the future of research computing and data @ MIT

Dr. James Cuff

Executive Director

20th June, 2023

ORCD Office of Research Computing and Data

orcd@mit:~$ background

University of Oxford: D. Phil. Molecular Biophysics

Neural networks for protein structure prediction

Wellcome Trust Sanger Institute: Group Leader

Built the Informatics Systems Group, (Human Genome)

Broad Institute of MIT & Harvard: Group Leader

Built the Applied Production Systems Group

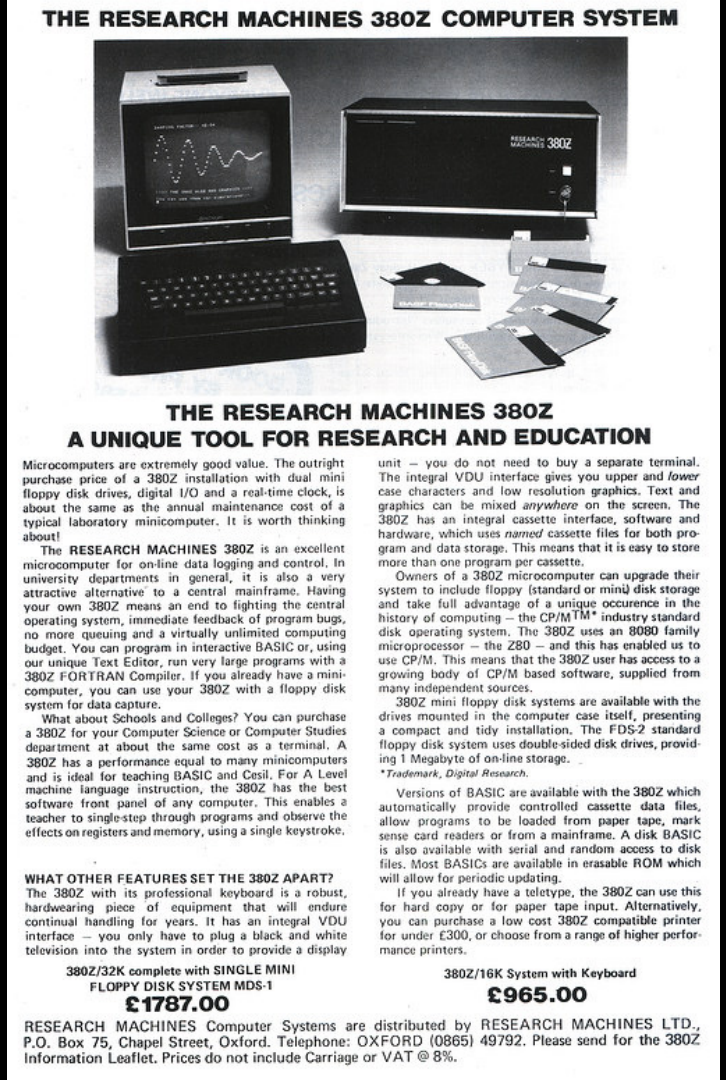
Harvard: Assistant Dean & Distinguished Engineer

Built the 100,000+ CPU cluster & MGHPCC from scratch

Strategic Scientific Advisor & Independent Consultant

5+ years learning “cheat-codes” in .com

ORCD Office of Research Computing and Data



THE RESEARCH MACHINES 380Z COMPUTER SYSTEM

THE RESEARCH MACHINES 380Z
A UNIQUE TOOL FOR RESEARCH AND EDUCATION

Microcomputers are extremely good value. The outright purchase price of a 380Z installation with dual mini floppy disk drives, digital I/O and a real-time clock, is about the same as the annual maintenance cost of a typical laboratory minicomputer. It is worth thinking about!

The **RESEARCH MACHINES 380Z** is an excellent microcomputer for on-line data logging and control. In university departments in general, it is also a very attractive alternative to a central mainframe. Having your own 380Z means an end to fighting the central operating system, immediate feedback of program bugs, no more queuing and a virtually unlimited computing budget. You can program in interactive BASIC or, using our unique Text Editor, run very large programs with a 380Z FORTRAN Compiler. If you already have a mini-computer, you can use your 380Z with a floppy disk system for data capture.

What about Schools and Colleges? You can purchase a 380Z for your Computer Science or Computer Studies department at about the same cost as a terminal. A 380Z has a performance equal to many minicomputers and is ideal for teaching BASIC and Cesil. For A Level machine language instruction, the 380Z has the best software front panel of any computer. This enables a teacher to single-step through programs and observe the effects on registers and memory, using a single keystroke.

WHAT OTHER FEATURES SET THE 380Z APART?

The 380Z with its professional keyboard is a robust, hardwearing piece of equipment that will endure continual handling for years. It has an integral VDU interface – you only have to plug a black and white television into the system in order to provide a display unit – you do not need to buy a separate terminal. The integral VDU interface gives you upper and *lower* case characters and low resolution graphics. Text and graphics can be mixed *anywhere* on the screen. The 380Z has an integral cassette interface, software and hardware, which uses *named* cassette files for both program and data storage. This means that it is easy to store more than one program per cassette.

Owners of a 380Z microcomputer can upgrade their system to include floppy (standard or mini) disk storage and take full advantage of a unique occurence in the history of computing – the CP/M™* industry standard disk operating system. The 380Z uses an 8080 family microprocessor – the Z80 – and this has enabled us to use CP/M. This means that the 380Z user has access to a growing body of CP/M based software, supplied from many independent sources.

380Z mini floppy disk systems are available with the drives mounted in the computer case itself, presenting a compact and tidy installation. The FDS-2 standard floppy disk system uses double-sided disk drives, providing 1 Megabyte of on-line storage.

**Trademark, Digital Research.*

Versions of BASIC are available with the 380Z which automatically provide controlled cassette data files, allow programs to be loaded from paper tape, mark sense card readers or from a mainframe. A disk BASIC is also available with serial and random access to disk files. Most BASICs are available in erasable ROM which will allow for periodic updating.

If you already have a teletype, the 380Z can use this for hard copy or for paper tape input. Alternatively, you can purchase a low cost 380Z compatible printer for under £300, or choose from a range of higher performance printers.

380Z/32K complete with SINGLE MINI FLOPPY DISK SYSTEM MDS-1
£1787.00

380Z/16K System with Keyboard
£965.00

RESEARCH MACHINES Computer Systems are distributed by RESEARCH MACHINES LTD., P.O. Box 75, Chapel Street, Oxford. Telephone: OXFORD (0865) 49792. Please send for the 380Z Information Leaflet. Prices do not include Carriage or VAT @ 8%.

orcd@mit:~# y2k_genomes.pl

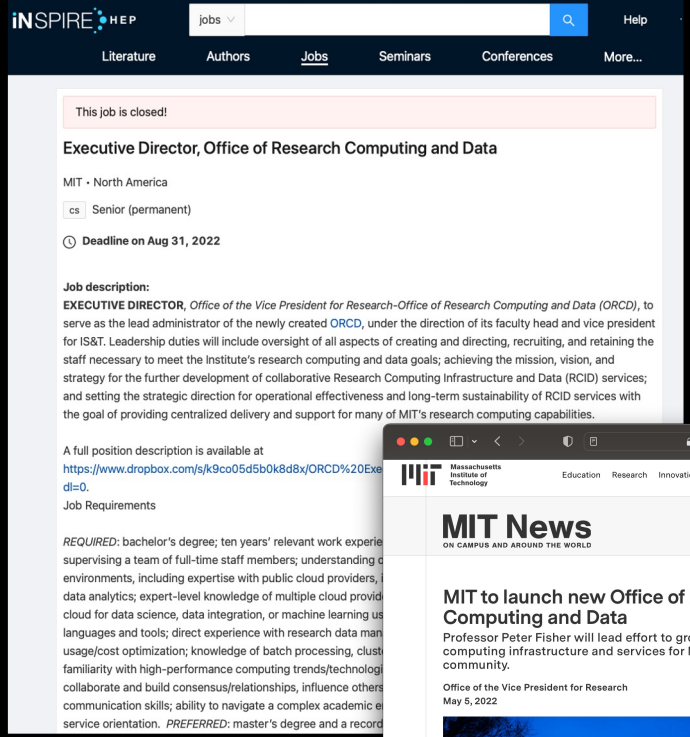
orcd@mit:~$ jobs

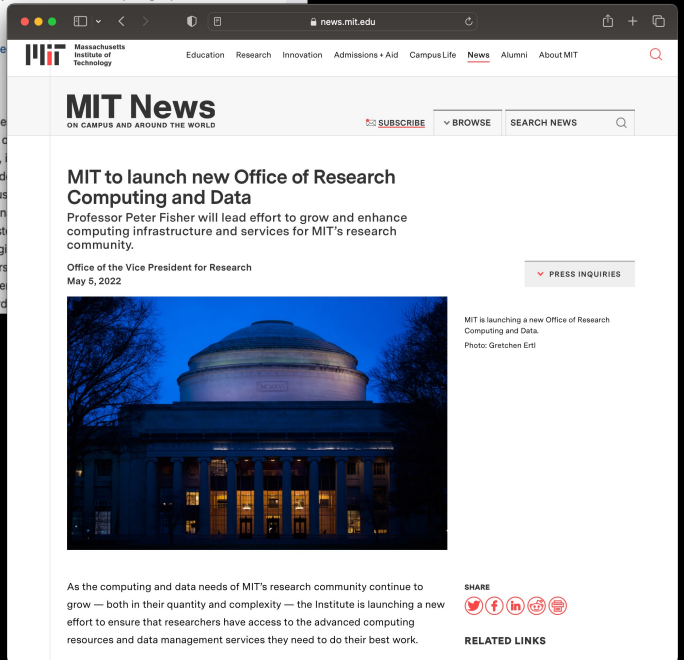
Started 26th Sept 2022

10+ years of RCP set the foundation, epic kudos to Dr. Chris Hill for this!

