Computational Imaging

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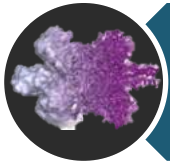
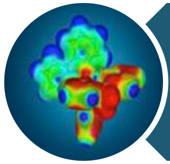
Computational Imaging Applications


Virtual Reality


Science


Engineering

Security


Medicine

Imaging in Virtual Reality

Virtual Reality

Computational Refocusing

Source: wikib=oedia and Tecnolgy Review

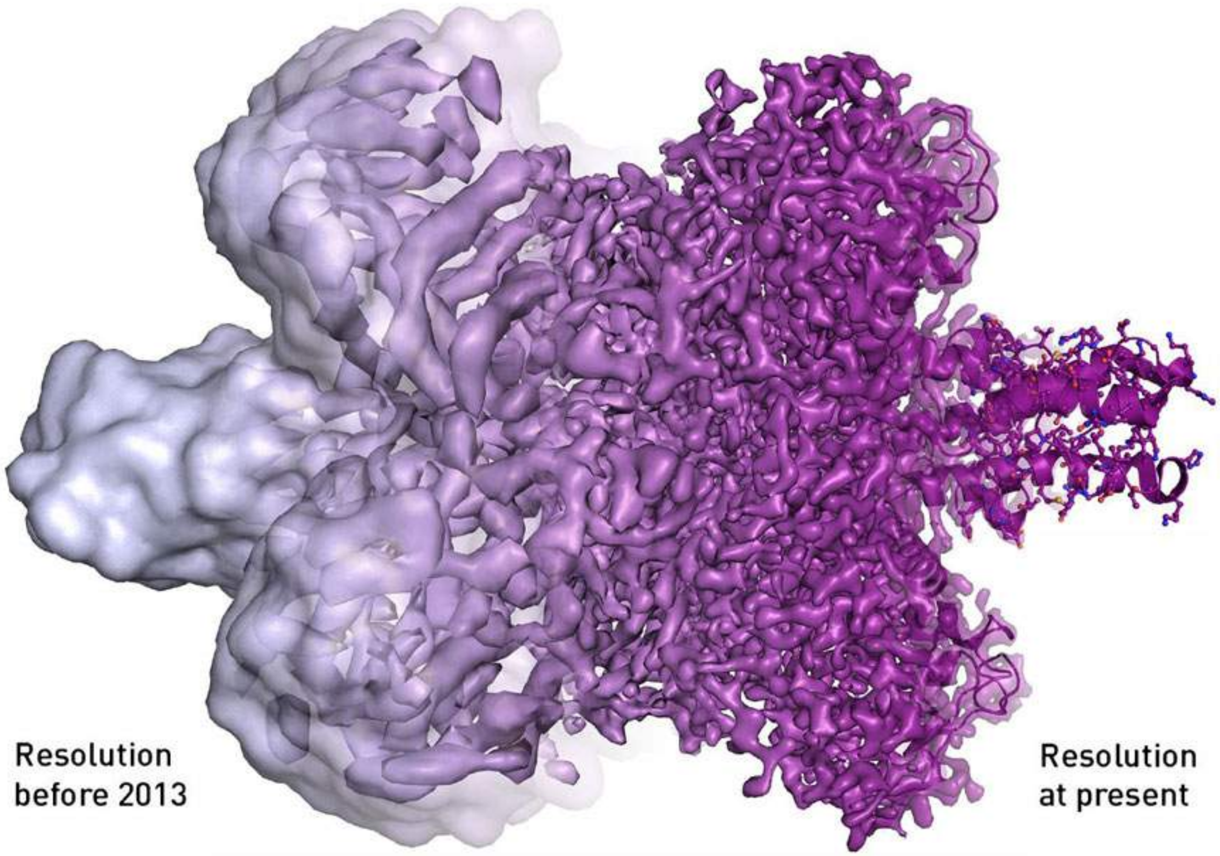
