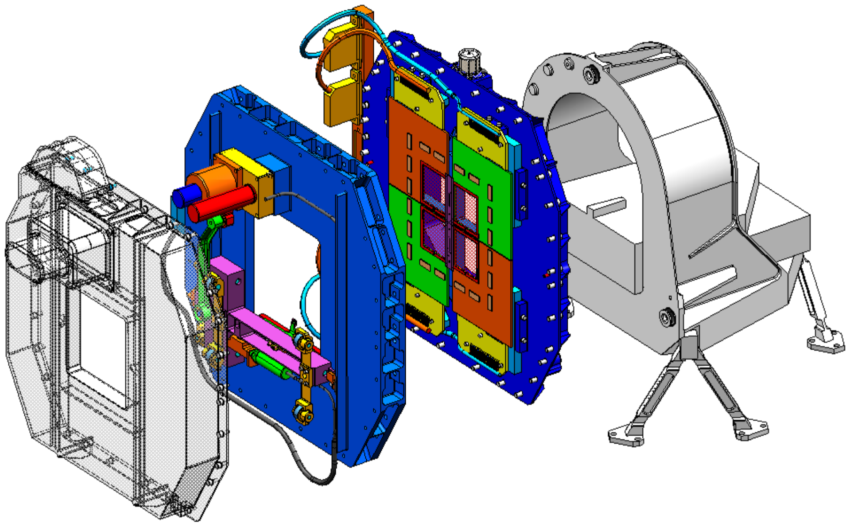
The Microshutter Array System:

Providing a Multi-Object Capability for the NIRSpec on JWST



ELIXIR Summer School

Astrium - Ottobrunn

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Microshutter PI
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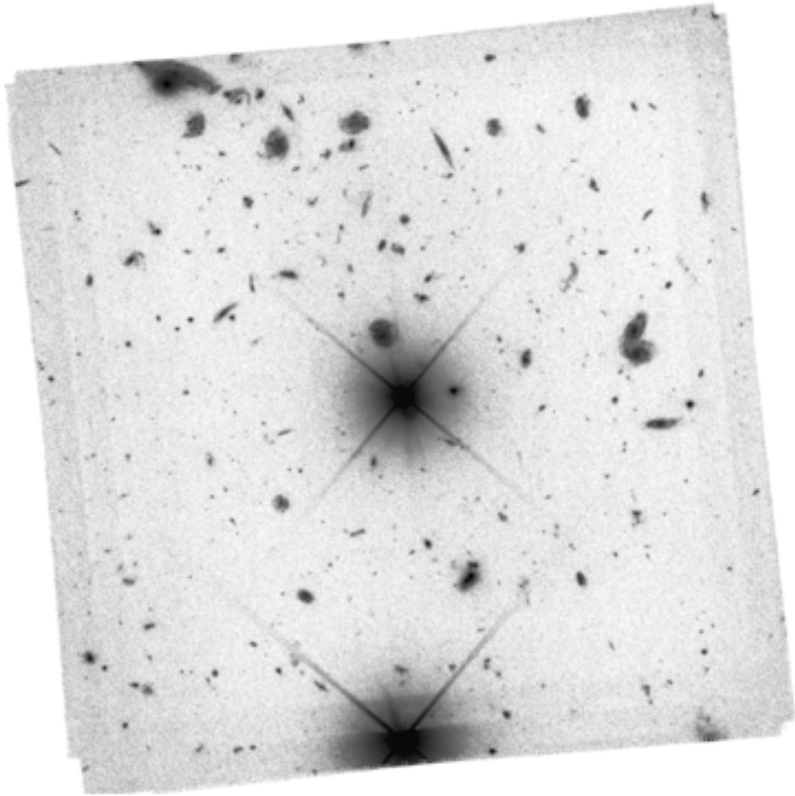
Ancient History

- In 1996, Ed Weiler, then head of Astrophysics at NASA HQ, asked John Mather to initiate a study of a large telescope to be the successor Hubble.
  - HQ had solicited mission concept proposals that year, and no one had proposed to study a Hubble successor, so Weiler took it into his own hands.
  - John initiated some engineering studies, and organized the Ad Hoc Science Working Group (AHSWG), a group of scientists whose task was to develop a vision of what this Next Generation Space Telescope should be.
- After a couple of years of science and engineering studies, the AHSWG produced a document that largely set the direction for the observatory.
- The Near Infrared Spectrometer study set priorities on the characteristics of a the instrument needed for the high priority science identified by the team.

What Was Known about the High-z Universe?

- HDF had been obtained, and it was clear that a sensitive near IR telescope could probe deeply into the early universe
- A high sensitivity spectrometer was required to quantify the evolution of the early universe
  - Redshifts, Abundances, and Kinematics



STIS HDF-S image showing AB=30 galaxies

Derived Instrument Requirements

- *The requirements of a Near Infrared Spectrometer that could carry out the science reference missions set by the AHSWG were derived. They are:*
  - *R=100 spatially-integrated spectroscopy at maximum sensitivity with multiplexing performance secondary.*
  - *R=1000 spatially-integrated spectroscopy of multiple objects distributed over arcminute regions of sky with multiplexing performance paramount up to the expected number density of targets.*
  - *R=3000-5000 spatially-resolved 2-d spectroscopy at the diffraction limit of NGST of individual objects extended on the scales of a few arcsec.*
  - *R=1000 spatially resolved spectroscopy and R=3000-5000 spatially integrated spectroscopy.*

