

CAPTools Project: Evaluation and Application of the Computer Aided Parallelization Tools

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Outline

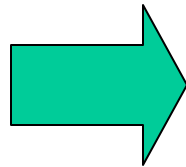
- **CAPTtools overview**
- **Applications**
- **Summary of results**
- **Recommendations**

What is CAPTools?

A software environment to transform Fortran source code from scalar to parallel source form with message passing MPI or OpenMP directives in an interactive semi-automatic way

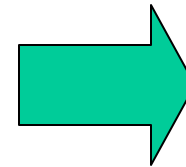
INPUT

**Fortran77
code**



CAPTools

**Transformation
to parallel code**



OUTPUT

**Fortran77
+ MPI calls**

OR

**+ OpenMP
Directives³**

Main components

- **State-of-the-art interprocedural dependence analysis techniques**
- **In depth analysis using symbolic algebra methods**
- **User supplied knowledge to assist parallelization**
- **GUI interactive front end**
- **Automatic user directed array partitioning**
- **Automatic parallel source code generation**

Input codes

- **Fortran 77 (Fortran 90/95 in development)**
- **Multiple program files**
- **Include statements**
- **Conditional compilation directives should be preprocessed**

Design

**CAPTools generated
parallel source code**

CAPLib API

MPI

PVM

**Cray
SHMEM**

**Transtech
i860toolset**

Steps

- **Load Fortran 77 code**
- **Volunteer knowledge to the system**
- **Perform dependence analysis**

Steps (cont.)

- **Partition the data**
- **Generate control masks**
- **Generate communication calls**

Steps (cont.)

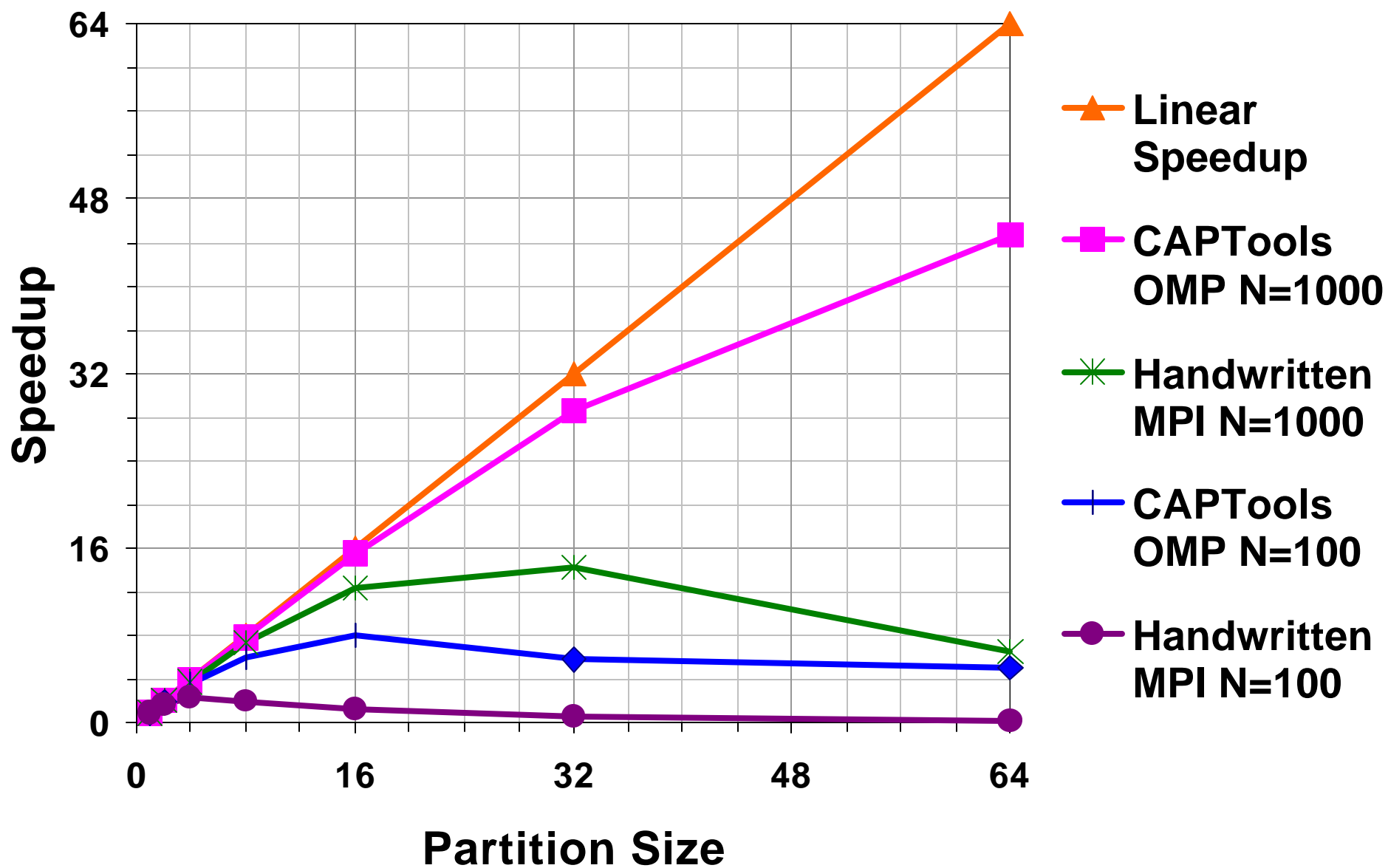
- **Generate parallel source code**
- **Compile/link/run the code**
- **Validate the results**

