NIF Optics Inspection Analysis

Laura Mascio Kegelmeyer

CASIS Signal and Imaging Workshop
November 16-17, 2006

UCRL-PRES-226124

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Optics Inspection: Interdisciplinary effort merges engineering, computer science, physical optics theory, and customer interface

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- **Algorithms & Application Development: Steve Glenn, Judy Liebman**
- **FRODO TechBase: Anthony Azevedo, Mina Bionta, Barry Chen, Aseneth Lopez**
- **Summer Projects: Ketrina Yim, Jack Tzeng, Philip Fong, Dan Potter, John Pate**
- **Image Acquisition Software: Vicki Miller Kamm**
- **Physical Optics theory: Erlan Bliss and Thad Salmon**
- **Systems Engineering: Steve Azevedo, Scott Burkhart, Walter Ferguson**
- **Web, Java GUI Development: John Carlson, Stephanie Daveler**
- **Eng/Scientists/Customers: Jim Chang, Chris Choate, Alan Conder, Chris Haynam, Mike Nostrand, Tom Parham, Rahul Prasad, Mary Spaeth, Pam Whitman, Shot Directors and Control Room Operators.**
- **Support & feedback: testers, configuration management team, system administrators, database administrators**

NIF has thousands of optics on the beamlines which must be inspected after every shot

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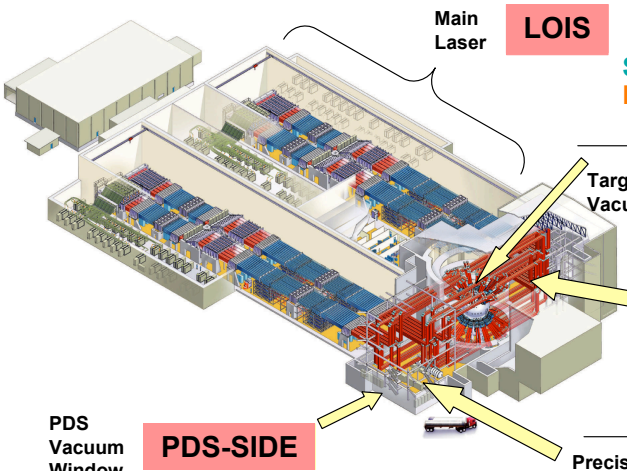

LOIS — Laser Optic Inspection System

SF3/4 – Confirm allowable defect size

Full - Prevent propagated damage

SIDE — Side-Illuminated Damage Evaluation

Confirm allowable defect size

FODI — Final Optics Damage Inspection

Recycle optics via mitigation

PDS-SIDE

Confirm allowable defect size

PODI — PDS Optics Damage Inspection

Recycle optics via mitigation

On-beamline inspections can be like looking through a house of mirrors

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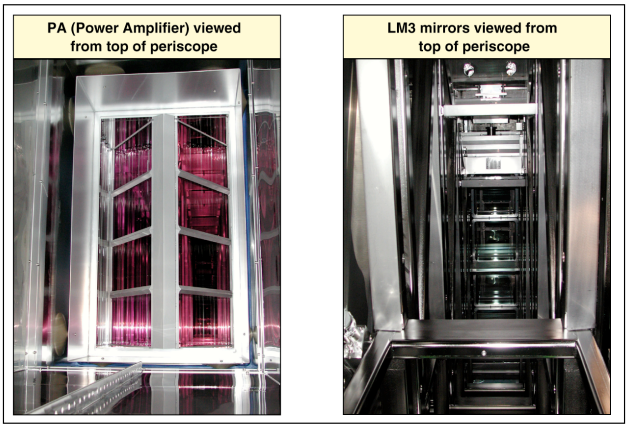
- Focusing on clear glass can be tricky
- Images are relayed to camera through mirrors/periscope, spatial filters and other lenses and optics
- Must keep track of orientation



The LOIS inspection system for the Main Laser has mirrors, relay optics and intervening glass. Light scattering sites can still be detected

