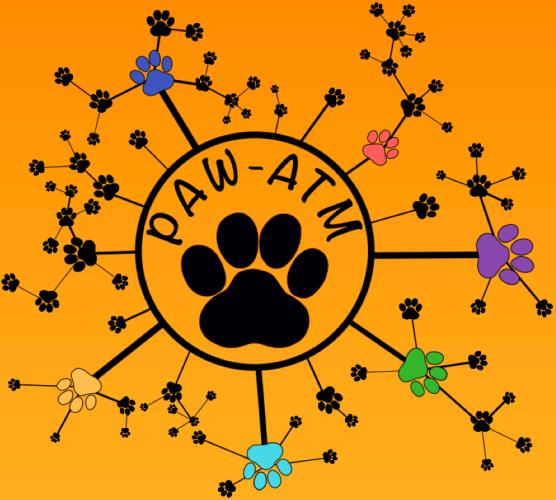
- Rosa M. Badia
- Barcelona Supercomputing Center
- Bradford L. Chamberlain
- Cray, a Hewlett Packard Enterprise company
- Sean Treichler
- NVIDIA

Program Committee Chairs

- Bill Long
- Cray, a Hewlett Packard Enterprise company
- Francesco Rizzi
- NexGen Analytics

Advisory Committee

- Salvatore Filippone
- Cranfield University
- Katherine A. Yellick
- Lawrence Berkeley National Laboratory
- Damian W. I. Rouson
- Sourcery Institute



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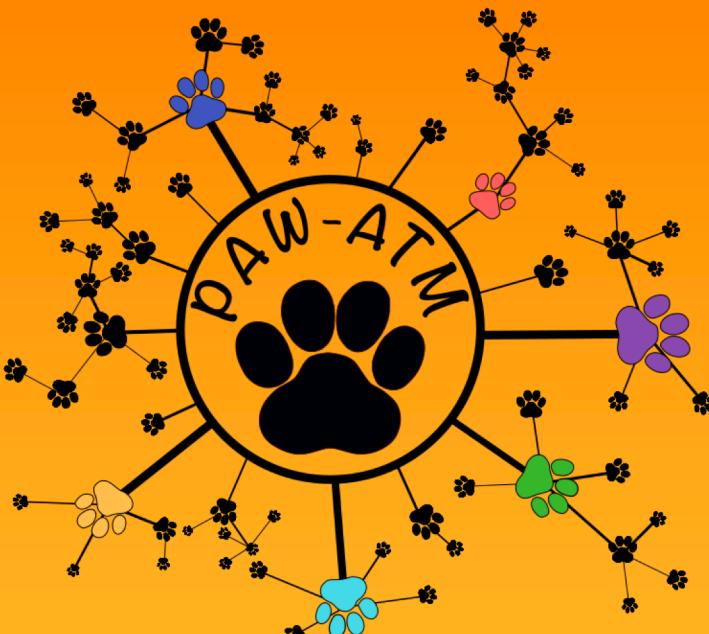
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Please send in your feedback!

After the workshop, *please* send in your feedback:
<https://sc19.supercomputing.org/session/?sess=sess108>

The screenshot shows the SC19 website interface. At the top, there is a navigation bar with the SC19 logo, PROGRAM, EXHIBITS, SCINET, ATTEND, SUBMIT, and a purple REGISTER button. Below the navigation bar, there are five colorful geometric shapes (triangles and rectangles) in various colors (yellow, orange, purple, red, green). The main content area has a header "Session" with a back arrow and a home icon. Below the header, there are links to FULL PROGRAM, CONTRIBUTORS, ORGANIZATIONS, SEARCH PROGRAM, FLAGGED, HAPPENING NOW, and MAPS. The title "Parallel Applications Workshop, Alternatives to MPI+X" is displayed in bold. Underneath the title, it says "Session Chairs: Karla Morris - Sandia National Laboratories, Brad Chamberlain - Cray Inc, Rosa M. Badia - Barcelona Supercomputing Center, Sean Treichler - Nvidia Corporation, Bill Long - Cray Inc, Francesco Rizzi - Independent". To the right of this text, a "give feedback" button is highlighted with a red oval. Further down, there are sections for "Event Type: Workshop", "Registration Categories: W", "Tags: MPI, Parallel Application Frameworks, Parallel Programming Languages, Libraries, and Models, Scalable Computing", "Time: Sunday, 17 November 2019, 9am - 5:30pm", and "Location: 507".

