EPiGRAM Software for Space Missions

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Outline

• EPIGRAM project
  – Overview
  – Motivation and Integrated Vision
  – Applications

• EPIGRAM Software for Space Physics
  – Implementation.
  – EPIGRAM-enabled magnetosphere simulations and link to space missions.
  – Current work
EPiGRAM Project

STREP project started in Nov 2013
3 years duration
Total budget: 3 051 679 €
Web site: www.epigram-project.eu
Project partners:
• KTH SE (coordinator)
• TUW AT
• FRAUNHOFER DE
• CRAY UK UK
• UEDIN UK
• UIUC USA
EPiGRAM = Exascale Programming Models

Focus on preparing Message-Passing and PGAS programming models for exascale:

- novel concepts and algorithms in programming models with exascale potential. Prototype implementations in MPI and GPI-2 (PGAS library developed by Fraunhofer).

- combine Message-Passing and PGAS for enhanced interoperability and scalability.

- follow and support the standardization process of MPI and GASPI.
Motivation - Programming Models for Exascale

• MPI is the dominant programming system in applications at Petascale.
• MPI is at the base of many novel programming and runtime systems for internode communication.
• Some MPI “limitations”:
  – Collective bottleneck and not optimized to absorb imbalance.
  – MPI RMA (feature we need to use at exascale) not adopted by application community.
  – MPI RMA high performance might need enhanced synchronization (notified access).
• PGAS and in particular GPI-2 make RMA easy to be used and provide HP RMA synchronization.
• Both MP and PGAS ready to be tuned for exascale that is coming in 2020!
EPiGRAM Integrated Vision

MPI:
- Persistent Collectives
- Neighborhood collectives

GPI-2
- Fast RDMA
- Fault-tolerance

PGAS-based MPI

MPI endpoints

GPI-2 Isolation of library

EMPI4RE
EPiGRAM MPI for RESEARCH
EPiGRAM Applications

• The new concepts and software are tested in the communication kernel of two-real world applications:
  – iPIC3D for space physics, C++ particle-based code, 20,000 LOC
  – Nek5000 CFD code, Fortran77 semi-spectral code, 70,000 LOC

• EPiGRAM application forum: set of 12 applications we present EPiGRAM results to in ad-hoc workshops.
Space Physics

• It studies of the physical phenomena occurring during the interaction of solar wind and Earth magnetosphere.

• **Science question:**
  – What is the Aristotele’s Unmoved Mover that drives plasma flows in space? Magnetic reconnection, turbulence?

• **Technological key issue:**
  – Can we predict solar storms and violent event in space to protect our satellites and astronauts in space?
EPiGRAM for Space Physics

- We analyzed the performance of the communication kernel in iPIC3D
- We redeveloped the communication kernel of the iPIC3D code:
  - All non-blocking P2P MPI
  - Use of MPI derived data-types.
  - Use of GPI-2 mixed with MPI.
- We developed parallel I/O based on MPI I/O.
- Overall improvement of performance → EPiGRAM allowed to carry out first realistic large scale particle simulations of magnetospheres.
EPiGRAM-enabled Simulations
EPiGRAM enabled-simulations

EPiGRAM results are/will be used:
- in preparation of the NASA MMS mission to study magnetic reconnection
- ESA Thor proposed mission to study turbulence close to bow Shock
Impact of Simulations on Space Missions

• Simulations are used to have the” big picture” as spacecraft provides only a set of quantities at a given point at a certain time.

• Simulations are used to identify possible signatures of important intermittent phenomena.

• Simulation of spacecraft charging and damage.
Current Work

- The iPIC3D code has been coupled to other codes within the SWMF framework [http://csem.engin.umich.edu/tools/swmf/](http://csem.engin.umich.edu/tools/swmf/) to allow for large scale simulation in realistic set-up (coupling with inner magnetosphere/ ionosphere).

- Simulation of Earth’s magnetosphere requires multi-physics simulations.

- The code coupling is via Message-Passing.

- Studying best strategies for allocating and scheduling resources for the multi-physics framework.
Conclusions

• EPIGRAM focuses on MPI + PGAS for exascale:
  – Improve MP and PGAS.
  – Combine their best features.
  – Prepare a PGAS-based MPI.

• Impact on space physics applications
  – We improved iPIC3D by redesigning its communication kernel and I/O
  – We carried out large-scale simulation to support science of space mission
  – Focus on coupling scheduling for different codes in the same framework by Message Passing.