- **Project Information**

    - Reducing jet aircraft noise by harnessing the heterogeneous XK nodes on Blue Waters
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- **Executive summary (150 words)**

Jet engine exhaust noise caused by military and commercial aircraft is an unwanted byproduct that negatively impacts the quality of life for residents living near airports and creates operational challenges and risks for carrier-borne personnel. Without effective reduced-order models that connect jet engine designs to the noise they create, large scale simulations are required to predict jet engine exhaust noise and develop noise-reducing designs. The computational demands of jet exhaust noise predictions are beyond current petascale systems so we are developing the tools needed for a computational fluid dynamics code to utilize heterogeneous architectures envisioned for future exascale systems.

- **Description of research activities and results**

Key Challenges: Developing quieter jet engines that achieve the same aerodynamic performance (thrust and fuel consumption) requires detailed knowledge of how the engine design impacts the sound-generating motion of the exhaust gases. Unfortunately, no applicable reduced-order theory exists that accurately connects the design to the sound. Instead, experimentation or numerical predictions are required. The fundamental problem that must be overcome is predicting the generation of sound by a compressible, viscous fluid in turbulent motion.

Why it Matters: The computational demands of simulating turbulence required for accurate jet noise predictions exceeds current computational capacity. An MPI-only expression of the parallelism in our computational fluid dynamics (CFD) code *PlasComCM* performs well on existing homogeneous petascale computers, such as Blue Water's XE nodes, but cannot leverage the compute capability contained in the XK nodes nor on the half of the projected CORAL-procured exascale machines under development by the Department of Energy (see figure). Machines like Sierra are expected to be comprised of IBM Power 9 CPUs with limited double precision capability that will manage one or more NVIDIA GPGPUs connected by NVLINK that will perform most of the double precision arithmetic.

Why Blue Waters: Blue Waters' XK7 nodes are a surrogate for the expected heterogeneity and this project seeks to develop the software tools required to transform an existing MPI-only CFD code into one that take advantage of on-node heterogeneity. Our approach has two parts. In the first part we are generalizing our parallelism into an MPI+OpenMP 4.X framework where the newly-supported OpenMP task parallelism will be leveraged to asynchronously schedule the work to be done on nodes with significant compute capability accessible by OpenMP (such as Intel and AMD sockets and the Knights' Landing implementation of the Intel Xeon Phi).

Accomplishments: In the second part of our approach, we wish to develop software tools to transform the computational kernels expressed in Fortran into higher-level abstractions that can then utilize the attached accelerators. In collaboration with Professor Wen-mei Hwu in the University of Illinois Electrical and Computer Engineering Department, we developed a complier infrastructure (H-MxPA) that could take a CFD kernel written in OpenCL and asynchronously execute it on NVIDIA GPGPUs as well as on the host CPU, providing significant flexibility. When executed on XK7 nodes on Blue Waters the tool was able to individually utilize the AMD socket, the NVIDIA K20, as well as use them in parallel with measurable speed-up.