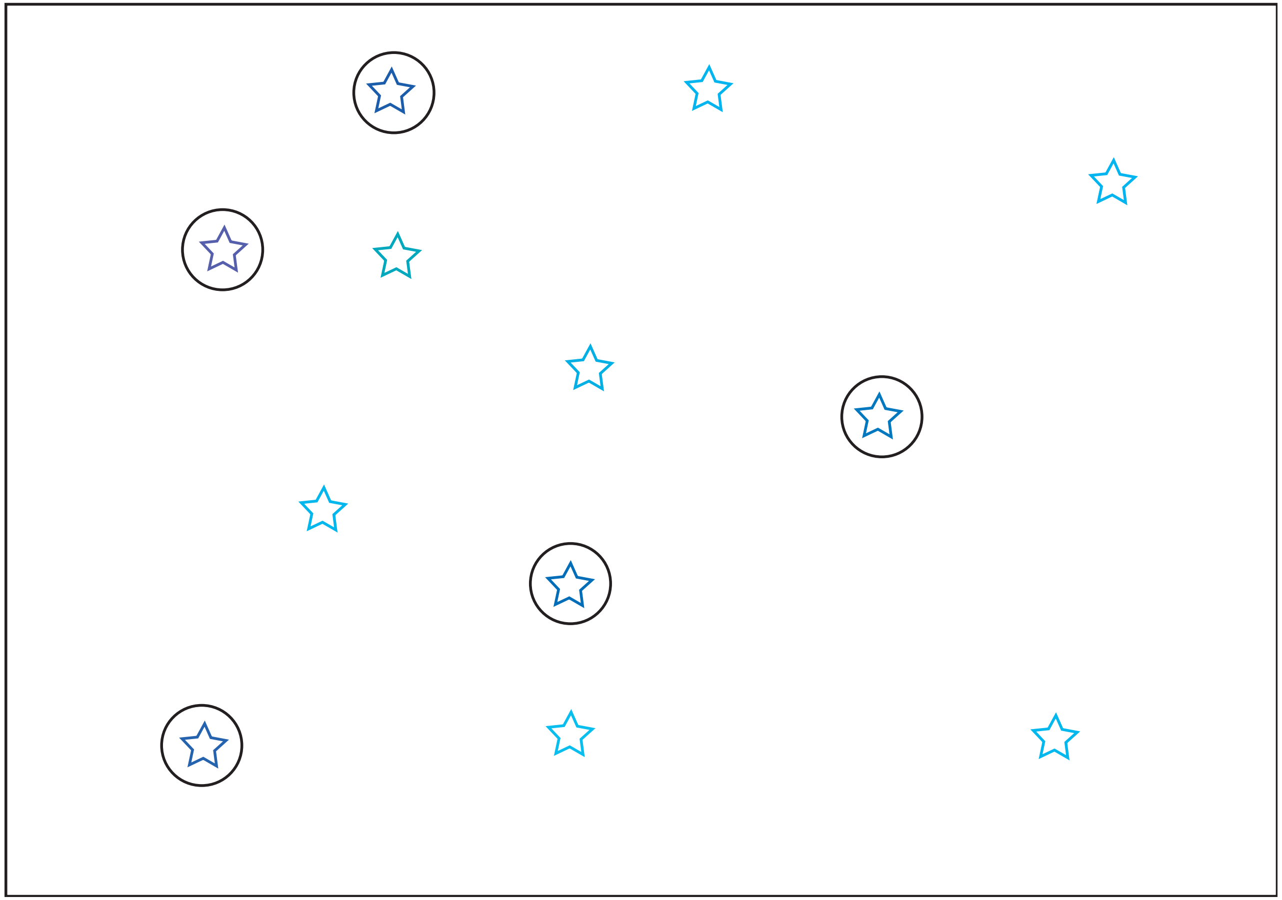
The Prime Directives

1. Ultimate point source sensitivity at R~100-1000. This implies modest undersampling of the PSF.
2. For R ~ 1000 and less, the need to cover the entire 1-5µm range for most objects although not necessarily simultaneously. For higher resolutions, a subset of the range is likely to be all that is required for a given object.
3. Ability to acquire multiple spectra at especially R~1000. DRM 7 drives this need most strongly. Acquiring spectra of adequate numbers of rare objects such as high-z AGN also drives the need for a large accessible field.
4. Resolutions of 3000 and higher are important but are most important at wavelengths longer than 2.5 microns where there is no competition from the ground. There is no need for multiple object spectroscopy at these resolutions.
5. At R~100-1000, spatial resolution is not as important as sensitivity while at R~3000 and greater, spatial resolution is important although the trade between full Nyquist sampling and somewhat lesser resolution needs to be made carefully.

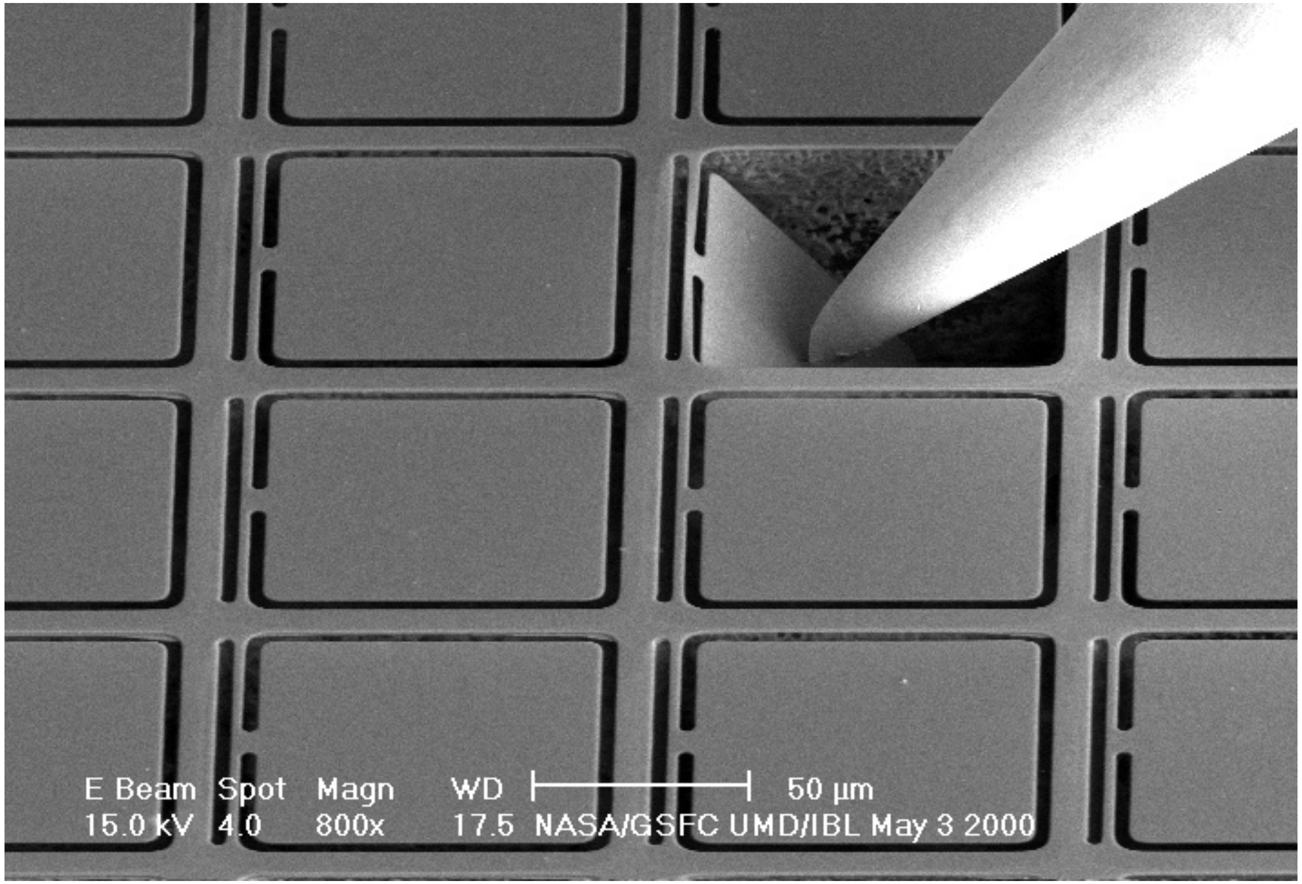
The Contenders

Parameter	IFTS	Integral Field	MOS/MMA	MOS/slits
Point source sensitivity	Poor	Excellent	Excellent	Excellent
Mapping speed	Excellent	Good	Good	Good
Areal coverage	Excellent	Good	Excellent	Excellent
Chance of Serendipity	Excellent	Excellent	Poor-Good	Poor-Good
Throughput	Good	Good	Good	Good
Volume/mass	Poor	Good	Poor	Poor-Good
Operational Risk	Medium -- needs a mechanism	Low -- may not require any mechanisms	Low- Medium -- may require a mechanism	Low- Medium -- may require mechanisms
Operational Complexity	Medium -- low accuracy on pointing but high data volume	Low	High -- requires autonomous positioning of slits	High -- requires autonomous positioning of slits, mechanical slits most complex
Spectral Resolution	Broad range and easily changed	Fixed by design	Can be changed with grating selector	Can be changed with grating selector

Drilled Plate MOS



Shutter and Hinge are Basis for Microshutter Array Design



Why Microshutters?

