

Green Multicore Computing: Co-design of Software and Architecture



Hironori Kasahara

IEEE Computer Society President Elect 2017, President 2018

Professor, Dept. of Computer Science & Engineering

Director, Advanced Multicore Processor Research Institute

Waseda University, Tokyo, Japan

URL: <http://www.kasahara.cs.waseda.ac.jp/>

1980 BS, 82 MS, 85 Ph.D. , Dept. EE, Waseda Univ.

1985 Visiting Scholar: U. of California, Berkeley

1986 Assistant Prof., 1988 Associate Prof., 1997 Prof., Dept. EECE, Waseda U. Now Dept. Comput. Sci. & Eng.

1989-90 Research Scholar: U. of Illinois, Urbana-Champaign, Center for Supercomputing R&D

2017 Member: Science Council of Japan, Engineering Academy of Japan, IEEE Eta-Kappa-Nu

1987 IFAC World Congress Young Author Prize

1997 IPSJ Sakai Special Research Award

2005 STARC Academia-Industry Research Award

2008 LSI of the Year Second Prize

2008 Intel Asia Academic Forum Best Research Award

2010 IEEE CS Golden Core Member Award

2014 Minister of Edu., Sci. & Tech. Research Prize

2015 IPSJ Fellow

2017 IEEE Fellow

Reviewed Papers: 214, Invited Talks: 145, Published Unexamined Patent Application: 59 (Japan, US, GB, China Granted Patents: 30), Articles in News Papers, Web News, Medias incl. TV etc.: 572

Committees in Societies and Government 245

IEEE Computer Society President 2018, BoG(2009-14), Multicore STC Chair (2012-), Japan Chair (2005-07), IPSJ Chair: HG for Mag. & J. Edit, Sig. on ARC.

【METI/NEDO】 Project Leaders: Multicore for Consumer Electronics, Advanced Parallelizing Compiler, Chair: Computer Strategy Committee 【Cabinet Office】 CSTP Supercomputer Strategic ICT PT, Japan Prize Selection Committees, etc. 【MEXT】 Info. Sci. & Tech. Committee, Supercomputers (Earth Simulator, HPCI Promo., Next Gen. Supercomputer K) Committees, etc.

Hironori Kasahara Voted 2017 IEEE Computer Society President-Elect

LOS ALAMITOS, Calif., 30 September 2016 – **Hironori Kasahara**, a Professor of Computer Science at Waseda University in Tokyo, and Director of the Advanced Multicore Research Institute, has been voted **IEEE Computer Society 2017 President-Elect**.

Kasahara is a former member of the IEEE-CS Board of Governors, has served as chair of the IEEE-CS Multicore STC and CS Japan Chapter, and board member of the IEEE Tokyo Section. Kasahara will serve as the 2018 IEEE CS President for a one-year term beginning 1 January 2018. Kasahara garnered 3,278 votes, compared with 2,804 votes cast for Hausi A. Müller, a Professor of Computer Science and Associate Dean of Research, Faculty of Engineering at University of Victoria, Canada, and a member of IEEE-CS Board of Governors.

The President oversees IEEE-CS programs and operations and is a nonvoting member of most IEEE-CS program boards and committees. The 2016 election had a 12.69% turnout, with 6,357 ballots cast. The turnout was higher than the 2015 election with and 12.68% turnout (6,239 ballots cast) and the 2014 election with a 12.66% turnout (6,728 ballots cast).

2016 IEEE Computer Society Election Results

[Press Release](#) | [Ballot counts](#)

Posted 29 September 2016

Hironori Kasahara selected 2017 President-Elect (2018 President)



Hironori Kasahara has served as a chair or member of 225 society and government committees, including a member of the CS Board of Governors; chair of CS Multicore STC and CS Japan chapter; associate editor of IEEE Transactions on Computers; vice PC chair of the 1996 ENIAC 50th Anniversary International Conference on Supercomputing; general chair of LCPC; PC member of SC, PACT, PPOPP, and ASPLOS; board member of IEEE Tokyo section; and member of the Earth Simulator committee.

He received a PhD in 1985 from Waseda University, Tokyo, joined its faculty in 1986, and has been a professor of computer science since 1997 and a director of the Advanced Multicore Research Institute since 2004. He was a visiting scholar at University of California, Berkeley, and the University of Illinois at Urbana–Champaign's Center for Supercomputing R&D.

Kasahara received the CS Golden Core Member Award, IFAC World Congress Young Author Prize, IPSJ Fellow and Sakai Special Research Award, and the Japanese Minister's Science and Technology Prize. He led Japanese national projects on parallelizing compilers and embedded multicores, and has presented 210 papers, 132 invited talks, and 27 patents. His research has appeared in 520 newspaper and Web articles.

IEEE Computer Society BoG (Board of Governors) Feb.1, 2017



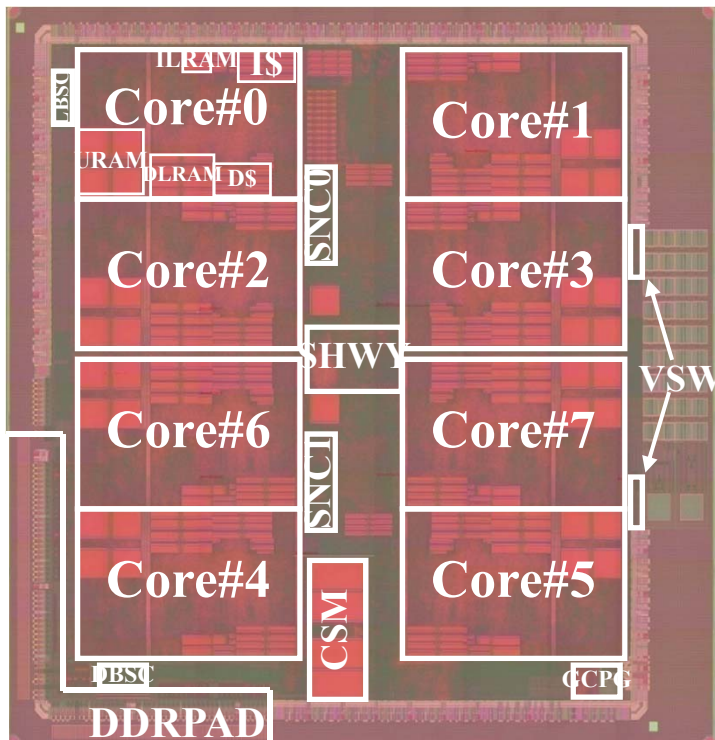
<https://www.computer.org/web/cshistory/officers-2017>

Toward 2018

1. Refining content and services to further improve the satisfaction of CS members;
2. Considering an incentive for volunteers to further accelerate CS activities and promptly provide technical benefits for people around the globe;
To express appreciation to volunteers:
CS Point (Mileage) System: Annual & Life Time Honor, Premier Seating, Premier Registration, Distinguished Reviewer, etc
3. Offering more attractive services for practitioners in industry;
4. Providing the world's best educational content and historical treasures for future generations, which only the CS can create with our pioneering researchers (for example, the Multicore Compiler Video Series found at www.computer.org/web/education/multicore-video-series);
5. Thinking about sustainable membership fees while considering the diversity of economic situations within the 10 regions;
6. Cooperating with other IEEE societies and sister societies in a timely and efficient manner;
7. Intelligibly introducing the latest computer-related technologies to younger generations, including children, so that they can realize their technological dreams.

Multicores for Performance and Low Power

Power consumption is one of the biggest problems for performance scaling from smartphones to cloud servers and supercomputers (“K” more than 10MW) .



IEEE ISSCC08: Paper No. 4.5,
M.ITO, ... and H. Kasahara,
“An 8640 MIPS SoC with
Independent Power-off Control of 8
CPUs and 8 RAMs by an Automatic
Parallelizing Compiler”

$$\text{Power} \propto \text{Frequency} * \text{Voltage}^2$$

(Voltage $\propto$ Frequency)

➔ Power $\propto$ Frequency³

If Frequency is reduced to 1/4
(Ex. 4GHz→1GHz),
Power is reduced to 1/64 and
Performance falls down to 1/4 .

<Multicores>

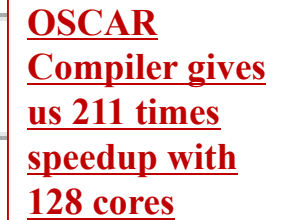
If 8cores are integrated on a chip,
Power is still 1/8 and
Performance becomes 2 times.

- Just more cores don't give us speedup
- Development cost and period of parallel software are getting a bottleneck of development of embedded systems, eg. IoT, Automobile

■ original (sun studio) ■ proposed method



Fjitsu M9000 SPARC Multicore Server

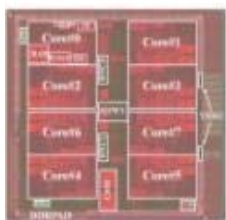


Commercial compiler gives us 0.9 times speedup with 128 cores (slow-downed against 1 core)

- 6

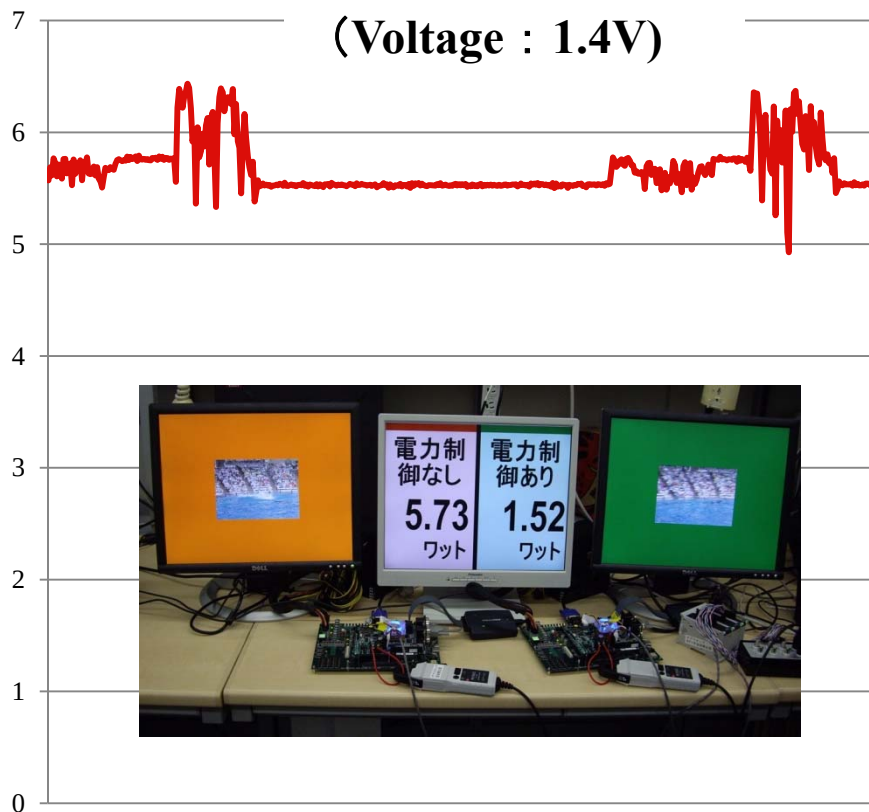
Power Reduction of MPEG2 Decoding to 1/4 on 8 Core Homogeneous Multicore RP-2 by OSCAR Parallelizing Compiler

MPEG2 Decoding with 8 CPU cores



Without Power
Control

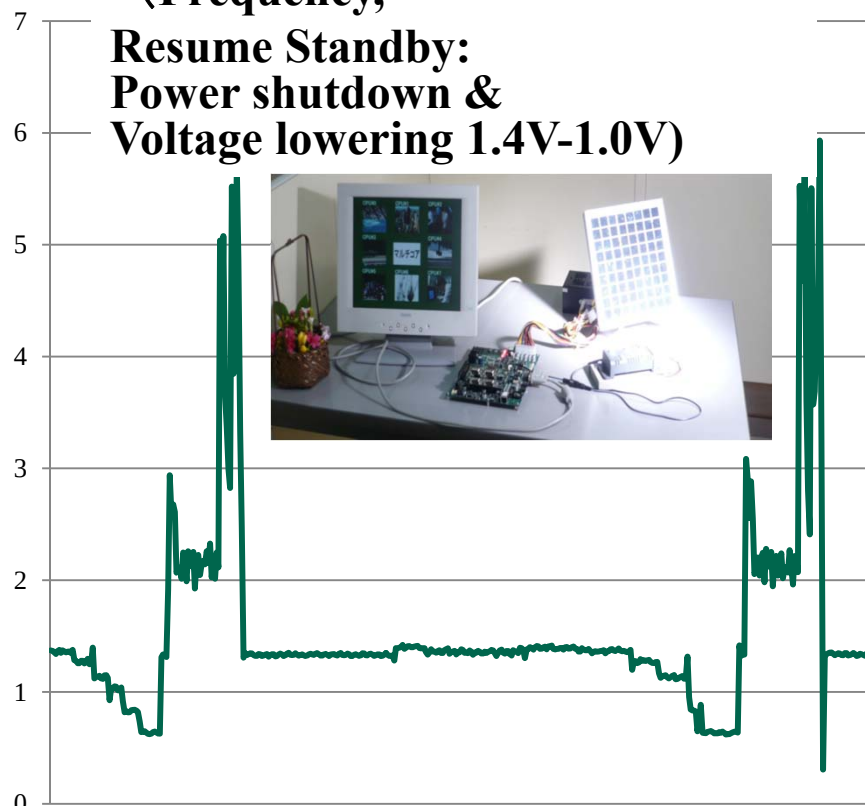
(Voltage : 1.4V)



Avg. Power
5.73 [W]

With Power Control
(Frequency,
Resume Standby:

Power shutdown &
Voltage lowering 1.4V-1.0V)



Avg. Power
1.52 [W]

73.5% Power Reduction



Demo of NEDO Multicore for Real Time Consumer Electronics at the Council of Science and Engineering Policy on April 10, 2008

第74回総合科学技術会議【平成20年4月10日】



第74回総合科学技術会議の様子(1)



第74回総合科学技術会議の様子(2)



第74回総合科学技術会議の様子(3)



第74回総合科学技術会議の様子(4)

CSTP Members

Prime Minister:

Mr. Y. FUKUDA

**Minister of State for
Science, Technology
and Innovation
Policy:**

Mr. F. KISHIDA

**Chief Cabinet
Secretary:**

Mr. N. MACHIMURA

**Minister of Internal
Affairs and
Communications :**

Mr. H. MASUDA

Minister of Finance :

Mr. F. NUKAGA

**Minister of
Education, Culture,
Sports, Science and
Technology:**

Mr. K. TOKAI

**Minister of
Economy, Trade and
Industry:**

Mr. A. AMARI

Green Computing Systems R&D Center

Waseda University

Supported by METI (Mar. 2011 Completion)

<R & D Target>

Hardware, Software, Application
for Super Low-Power Manycore

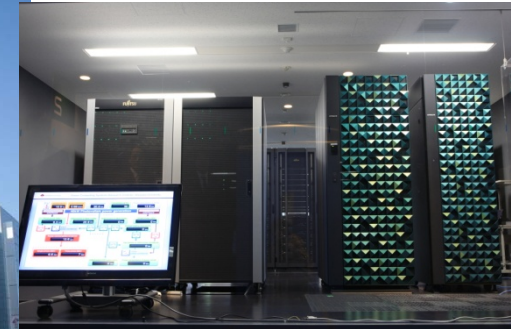
- More than 64 cores
- Natural air cooling (No fan)
Cool, Compact, Clear, Quiet
- Operational by Solar Panel

<Industry, Government, Academia>

Hitachi, Fujitsu, NEC, Renesas, Olympus,
Toyota, Denso, Mitsubishi, Toshiba,
OSCAR Technology, etc

<Ripple Effect>

- Low CO₂ (Carbon Dioxide) Emissions
- Creation Value Added Products
- Automobiles, Medical, IoT, Servers



Hitachi SR16000:

Power7 128coreSMP

Fujitsu M9000

SPARC VII 256 core SMP



Beside Subway Waseda Station,
Near Waseda Univ. Main Campus

OSCAR Parallelizing Compiler

To improve **effective performance**, **cost-performance** and **software productivity** and **reduce power**

Multigrain Parallelization^(LCPC1991,2001,04)

coarse-grain parallelism among loops and subroutines (2000 on SMP), near fine grain parallelism among statements (1992) in addition to loop parallelism

Data Localization

Automatic data management for distributed shared memory, cache and local memory
(Local Memory 1995, 2016 on RP2, Cache2001,03)
Software Coherent Control (2017)

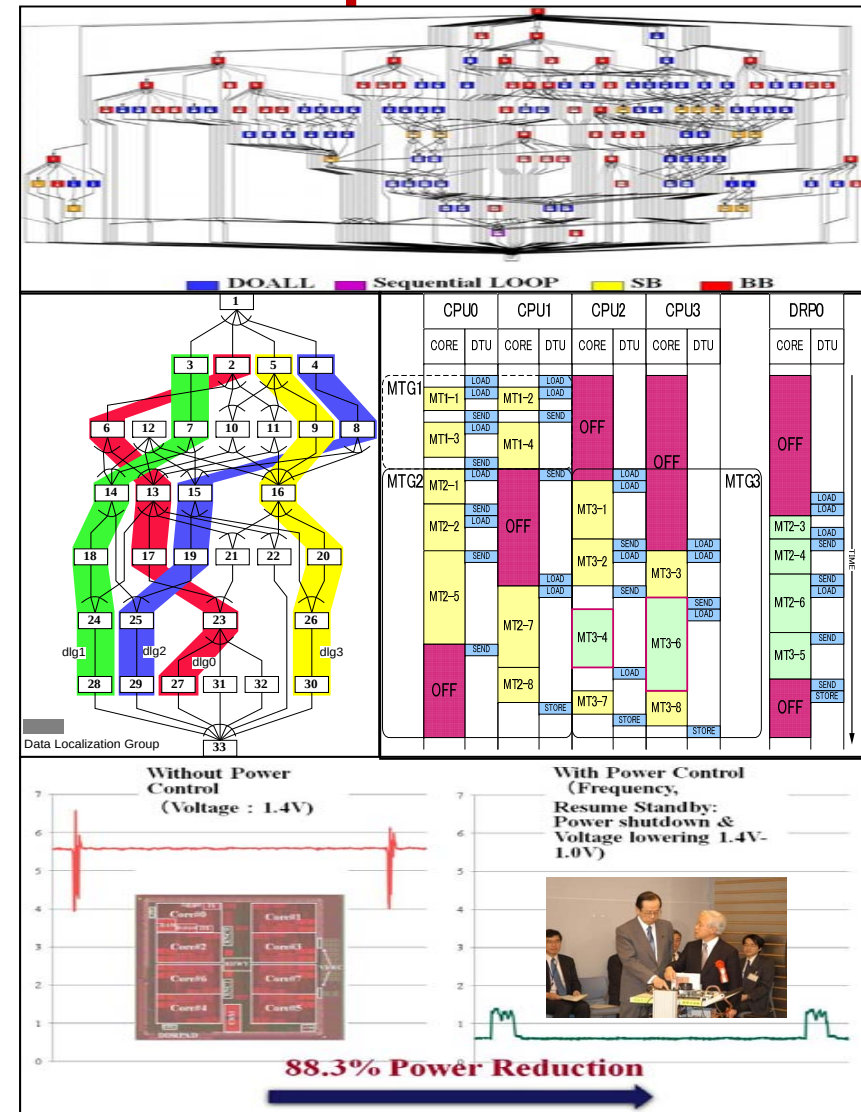
Data Transfer Overlapping^(2016 partially)

Data transfer overlapping using Data Transfer Controllers (DMAs)

