資料1－1

A Study of the Ripple Effects From The K Computer And The Potential Impacts Of The Post K Computer

Earl Joseph, ejoseph@idc.com
Steve Conway, sconway@idc.com
Robert Sorensen, bsorensen@idc.com
Kevin Monroe, kmonroe@idc.com
Nishi Katsuya, nishi@hpcwire.jp

December 5, 2016

IDC Company Overview

- IDC is an independent global market intelligence, events, and advisory firm for information technology, telecommunications, and consumer technology markets (ICT)
- More than 1,200 IDC analysts, including in-house statisticians and economists, provide global, regional, and local expertise on technology and industry opportunities and trends in over 110 countries
- IDC has been delivering IT intelligence, industry analysis, market data, and strategic guidance since its 1964 founding by Patrick McGovern
- Our multilingual, multicultural workforce surveys over 360,000 technology users and decision makers annually, delivering unrivaled coverage

IDC Has Over 1,200 Analysts In 62 Countries

About IDC: IDC HPC Activities

- **Track all HPC servers sold each quarter**
- **4 HPC User Forum meetings each year**
- **Publish 85+ research reports each year**
- **Visit major supercomputer sites & write reports**
- **Assist buyers/users in planning and procurements**
- **Maintain 5 year forecasts in many areas/topics**
- **Assist governments in HPC plans, strategies and direction**
- **Developing a worldwide ROI measurement system**

Recent IDC Government HPC Studies (Examples)

U.S. Government

- **NSF:** Best practices in government-industry partnerships (worldwide)
- **Blue Waters:** Scientific Results from the Blue Waters Supercomputer System
- **USG:** Best cyber security practices in US private sector (2 studies)
- **DOE:** ROI related to HPC investments (worldwide)
- **DOE:** Labs' ideas for improving US economic competitiveness
- **DOE:** HPC workforce development
- **NASA**: Recommendations for expanding HPC capacity
- **DOE:** Evaluation of the ASC/ASCI program, recommendations

Other Governments

- **EU:** Evaluation of HPC progress, recommendations
- **EU:** Highly parallel software – status, recommendations
- **EU:** Recommendations for first Europe-wide HPC strategy
- **Germany:** National HPC center user satisfaction
- **Netherlands**: National HPC center user satisfaction
- **South Korea:** National HPC status and recommendations
- **Saudi Arabia:** Using HPC to diversify the economy, recommendations

The Purpose of This Study: Ripple Effects of K and Post-K

The purpose of this study was to gain insights and gather quantitative data related to the ripple effect of RIKEN's existing K supercomputer and the potential benefit of a RIKEN development for a new flagship Post-K computer with a planned operational date of around fiscal 2020.

- Currently, the Post-K computer effort is supported as a development and maintenance project with a total project cost of investment 130 billion yen (of which the national fund is worth about 110 billion yen) in 2014 by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).
- For the purpose of this study, RIKEN and IDC jointly defined the so-called ripple effect as the widespread impact of the availability of K and Post-K computers on Japan's overall scientific, industrial and economic sectors.

Methodology

IDC used the methodology first developed in the 2013 HPC ROI (return-on-investment) study for the U.S. Department of Energy.

- Gain insights into the overall financial impact of leadership supercomputers using two specific quantitative metrics:
  - The financial return on investment (ROI) on a scientific or technological advancement achieved through the use of K and Post-K computers.
  - An innovation return on research (ROR) metric that measured the innovative quality of a research effort supported by K and Post-K computers.

Questions Used In The Study

As a first step, IDC worked with RIKEN to develop a broad set of questions that would address the issue from multiple interrelated perspectives:

For example:

- What is your research area?
- What are (or is expected to be) THE TOTAL REVENUES/SALES from this study
- What are (or will be) the COST SAVINGS from this study
- How would you rate the IMPORTANCE this innovation
- How would you rate the IMPACT of this innovation to multiple organizations

Additional Key Topics Researched:

- How the Post-K computer Could Help Their Research
- The importance to Japan of having a world class Post-K computer

The Researchers Surveyed

IDC conducted a set of surveys of researchers and people using the K computer and planning to use the Post-K computer.

The people surveyed included:

- HPC researchers using the K computer:
  - For “Strategic Programs for Innovative Research (SPIRE) ”, we surveyed all of the cases that each representative organization suggested.
  - For other programs, we surveyed all of the cases that we could find that had issued press releases.
- HPC researchers that may use the Post-K computer:
  - For “the priority issues”, we surveyed all of the cases that each representative organization suggested.
- Industrial users of the K computer:
  - We surveyed all of the cases that had issued a press releases and/or major results.

