ClearSpeed

The Method Moments: The Perfect ClearSpeed Application

ClearSpeed Technology plc

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

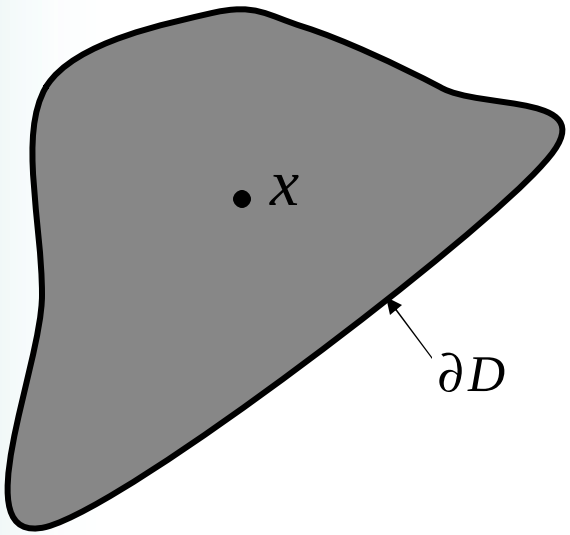
ClearSpeed

What is the Method of Moments?

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Solution on the boundary is sufficient



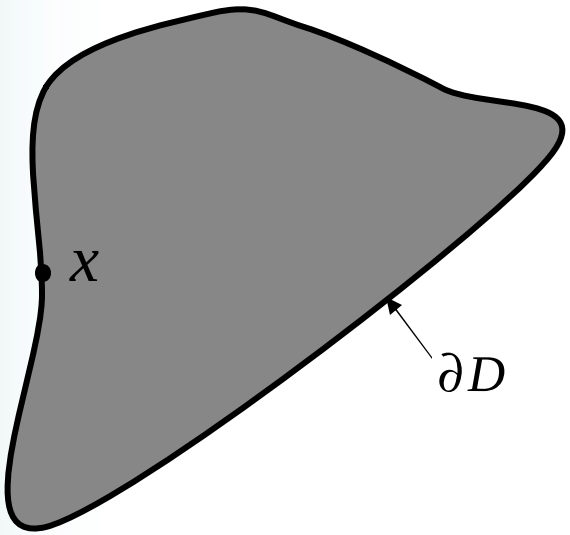
- **The field (F) at any point can be calculated from**
  - the field on the boundary (F)
  - the gradient of the field normal to the boundary ($\frac{\partial F}{\partial n}$)
  - a Green's function (G).

$$F(x) + \int_{\partial D} F \frac{\partial G}{\partial n} ds = \int_{\partial D} G \frac{\partial F}{\partial n} ds$$

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Also works for boundary points



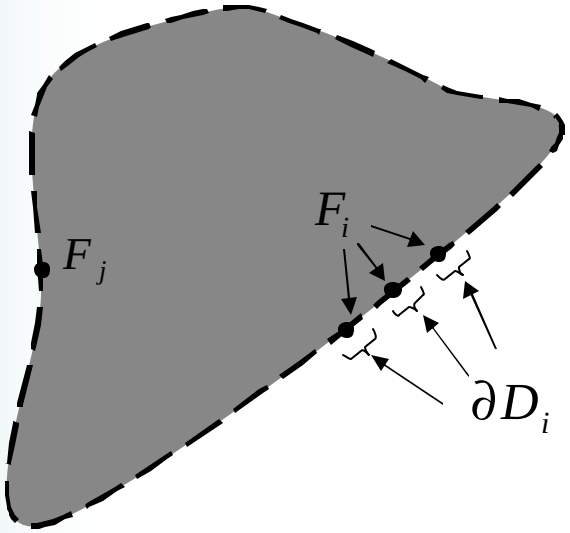
- **Small change to formula**

$$\frac{1}{2}F(x)+\int_{\partial D}F\frac{\partial G}{\partial n}ds=\int_{\partial D}G\frac{\partial F}{\partial n}ds$$