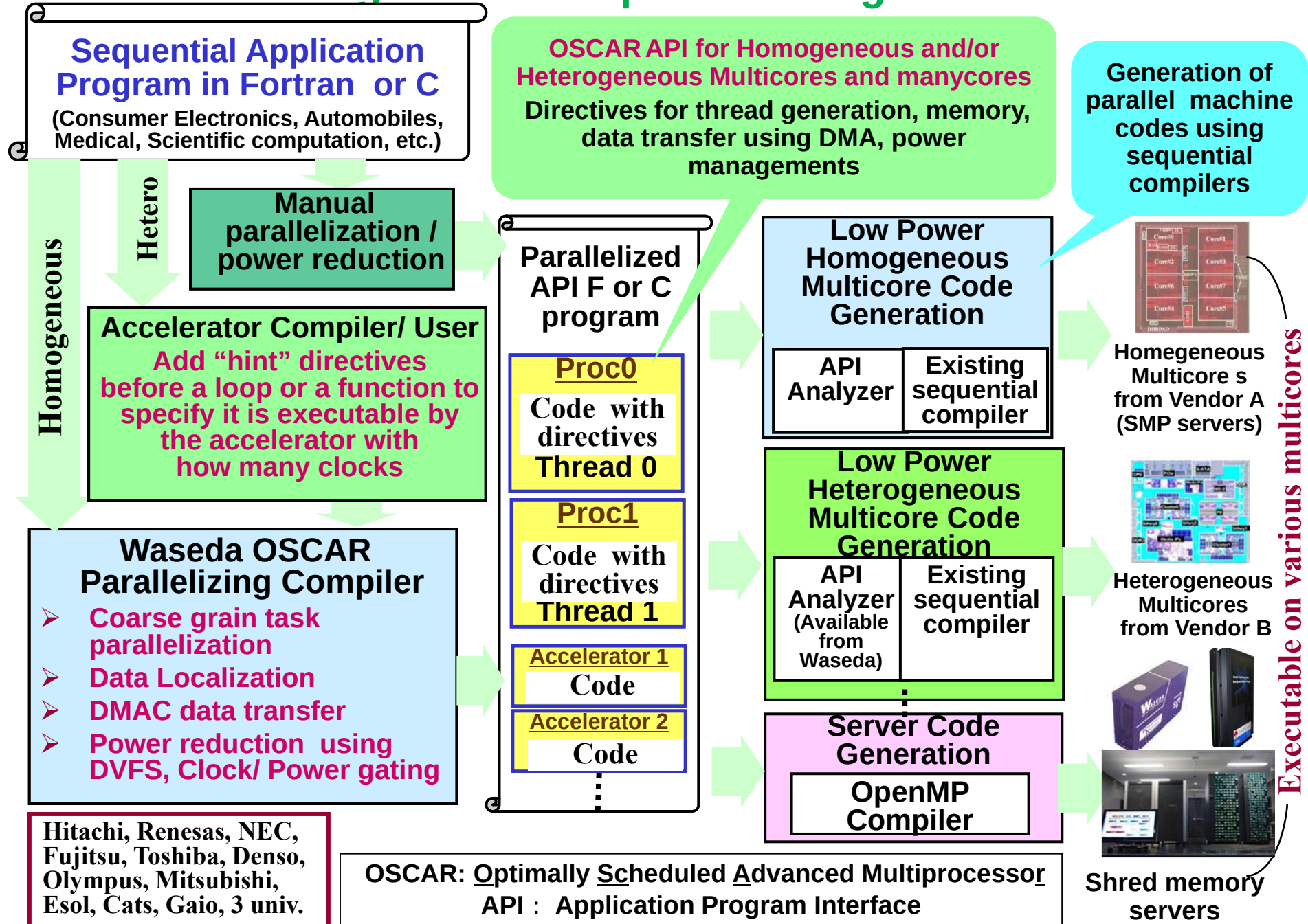
Power Reduction

(2005 for Multicore, 2011 Multi-processes, 2013 on ARM)

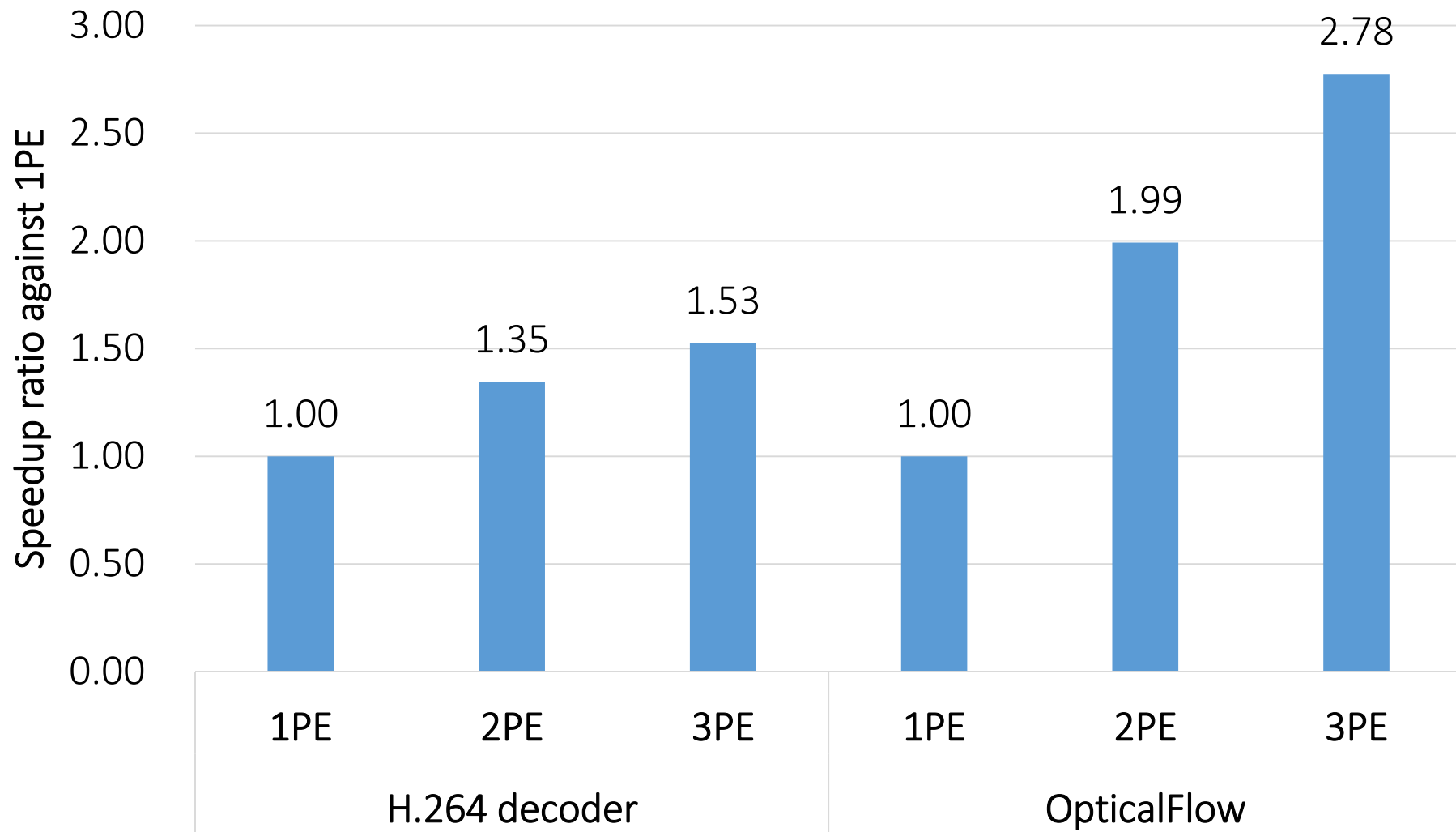
Reduction of consumed power by compiler control DVFS and Power gating with hardware supports.



Multicore Program Development Using OSCAR API V2.0



Speedup ratio for H.264 and Optical Flow on ARM Cortex-A9 Android 3 cores by OSCAR Automatic Parallelization

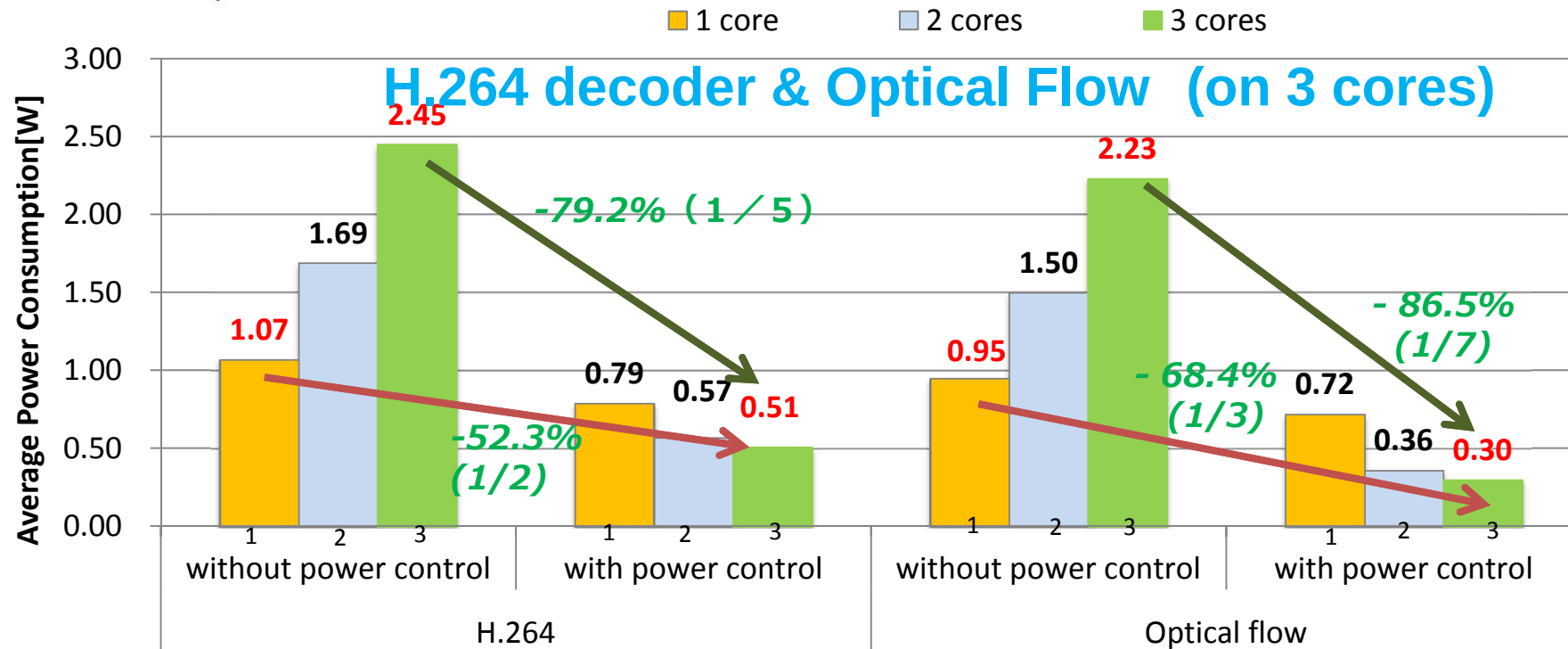
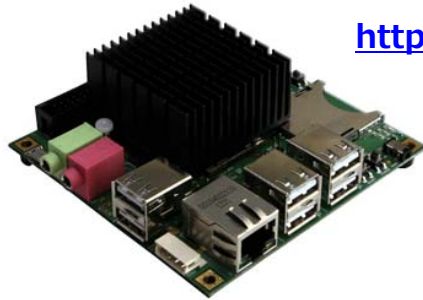


Automatic Power Reduction on ARM CortexA9 with Android

http://www.youtube.com/channel/UCS43INYEIkC8i_KIgFZYQBQ

ODROID X2

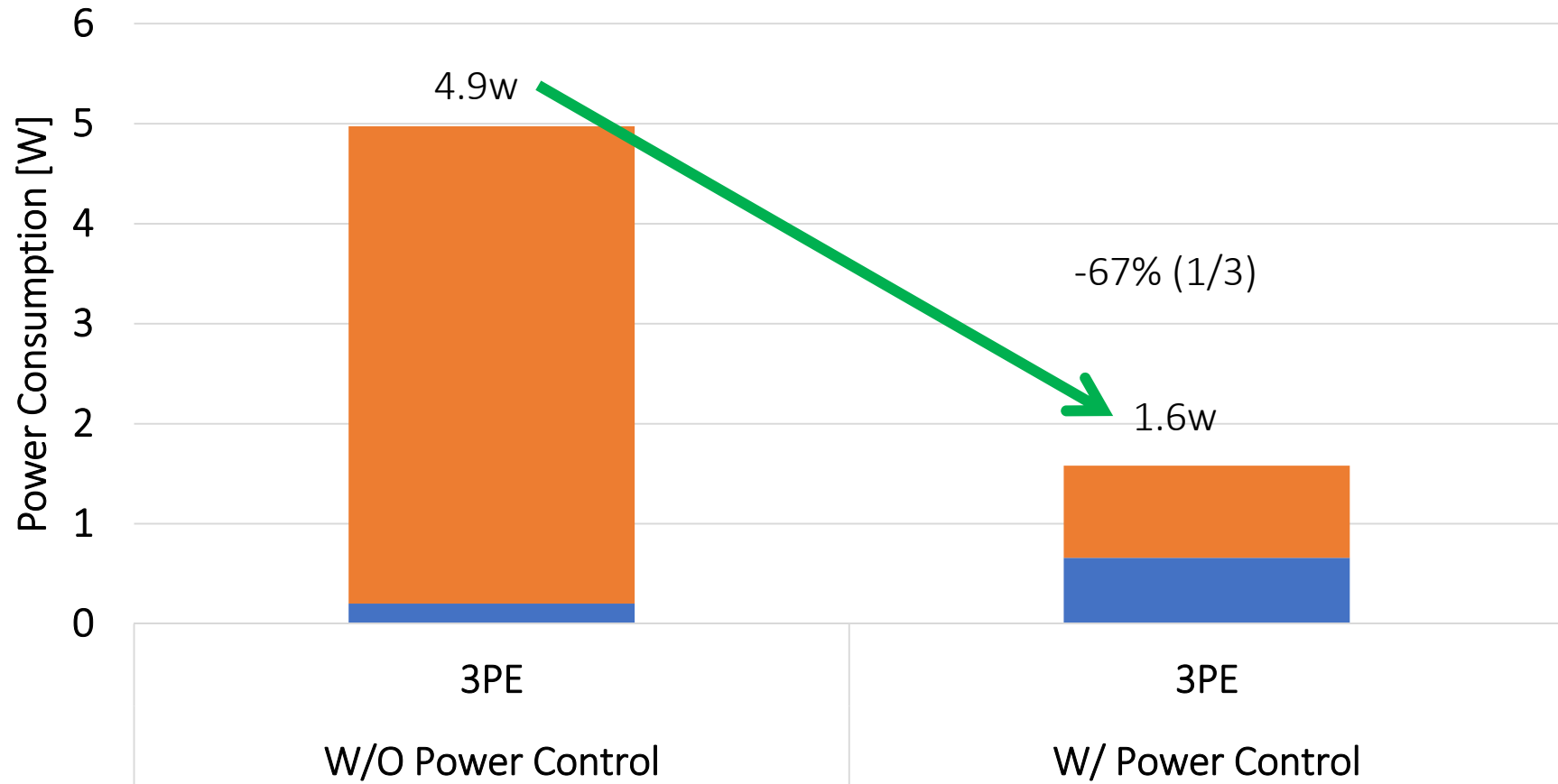
Samsung Exynos4412 Prime, ARM Cortex-A9 Quad core
1.7GHz~0.2GHz, used by Samsung's Galaxy S3



Power for 3cores was reduced to **1/5~1/7** against without software power control

Power for 3cores was reduced to **1/2~1/3** against ordinary 1core execution

Automatic Power Reduction of OpenCV Face Detection on big.LITTLE ARM Processor



- ODR0ID-XU3

■ Cortex-A7 ■ Cortex-A15

- Samsung Exynos 5422 Processor

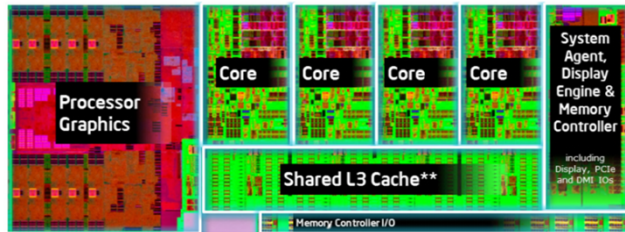
- 4x Cortex-A15 2.0GHz, 4x Cortex-A7 1.4GHz big.LITTLE Architecture

- 2GB LPDDR3 RAM

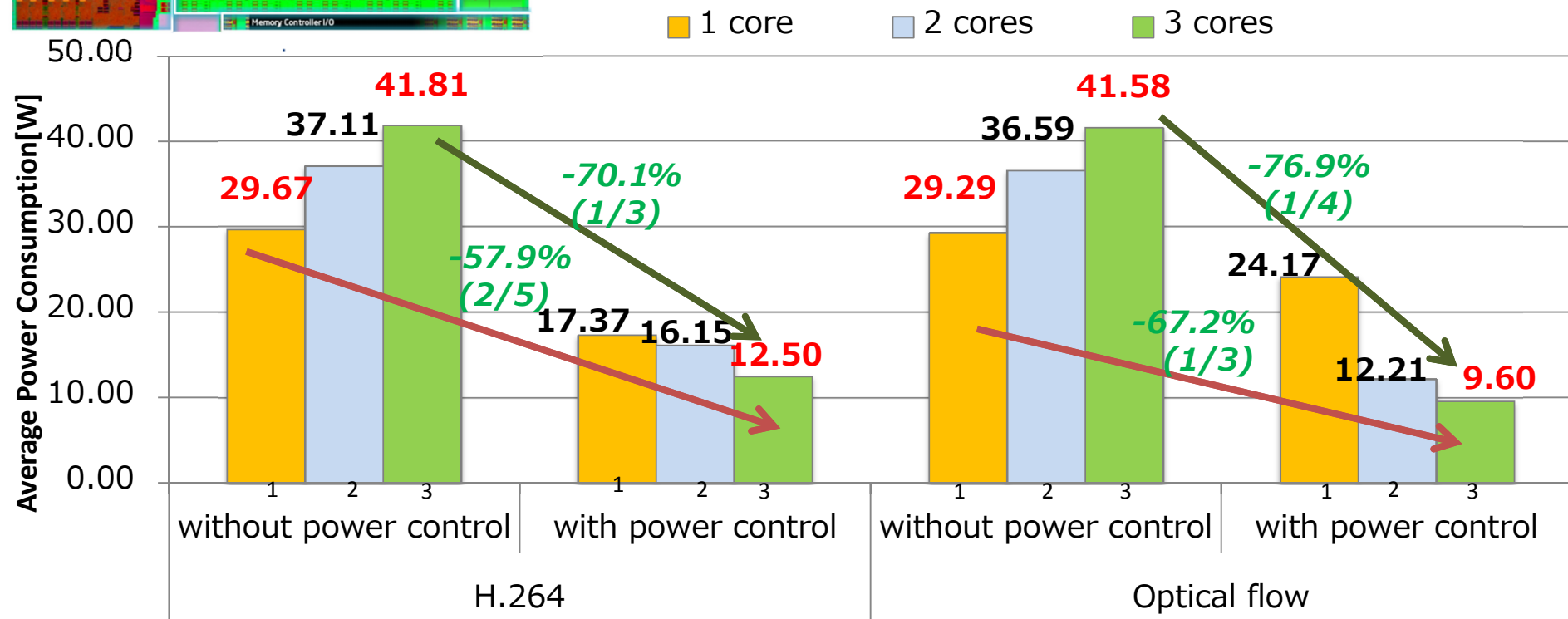
Frequency can be changed by each cluster unit