Study Overview: Project Background

- IDC conducted a series of in-person, in-depth interviews with specified groups on the ripple effects of the K computer, and the Post-K computer.
  - We have interviewed a total of 21 different organizations and 48 different researchers.
  - The survey included a total of 117 innovation project s and 29 financial ROI cases, for a total of 146 cases (a few projects had both innovation and an ROI data).
  - Covering all nine major areas
  - The sample was focused on the top successful projects

Study Background: Review Experts

In order to triple ensure that the data is correct, believable and defensible, we are using a two tier process:

1. Submissions forms are reviewed and accepted or rejected
    1. First, IDC experts review each submission to see if the information is correct
        - If not, IDC experts work with the submitter to collect better data
    2. Then the HPC User Forum Steering Committee (listed at: www.hpcuserforum.com) reviews each submission for accuracy and for importance
    3. When required, vertical experts then review the submissions
    4. → If successful the submission goes into consideration for both an innovation award and for inclusion in the economic database
2. Then two expert groups review them prior to being entered into the main database
    1. For economic soundness
    2. For technical soundness

About The International Review Committee

Extended Review Committee by Sector:

- Education--University/Academic 216
- Energy--and geosciences 39
- Entertainment--Digital Content Creation & Distribution 5
- Finance/Insurance--Economics/Financial 26
- Government--Defense, Labs, Research Centers, etc. 123
- Health, Bio-Sciences, life sciences 63
- Manufacturing--Discrete & Process – CAE, EDA/IT/ISV 105
- Other 109
- Transportation 8
- Weather--Climate and Earth Sciences 27

- Around 721 at this time

About The Japanese Review Committee

Extended Review Committee by Sector:

- Education--University/Academic = 32
- Weather--Climate and Earth Sciences = 11
- Material sciences, etc. = 11
- Physics = 11
- Manufacturing -- CFD = 4
- Health, Bio-Sciences, life sciences = 3
- Chemistry = 1
- Other international experts = 23

Additional Key Topics Studied

- The importance of having access to a K-like supercomputer to their research
- The importance of having access to the Post K-like supercomputer to their research
- How their current research would be impacted if they had to use regular clusters
- How their research would be impacted in 2020 if they had to use regular clusters
- How the Post-K computer Could Help Their Research
- The importance to Japan of having a world class Post-K computer

Study Highlights

Brief Project Summary

International Data Corporation (IDC) has evaluated the return-on-investment (ROI) and the return-on-research (ROR) for K and Post-K computers.

- For Strategic Programs, Post-K priority issues, and research cases which have a press release
- A total of 21 different organizations and 48 different researchers were interviewed in Japan.
- Original 721 reviewers and 68 new Japanese reviewer confirmed 117 ROR and 29 ROI cases.

K computer:

- The total revenue return on the K computer was return at least 2.7 billion US dollars – plus cost savings of 6.9 billion US dollars.
- Looking at the financial rate-of-returns, the K computer provides $571 in revenues, and $278 in cost savings for each dollar invested.
  - Cost saving ROI is much higher than that of the other flagship supercomputers around the world.
- ROR on the K computer's Strategic Programs for Innovative Research (SPIRE) generate extremely high innovation levels compared with other supercomputers in the world.
  - 50% priority use of SPIRE was very efficient to generate those high level innovations.
  - The ratios of priority use are smaller in other supercomputers.

Post-K computer:

- The projected revenue is an extremely strong $5 billion – plus cost savings of $5 billion US.
  - *Note that the actual return is much higher because this is only for the researchers that participated in this study. And simple comparison of actual return are in principle impossible between future Post-K computer and present super computers like K computer.*
- The ROR on the Post-K computer also generate extremely high innovation levels compared with other supercomputers in the world.
- ROI and ROR indicates Post-K computer stands out among leadership projects around the world because most other systems are used on many smaller projects than as done on the K computer.

Success Stories

Scientific Success Stories

- The K computer has enabled multi-scale heart simulation from the protein level. This has contributed to basic medicine (elucidation of hypertrophic cardiomyopathy), and also demonstrates the effectiveness of the clinical application of a simulation model developed for heart surgery.
- The K computer enabled the simulation of the formation process of galaxies that requires very large-scale calculations.
- In order to simulate an entire virus with all atoms, it is necessary to deal with environments of over 10 million atoms, a capability available only on the K computer.
- Highly accurate molecular simulation became possible, and can applied to various proteins, enabling accurate biological response simulation. As a result, the mechanism of the drug resistance of non-small cell lung cancer treatment drugs has been elucidated.

Industry Success Stories

- The K computer has enabled advanced simulations to reduce by about 20 billion yen the combined cost for wind tunnel experiment per year, or about 1.8 billion yen per wind tunnel per year.
- With Post-K computer, Simulation that supports coupled analysis of multi-physics can shorten the process of commercialization, which is very important for the international competitiveness of the coal gasification furnace process.
- The Post-K computer is required for the simulation in the time scale of biological reactions in the millisecond level, a capability already achieved by the US.