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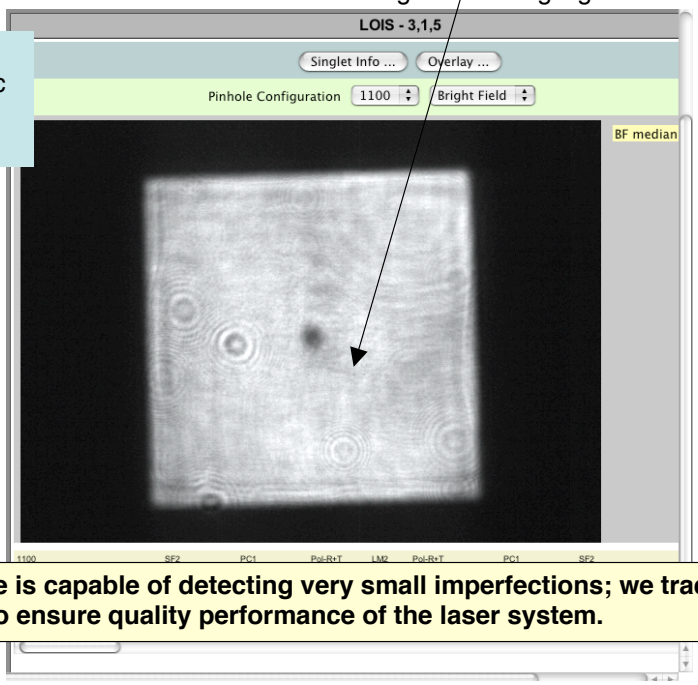
Real light scattering sight

We must detect the site, identify the optic on which it resides and estimate its size



Analysis software is capable of detecting very small imperfections; we track these over time to ensure quality performance of the laser system.

In addition, every optic is inspected (off-beamline) before and after going on the beamline

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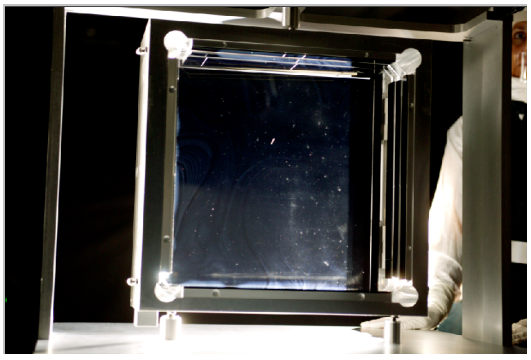
- Verify manufacturing specifications
- Pass/Fail quality of coatings
- Confirm Conditioning
- Migitation
- Refurbishment



To track the evolution of a defect requires tracking a variety of conditions:
- Illumination settings
- Exposure times
- Operator-specific methods
- Orientation!

Most on-beamline and off-beamline images go through the same "one" algorithm (Local SNR for each pixel in image) with specified parameters

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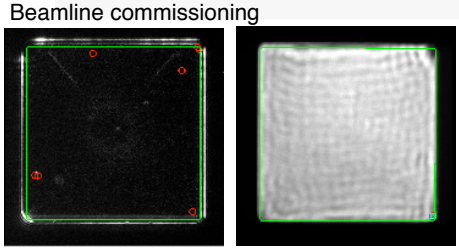
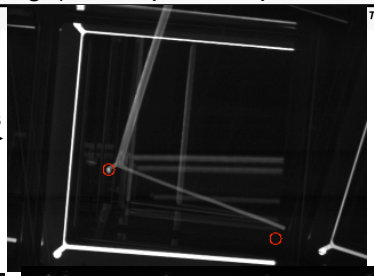
Beamline commissioning



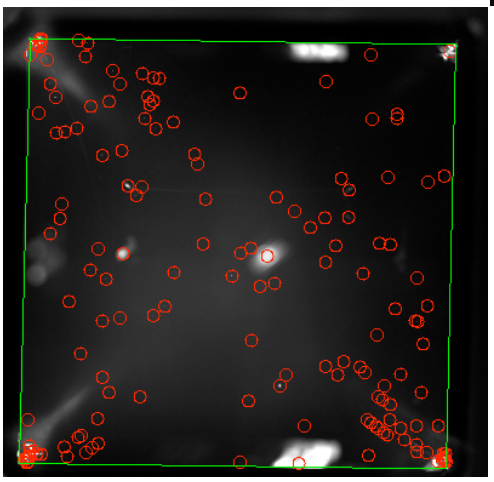
High Level Reporting for Shot Readiness →

