# Massively Parallel Fine-Grained MPFG) Computing Task

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# Major Elements

- NIM Performance & Portability

  "Parallelization and Performance of the NIM Weather Model for CPU, GPU and MIC Processors"

  Govett, Rosinski, Middlecoff, Henderson, Lee, MacDonald, Madden, Schramm, and Duarte

  - Submitted to BAMS for review
- MPFG Procurement
  - Initial delivery in May / June
- GFS parallelization
- NGGPS work

ESRL
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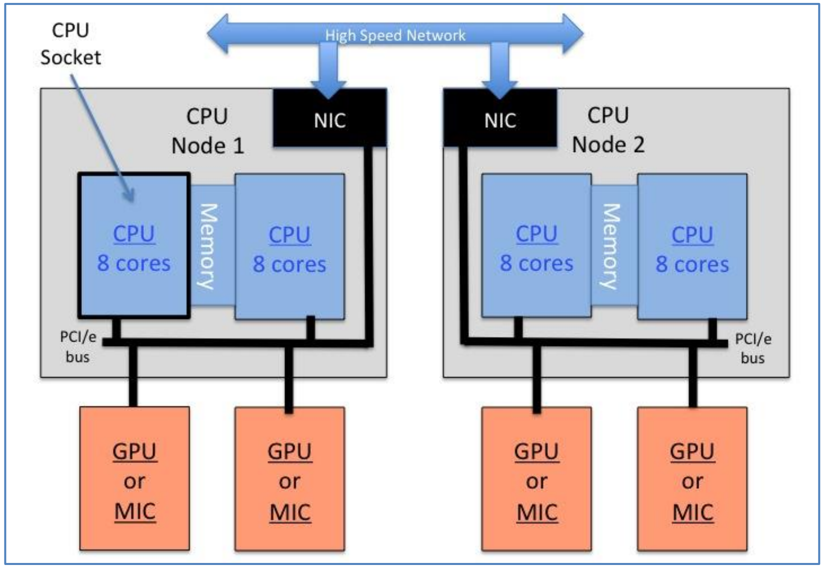
# Survey of Work on MIC, GPU

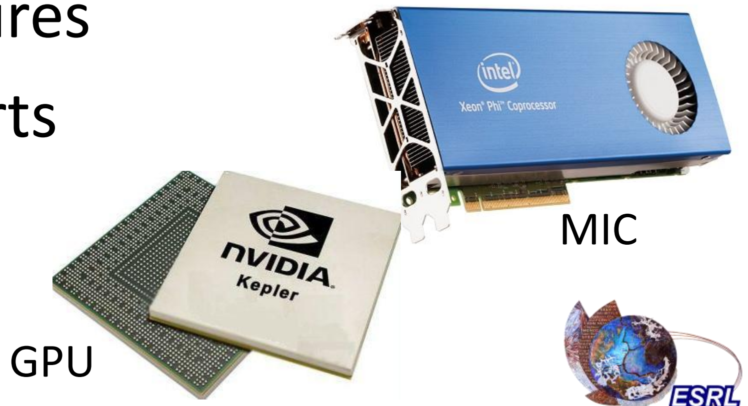
- Models: COSMO, ICON, CAM-SE, FV3, NICAM, GEOS-5, Gungho, FIM, NIM
- MIC
  - Trivial to port codes to the MIC
  - Performance results slower than CPU
- GPU
  - Challenging to port codes
  - ~2X faster than dual socket CPU

# Performance Comparisons

- Results in presentations & literature inconsistent
  - Core, socket, node
  - Different code used
  - Optimized for 1 architecture
  - Different generation chips