ORCD now reports to the VPR and Provost

Returning to MIT & MGHPCC has been awesome!





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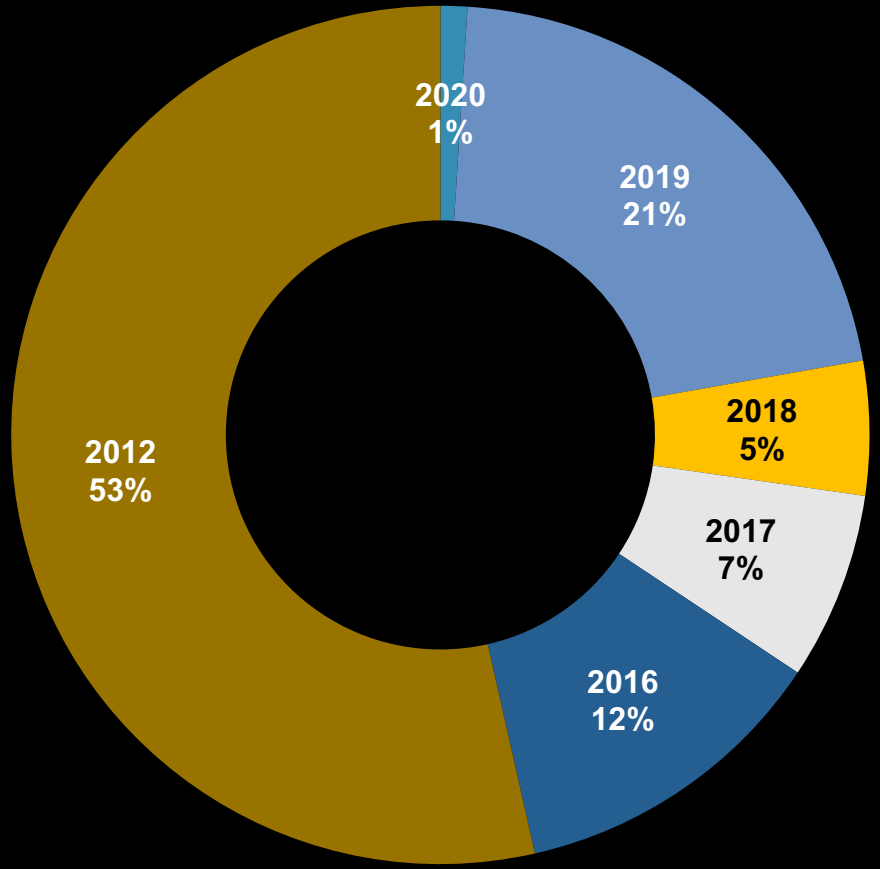
orcd@mit:~# uptime -p

Engaging1 – an example shared ORCD cluster

As of Q4 2022, there now exist over 1,463 machines in the computer cluster called “Engaging-1”

Of those 1,463 machines, 1,097 are currently available for processing. Of those 1,097 available, 797 are between 5 and 11 years old, 300 are less than 5 years old, and 244 remain under some form of warranty and are available for repair.

Of the total machines available, those considered viable for modern computing represent less than 16% of the total available fleet, after taking into consideration damaged, out of warranty, legacy and currently unavailable systems.



CPU	Samsung 32-bit RISC ARM1176JZ(F)-S v1.0 - 620 MHz Underclocked to 412 MHz
GPU	PowerVR MBX Lite 3D GPU
Memory	**128 MB eDRAM**
Storage	4, 8, or 16 GB flash memory
Battery	3.7 V 1400 mAh Lithium-ion battery
Display	90 mm (3+ 1/2 in) screen (diagonally) **480x320 pixel resolution at 163 ppi** 3:2 aspect ratio 18-bit (262,144 colors) LCD
Sound	Single loudspeaker
Rear camera	**2.0 MP** with geotagging (not GPS-based)
Connectivity	Quad-band GSM/GPRS/EDGE Wi-Fi (802.1 b/g) Bluetooth 2.0 USB 2.0 / dock connector

June 2007

Did we mention technical debt?

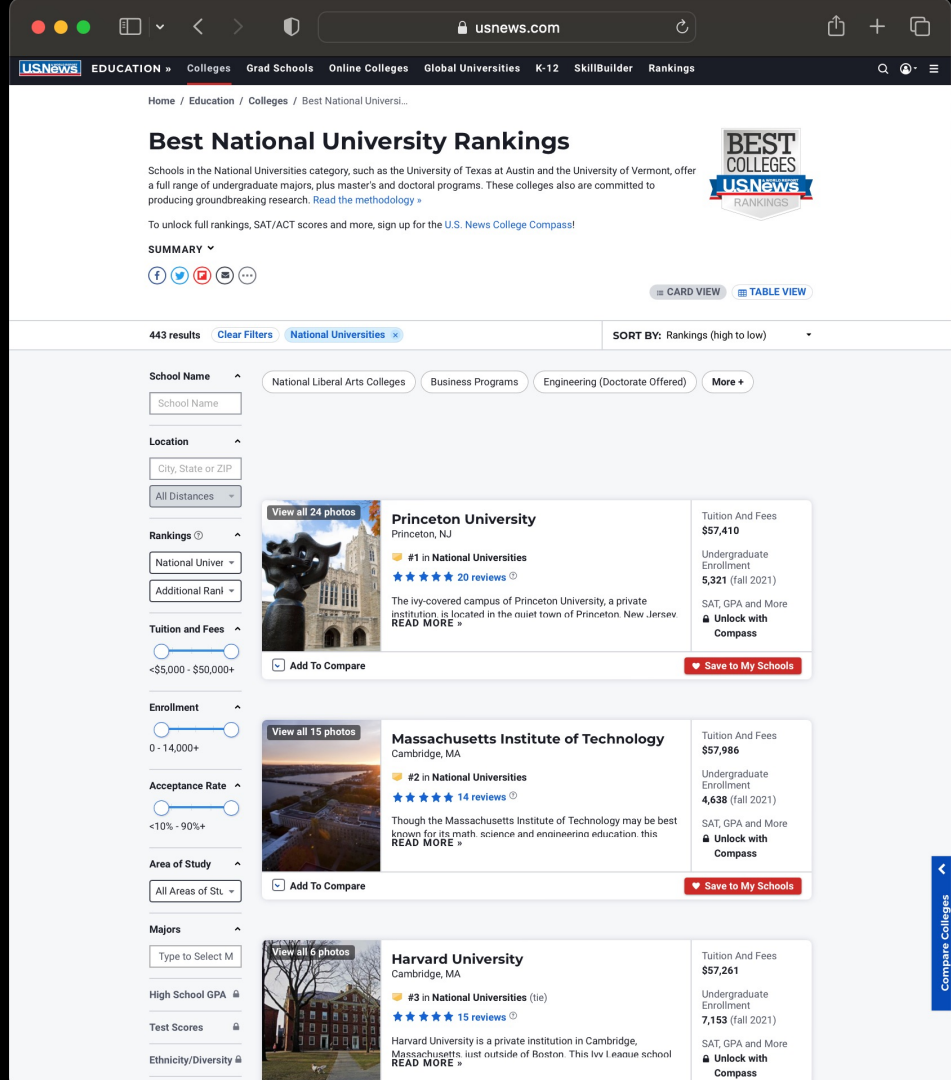
Credit: Heather Sardis of MIT Libraries & MidJourney

Did we?

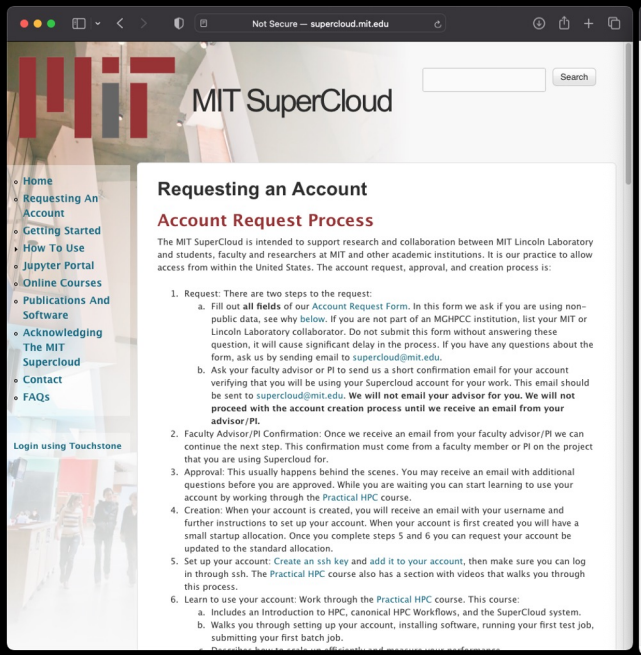
There may, or may not be some of these iPhone 1 vintage servers still in production…

It’s clearly not all bad news.