Financial ROI Results

The Financial ROI Model

IDC created a macroeconomic model to measure the financial returns from investments in HPC:

- The model inputs are the costs to conduct the research on the computer
  - The overall guideline is that the inputs are the "Actual" or "Equivalent" costs for a researcher in their country, in their industry, in their organization.
    - For K and Post-K computer, Costs include e.g., research budget, labor cost, and equivalent charge of use (K computer :14.53JPY per node hour)
    - For International, Most academic and government sites, such as NSF and ORNL, will provide the HPC resources with free or very small amount of charge, like only the operational costs – power & cooling costs. Large companies like a bank, car company or oil company sometimes charges a full allocation of the hardware, software, power, building, etc. costs .
- The model outputs include:
  - Sales revenues and/or
  - Cost savings
- The ROI calculation = outputs(returns) / inputs(costs)

The ROI and ROR Data Validation Process

IDC adopted a multi-layered process that harnessed a broad range of HPC-related expertise from a number of different subject matter experts:

- Forms were reviewed by IDC experts to see if all of the information was correct and the form met standards necessary to be considered for inclusion in the study.
- Accepted forms were then turned over to members of the HPC User Forum Steering Committee (listed at: www. hpcuserforum.com) for review.
- Submissions approved by the HPC Steering Committee were considered for both an innovation award and for inclusion in the study's economic database.
- In the case of the Post-K system, we used estimates of future results as opposed to actual results.

The K Computer Has Been a Major Financial Success

- **The combined total financial value of the K computer was an amazing $9.6 billion US dollars (in revenues and cost savings) for the projects in this study.**
- **Looking at both the K and Post-K computers, the overall financial value exceeds $19 billion US dollars, for the cases in this study.**
- **The overall financial return on investment averaged an extremely strong $571 dollars in revenue per dollar invested in HPC (for the K computer).**
- *Note that the actual amounts are much higher, as this is only a subset of the projects on these systems.*

Financial Benefits From the K and the Post-K Computers

- As Table 1 shows, the cost savings were very impressive, at $7 billion with the K computer.
- And $5 billion planned for the Post-K computer.

Table 1

Summary of the Financial ROI from HPC in Japan

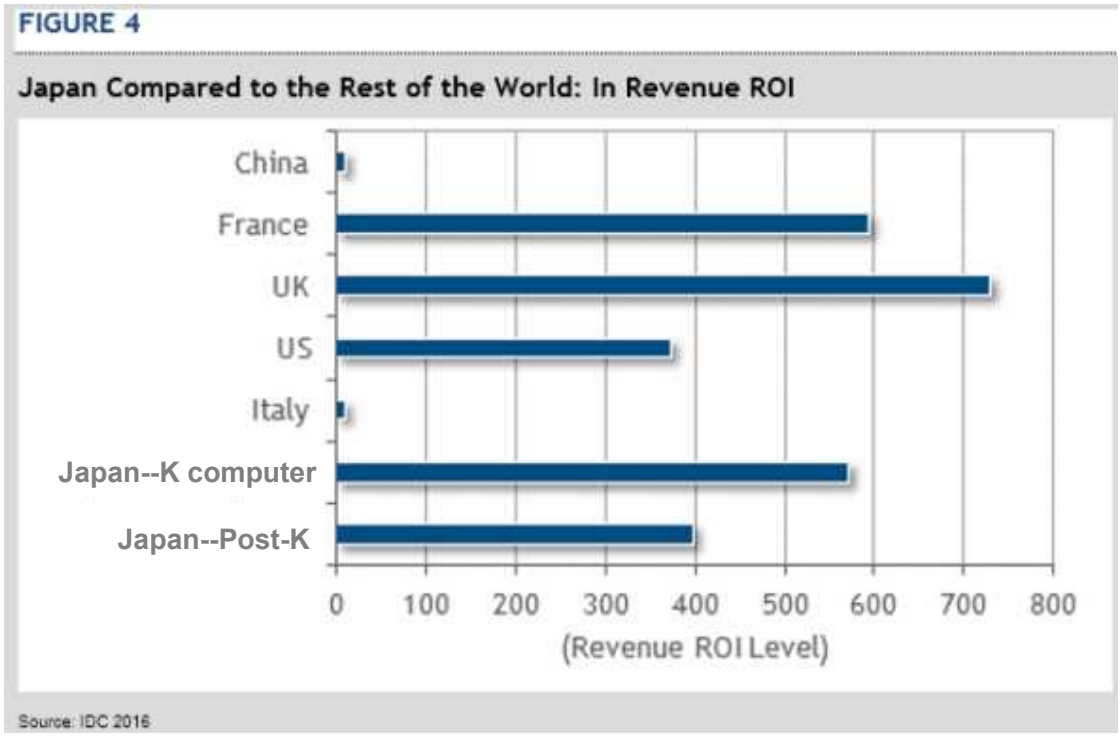
	Total Revenues	ROI Average of Revenue $ per HPC $ Inputs	Total Cost Saving	ROI Average of Cost Saving $ per HPC $ Inputs	Total Financial Returns
Japan K computer	$2,690	$571	$6,888	$278	$9,578
Post-K computer	$5,100	$398	$4,950	$234	$10,050
Total	$7,790	$423	$11,838	$251	$19,628

Source: IDC 2016

- Assume $1 = **100** JPY throughout this study.