Automatic Power Reuction on Intel Haswell

H.264 decoder & Optical Flow (3cores)



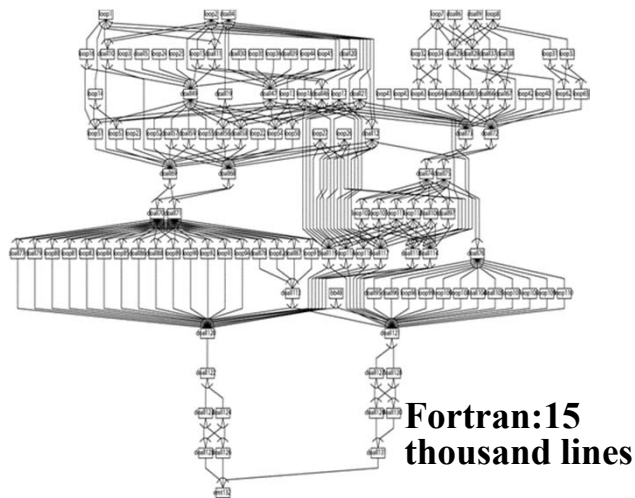
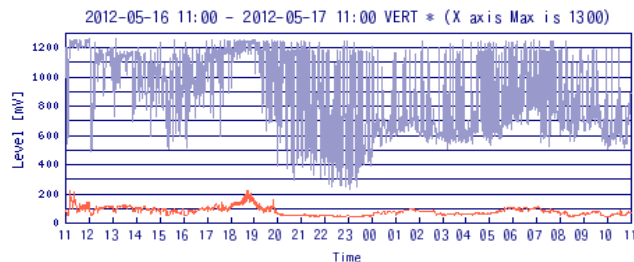
H81M-A, Intel Core i7 4770k
Quad core, 3.5GHz~0.8GHz



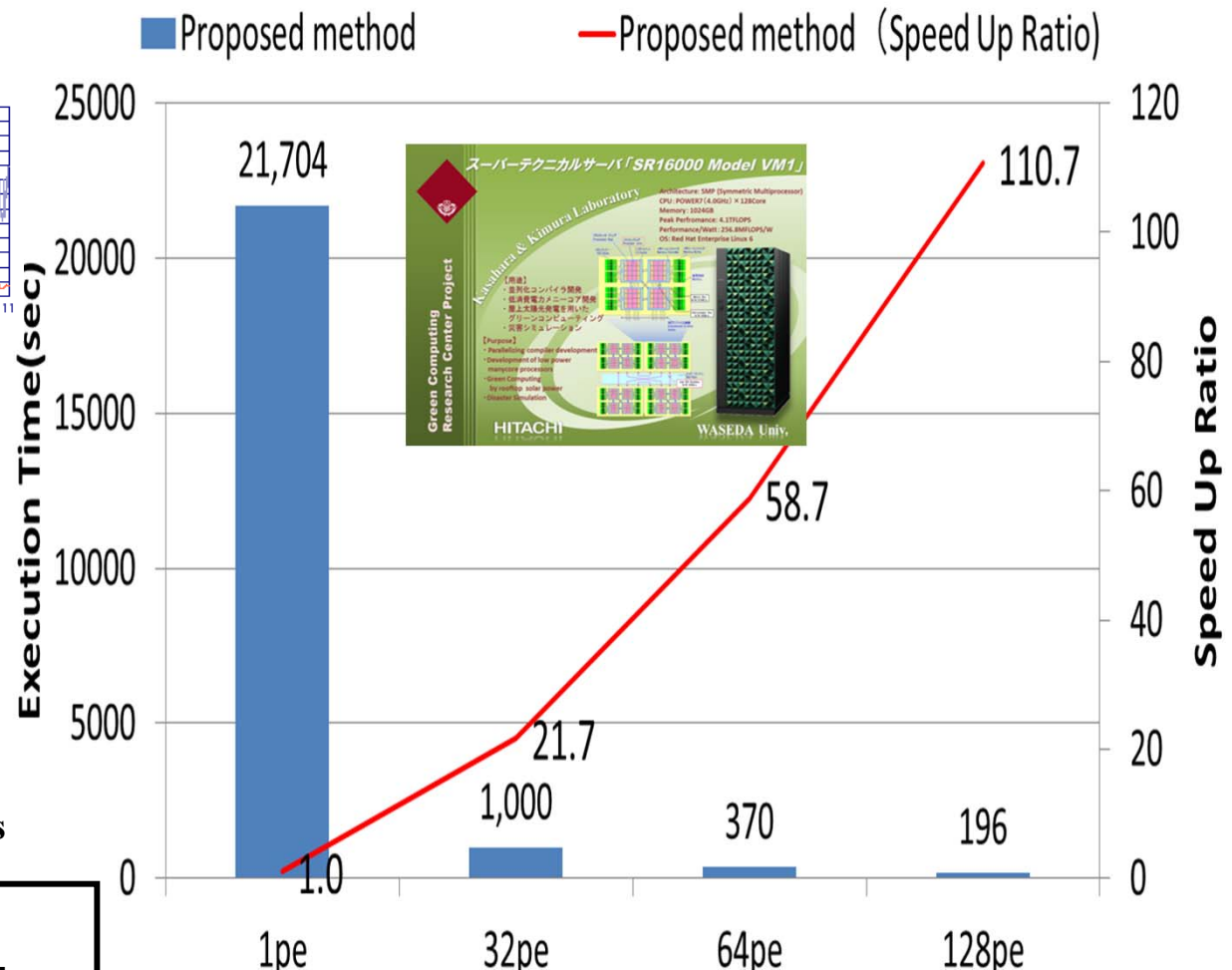
Power for 3cores was reduced to **1/3~1/4** against without software power control
Power for 3cores was reduced to **2/5~1/3** against ordinary 1core execution

110 Times Speedup against the Sequential Processing for GMS Earthquake Wave Propagation Simulation on Hitachi SR16000

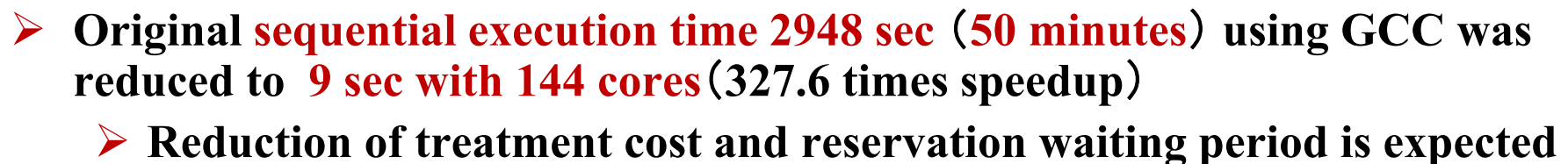
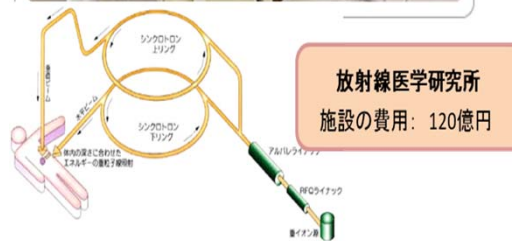
(Power7 Based 128 Core Linux SMP) ([LCPC2015](#))



First touch for distributed shared
memory and cache optimization over
loops are important for scalable speedup

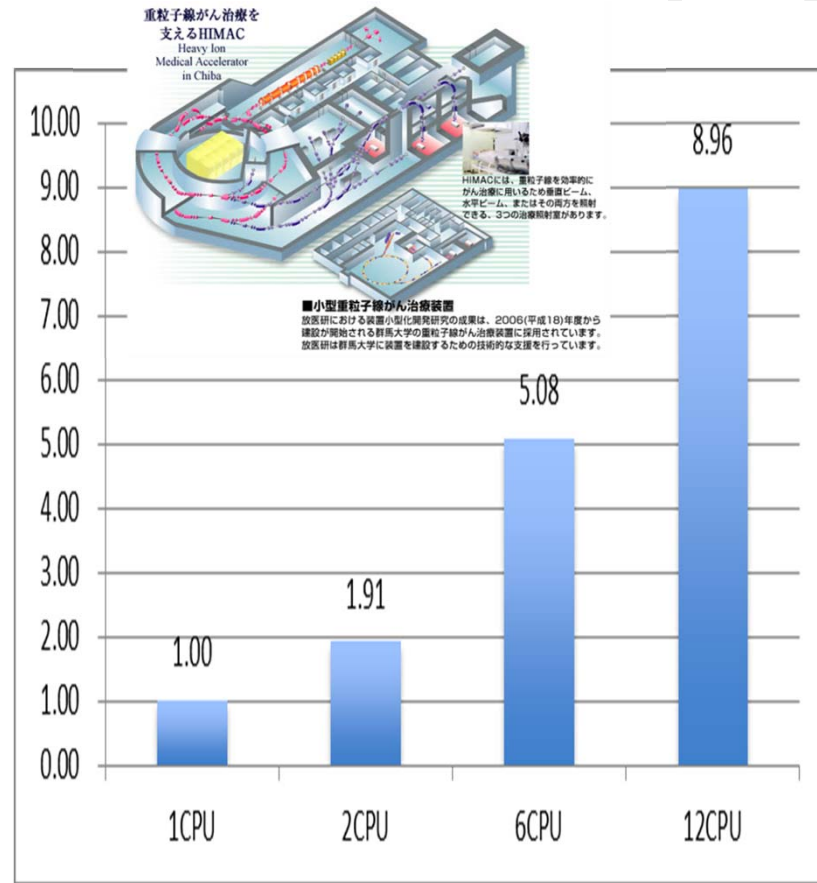


327 times speedup on 144 cores



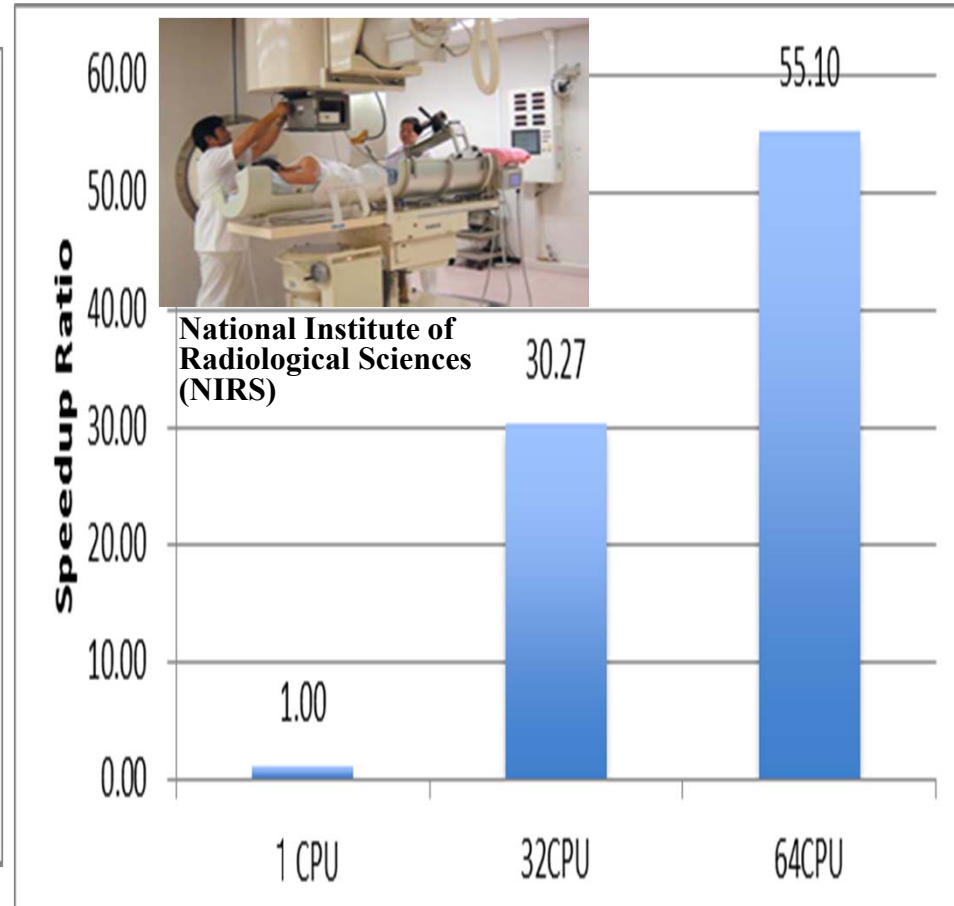
Cancer Treatment Carbon Ion Radiotherapy

(Previous best was 2.5 times speedup on 16 processors with hand optimization)



8.9times speedup by 12 processors

**Intel Xeon X5670 2.93GHz 12
core SMP (Hitachi HA8000)**



55 times speedup by 64 processors

**IBM Power 7 64 core SMP
(Hitachi SR16000)**

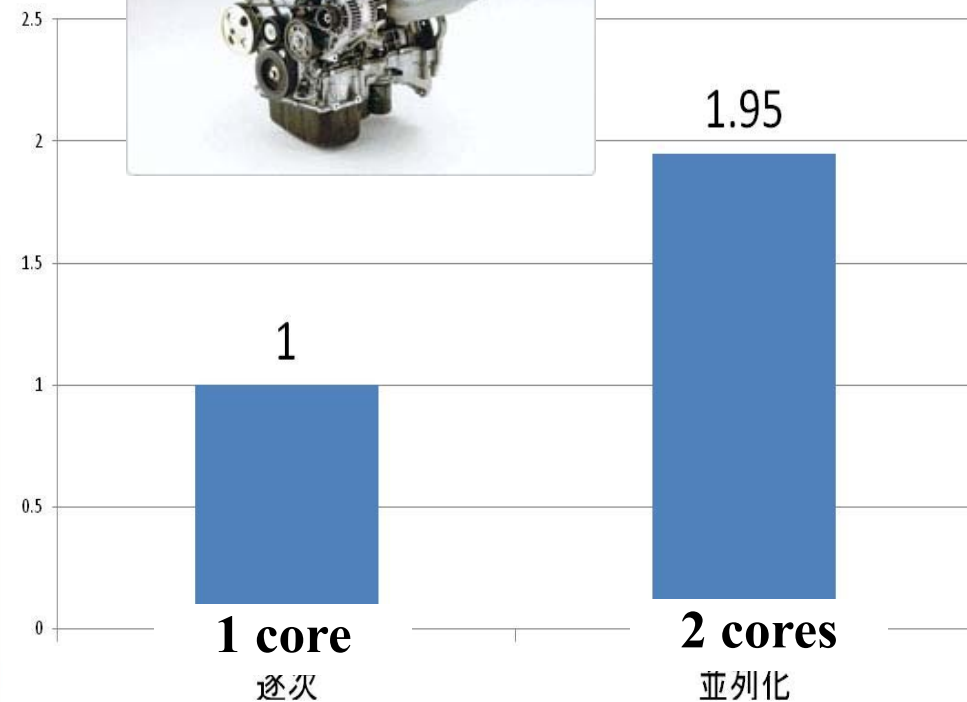
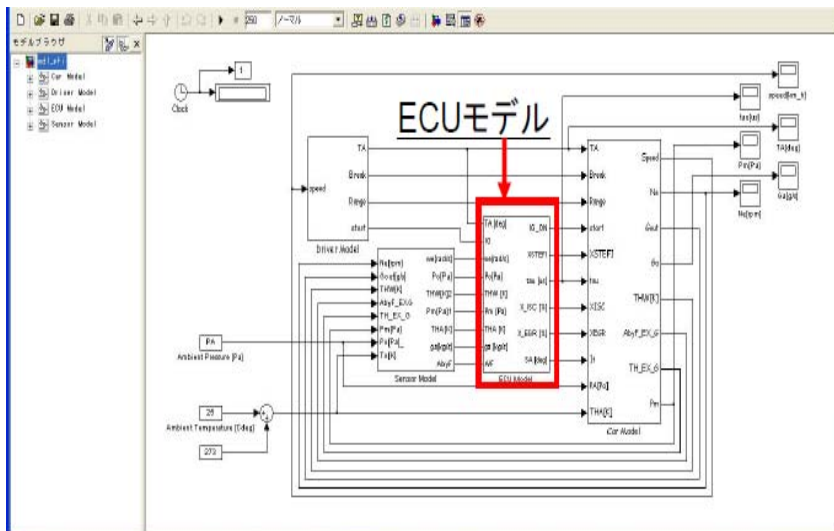


Engine Control by multicore with Denso

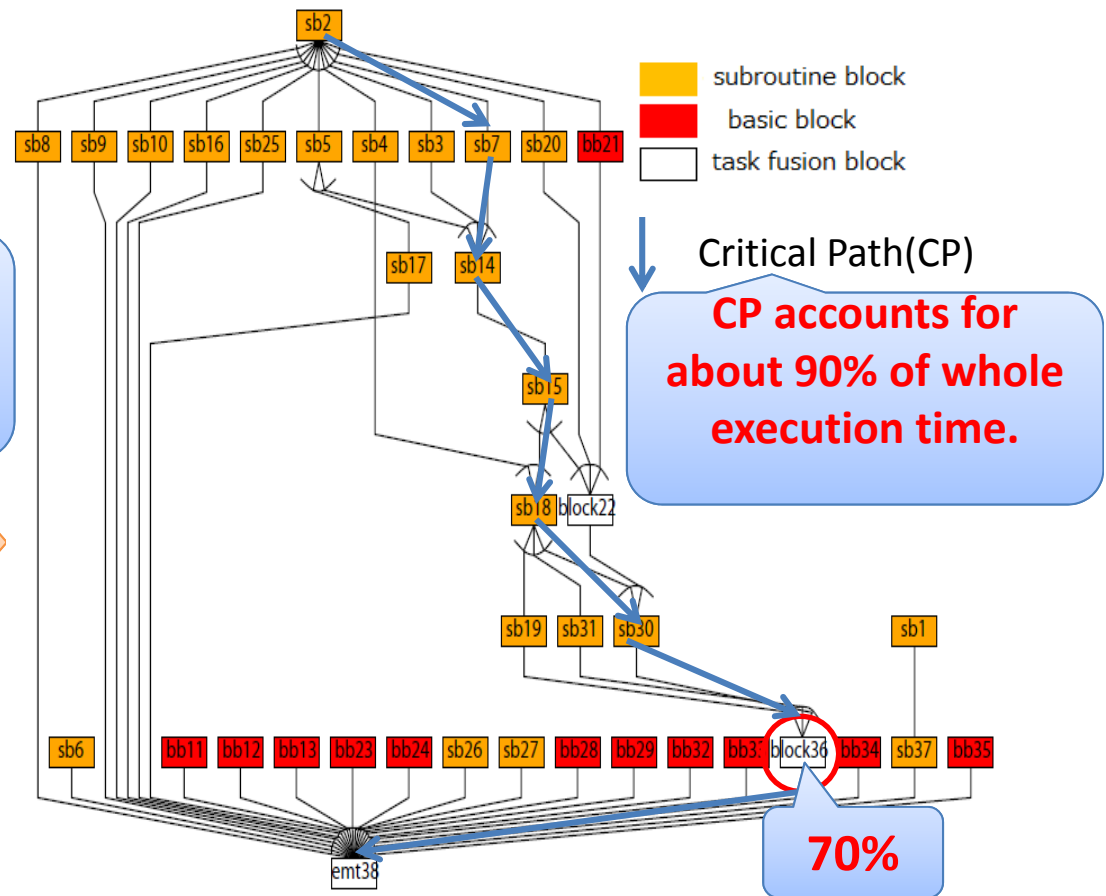
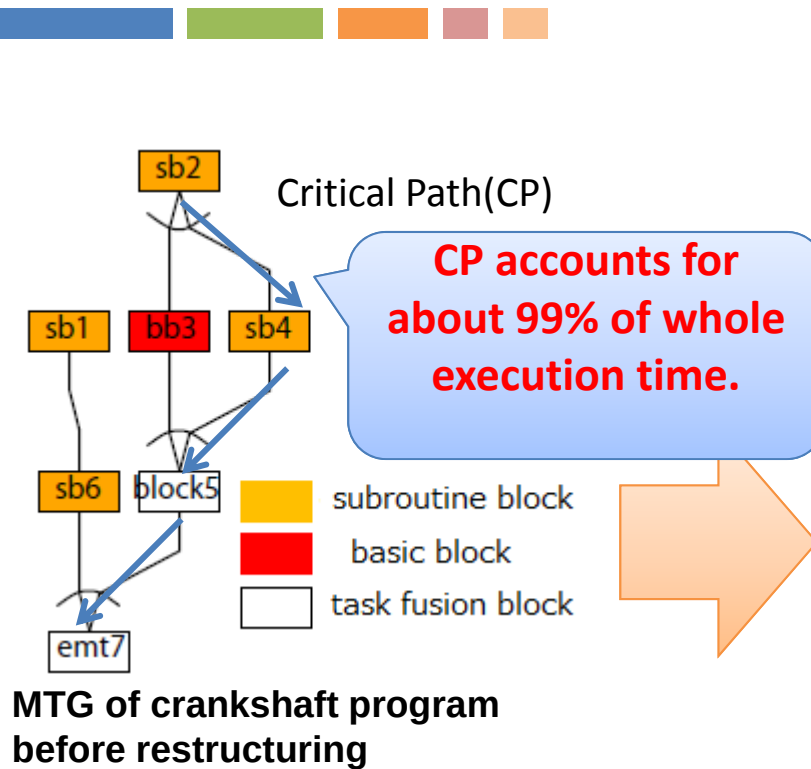
Though so far parallel processing of the engine control on multicore has been very difficult, Denso and Waseda succeeded 1.95 times speedup on 2core V850 multicore processor.