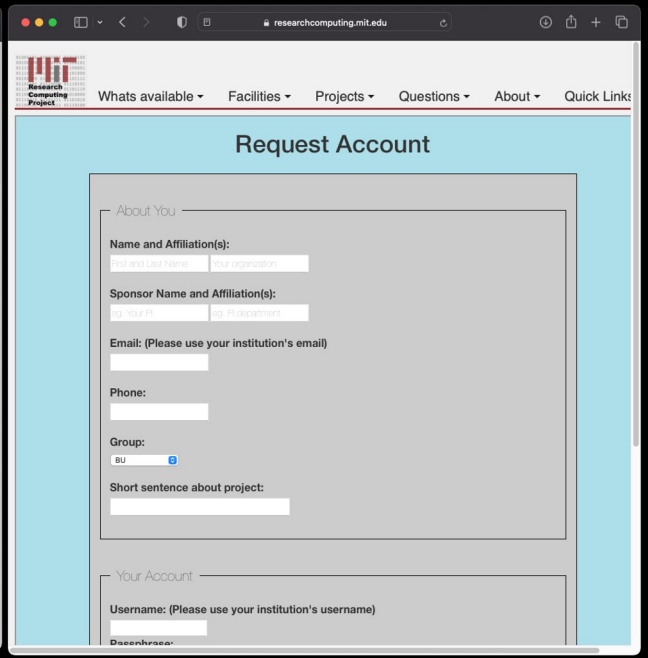
How do we do this?



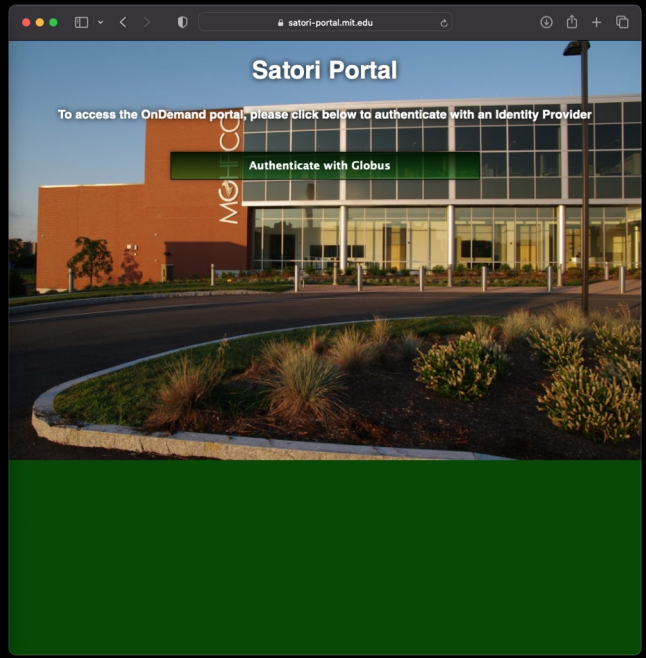
orcd@mit:~# sinfo -a



SuperCloud

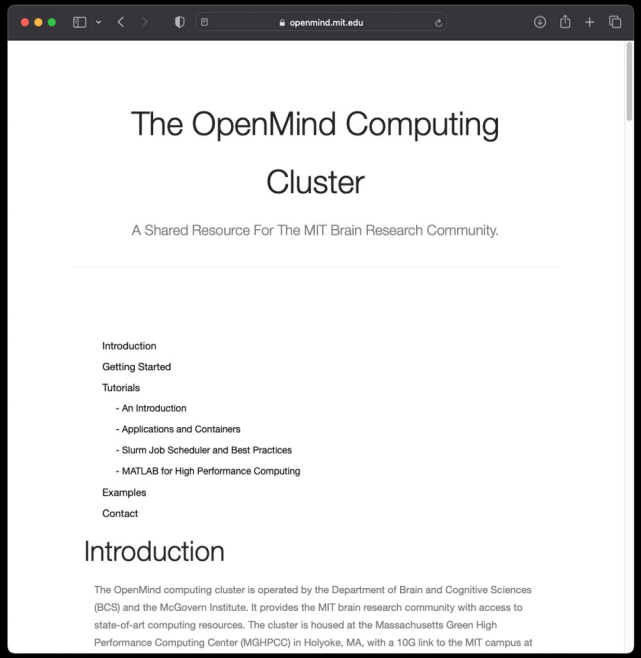


C3DDB

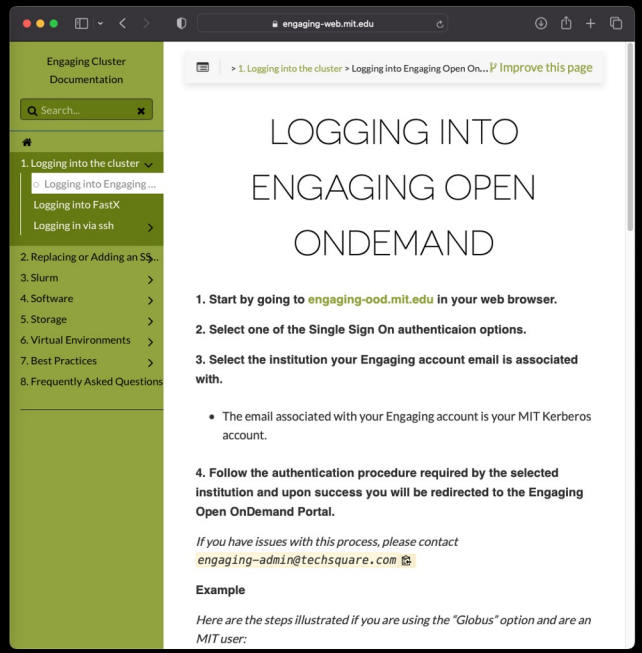


Satori

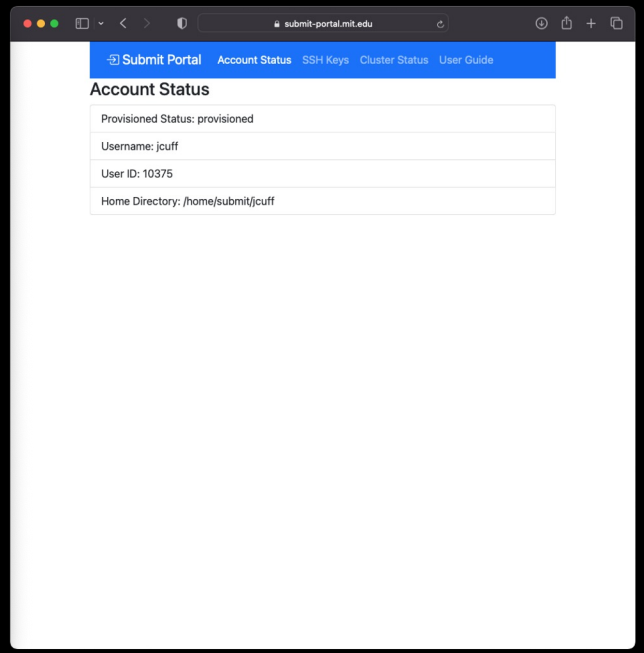
orcd@mit:~# !!



OpenMind



Engaging



SubMIT

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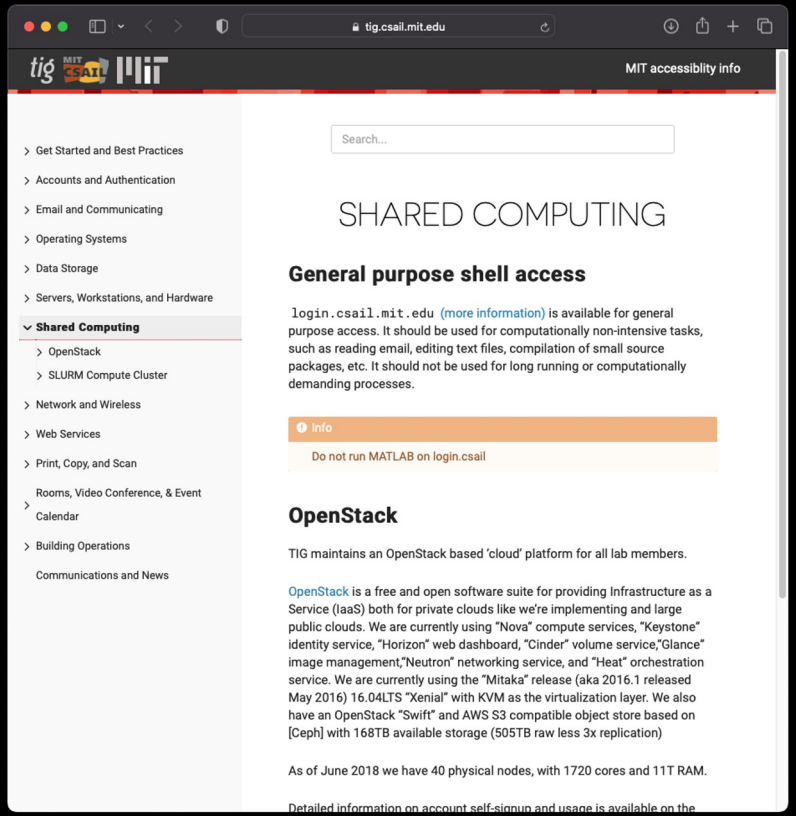
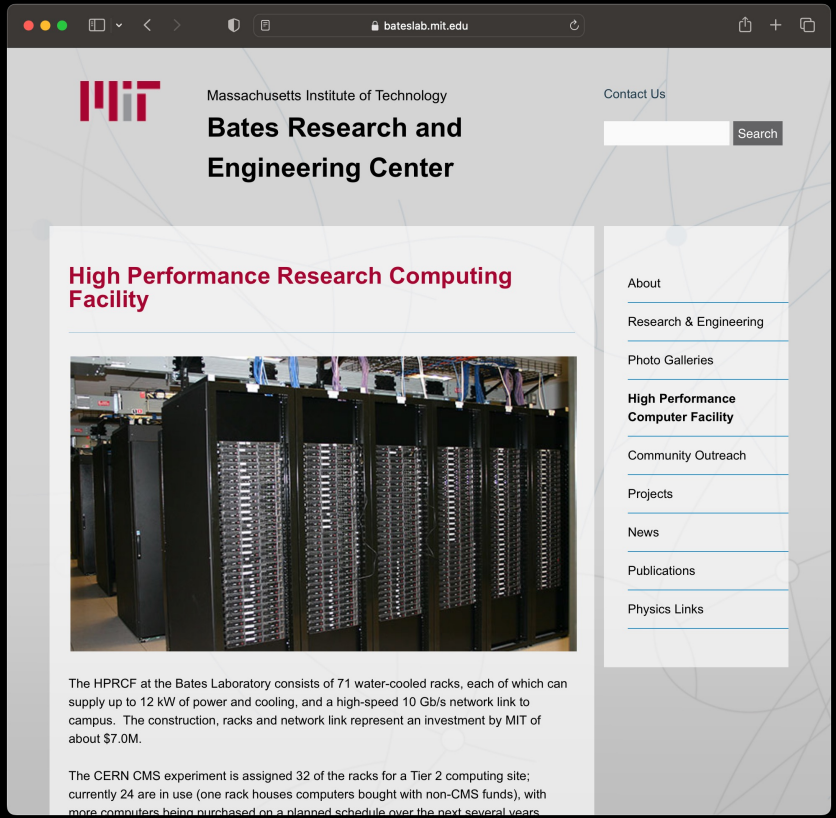
orcd@mit:~# !!

