Shared Memory HPC Programming: Past, Present, and Future

Bill Carlson
IDA Center for Computing Sciences
June 13, 2015

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Our Problem in 1993

How do we program this? And get good performance?

AC for the Cray T3D

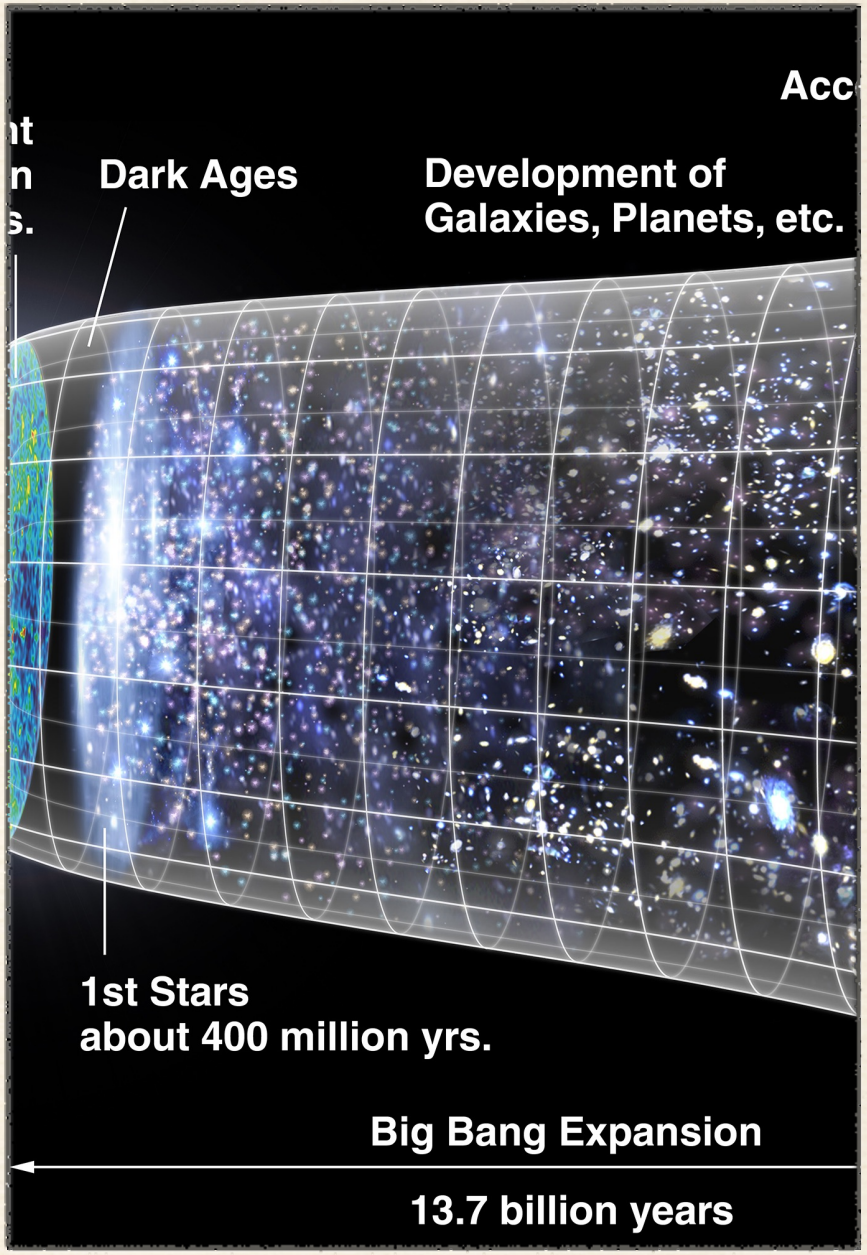
- An outgrowth of our work on CM5
- Shared memory on a distributed memory machine
  - "dist" keyword is the only syntax change
  - Performance high from special hardware on T3D
  - Much faster than "shmem" library, due to low overhead

UPC = AC + Split-C + PCP

- Collaboration with UC Berkeley and LLNL
  - Takes “shared” from AC’s “dist”
  - “strict” and “relaxed” shared memory semantics
  - Split barriers: “notify/wait”
  - Locks
  - Adds several data distributions

PGAS: Expanding the collaboration

- SHMEM Library
- CoArray Fortran
- Global Arrays
- Titanium



DARPA's HPCS Program

- High ***Productivity*** Computing Systems
- Productivity: Output per unit of Input
  - Output is problems solved
  - Input is money, energy, people time
- Goal: Increase productivity of HPC by 10x:
  - Systems performance 10x for many metrics
  - Algorithm and Software developers 10x effective in making good code
  - System operators spend 1/10 effort to manage system