- Hard real-time automobile engine control by multicore using local memories
- Millions of lines C codes consisting conditional branches and basic blocks



MTG of Crankshaft Program Using Inline Expansion



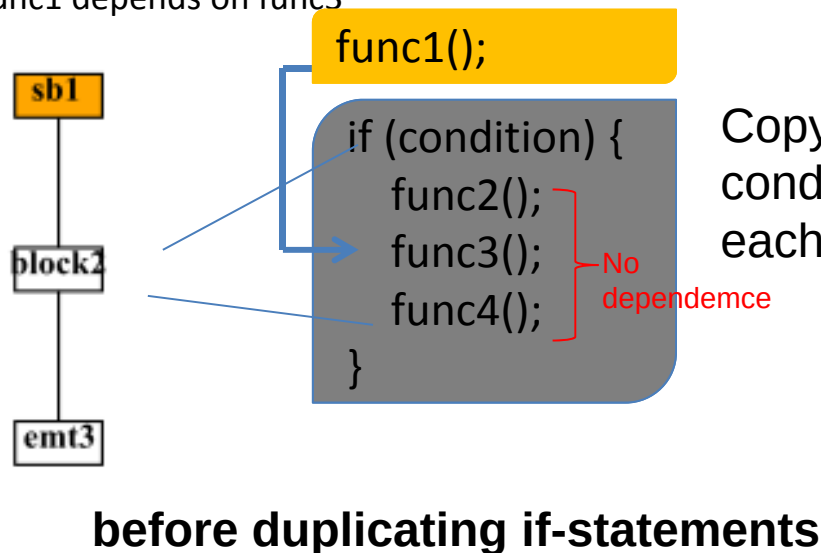
Not enough coarse grain parallelism yet!

3.2 Restructuring: Duplicating If-statements

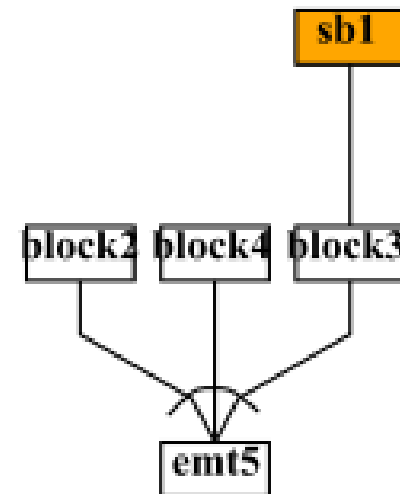
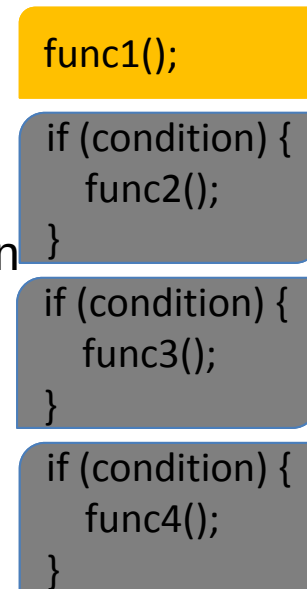
- Duplicating if-statements is effective
 - To increase coarse grain parallelism
- Duplicates fused tasks having inner parallelism

Improves coarse grain parallelism

Func1 depends on func3



Copying if-condition for each function



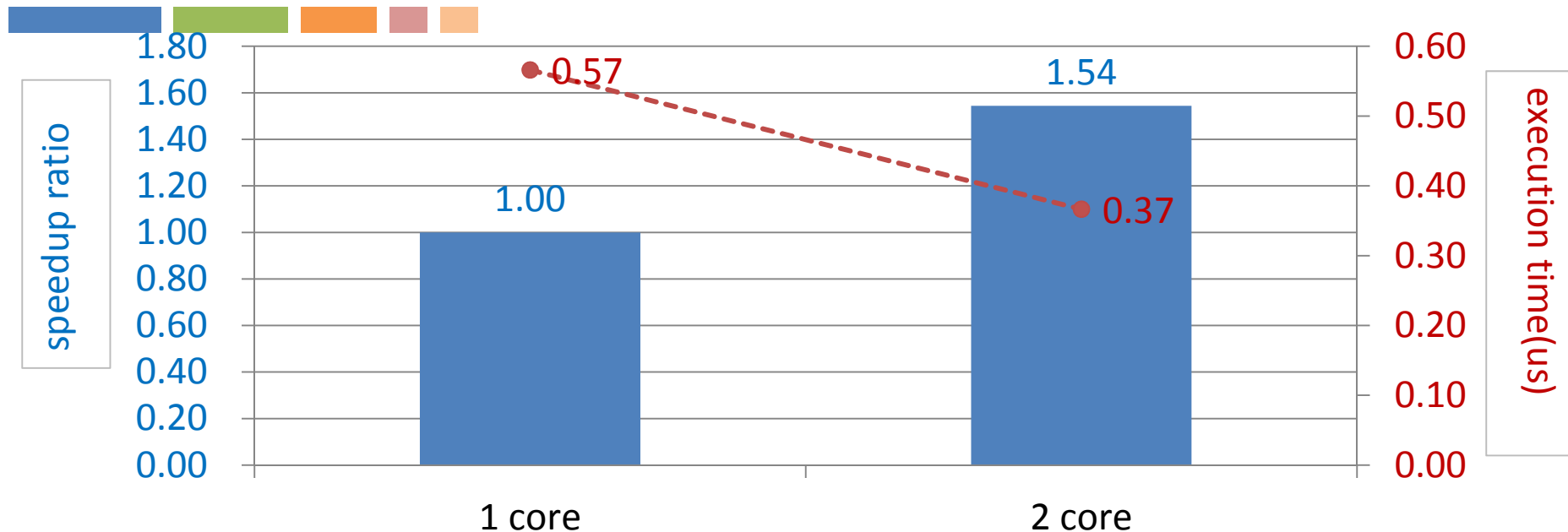


- Succeed to reduce CP
 - 99% -> 60%



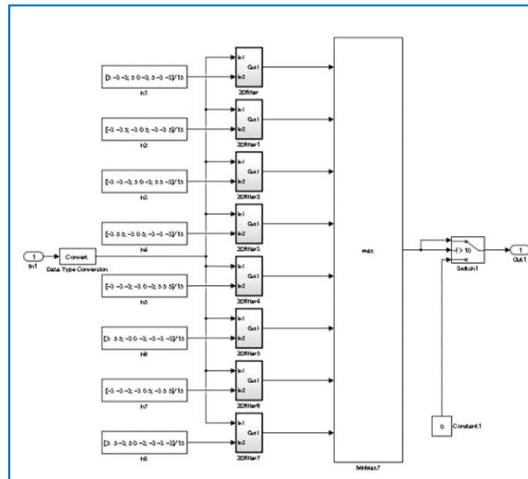
Successfully increased coarse grain parallelism

Evaluation of Crankshaft Program with Multi-core Processors



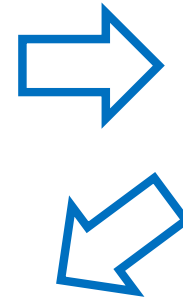
- Attain 1.54 times speedup on RPX
 - There are no loops, but only many conditional branches and small basic blocks and difficult to parallelize this program
- This result shows possibility of multi-core processor for engine control programs

OSCAR Compile Flow for Simulink Applications



Simulink model

Generate C code
using Embedded Coder



```
/* Model step function */
void VesselExtraction_step(void)
{
    int32_T i;
    real_T u0;

    /* DataTypeConversion: '<S1>/Data Type Conversion' incorporates:
     * Import: '<Root>/In1'
     */
    for (i = 0; i < 16384; i++) {
        VesselExtraction_B.DataTypeConversion[i] = VesselExtraction_U.In1[i];
    }

    /* End of DataTypeConversion: '<S1>/Data Type Conversion' */

    /* Outputs for Atomic SubSystem: '<S1>/2Dfilter' */

    /* Constant: '<S1>/h1' */
    VesselExtraction_Dfilter(VesselExtraction_B.DataTypeConversion,
        VesselExtraction_P.h1_Value, &VesselExtraction_B.Dfilter,
        (P_Dfilter_VesselExtraction_T *)&VesselExtraction_P.Dfilter);

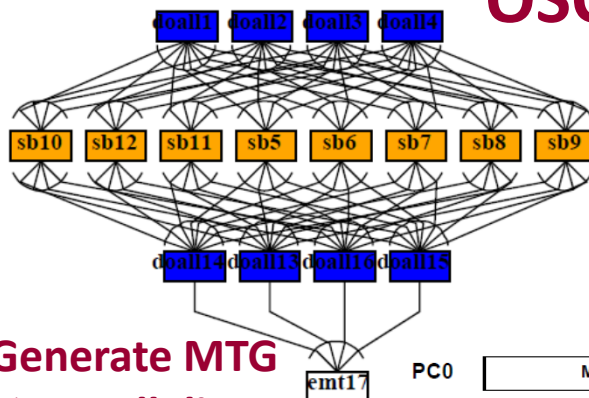
    /* End of Outputs for SubSystem: '<S1>/2Dfilter' */

    /* Outputs for Atomic SubSystem: '<S1>/2Dfilter1' */

    /* Constant: '<S1>/h2' */
    VesselExtraction_Dfilter(VesselExtraction_B.DataTypeConversion,
        VesselExtraction_P.h2_Value, &VesselExtraction_B.Dfilter1,
        (P_Dfilter_VesselExtraction_T *)&VesselExtraction_P.Dfilter1);
}
```

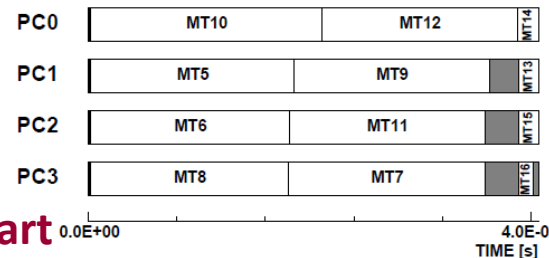
C code

OSCAR Compiler



(1) Generate MTG
→ Parallelism

(2) Generate gantt chart
→ Scheduling in a multicore



```
void VesselExtraction_step ( )
{
    int thr1 ;
    int thr2 ;
    int thr3 ;

    void thread_function_001 ( void )
    {
        VesselExtraction_step_PE1 ( ) ;
    }

    oscar_thread_create ( & thr1 ,
        thread_function_001 , (void*)1 ) ;
    oscar_thread_create ( & thr2 ,
        thread_function_002 , (void*)2 ) ;
    oscar_thread_create ( & thr3 ,
        thread_function_003 , (void*)3 ) ;

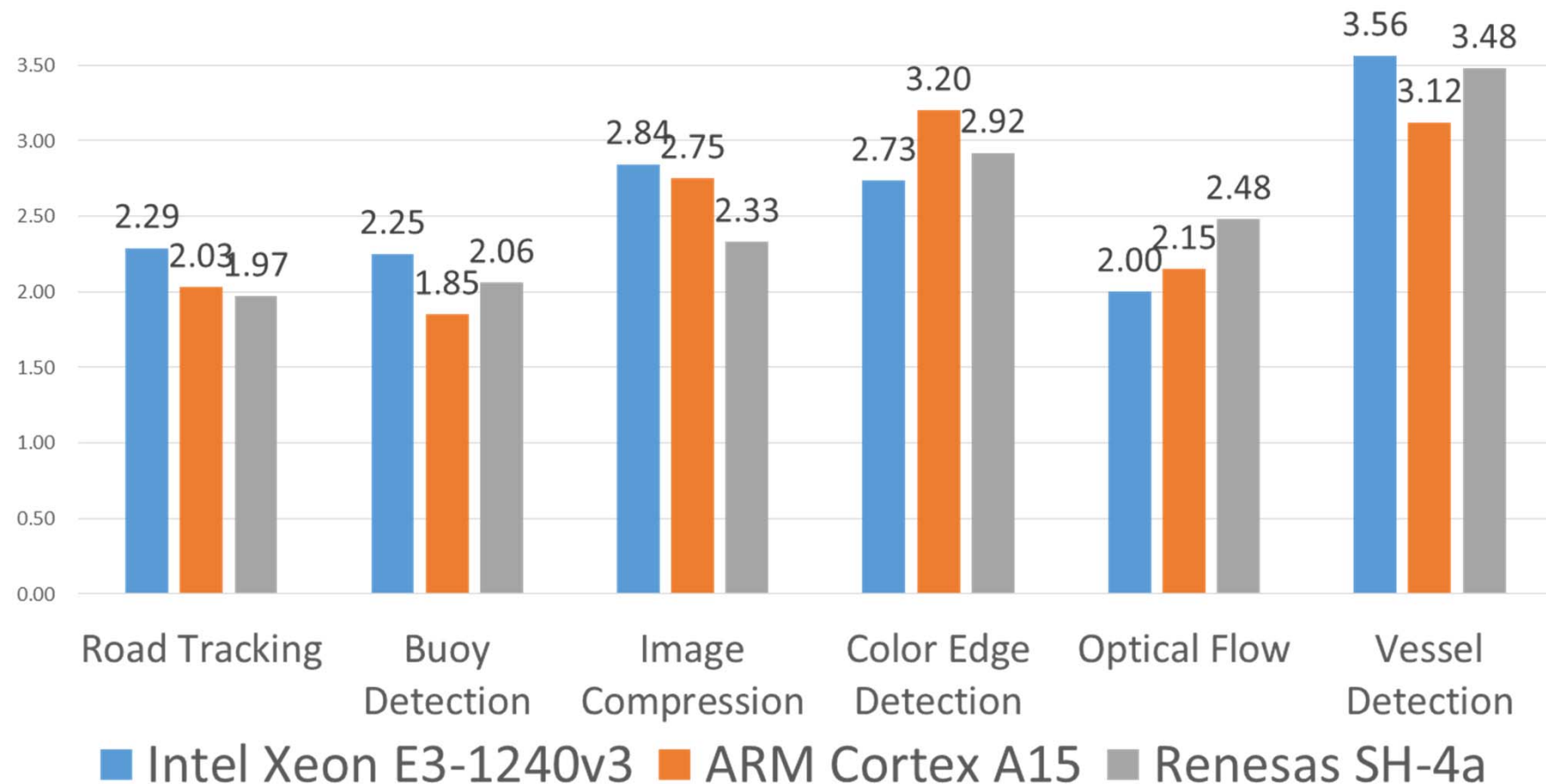
    VesselExtraction_step_PEO ( ) ;

    oscar_thread_join ( thr1 ) ;
    oscar_thread_join ( thr2 ) ;
    oscar_thread_join ( thr3 ) ;
}
```

(3) Generate parallelized C code
using the OSCAR API
→ Multiplatform execution
(Intel, ARM and SH etc)

Speedups of MATLAB/Simulink Image Processing on Various 4core Multicores

(Intel Xeon, ARM Cortex A15 and Renesas SH4A)



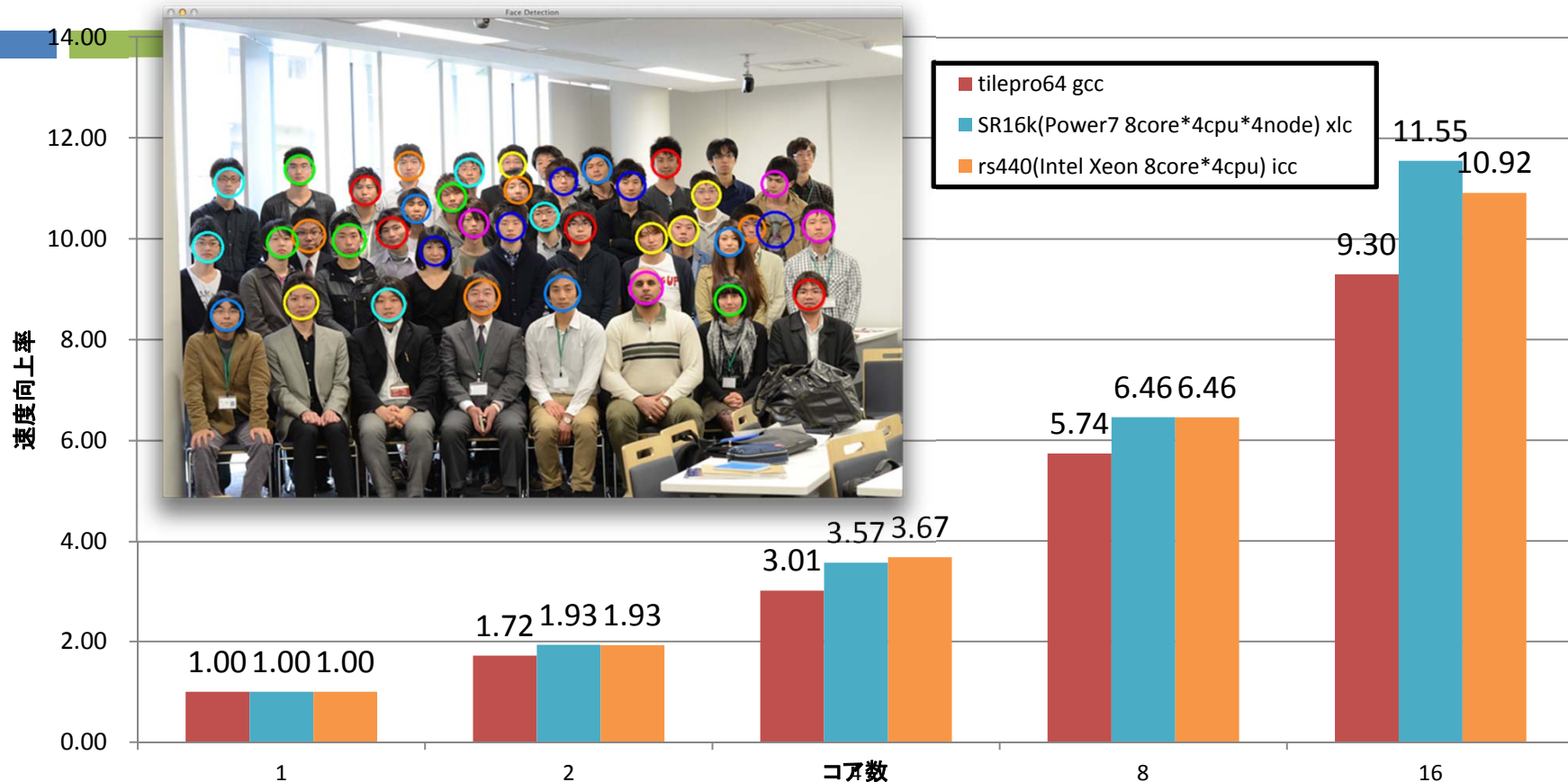
Road Tracking, Image Compression : <http://www.mathworks.co.jp/jp/help/vision/examples>