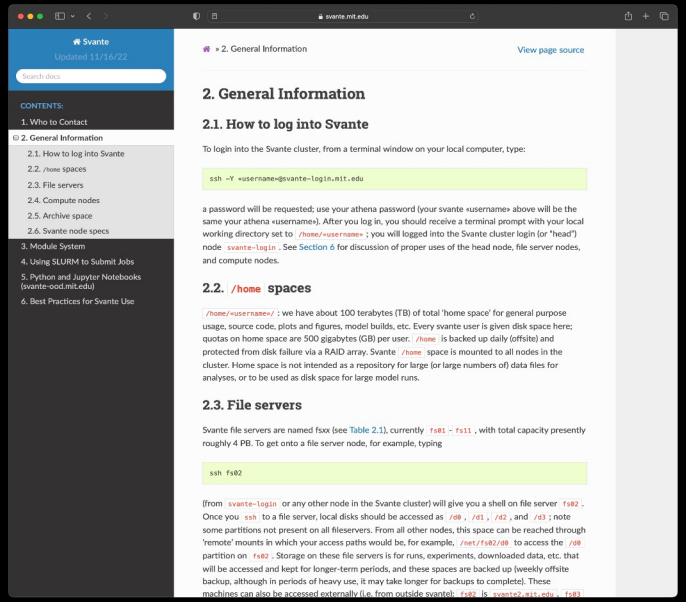


CSAIL - TIG

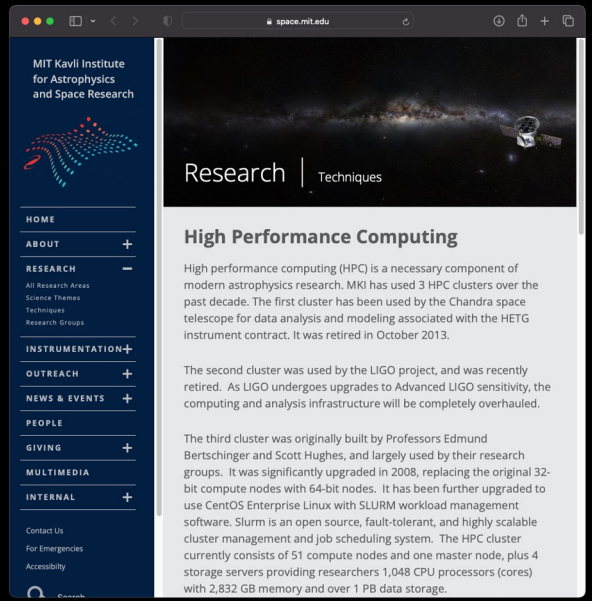


Bates

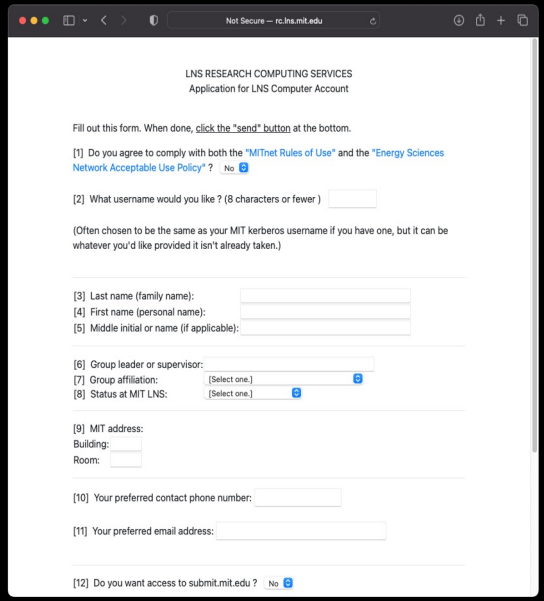
orcd@mit:~# !!



SVANTE



KAVLI



LNS

orcd@mit:~$ CTRL-C

11 clusters, each independently staffed, funded & operated – they do share one thing though… a TLD.

```
# whois.arin.net

NetRange:       18.0.0.0 - 18.31.255.255
CIDR:           18.0.0.0/11
NetName:        MIT
NetHandle:      NET-18-0-0-0-1
Parent:         NET18 (NET-18-0-0-0-0)
NetType:        Direct Allocation
OriginAS:       AS3
Organization:   Massachusetts Institute of Technology (MIT-2)
RegDate:        1994-01-01
Updated:        2021-12-14
Ref:            https://rdap.arin.net/registry/ip/18.0.0.0


OrgName:        Massachusetts Institute of Technology
OrgId:          MIT-2
Address:        Room W92-167
Address:        77 Massachusetts Avenue
City:           Cambridge
StateProv:      MA
PostalCode:     02139-4307
Country:        US
RegDate:
Updated:        2017-01-28
Ref:            https://rdap.arin.net/registry/entity/MIT-2
```

orcd@mit:~$ quota -v

Engaging-1 today *could* be divided up equitably as:

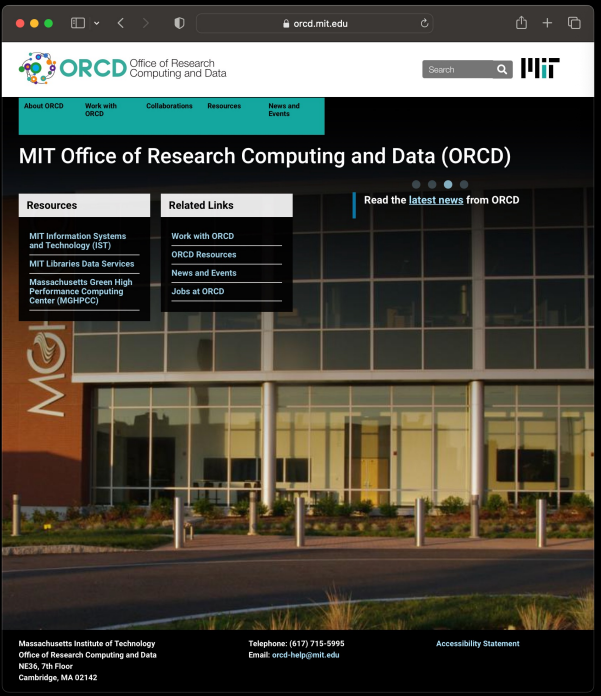
10,000 TB =~ 1TB dedicated per MIT Researcher
45,000 CPU =~ 4 CPU dedicated per MIT Researcher

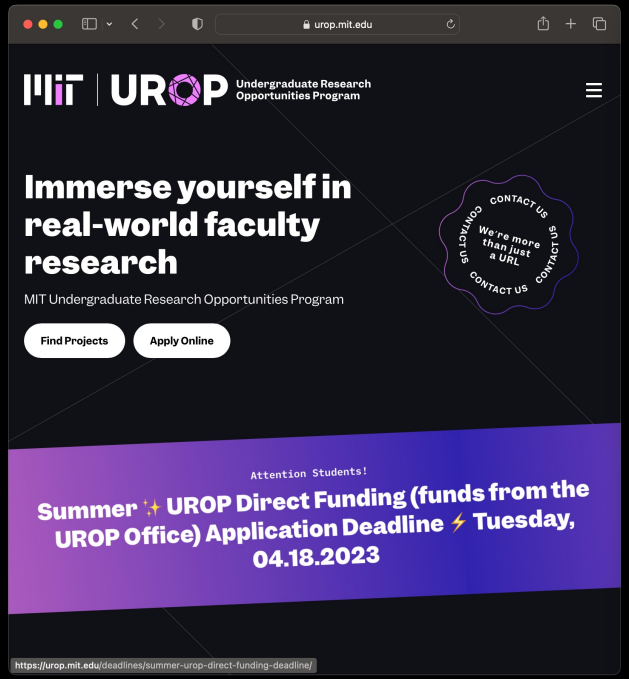
Does not include, SuperCloud (32,000 cores, 450GPU), Satori, CSAIL, Kavli, OpenMind, Svante, Submit, LNS & Bates (70+ racks)