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Discrete version for computation



- **Divide the boundary into *m* elements**

$$\frac{1}{2}F_j + \sum_{i=1}^{m} \int_{\partial D_i} F_i \frac{\partial G_j}{\partial n_i} ds_i = \sum_{i=1}^{m} \int_{\partial D_i} G_j \frac{\partial F_i}{\partial n_i} ds_i$$

$$j = 1 \cdots m$$

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Matrix formulation

- **Rewrite as matrix of equations (four equations in this example)**

$$\begin{bmatrix} \int_{\partial D_1} \frac{\partial G_1}{\partial n} ds + \frac{1}{2} & \int_{\partial D_1} \frac{\partial G_1}{\partial n} ds & \int_{\partial D_1} \frac{\partial G_1}{\partial n} ds & \int_{\partial D_1} \frac{\partial G_1}{\partial n} ds \\ \int_{\partial D_2} \frac{\partial G_2}{\partial n} ds & \int_{\partial D_2} \frac{\partial G_2}{\partial n} ds + \frac{1}{2} & \int_{\partial D_2} \frac{\partial G_2}{\partial n} ds & \int_{\partial D_2} \frac{\partial G_2}{\partial n} ds \\ \int_{\partial D_3} \frac{\partial G_3}{\partial n} ds & \int_{\partial D_3} \frac{\partial G_3}{\partial n} ds & \int_{\partial D_3} \frac{\partial G_3}{\partial n} ds + \frac{1}{2} & \int_{\partial D_3} \frac{\partial G_3}{\partial n} ds \\ \int_{\partial D_4} \frac{\partial G_4}{\partial n} ds & \int_{\partial D_4} \frac{\partial G_4}{\partial n} ds & \int_{\partial D_4} \frac{\partial G_4}{\partial n} ds & \int_{\partial D_4} \frac{\partial G_4}{\partial n} ds + \frac{1}{2} \end{bmatrix} \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{bmatrix} = \begin{bmatrix} \int_{\partial D_1} G_1 ds & \int_{\partial D_1} G_1 ds & \int_{\partial D_1} G_1 ds & \int_{\partial D_1} G_1 ds \\ \int_{\partial D_2} G_2 ds & \int_{\partial D_2} G_2 ds & \int_{\partial D_2} G_2 ds & \int_{\partial D_2} G_2 ds \\ \int_{\partial D_3} G_3 ds & \int_{\partial D_3} G_3 ds & \int_{\partial D_3} G_3 ds & \int_{\partial D_3} G_3 ds \\ \int_{\partial D_4} G_4 ds & \int_{\partial D_4} G_4 ds & \int_{\partial D_4} G_4 ds & \int_{\partial D_4} G_4 ds \end{bmatrix} \begin{bmatrix} dF_1 \\ dF_2 \\ dF_3 \\ dF_4 \end{bmatrix}$$