Light field cameras

Lytro Immerge Camera

Google's Light field Camera

Source: wikipedia and Technology Review

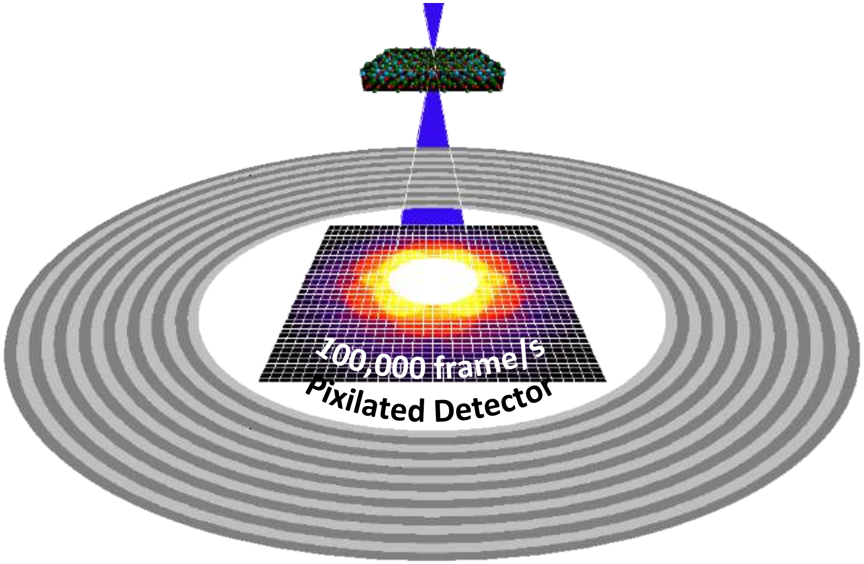
Detectors: the "sensory system" for science



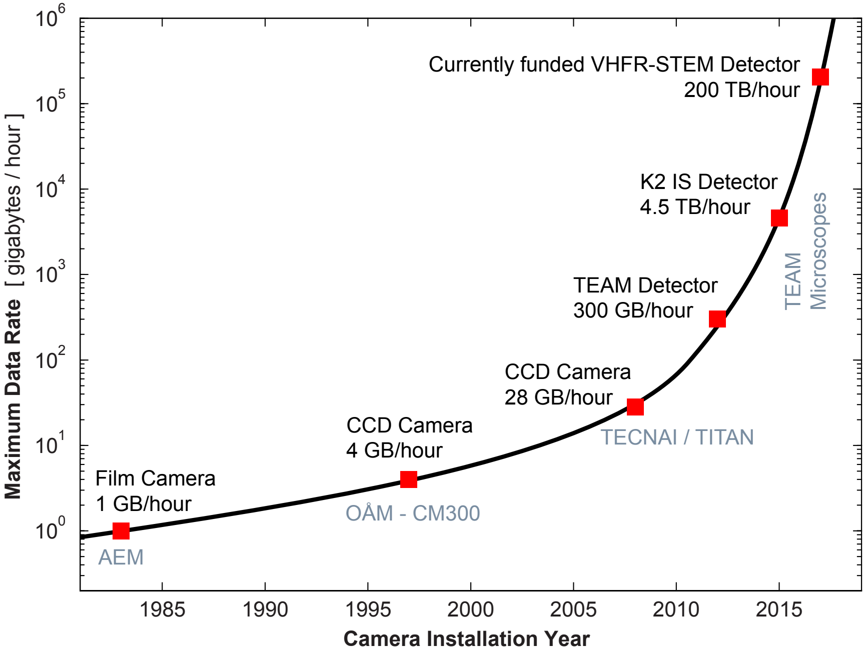
Berkeley Lab advances detector technology for many fields of science, including (above CryoEM) biology, cosmology, material science, physics, and more.