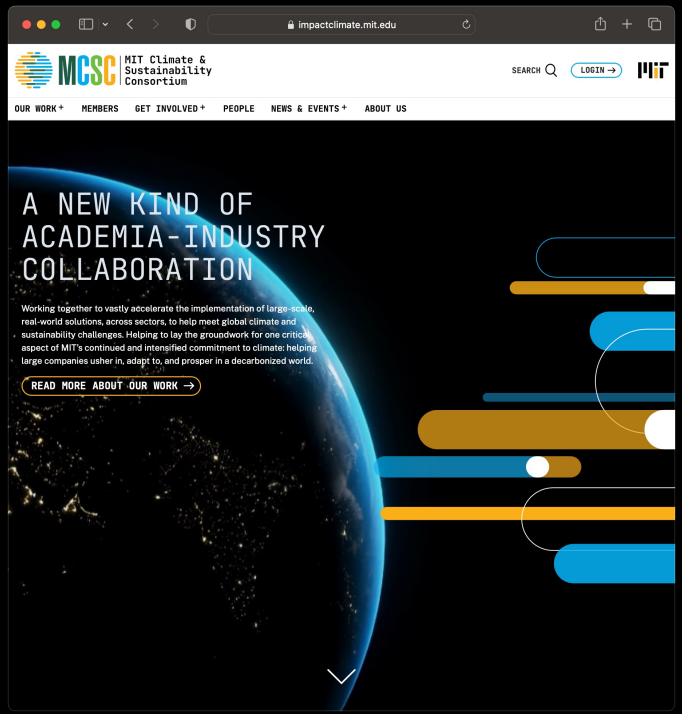
And… 100’s more systems in Closets, Clouds and Chaos!

What is MIT’s total? Over 1,000,000 CPU cores? More?

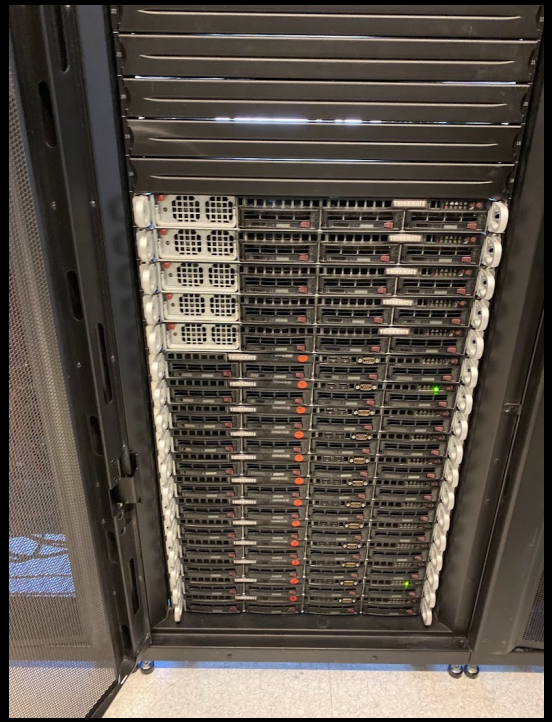
orcd@mit:~# find ./mit -name hpc_cluster*

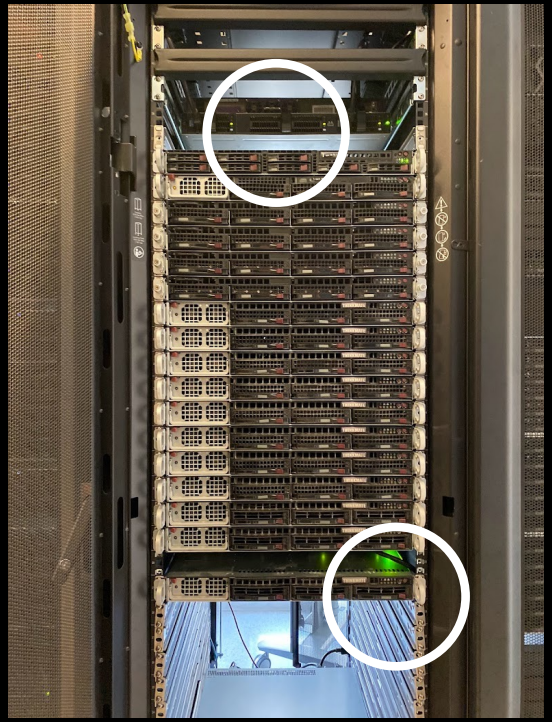


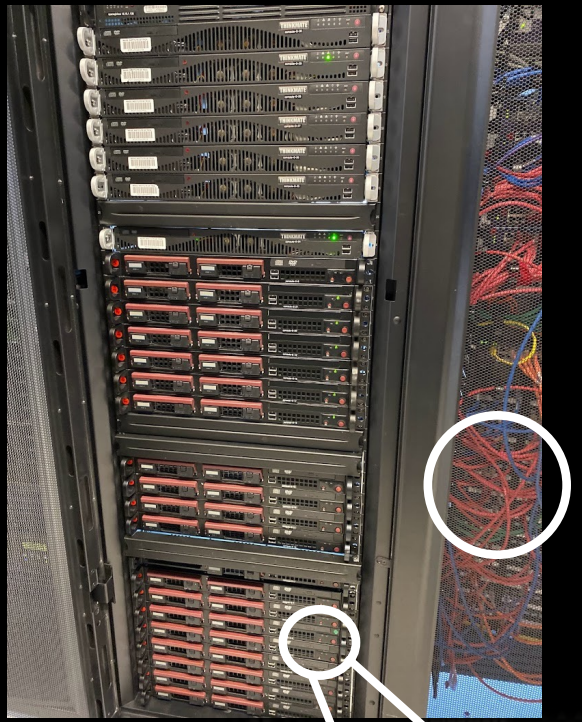


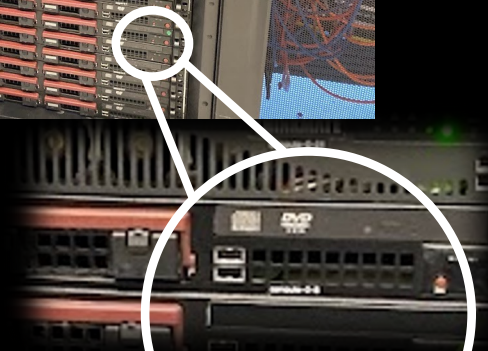


orcd@mit:~# go ./urops.go









Wendy Zhang & Yichen Gao

```
orcd@mit:~# future --predict

ORCD_8ball: Future Looks Cloudy

Try again? (y/n)
```

orcd@mit:~$ ssh root@openai.com /usr/bin/irssi

"The future of research computing is expected to be shaped by several factors, including advances in hardware and software technology, changes in research practices, and new data-driven research methods.

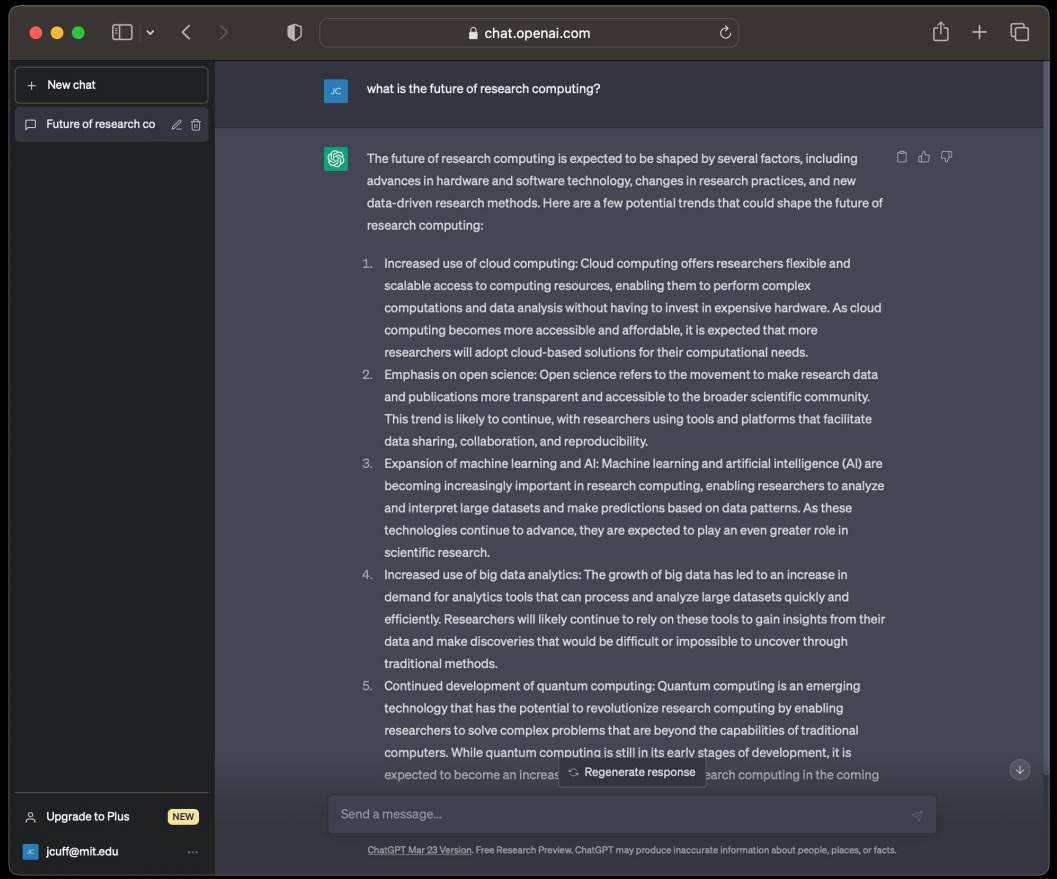
1) Increased use of cloud computing

2) Emphasis on open science

3) Expansion of machine learning and AI

4) Increased use of big data analytics

5) Continued development of quantum computing"