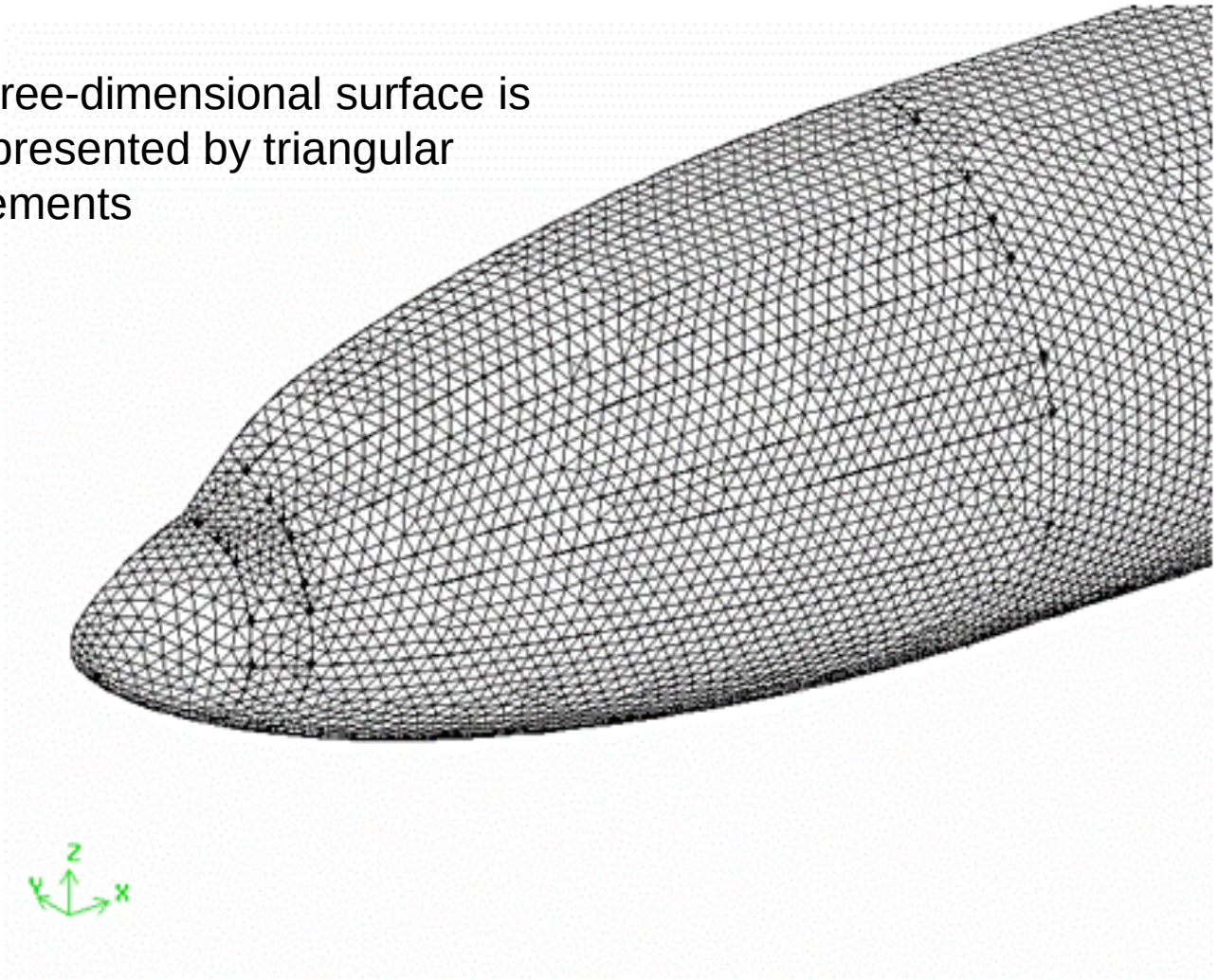
- **Evaluate coefficients and solve set of linear equations**

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Three-dimensional version

Three-dimensional surface is represented by triangular elements



Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

The Method of Moments for Computational Electromagnetics

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

Radar cross-section

Lockheed
F-117A Nighthawk

Northrop Grumman
B-2 Spirit

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Antenna design

Helical antenna

Short-wave transmitter

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Algorithm for solving Maxwell's equations

- **Build triangular mesh representation of geometry of target**
- **Calculate coefficients of equations using numerical integration**
  $O(n^2)$ **operations**
- **Perform LU-decomposition of matrix**
  $O(n^3)$ **operations**
- **Back-substitution with multiple right-hand sides**
  $O(n^2)$ **operations**
- **Overall computation dominated by LU-decomposition — can be weeks of computation**