- High contrast
- High open efficiency
- No phase errors between open cells

Actuation Concept

- Large displacement actuation done magnetically
  – Requires magnet scan mechanism

- Electrostatic Latching and Addressing
  – Crosspoint addressing requires no on-chip active electronics

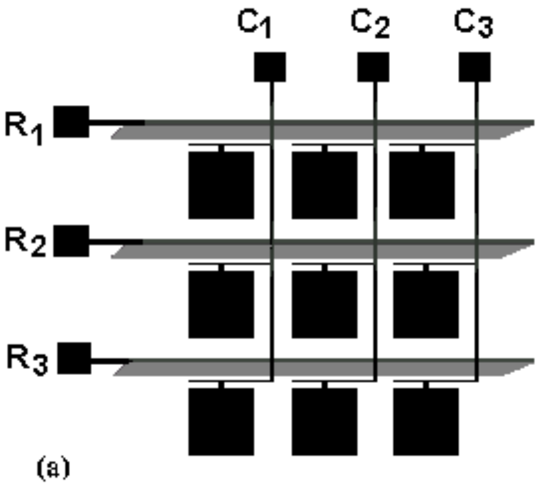
Required Functions

- Shutter Operation
  - Magnetic actuation
    - Magnet, magnet coatings
    - Transport Stage
  - Electrostatic hold
    - Addressing electronics, vertical electrodes
- Optical performance demonstration
  - "On" transmission
  - "Off" transmission