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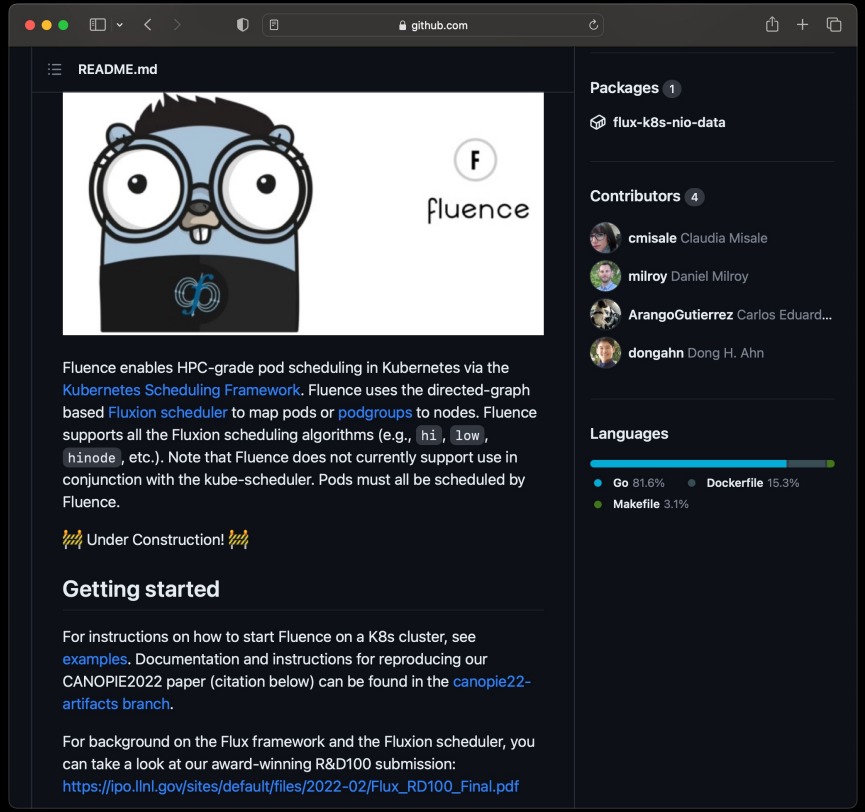
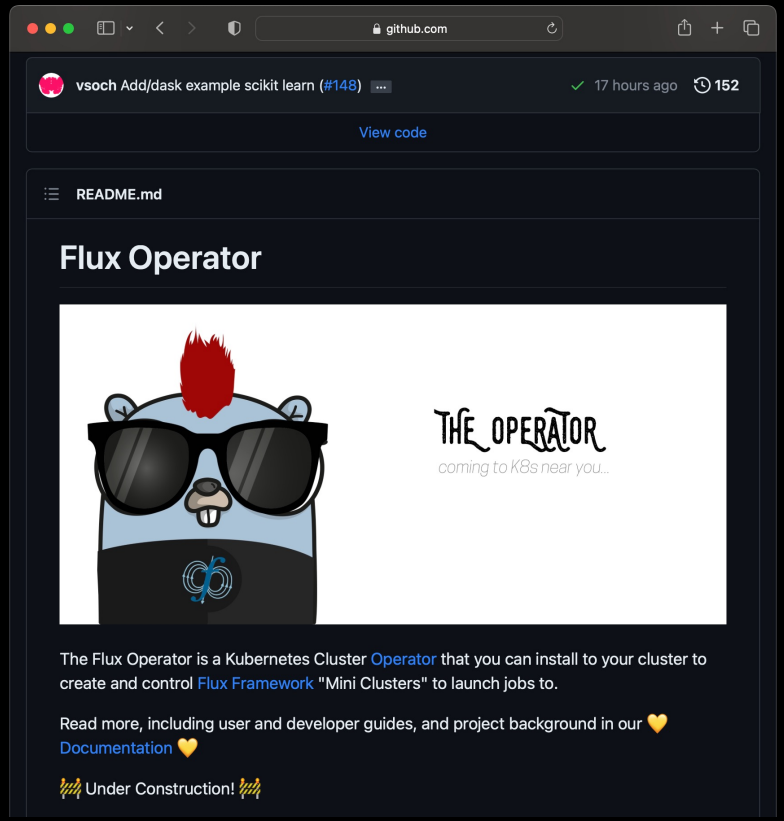
orcd@mit:~# kool_kids_k8.py --hpc --future

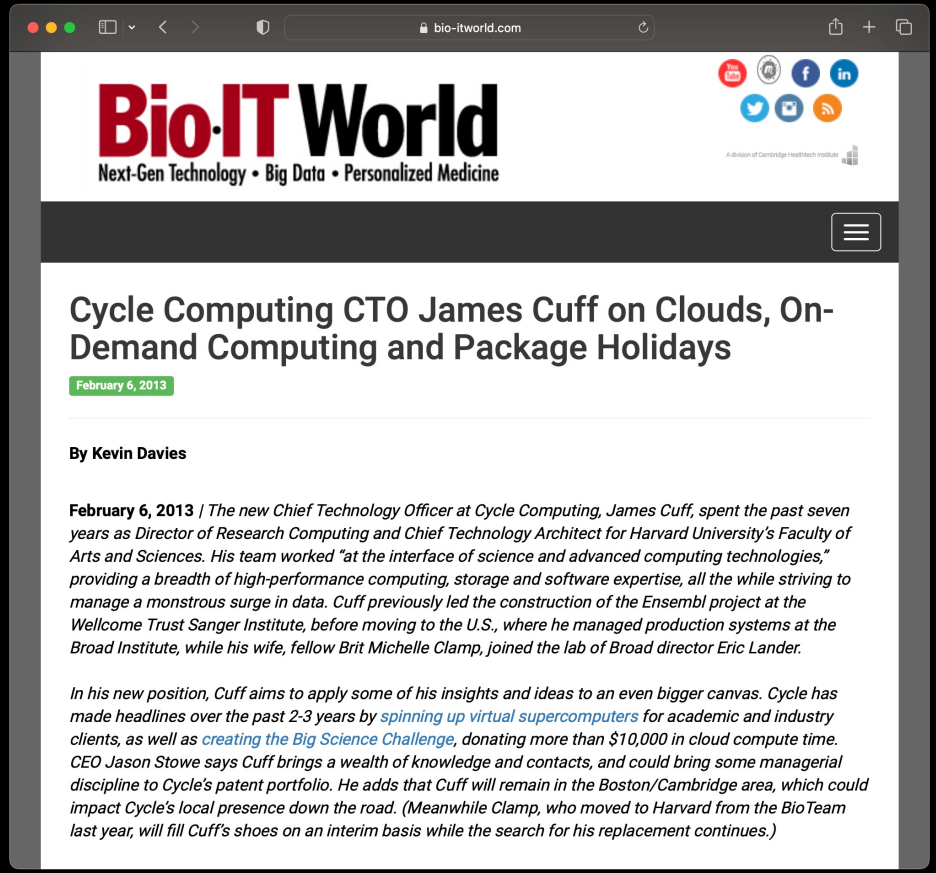




Do check out: https://github.com/flux-framework

orcd@mit:~# cat /dev/null > ./buzzwords.txt

- We've been predicting, and doing all of this stuff for decades
- The Office of Research Computing & Data is all about supporting research **WITH** computing
- The cloud / anti-cloud religion is exhausting & not important, it's just compute, network & storage
- I'll tell you what we're going to do **here** @ MIT for **everyone** @ MIT



BioIT World interview 2013

orcd@mit:~# cat /proc/orcd/mission

1. Provide support to Principal Investigators (PIs) and other researchers across MIT for advanced research computing through training, documentation, facilitation, and other means.
2. Ensure a basic level of access to advanced computing and data management to PIs across MIT that allows them to complete research projects, develop new ideas, and compete successfully for research support. Includes coordination with IS&T and Libraries.
3. Ensure efficient use of all of MIT's advanced research computing and data management resources through sharing, curation, and renewal.
4. Coordinate with other MIT Offices including IS&T, Libraries, and School/College Deans in providing advanced computing and data management resources to the educational program through the Office of the Vice Chancellor (OVC).