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

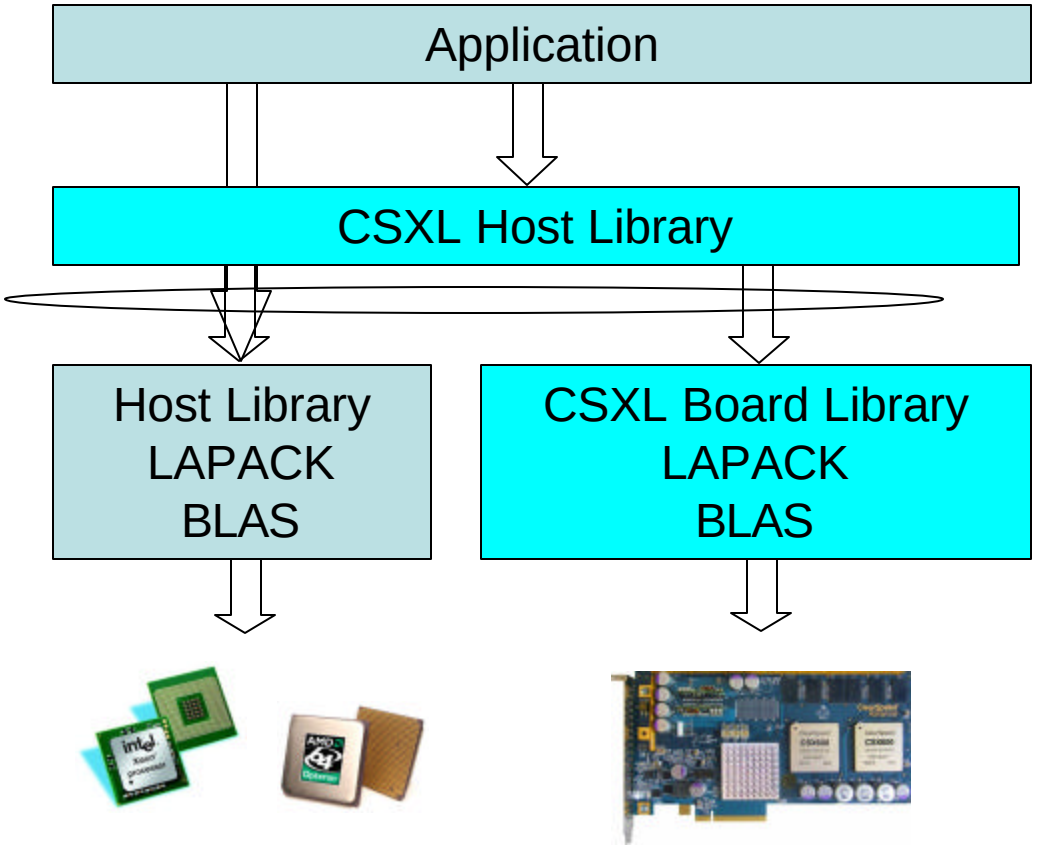
How to Accelerate the Method of Moments

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Plug and play acceleration with libraries