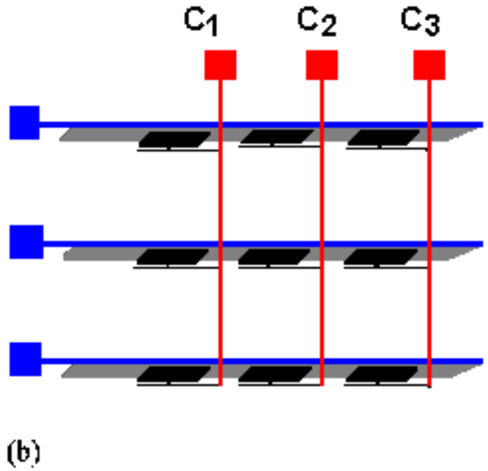
Principle of Operation

Release by Grounding Row

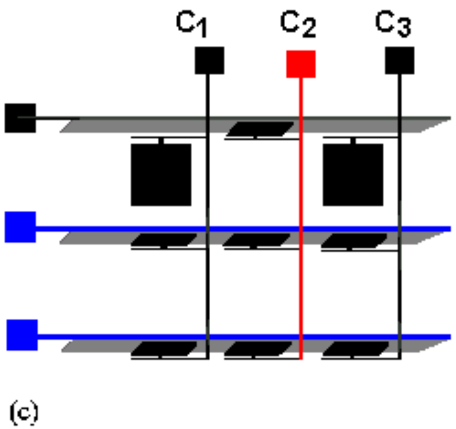
AND Column Addresses



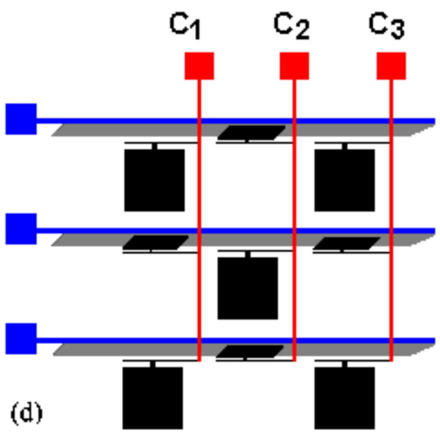
All Closed



Actuate and Latch All

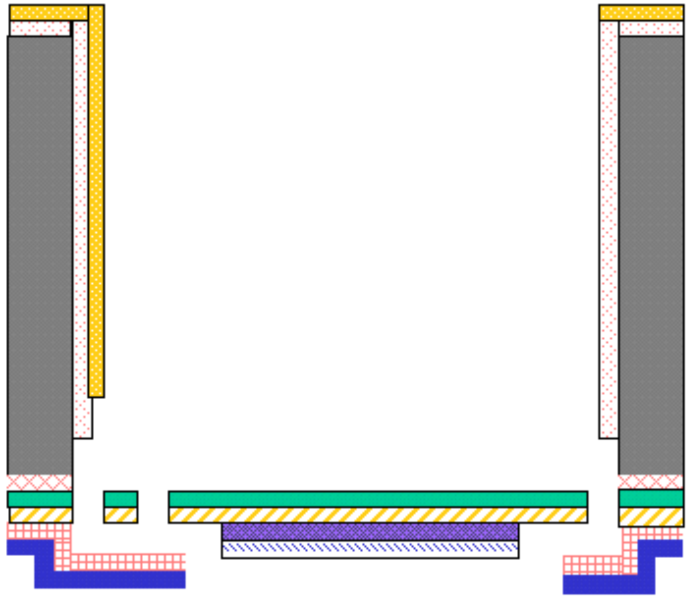


Release Selected Row 1



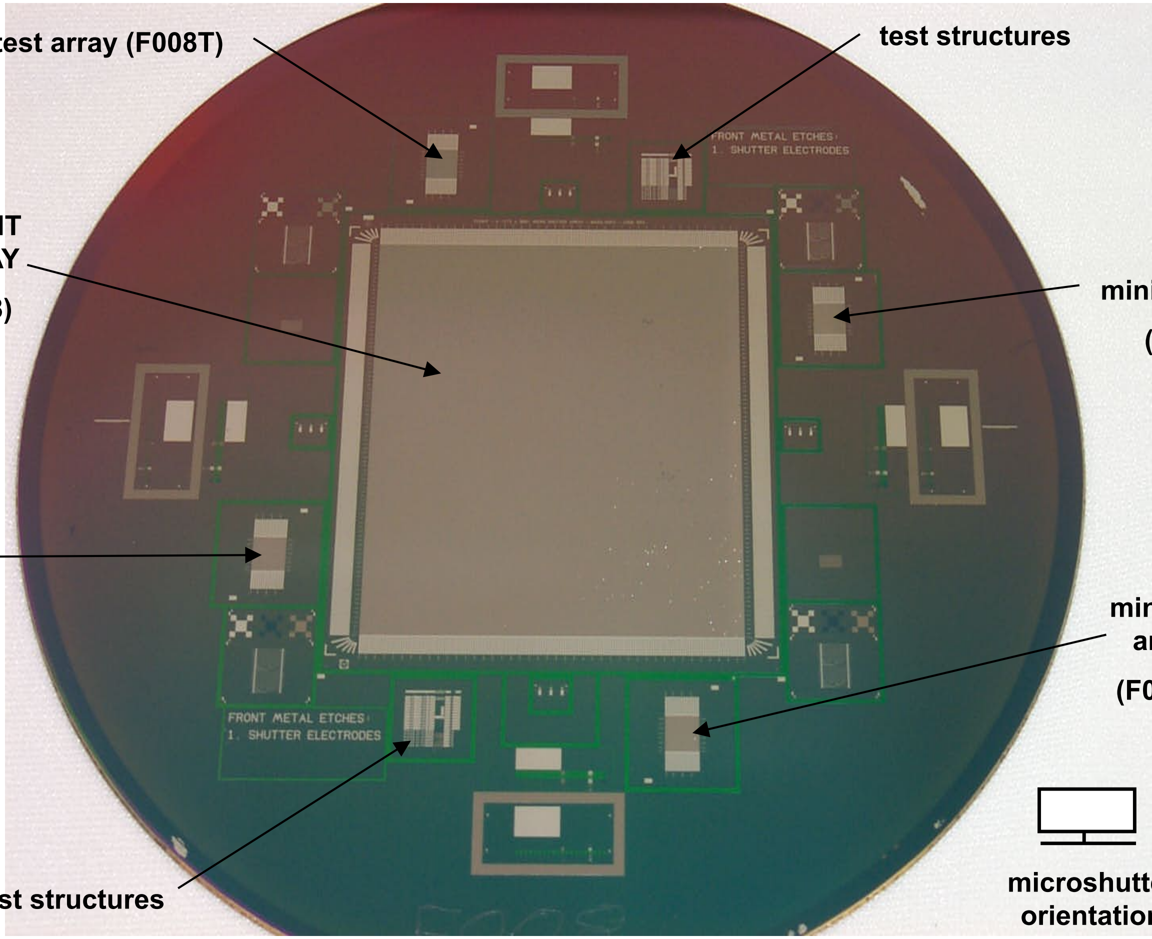
Hold Configuration

Cross Section of Unit Cell



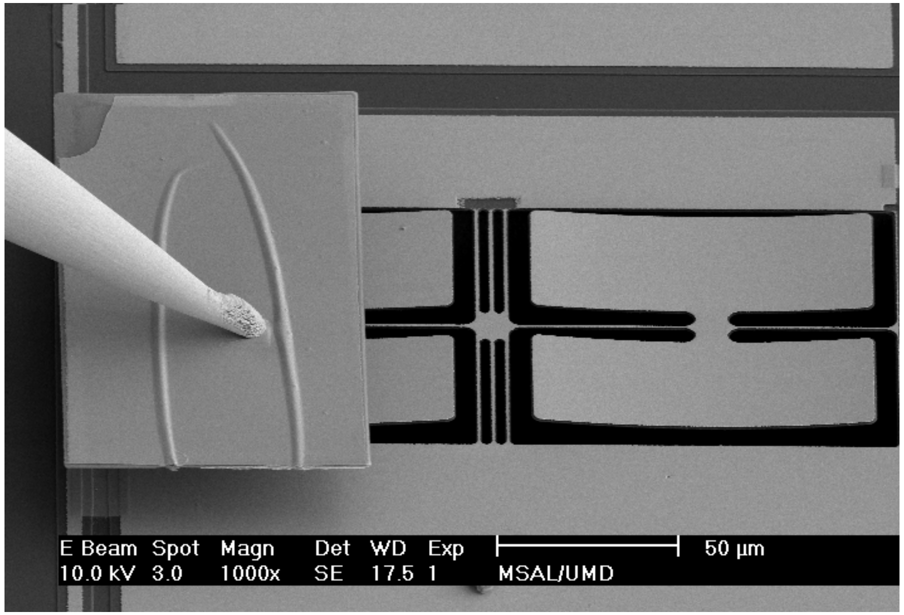
- Light Shield: Aluminum
- Support Grid: Silicon
- Etch Stop: Silicon Dioxide
- Interconnect/Shutter Electrode: Gold
- Light Shield Insulator: Silicon Dioxide
- Magnetic Pad: CoFe
- Shutter Mechanical Layer: Silicon Nitride
- Vertical Electrode: Gold
- Vertical Electrode Insulator: Aluminum Oxide
- Magnetic Pad Passivation: Aluminum