Revenue ROI Comparisons:

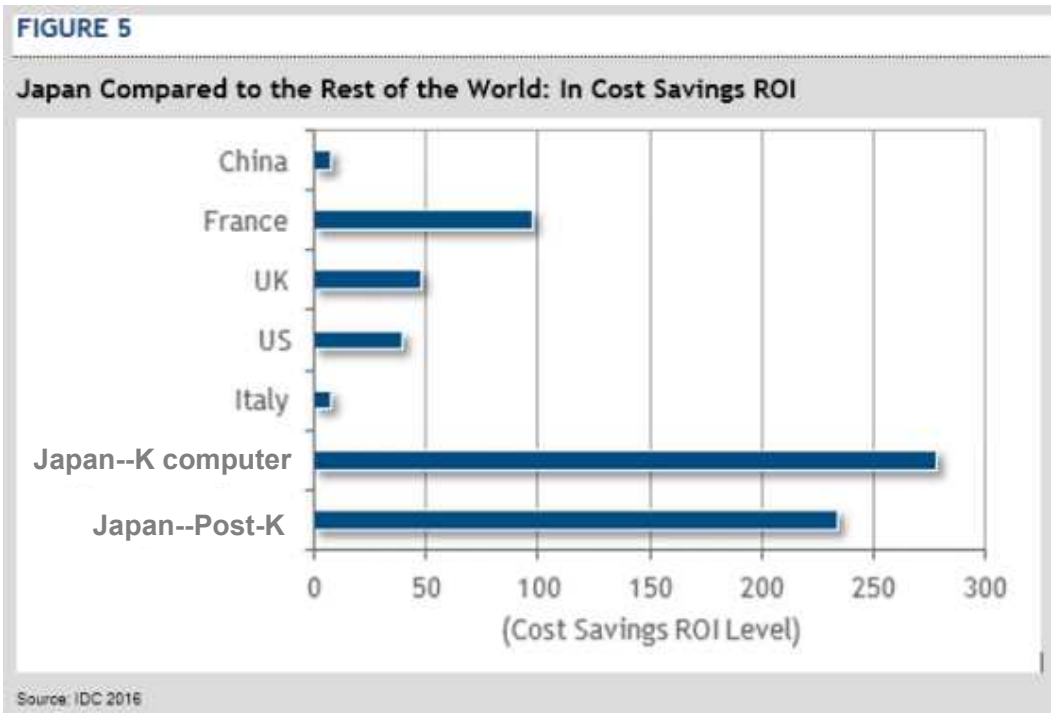
Average Revenue Generated per $1 HPC Investment



- Japan has seen strong revenues from the K and Post-K projects

Cost Savings ROI:

Average Cost Savings per $1 HPC Investment



- Japan leads the world in cost savings projects on the K and Post-K computers
- Driven by the focus on large nationally important projects in areas like disaster research and in highly important bio-medical research projects

Scientific Innovation Results

The Innovation Return on Research (ROR) Metric Used in the Study

- In order to properly quantify the overall impact of leadership class supercomputers in Japan, IDC analysts used a rating system that measured both the *importance* and *impact* of each leadership class supercomputer-based innovation in the existing data set, plus all of the new Japanese innovations collected in this research study.

- IDC developed this measurement method as part of a successful 2013 global study for the U.S. Department of Energy.