Data Rates from the Latest Detectors

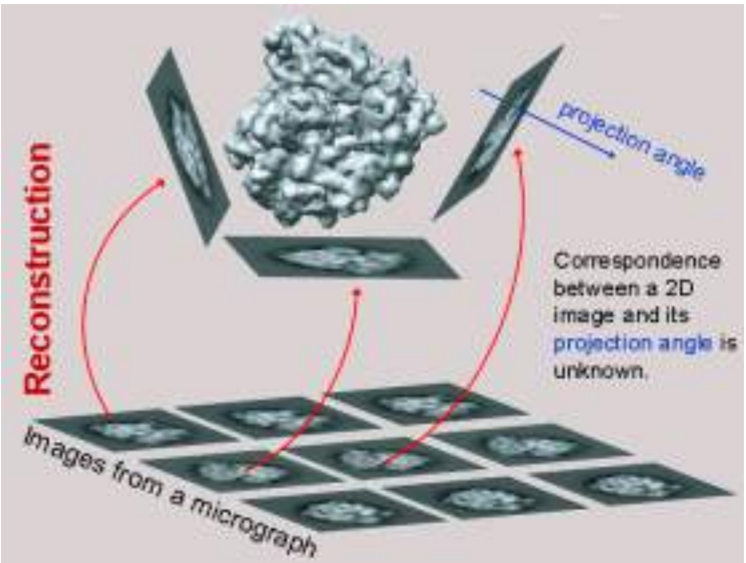
100,000 fps STEM detector for Electron Microscopy



Using 400 gbps WAN to move data from EM facility to NERSC



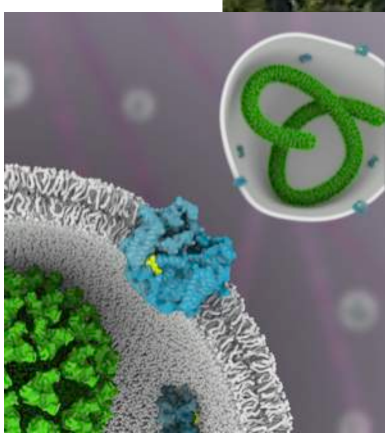
Cryo-EM Computational Issues



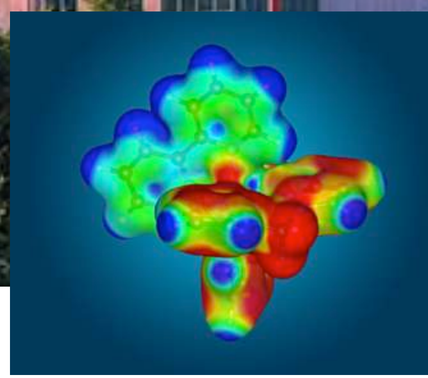
- **Many 2D projections of the 3D object need to be aligned to create a 3D reconstruction**
- **Many images must be held in memory (32-64GB per core)**
- **Current algorithms do not scale well**
- **Current codes do not scale well**

Current best practice is the use of Bayesian methods (RELION) and a single high resolution reconstruction will use 100-200 thousand particles and ~two weeks of 200-300 cores running in parallel