Applications

- **N-Body**
- **PFEM**
- **R-Jet**
- **FDL3DI**

N-Body

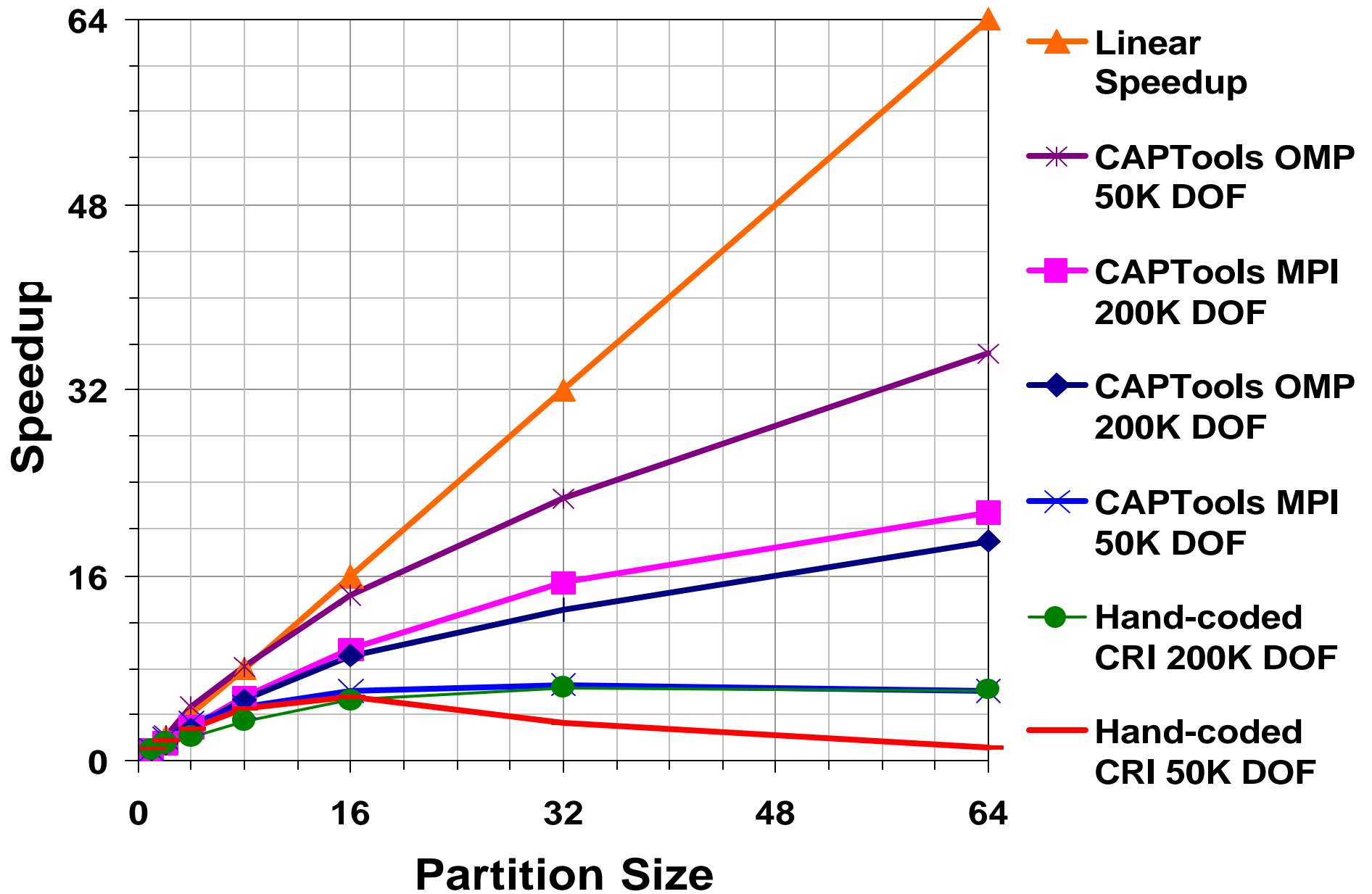
- **Distributes points evenly on the unit sphere**
- **3D n-body model**
- **Hand-written MPI**
- **CAPTtools generated OpenMP**



