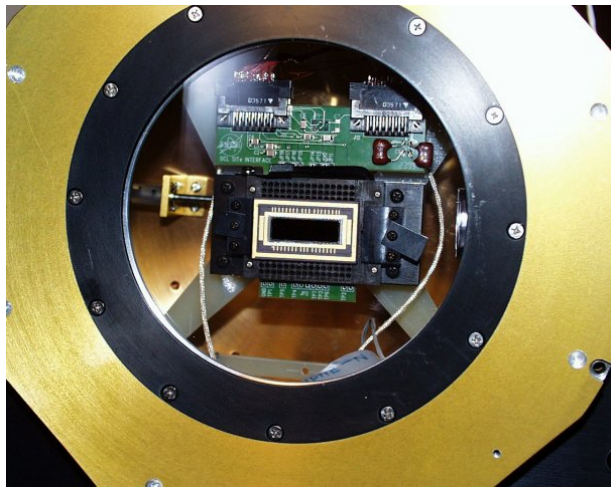

Detector Characterization Laboratory (DCL)

Status Review for

WFC3 Scientific Oversight Committee

November 2, 2000

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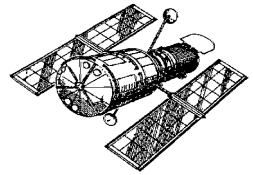
Wide Field Camera 3
DCL Presentation for SOC



- 13:30 - 13:45 DCL Goals and Objectives - John Maliszewski
- 13:45 - 14:00 Laboratory Management - John Maliszewski
  - Today's Objective
  - Functional Sections
  - Support Personnel/Staffing
- 14:00 - 14:15 Systems Overview - Augustyn Waczynski
  - Basic Test Capability
  - Laboratory Block Diagram
  - Hardware Systems and Data Flow
- 14:15 - 14:45 Hardware Hugh Philipp, Augustyn Waczynski
  - Light Sources - Hugh Philipp
  - Optics - Hugh Philipp
  - Data Acquisition System- Augustyn Waczynski
- 14:45 - 15:00 Break

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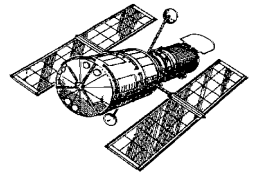
Wide Field Camera 3
DCL Presentation for SOC



- 15:00 - 15:15 Software - Bob Hill, Elizabeth Polidan
  - Lab Data Acquisition - Bob Hill
  - Data Archiving - Elizabeth Polidan
- 15:15 - 15:20 Operations Concepts - John Maliszewski
- 15:20 - 16:00 Procedures/Test Cases
  - Supported Devices - Bob Hill
  - Example of type of measurements - Bob Hill
  - Analysis - Elizabeth Polidan, Scott Johnson
- 16:00 - 17:30 - DCL Visits
  - Groups of six only.

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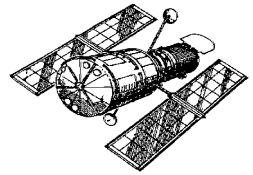

Laboratory Goals and Management

John Maliszewski

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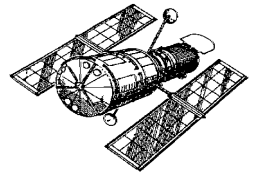
Laboratory Goals



- The DCL is a joint venture between Code 680 and Code 550.

- The Detector Characterization Laboratory (DCL) is a facility for the complete optical and electrical characterization of UV, optical, and infrared detectors. The goal of the DCL is to become a self-sufficient facility serving the needs of the GSFC scientific and engineering community, as well as academic and commercial customers.

- The laboratory currently supports the characterization of CCD's and HgCdTe detectors for the Hubble Space Telescope Wide Field Camera 3 instrument. The laboratory resides in Room 83 of Building 20 at the Goddard Space Flight Center with support from Building 21, Code 685 laboratories.

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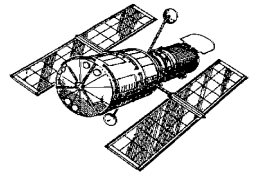
Laboratory Management



- Today's Objectives
  - Present DCL's organization and its facilities to the SOC.
  - Illustrate DCL's testing capabilities developed to meet the requirements set by the WFC3 project.
  - Describe testing and data analysis methodologies for both the CCD and IR detectors.
  - Provide evidence of controlled environment within the DCL to allow safe handling of the flight hardware.
  - Provide evidence of documentation methodologies and facility control procedures that are consistent with the ISO 9000 rules.

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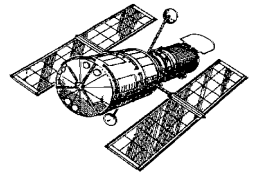
Laboratory Management



- The Detector Characterization Laboratory (DCL) is divided in the following functional sections:
  - Detector Systems - This section is responsible for all activity related to detector characterization, optimization of detector performance and detector data analysis methodologies.
    - Detector Engineering
    - Detector Interfaces
    - Laboratory Test and Instrumentation
    - Detector Data Acquisition and Analysis
  - Software Development - This section is responsible for development of the front end software for the detector data acquisition systems and any software needed to support detector data archiving and detector data base management.
    - DCL Data Base
    - DCL Web Page

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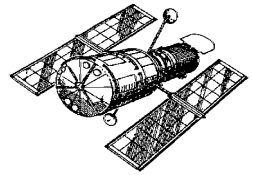
Laboratory Management



- Scientific Community Interface - This section is responsible for interface with the scientific and industrial community by representing the DCL's capabilities and achievements at the scientific meetings, symposia and fairs.
  - Detector Applications
  - Data Dissemination
  - DCL Web Page outreach
- Laboratory Systems - This section is responsible for creating the laboratory conditions data acquisition system. These data are archived in order to provide environment traceability for each experiment.
  - Laboratory Conditions Data Acquisition
  - Systems Automation

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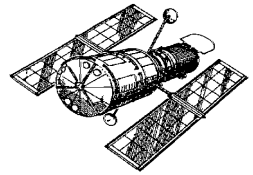
Laboratory Management



- Laboratory Facilities - This section is responsible for maintaining an organized environment within the DCL consistent with good laboratory practices and compliant with the ISO 9000 GSFC directives.
  - Laboratory Maintenance
  - Laboratory Activity Schedule
- Laboratory Documentation - This section is responsible for maintaining documentation that defines procedures in the laboratory and captures the data associated with each detector for archival purposes.
  - Operational Procedures
  - Project Documentation
  - Detector Documentation
  - Customer Specific Documentation

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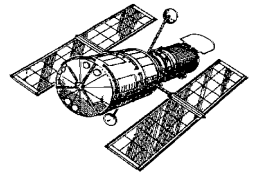
Laboratory Management



- WFC3 Project Support - This activity is geared toward supporting the WFC3 project through the integrated product team (IPT) and intends on using all the DCL resources to maximize the science return within the detector subsystem area by reviewing the proposed vendor designs and to influence those designs as necessary.
  - Detector Packaging
  - Detector Housing
  - Detector Electronics

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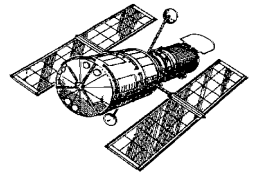
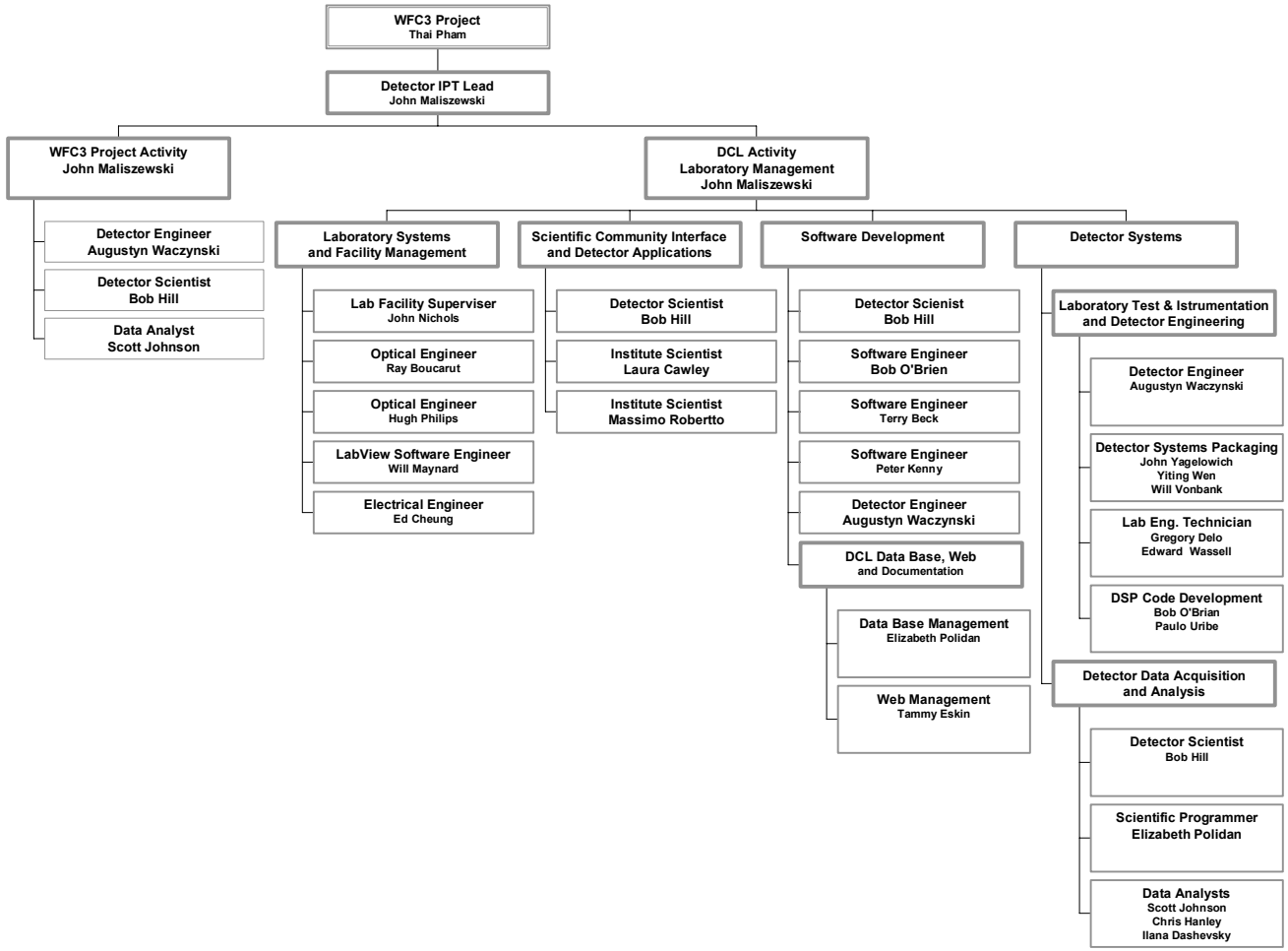
Laboratory Management

DCL Functional Chart





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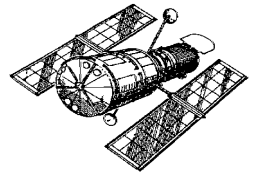
Laboratory Management



- Laboratory Task List
  - We are maintaining a comprehensive task list containing all the detector testing related activity in a Microsoft Project Schedule.
  - We also have a weekly meeting with the “Instrument Scientist” to determine priority of lab activities and input any new assignments.
  - The DCL staff meets weekly to discuss priorities and status of the activities within the lab.
  - Current testing in DCL:
    - Marconi CCD44UV and Vis
    - Testing of WFC3-1R Multiplexers packaged in PGAs from Rockwell Science Center.
    - Testing of Lockheed 512K x 512K devices.
    - Testing ACS enclosure window for phosphorescence effects using SITe 2K x 4K ST108 detector.

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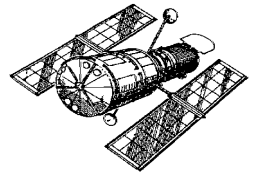

Systems Overview

Augustyn Waczynski

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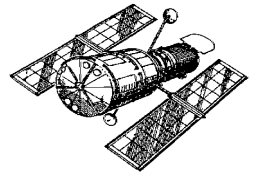
Systems Overview



- Basic Test Capabilities:
  - Charge Transfer Efficiency (CTE)
    - Fe55, Cd109
    - Extended Pixel Edge Response (EPER)
    - First Pixel Response (FPR)
    - mitigation strategies
  - Quantum Efficiency (QE):
    - absolute and relative, 200 nm to 1800 nm
  - Dark Current:
    - down to 0.5 electron/pixel/hour in CCD imaging mode
    - down to 0.05 electron/pixel/second for IR detectors
    - mitigation strategies
  - Noise:
    - 0.2 electron rms; CCD
    - less than 2 electron rms for IR
  - PSF/MTF: diffraction limited resolution; f 9
  - Linearity: 99.99%
  - Flat fields: flatness of 2% to 6%, correctable to 0.5%
  - Capability to do special testing

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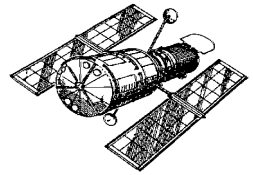
Systems Overview



- DCL testing approach:
  - automation of measurements
    - data acquisition and motion components are integrated into single system and computer controlled.
    - most of the test activities will be automated and executed from software script.
  - remote control
    - lab can be remotely accessed through Internet and lab activities can be remotely controlled from the local computer.
  - controlled environment
    - temperature, pressure, humidity as well as RF power and power line in the lab, are continuously monitored and recorded.
    - lab and laminar flow bench cleanliness are periodically verified.
    - ESD protection is continuously monitored.
    - vacuum gauges are being installed into test dewars to monitor dewar pressure.

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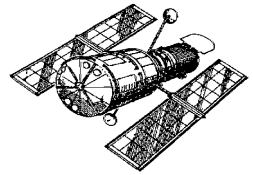

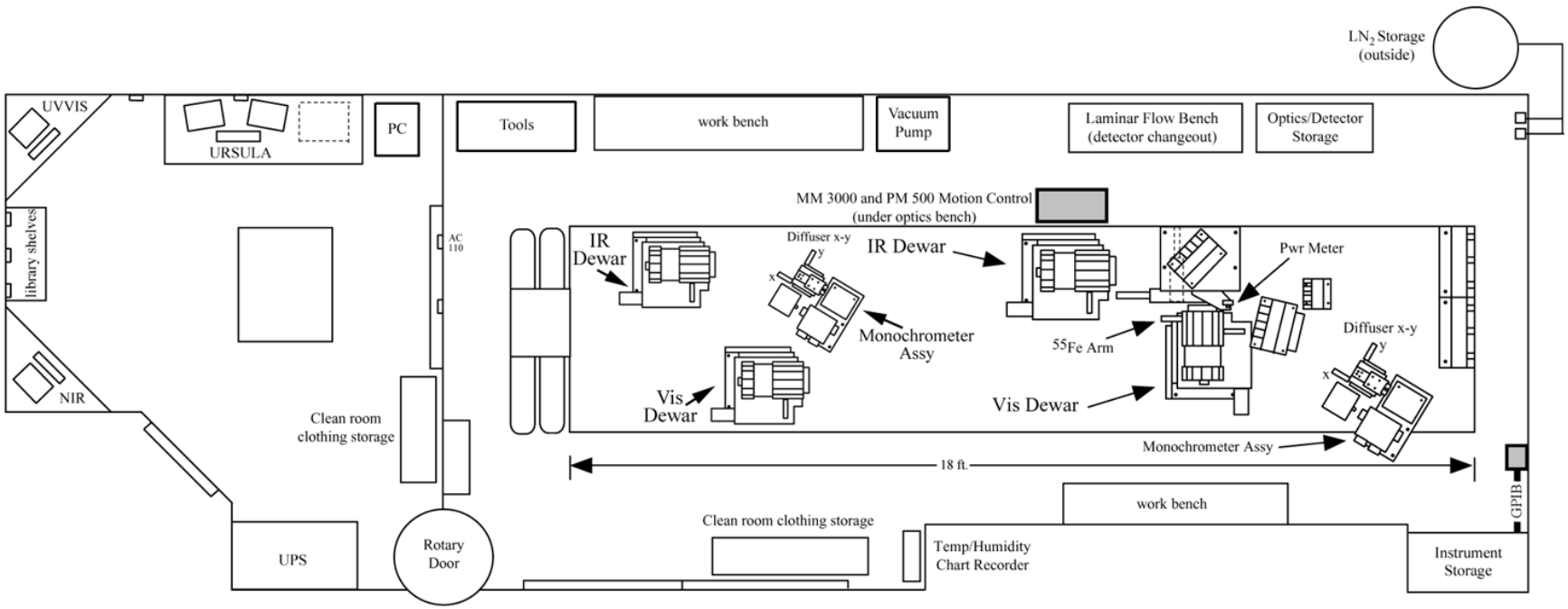

DCL Physical Layout

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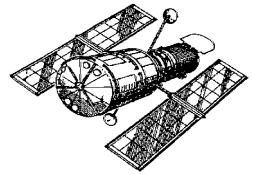
Systems Overview



- Facility
  - separate computer room
  - continuous purge of the test room with filtered air
  - certified laminar flow bench
  - class 100,000 clean room rules
  - 18' x 4' air supported optical bench
  - LN2 fill up system, vacuum jacketed lines
  - GN2 supply
  - Uninterruptible Power Supply (UPS) for computers and critical hardware