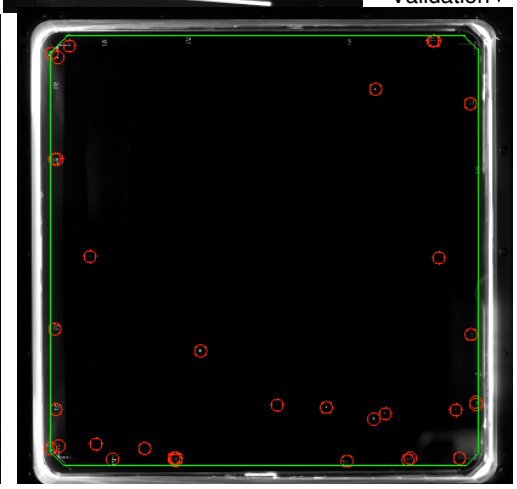


Off-line QA
Conditioning
Validation ↓

Detect tiny flaws online

Interface to prediction codes for recycling optics





Example of 1 (manufactured) defect imaged from online to offline inspections

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SIDE (Online image of TCVW)
–Check for damage exceeding 1 mm.

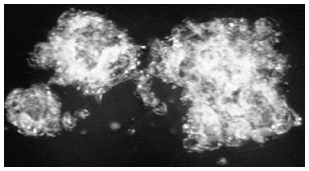
Portion of SIDE image (640x480) 1 mm / pixel

DMS-OPL (Damage Mapping System - Optics Processing Lab)
-Confirm size and location of surface flaws - 97 microns per pixel

CIM (Conditioning, Initiation & Mitigation)
–Test and condition the optic with increasing laser energies
–Scattering sites smoothed (mitigated) with a CO2 laser

Portion of laboratory image of full optic (4kx4kx2) 97 microns / pixel. *[OPL 750020]*

Micrographs
- Evaluate "true" size of flaws for calibration and validation - 6 microns per pixel



Micrograph / "Truth" Image = 1/16th full size 6 microns/pixel

We may be able to find some defects by using their out-of-focus rings to estimate location and size -- FindingRingsOf Damage on Optics

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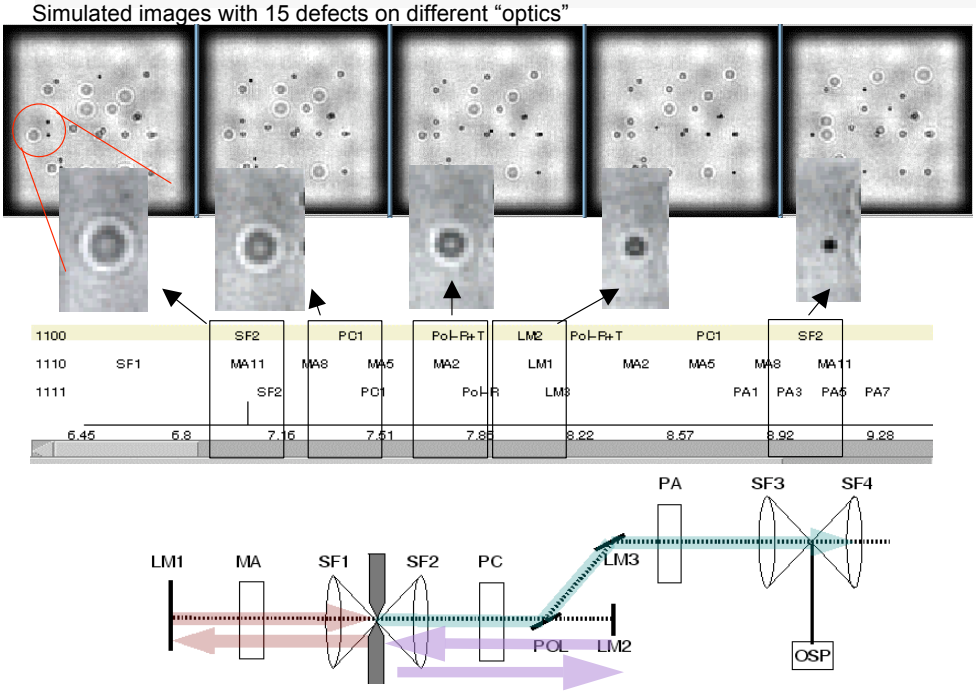
Simulated images with 15 defects on different “optics”