Buoy Detection : <http://www.mathworks.co.jp/matlabcentral/fileexchange/44706-buoy-detection-using-simulink>

Color Edge Detection : <http://www.mathworks.co.jp/matlabcentral/fileexchange/28114-fast-edges-of-a-color-image--actual-color--not-converting-to-grayscale-/>

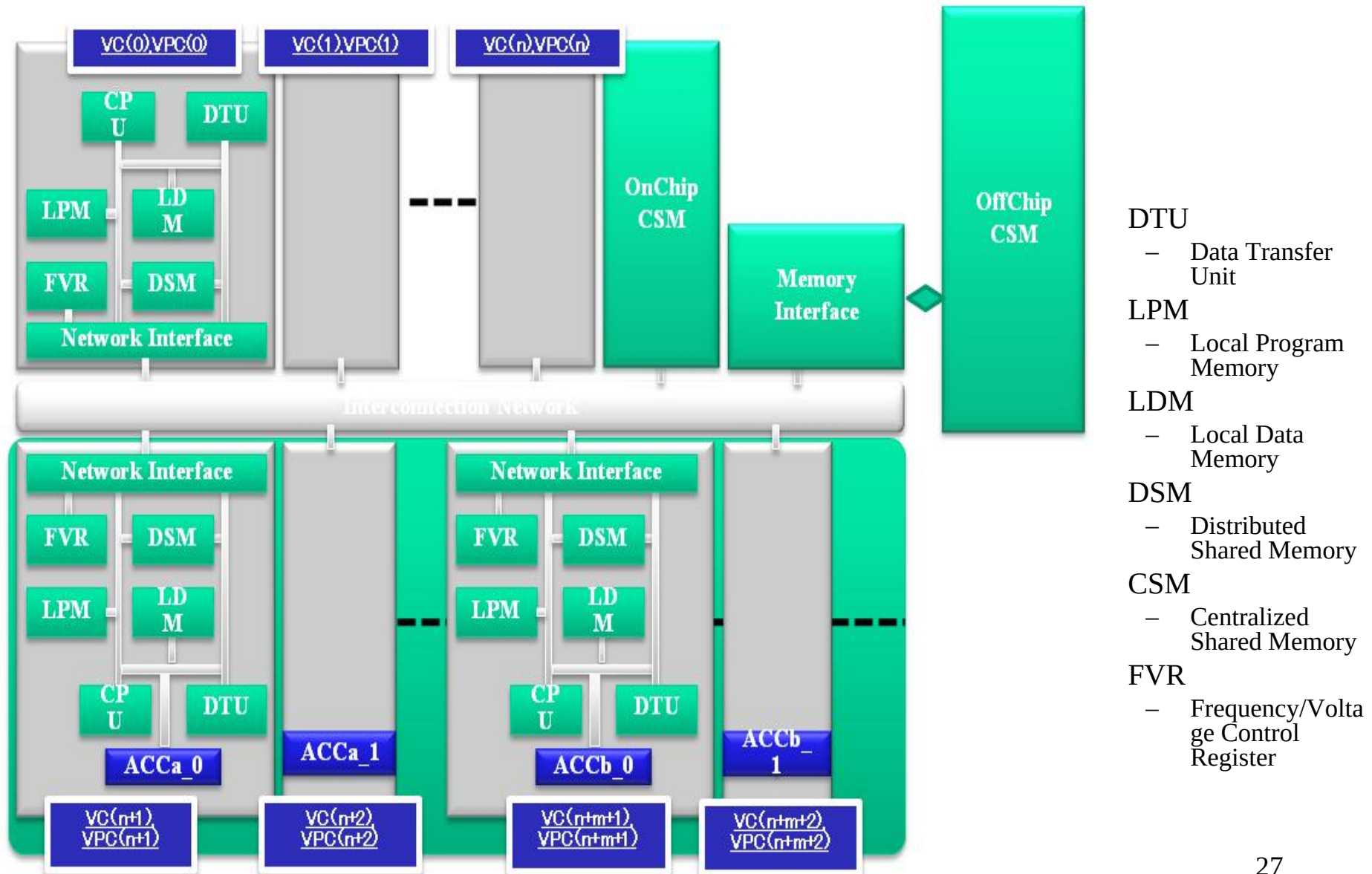
Vessel Detection : <http://www.mathworks.co.jp/matlabcentral/fileexchange/24990-retinal-blood-vessel-extraction/>

Parallel Processing of Face Detection on Manycore, Highend and PC Server

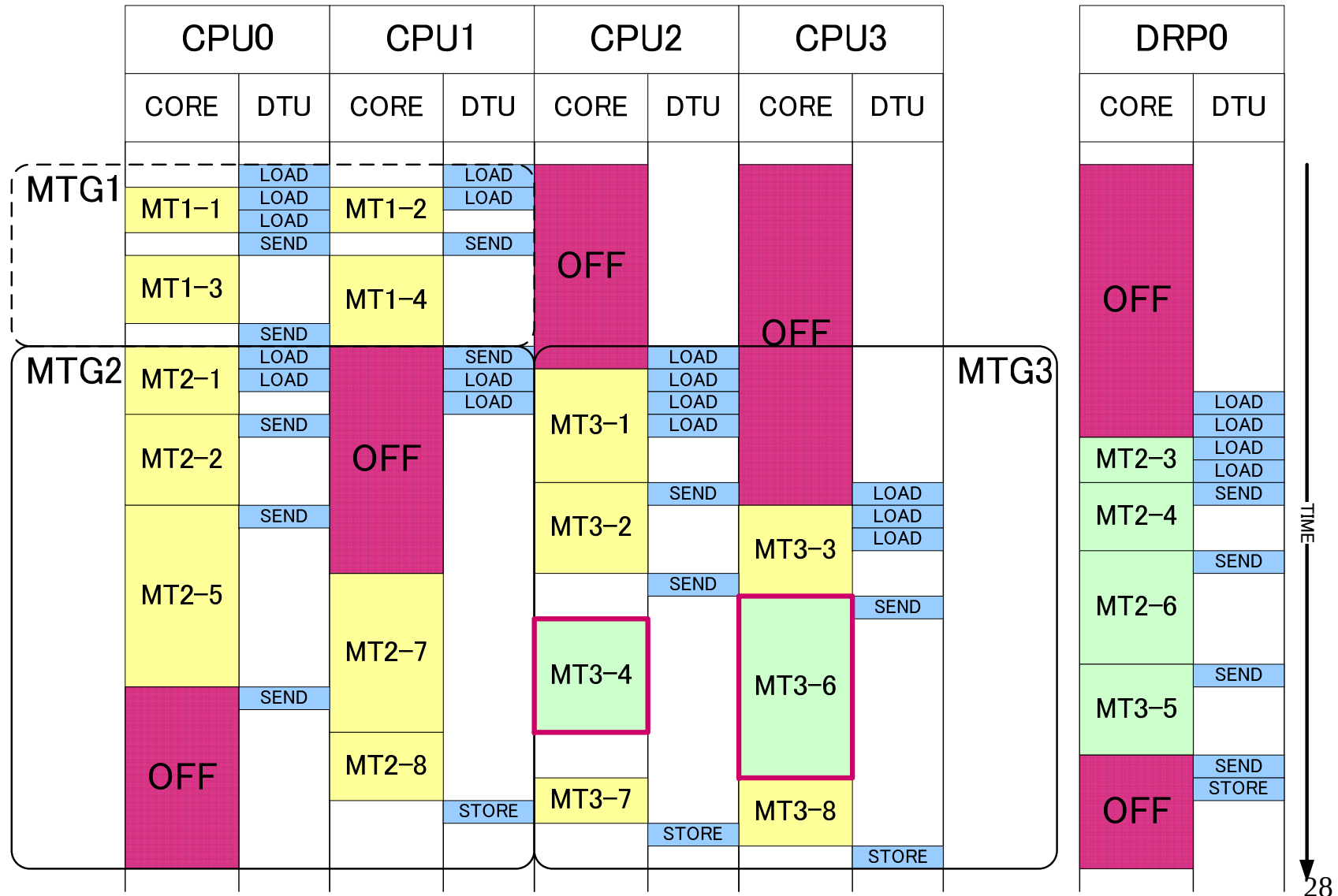


- OSCAR compiler gives us **11.55 times** speedup for 16 cores against 1 core on SR16000 Power7 highend server.

OSCAR Heterogeneous Multicore



An Image of Static Schedule for Heterogeneous Multi-core with Data Transfer Overlapping and Power Control



OSCAR API Ver. 2.0 for Homogeneous/Heterogeneous Multicores and Manycores (LCPC2009Homo, 2010 Hetero)

List of Directives (22 directives)

- ▶ **Parallel Execution API**
 - ▶ **parallel sections (*)**
 - ▶ **flush (*)**
 - ▶ **critical (*)**
 - ▶ **execution**
- ▶ **Memoay Mapping API**
 - ▶ **threadprivate (*)**
 - ▶ **distributedshared**
 - ▶ **onchipshared**
- ▶ **Synchronization API**
 - ▶ **groupbarrier**
- ▶ **Data Transfer API**
 - ▶ **dma_transfer**
 - ▶ **dma_contiguous_parameter**
 - ▶ **dma_stride_parameter**
 - ▶ **dma_flag_check**
 - ▶ **dma_flag_send**

(* from OpenMP)

- ▶ **Power Control API**
 - ▶ **fvcontrol**
 - ▶ **get_fvstatus**
- ▶ **Timer API**
 - ▶ **get_current_time**
- ▶ **Accelerator**
 - ▶ **accelerator_task_entry**
- ▶ **Cache Control**
 - ▶ **cache_writeback**
 - ▶ **cache_selfinvalidate**
 - ▶ **complete_memop**
 - ▶ **noncacheable**
 - ▶ **aligncache**

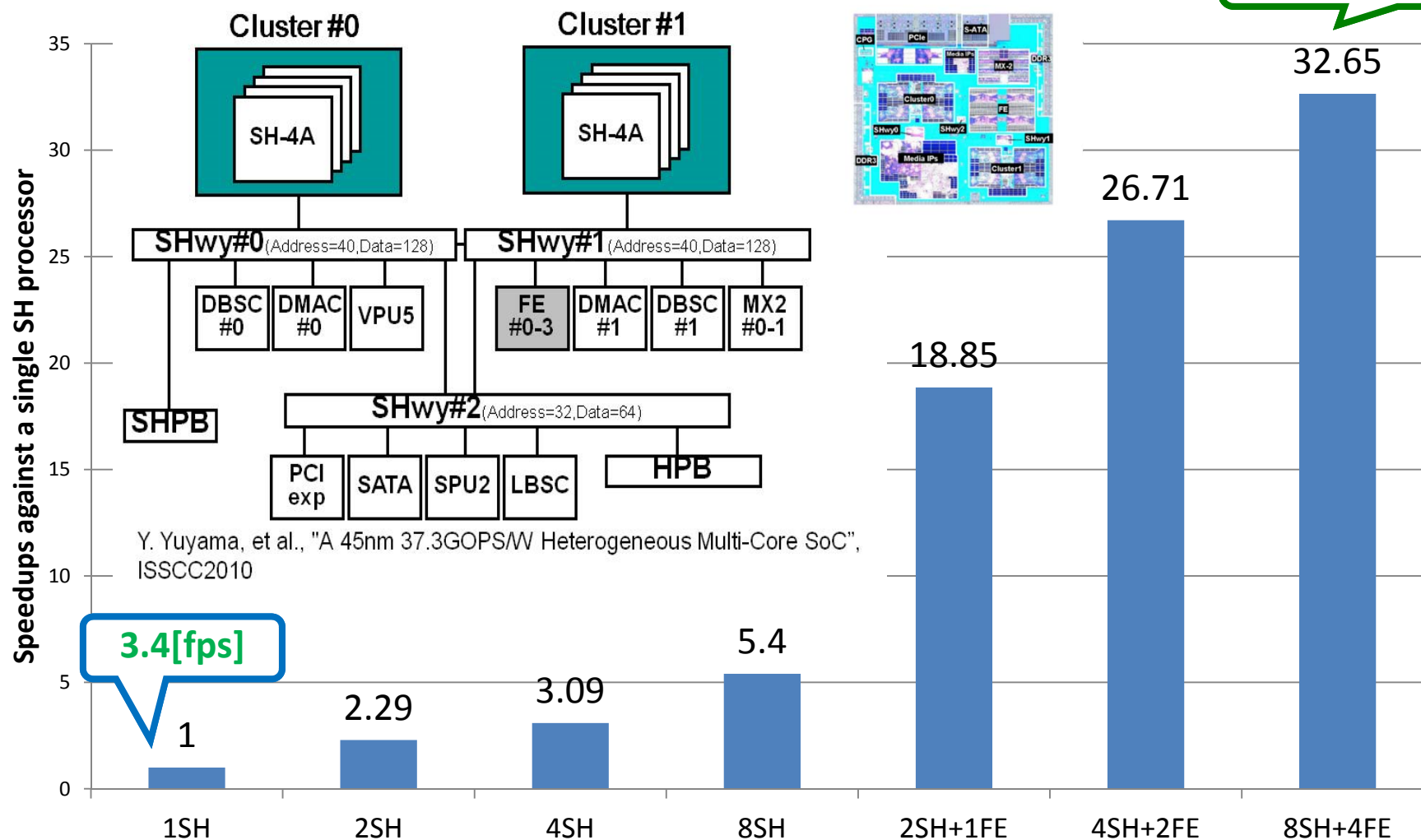
2 hint directives for OSCAR compiler

- **accelerator_task**
- **oscar_comment**

from V2.0

33 Times Speedup Using OSCAR Compiler and OSCAR API on RP-X (Optical Flow with a hand-tuned library)

111[fps]



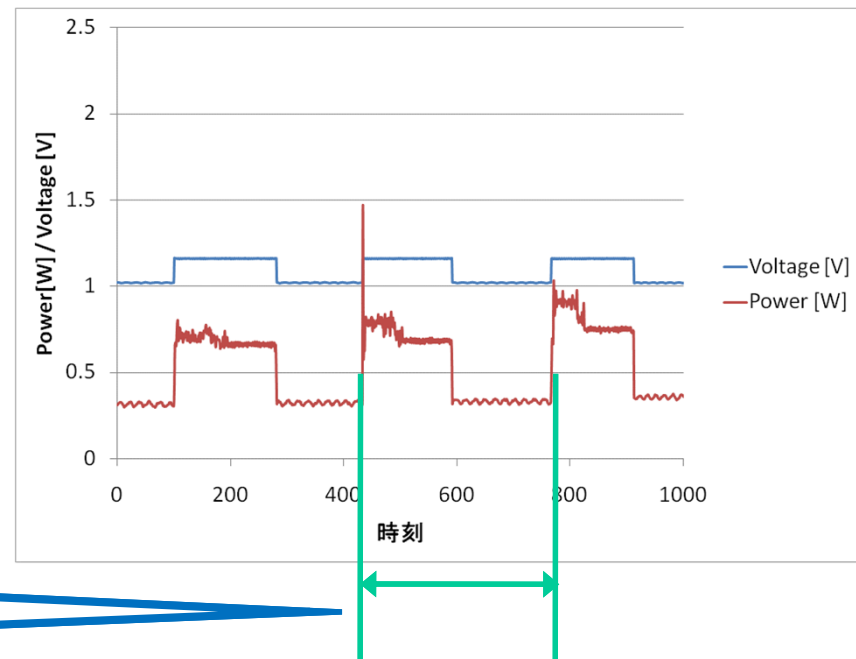
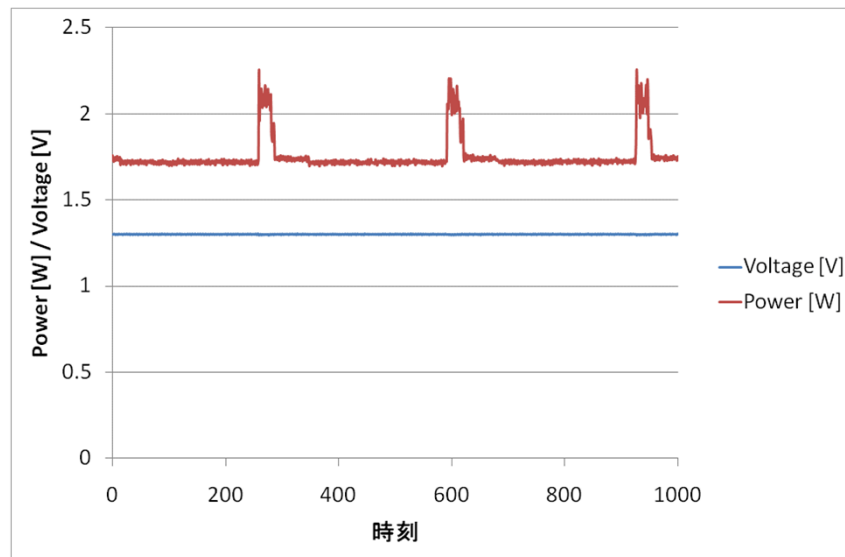
Power Reduction in a real-time execution controlled by OSCAR Compiler and OSCAR API on RP-X (Optical Flow with a hand-tuned library)