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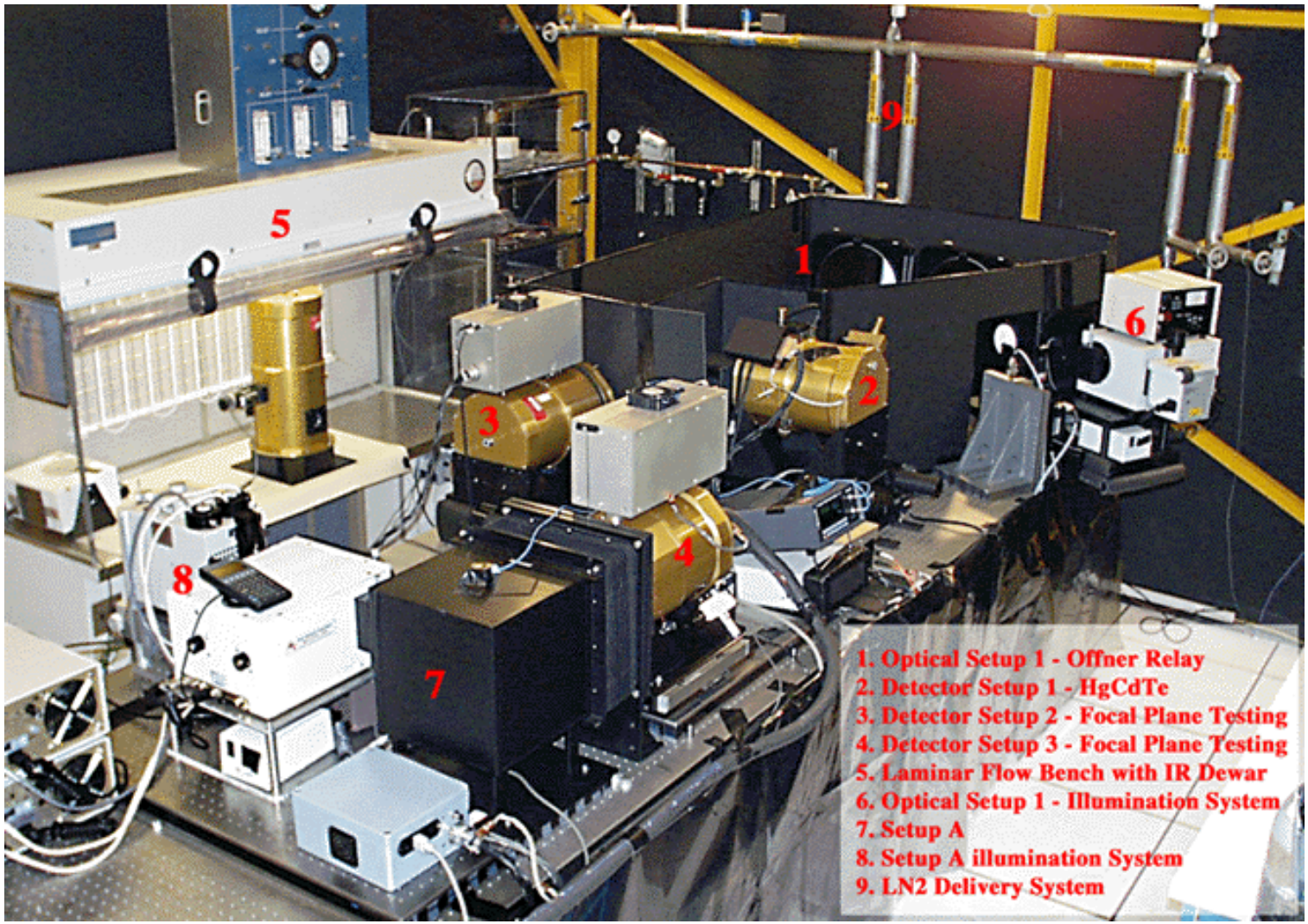
Systems Overview



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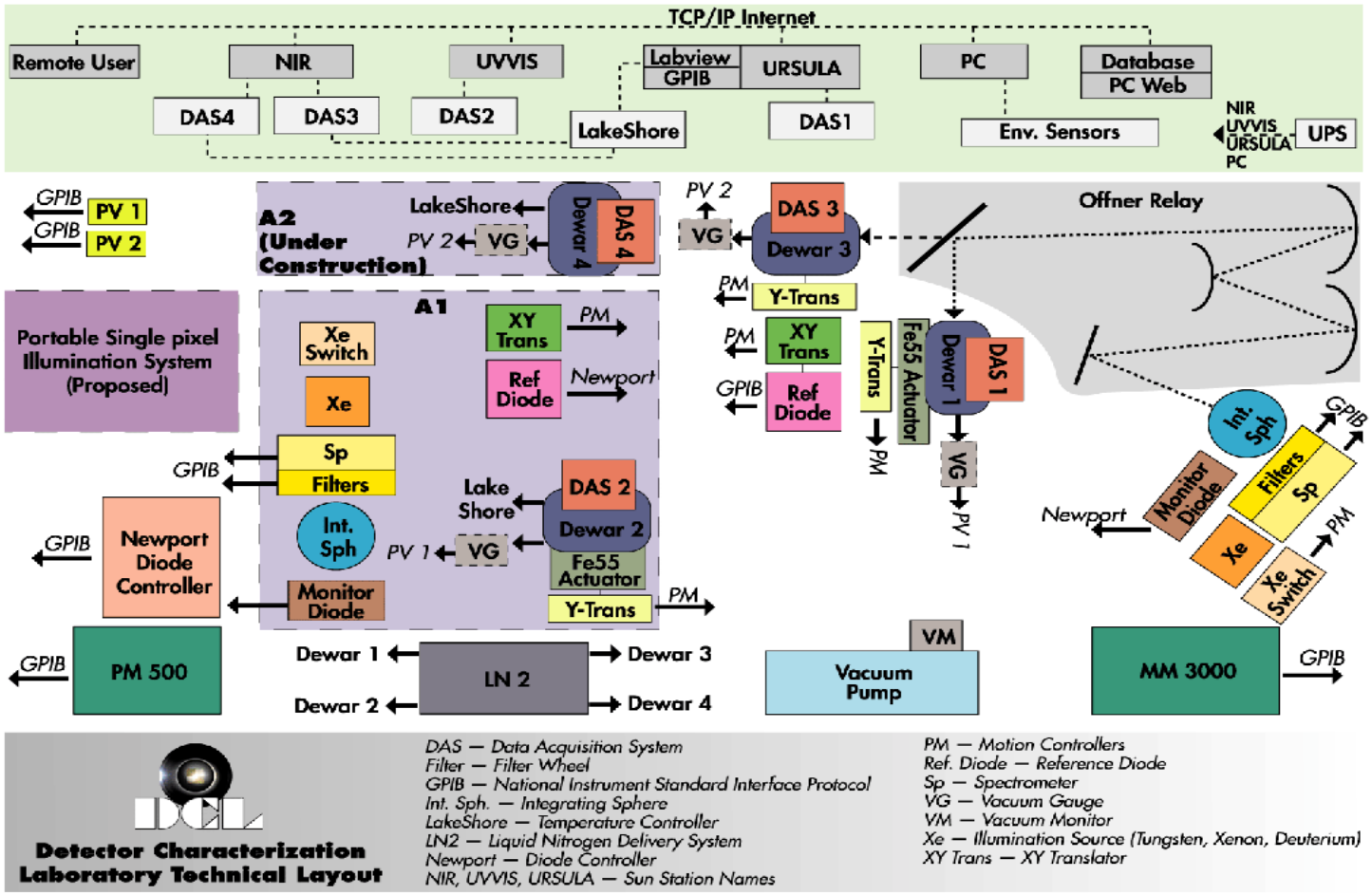
Systems Overview

- DCL HARDWARE LAYOUT



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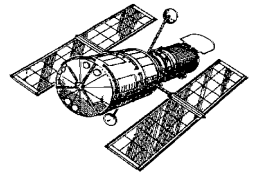

- Electro-optical test setups:
  - three in operation, one in construction
  - two CCD test setups
  - two IR detector test setups
  - Max Plank test setup
  - total of three optical illumination systems
  - one IR and one CCD setup are sharing imaging, Offner based illumination system with a beam switch
  - remaining two systems have independent illumination

- Imaging illumination system includes:
  - light sources: Xenon, Halogen and Deuterium lamps
  - monochromator
  - integrating sphere
  - monitoring photodiode
  - Offner relay
  - Image of the integrating sphere output port is projected onto focal plane of the detector being tested.

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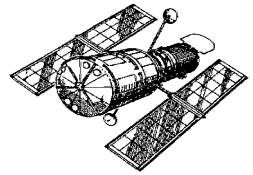

- Diffused illumination systems include:
  - light sources: Xenon, Halogen and Deuterium
  - monochromator
  - integrating sphere
  - monitoring diode
- Each test setup has:
  - monochromatic flat field illumination from 200 nm to 2500 nm (up to 5000 nm with different grating)
  - 0.1 nm to 10 nm slit adjustable bandwidth
  - NIST calibrated diode to monitor light source intensity
  - XY translator with NIST traceable calibration diode for QE reference measurements
  - four independent channels
  - speed from 10 kHz to 1 MHz per channel
  - Detector control electronics is optically linked with a Sun computer.
- Fourth setup is in process of construction. It will be:
  - purged with GN2
  - spectral coverage down to 190 nm

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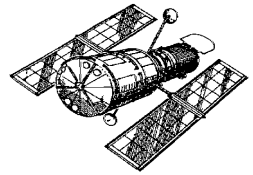
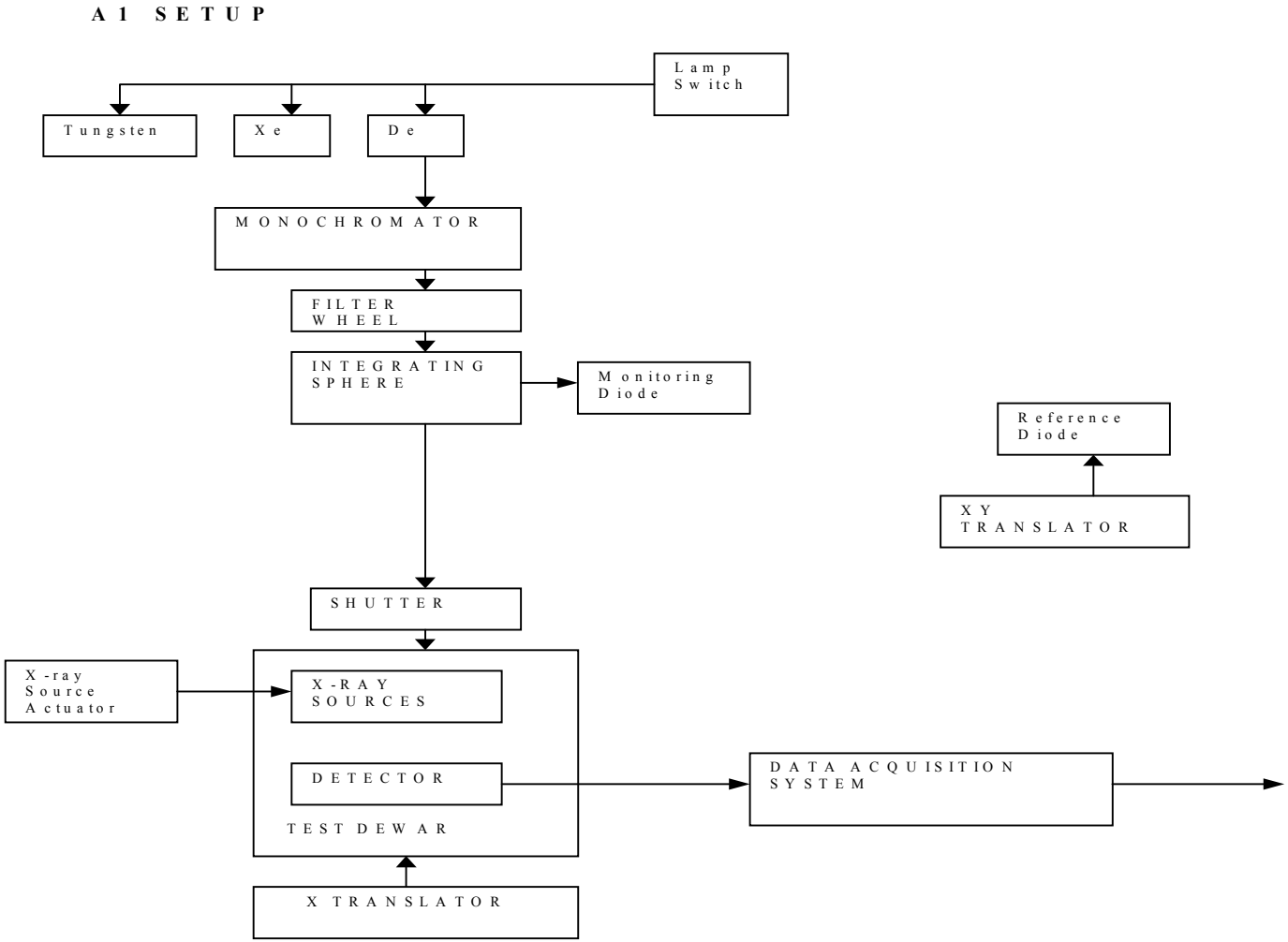
Systems Overview





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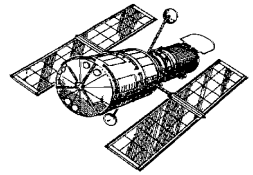

- Experiment control:
  - each test setup is supported by x, xy and xyz translators and other motion components (like light source switch and X-ray source actuators)
  - When fully integrated, would allow for remote experiment control and reconfiguration
  - GPIB interface to motion elements through PM500 and MM3000 controllers
  - GUI interface for data acquisition and motion control

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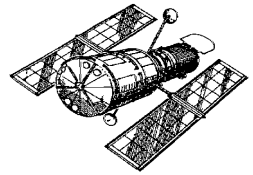

- Single Pixel Illumination - fiber based optical system is being developed to project few micron spot of light on the detector focal plane.
  - 3 to 10 um spot size
  - xy raster capability
  - attachable to any of the test dewars
  - designed to measure PSF and to investigate intra pixel properties

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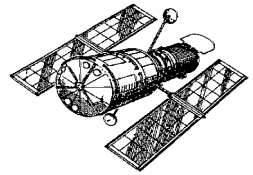
Systems Overview



- Environment control/monitoring:
  - all relevant environment variables are continuously monitored and recorded: temperature, pressure, humidity, power line, RF power, background level light.
  - PC based sensor data acquisition
  - PC communicates with Sun station (URSULA) through the Internet
- Detector handling and storage
  - detectors stored in dry boxes with continuous GN2 purge
  - detector changeout and handling limited to clean, laminar flow bench with ESD protection
- Vacuum pumps and cryogen
  - two dry vacuum pumps for dewar pressure restoration
  - LN2 delivery system

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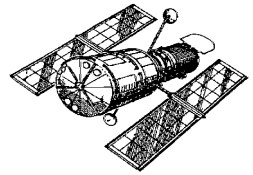

DCL Optics Hardware

Hugh Philipp

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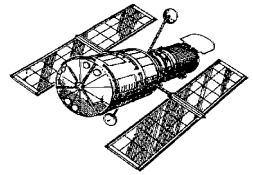
Design Goals



	DCL Design Goals
Photon Flux	**Photon Noise <0.1%**
Wavelength Range	**190nm-1800nm**
Flatness	**2% correctable to 0.5%**
Field of View	**87mm diameter**
Resolution	**Single Pixel Illumination (15um x15um pixel)**

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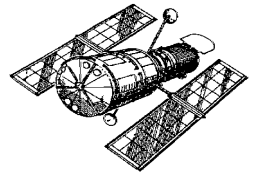
Light Sources



- Available Lamps
  - Xenon (75W, 150W) 250nm - 2000nm XS-432
  - Deuterium (30W) 190nm-450nm DS-421
  - Tungsten Halogen (150W)

- Stability monitoring
  - A monitoring diode is mounted to an extra port on the integrating sphere.

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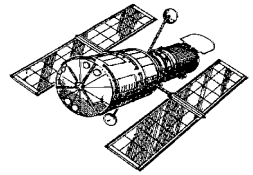
Monochromator



- Acton Research Corporation (ARC) 300mm focal length Czerny-Turner design.
- Features:
  - A filter wheel to cut off higher order diffraction wavelengths produced by the grating.
  - Variable slits to control:
    - amount of light transmitted
    - band-pass width of the monochromator
  - 3 grating turret loaded with gratings optimized for different wavelength ranges.
  - Computer control of wavelength, grating, filter and slit width.

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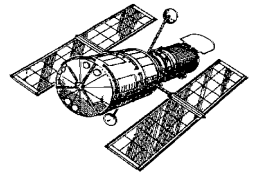
Integrating Sphere
Producing a flat field



- 10 inch internal diameter spectralon sphere with a 4” diameter exit port.
- Spectralon yields reflectance in UV.
- The specified flatness (from LabSphere - the manufacturer) is 1% - 2%
- The sphere is customized with an extra port at the ‘north’ pole so that a diode can monitor the stability of the light source.

