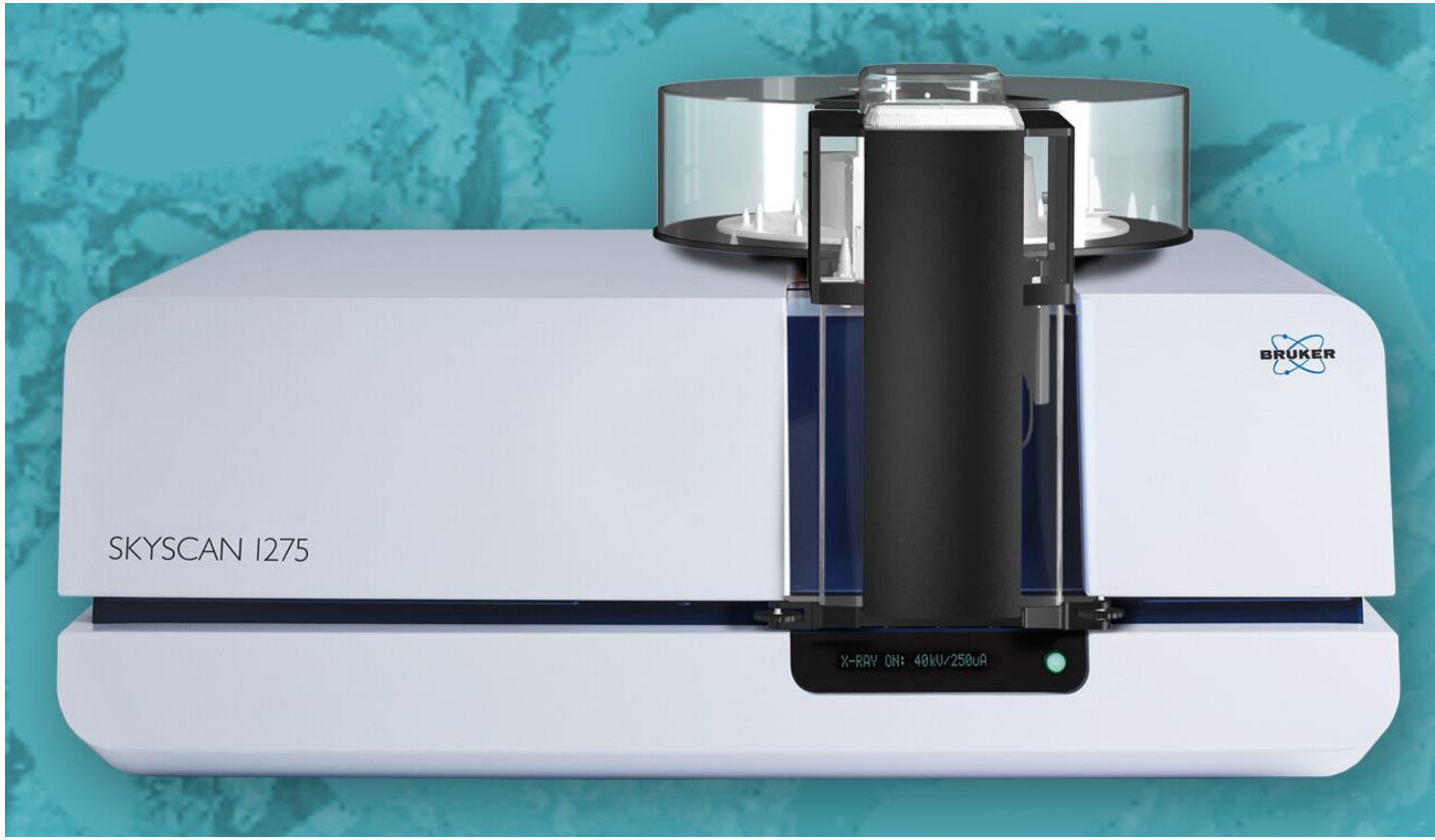
3D Imaging systems range in their price and capability

~$3,000



~$300,000

Example microCT Datasets

1024x1024x1024 voxels (1 Gigavoxel) (can be processed in a laptop)

8 bit volume (0-255 grayscale)

is **1GB uncompressed**.

1024x1024x4096 voxels (4 Gigavoxels)

16 bit volume (or 0-65535 grayscales)

is **8GB uncompressed**.

2048x2048x2048 voxels (8 Gigavoxels)

8 bit volume (0-255 grayscales)

is **8GB uncompressed**.