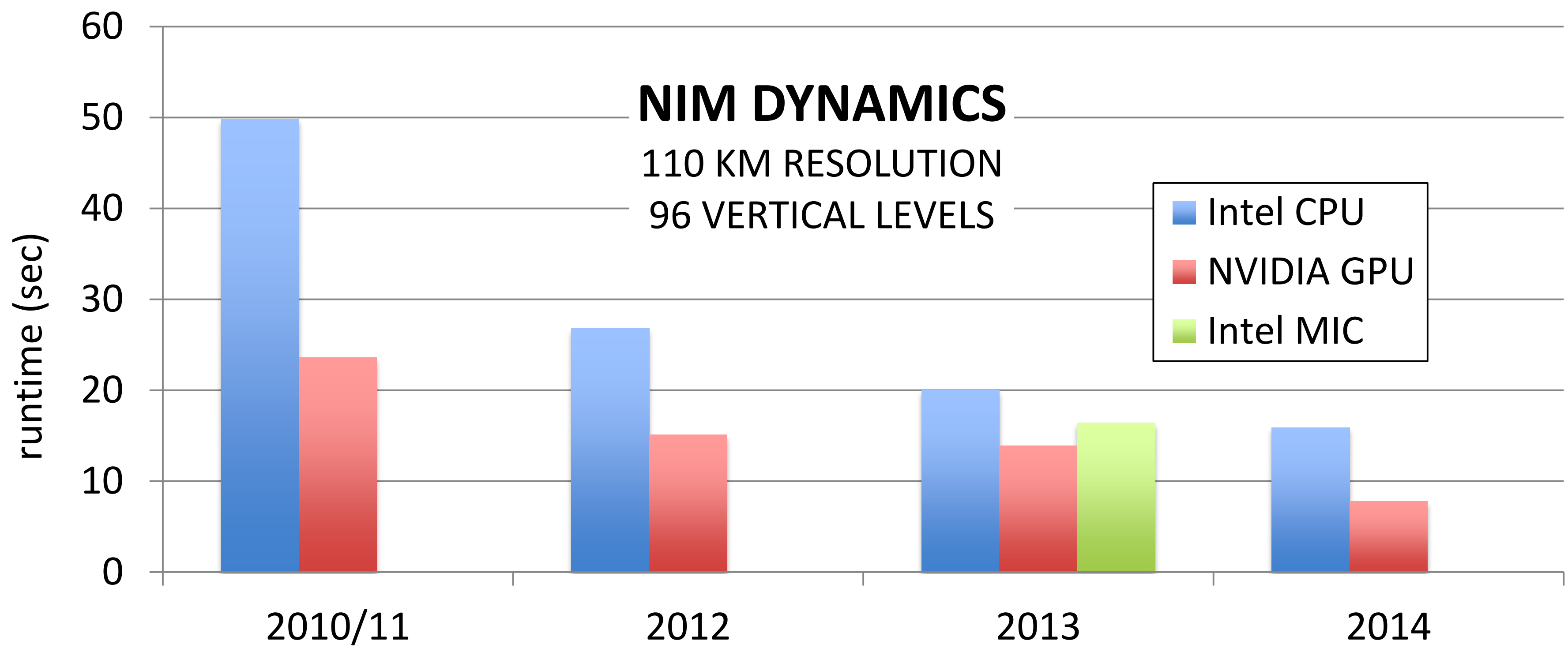



- NIM comparisons
  - Same source code
  - Optimized code for all architectures
  - Use of standard high-volume parts
  - Device, node & multi-node
  - Cost benefit analysis