Without Power Reduction

**With Power Reduction
by OSCAR Compiler**
70% of power reduction

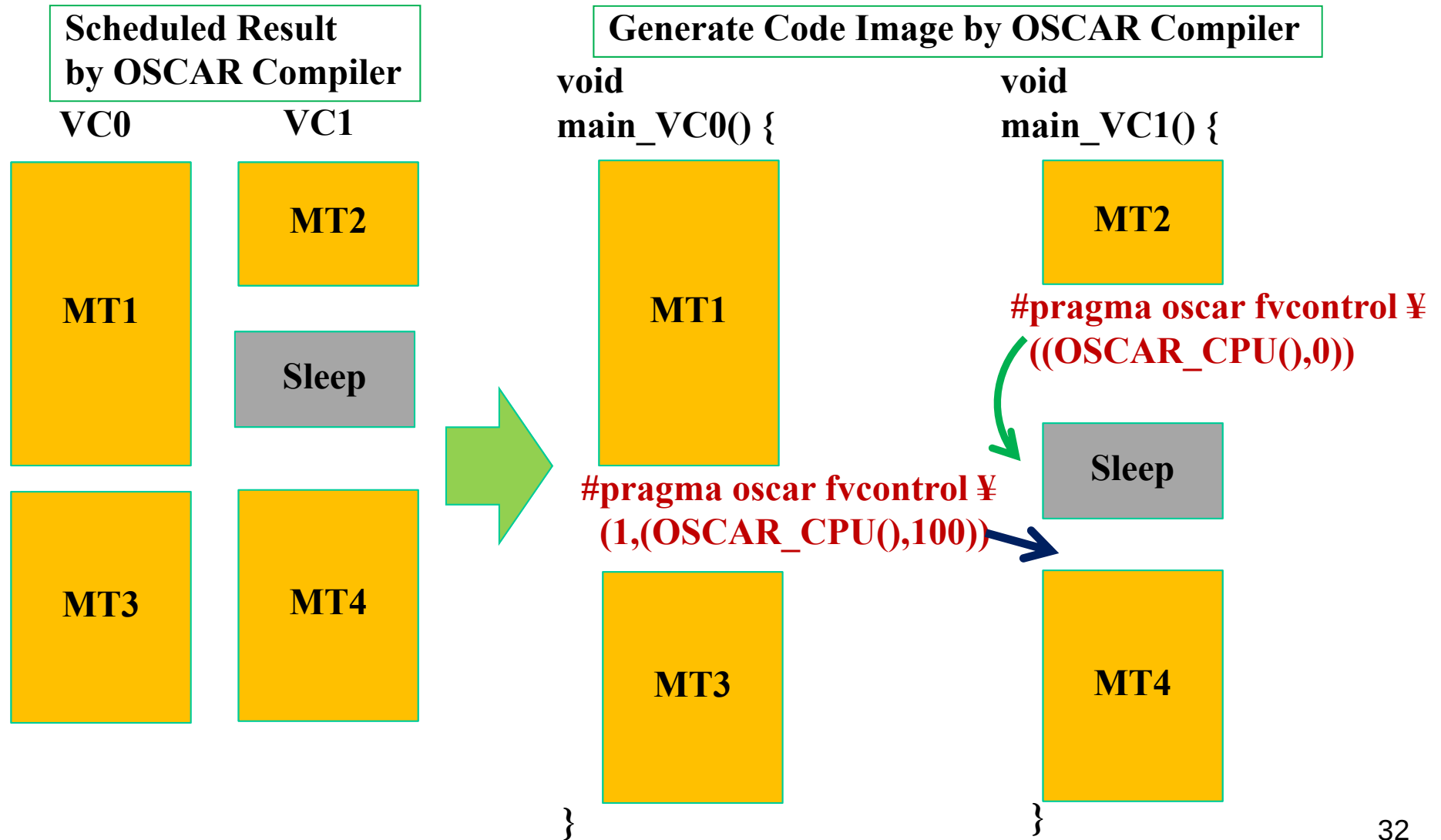
Average: 1.76[W]

Average: 0.54[W]



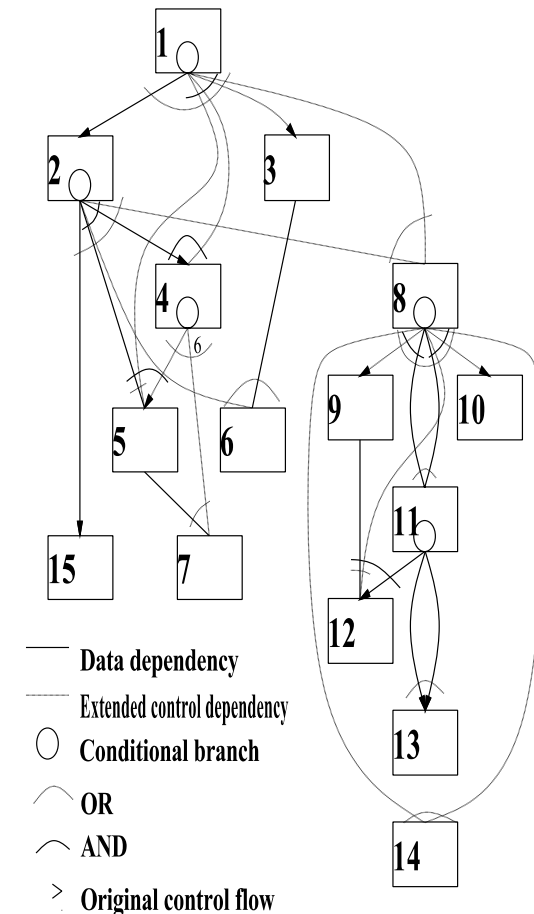
**1cycle : 33[ms]
→30[fps]**

Low-Power Optimization with OSCAR API



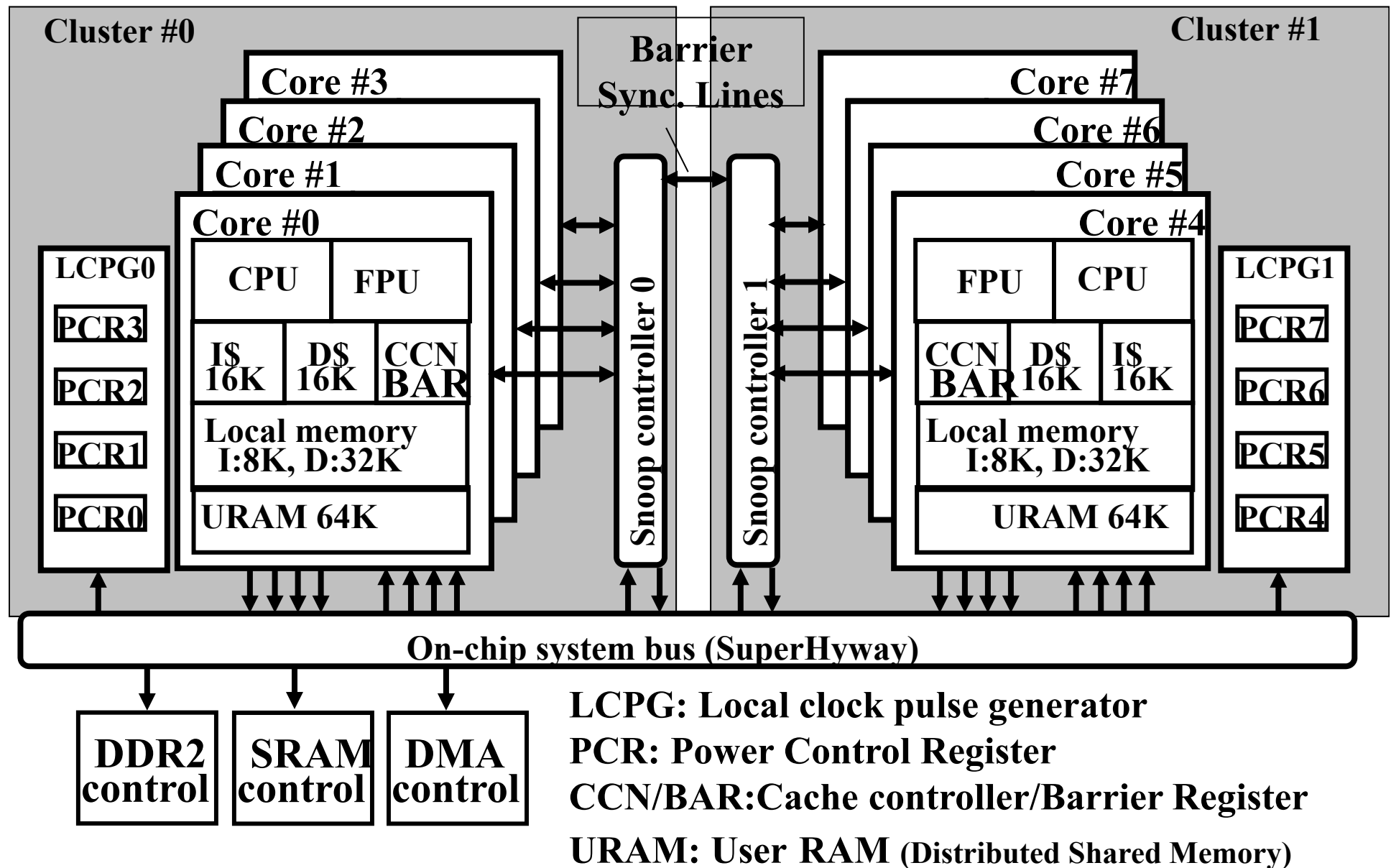
Software Coherence Control Method on OSCAR Parallelizing Compiler

- Coarse grain task parallelization with **earliest condition analysis** (control and data dependency analysis to detect parallelism among coarse grain tasks).
- OSCAR compiler automatically controls coherence using following simple program restructuring methods:
 - To cope with stale data problems:
 - ◆ **Data synchronization by compilers**
 - To cope with false sharing problem:
 - ◆ **Data Alignment**
 - ◆ **Array Padding**
 - ◆ **Non-cacheable Buffer**



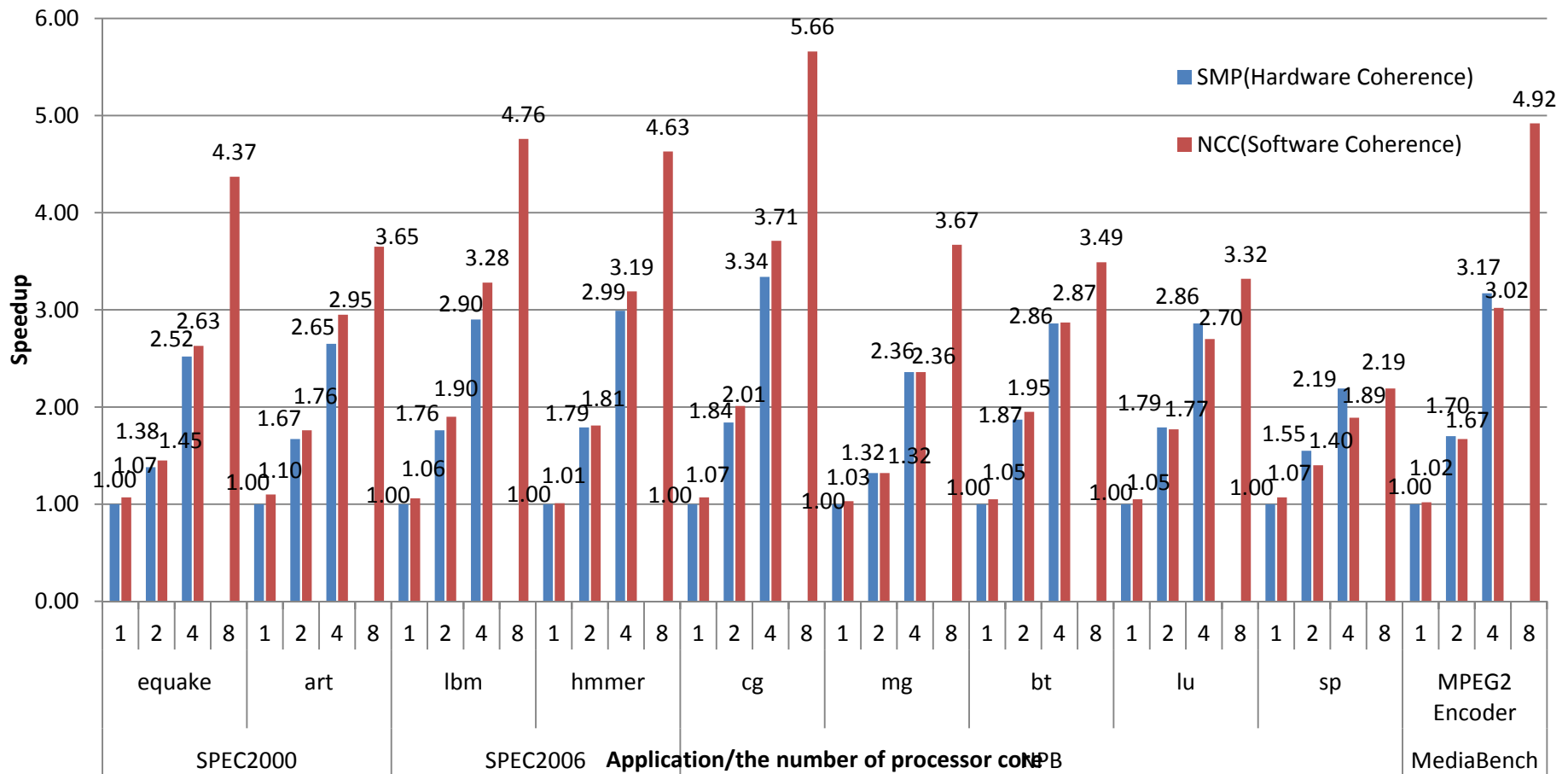
**MTG generated by
earliest executable
condition analysis**

8 Core RP2 Chip Block Diagram



Automatic Software Coherent Control for Manycores

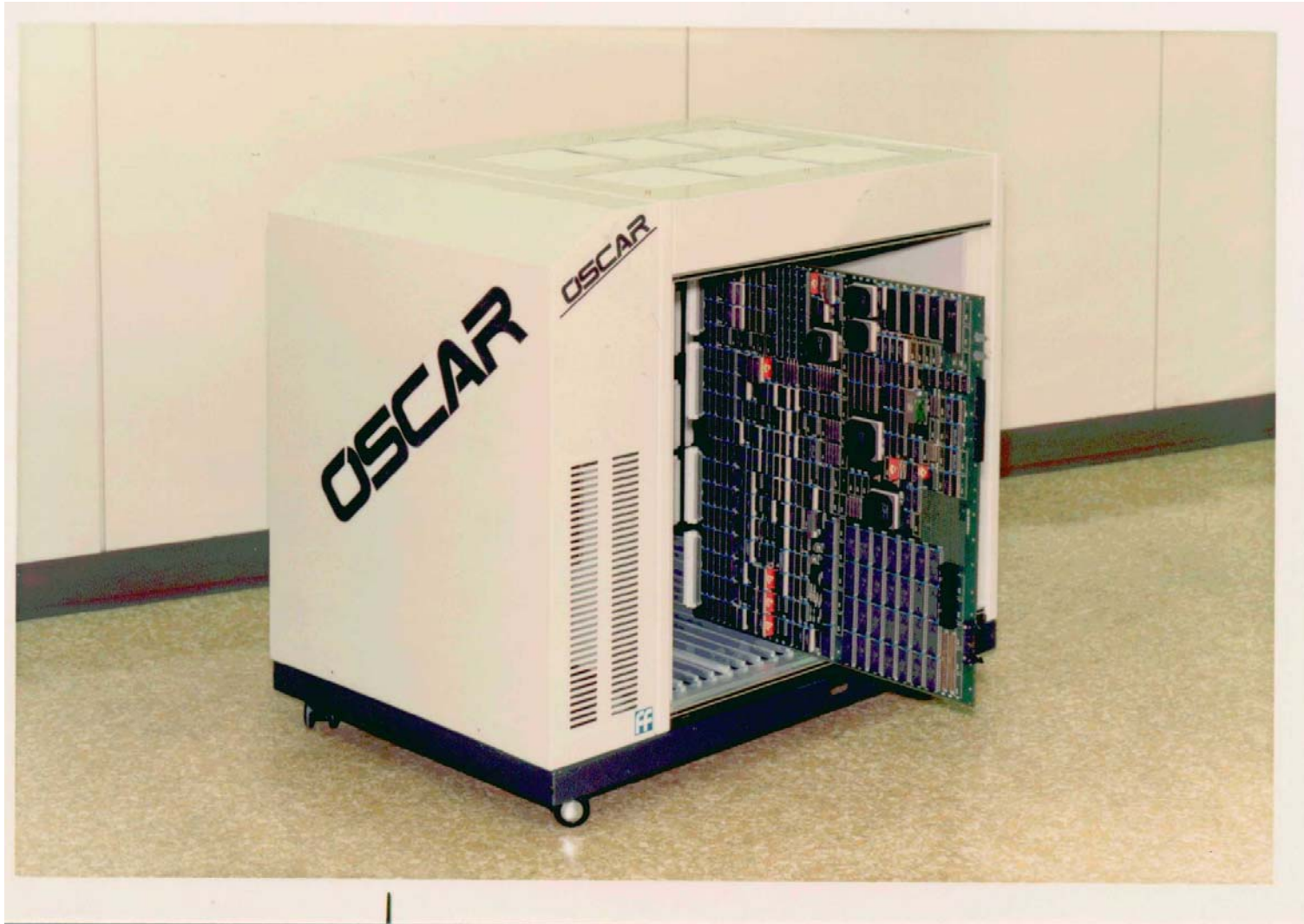
Performance of Software Coherence Control by OSCAR Compiler on 8-core RP2



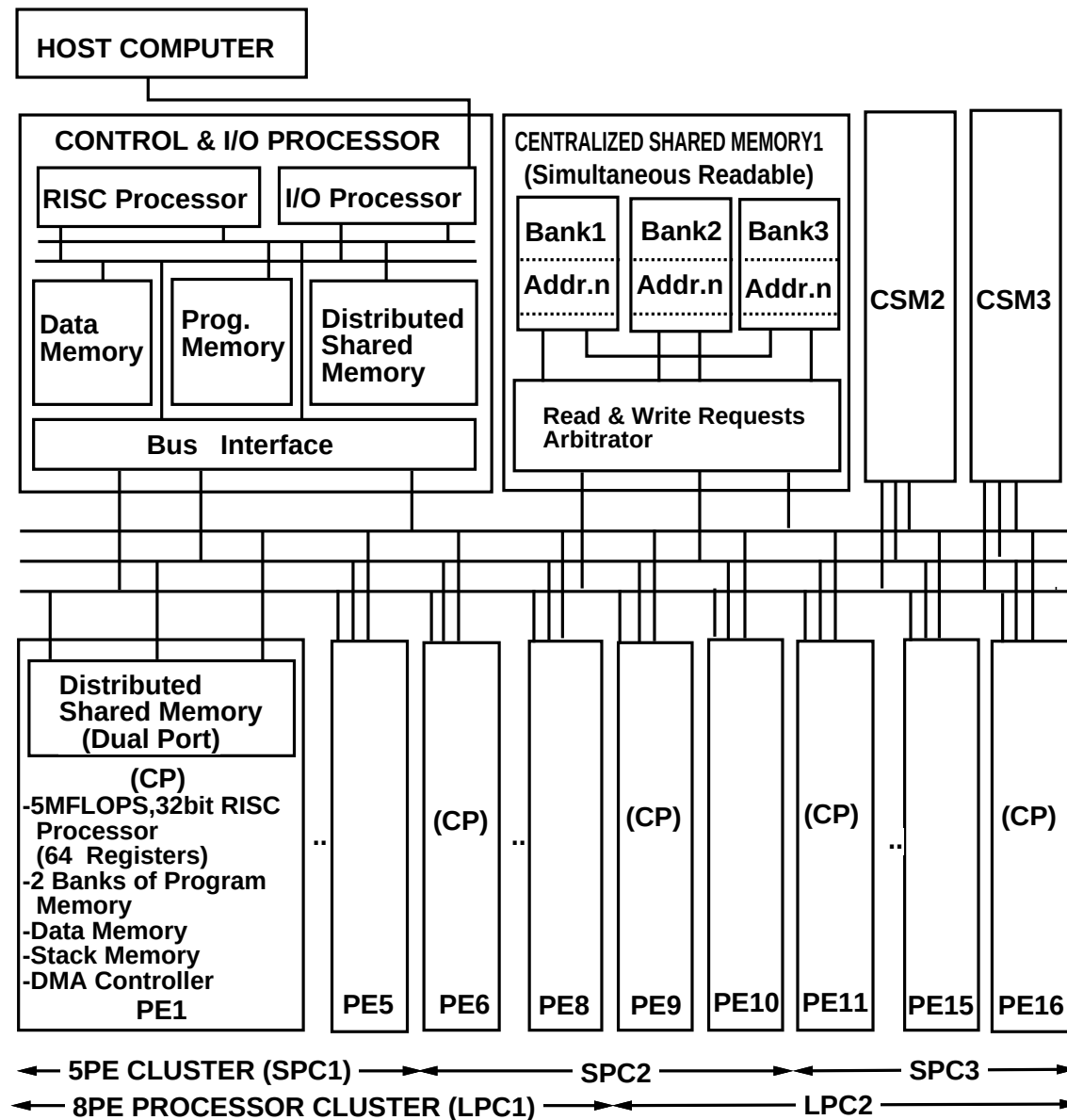
1987 OSCAR(Optimally Scheduled Advanced Multiprocessor)