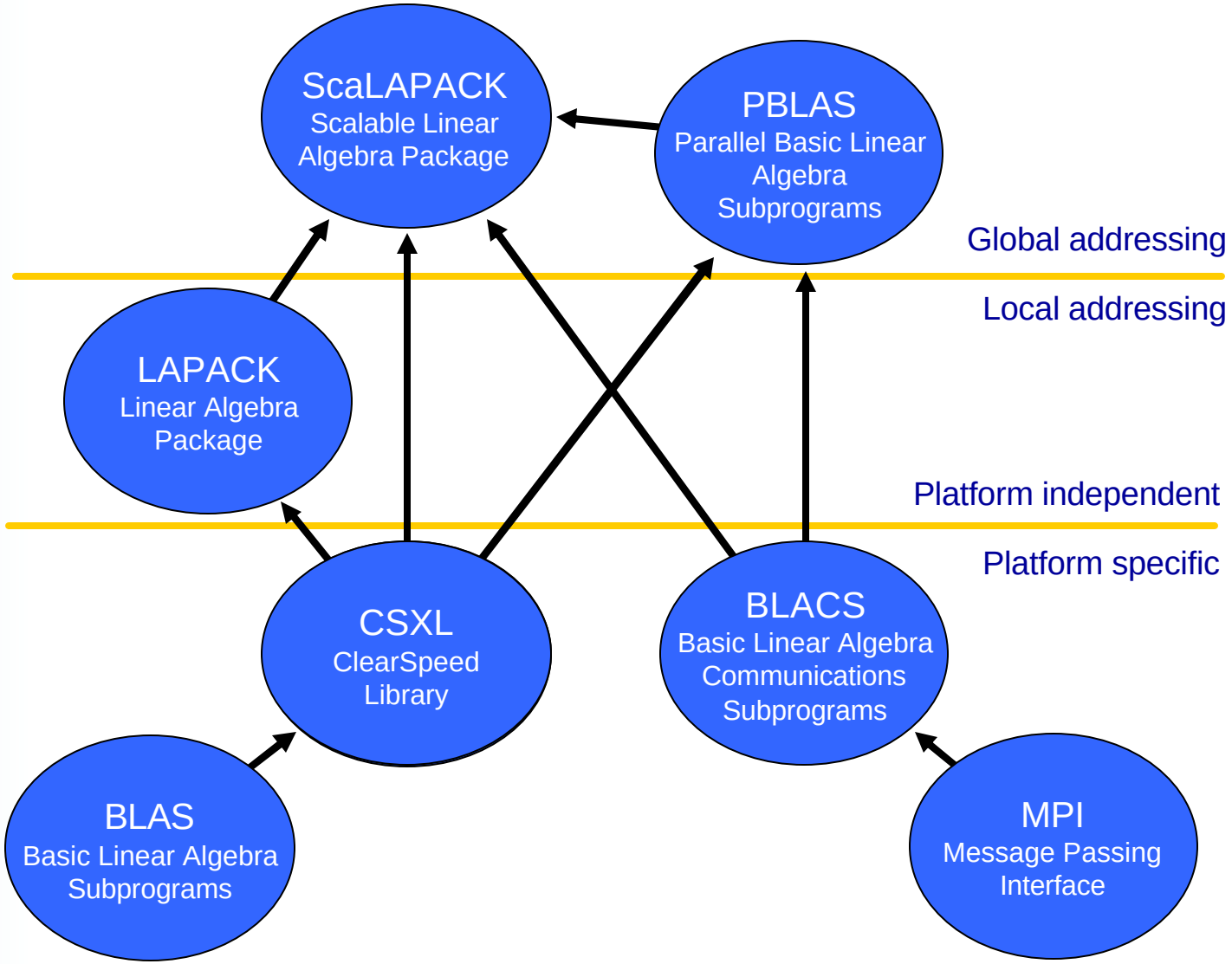
Automatically select optimum path



Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Linear algebra software stack



Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

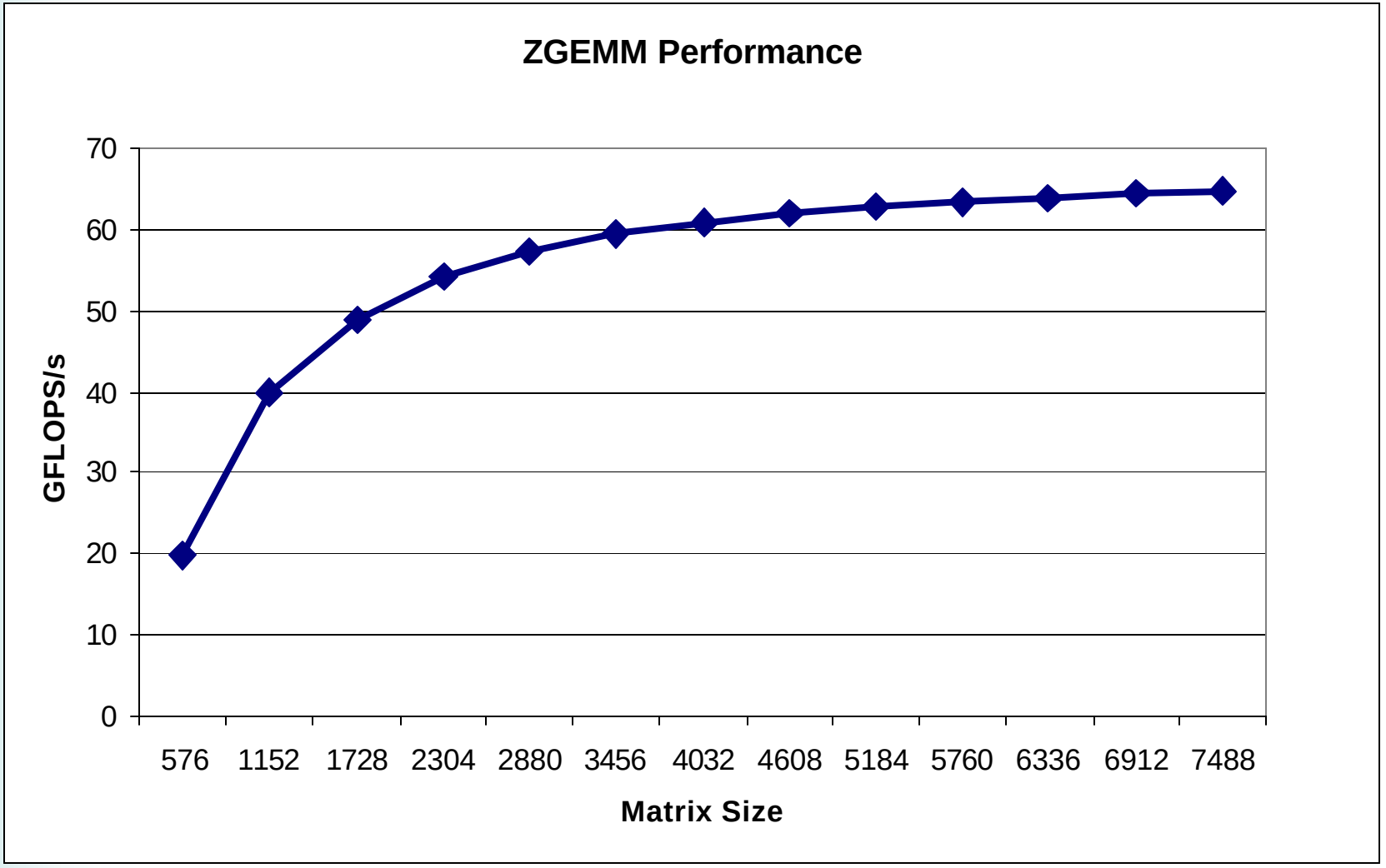
ClearSpeed

How Much Acceleration?