Basic And Applied Innovation Samples In This Study

Table 8

Number of Innovation Examples in the Study

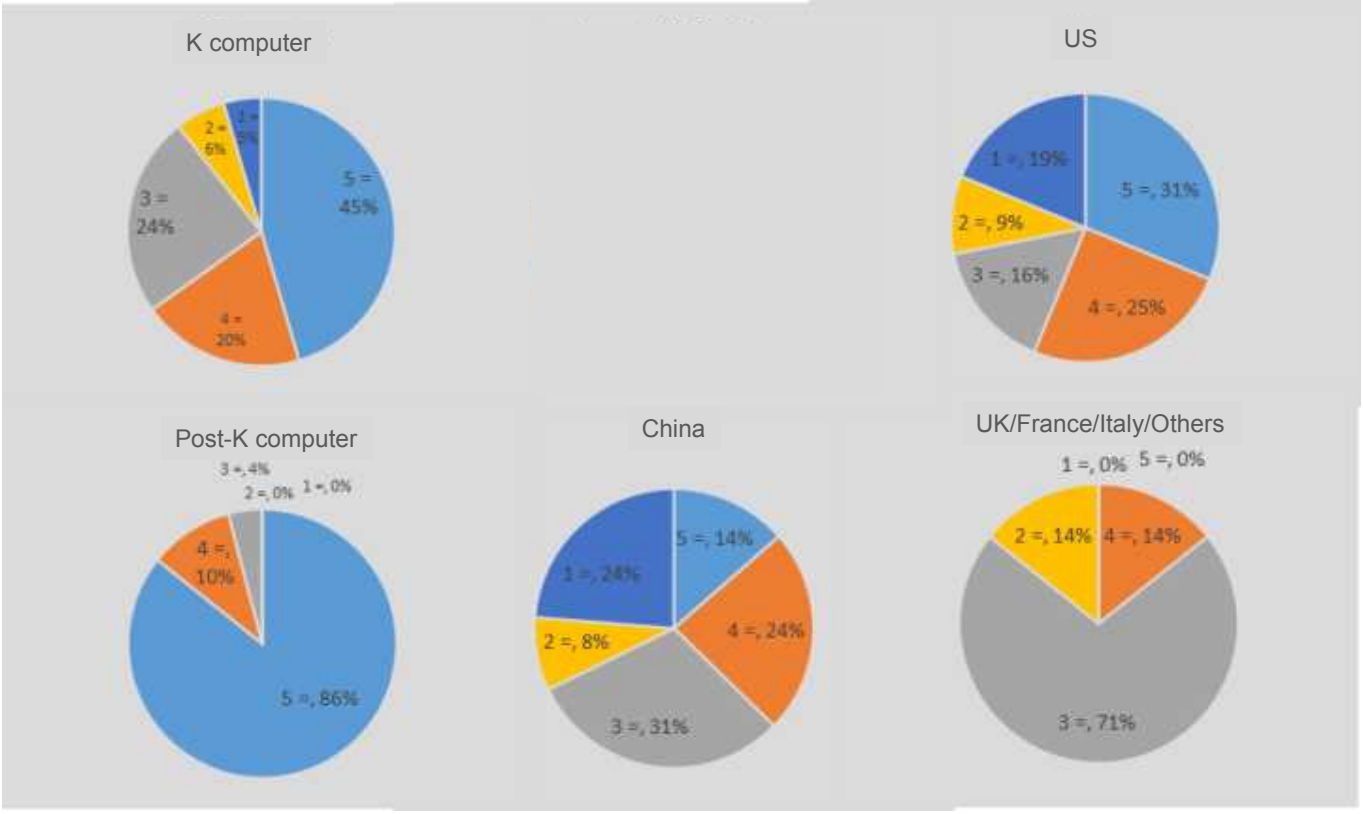
Country	Count of Applied Innovations	Count of Basic Innovations	Total Count of Innovations
China	30	41	71
France	10	1	11
UK	20	53	73
US	70	32	102
Italy	6	0	6
Japan K & Post-K	49	72	121
Others	5	4	5
Overall Total	190	203	389

Source: IDC 2016

- A few of Japan's samples are both basic and applied.