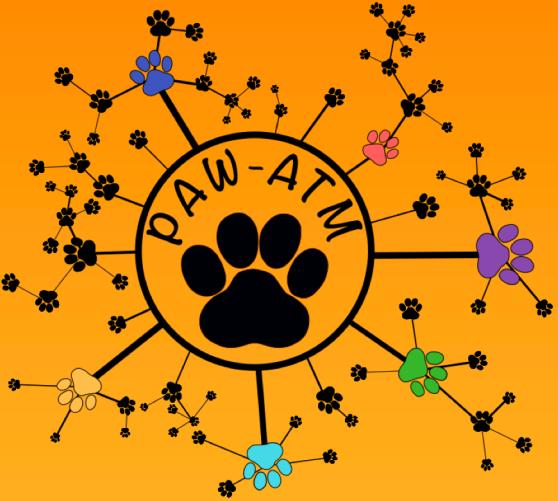


Welcome to PAW-ATM 2019!



In cooperation with:





Parallel Applications Workshop Alternatives to MPI+X

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Session 1

• Scientific Simulations

10:30 - *Soleil-X: Turbulence, Particles, and Radiation in the Regent Programming Language*

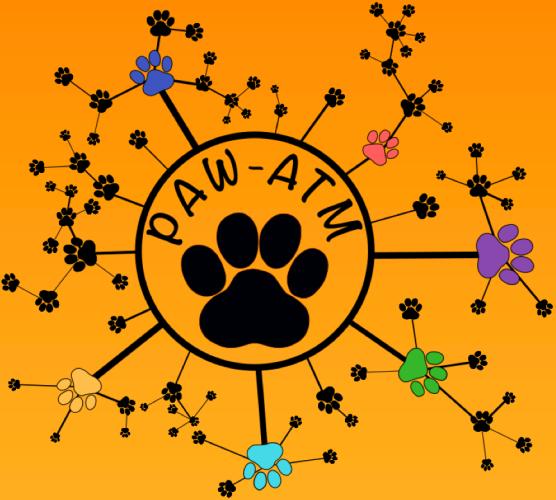
Hilario C. Torres, Manolis Papadakis, Lluis Jofre, Wonchan Lee, Alex Aiken and Gianluca Iaccarino

10:50 - *Exploring the Use of Novel Programming Models in Land Surface Models*

Ethan T. Coon, Wael Elwasif, Himanshu Pillai, Peter E. Thornton and Scott L. Painter

11:10 - *Simulating Ultralight Dark Matter with Chapel: An Experience Report*

Nikhil Padmanabhan, Elliot Ronaghan, Jovana L. Zagorac, and Richard Easterer



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Session 2

- Applying MPI+X Alternatives: from Shallow Water to Deep Learning

11:30 - *A UPC++ Actor Library and Its Evaluation On a Shallow Water Proxy Application*

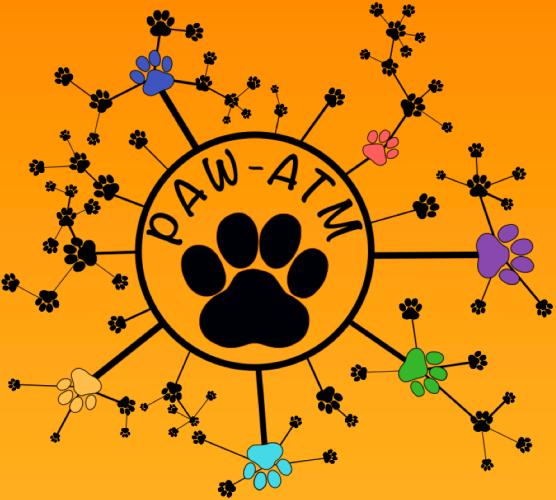
Alexander Pöppl, Scott Baden, and Michael Bader