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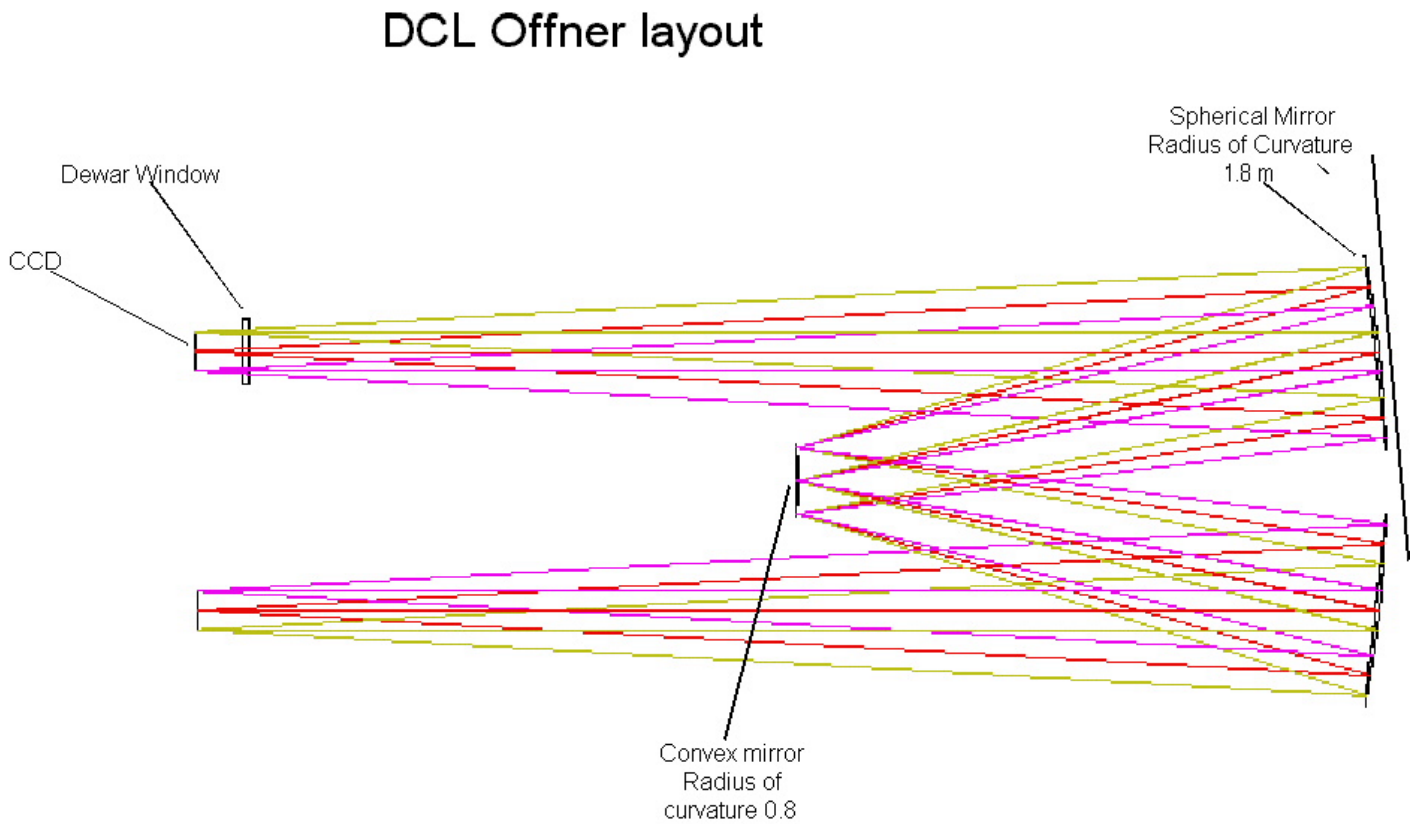
Offner Design

- Eric Mentzell designed a modified Offner system for the lab. The design layout is shown here:



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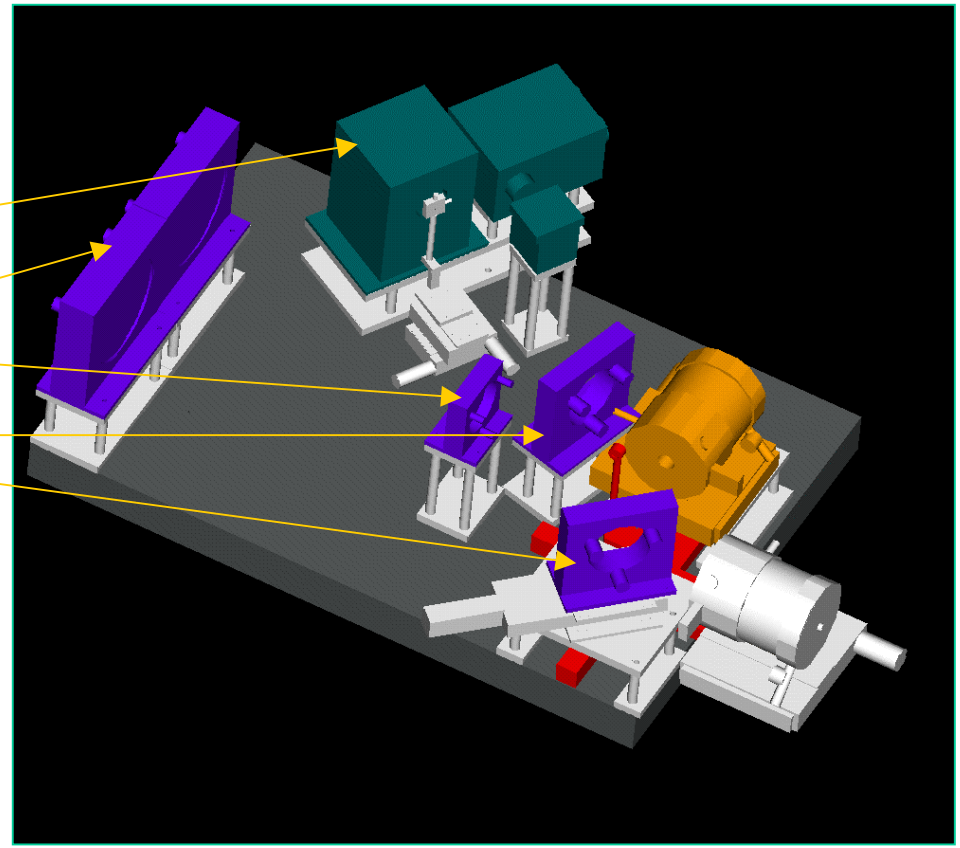
Actual Offner Layout

- CAD model
- Photo
  - Integrating Sphere
  - Spherical mirrors
  - Fold mirrors



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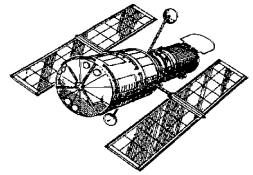
Offner system



- Metrology group determined the position of the mirrors and initial alignment was performed with this information.
- The lab maintenance schedule includes a procedure for periodic fine alignment of the Offner system.
- All mirrors were made to be a standard size so off the shelf mounts could be used.
- The image quality predicted by the model (the system was designed using Zemax^{tm}) was characterized with a Spot diagram, Ensquared/Encircled energy, and the diffraction limit.
- For an f/9 system the diameter of the diffraction limit spot is given by
  - D(wavelength) = 2.44 (f-number) (wavelength)
    = 21.96 (wavelength)
  - Yielding
    - D(900nm) = 19.8 um
    - D(500nm) = 11.0 um

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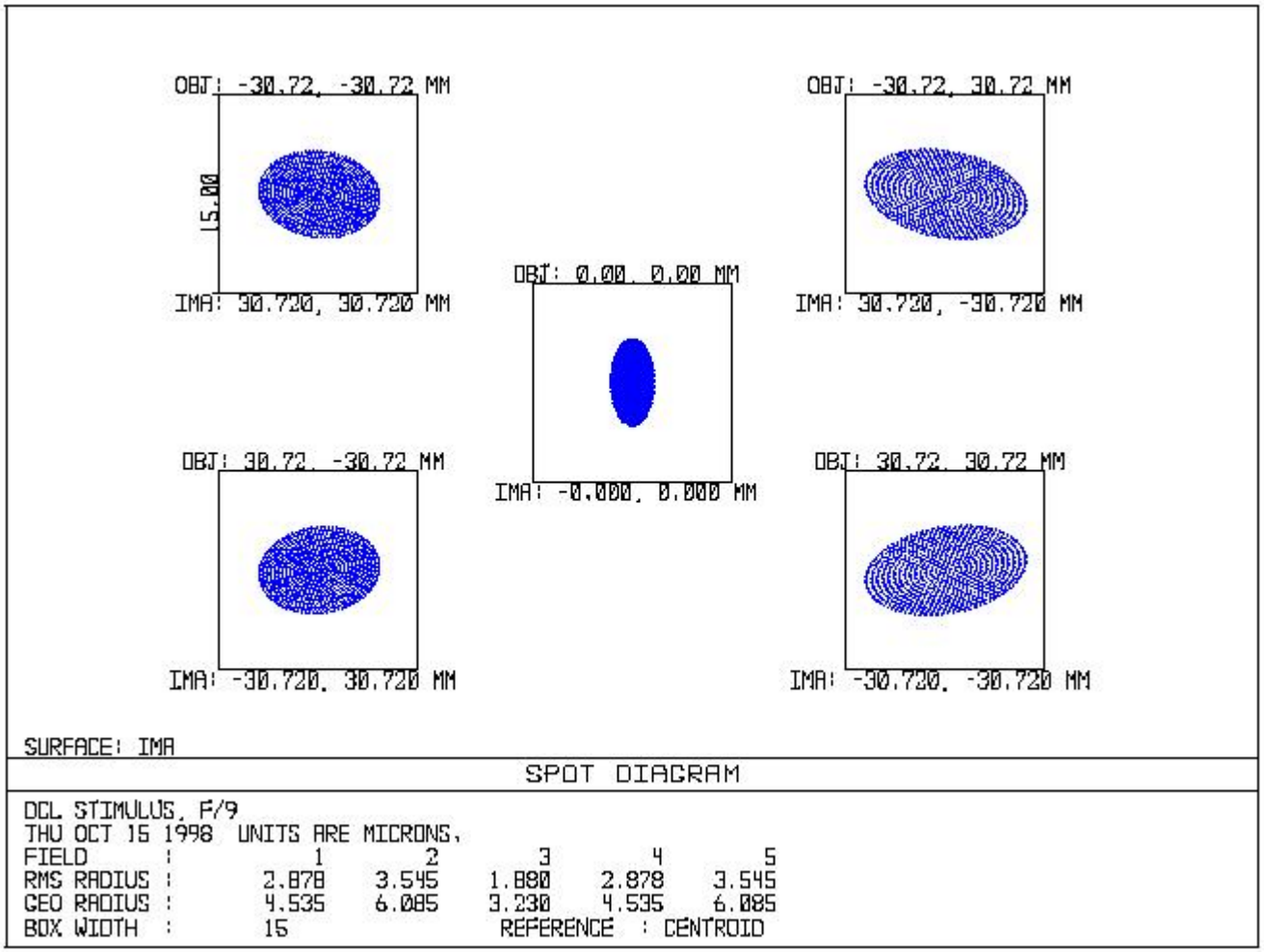
Spot Diagram of the Offner System



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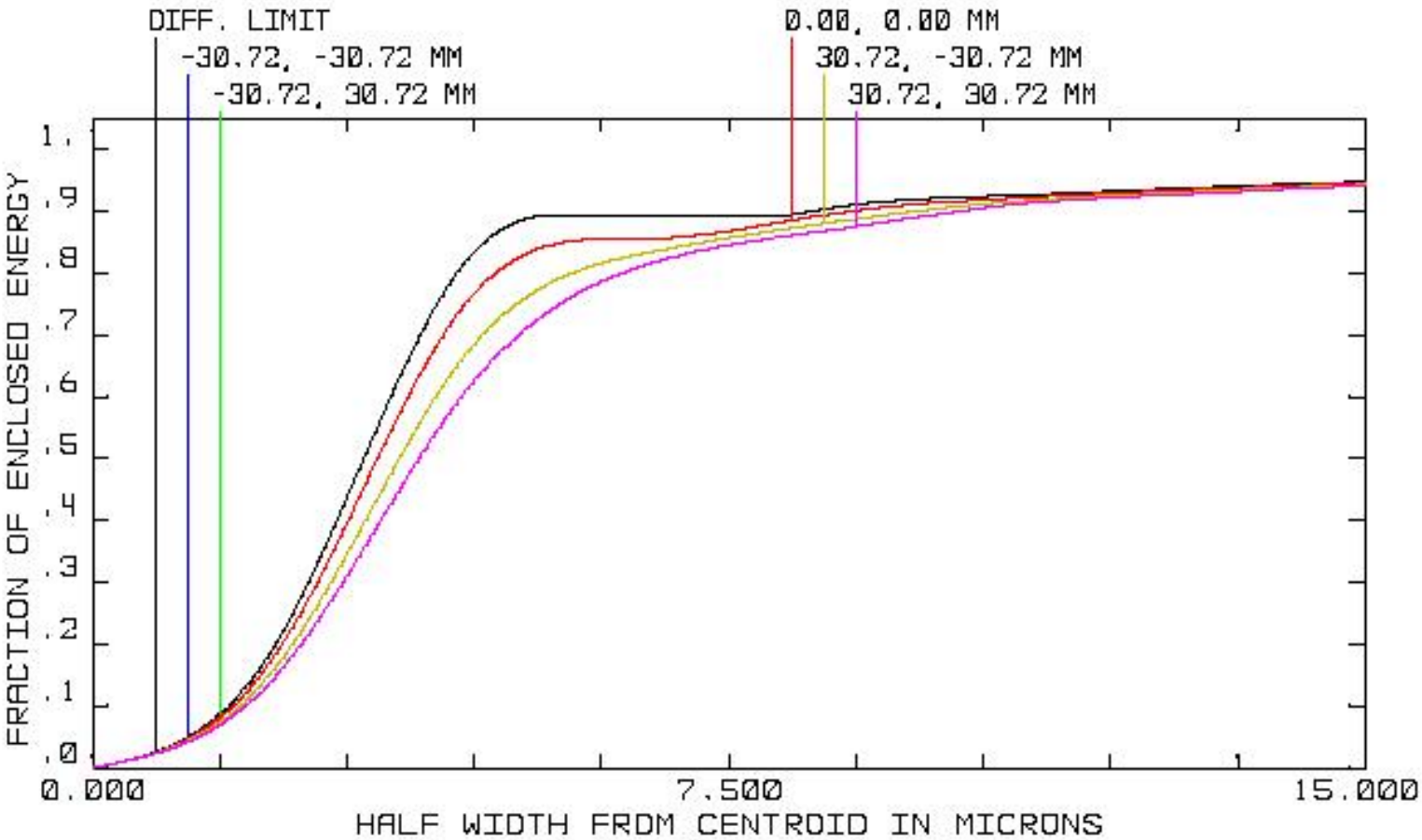
Encircled Energy of the Offner System



Wavelength: 500nm

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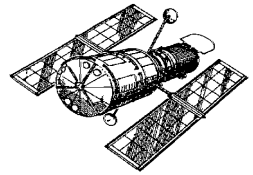
Measured Image quality



- Three methods used to evaluate image quality of the system experimentally
  - In Focus pinhole images
  - Out of focus pinholes images
  - Air Force Target images

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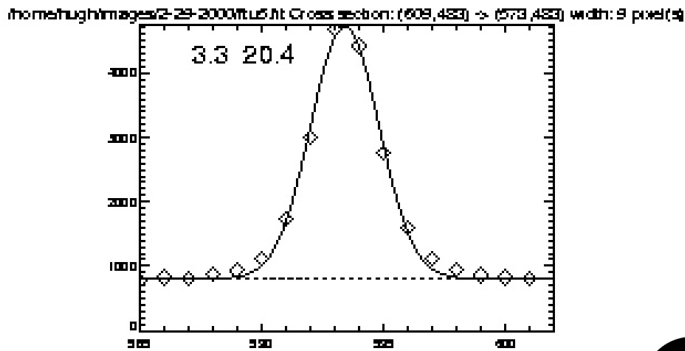
Measured image quality (continued)

Measured Pinhole image sizes (8um pinhole):

Wavelength	Date	FWHM (Vertical)	FWHM (Horizontal)
633	10-18-1999	14um +/- 1um	15um +/- 1um
900	10-20-1999	21um +/- 1um	23um +/- 1um
900	03-15-2000	22um +/- 1um	22um +/- 1um
900	11-01-2000	22um +/- 1um	21um +/- 1um

Note: Pinhole cross-sections were fit to gaussians to obtain the FWHM.