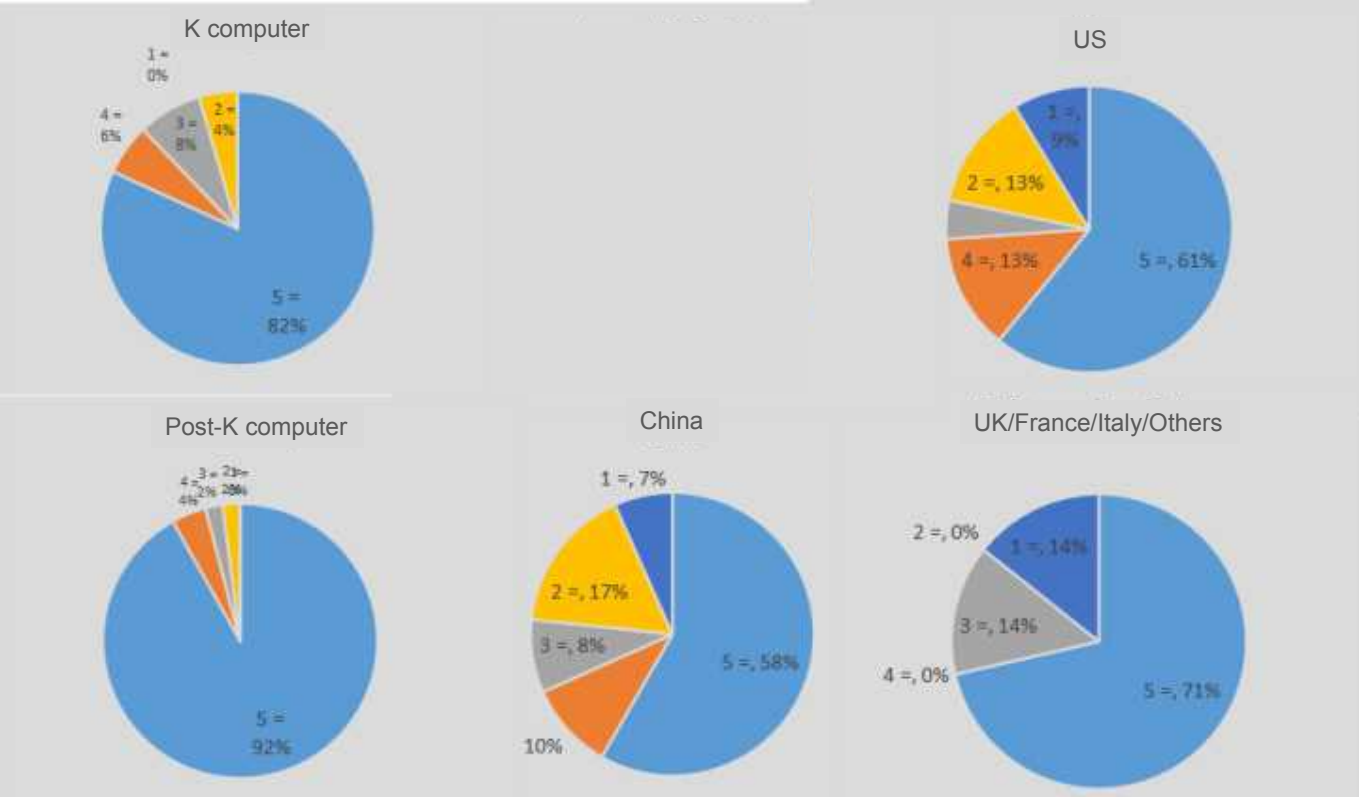
Results: Innovation Ratings: Importance

- Japan leads the world in the percentage of projects that are the top in importance in each research field



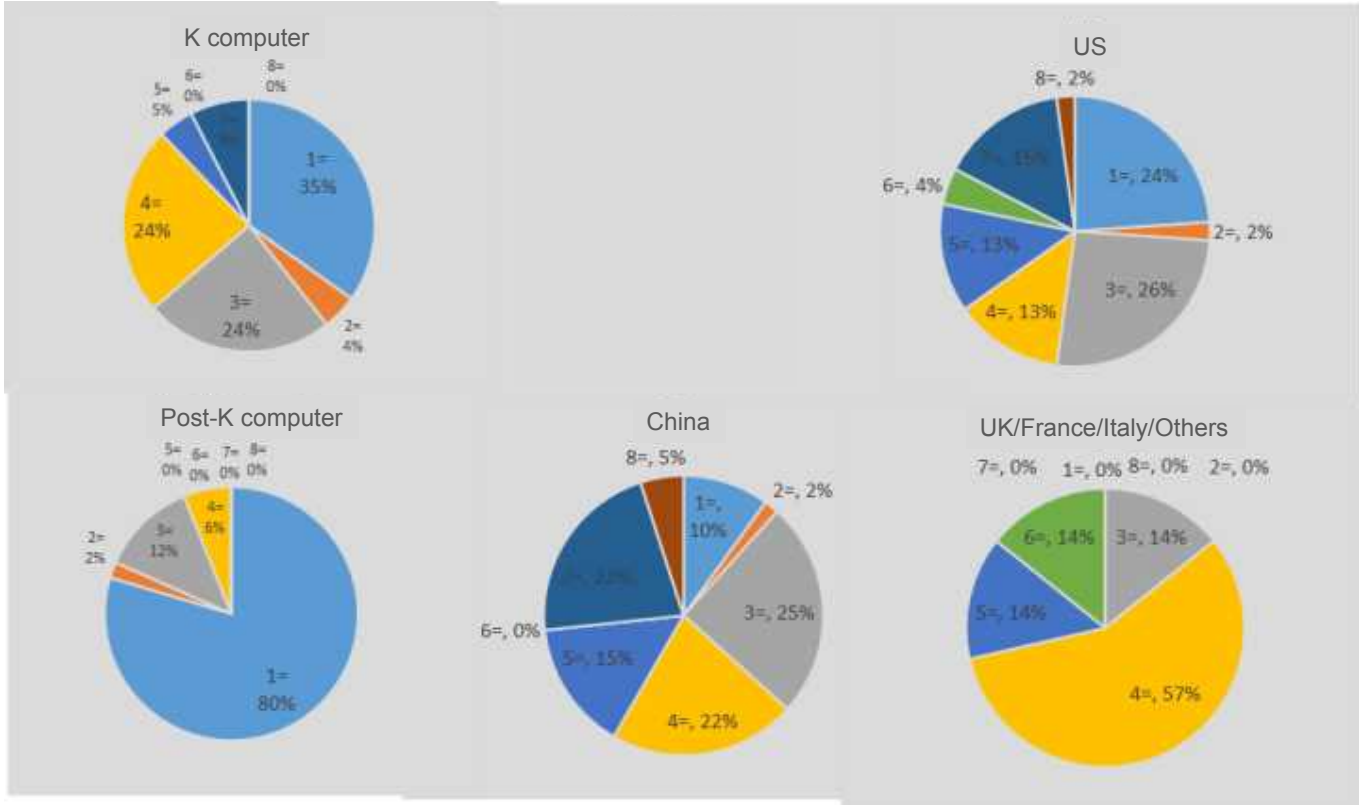
Results: Innovation Ratings: Impact

- Japan leads the world in the percentage of projects that are important to many organizations (combining the first two sets below)