Speedup Curves for the N-Body Code

PFEM

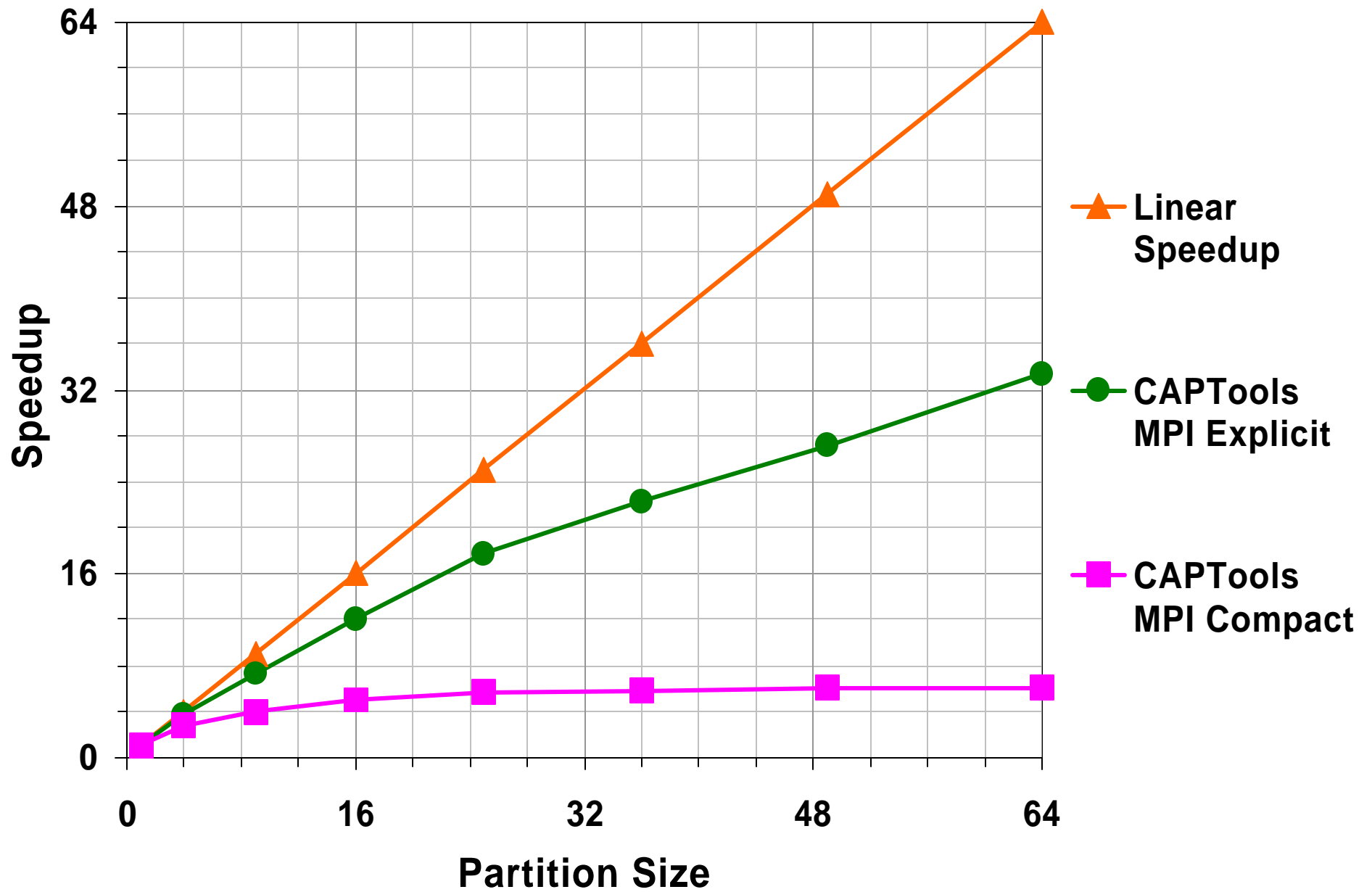
- **Solves 2D highly nonlinear BVP in CSM**
- **Domain decomposition (two-colorings)**
- **Hand-coded directive-driven and message passing**