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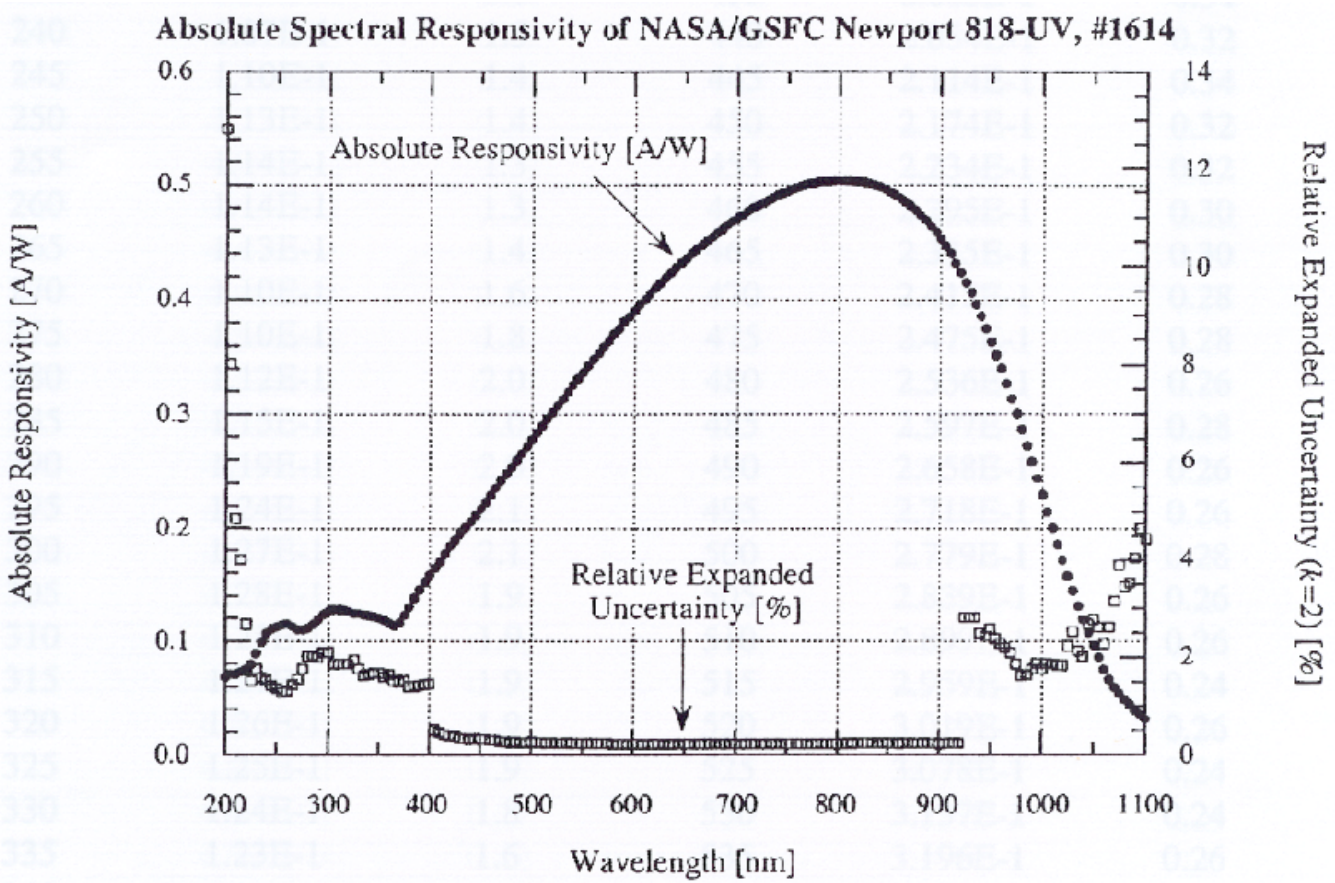
Photodiode calibration

- Newport provides NIST traceable calibration with each diode
- One 818-UV diode was also calibrated at NIST.



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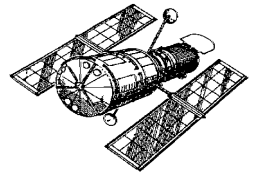
Other Optical Systems



- In addition to the Offner system we have a non-imaging system (known as the “A” setup).
  - It is composed of an integrating sphere and a monochromator that are similar to the those in the Offner.
  - Produces flat field.
  - Used in the measurement of QE.

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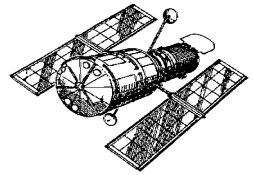

DCL Hardware

Augustyn Waczynski

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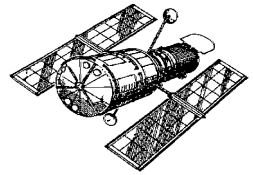
DCL Hardware



- Specification of the SDSU system:

	CCD	IR
noise	0.2 e @ 50kHz	< 2 e @ 100 kHZ
speed	20 kHZ to 1 MHz	20kHz to 1MHz
dynamic range	16 bit	16 bit
capacity	4 channels (up to 32)	4 channels (up to 32)

programming flexibility - gain, bandwidth, timing patterns and detector biases are fully software programmable

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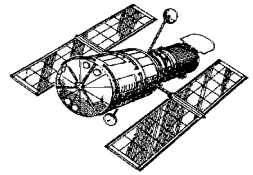
DCL Hardware



- Dewar description and its capability:

  - CCD dewars:

window diameter	125 mm
detector dimensions	90 x 90 mm
temperature	100K to 273K
hold time	24 hrs

Modular design allows for easy modification and changes to the wiring and working space.

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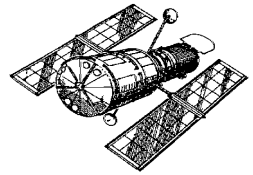
DCL Hardware



- IR1 dewar
  - window diameter 80 mm
  - detector dimension 40 x 40 mm; limited by filter size
  - temperature 77K to 200 K, LakeShore controller
  - hold time 24 hrs
  - six position cold filter wheel, cold shield and optical baffling
- IR2 dewar
  - window diameter 80 mm
  - detector dimension 40 x 40 mm; limited by filter size
  - temperature 4 K to 200 K, LakeShore controller
  - hold time 24 hrs
  - six position, motorized, cold filter wheel, cold shields and optical baffling, separate tanks for LN2 and He

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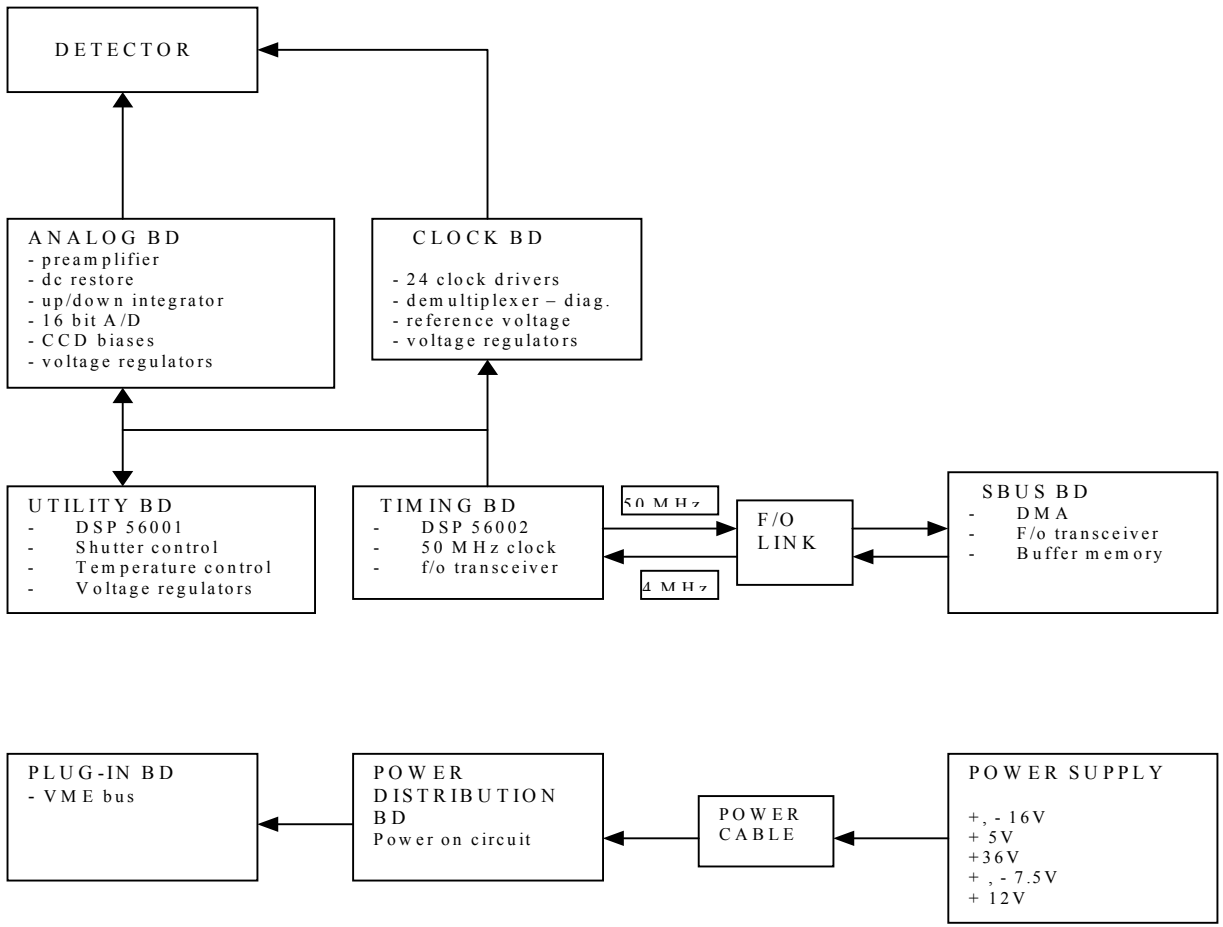
DCL Hardware

Data Acquisition System

DAS BLOCK DIAGRAM



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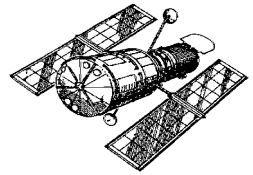

Software

Bob Hill, Elizabeth Polidan

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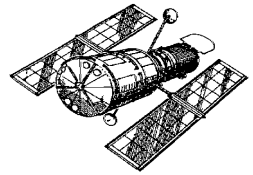
Lab Data Acquisition



- What data is collected?
  - detector characterization data
    - experiments designed to yield device performance in areas requested by customer (WFC3)
    - characterization data includes parameters such as detector temp., gain, output amp, etc.
    - complete set of detector operating parameters (voltages, timing, etc.)
  - lab monitoring data
    - want to monitor conditions in lab which may affect detector characterization data, e.g. high humidity could cause condensation on optical surfaces

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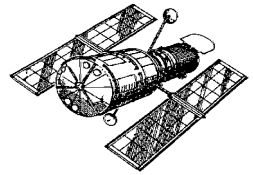
Lab Data Acquisition



- What happens to acquired data?
  - detector output data written to FITS file
  - detector status parameters included in FITS header
  - detector operating parameters saved to separate file(s) with names included in FITS header
  - lab monitoring data continuously appended to separate files
  - detector data acquisition systems query files to check that conditions fall within acceptable limits and remain stable during experiment
    - association between different data sets made using timestamps from data acquisition computers

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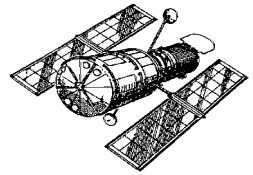
Lab Data Acquisition



- FITS data file headers include entries for lab data and flags to be set if data falls outside limits
  - if outside limits, appropriate data is copied to a new file to be archived
- filenames for auxiliary data have the same root names as the detector data files; suffixes used to identify different types of data

– detector data stored on local data acquisition system
- quality of data judged by preliminary evaluation by data analyst
- if data is acceptable, it is copied to the archive
- if not, notification made to request new data

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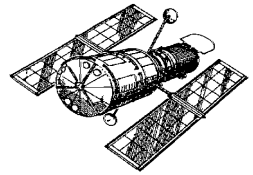
Data Archiving



- Validated data is moved to the archive
  - Scripts to move data test their integrity before it is deleted from the original site
- All data for particular experiment are catalogued under the same test number
- Database
  - IDL Based (similar to STIS and ACS databases)
  - Search returns information on FITS files meeting requirements
  - Web Based and Online Database Access

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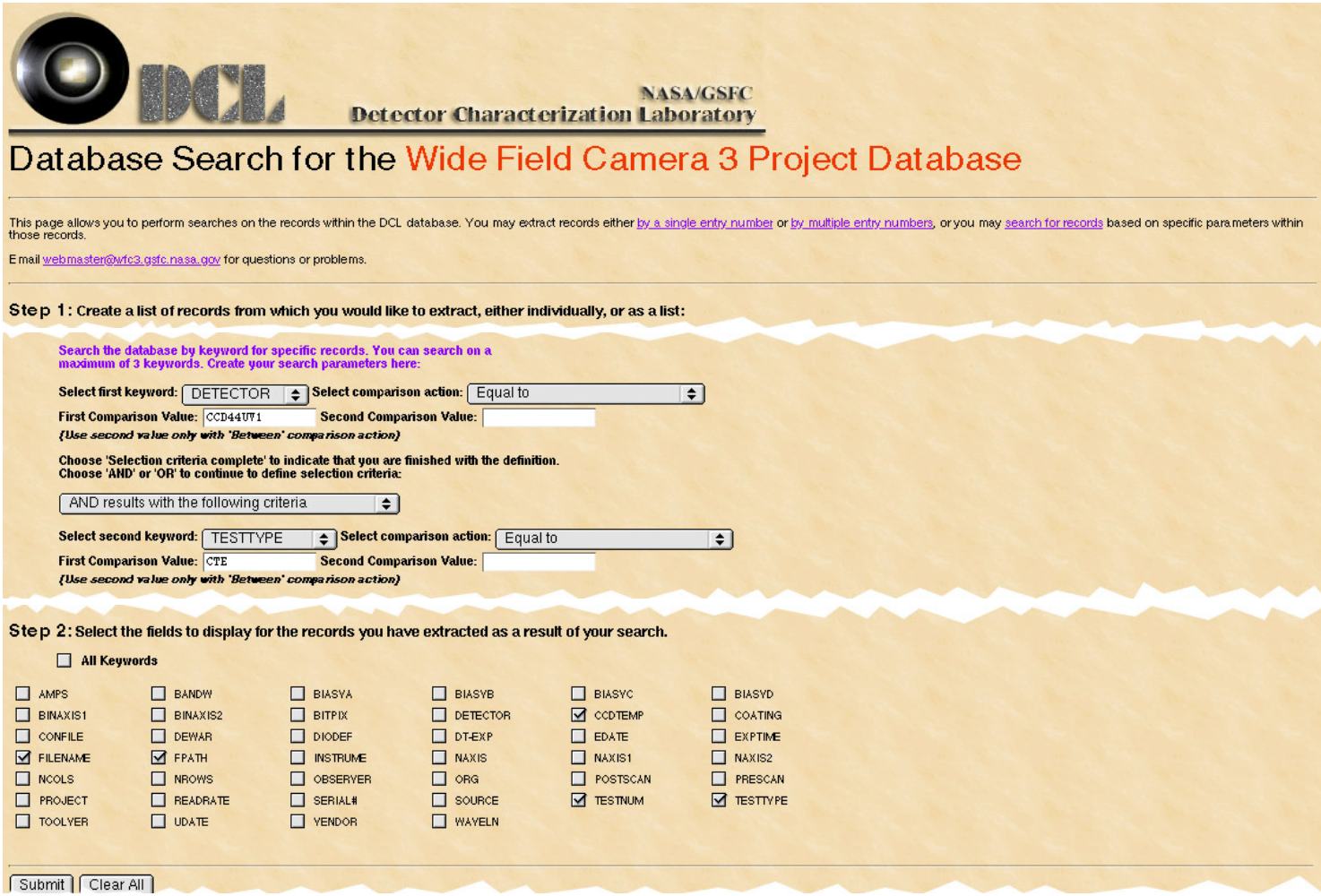
Database Search



DCL

NASA/GSFC
Detector Characterization Laboratory

Database Search for the Wide Field Camera 3 Project Database

This page allows you to perform searches on the records within the DCL database. You may extract records either by a single entry number or by multiple entry numbers, or you may search for records based on specific parameters within those records.

Email webmaster@wfc3.gsfc.nasa.gov for questions or problems.

Step 1: Create a list of records from which you would like to extract, either individually, or as a list:

Search the database by keyword for specific records. You can search on a maximum of 3 keywords. Create your search parameters here:

Select first keyword: DETECTOR Select comparison action: Equal to

First Comparison Value: CCD44UV1 Second Comparison Value:

{Use second value only with 'Between' comparison action}

Choose 'Selection criteria complete' to indicate that you are finished with the definition.
Choose 'AND' or 'OR' to continue to define selection criteria:

AND results with the following criteria

Select second keyword: TESTTYPE Select comparison action: Equal to

First Comparison Value: CTE Second Comparison Value:

{Use second value only with 'Between' comparison action}

Step 2: Select the fields to display for the records you have extracted as a result of your search.

☐ All Keywords

☐ AMPS	☐ BANDW	☐ BIASVA	☐ BIASVB	☐ BIASVC	☐ BIASVD
☐ BINAXIS1	☐ BINAXIS2	☐ BITPIX	☐ DETECTOR	☑ CCDTEMP	☐ COATING
☐ CONFILE	☐ DEWAR	☐ DIODEF	☐ DT-EXP	☐ EDATE	☐ EXPTIME
☑ FILENAME	☑ FPATH	☐ INSTRUME	☐ NAXIS	☐ NAXIS1	☐ NAXIS2
☐ NCOLS	☐ NROWS	☐ OBSERVER	☐ ORG	☐ POSTSCAN	☐ PRESCAN
☐ PROJECT	☐ READRATE	☐ SERIAL#	☐ SOURCE	☑ TESTNUM	☑ TESTTYPE
☐ TOOLVER	☐ UDATE	☐ VENDOR	☐ WAVELN		

Submit Clear All

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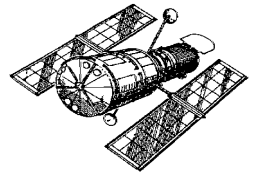
Data Base Search



- Data Access
  - Online and ftp access for authorised users
  - Future plans to offer auto ftp option in web-based search
- Data Security
  - Daily backups
  - Database administrators are only ones with write privileges
- Data Storage
  - We currently have 173 Gbytes of online storage and one terabyte of near line storage
  - All data for a single detector are kept online for at least 2 months after the final report has been issued
  - Data are finally moved to near line storage and database is update

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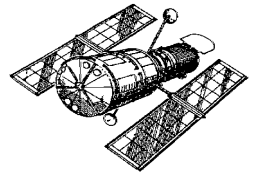

Operations Concepts

John Maliszewski

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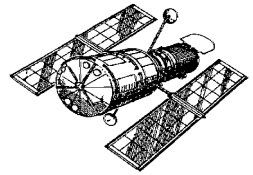
Operations Concepts



- Typical Detector Characterization Sequence:
  - Detector Interface Definition for both mechanical, electrical and software parameters.
  - Interface design and fabrication (fanout PCB, detector mounting and attachment to the cold finger).
  - Detector assembly with the interface into a dewar on the Clean/ESD bench.
  - Initial signal checkout on the Clean/ESD bench.
  - Transfer to the optical bench and first data acquisition.
  - Optimization of timing sequences and bias voltages.
  - Data acquisition for the specific test suite.
  - Initial data analysis.
  - Reoptimization of timing sequences and bias voltages, if required.
  - Full test data acquisition.
  - Data analysis.
  - Device performance test report.
  - Archiving of the data, results and the device operational parameters.

