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Sandia National Laboratories

RED STORM CASE STUDY

IPO Integrated Partnerships Organizations

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

BACKGROUND

Sandia and Cray Inc. co-developed Red Storm, a distributed memory, massively paralleled high-performance supercomputer modeled on ASCI Red[1], to run computer codes used for conducting materials science simulations for national security.[2] Supercomputers have some of the fastest high-performance systems available and are used primarily for scientific and engineering work requiring exceedingly high-speed computations. Unlike conventional computers, supercomputers have large storage capacity; more than one central processing unit to rapidly retrieve stored data and program instructions; and input/output capability.[3,4]

Figure 1: Sandia's Red Storm is approximately 3,500 sq. ft. and uses 2.2 megawatts.

Red Storm was the first supercomputer to surpass the one terabyte-per-second performance mark for measuring communications among processors; which is a measure that indicates the capacity of the network to communicate when dealing with complex situations.[5] Researchers have used Red Storm for various modeling scenarios, for example understanding how much explosive power it would take to destroy an asteroid tracking toward Earth, how a raging fire would affect critical components in a variety of nuclear weapons, or how changes in the composition of Earth's atmosphere might impact global warming.[6] In addition, researchers have used Red Storm for both classified and unclassified projects in a wide range of topic areas, such as climate modeling, cyber defense, vulnerability assessments, network discovery, space systems threats, and image processing. Sandia and Cray designed a specialized feature called the Red-Black Switch, which allows Red Storm to run both classified (red) or unclassified (black) material separately or split both to run each simultaneously with a physical air gap to ensure security.[7]

In January 2008, researchers used Red Storm in Operation Burnt Frost, a program that aimed to shoot down a satellite that could spray toxic fuels over its crash site country. Sandia simulated thousands of variations of strikes against the satellite using Red Storm and successfully launched a strike on Feb. 20, 2008 against the satellite. In 2012, Red Storm was decommissioned.[8] However, the Red Storm design became the basis for the Cray XT3 massively parallel processor supercomputer, which became the foundation for Cray's current CS and XC Series of supercomputers.[9]

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[1] https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2011/110068.pdf
[2] https://share-ng.sandia.gov/news/resources/releases/2006/red-storm.html
[3] https://www.britannica.com/technology/supercomputer
[4] https://share-ng.sandia.gov/news/resources/releases/2006/red-storm.html
[5] http://www.sandia.gov/news/publications/research_magazine/archive/_assets/documents/st2006v8no2.pdf
[6] http://www.sandia.gov/news/publications/research_magazine/archive/_assets/documents/st2006v8no2.pdf
[7] https://www.datacenterdynamics.com/analysis/after-the-storm-the-supercomputer-that-saved-cray/
[8] https://www.datacenterdynamics.com/analysis/after-the-storm-the-supercomputer-that-saved-cray/
[9] https://phys.org/news/2006-11-red-storm-sandia-supercomputer-2nd.html

RETURN ON INVESTMENT

PROGRAM DEVELOPMENT

Red Storm was designed and funded under the NNSA's Advanced Simulation and Computing Initiative (ASCI) and took three years to build from its original concept to its final release for consumer shipment. Sandia developed the architectural specifications and the software development of the machine, while Cray built the physical components of the machine. Sandia pioneered the original technology on its ASCI Red machine, built by Intel Corporation, which was the world's first tera-scale supercomputer. [10]

In 2006, Sandia conducted a $15 million upgrade to Red Storm and increased its peak performance speed from 41.5 to 124.4 teraflops. The upgrade included the addition of a fifth row of cabinets and an upgrade to the entire system with dual-core AMD Opteron TM processors.[11] Sandia and Cray sold 15 copies of the supercomputer in various sizes to US government agencies, universities, and international customers.[12] Additionally, in 2006, Sandia won the Meritorious Achievement Award for Red Storm Design, Development, and Deployment Team. In 2010, Sandia won two National Federal Laboratory Consortium awards for its technology transfer efforts with Cray and Sandia won the National Nuclear Security Administration Defense Programs Award of Excellence.[13]

Although Red Storm was decommissioned in 2012, Cray has continued to use the project as a foundation for their commercial line of supercomputers. Cray's XT line was successful and won multiple awards. In 2009, the XT5 system won the Gordon Bell Prize for high-performance computing. Customers of Cray's XT3 include: Sandia National Laboratories, Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, the US Army, the UK's AWE Atomic Weapons Establishment program, national computing centers in Finland, Switzerland, and the UK, and the Pittsburgh Supercomputing Center (PSC).[14] The PSC has used the XT3 supercomputer to run its Advanced Regional Prediction System, a comprehensive regional to storm-scale atmospheric modeling/prediction system.[15]

Red Storm also served as the foundation for other research projects such as the Power Application Programming Interface (API) project, in which Sandia scientists developed a portable API for power measurement and control for high performance computing. The Power API project provides multiple levels of abstractions to satisfy the requirements of multiple types of users.[16] The Power API project won two awards in 2011 which are directly associated with work done on Red Storm: the National Nuclear Security Administration Defense Programs Award of Excellence and the National Nuclear Security Administration Environmental Stewardship Award.