Imaging in Science

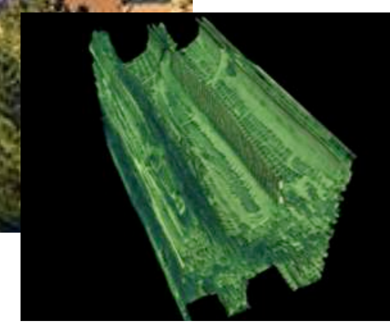


Drug testing



Nano device testing

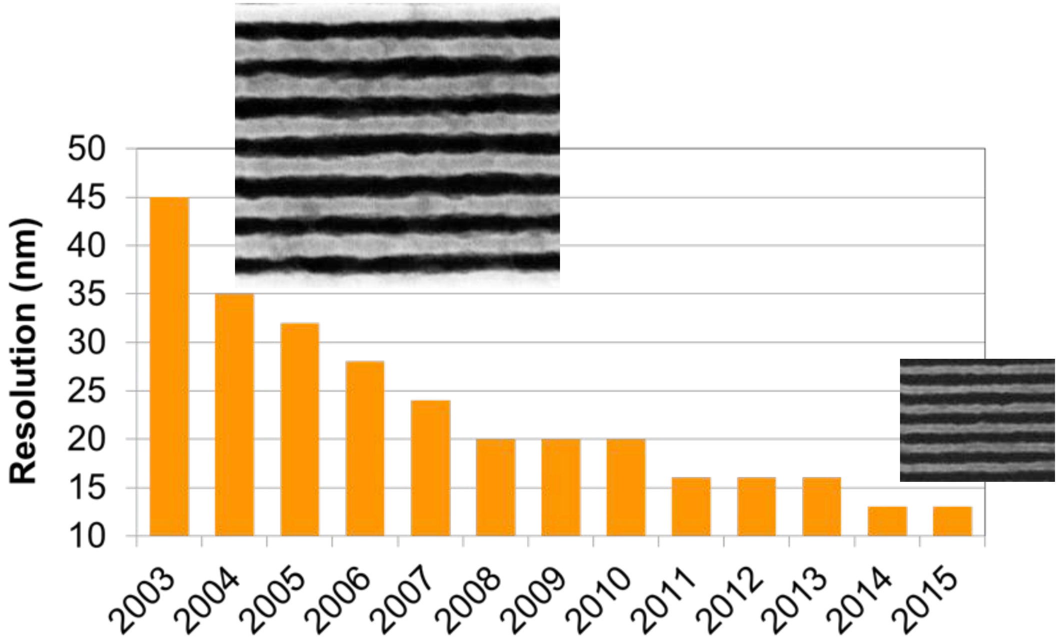
Coral exoskeleton

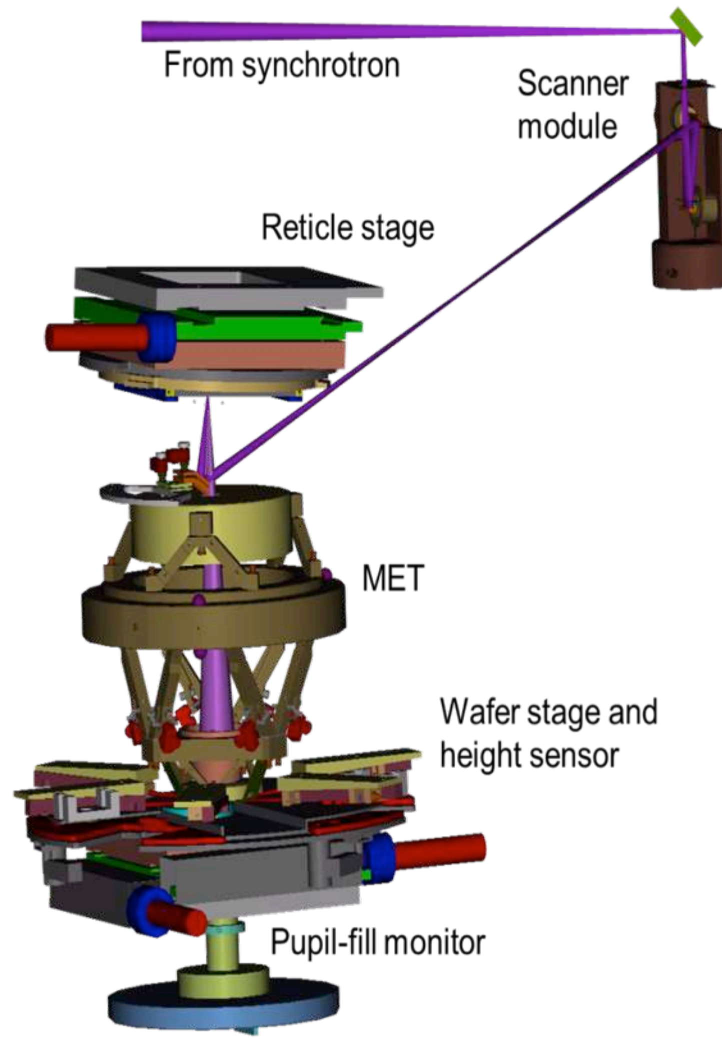


Grapevine hydraulics

Imaging essential to EUV lithography