HPCS added “modern” concepts

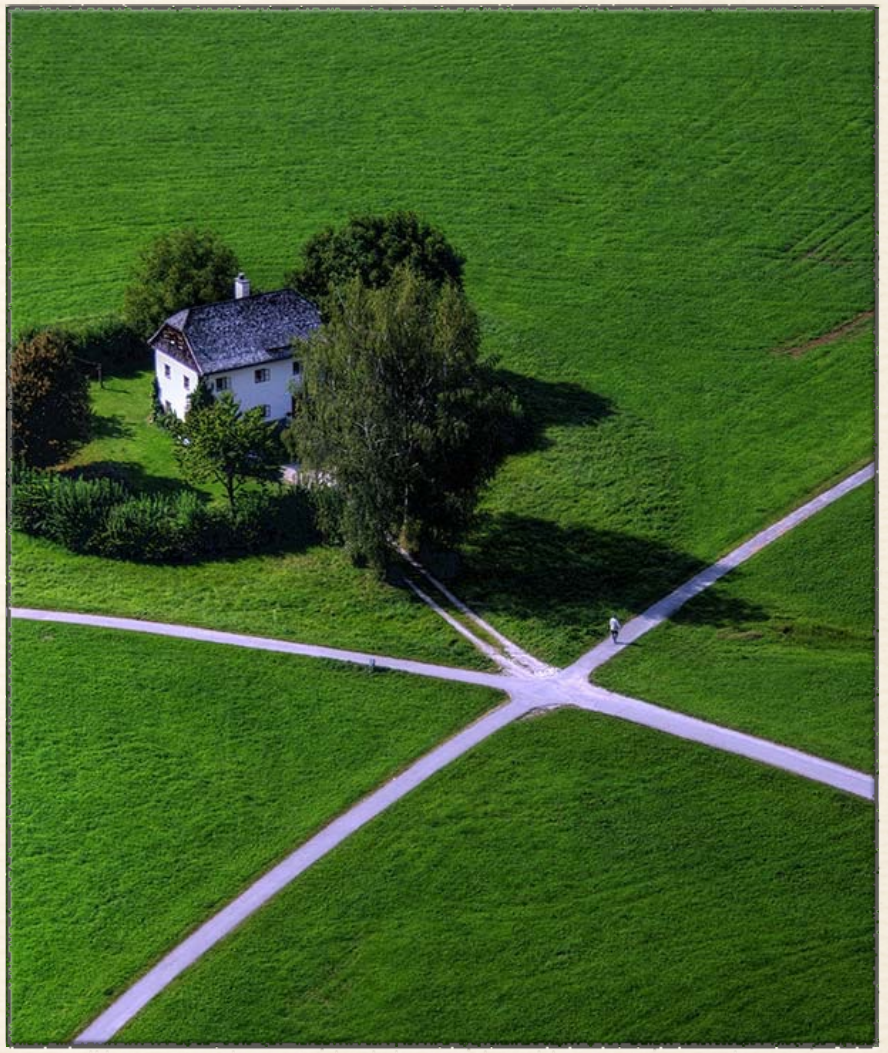
- Fortress: Implicit Parallelism, Strong Types
  - Cool look: like math in both ASCII and Unicode
  - Effort ended in 2012
- X10: Java-like syntax, asynchrony, locales
  - Going strong, a workshop at this conference
- Chapel: You all know this!

Post-HPCS PGAS efforts

- Habenaro C and UPC++ (Rice)
- UPC++ (Berkeley)
- CoArray C++ (Cray, EPCC)
- HPX (C++/11,14, LSU, FAU)
- XcalableMP (Tskuba)
- GASPI (Fraunhofer)