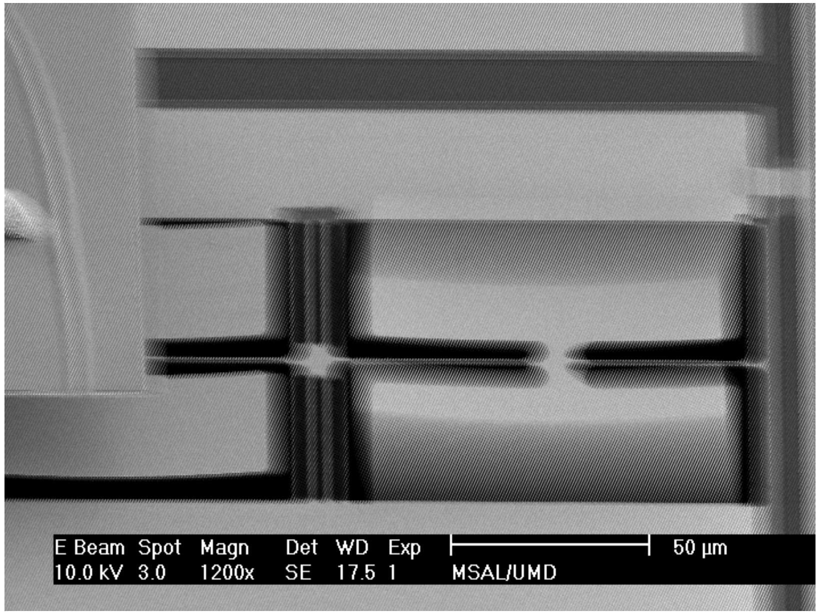
Flight Wafer Layout



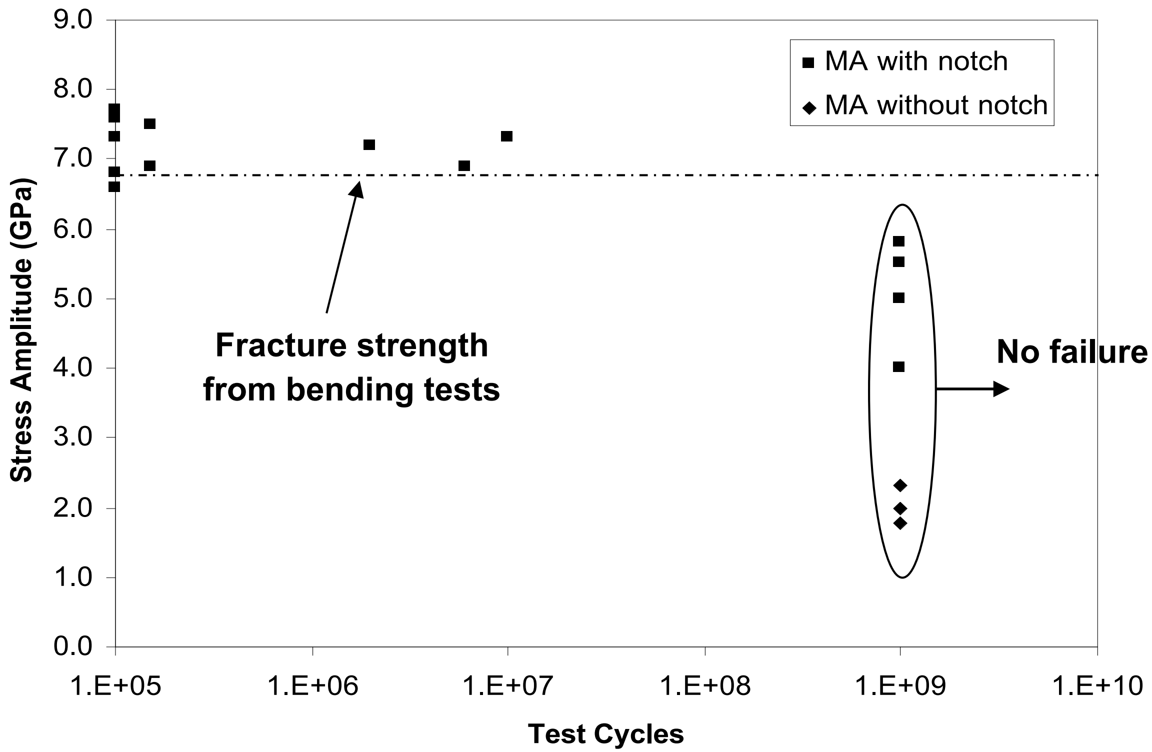
Note location of Mini Test Arrays in relation to FLIGHT ARRAY.