ORCD IS NOT JUST ANOTHER SHADOW IT ORGANIZATION

orcd@mit:~# echo “the 2 pillars of ORCD”

Platforms Infrastructure and Data Services

HPC & Scientific Consulting Services

Director of PIDS Starts July 31st 2023

orcd@mit:~# cat .plan

1. Funds to support ORCD staff and operations to enable basic access for 11,611 researchers + 4,400 undergraduates
2. Develop funding model for PI-driven initiatives
   - Sharing between PI, DLC, ORCD, School/College, Provost
3. Create and support secure repository for sensitive and shared data ORCD_ENCLAVE
4. “Get Well Plan” for shared resources

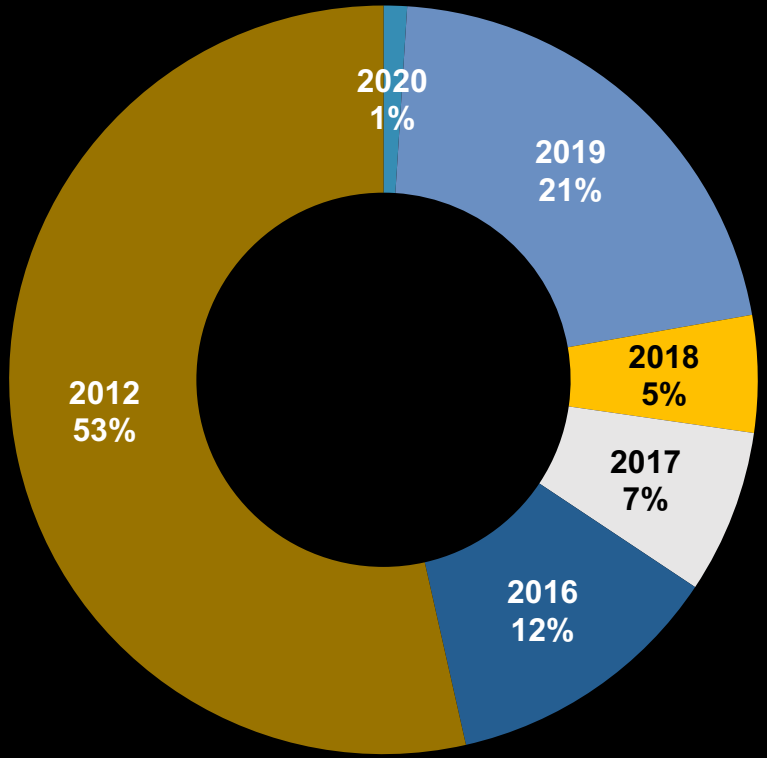
ORCD Office of Research Computing and Data

Ensure **basic** access to high performance research computing to **all** 11,611 researchers at MIT, support for PI driven computing initiatives, and consulting help for users and purchasers of computing and data resources.

We have been fully funded.

Modernizing $20M (replacement value) of over 10 years of legacy computing infrastructure and processes

1. Develop new organization based on **operational excellence and obsessive customer support** working with IS&T, Libraries, Facilities, Sustainability, Audit
   - Decommission legacy systems and infrastructure
   - Build a **reliable fault-tolerant foundation** and sharing platform (login, home, auth, access controls, storage, standards-based networks and on-call FTE)
   - **Secure, harden** all research computing endpoints & data at rest
   - Provide **frictionless** access through 2fA, Globus & Open on Demand
2. Build the ORCD_ENCLAVE: A **secure, sustainable** repository for all **sensitive and shared data**
3. Integrate remaining viable systems into a new shared research computing platform (“Engaging TNG”)



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orcd@mit:~# setenforce 1

The new ORCD_ENCLAVE is critical

Over the next 12 months will build MVP

Multi petabyte scale shared, secure storage you can compute against

Don’t be clever – be reliable, be predictable, be available!

orcd@mit:~# mghpcc --show --spare -orcd

MGHPCC Capacity report
Date: Apr 24 2023

Racks:	64
RU:	3000
Rack:	50KW
Date:	Oct 2023
MAX:	3200KW
Cooling:	Liquid
Invest:	$3,000,000
Tech Debt:	NONE

ORCD Office of Research Computing and Data

```
orcd@mit:~# python ./install.py
```

Over $3M of shared community hardware *installed,* and managed by ORCD since October 2022!

13 departments and 19 PIs

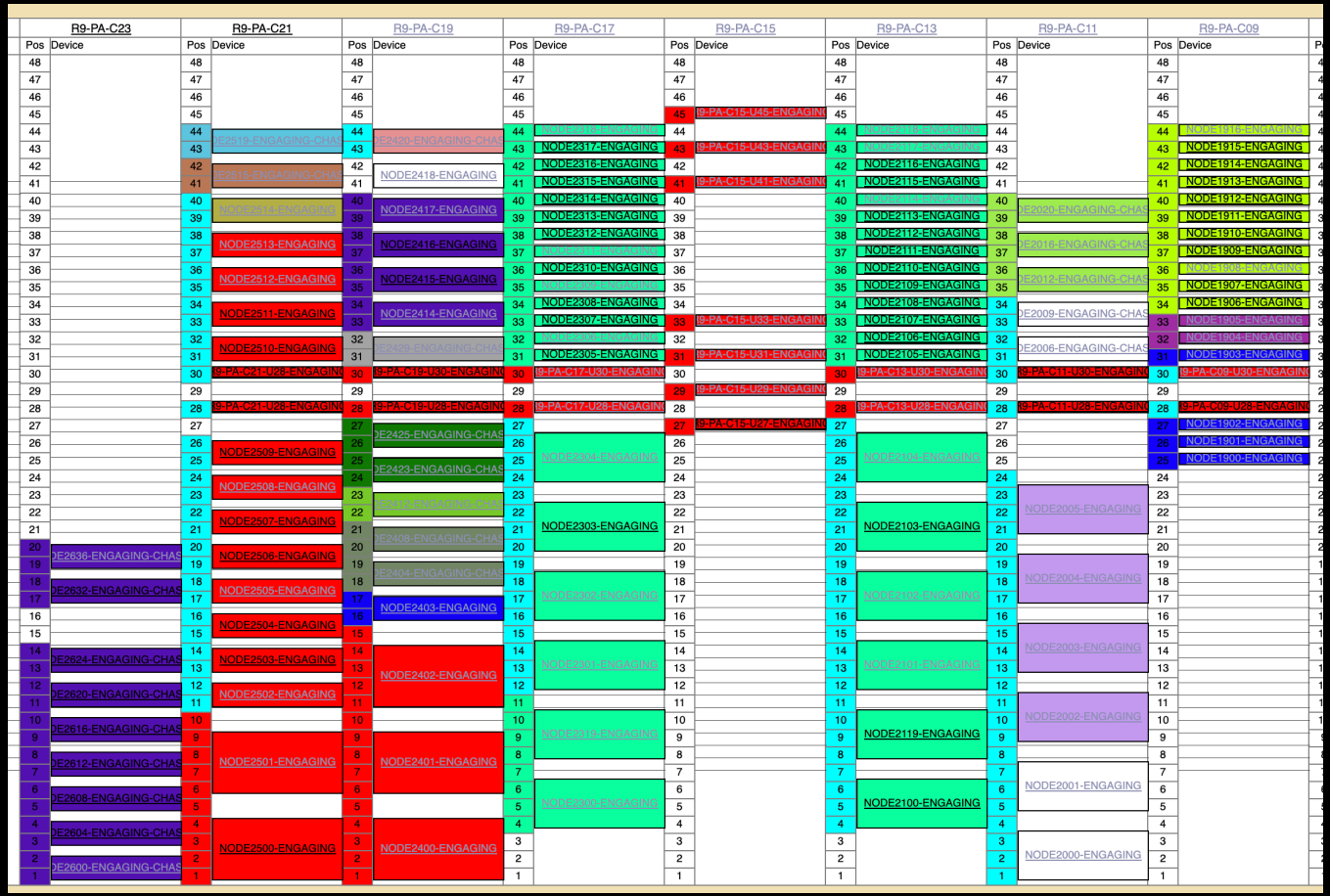
160 computers
13,768 CPU cores
130 Ampere and Hopper class GPUs

Operating savings
~400 tons of CO2 emissions avoided
~0.13MWh energy cost reduction

orcd@mit:~# nvidia-smi

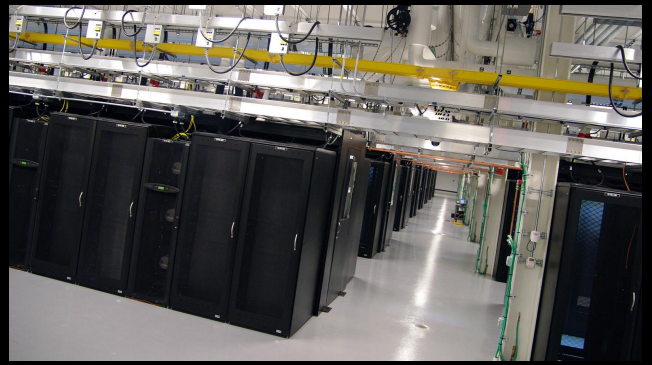
```
Mon Jun 19 07:55:42 2023
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 530.30.02              Driver Version: 530.30.02    CUDA Version: 12.1     |
|-------------------------------+----------------------+----------------------+
| GPU  Name                 Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf           Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  NVIDIA H100 80GB HBM3           On | 00000000:19:00.0 Off |                    0 |
| N/A   53C    P0             551W / 700W|  77753MiB / 81559MiB |     97%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+
|   1  NVIDIA H100 80GB HBM3           On | 00000000:3B:00.0 Off |                    0 |
| N/A   52C    P0             685W / 700W|  77653MiB / 81559MiB |     97%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+
|   2  NVIDIA H100 80GB HBM3           On | 00000000:4C:00.0 Off |                    0 |
| N/A   51C    P0             549W / 700W|  64345MiB / 81559MiB |     97%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+
|   3  NVIDIA H100 80GB HBM3           On | 00000000:5D:00.0 Off |                    0 |
| N/A   57C    P0             726W / 700W|  77573MiB / 81559MiB |     97%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+
|   4  NVIDIA H100 80GB HBM3           On | 00000000:9B:00.0 Off |                    0 |
| N/A   56C    P0             639W / 700W|  77945MiB / 81559MiB |     97%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+
|   5  NVIDIA H100 80GB HBM3           On | 00000000:BB:00.0 Off |                    0 |
| N/A   55C    P0             683W / 700W|  70665MiB / 81559MiB |     97%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+
|   6  NVIDIA H100 80GB HBM3           On | 00000000:CB:00.0 Off |                    0 |
| N/A   53C    P0             600W / 700W|  64345MiB / 81559MiB |     97%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+
|   7  NVIDIA H100 80GB HBM3           On | 00000000:DB:00.0 Off |                    0 |
| N/A   52C    P0             554W / 700W|  77389MiB / 81559MiB |     97%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+
```

orcd@mit:~# cat /proc/racktables | grep Oct22



MGHPCC: Massachusetts Green High Performance Computing Center

Power comes from a hydroelectric plant
Electricity costs ½ of what it does in Cambridge
Building operates 2x as efficiently as Cambridge
LEED Platinum building and operations since 2012



openDCIM
data center infrastructure management

openDCIM Computer Facilities
Data Center Statistics

Language en_US
admin/19.