FRODO (based on ICE GDM*) was able to find diffraction rings on NIF Final Optics by tuning 4 adjustable parameters

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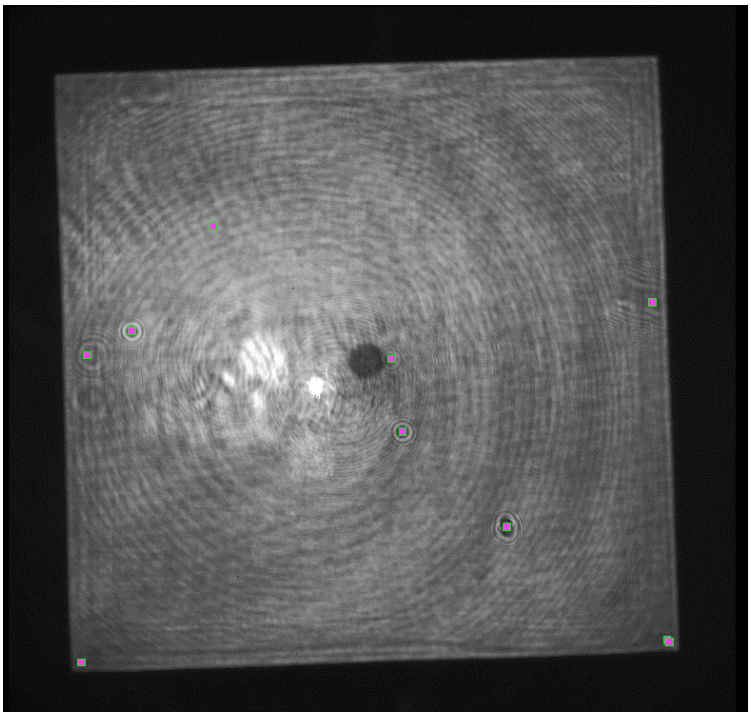

*Image Content Engine

Gradient Direction Matching

APPSPACK* optimized FRODO parameters; ReceiverOperatingCharacteristic curves provided performance metrics

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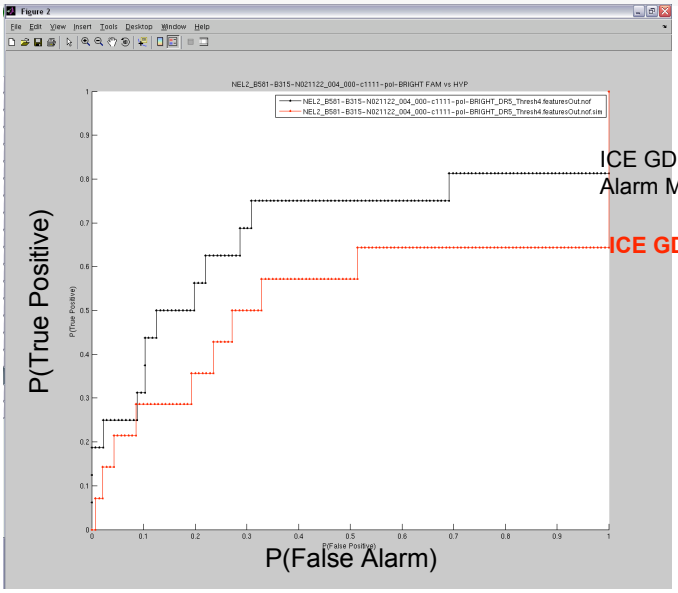

*APPSPACK (G Gray, T Kolda; Sandia, CA): derivative-free optimization software for solving nonlinear unconstrained and bound-constrained optimization problems, with possibly noisy and expensive objective functions.