11:50 - *Evaluation of Programming Models to Address Load Imbalance on Distributed Multi-Core CPUs: A Case Study with Block Low-Rank Factorization*

Yu Pei, George Bosilca, Ichitaro Yamazaki, Akihiro Ida, and Jack Dongarra

12:10 - *Scalable Machine Learning with OpenSHMEM*

Gerard Taylor, James Dinan, Md. Wasi-ur Rahman, and David Ozog



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Session 3

- Communication Libraries and APIs

2:00 - *Designing, Implementing, and Evaluating the Upcoming OpenSHMEM Teams API*

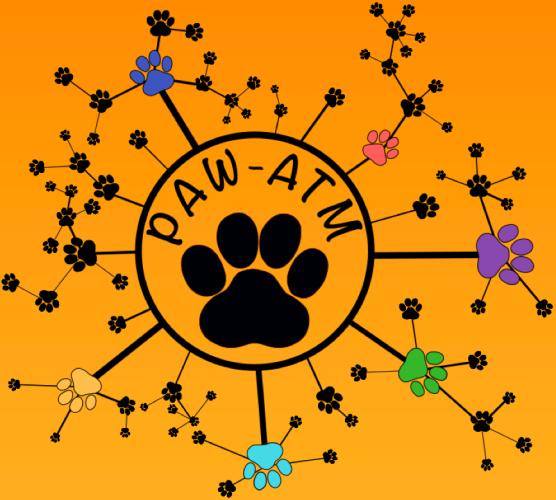
David Ozog, MD Wasi-ur- Rahman, Gerard Taylor, and James Dinan

2:20 - *Enabling Low-Overhead Communication in Multi-threaded OpenSHMEM Applications using Contexts*

Wenbin Lu, Tony Curtis, and Barbara Chapman

2:40 - *Efficient Active Message RMA in GASNet Using a Target-Side Reassembly Protocol*

Paul H. Hargrove and Dan Bonachea



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Session 4

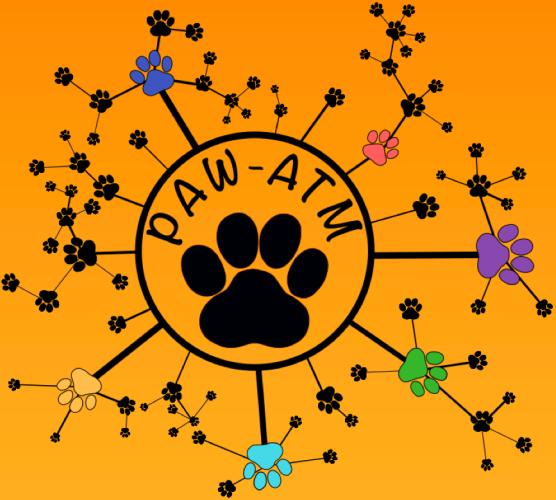
- Integrating Python into HPC

3:30 - *Pygion: Flexible, Scalable Task-Based Parallelism with Python*

Elliott Slaughter and Alex Aiken

3:50 - *Arkouda: NumPy-like arrays at massive scale backed by Chapel*

Michael H. Merrill, William Reus, and Timothy Neumann



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Panel Discussion

- Applications in Alternatives to MPI+X

- Panel Moderator:
 - Patrick McCormick
 - Los Alamos National Laboratory

- Panelists:
 - Alex Aiken
 - Stanford University
 - Rosia M. Badia
 - Barcelona Supercomputing Center
 - Michael Ferguson
 - Cray, a Hewlett Packard Enterprise company
 - Damian W. I. Rouson
 - Sourcery Institute
 - Potential Mystery Panelist - ???