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[10] https://phys.org/news/2006-11-red-storm-sandia-supercomputer-2nd.html
[11] https://share-ng.sandia.gov/news/resources/releases/2006/red-storm.html
[12] http://www.sandia.gov/news/publications/research_magazine/archive/_assets/documents/st2006v8no2.pdf
[13] https://www.eurekalert.org/pub_releases/2010-04/dnl-sw2042610.php
[14] https://share-ng.sandia.gov/news/resources/releases/2006/red-storm.html
[15] http://investors.cray.com/phoenix.zhtml?c=98390&p=irol-newsarticle&ID=634922
[16] https://powerapi.sandia.gov/

PARTNERSHIPS

In 2002, Sandia began negotiations with Cray for a multi-year partnership to develop and deliver a new massively parallel processing supercomputer, which came to be known as Red Storm.[17]

LDRD

There has been 18 years' worth of Laboratory Directed Research and Development (LDRD) related to the development of Red Storm.

PUBLIC GOOD

Supercomputers are used for a wide variety of applications ranging from fighting diseases to climate modeling to critical national security applications. Red Storm acts as the foundational framework for over 120 supercomputer systems at approximately 70 sites worldwide[18], which has contributed to the diversification and competitiveness of the high-performance computing (HPC) market. As a part of Sandia and Cray's contract, Cray was required to sell a system derived from Red Storm as a commercial product with the goal to ensure the HPC market stayed competitive. In response, the company built XT3 based off Red Storm architecture, followed by the XT4 and XT5 before those were replaced by its XC system in 2012.[19]

Climate Modeling

Researchers have used Red Storm to conduct atmospheric climate modeling simulations. For example, Red Storm and its successor, XT5 (Jaguar) at Oak Ridge National Laboratory, were used to produce high-fidelity climate models that revealed, for the first time in simulations, swirls of water (vortices) in the Indian Ocean. [20] At the time, this was the most detailed global atmospheric simulation ever performed and continues to be an integral part of the DOE's program to develop an Earth system model that will use future supercomputer architectures to address climate science issues such as the impact of climate change on freshwater supplies in the US and the stability of the Antarctic ice sheet.[21]

In September 2004, the National Science Foundation (NSF) announced a $9.7 million award to PSC to acquire and install a system based on the Red Storm architecture. This system enabled researchers to explore the limits of high-performance computing and to demonstrate the architecture for a wide range of scientific applications including blood-flow modeling, protein simulations, storm forecasting, global climate modeling, and simulations of earthquake ground vibration.[22] Other potential applications include astrophysics, complex biological systems, turbulence, and fluid dynamics. The PSC Red Storm was integrated with NSF's Extensible Terascale Facility cyberinfrastructure project in accordance with NSF's Terascale Computing Systems Initiative. [23]

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[17] https://www.sandia.gov/news/publications/computing_reports/_assets/documents/HPC_AnnualReport2017_FNL.pdf

[18] http://primeurmagazine.com/weekly/AE-PR-08-12-36.html

[19] https://www.datacenterdynamics.com/analysis/after-the-storm-the-supercomputer-that-saved-cray/

[20] http://primeurmagazine.com/weekly/AE-PR-08-12-36.html

[21] https://www.sandia.gov/news/publications/labnews/articles/2016/19-02/leland.html

[22] https://psc.edu/science/2004/cyberinfrastructure/cyberinfrastructure.pdf

[23] https://www.nsf.gov/news/news_summ.jsp?cntn_id=100435

RED STORM

ORIGIN

- Red Storm was designed and funded under the NNSA's Advanced Simulation and Computing Initiative.
- Three years to build from original concept to final release for consumer shipment.
- ASCI Red machine basis for Red Storm architecture.

DEPLOYMENT

- Used in classified operations such as Operation Burnt Frost, which aimed to shoot down a military reconnaissance satellite.
- Red Storm's Red-Black Switch can run classified and unclassified data simultaneously.
- Became the basis for future series of Cray supercomputers.

ROI

Public Good

Recognition & Credibility

Program Development

120+ Users of Red Storm Framework

Sandia began partnership negotiations with Cray for Red Storm

2002

Sandia conducted a $15 million upgrade to Red Storm

2006

Used in classified Operation Burnt Frost to simulate shooting down a military reconnaissance satellite that could spray toxic fuels over its crash site

2008

FLC
Federal Laboratory Consortium for Technology Transfer

Won two National Federal Laboratory Consortium awards for tech transfer with Cray

2010

Red Storm decommissioned, basis for Cray supercomputers

2012