Co-design of Compiler and Architecture

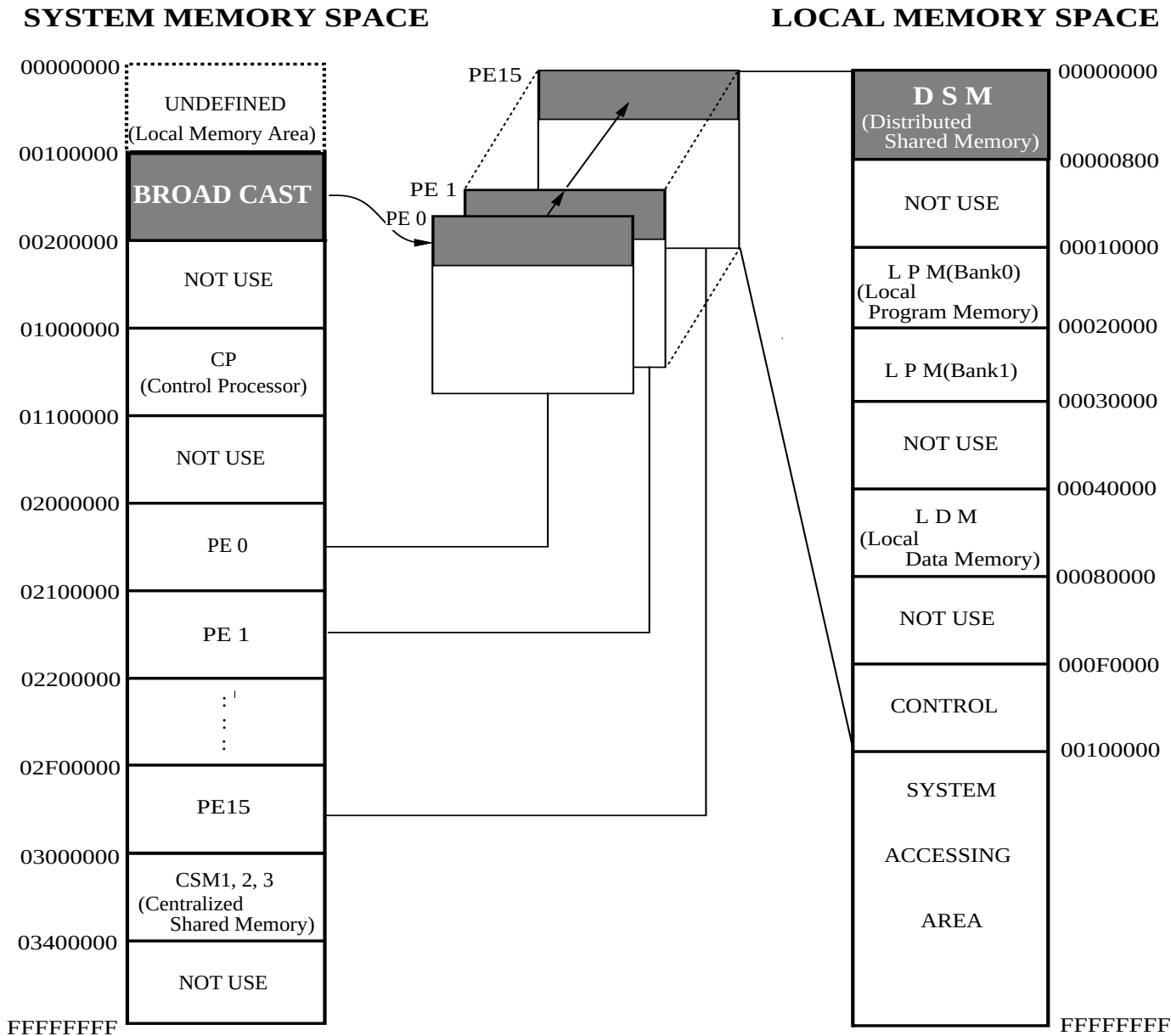
Looking at various applications, design a parallelizing compiler and design a multiprocessor/multicore-processor to support compiler optimization



OSCAR(Optimally Scheduled Advanced Multiprocessor)

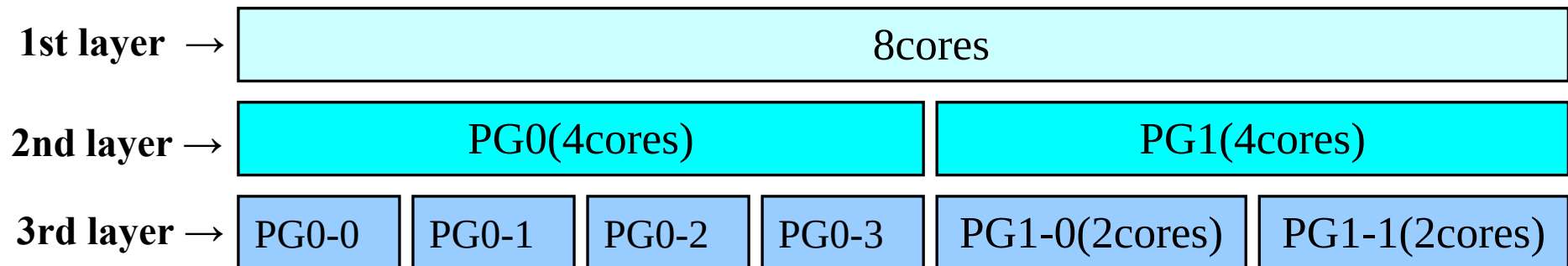


OSCAR Memory Space (Global Address Space)



Hierarchical Barrier Synchronization

- Specifying a hierarchical group barrier
 - `#pragma oscar group_barrier (C)`
 - `!$oscar group_barrier (Fortran)`



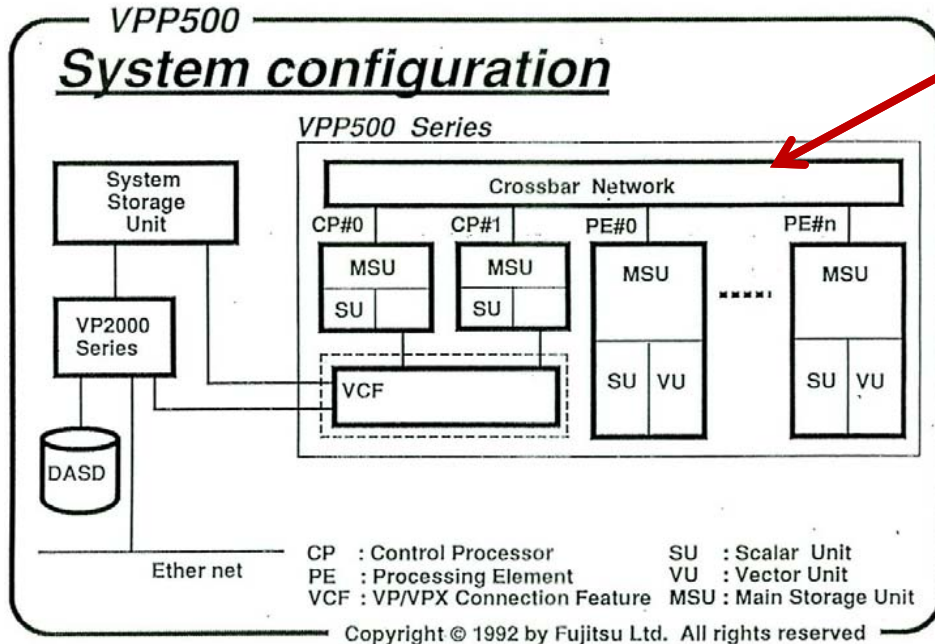
NWT



Machine Cycle Time	9.5ns (105MHz)
PE Performance	1.68GFlops
PE Memory Size	256MB/PE
Crossbar Bandwidth	4B/cycle x 2 (send/receive simultaneous)/PE = 421MB/s x 2 /PE
Number of PEs	140PEs + 2Control Proc.

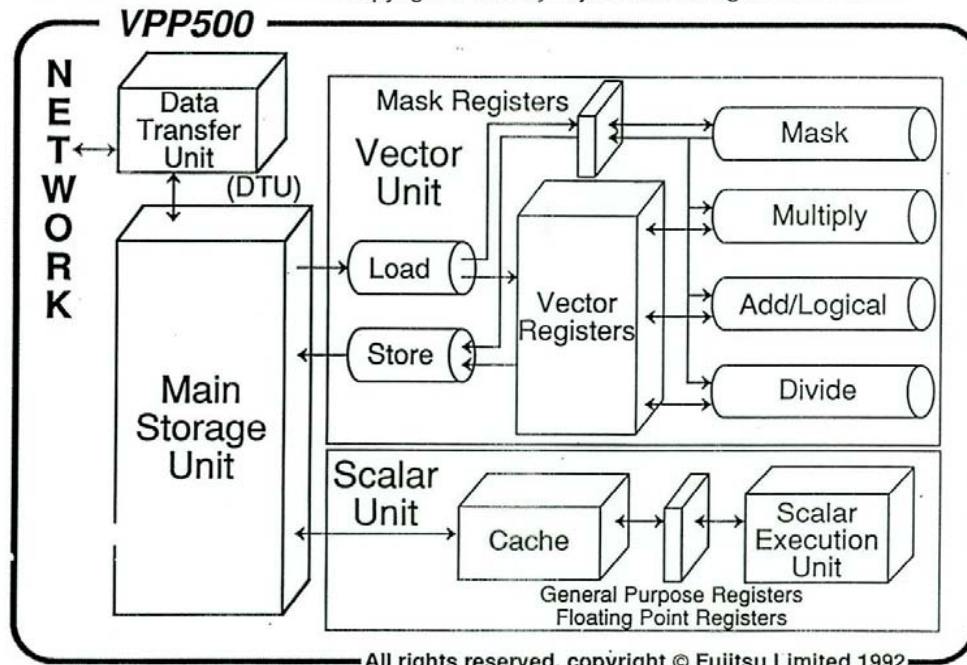
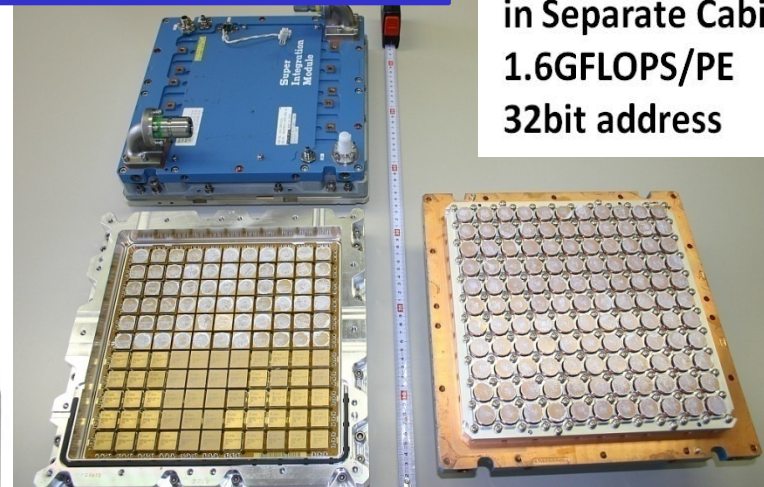
NAL computer center, Chofu, Tokyo, Feb. 1, 1993

Fujitsu Vector Parallel Supercomputer with Crossbar to a Chip



Crossbar Network
VPP500: 256*256
VPP5000:
1024*1024

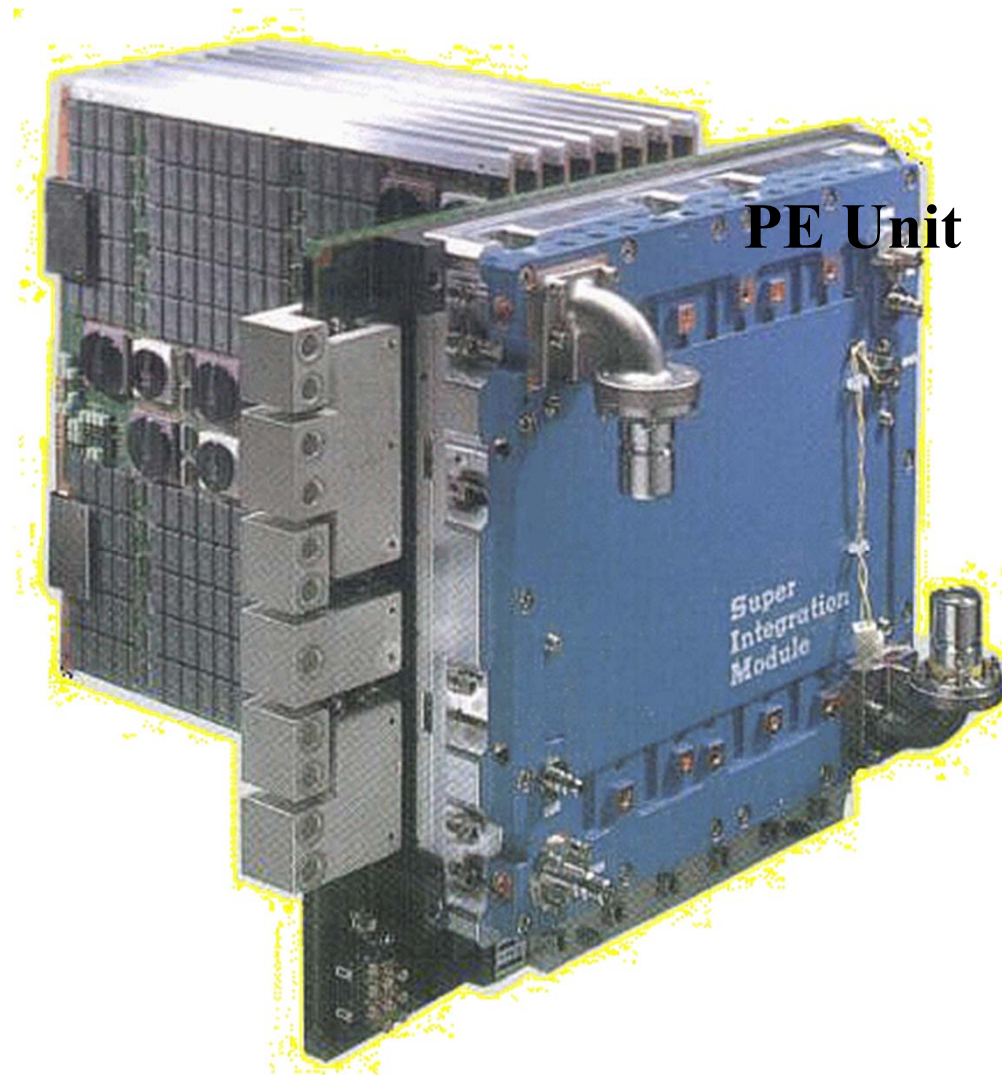
VPP500
GaAs/BiCMOS/ECL
Water Cooling
10ns
1GB/PE
in Separate Cabinet
1.6GFLOPS/PE
32bit address



VPP5000
0.25um CMOS
30M Tr./Chip
Forced Air Cooling
3.5ns clock cycle
8GB/PE
on PE Board
9.1GFLOPS/PE
32/64 bit address



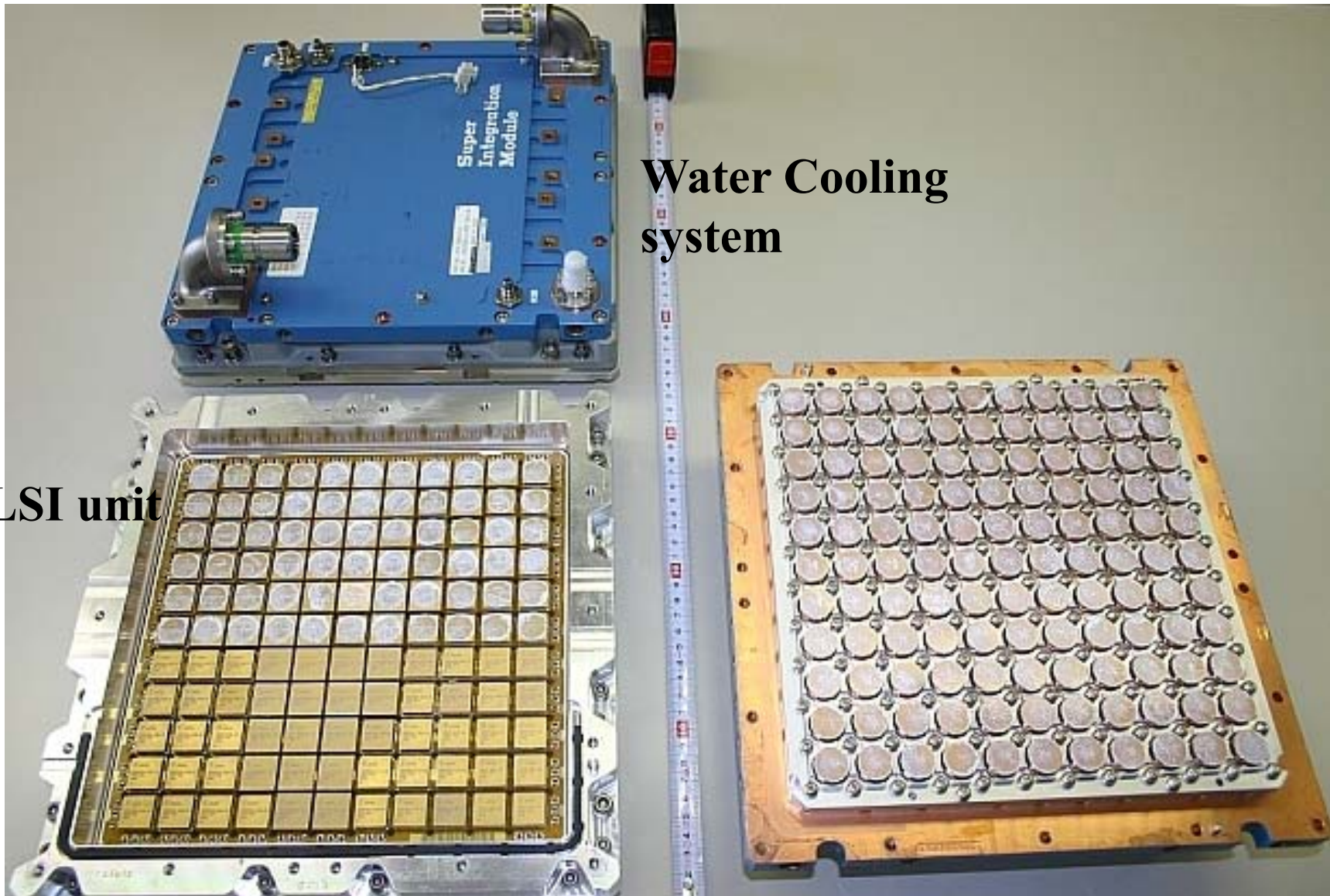
VPP500/NWT



PE Unit

VPP500/NWT

PE LSI unit



**Water Cooling
system**

Earth Simulator

(<http://www.es.jamstec.go.jp/>)

- Earth Environmental simulation like Global Warming, El Nino, Plate Movement for the all lives onr this planet.
- Developed in Mar. 2002 by STA (MEXT) and NEC with 400 M\$ investment under Dr. Miyoshi's direction.