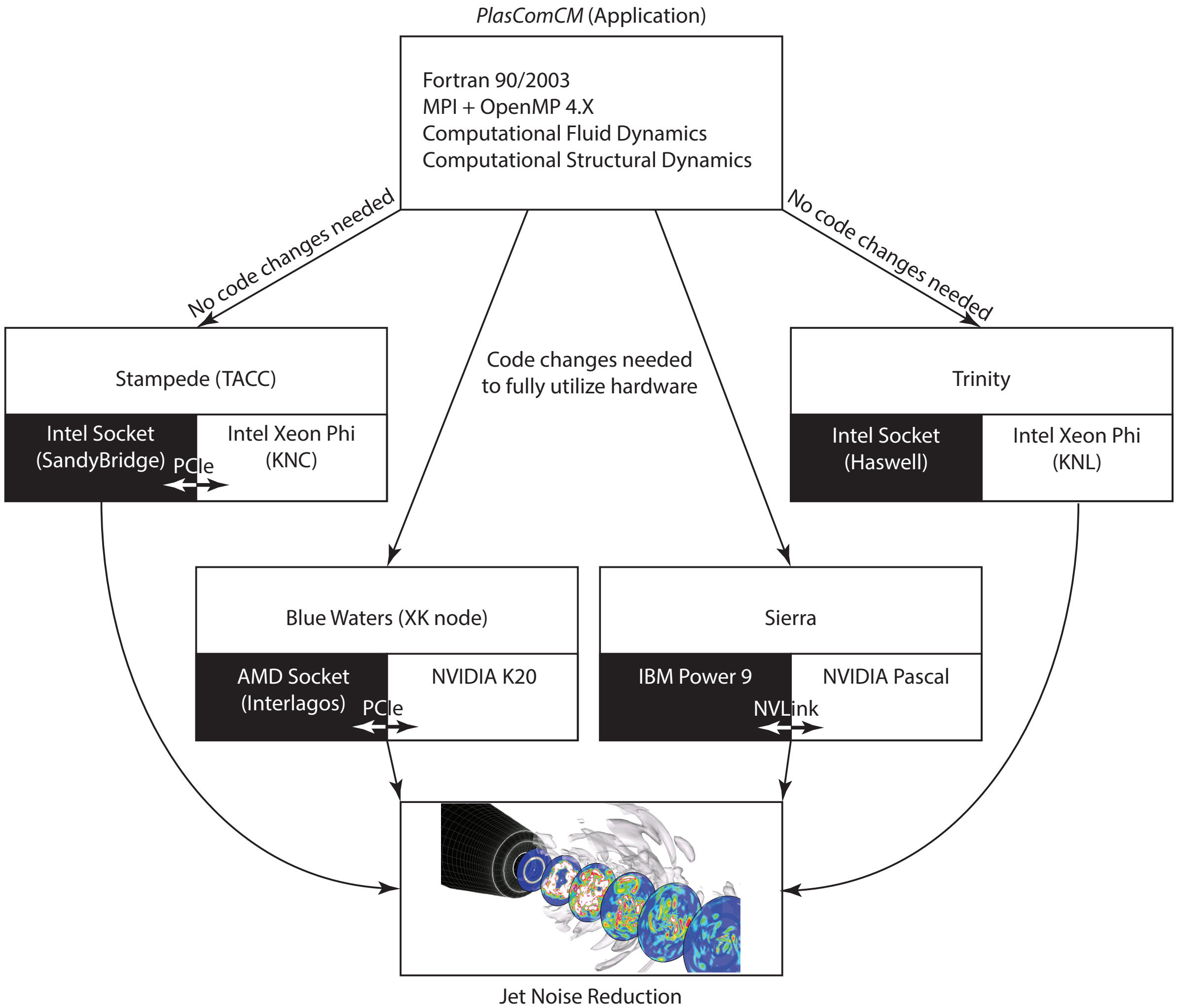
However, the PCIe bus limitations made ensuring memory coherency reduce the tool's effectiveness. On Sierra, however, the IBM-NVIDIA nodes are expected to have hardware-maintained cache coherency over NVLink that eliminates the need to manage the memory in software, thus removing our performance bottleneck.

- **List of publications and presentations associated with this work**

  ECSS Experience: Performance of a CFD Code Running on Stampede's Intel Xeon Phi in Symmetric Mode, by W. Zhang, D. J. Bodony, J. Larson, and L. Wilson, poster presented at XSEDE'15 in St. Louis, Missouri.

- **Plan for next year**

  A new runtime system is being developed that better handles the host-device cache coherency is being developed based on the HCC compiler. When integrated into the *PlasComCM*-H-MxPA tool chain we expect to have a performant, cross-platform compilation strategy that can seamless utilize the XE and XK nodes of Blue Waters. The tool will be tested on jet noise prediction simulations for which we anticipate needing 400,000 XK nodes hours for 2016-2017 and will split that between the four quarters as Q1: 20%, Q2: 20%, Q3: 45%, Q4: 45%. Our storage needs will be 500 TB for the entire year.


PlasComCM (Application)
Fortran 90/2003
MPI + OpenMP 4.X
Computational Fluid Dynamics
Computational Structural Dynamics
No code changes needed
No code changes needed
Code changes needed
to fully utilize hardware
Stampede (TACC)
Intel Socket
(SandyBridge)
Intel Xeon Phi
(KNC)
PCIe
Trinity
Intel Socket
(Haswell)
Intel Xeon Phi
(KNL)
Blue Waters (XK node)
AMD Socket
(Interlagos)
NVIDIA K20
PCIe
Sierra
IBM Power 9
NVIDIA Pascal
NVLink
Jet Noise Reduction