How OI Analysis is used in practice for NIF....

Our client-server design is a robust and flexible tool that allows many customers to access/display results as needed for many different purposes

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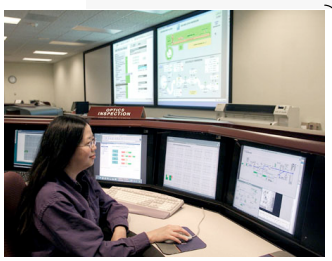


Control Room (Ada on Solaris)

Off-line Laboratories (LabView, MATLAB, Camera Controller software on PC or Mac)

NIF IT File Server

Application Server (Linux Cluster) Analysis & Upload scripts

Database server

Web server

Campaign Modeling

LPOM

ODAD

Daily Operations

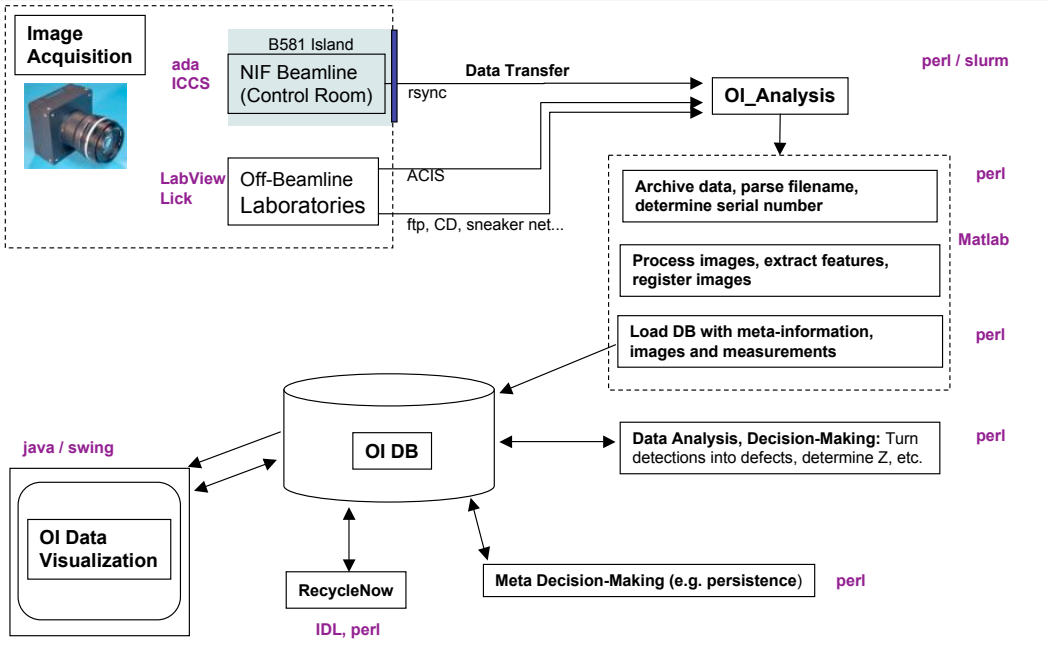
mozilla

Manuf QC

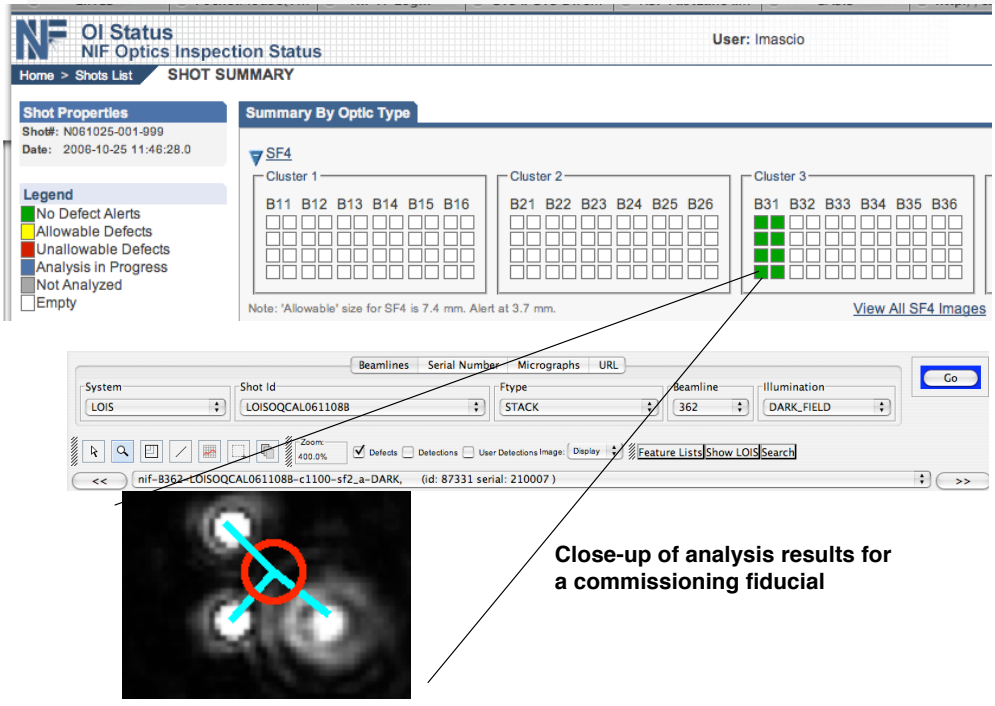
Conditioning & Mitigation

Open LabNet (Password protected)

Data Flow for NIF Optics Inspection



A java-based visualization application allows users to view inspection results from a birds-eye view or in great detail



OI Scaling to NIF: The amount of data storage will quickly become large

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	Inspection Type	Images per dataset	Estimated Image Size (GB)	Size per dataset (GB)	Anticipated no. datasets	Interval	Inspections Per Month	Size per beam per Month (GB)	Partial NIF Total for one year (GB)	Full NIF Total for one year (GB) *
On-line	FODI	16	0.032	0.512	1	per day	20	10.24	983.0	23,593.0
	NODI	16	0.032	0.512	0	per week	0	0.00	0.0	0.0
	PODI	16	0.032	0.512	1	per week	4	2.05	24.6	24.6
	SIDE	4	0.000	0.001	1	per shot	20	0.02	2.2	52.7
	LOIS	58	0.001	0.057	2	per week	8	0.91	87.0	2,088.0
	Sub-LOIS (SF3, SF4)	10	0.001	0.010	1	per shot	20	0.20	18.8	450.0