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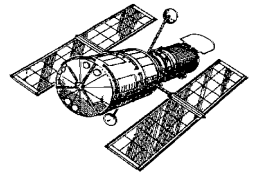
Operations Concepts



- Production Model:
  - Obtain “customer” test requirements for detector to be tested.
  - Assess the requested test against tests already performed identifying similarities, possible equipment to be used and potential existing interfaces.
  - Initiate design and fabrication work if new interface arrangement is needed.
  - Schedule the test activity in conjunction with other testing and “fixed overhead maintenance” being performed in the lab.
  - Establish test plan based on “customer’s” requirements.

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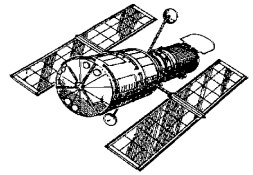

Procedures / Test Cases

Bob Hill, Elizabeth Polidan, Scott Johnson

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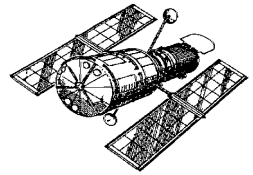
Procedures



- Devices DCL currently supports
  - Marconi CCD44-80
  - Marconi CCD42-80
  - Marconi CCD42-40
  - Marconi CCD43-80
  - Marconi CCD12
  - SITe ST1008 2K x 4K
  - SITe 1100 x 330
  - Lockheed 1024 x 512 Startracker
  - Rockwell Hawaii-1 Detector (1.7um cutoff)
  - Rockwell Hawaii-1 Multiplexer
  - Rockwell WFC3-1R Multiplexer

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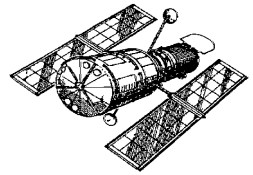
Procedures



- Devices to be supported in future
  - Lockheed CCD486 (4K x 4K)
  - Marconi CCD30-11
  - Rockwell Hawaii-WFC3-1R Detector (1.7um cutoff)

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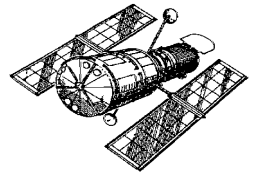
Procedures



- **TEST PROCEDURE PARAMETERS**
  - **CTE**
    - X-Ray, EPER, FPR
    - X-Ray
      - as a function of temperature, density and pixel residency time.
    - EPER
      - intensity range from 10 electrons/pixel to full well (100,000 e/p)
      - -70 to -100C range
      - three files per data point
      - approximately 100 pixels overscan in each direction; more heavily damaged devices require more overscan pixels.

Note: EPER raw data are used to calculate Full Well, Linearity and to verify Gain and Read Noise.

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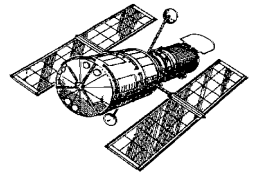
Procedures



- FPR
  - intensity range from 10 electrons/pixel to full well (100,000 e/p)
  - temperature -70 to -100C
  - three files per data point
  - transfer area cleaned approximately three times before shifting image

– **DARK CURRENT**

- exposure times from 30 min to 6 hrs, depending on temperature
- multiple frames per data point (from 2 to 6)
- CCD
  - temperatures of -65 to -100C
  - full frame data acquisition or binning
  - measured down to 0.5 electrons/pixel/hour
- IR
  - temperatures of -90 to -130C
  - multiple bias voltage settings
  - measured down to 0.05 electrons/pixel/second

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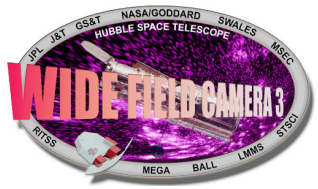
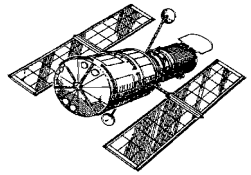


Procedures



- **QUANTUM EFFICIENCY**
  - absolute QE measurement based on the calibrated reference diode
  - spectral range 200 nm to 1800 nm; continuous coverage
  - Deuterium, Xenon and Tungsten lamps
  - NIST calibrated reference photodiodes
  - double diode reference system; light intensity continuously monitored
  - spectral ratio between reference and monitoring diodes measured during flat field calibration
  - spectral and spatial flat field calibration
  - spectral measurements at 25 nm and 50 nm intervals (UV and IR range respectively)
  - three frames collected per data point

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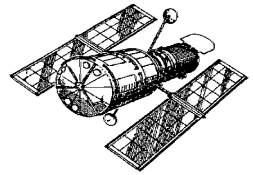
CTE Test Procedure
Using X-ray Source



- Purpose: This test procedure describes standard steps required to collect data for CTE determination using an X-ray source. The steps and conditions may need to be modified depending on the type of CCD and test requirements as defined in the Detector Test Specification Document.
- Scope: This document defines the conditions and steps required to collect data for CTE measurements with an Fe55 source.
- Relevant Documents
  - Detector Test Specification Document (DTSD)
- Conditions
  - The dewar has to be in thermal equilibrium; the target temperature should be reached at least 30 minutes prior to the test.
  - The test electronics should be warmed up; they should be on for a minimum of 15 minutes prior to the test.
  - Set detector operating conditions using DSP code and CCDTool GUI (script). Set electronics gain to the available maximum of 9.5. Set the device format to overscan in the horizontal direction by 100 pixels. Download code into system in advance of data collection, at least 15 minutes prior to test execution.

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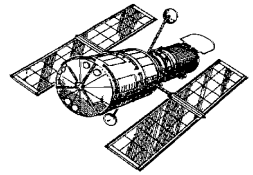
CTE Test Procedure
Using X-ray Source



- Data Acquisition Steps
  1. Collect a test data set for medium exposure time (~ 20 seconds). Compute the mean value of x-ray events per column (run the IDL routine 'quickcte.pro'). Compute the exposure time required to obtain one event per column, ETmin.
  2. Acquire two dark exposures for ETmax=128ETmin. Verify that there is no noticeable increase in dark in the image area compared to overscan (run the IDL routine 'quickdark.pro'; dark has to be lower than 2 electrons/ETmax to continue the test).
  3. Compute a set of exposure times in geometric progression (e.g. ET1 = 1ETmin, ET2=2ETmin, ET3 = 4ETmin, ..., ET8 = 128ETmin)
  4. Acquire 10 frames each for exposure times equal to 1ETmin, 2ETmin, 4ETmin, 8ETmin. Acquire 5 frames each for test point with ET higher than 8ETmin. Assign file name using the convention Date_typetemp_ETnumber.fits (e.g. JU21_fe100_4s1.fits, for July 21, FE55, -100C, ET=4s, first frame, 'fits' format). Store the data in the directory for a given CCD.
- Repeat steps 1 through 4 for each test temperature as defined in the DTSD
- Notify the Data Analysis Group when a set of data is available. Data acquisition may need to be repeated, depending on the results of analysis.

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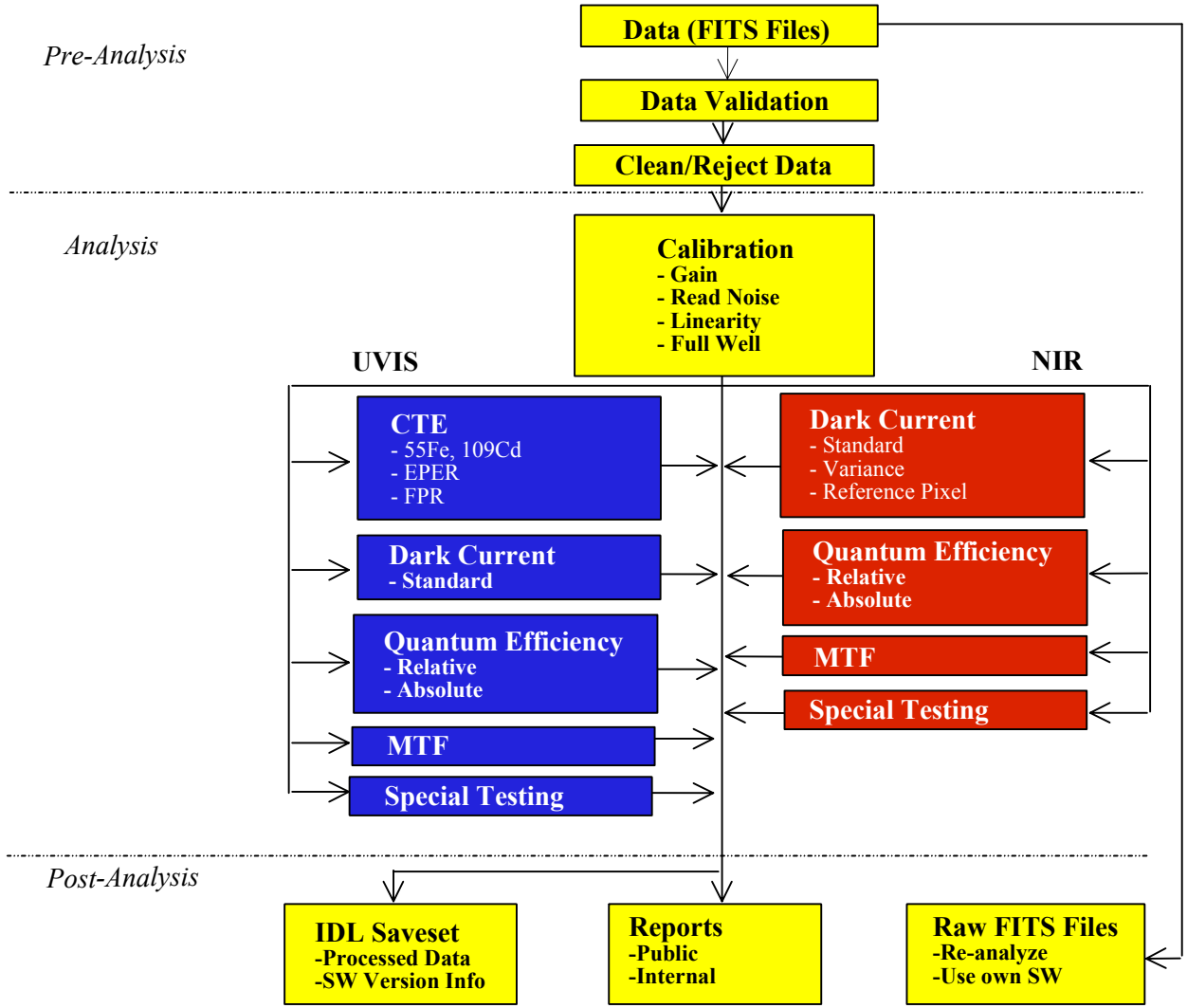
Analysis Flow Chart



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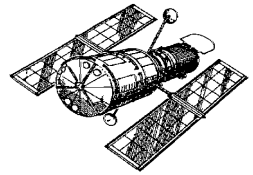
Pre Analysis



- Data Validation
  - Environmental data
    - Temperature, humidity, RF power, and pressure in the lab
    - Temperature and pressure within the dewar
  - Validation of image
    - Visual Inspection (cursory)
    - PSD (row and column)
    - Line plots (row and column)
    - Histogram
- Clean or reject data (if necessary)
  - Filters
  - Remove cosmic rays

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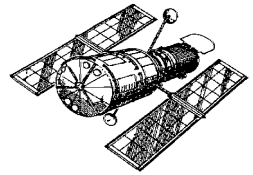
Analysis



- Quick analysis (to be reported to lab within a day or two)
- Calibration
  - Gain
  - Read Noise
  - Linearity
  - Full Well
- Measurements
  - Standard controlled versions of analysis software
  - Multiple approaches

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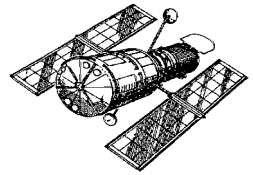
Post Analysis



- Reports
  - Public
  - Internal, more detailed, may not be for public access
- Results Storage
  - Reports
  - Data File from IDL (including software versions)
  - Raw Data

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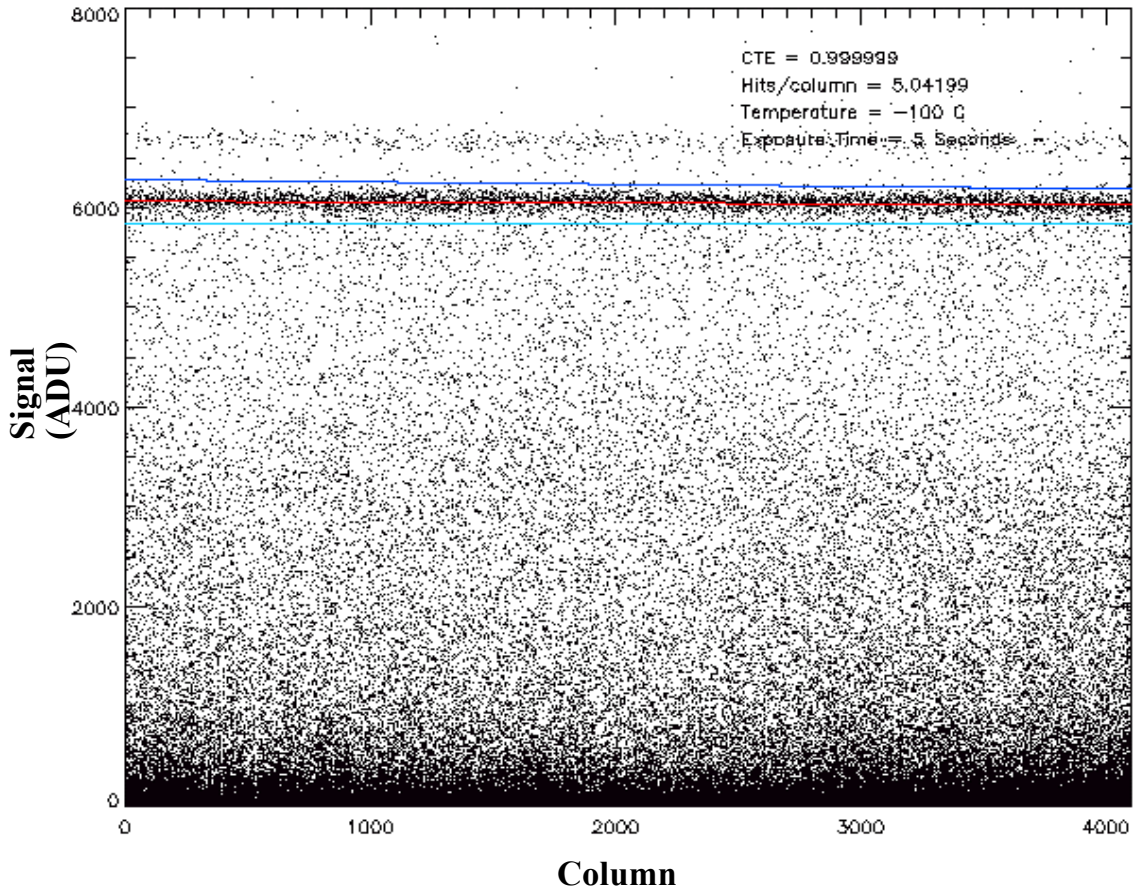
CTE Data Analysis Example

CCD44V1 Pre-Radiation 55Fe Image Stacking Plot
Overlayed With Defined Area of Interest for Parallel CTE Calculations