CXRO beamline at ALS/LBNL



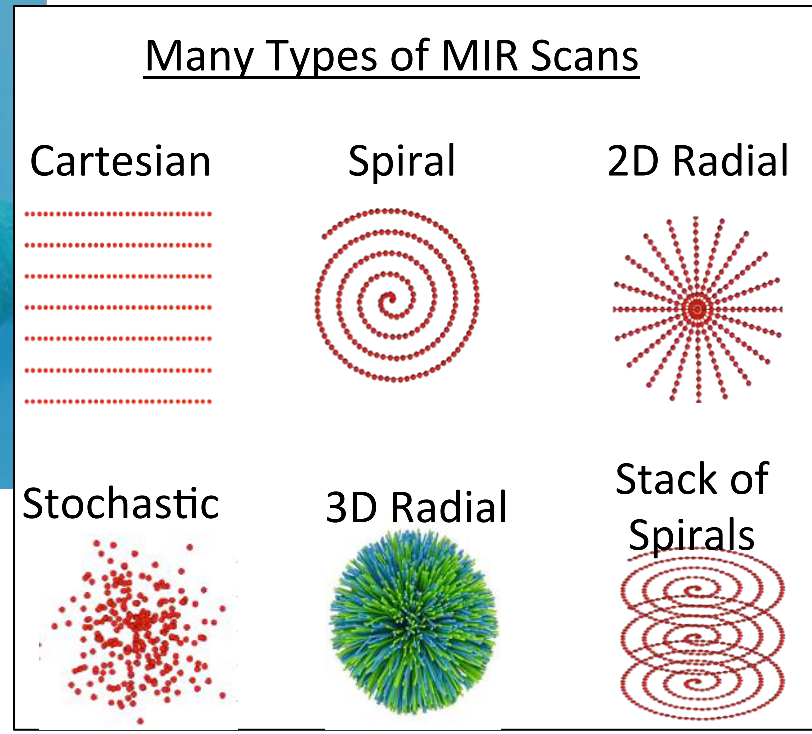


Roughness in masks is one of the major challenges in EUV lithography

Aamond Shankar, Patrick Naulleau, Laura Waller

Wearable MRI sensors + HPC Analytics

Wearable MIR sensors [Arias UCB]