Results: Innovation Ratings: Class Levels

- Japan greatly leads the world in the percentage of projects that rated the highest on the innovation class scale



Scientific Innovation Returns From the K Computer

Japan leads other countries in the ratio of innovations of the top class level:

- A much higher percentage of the Japanese innovations qualified in category 5, as one of the top 2 to 3 innovations of the last decade.
- A far greater percentage of the Japanese innovation cases qualified as "useful to over 50 organizations" than the other cases.
- Using the IDC innovation class ratings, Japan has a higher ratio of Class 1 innovations compared to the US, China and major European countries.
- IDC analyzed the reasons why the ROR of the Post-K is particularly high:
  - The K and Post-K computers are targeted at solving very important and Challenging problems.
  - The project is designed to provide leadership capabilities to researchers -- as a unified project with hardware development, system development, and research utilization in order to continuously advance the computational science technology developed in K computer towards the Post-K computer.

Conclusions

The K Computer Has Been a Major Scientific Success

- This study confirmed that many Japanese researchers have benefitted greatly from using the K computer and are ready to advance their work and tackle even more challenging problems on a more powerful Post-K computer.
- We are firmly convinced that developing a more powerful successor to the K computer is well worth the investment.
- The K computer has demonstrated that leadership-class supercomputers can produce returns far in excess of the amounts needed to fund them—and confirms that without competitive leadership-class computers, considerable scientific competitiveness would be lost.

Impact on Japanese Researchers of Not Having Post-K Computer

- Almost all surveyed HPC experts involved with the K computer were emphatic that a transition back to the use of regular clusters would deeply harm, and in some cases shut down, their current research activities.
  - Many stated that they would have to abandon their current efforts because the jobs that are now critical to their research agendas would take too long, be too complex, or have too much data to execute effectively in a regular cluster or cloud environment.
- Researchers stressed that such a transition would cause a loss of capability vis-a-vis foreign counterpart research efforts.

How Post-K Computer Stands Out Among Leadership Projects Around the World

- The results of this study shows how Japan is much better at getting value from its largest supercomputers when compared to the rest of the world.
- Where innovation is concerned, Japan also greatly outranks most other countries.
  - A much higher percentage of the Japanese innovations qualified as Class 1 innovations.
  - Using the IDC innovation class ratings, Japan has over 8 times as many class 1 innovations compared to China.

Questions?

ejoseph@idc.com

sconway@idc.com

bsorensen@idc.com

kmonroe@idc.com

Appendix

The Innovation Scales Used In The Surveys

The IMPORTANCE this innovation compared to all other innovations in this field over the last ten years:

- 5. One of the top 2 to 3 innovations in the last decade
- 4. One of the top 5 innovations in the last decade
- 3. One of the top 10 innovations in the last decade
- 2. One of the top 25 innovations in the last decade
- 1. One of the top 50 innovations in the last decade

The IMPACT of this innovation to multiple organizations:

- 5. An innovation that is useful to over 10 organizations
- 4. An innovation that is useful to 6 to 10 organizations
- 3. An innovation useful to 2 to 5 organizations
- 2. An innovation only useful to 1 organization
- 1. An innovation that is recognized ONLY by experts in the field

These were then combined to create a innovation "Class" scale (shown on the next slide)

The Innovation CLASS Scale Used

Class 1 innovations – One of the top 2-3 innovations in a field over the last ten years PLUS useful to over 10 organizations

Class 2 innovations -- One of the top 5 innovations in a field over the last ten years PLUS useful to over 10 organizations

Class 3 innovations – One of the top 5 innovations in a field over the last ten years PLUS useful to at least 5 organizations

Class 4 innovations – One of the top 10 innovations in a field over the last ten years PLUS useful to at least 5 organizations

Class 5 innovations – One of the top 25 innovations in a field over the last ten years PLUS useful to at over 10 organizations

Class 6 innovations – One of the top 25 innovations in a field over the last ten years PLUS useful to at least 2 organizations

Class 7 innovations – One of the top 50 innovations in a field over the last ten years PLUS useful to at least 2 organizations

Class 8 innovations – The rest of the innovations in the study

HPC USER FORUM **Steering Committee**

Paul Muzio
Chairman, City University of New York

Rupak Biswas
NASA Ames
Vice Chairman

Earl Joseph
IDC, Executive Director

Vijay Agarwala
Virginia Tech.