Speedup Curves for the PFEM Code ¹⁴

R-Jet

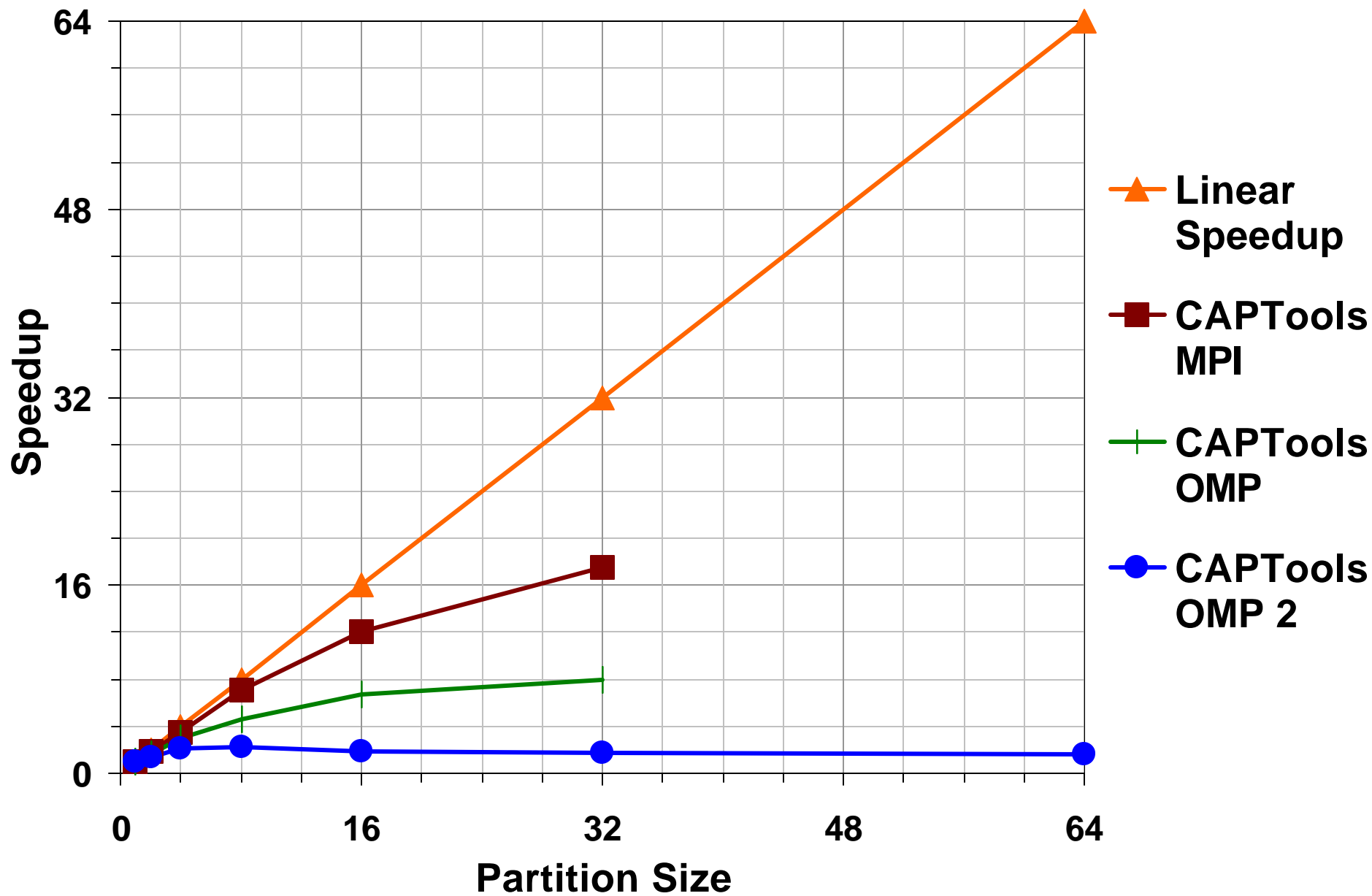
- **Simulates vortex dynamics and breakdown in turbulent jets**
- **Hybrid, high-order, compact finite difference spectral method**



Speedup Curves for the R-Jet Code

FDL3DI

- **Flight Dynamics Lab 3D Implicit**
- **Simulates aeroelastic effects**
- **High-frequency Navier-Stokes model**
- **1D structural solver component**



Speedup Curves for the FDL3DI Code

Summary of results

- **CAPTtools successfully applied to 2 DoD and 2 academic research codes**
- **OpenMP model quick & simple**
- **CAPLib model works well on mesh-based codes and algorithm permitting**
- **Meshless codes require hand-tuning (block & collective communication calls)**
- **CAPLib model requires detailed knowledge of the input source code**
- **CAPLib source code more difficult to debug**

Accelerating code parallelization with CAPTools

	Code analysis	Parallel strategy	Parallel code generation	Numerical validation debugging	Optimization
Hand	1 mth	1 mth	3 mths	6 mths	3 mths
CAP Tools	2 days	2 days	< 1 hour each time	1 week	1 week

Parallelization process reduced
from ~1 year to less than 1 month²⁰

Recommendations

- **Use of CAPTools to parallelize Fortran 77 serial codes highly recommended**
- **Work with OpenMP first (if possible)**
- **Work with OpenMP on meshless codes**
- **Work with CAPLib model on mesh-based codes**

**[http://www.asc.hpc.mil/
PET/PTES/CAPTtools/
index.html](http://www.asc.hpc.mil/PET/PTES/CAPTtools/index.html)**

<http://captools.gre.ac.uk>

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