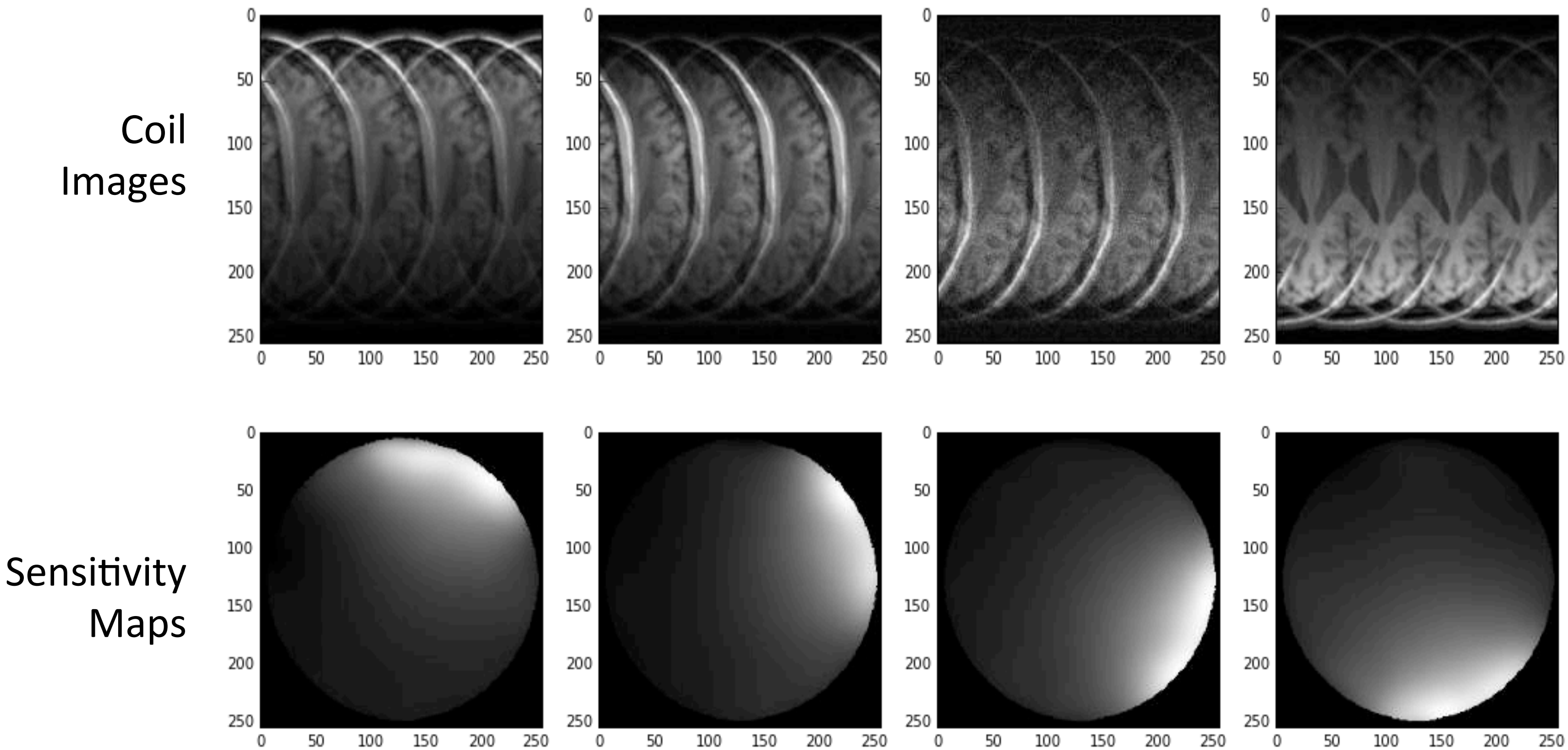
Compressed sensing algorithms [Lustig, UCB]

Goals:

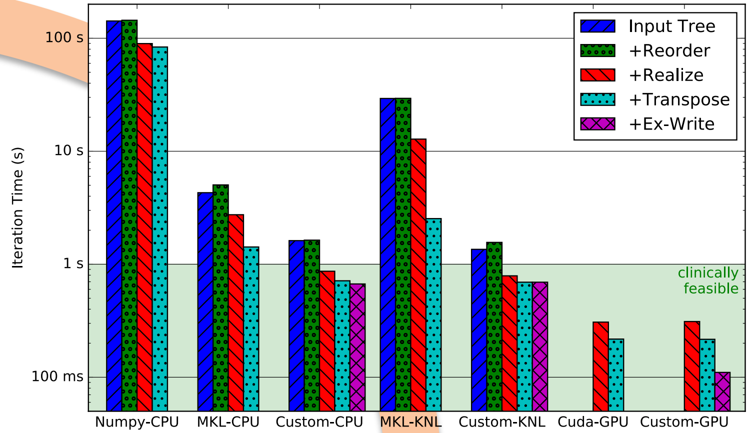
1) **reduce time in MRI**
2) **improve patient experience**
3) **better quality of images**

Parallel MRI and Undersampling

- Use multiple receive coils to acquire signal.
- Subsample Fourier space by factor (2,4,8, etc) ⇒ reduces scan time linearly
- Incur aliasing, but use coils' spatial sensitivity to resolve it.