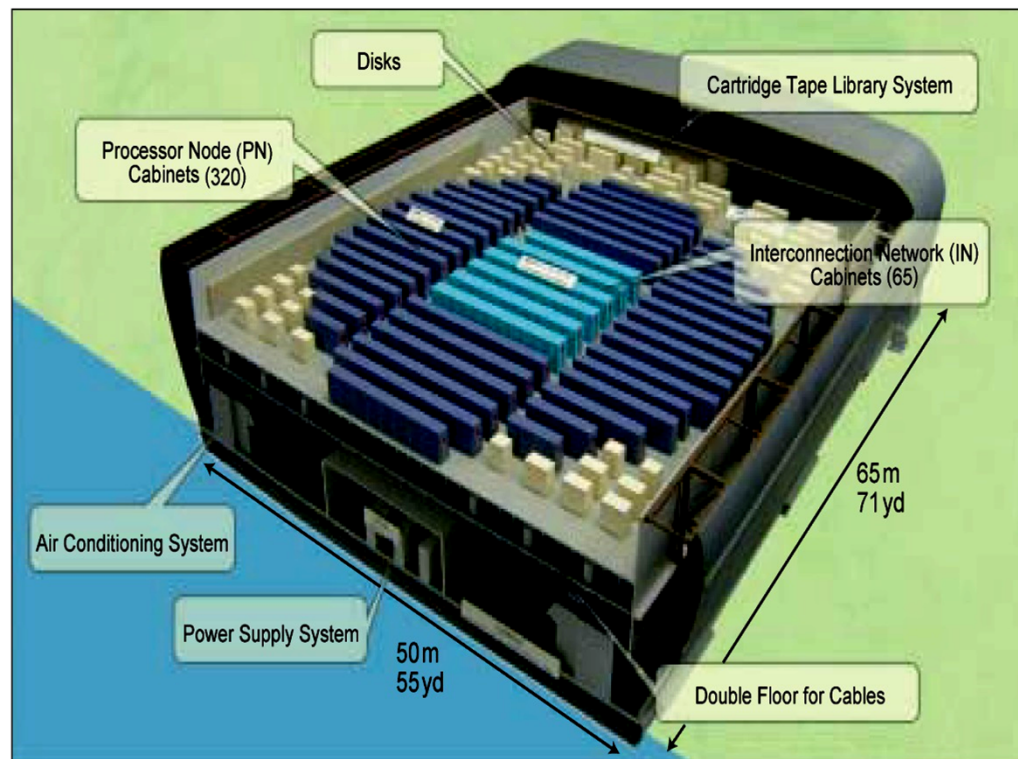
(Dr.Miyoshi: Passed away in Nov.2001. NWT, VPP500, SX6)



Mr. Hajime Miyoshi

Image of Earth Simulator

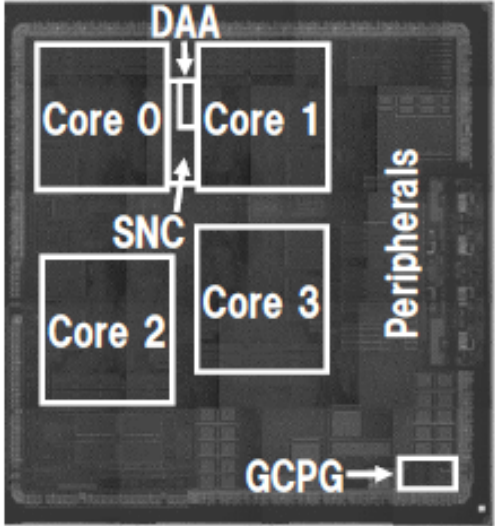
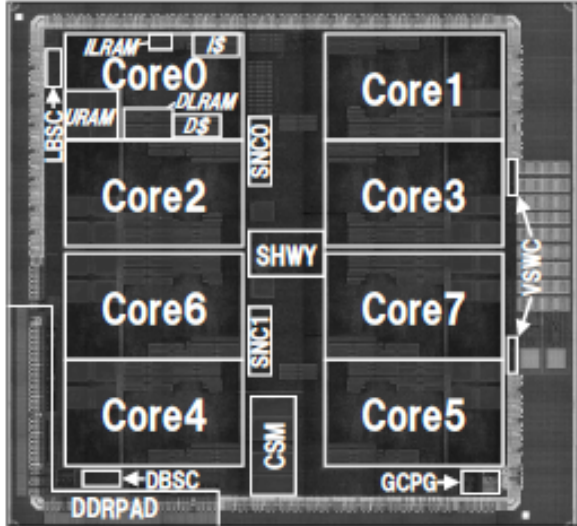
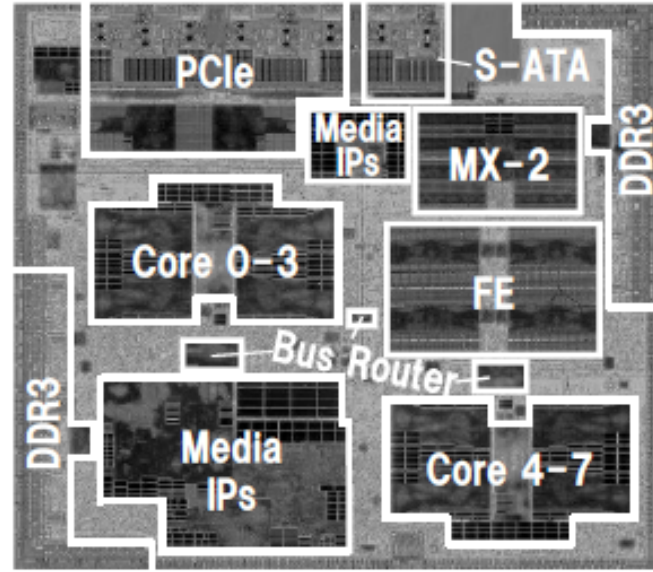
4 Tennis Courts



40 TFLOPS Peak (40×10^{12})
35.6 TFLOPS Linpack



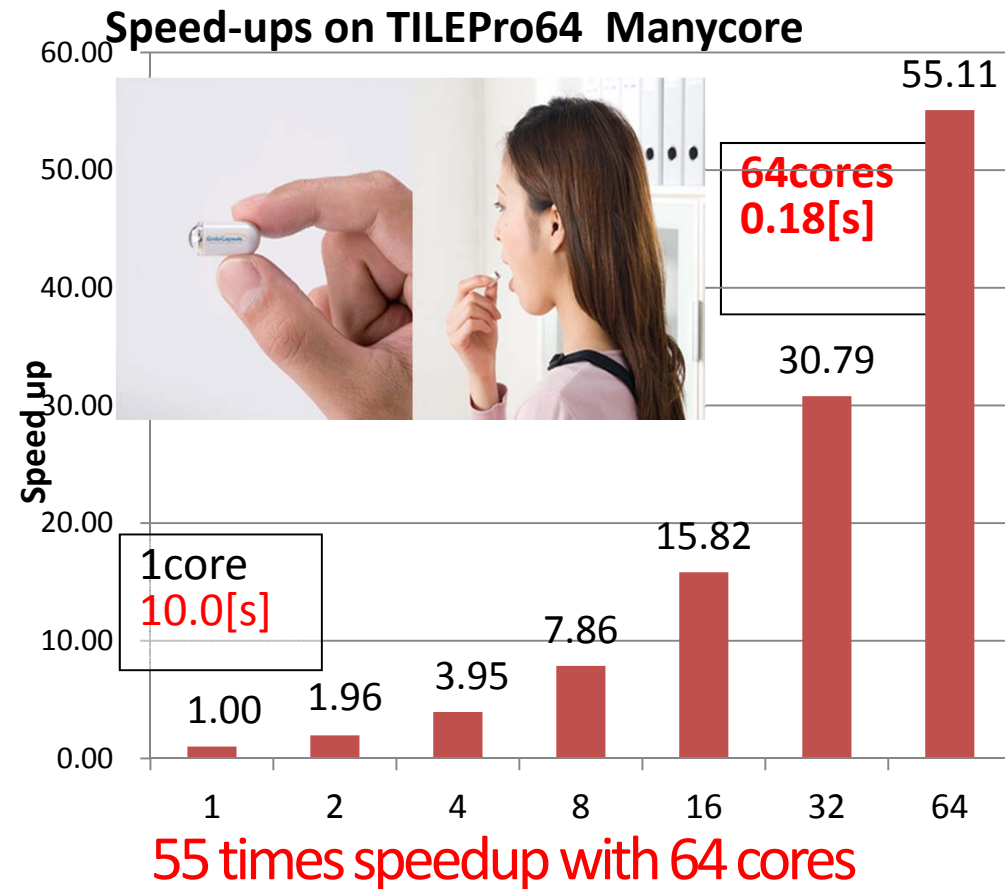
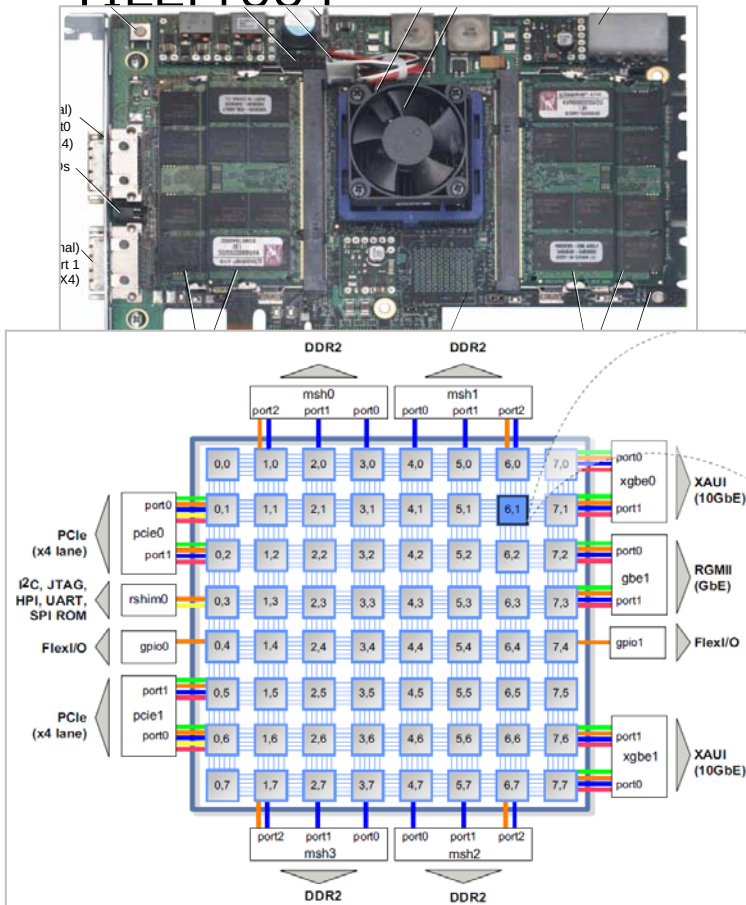
4 core multicore RP1 (2007) , 8 core multicore RP2 (2008) and 15 core Heterogeneous multicore RPX (2010) developed in NEDO Projects with Hitachi and Renesas

<i>RP-1</i> (ISSCC2007 #5.3)	<i>RP-2</i> (ISSCC2008 #4.5)	<i>RP-X</i> (ISSCC2010 #5.3)
		
90nm, 8-layer, triple-Vth, CMOS	90nm, 8-layer, triple-Vth, CMOS	45nm, 8-layer, triple-Vth, CMOS
97.6 mm ² (9.88 x 9.88 mm)	104.8 mm ² (10.61 x 9.88 mm)	153.8 mm ² (12.4 x 12.4 mm)
1.0V (internal), 1.8/3.3V (I/O)	1.0-1.4V (internal), 1.8/3.3V (I/O)	1.0-1.2V (internal), 1.2-3.3V (I/O)
600MHz ,4.32 GIPS,16.8 GFLOPS	600MHz , 8.64 GIPS, 33.6 GFLOPS	648MHz, 13.7GIPS, 115GOPS, 36.2GFLOPS
11.4 GOPS/W (32b換算)	18.3 GOPS/W (32b換算)	37.3 GOPS/W (32b換算)

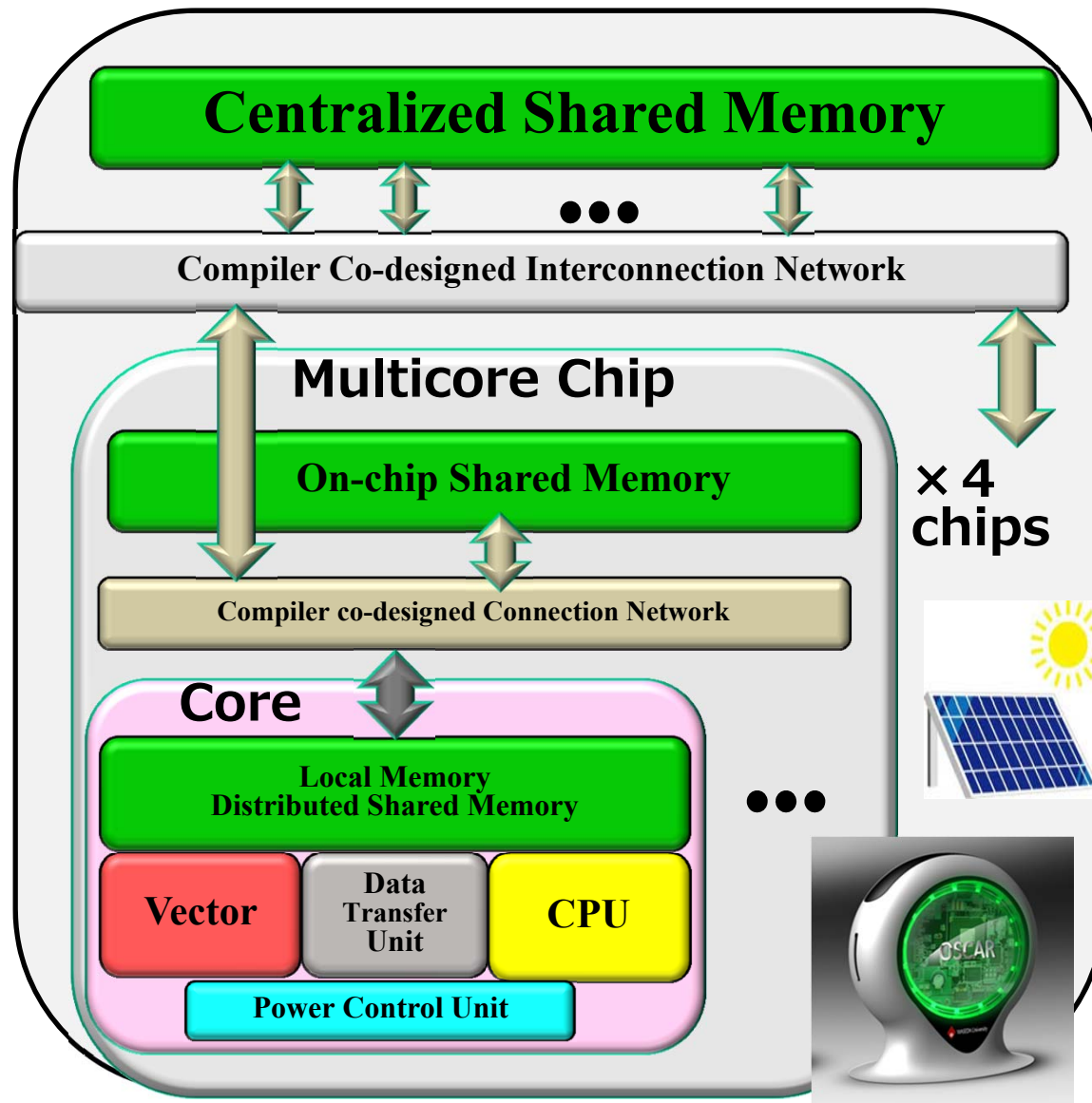
Automatic Parallelization of JPEG-XR for Drinkable Inner Camera (Endo Capsule)

10 times more speedup needed after parallelization for 128 cores of
Power 7. Less than 35mW power consumption is required.

- TILEPro64



OSCAR Vector Multicore and Compiler for Embedded to Servers with OSCAR Technology



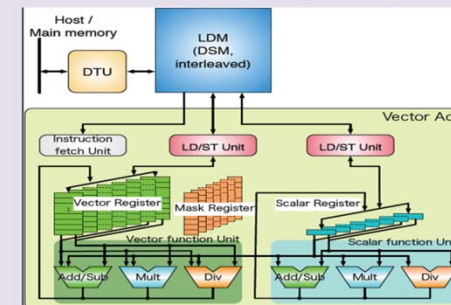
Target:

- Solar Powered
- Compiler power reduction.
- Fully automatic parallelization and vectorization including local memory management and data transfer.

Vector Accelerator

Features

- Attachable for any CPUs (Intel, ARM, IBM)
- Data driven initiation by sync flags

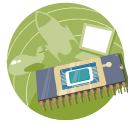


Function Units [tentative]

- **Vector Function Unit**
 - 8 double precision ops/clock
 - 64 characters ops/clock
 - Variable vector register length
 - Chaining LD/ST & Vector pipes
- **Scalar Function Unit**

Registers[tentative]

- **Vector Register** 256Bytes/entry, 32entry
- **Scalar Register** 8Bytes/entry
- **Floating Point Register** 8Bytes/entry
- **Mask Register** 32Bytes/entry



Future Multicore Products



Next Generation Automobiles

- Safer, more comfortable, energy efficient, environment friendly
- Cameras, radar, car2car communication, internet information integrated brake, steering, engine, motor control

Smart phones



- From everyday recharging to less than once a week
- Solar powered operation in emergency condition
- Keep health

Advanced medical systems



Cancer treatment, Drinkable inner camera

- Emergency solar powered
- No cooling fan, No dust, clean usable inside OP room



Personal / Regional Supercomputers



Solar powered with more than 100 times power efficient : FLOPS/W

- Regional Disaster Simulators saving lives from tornadoes, localized heavy rain, fires with earthquakes

Summary

- Waseda University Green Computing Systems R&D Center supported by METI has been researching **on low-power high performance Green Multicore** hardware, software and application with industry including Hitachi, Fujitsu, NEC, Renesas, Denso, Toyota, Olympus and OSCAR Technology.
- OSCAR Automatic Parallelizing and Power Reducing Compiler has succeeded speedup and/or power reduction of scientific applications including “Earthquake Wave Propagation”, medical applications including “Cancer Treatment Using Carbon Ion”, and “Drinkable Inner Camera”, industry application including “Automobile Engine Control”, “Smartphone”, and “Wireless communication Base Band Processing” on various multicores from different vendors including Intel, ARM, IBM, AMD, Qualcomm, Freescale, Renesas and Fujitsu.
- In automatic parallelization, **110 times speedup** for **“Earthquake Wave Propagation Simulation”** on **128 cores of IBM Power 7** against 1 core, **55 times speedup** for **“Carbon Ion Radiotherapy Cancer Treatment”** on **64cores IBM Power7**, **1.95 times** for **“Automobile Engine Control”** on **Renesas 2 cores** using **SH4A or V850**, **55 times** for **“JPEG-XR Encoding for Capsule Inner Cameras”** on **Tilera 64 cores Tile64 manycore.**
 - The compiler will be available on market from OSCAR Technology.
- In automatic power reduction, consumed powers for real-time multi-media applications like **Human face detection, H.264, mpeg2 and optical flow** were **reduced to 1/2 or 1/3 using 3 cores** of ARM Cortex A9 and Intel Haswell and **1/4 using Renesas SH4A 8 cores** against ordinary single core execution.
- **Local memory management** for automobiles and **software coherent control** have been patented and already realized by OSCAR compiler.