# NIM Performance: Single Device

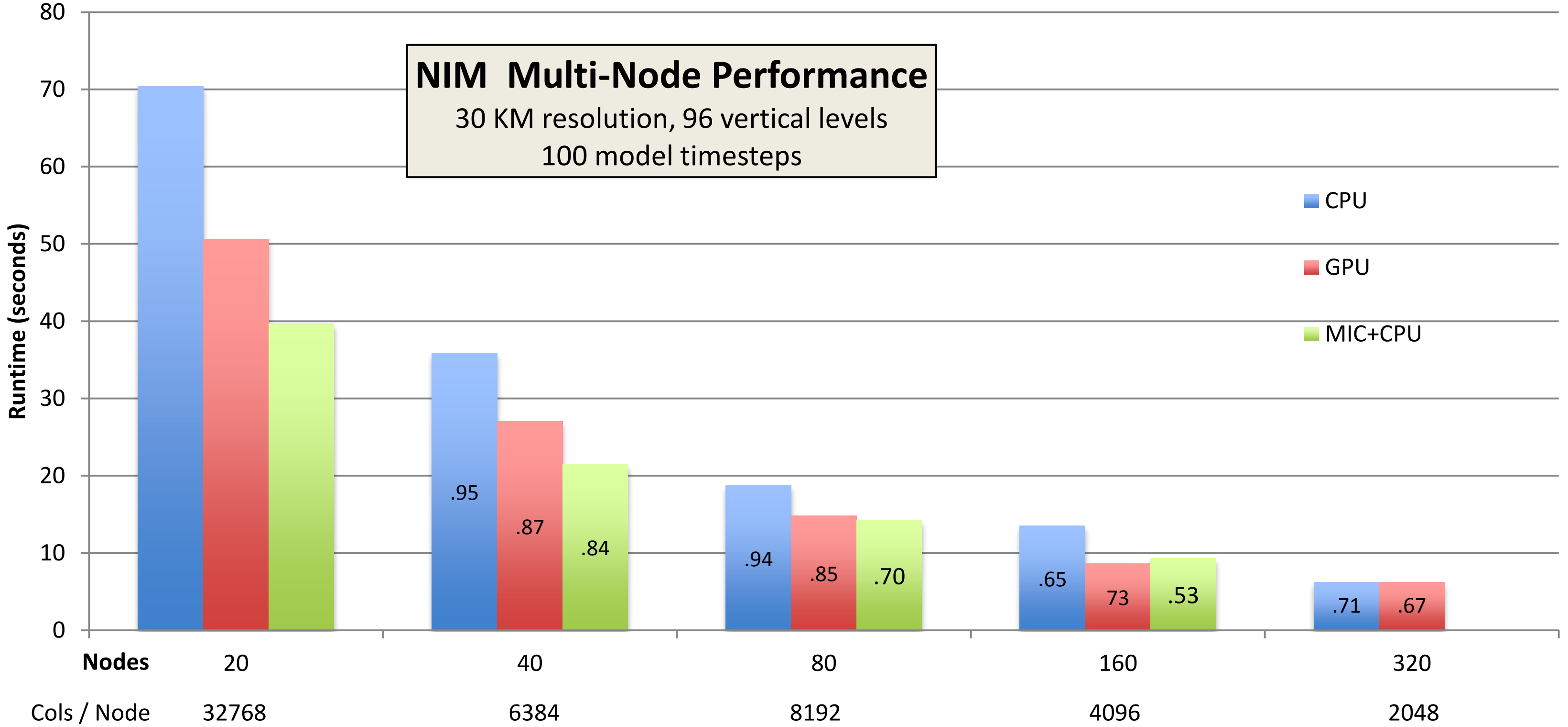
## GPU, MIC versus dual socket CPU




| Year | CPU (cores) | GPU (cores) | MIC (cores) |
|---|---|---|---|
| 2010/11 | Westmere (12) | Fermi (448) | |
| 2012 | SandyBridge (16) | Kepler K20x (2688) | |
| 2013 | IvyBridge (20) | Kepler K40 (2880) | Knights Corner (61) |
| 2014 | Haswell (24) | Kepler K80 (4992) | |

# Strong Scaling Performance

- CPU, GPU, MIC+CPU
- Decreasing efficiency when less work to do



# NIM Performance

- Useful for comparing technologies
- Led to strong collaborations
  - Improved compilers, hardware, libraries
- 11% of peak perf on CPU (SandyBridge)

- Vendors are telling us the NIM:
  - - *"has the best thread scaling on the MIC of any weather or climate application" (Intel)*
  - - *"is the only weather or climate model where we can make comparisons between CPU, GPU and MIC architectures" (NVIDIA, Intel)*
  - - *"is the best weather model we've seen on the GPU" (NVIDIA)*