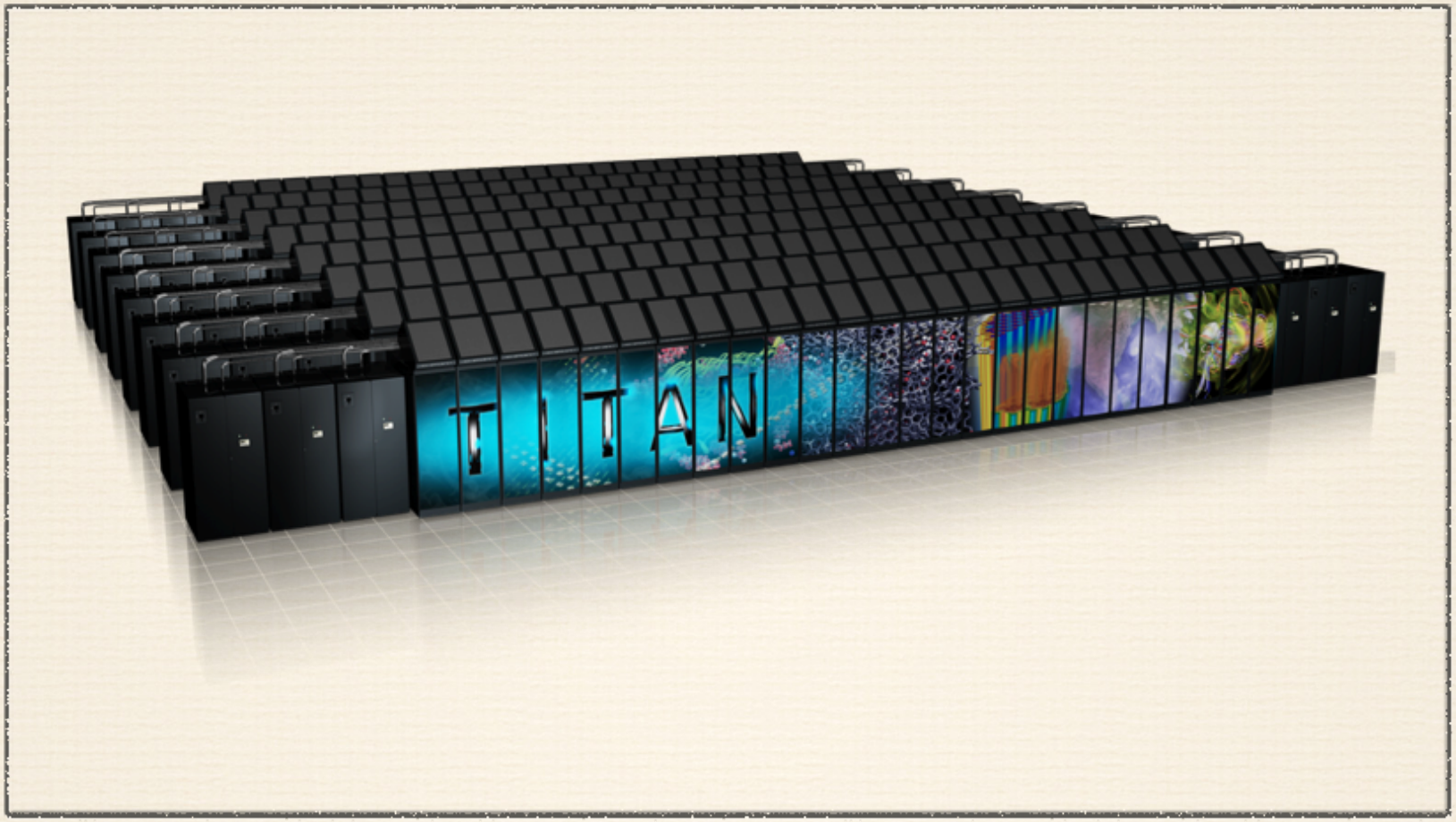
HPC at a Crossroads

- Path to ExaScale is underway
- Market is experiencing growth
- Systems increasingly specialized
  - Driven by ExaScale goals
- Application development is getting harder, not easier



PGAS at a Crossroads

- Many implementations exist of PGAS techniques
- Provide a wealth of programming metaphors
- Performance has been shown to be very good
  - A number of cases which exceed best message passing code
    - Because you have a wider choice of algorithms!
- Programmer “base” is
  - (somewhat) small, and
  - (somewhat) static



Our Problem in 2015

How do we program this? And get good performance? And expand use?

Thought Questions for Today

- Should the programming model be multi-level?
- Will future HPC systems be more complex?
- Can PGAS bring entire new use cases to HPC?
- Should PGAS care about HPC?

Multi-Level Parallelism?

- Hardware is becoming increasingly hierarchical
  - Start with SMP "nodes" in distributed machines
  - Add threads within cores within processors
    - GPUs and other accelerators only add to the mess
- Two distinct issues:
  - What is shared among threads on a "node"? But not globally?
  - What controls the parallel activity on a node?

Multi-Level Parallelism?

- Some programming models urge multi-level
  - SHMEM + pthreads or OpenMP
  - Programmers then write two levels of control flow, one for across nodes, one for on nodes
- UPC supports only local and shared
  - What is the problem with a PGAS thread per thread?
  - An extension was made to allow shared allocation on node

Complexity of Next Gen HPC?