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

ZGEMM performance



Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

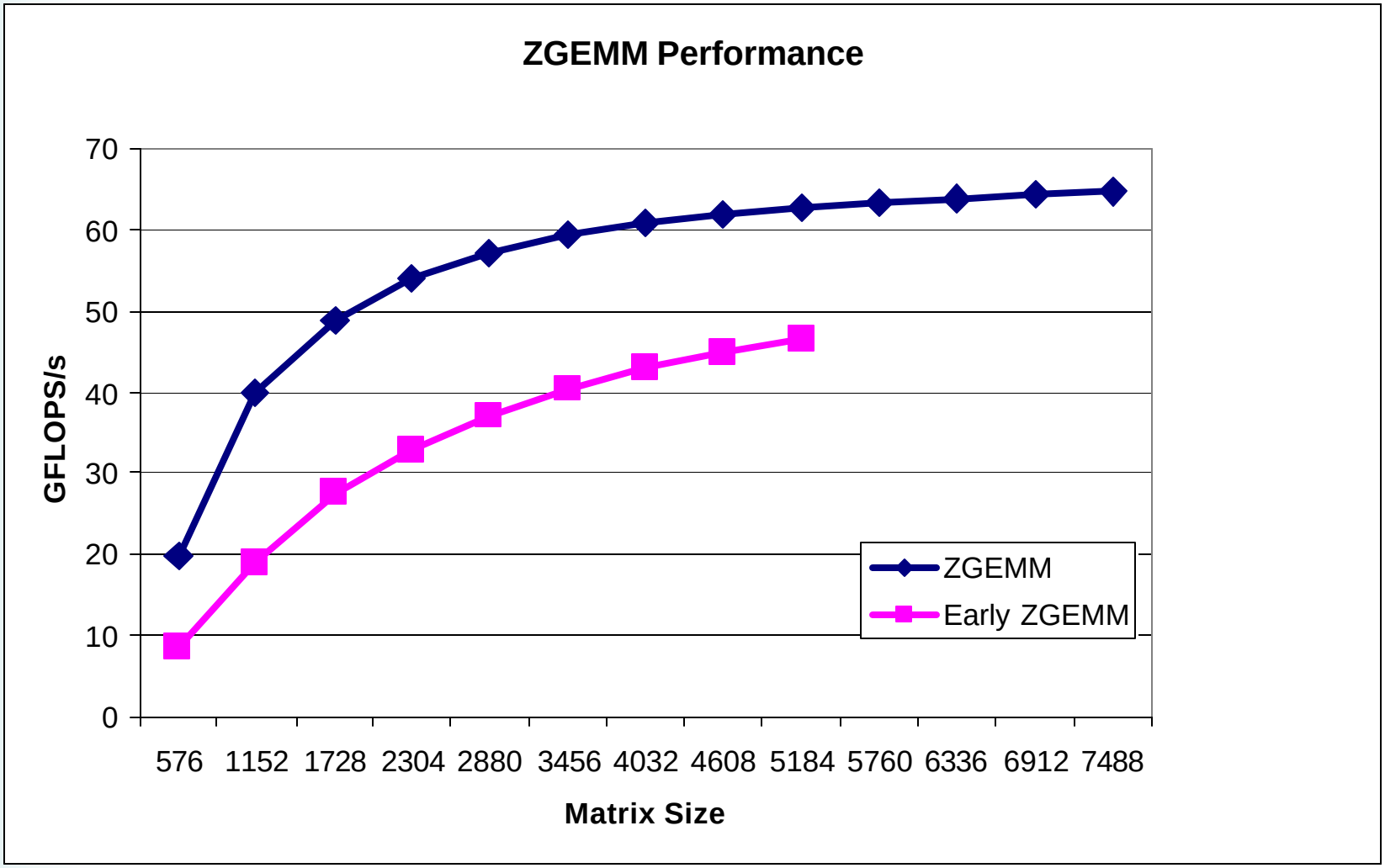
ClearSpeed

Complete linear solver implementation

- **Host system**
  - Intel Xeon quad-core *Clovertown*, 2 GHz clock frequency
    Only one core used for these tests
  - 16 Gbytes memory
- **Accelerator**
  - ClearSpeed Advance e620
- **Software stack**
  - ScaLAPACK, PBLAS, BLACS from Netlib
  - LAPACK, BLAS from AMD Core Math Library (ACML)
  - MPI from MPICH or MVAPICH
  - Fortran and C compilers from Intel
  - Early implementation of ClearSpeed ZGEMM with reduced performance

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

Early ZGEMM performance



Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Problem definition and performance

	Host	Accelerator
Number of equations	15552	15552
Block size	256	576
% time spent in ZGEMM	92%	65%
Run time	1998 seconds	889 seconds

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.

ClearSpeed

Further improvements

- Host and accelerator together
- Improved ZGEMM
- Multi-core host and multiple accelerators
- ClearSpeed Advance e710 accelerator

Copyright © 2008 ClearSpeed Technology plc. All rights reserved.


ClearSpeed™