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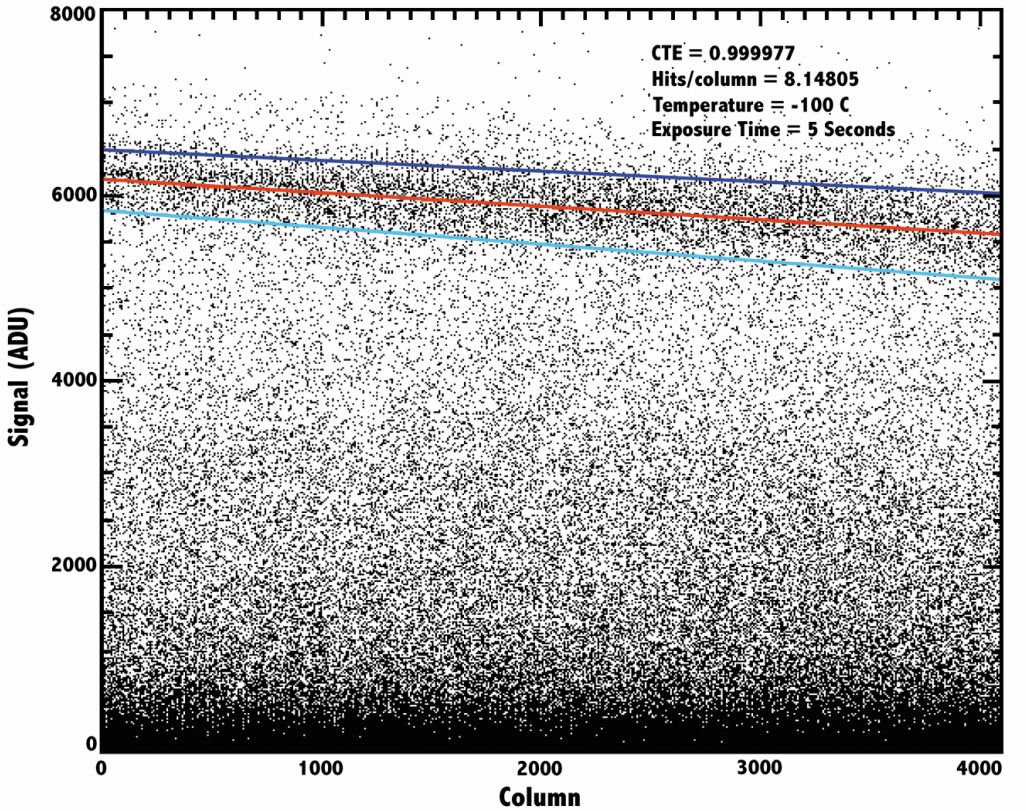
CTE Data Analysis Example

CCD44V1 Post-Radiation (1 Year) 55Fe Image Stacking Plot
Overlayed With Defined Area of Interest for Parallel CTE Calculations



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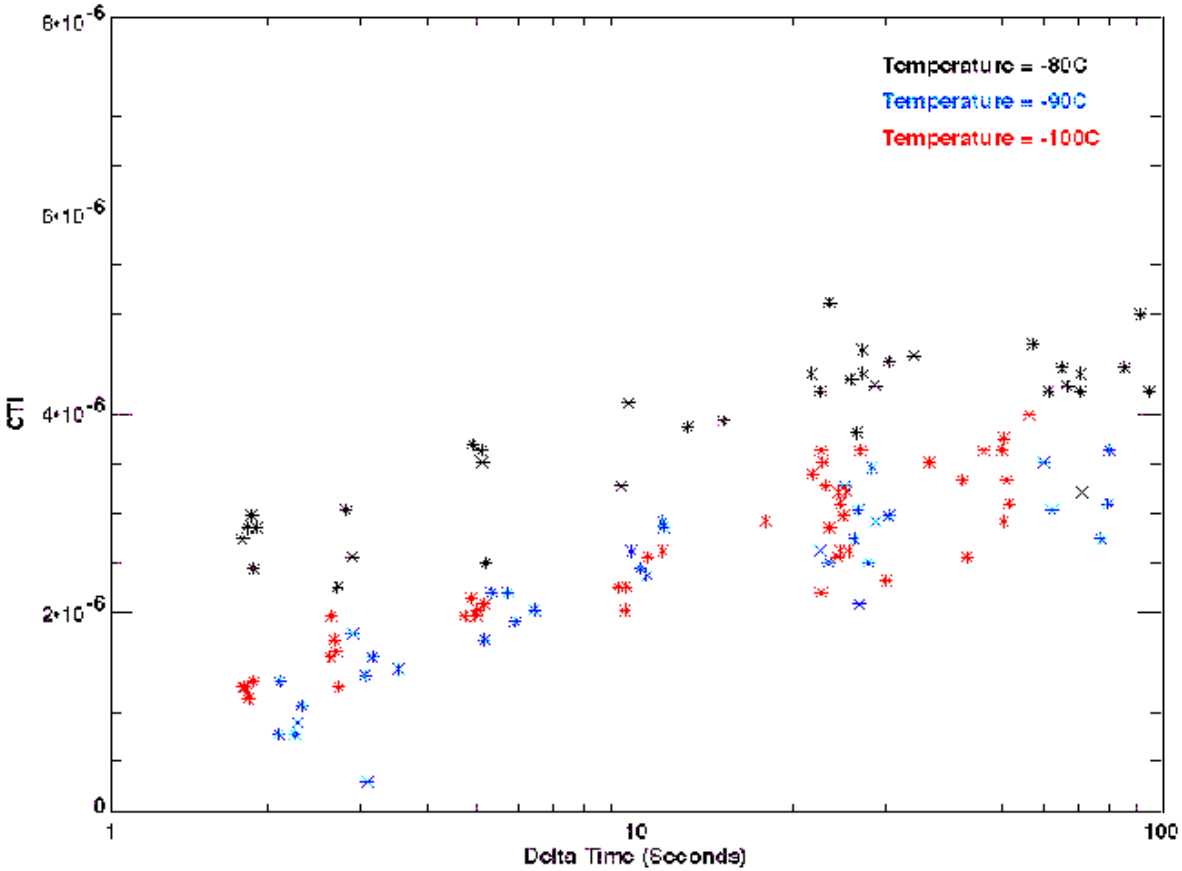
CTE Data Analysis Example

CCD44V1 Pre-Radiation Parallel CTI vs Delta Time



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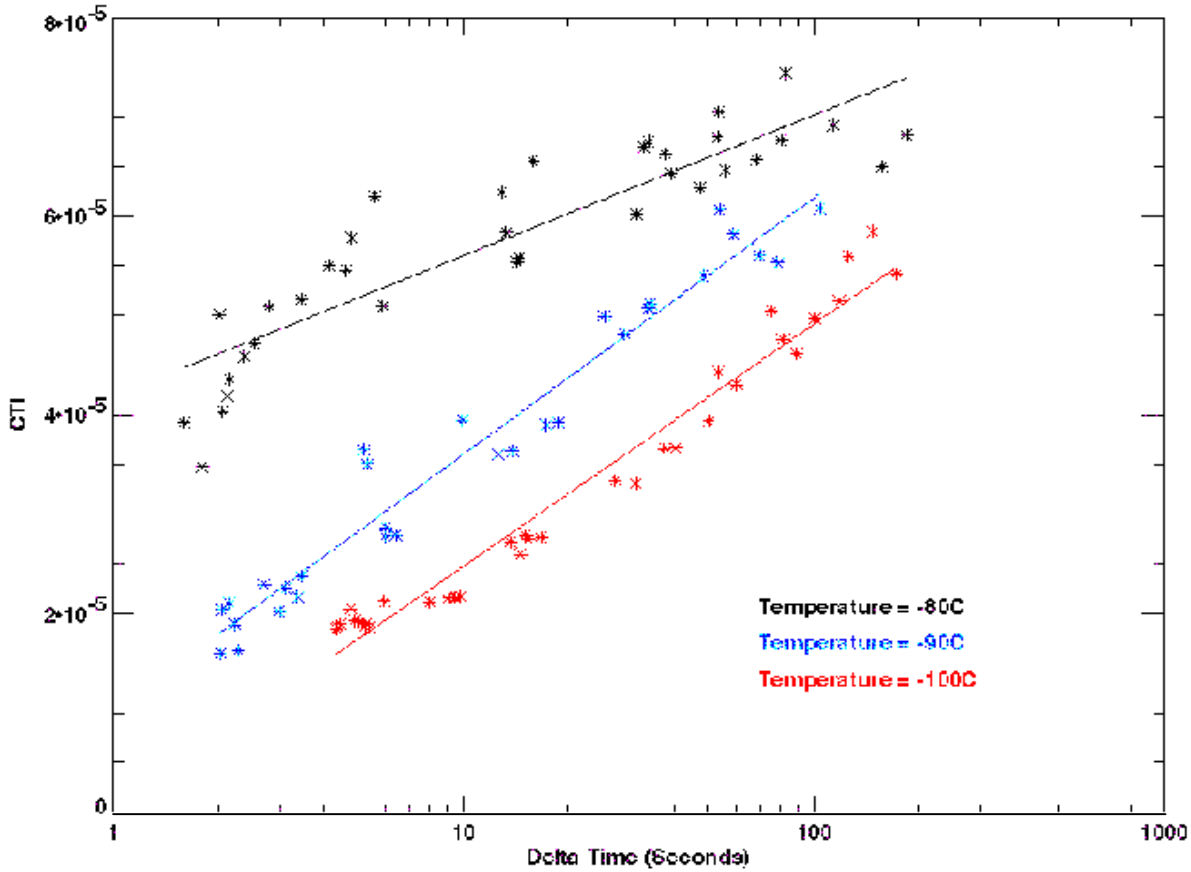
CTE Data Analysis Example

CCD44V1 Post-Radiation (1 year) Parallel CTI vs Delta Time



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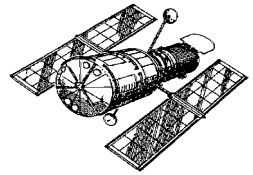
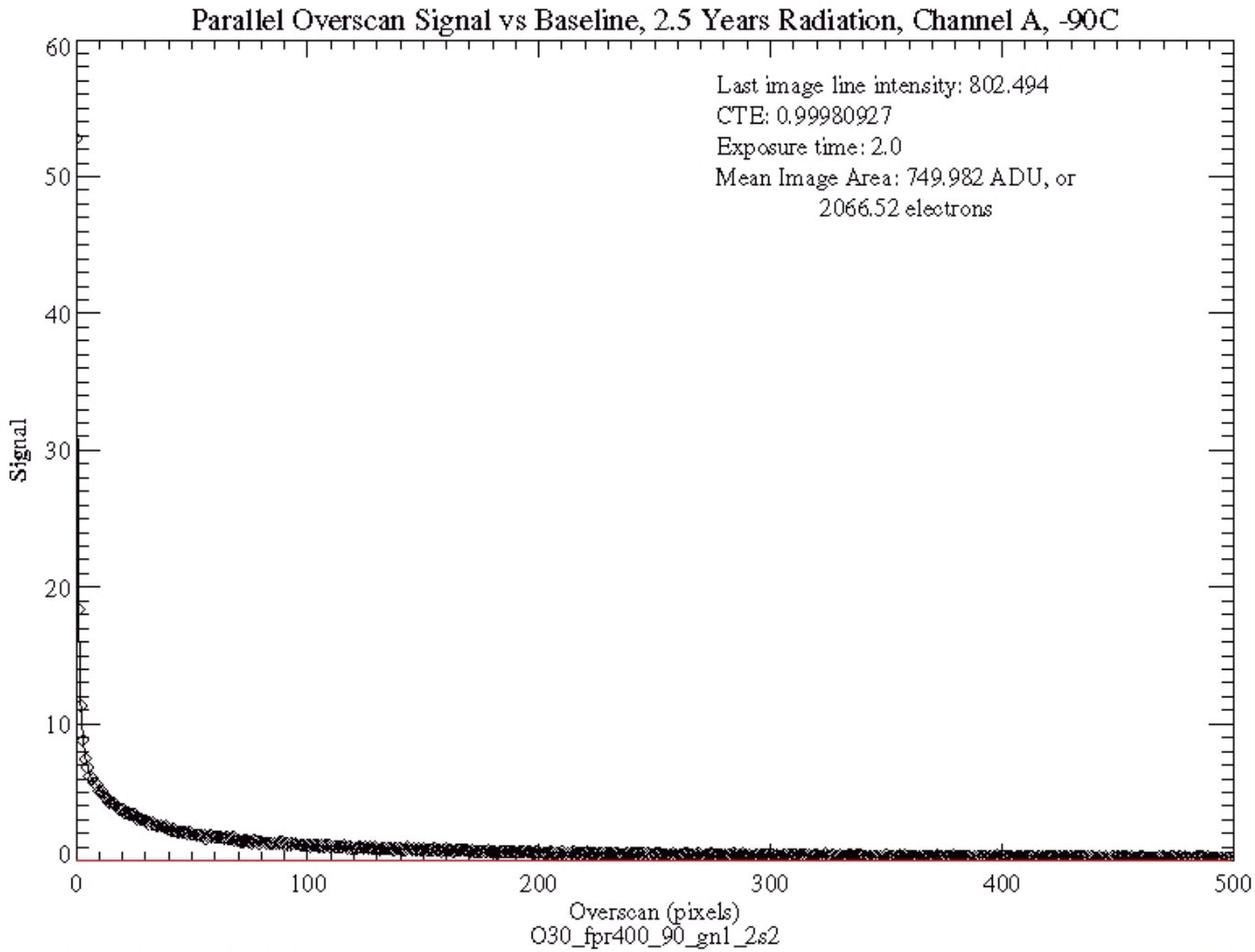
EPER Example





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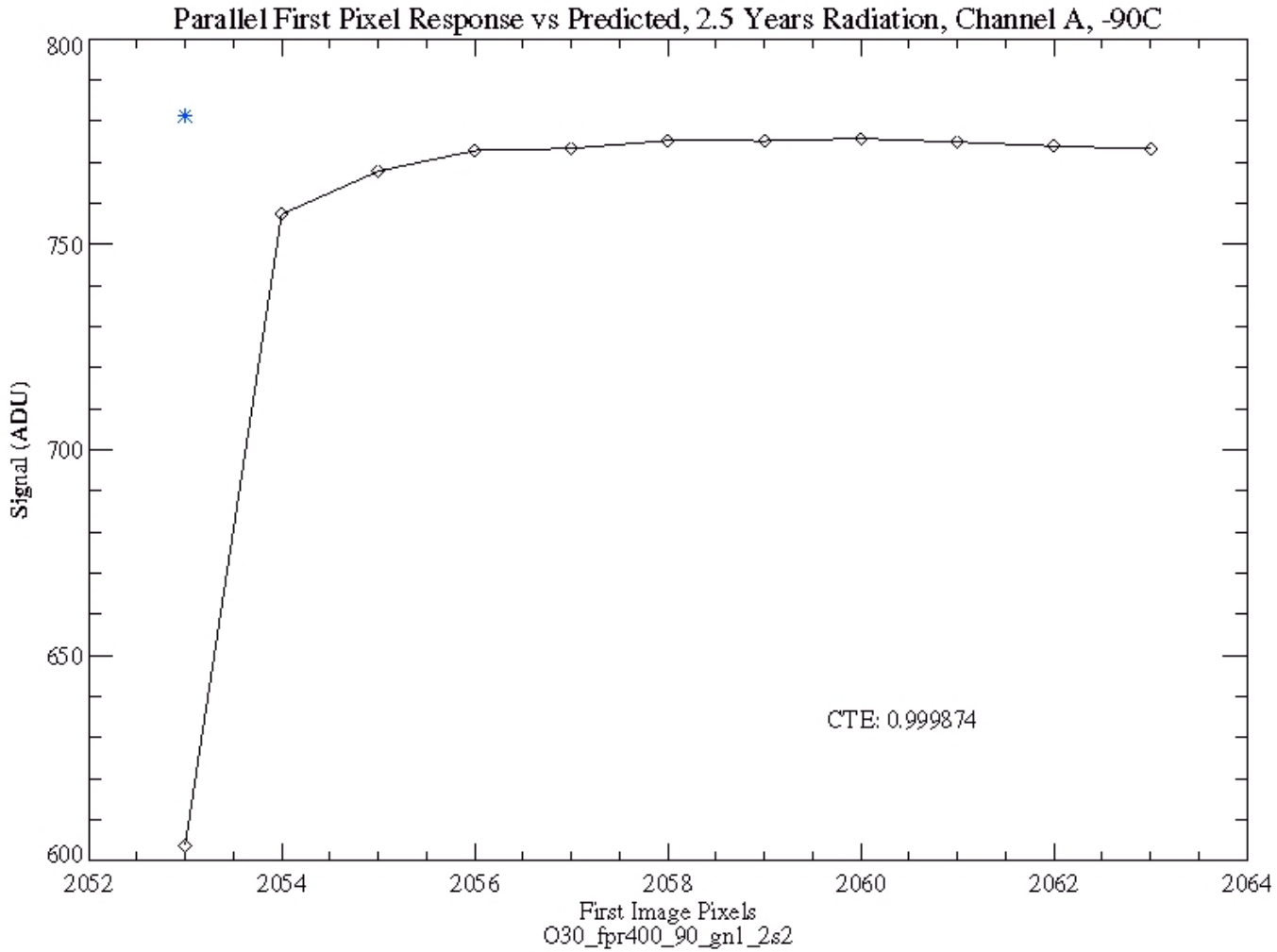
FPR Example



