Cryogenic Computer Complexity (C3)

The Path to the Next Generation of High Performance Computers

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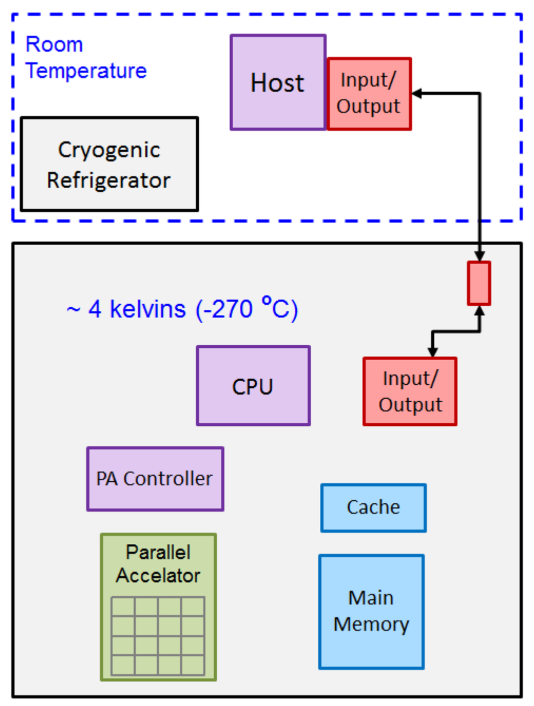
The ultimate program goal is a prototype superconducting computer that will enable the IC to evaluate the technology

- Prototype will have a simple SIMD-type architecture
- Goals and metrics derived with IC partners to provide high value insights into the technology

Metric	Goal
Clock rate for superconducting logic	10 GHz
Throughput (bit-op/s)	10^{13}
Efficiency @ 4 K (bit-op/J)	10^{15}
CPU count	1
Word size (bit)	64
Parallel Accelerator count	2
Main Memory (B)	2^{28}
Input/Output (bit/s)	10^{9}



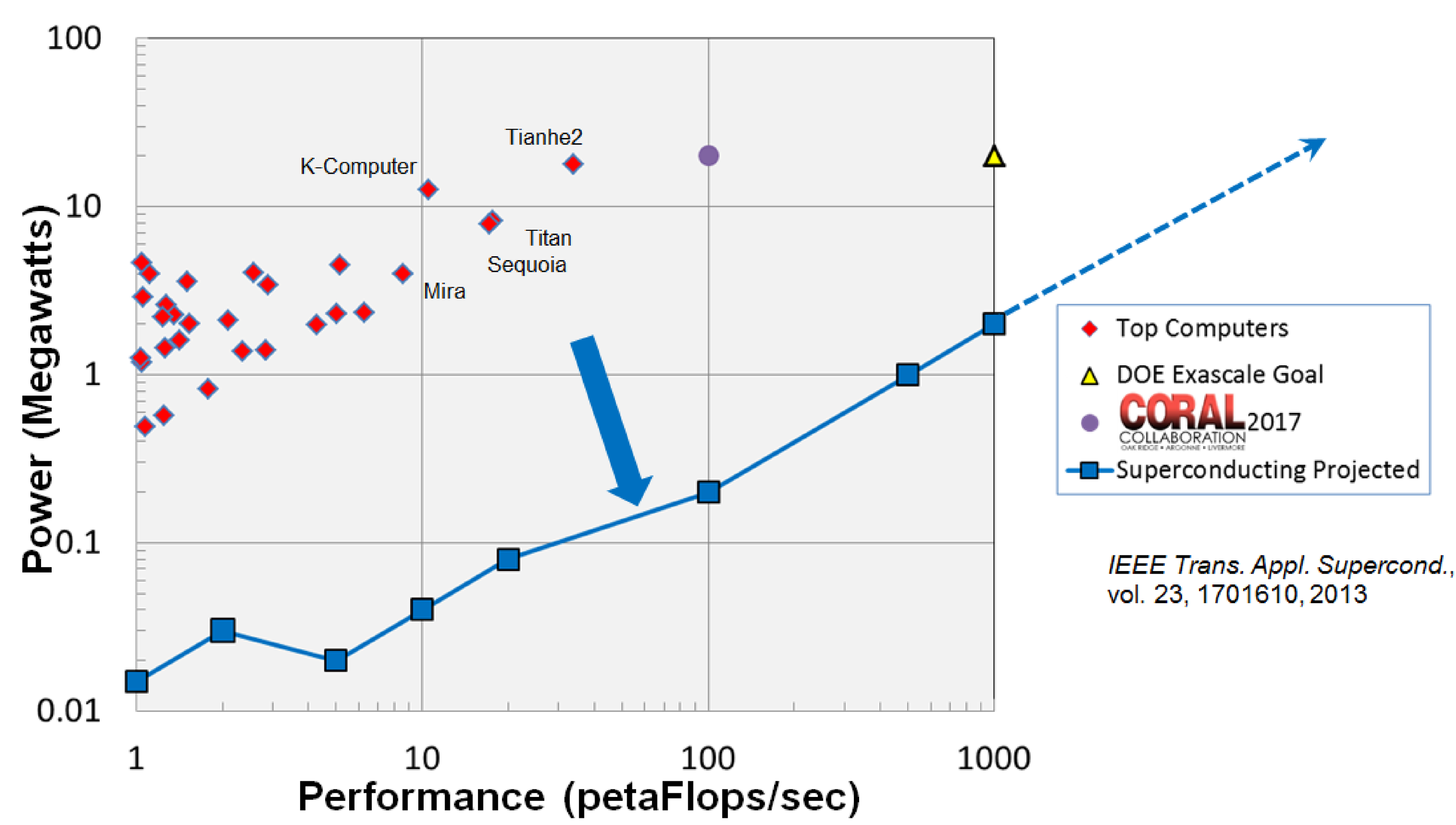
C3 is divided into two thrusts, one to develop energy-efficient cryogenic memory, and the other to develop the logic, interconnects and system plan