Real-Time Analytics in Health



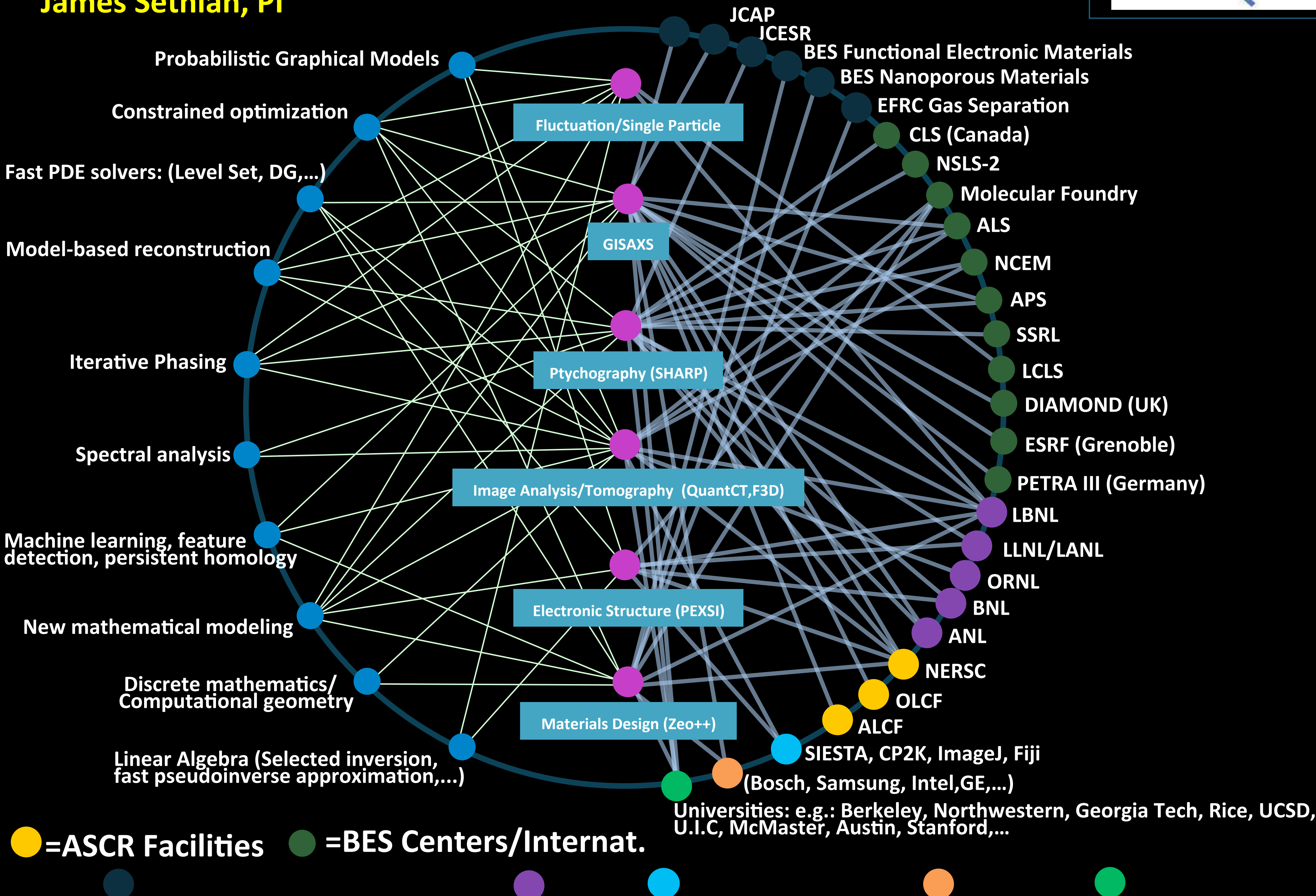
3 min goal (1 sec/iteration)
Michael Driscoll HPC optimization

Compressed Sensing Approach by Mike Lustig et al
MRI results Wenwen Jiang

Algorithms / Motifs

Math Challenges in Energy Science Data

James Sethian, PI



Analytics vs. Simulation Kernels: Redo?