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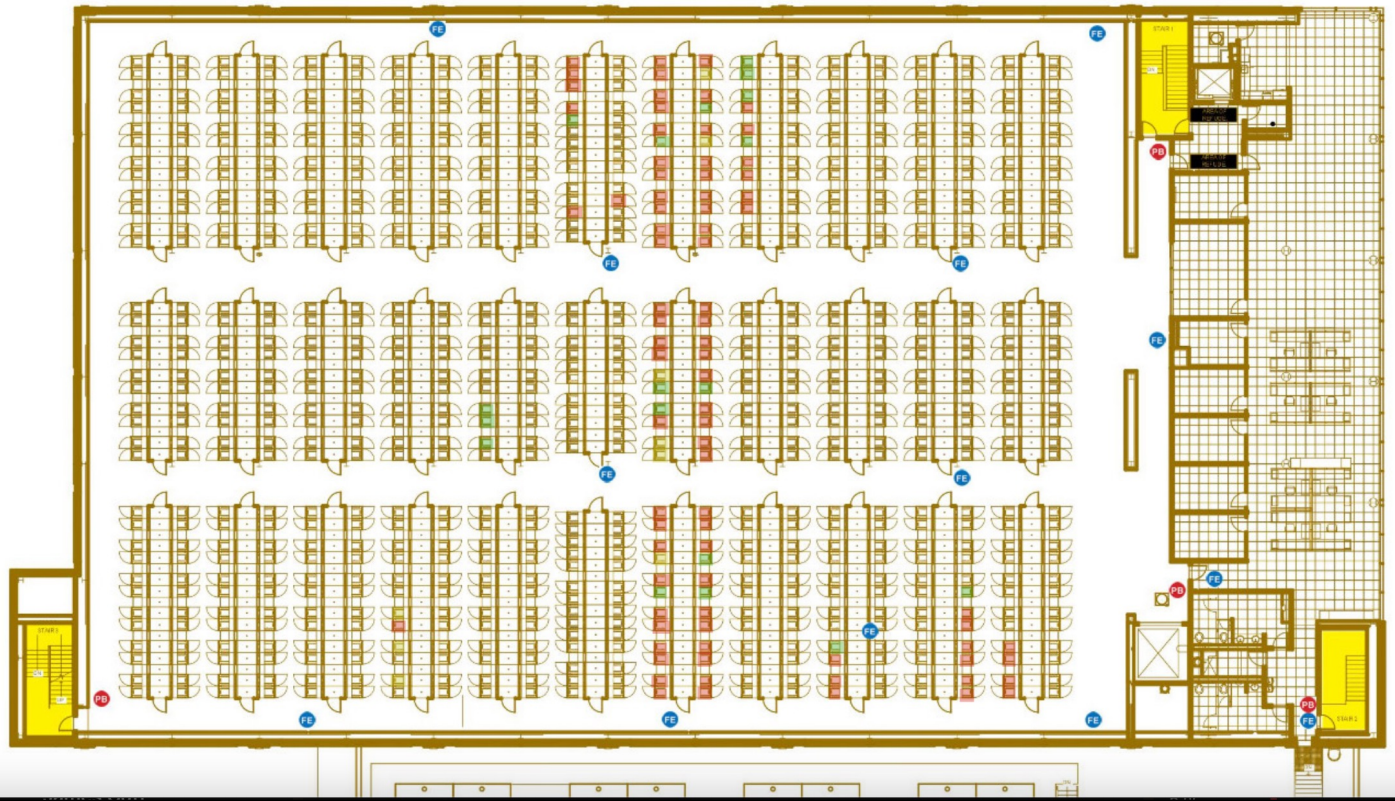
Composite View of Cabinets

Overview



ORCD Office of Research Computing and Data

orcd@mit:~$ play hua_rong_dao.wav

In the year 208 Cao Cao led 220,000 troops of the Wei army to fight against an army of 50,000 Shu troops in a mountainous area near Chibi in today's Hubei province. Because of some strategic errors, Cao Cao's troops were badly defeated in the Battle of Chibi, and he fled with only a handful of his soldiers.

The opening at the bottom of the board is Huarong Pass. Initially the blocks are arranged as shown here, with Cao Cao's block trapped by the other nine. The player's job is to slide blocks horizontally and vertically so that Cao Cao can eventually escape through the pass.

(Hint: The game can be solved in 81 moves of 25,955)

So, in summary…

- Provide a “One MIT” research computing and data infrastructure
- Enable MIT to be competitive for MRI & other $10-$100M+ computationally intensive next generation awards
- Provide a **safe, professional and secure environment** for research scientists and their data
- Develop **highly skilled technical systems support staff** and research facilitators & engineers to support faculty and researchers
- Provide significant **economies of scale** and be a forcing function for research computing **best practices**, a **safe place** for investments, and USG data requirements
- Direct **sustainable core funding** to **make every dollar count** towards research -- more compute per KW

Be a first-class citizen of science to support MIT’s research mission

ORCD Office of Research Computing and Data

orcd@mit:~# finger orcd

```
Login: orcd                         Name: Office of Research Computing
Directory: /mit/vpr/orcd            Shell: /bin/tcsh
Last login Thur Jan  5 04:56 2023 (EDT) on pts/0 from 192.168.99.5
New mail received Fri Jan  6 05:25 2023 (EST)
     Unread since Fri Jan  6 05:24 2023 (EST)

Plan:
Build a great, sustainable, reliable and professional “One MIT”
research computing experience for faculty, staff and students

URL:                    https://orcd.mit.edu
JAMES CUFF:             https://mit.edu/~jcuff
EMAIL:                  jcuff@mit.edu; fisherp@mit.edu
MAILING LIST:           orcd-admin@mit.edu
```

orcd@mit:~# cat ~/acknowledgements.txt

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Heather Williams

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The VPR web team & all @ TechSquare

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Mark Silis

Jeremy Gregory

Joe Higgins

Greg Moffatt

Glen Shor

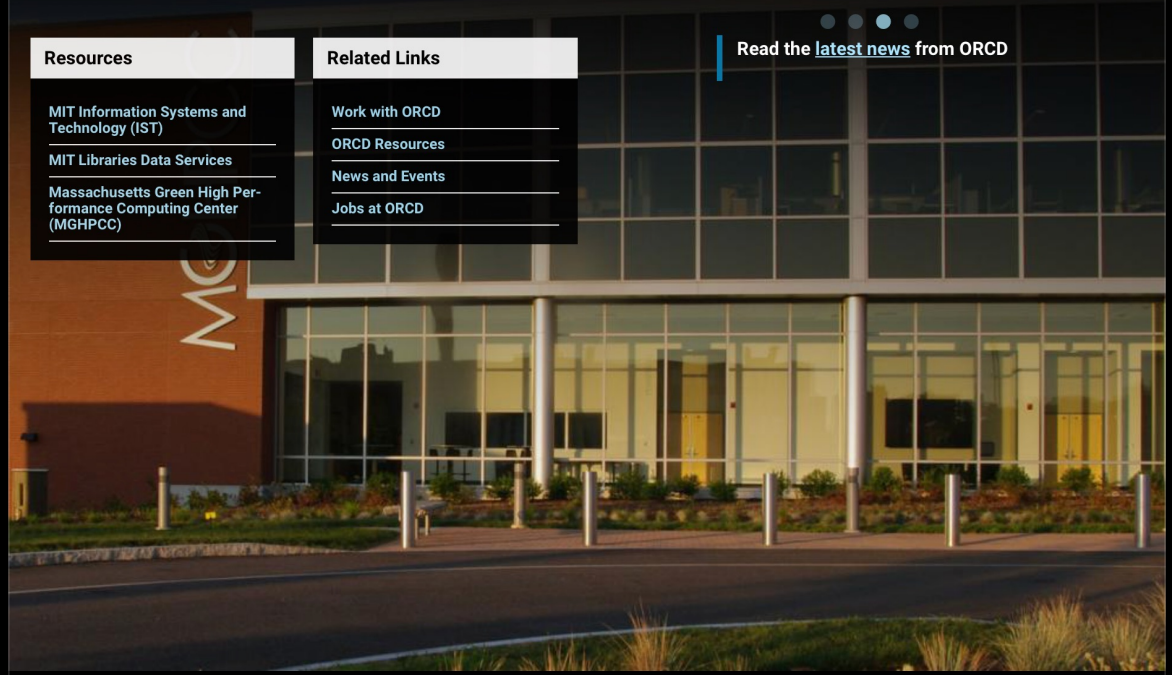
Prof. Maria Zuber

Prof. Cynthia Barnhart

```
orcd@mit:~$ echo ‘echo anyone?’ \
> questions.sh

orcd@mit:~$ while true; \
do sh ./questions.sh; done
```

MIT Office of Research Computing and Data (ORCD)



Resources

- MIT Information Systems and Technology (IST)
- MIT Libraries Data Services
- Massachusetts Green High Performance Computing Center (MGHPCC)

Related Links

- Work with ORCD
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