Swamy Akasapu
General Motors

Alex Akkerman
Ford Motor Company

C. Scot Atkins
Industry Expert - Advanced Analytics/Dense Supercomputing

Doug Ball
The Boeing Company

Jeff Broughton
NERSC/Lawrence Berkeley National Lab

Paul Buerger
Avetec

Clayton Chandler
Credit Suisse Group AG

Sharan Kalwani
Fermilab

Chris Catherasoo
California Institute of Technology

Simon Burbidge
Imperial College London

Jack Collins
National Cancer Institute

Steve Conway
IDC Research Vice President

Steve Finn
Emagine IT

Merle Giles
NCSA/University of Illinois

Keith Gray
BP

Arno Kolster
PayPal

Doug Kothe
Oak Ridge National Laboratory

Jysoo Lee
KAUST

David Martin
Argonne National Laboratory

Michael Resch
HLRS, University of Stuttgart

Ryan Quick
PayPal

Stephane Requena
GENCI

Vince Scarafino
Industry Expert

Suzy Tichenor
Oak Ridge National Laboratory

https://hpcuserforum.com/steeringcommittee.html

Research Areas of the Survey Participants

Table 3 B

Research Areas of the Survey Respondents

Research Areas	Number	Percentage of Sample
General Science Areas	35	33.0%
Manufacturing/Automotive/CFD/Design Optimization	21	19.8%
Molecular Dynamics/Science/Engineering	13	12.3%
Biology, Precision Medicine, Life Sciences	12	11.3%
Tools & Library	10	9.4%
Weather Research & Climate	10	9.4%
Astrophysics, Astronomy, Precision Cosmology	5	4.7%
Total	106	100.0%

Source: IDC 2016

Planned Areas of Research on the Post-K Computer

Japanese researchers surveyed for this study have high expectations for a new Post-K class supercomputer that spans a wide range of scientific disciplines, academic areas and industrial applications.

Areas of noted interest included but were not limited to:

- Energy issues, including solar cells, batteries, and coal gasifier furnaces,
- Materials studies including high temperature superconductors
- Earth studies including magnetic field and global climate modeling
- Astrophysics including the coalescence of supernova explosions and neutron star binary star models in both long-term and high resolution
- Medical studies including multiphysics heart simulation, cancer drugs, precision medicine,
- Simulation techniques including quantum Monte Carlo techniques, molecular dynamics simulation, fluid dynamics for aircraft simulation, and social simulation.

Japan's Advantages In The Exascale Race

- A long history of developing and using highly innovative, leadership-class supercomputers in a wide variety of scientific and industrial domains
- Strong, mature HPC vendor and user communities
- Holistic skills that span hardware, system software, applications software, storage, and technical support.

Example Post-K Computer Projects:

- Application of the tailor-made medical care with heart simulator
- Applied to the development of the fuel cell of the functional analysis approach in the composite material
- Building materials database
- Continue to develop RSDFT software for The scale, precision and time axes.
- Control of solar cells of non-equilibrium state
- Control of the topological insulator
- Development of battery simulator
- Development of Coal Gasifier Furnace Simulation software
- Development of MACE (Multi-scale Ab initio scheme for Correlated Electrons) software
- Development of Next Generation of Multi-Scale Multi-Physics Heart Simulator
- Development of photosynthesis simulator
- Development of innovative drug discovery
- Elucidation of the drug-resistant mechanism of the non-small cell lung cancer therapeutic drug
- Elucidation of the nanowire properties and boundary surface structure
- Establishment of material design approach
- High accuracy of the data assimilation of the global model
- High temperature superconductors simulation of copper oxide
- Precision medicine. Such as the development of biomarkers and companion reagents.
- Improve Functionality of MODYLAS
- Improvement of the quantum Monte Carlo method program
- Calculation of the force acting between elementary particles.
- Molecular dynamics calculations in the high-temperature and high-pressure
- NTChem continued development
- Social Simulation
- The development of multi-scale thermoplastic CFRP molding simulator
- The development of traffic-related simulator
- The design and operational techniques of aircraft to develop the FF-VHC-COMP for high-speed fluid.
- Magnetic field simulation
- Transition temperature change simulation
- A six-dimensional simulation with good accuracy

Example International Supercomputer Plans

Examples Of The Supercomputers Evaluated In This Study				
Computer Names	Project Names	Organization	Country	Planned Delivery Date
Sierra	CORAL	LLNL	USA	2017
Summit	CORAL	ORNL	USA	2017
Aurora	CORAL	ANL	USA	2018
CORI	NERSC-8	NERSC	USA	Late 2016
Crossroads	APEX 2020	LANL	USA	2020
NERSC-9	APEX 2020	LLBL	USA	2020
Cheyenne		NCAR	USA	2017
TaihuLight		Sunway	China	2016
Milkway Way-2	TianHe2 A	NUDT	China	2016(?)
Hazel Hen		HLRS	Germany	2015
SuperMUC	Phase 2	LRZ	Germany	2015
Piz Diant		CSCS	Switzerland	2016
CEA/Bull		CEA/ Bull	France	2020
Source: IDC 2016				

The Survey Guide

-