- **A Testing Mechanical-Amplifier Device**



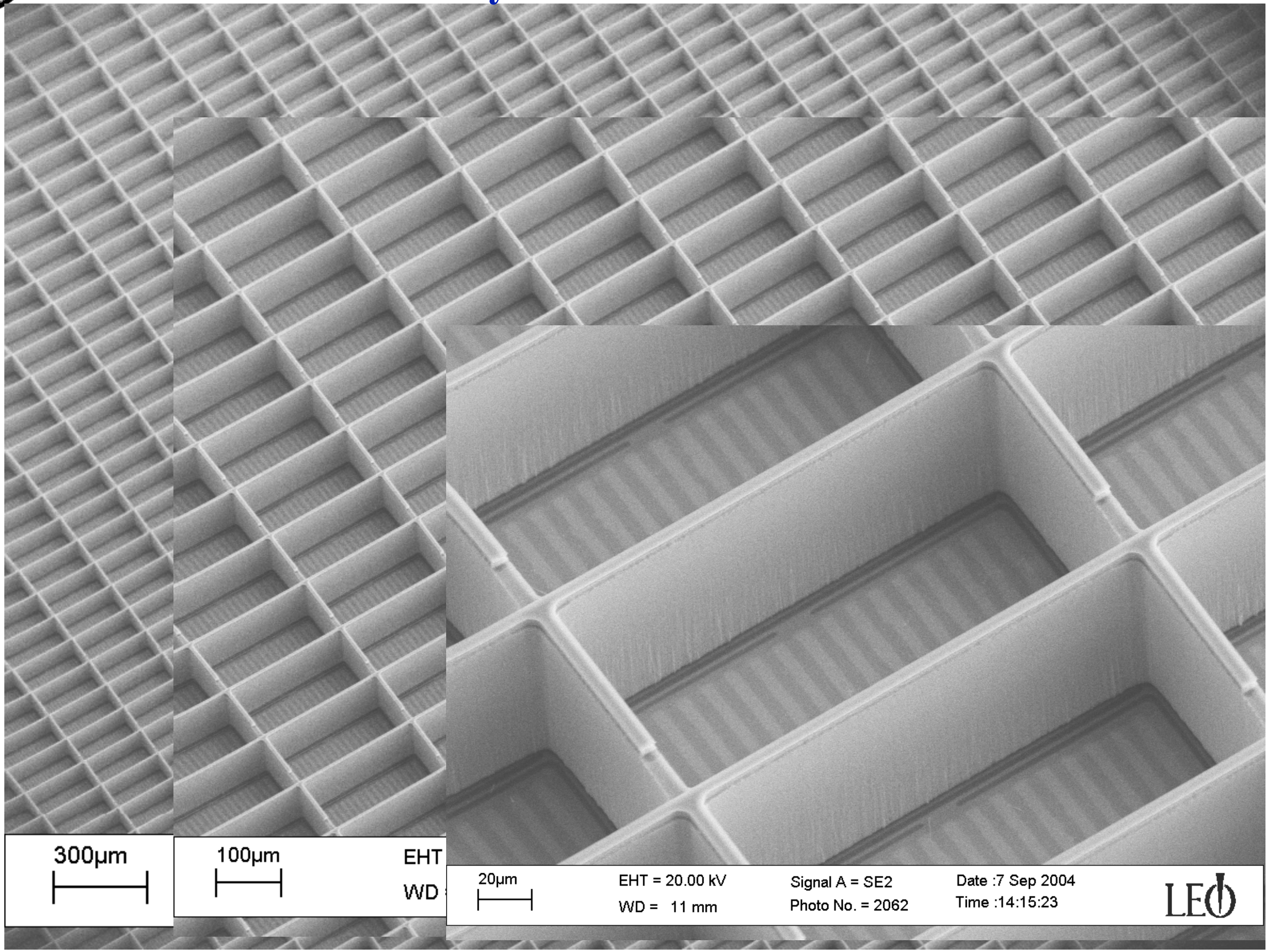


- **Test Results of Silicon Nitride Thin Films at Room Temperature**

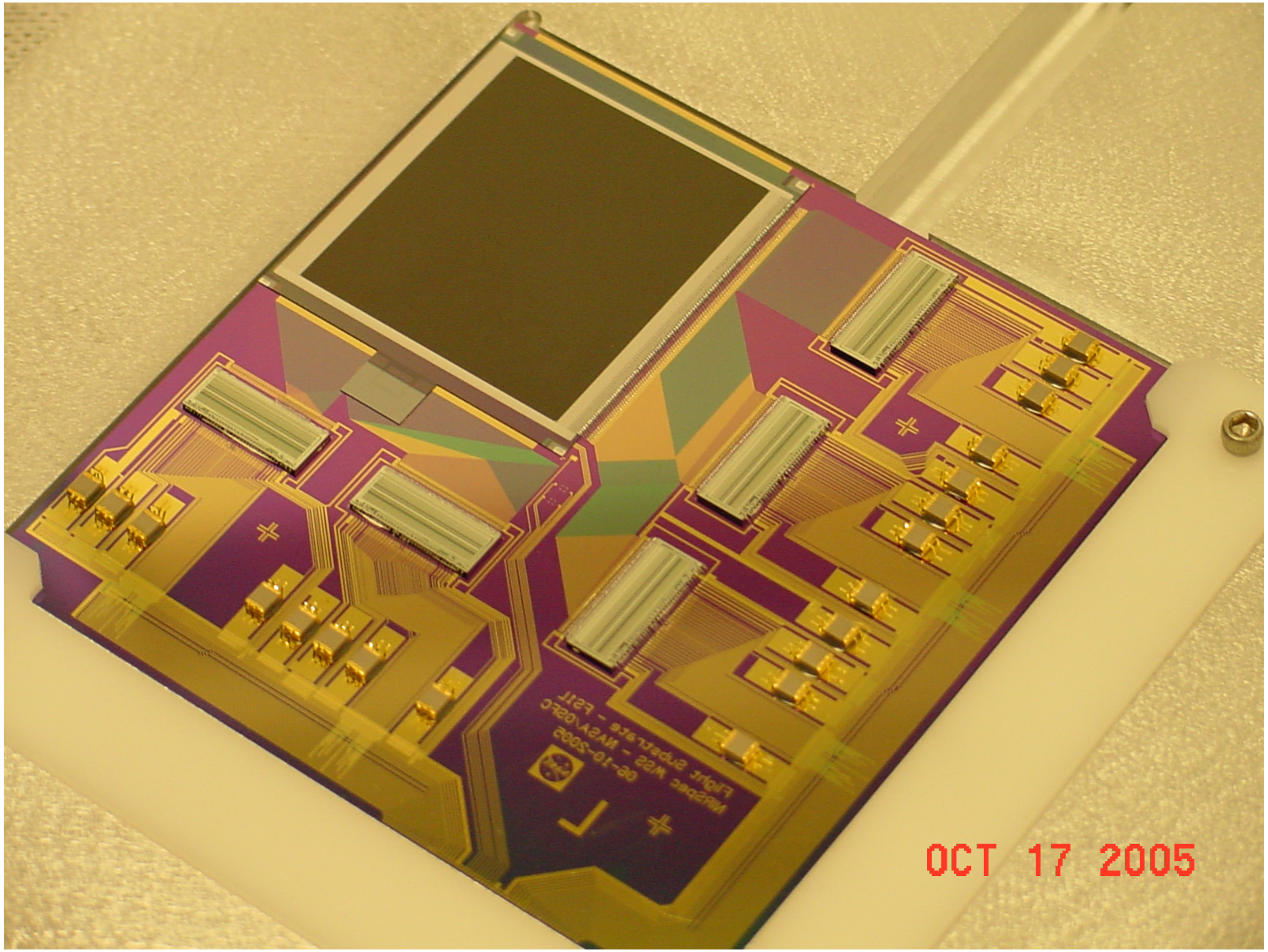


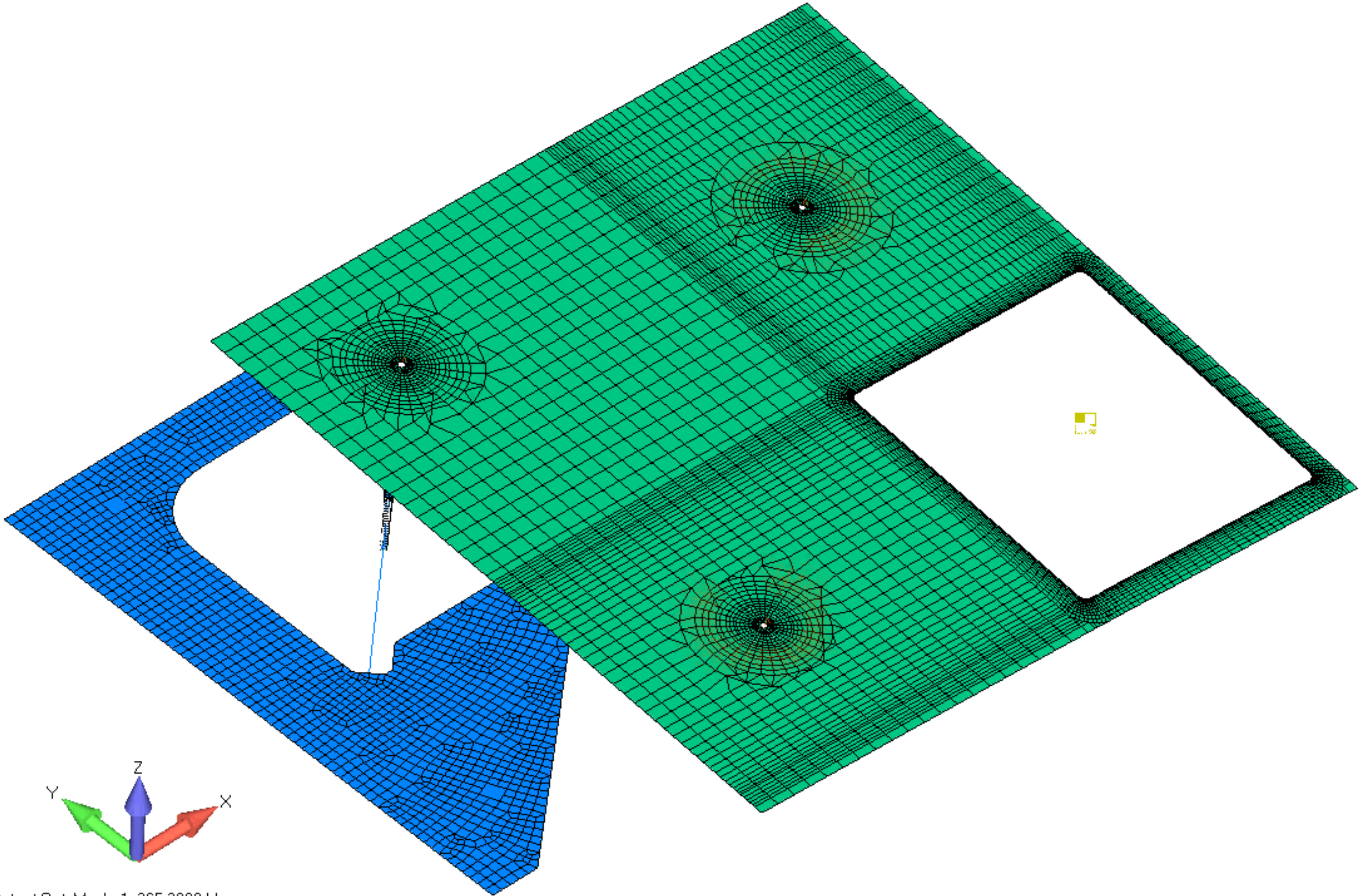
Stress-life testing data for silicon nitride thin films

Continuation of 175x384 Array Fabrication



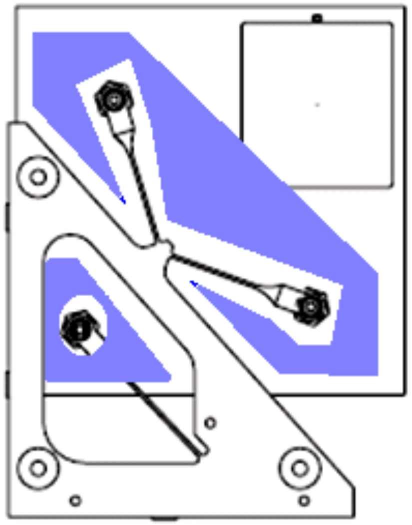
First fully populated substrate with array 015