# NIM Dynamical Core

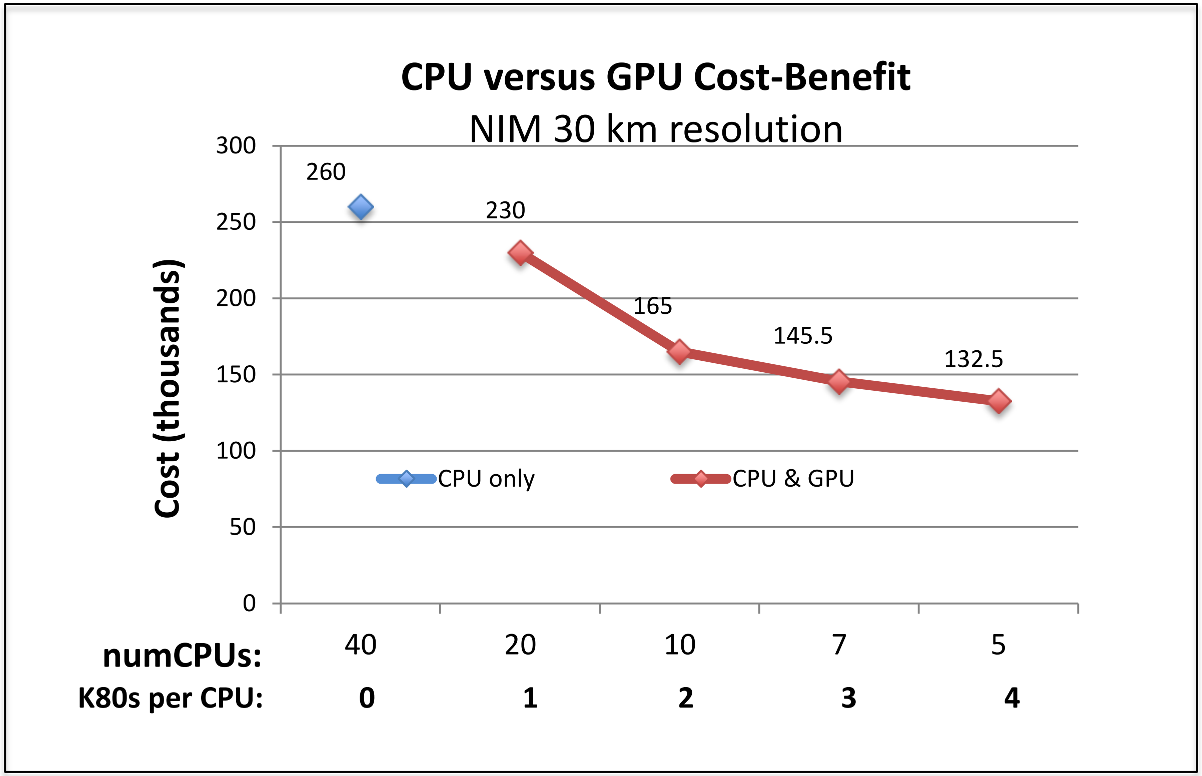
- Designed for fine-grain computing (2008)
  - Uniform Icosahedral grid
  - Minimize branching, maximize parallelism
- Single source code (~5K lines of Fortran)
- Performance portable
  - Directives for parallelization
    - CPU, MIC OpenMP
    - GPU OpenACC, F2C-ACC
    - SMS MPI-based parallelization
- Run on 130K CPU cores (Edison), 10K GPUs (Titan), 600 MIC (Stampede)

# CPU – GPU Cost-Benefit

- NIM Dynamics only
- Different CPUs and GPU configurations
  - 40 Haswell CPUs, 20 K80 GPUs
  - incorporate off-node MPI communications
- All runs executed in the same time
  - Meets a 1% operational time constraint for a 3KM resolution model
  - 20K columns / GPU used which equates to 95% GPU efficiency

# CPU-GPU Cost-Benefit

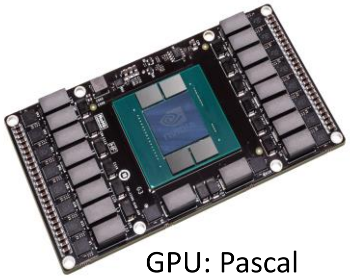
- Limitations
  - Use of list price (K80: $5000, Haswell $6500) is naïve
  - Based on NIM dynamics only
    - Adding physics would lower GPU cost-benefit
  - Did not consider cost of system inter-connect, energy use



# Next Generation Chips

- New hardware, better compilers in 2016 should improve programmability and performance
  - 3 - 5X faster memory for GPU & MIC
    - MIC Knights Landing:  Hostless processor
    - GPU, NVIDIA Pascal: Unified memory
  - Improvements to OpenACC compilers
    - Performance & capabilities

MIC: KNL


GPU: Pascal

# MPFG Parallelization of GFS Physics

- Initial work focused on porting to MIC
- Trivial to port using OpenMP directives
  - Tailored to FIM with icosahedral grid
  - Column-based thread parallelism
    - Eg. micro-physics, radiation routines
- Performance: *Rosinski 2015, NCAR Multi-core Workshop*
  - MIC+CPU is ~20% faster than the CPU
  - MIC only is 40% slower than CPU (SNB)
  - Optimizations targeting MIC, gave benefit on CPU
- Future work
  - Port to GPU
  - Further MIC optimizations
    - Push I loop into column routines if not there already

# NGGPS Work

- FV3 & MPAS optimizations targeting CPU performance
  - 2X performance improvement for MPAS
  - ~10% improvement for FV3
- Current focus on MIC, GPU
  - FV3 initial results
    - MIC is 50% slower than CPU (SNB)
    - NVIDIA tests show GPU is significantly slower than CPU
  - No baseline results for MPAS yet
- Develop standalone tests to determine what changes are needed to improve performance
  - NIM results are considered a high-water mark
    - ~2X faster on GPU, 1.3X faster on MIC

# Questions?

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