Computing investment for data analysis

- **CPU:** Many (but not all) filters and operations in Slicer benefit from multi-core. Get as many cores as you can, without crippling the other components (Min. suggested 12 cores)*
- **Memory (RAM):** Minimum RAM 10X as your largest data*
- **GPU:** We do not recommend ATI (sorry Mac folks). Nvidia
- **Storage:** Decide speed vs capacity and probably have a tiered approach.
- **Backup:** Talk to your local IT folks for professionally maintained backup

***will vary if you plan for a multi-user server**

GPU: Nvidia Geforce series is sufficient for Slicer

$3000-2500, 24Gb VRAM

$1500-1200, 11GB VRAM

- Comparable rendering performance (i.e., they have similar number of graphical cores, but TITAN RTX has more than twice the Video RAM of 2080TI. This matters if system is shared across users.
- You need the video RAM to be able to load large datasets in full resolution:
- For 3D Slicer (or any visualization software based on VTK library) [GL_MAX_3D_TEXTURE_SIZE] of GPU is crucial: Check reported values as **https://opengl.gpuinfo.org/**
- Even high-end ATI cards seem to be capped at 2,048. In recent Nvidia Geforce cards this is 16,384.
- What does this mean: **100x100x2049** volume will not GPU render in any ATI card, but will work fine with on most laptops with recent Nvidia cards (sorry Mac folks, this is one place where your H/W definitely fails you!).
- **For now buy RTX 2080TI, but if you are considering a multi-user setup, invest in TITAN RTX**

Storage: Types and performances

HDD Baseline 1X **SATA SSD 5X** **NVME SSD 25X**

Storage: Types and price

HDD:
10TB ~$300
$30/TB

SATA SSD
4TB ~$400-500
~$100/TB

NVME SSD
1TB~$200
8TB~$2,000

A performance test and deciding trade-offs

1. Reading a sequence of **2200 PNG** images that resulted in a **10GB volume** took **3’ 25"** on a 32GB laptop with a 1TB NVME drive using ImageStacks.

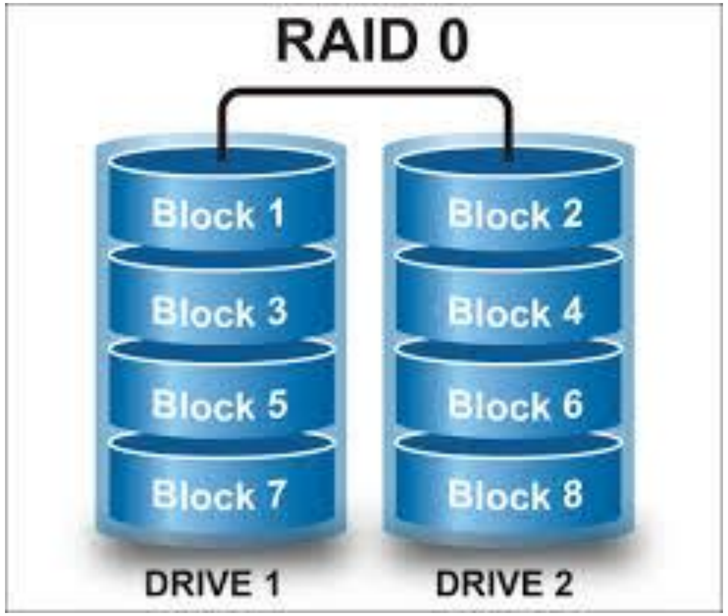
2. Saving same volume as **NRRD without compression** took about 4” (secs). When **compression enabled**, saving same NRRD takes about **5 minutes** as oppose to 4 seconds.

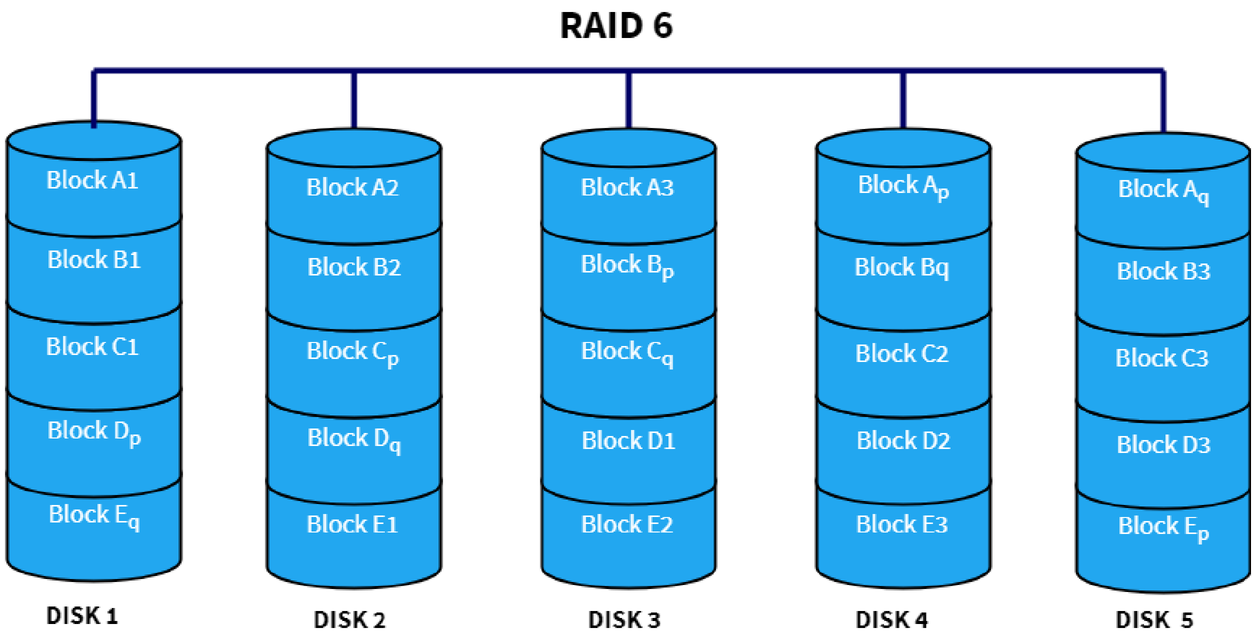
3. Flushing the cache and reloading the uncompressed **10GB NRRD** into a fresh instance of Slicer (so no caching is used) took **26”**.