- Strong forces for higher complexity
  - Need to control energy leads to specialization
    - Accelerators like GPUs
    - Small, specialized memories
    - Communication at a distance is always limited by cost
  - ExaScale goals are pushing for large performance gains
- Some trends to lower complexity
  - Many applications can fit “on a node” or small segment of system
  - Communication bound algorithms might ignore complex parts of system

New Uses for HPC/PGAS

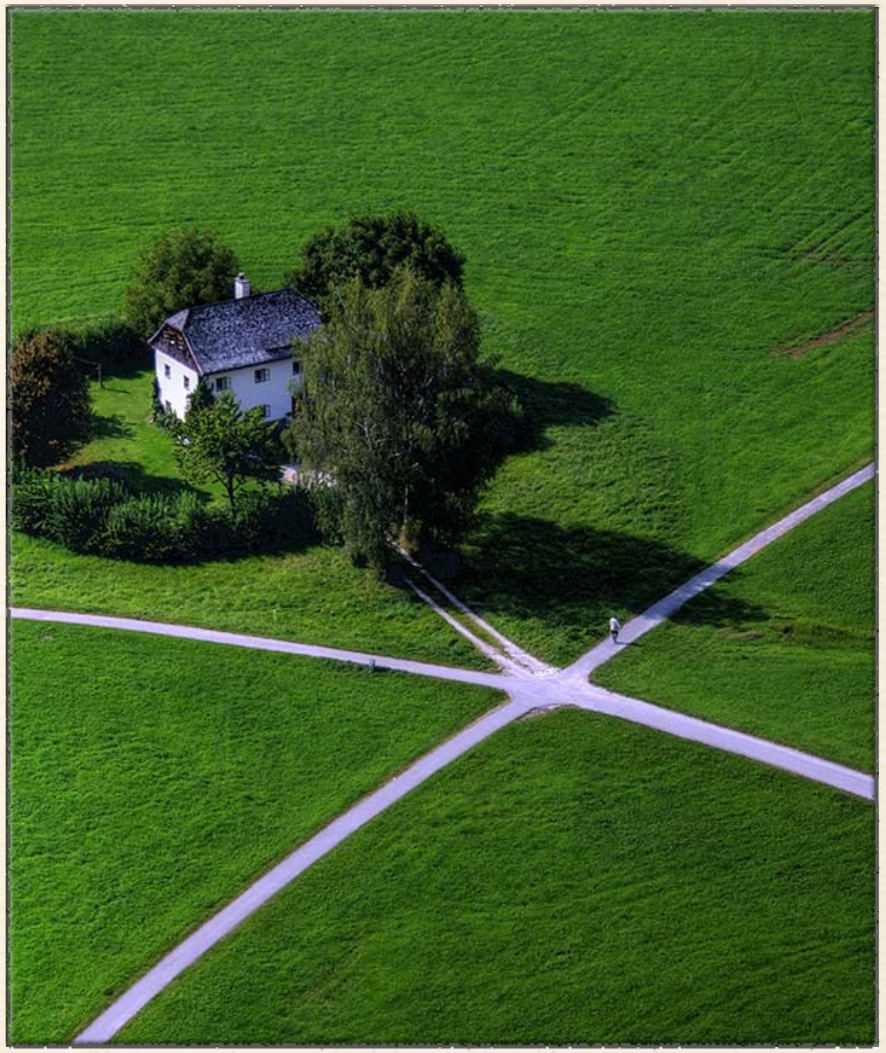
- A lot of emphasis on “Big Data”
  - How about an awesomely fast PGAS key-value store
- Machine “Deep” “learning”
  - Can PGAS allow real advances in this field
- Previously “Abandoned” HPC applications
  - Industrial uses in manufacturing
- My assertions:
  - PGAS languages could help add new application areas
  - All of these areas are not using HPC (much) because it is too hard to get apps on systems

Is “HPC” the only PGAS “market”?

- Mostly yes
  - Pointless to “partition” a tiny system
- But maybe not!
  - No widely-useful model for programing SMP processors
    - Most restricted to concurrency (e.g., go)
  - PGAS could provide a path to scalable apps
  - PGAS can be powerful metaphor in progammer education

PGAS Future?

- Stay the Course?
- Another Unification?
- Another Adaptation?