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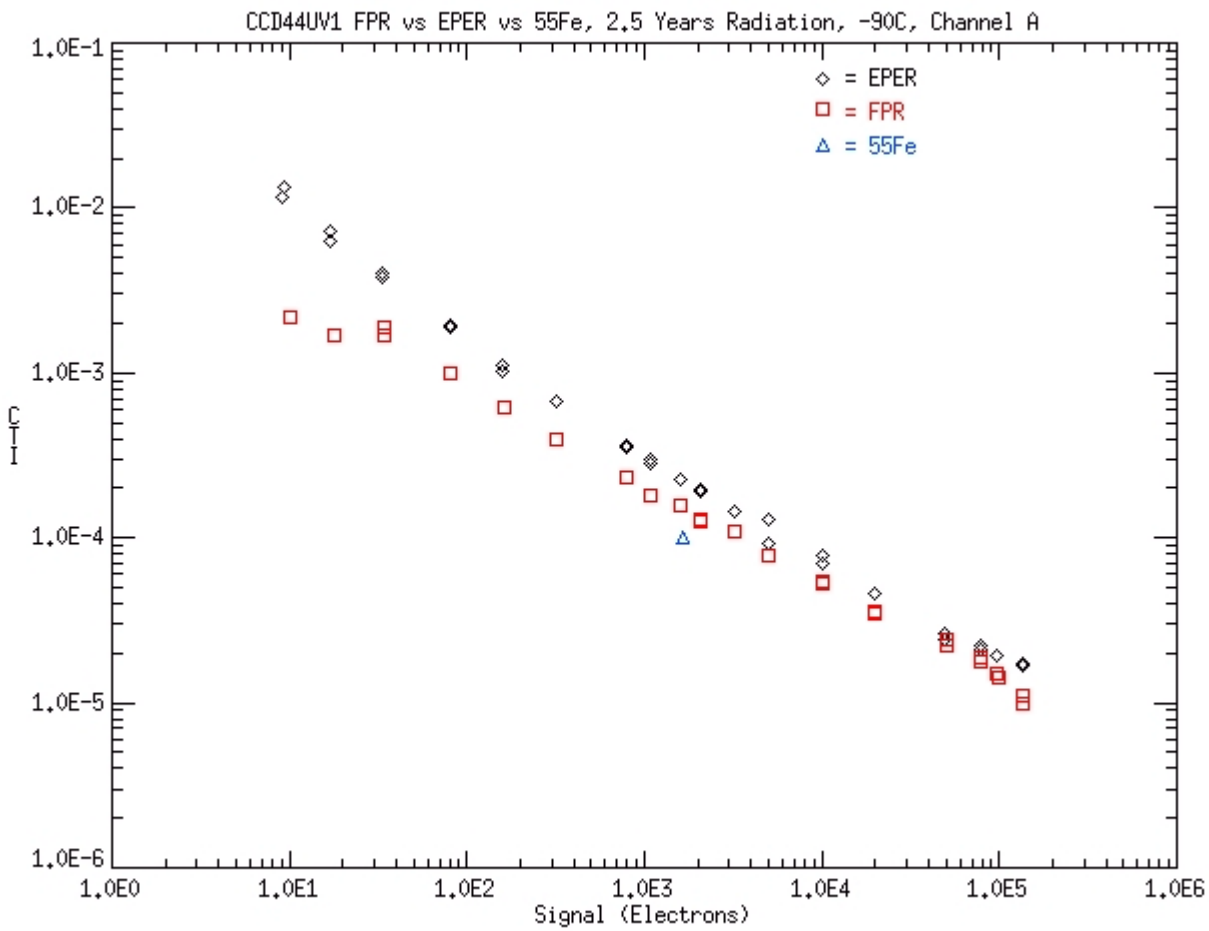
FPR vs EPER vs 55Fe



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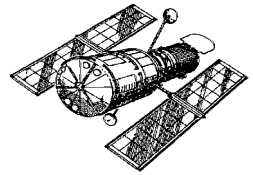
Dark Current Example



- Problems
  - Non-linear drift
  - Other sources of noise
- Solutions
  - Multiple analysis techniques
    - Modified standard method
    - Reference pixel method
    - Variance method

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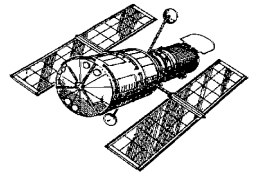
Methods for Dark Current



- Modified Standard Method
  - Follows standard method of subtracting reset frame from signal frame
  - Subtracts a second reset frame to correct for drift
- Reference Pixel Method
  - Uses unbonded pixels as a bias reference to correct for drift
  - Apply to dark image
  - 1-R Mux has been designed to facilitate this method

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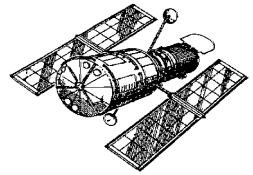
Methods of Dark Current (cont.)



- Variance Method
  - Exploits the fact that the dark current follows Poisson statistics
  - Use two alike dark files
  - Subtracts the two darks and uses the total variance plus the read noise variance to calculate the mean dark current
  - Insensitive to drift
  - Sensitive to other sources of noise

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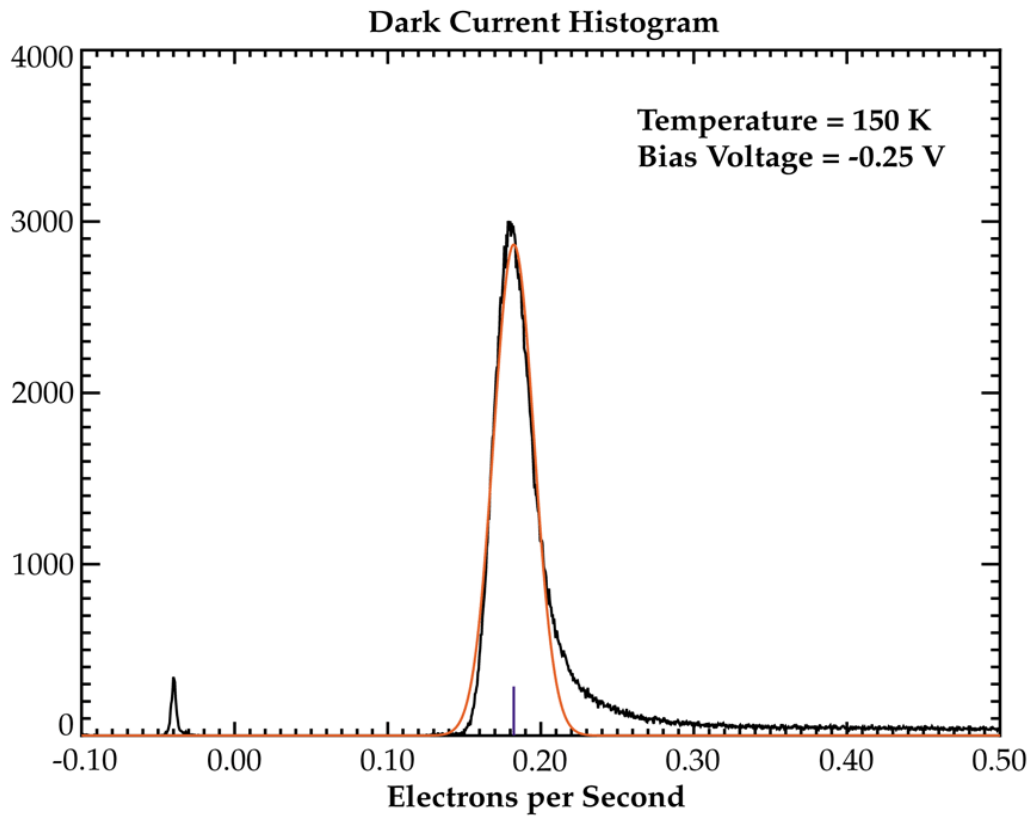
Histogram Example



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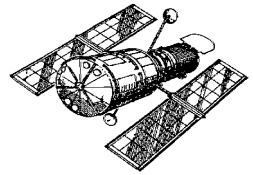
Dark Current Results



Temperature	Bias Voltage	Dark Current Variance Method	Dark Current Modified Method	Dark Current Reference Pixel Method
140 K	-0.02	0.035	0.019 +/- 0.003	0.017 +/- 0.00004
140 K	-0.25	0.045 +/- 0.010	0.1 +/- 0.2	0.020 +/- 0.012
140 K	-0.5	0.039 +/- 0.007	0.045 +/- 0.010	0.043 +/- 0.008
150 K	-0.02	0.19 +/- 0.05	0.20 +/- 0.02	0.22 +/- 0.037
150 K	-0.25	0.24 +/- 0.05	0.29 +/- 0.06	0.31 +/- 0.0077
150 K	-0.5	0.30 +/- 0.02	0.53 +/- 0.03	0.47 +/- 0.0012

Table 1: Comparison of dark currents (electrons/pixel/second) for different bias voltages and temperatures

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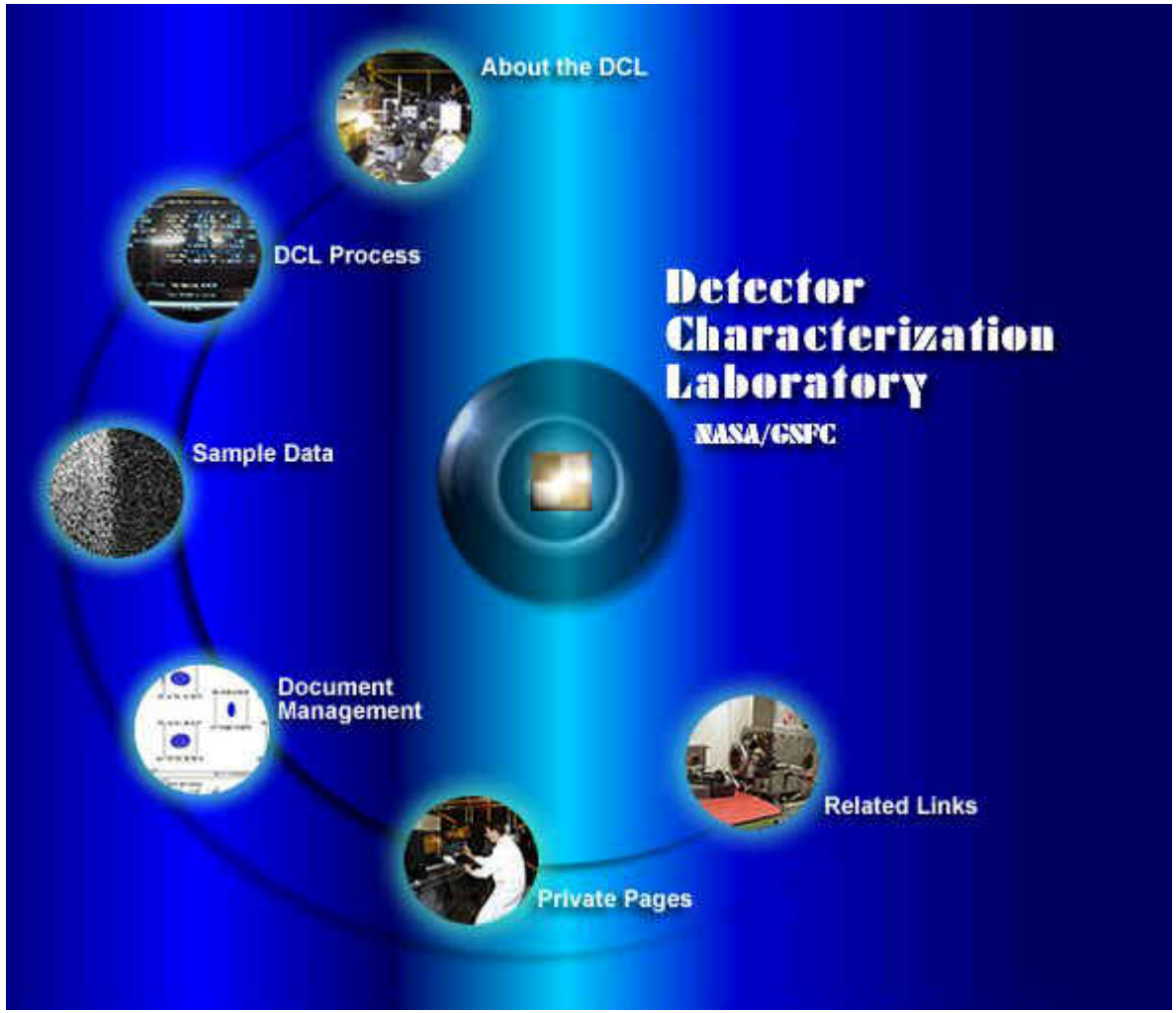
The DCL Web Site
http://dcl.gsfc.nasa.gov



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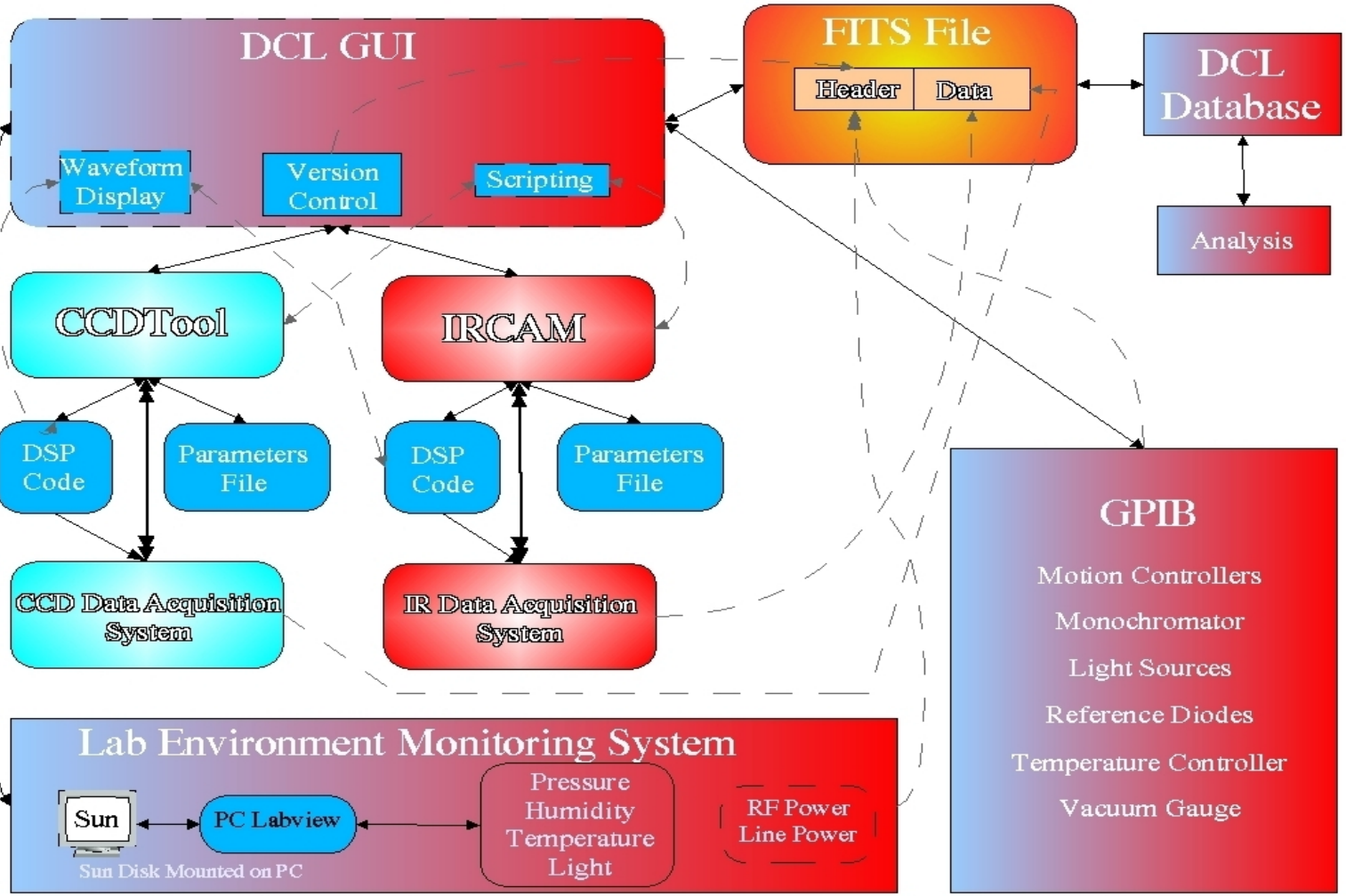
Appendix
DATA ACQUISITION; UVIS and IR



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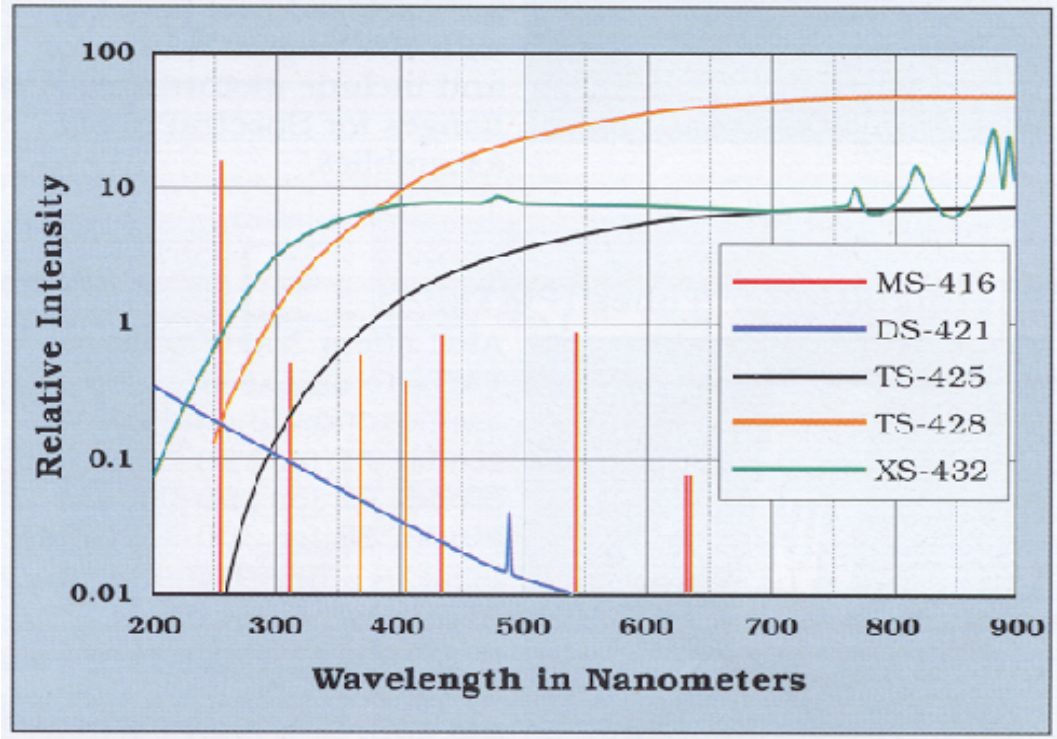
Appendix
Light Sources