Program began in September. Key performers are:

- Cryogenic memory:
  IBM, NORTHROP GRUMMAN
- Logic, Systems, Interconnect:
  NORTHROP GRUMMAN, Raytheon BBN Technologies
- With superconducting circuit fabrication provided by MIT Lincoln Laboratory
- And independent test and evaluation by NIST, Boulder

The power, space, and cooling infrastructure required by computer facilities is an impediment to upgrading facilities and to engineering the next generation of supercomputers

- Exascale-and-beyond computing for less than 20 MW of electricity may be impossible to attain with conventional semiconducting technology.
- Supercomputers based on cryogenic superconducting technology may be an energy efficient path forward.



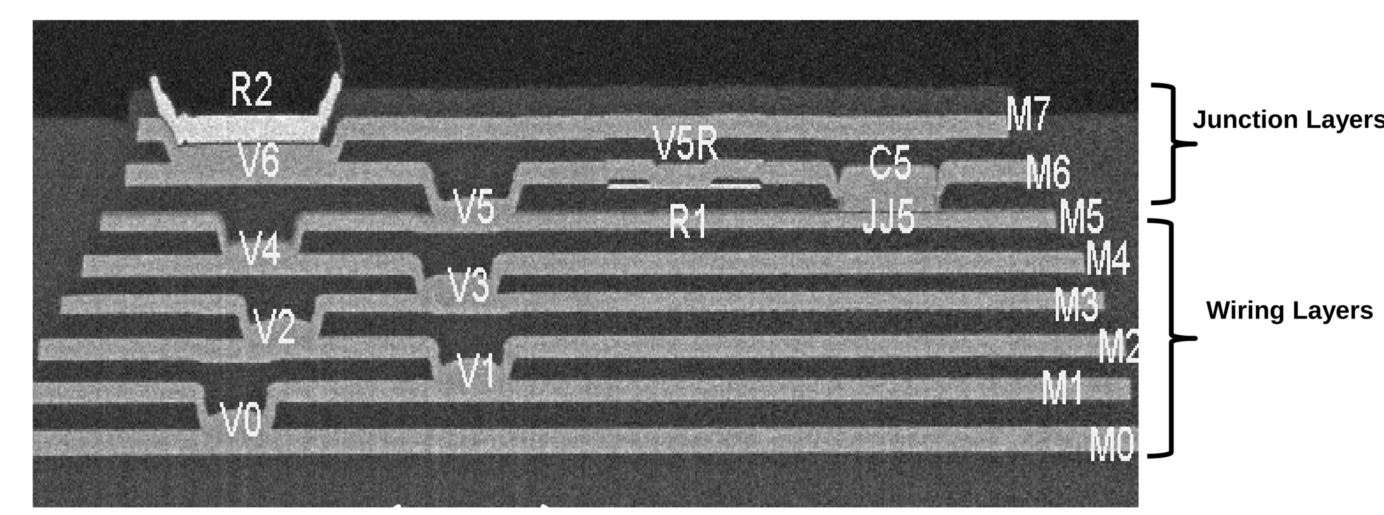
Performance predictions for superconducting computing are based on key technology advantages and developments.

- Near zero-energy interconnect
- New ideas for energy-efficient cryogenic memory
- New zero static power dissipation logic
- Engineering solution for data ingress and egress
- High reliability cryogenic refrigerators

Accomplishments to date

Lincoln Laboratory has been upgrading its niobium fabrication facility over the past year. The facility has made two noteworthy achievements.

- The Lincoln Laboratory niobium foundry is now the most advanced niobium foundry in the world, with sub-micrometer-scale feature size, 100 MA/m^2 junction critical current density, eight metallization layers, and full layer planarization
- Lincoln Laboratory has fabricated the most complex fully-functioning digital superconducting circuit, containing more than 40,000 Josephson junctions; the most complex fully-functioning chip with more than 70,000 Josephson junctions.



8 niobium layer cross-section

There are two key questions that this program needs to answer in order to be a success.

- Can we build an energy efficient superconducting computer at scale that is useful for solving intelligence community problems?
- Is this computer sufficiently better than a computer based on conventional technology that we want to build it?