TRADE OFF: If you enable compression, there is not much benefit from having the expensive NVME apart from loading programs and booting somewhat faster. If you don’t enable compression, your NVME will fill very quickly.

https://discourse.slicer.org/t/can-slicer-utilise-multiple-cores-on-linux/9240/6?u=muratmaga

Redundant Array of Inexpensive Disks (RAID)





Redundant Array of Inexpensive Disks (RAID)

Increasing redundancy and failure protection

RAID Level	Read/ write	4 Disks	8 Disks	4 SSDs	8 SSDs
RAID 1+0	Read	536 MB/sec	904 MB/sec	1,466 MB/sec	2,338 MB/sec
	50% usable cap.	342 MB/sec	629 MB/sec	686 MB/sec	1,270 MB/sec
RAID 5	Read	534 MB/sec	1,220 MB/sec	1,038 MB/sec	2,129 MB/sec
	Write	75% usable 526 MB/sec	88% usable 1,158 MB/sec	947 MB/sec	1,564 MB/sec
RAID 4	Read	534 MB/sec	1,220 MB/sec	1,038 MB/sec	2,129 MB/sec
	Write	526 MB/sec	1,158 MB/sec	947 MB/sec	1,564 MB/sec
RAID 0 (no protection from disk failure)	Read	696 MB/sec	1,397 MB/sec	1,524 MB/sec	2,438 MB/sec
	100% usable	688 MB/sec	1,379 MB/sec	1,380 MB/sec	2,569 MB/s

Spinning hard disk performance is capped about ~150-250MB/sec
SATA SSD performance is capped about 400-500MB/sec
Current NVME performance is about 3000-5000MB/sec, will probably double in

24 x 10TB drives = 240TB raw capacity
(Drives will cost about $3K, unit and the RAID controller will be about another $4-5K, so about $10K)

RAID0 = 240TB usable (extremely fast, extremely dangerous like NASCAR, F1)

RAID6 = 220TB usable (two disk redundancy, still fast, but more disks for redundancy will be safer)

RAID10 = 110TB usable (half of disks are used for redundancy, Toyota corolla of RAID)

Keep in mind if disk annual failure rate is e.g., 5/100 and you have 24 disks in your array, expect to have at least one failure per year. So keep replacements in lab.

RAID≠BACKUP

How you connect your storage matters:

- **Network attached storage (NAS):** If the user access it through gigabit connection, regardless of the array performance, you can only pull/push data at the gigabit network speed (about 100MB/s, or a performance of a slow spinning HDD).
- **Direct attached storage (DAS).** Can be anywhere from **5,000-10,000MB/sec.** (options are myriad thunderbolt to optical SPF). But cannot be shared across users unless users login into the server.

Finally good monitors and…

… a three-button mouse is a must!

Curse of dimensionality:

About 2 megapixels on screen (i.e., GPU happily spinning your specimen in a maximized 3D window).

About 8 megapixels on screen (i.e., GPU breaking a sweat rendering the same specimen in a maximized 3D).

Space-mice, digitization tablets and monitors

Consider using Linux as your OS.

- **No OS fees** (every computer you buy will cost at least $200 less, thousands if you are buying a server).
- Almost all **open-source scientific software development is done on Linux**. Meaning less headache when building other people's code.
- You can design a **multi-user environment**, in which student's use their low-end computers or laptops to remote into and run Slicer (and other 3D programs) using the high-end GPU inside your lab server. (I.e., no need to put $10K computer in front of every student, just decent monitors and mouse).
- You can design a tiered direct-attached storage in a server:
  - /scratch or /tmp: A few TBs of space with really high speed (RAID0 of NVMEs or SSDs). Not backed up, only for transient data (like importing, saving temporarily)
  - /home: People's directories on a highly redundant, high-capacity performant systems
  - /backup: Extremely redundant, heaps of storage not necessarily fast that mirrors your system hourly, daily, weekly, monthly and yearly increments. (only accessible to admin)
- When configured correctly RSYNC is as good as any commercial backup program.

Suggestions:

- When starting new, do **NOT** spend all your computer budget at once.
- Try to go get by with the minimum/cheapest that you can for a while until you figure out:
  - Your average data size (is it in 1-2gigavoxel range or 5-10?)
  - How much data you generate annually.
  - What data management strategy you want to use

    Do you keep everything? Datasets multiply:

    Scan files->Image Stacks->3D Volumes->Segmentation->Models
  - How many people in your lab will be working with 3D data and what their needs are?
  - What kind of IT support there is and what are the restrictions in your environment
- You ask for $20-30K in your computer budget.