7 Giants of Data	7 Dwarfs of Simulation
Basic statistics	Monte Carlo methods
Generalized N-Body	Particle methods
Graph-theory	Unstructured meshes
Linear algebra	Dense Linear Algebra
Optimizations	Sparse Linear Algebra
Integrations	Spectral methods
Alignment	Structured Meshes

Sorting/Search and Hashing?

Algorithms / Motifs

- **CNNs**
- **ADMM: Alternating Direction Method of Multipliers**
  - Inner loop is linear algebra
- **Optimization methods in general**
- **Ray Tracing**
- **Image processing algorithms**
  - Convolutions
  - FFTs
  - Dense linear algebra
  - Sparse (structured) linear algebra
- **Image/signal sampling and resampling**

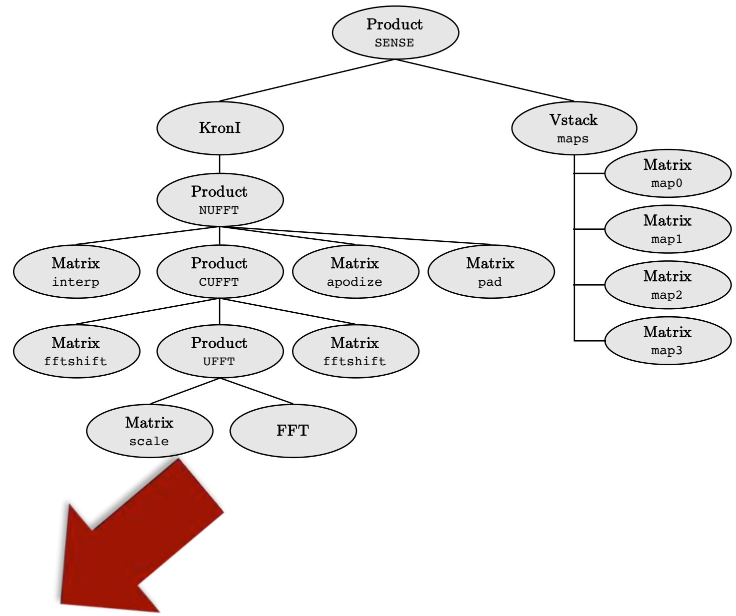
Hardware / Programming

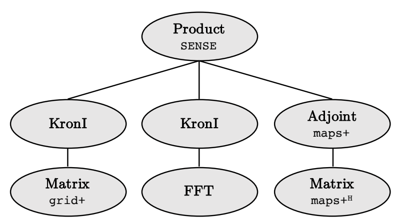
Most commonly used hardware

- GPUs: CAMERA, etc.
- FGPAs: LCLS/SLAC,
- ASICS: Darkroom
- (Although surely many CPUs as well)

Programming Approaches

- Matlab → python → Halide or cloud/clusters
- Libraries
- Stencils only (Darkroom)
- Loops / Compilers (ChiLL)
- Loops / DSLs (Halide)
- Matrices / DSLs (Indigo)





Hardware (input from SLAC)

- **FPGAs in the data reduction pipeline (DRP)**
  – for the analyses that do not change significantly across different experiments.
- **In general, the DRP will perform one of the following:**
  – Feature extraction (eg determine the list of peaks from a diffraction image; beam center determination and radial integration; time of flight determination by measuring the peaks in a digitizer waveform; etc)
  – Compression (lossy and lossless)
  – Vetoing (drop events which are not hits, ie the xray pulse didn't illuminate the sample - useful for experiments which use an injector)
  – Histogramming (assign events to specific bins in a predefined phase space)