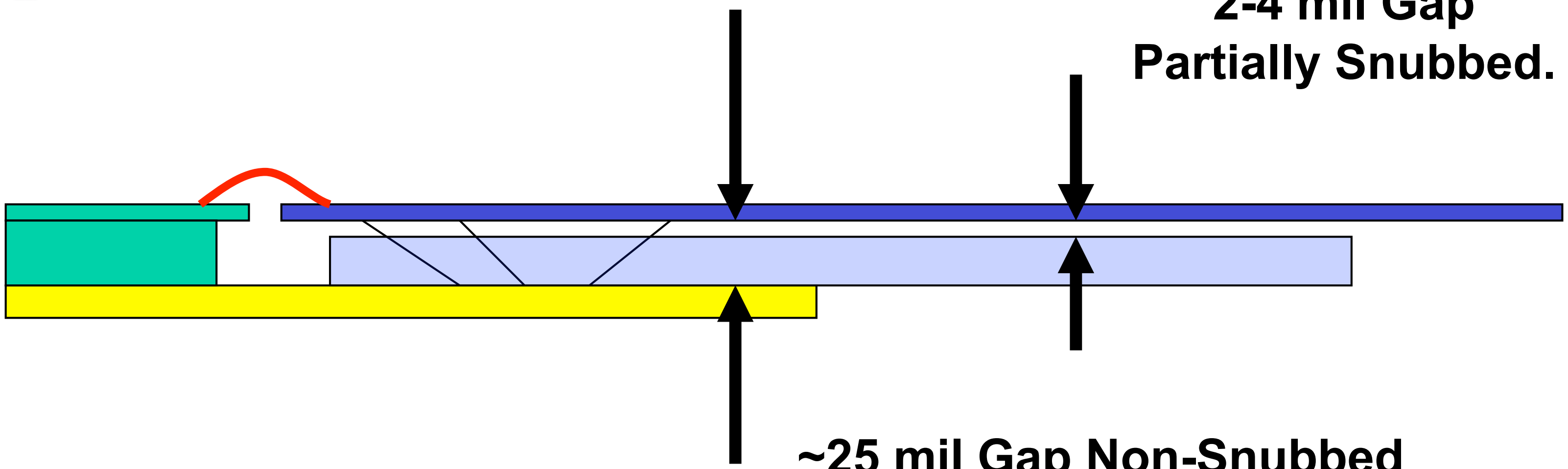


Output Set: Mode 1, 365.3099 Hz
Animate(18.43): Total Translation

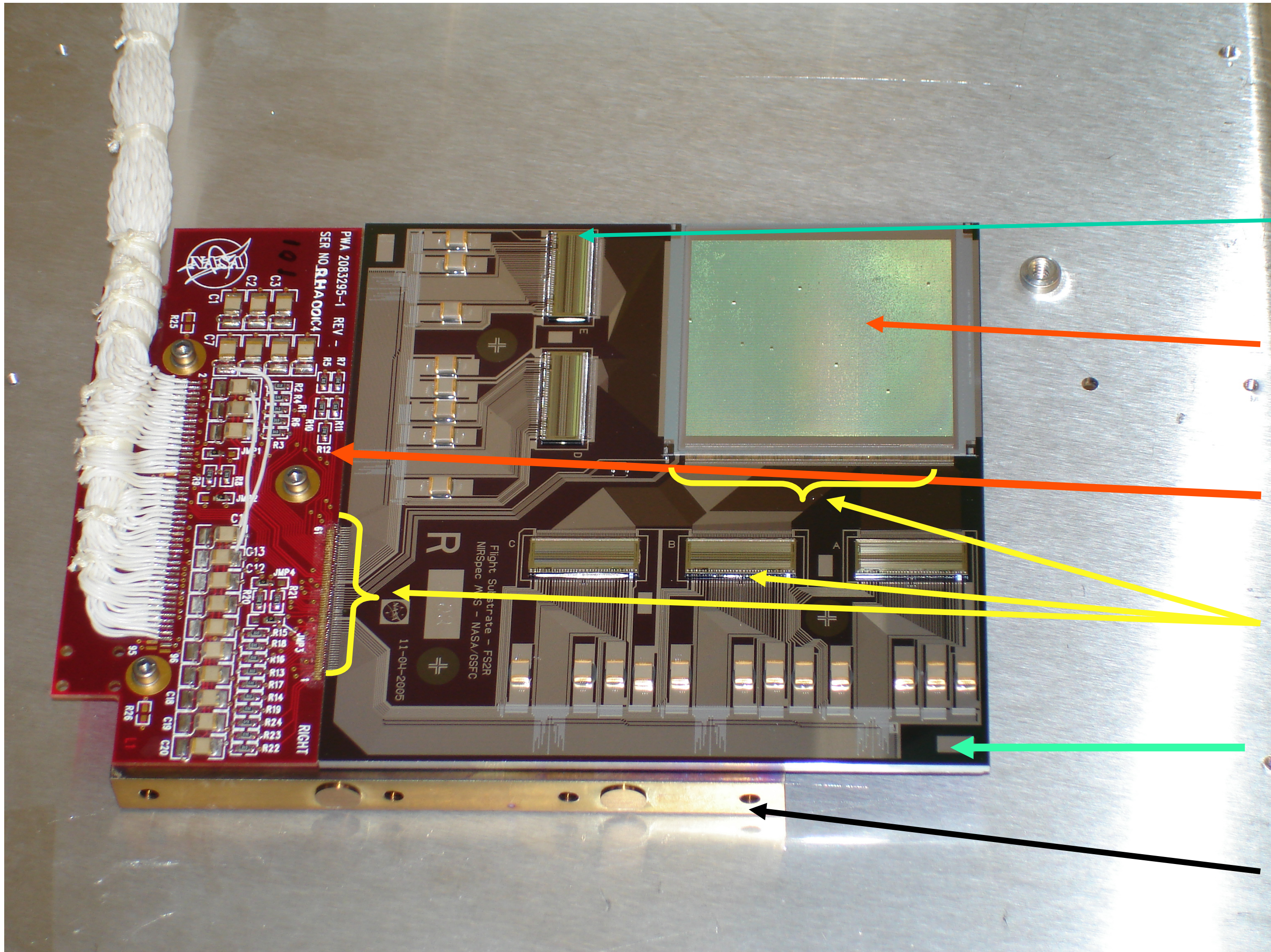
Snubber



- Wire bond failure on substrate side for all failures.
  - Tests demonstrate a passing value for shock in 3-axis with a partially snubbed configuration, spacing up to 2 mils.
  - Tests confirm failure under two test configurations in the Z-axis, with a partially snubbed configuration, spacing 4 mils.
- 4 mil Physical Limit: Worst Case Scenario