Path Forward One: Keep Pressing

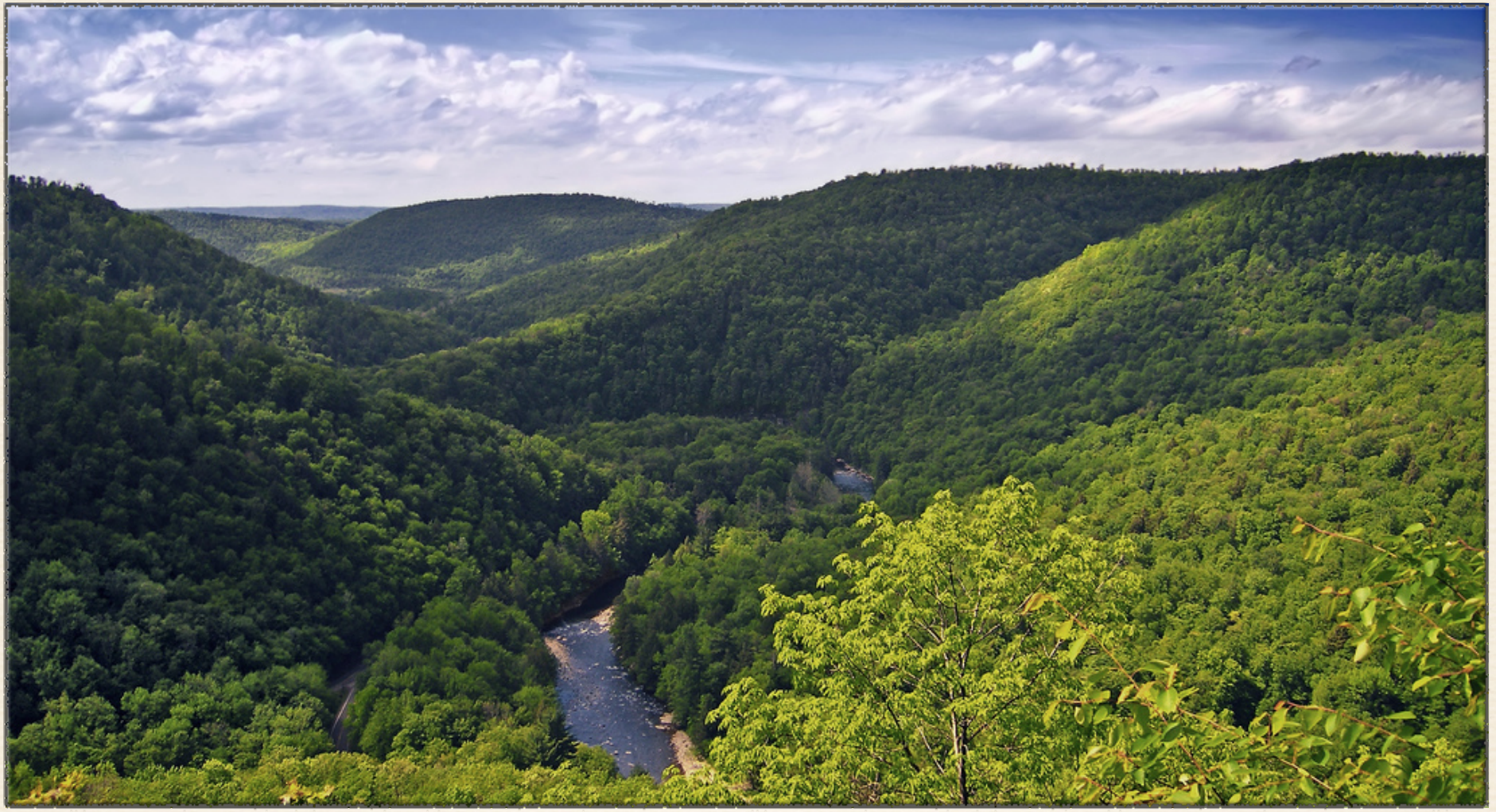
- Our current languages are good!
- Our current programmers are good!
- We are growing friends all the time
- To Do List:
  - Implement github-scale sharing of PGAS utilities
  - Start work on new application areas
  - Develop curriculum

Path Forward Two: New Unification

- UPC took three smaller, locally used languages
  - And made something better than sum of parts
- Many C++ based PGAS efforts are underway
  - And others have been considered as well
  - C++ recently gaining “popularity”
  - Recent changes in C++ standard help
    - Maybe admits a “PGAS class” without language change
- But gaining branding and adoption is always hard

Path Forward Three: New Adaptation

- Python
  - Very popular, including at many HPC centers
  - My view: current parallel classes poor fit for Python
    - Opportunity!
- Go (Google)
  - Already has a concurrency model, can parallel be added?
- Swift (Apple)
  - Will be a huge programmer base due to iPhone
- Any of these (and probably many others) could admit PGAS as a “class”



Future Vistas for PGAS

The fun has only begun

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