Off-line	OPL (DMS maps)+ FADLib	2	0.032	0.064	500	per year	n/a	n/a	32.0	32.0
	CIM	12	0.032	0.384	250	per year	n/a	n/a	96.0	96.0
	PSDI			0.100	350	per year	n/a	n/a	35.0	35.0
	IMS	18	0.073	1.318	250	per year	n/a	n/a	329.6	329.6
	Calib (micrographs)	10	0.001	0.010	45	per year	n/a	n/a	0.4	0.4
	Total Storage Needed								**1,608.6**	**26,701.3**

* Size estimates are for early NIF (FY '09 - FY '10)

Summary

- **27 TBytes/year (50 if full FODI) – ~6000 DVD's**
- **NIF Ops (/nif) has ~6 TByte now**
- **300 GB drives are $300 now (Maxtor) or $1/GB**
- **Archival plans are being made with NIF IT**

OI Analysis supports on-beamline inspections for shot readiness and optics recycling as well as off-beamline for QA, conditioning, validation...

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- Automated inspection for images from 9 camera systems on the NIF beamline and 11 offline. (One fundamental algorithm to analyze them all.) — **Phil Fong**
- Track defects on thousands of optics through their lifetime (across different camera systems). Detect and measure defects over a range of sizes to assure quality performance and safety. — **Alan Conder**, **Judy Liebman**
- We can keep up with speed requirements by expanding our Linux cluster for parallel analysis of all on-beamline and offline systems. — **Steve Glenn**
- Image analysis runs on an application server and all images and results are stored in a database.
- Java-based visualization application can be downloaded from any browser. It allows each customer to review results appropriately via dynamic database queries.