Xenon (75W, 150W) 250nm - 2000nm XS-432
Deuterium (30W) 190nm-450nm DS-421
Tungsten Halogen (150W)



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Appendix
Light Sources (Continued)

- 150W Xenon graph between 250nm and 2500nm

RANGE (nm) $\lambda_1 - \lambda_2$	UVC <250	UVC 250-280	UVB 280-320	UVA 320-350	UVA 350-400	VISIBLE 400-450	VISIBLE 450-500	VISIBLE 500-550	VISIBLE 550-600	VISIBLE 600-650	VISIBLE 650-700	INFRARED 700-800	INFRARED 800-900	INFRARED 900-1000	INFRARED 1000-1100	INFRARED 1100-1500	INFRARED 1500-2000	INFRARED 2000-2500
% OF 200-2500nm C - λ_2	0.2	0.76	2.2	3.7	6.9	10.5	14.6	18.2	21.7	25.1	28.5	35.3	52.5	70.4	75.8	85.5	94.6	100
% OF 200-2500nm λ_1 - λ_2	0.2	0.56	1.4	1.5	3.2	3.6	4.1	3.6	3.5	3.4	3.4	6.8	17.1	17.9	5.5	10.7	8.1	5.4

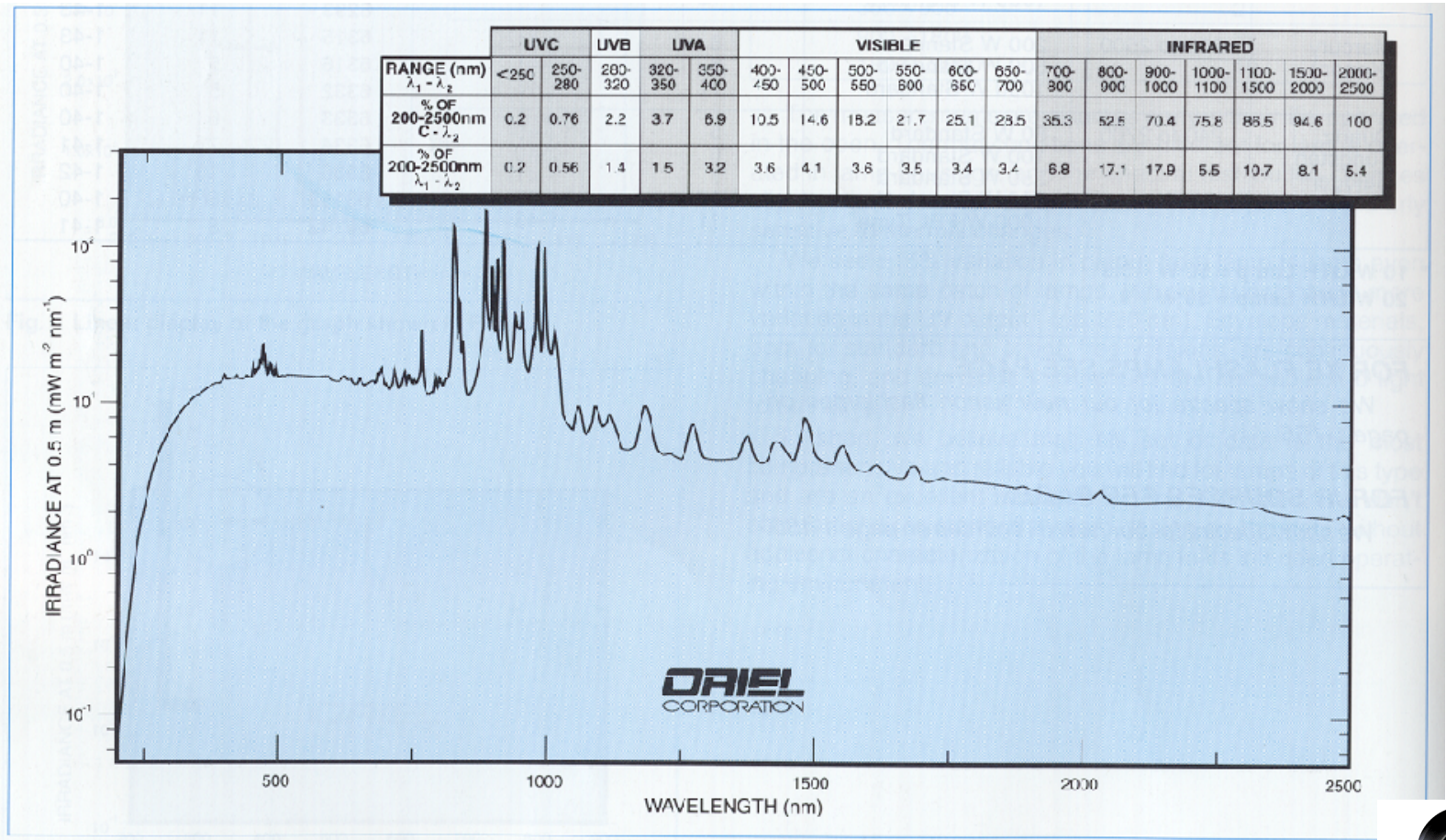

Fig. 2 250 to 2500 nm spectral irradiance curve of 6253 150 W Xe Arc Lamp.

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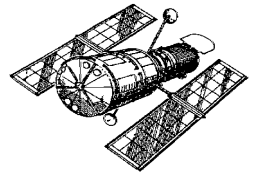
Appendix
Order Sorting Filters



- Available filters with their wavelength ranges
  - Bandpass filter
    - band-pass at 221.8nm, band width (FWHM) 12nm
    - Assorted band-pass filters between 200 and 1100nm
  - Cut-on filters
    - Oriel 57365-03 cut-on 900nm
    - Oriel 57355-02 cut-on 650nm
    - Oriel 57345-03 cut-on 400nm
    - Oriel 57345 cut-on 400nm
    - Oriel 57357 cut-on 700nm
    - Oriel 57369 cut-on 1000nm
  - Cut-Off
    - Oriel 57371 cut-off 450nm

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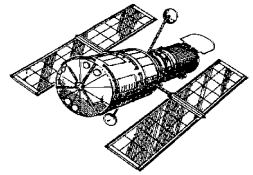
Appendix
Bandwidth Filter Sets



- Available Filter Sets
  - Melles Griot UV-10 (10nm Bandwidth Filter Set)
  - Melles Griot VIS-10 (10nm Bandwidth Filter Set)
  - Melles Griot VIS-40 (40nm Bandwidth Filter Set)

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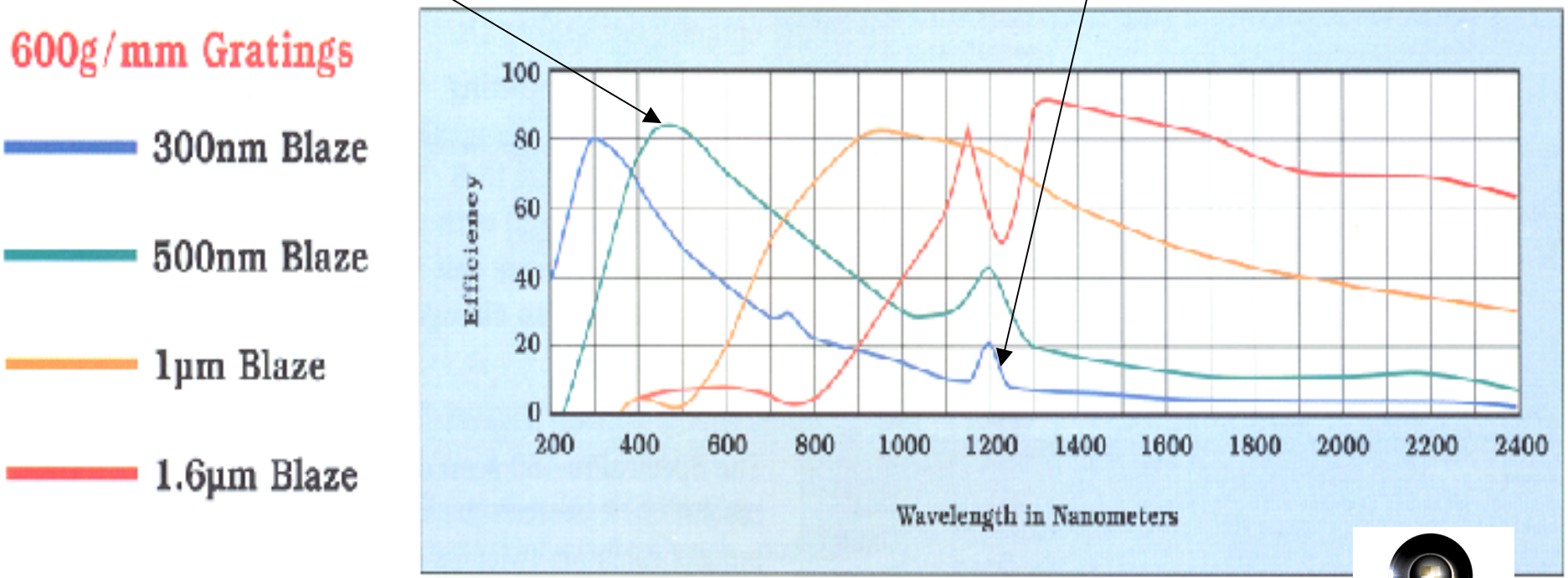
Appendix
Grating efficiencies

- The gratings have the blaze wavelengths of 300nm (600g/mm), 500nm (600g/mm) and 1000nm (300g/mm).



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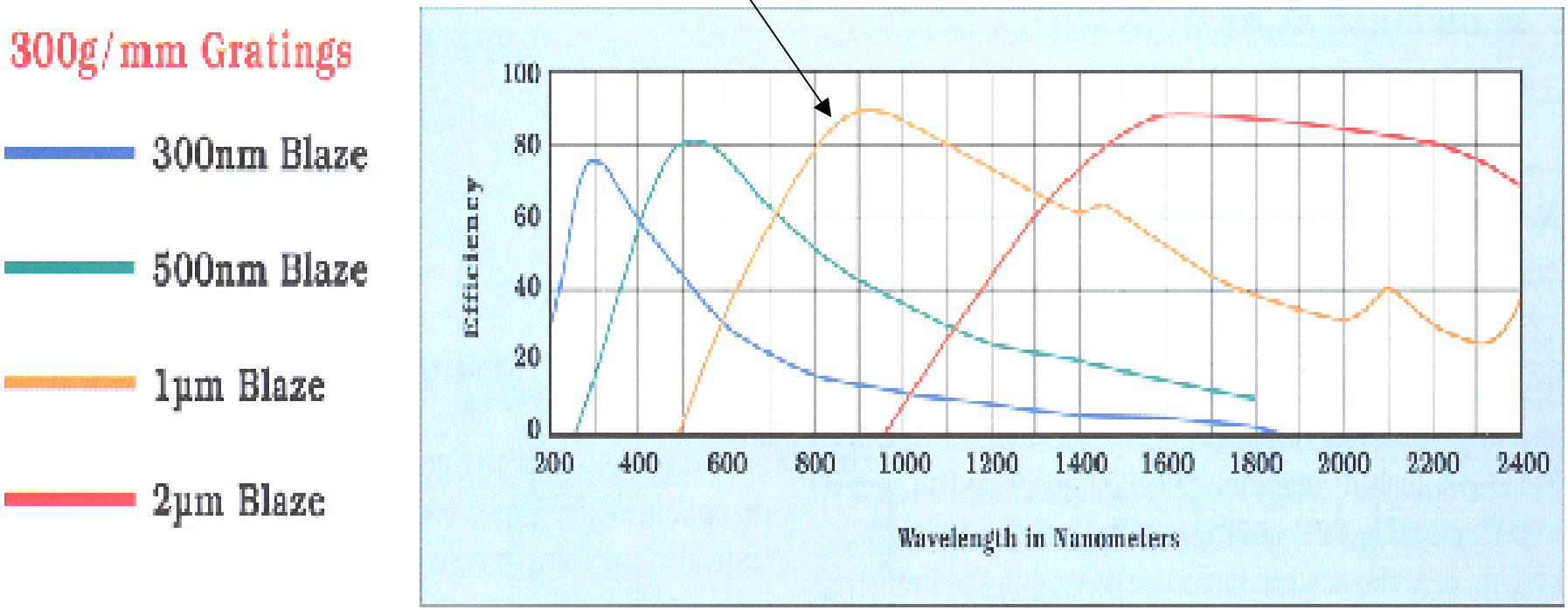
Appendix
Grating Efficiencies (Continued)

- Efficiency of the 1000nm blaze grating (300g/mm)



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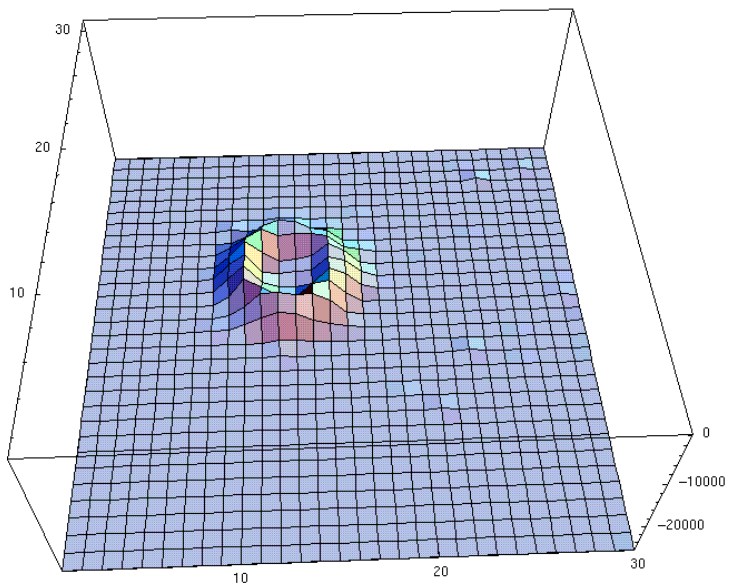
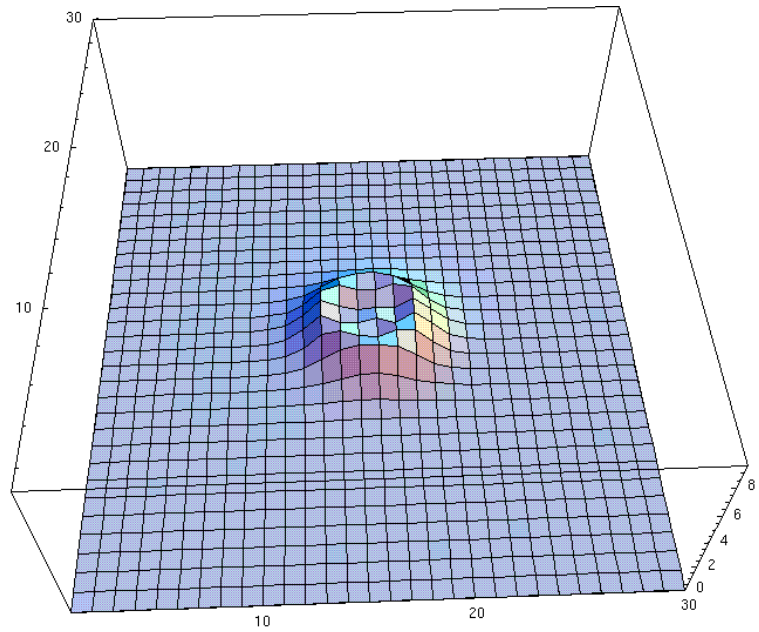
Appendix
Measured Image Quality

- Out of focus pinhole images agree with model

Measured out of focus pinhole image
+1.7mm from focus



Expected out of focus image at
+1.5mm from focus
(Data from Zemax design)



Note: 8um pinhole was used.

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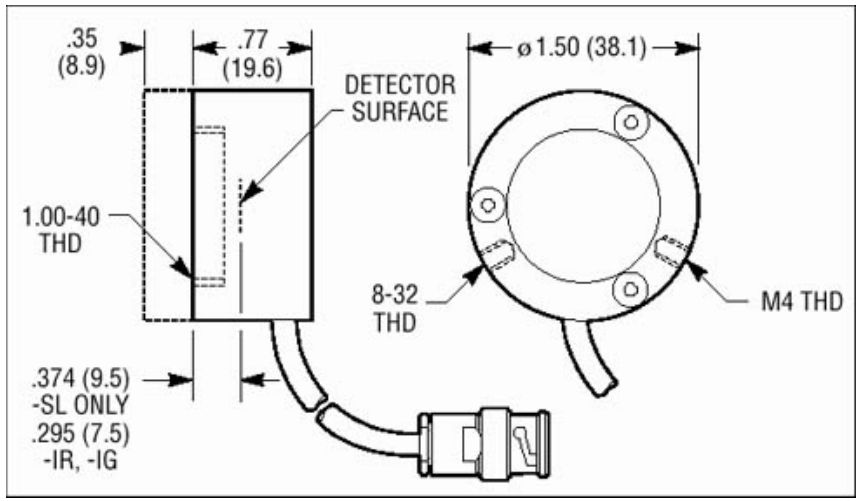
Appendix
Photodiodes

- The photodiodes used are Newport 818-UV and the Newport 818-IR
- The spectral range for the 818-UV is 190-1100nm
- The spectral range for the 818-IR is 700-1800nm



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