Substrate and Daughter Board Mounted on Flex Plate



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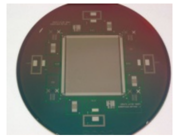
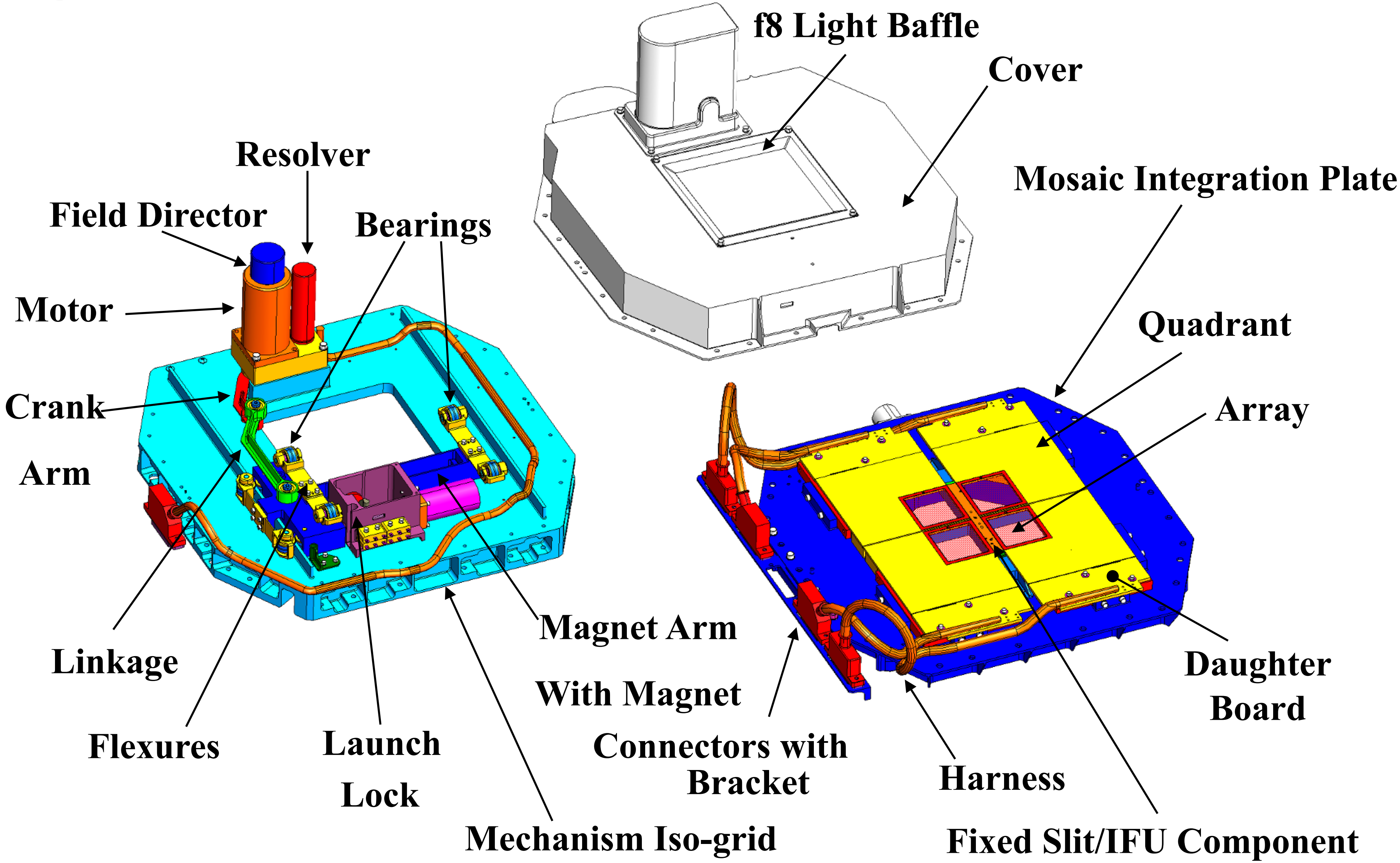
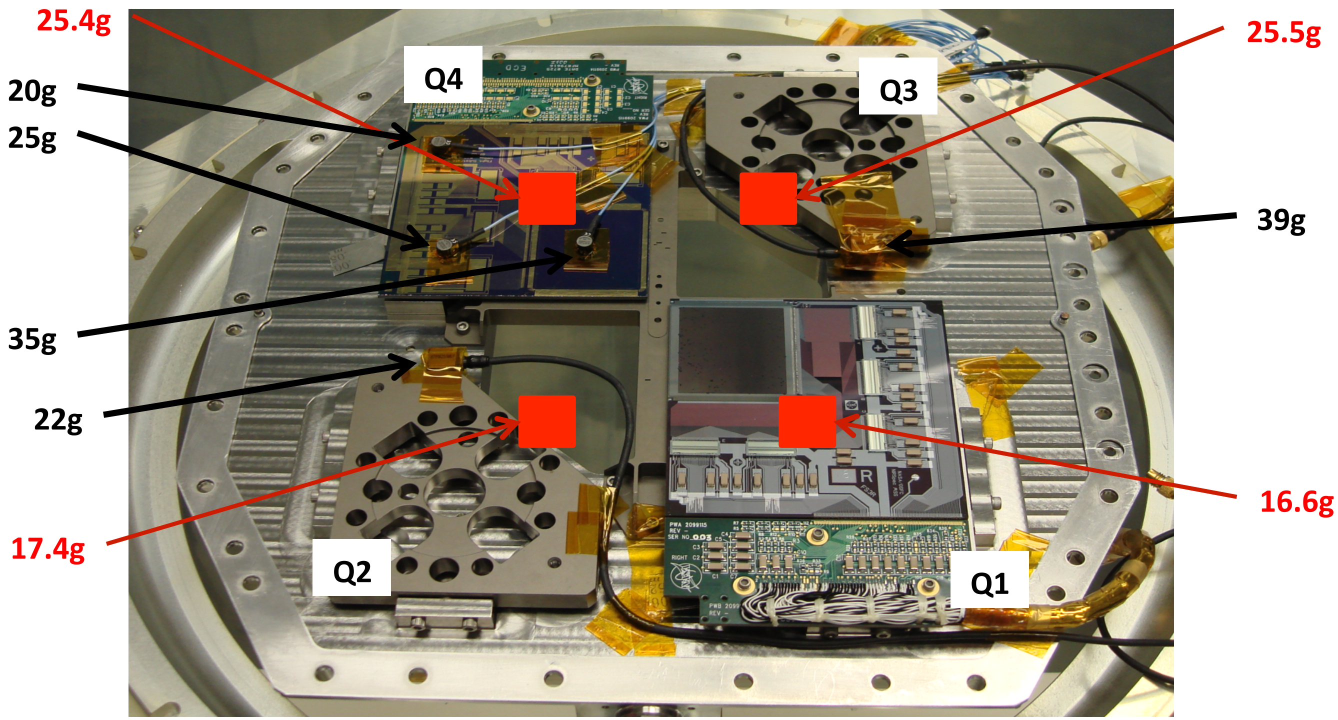


Transport Mechanism Layers



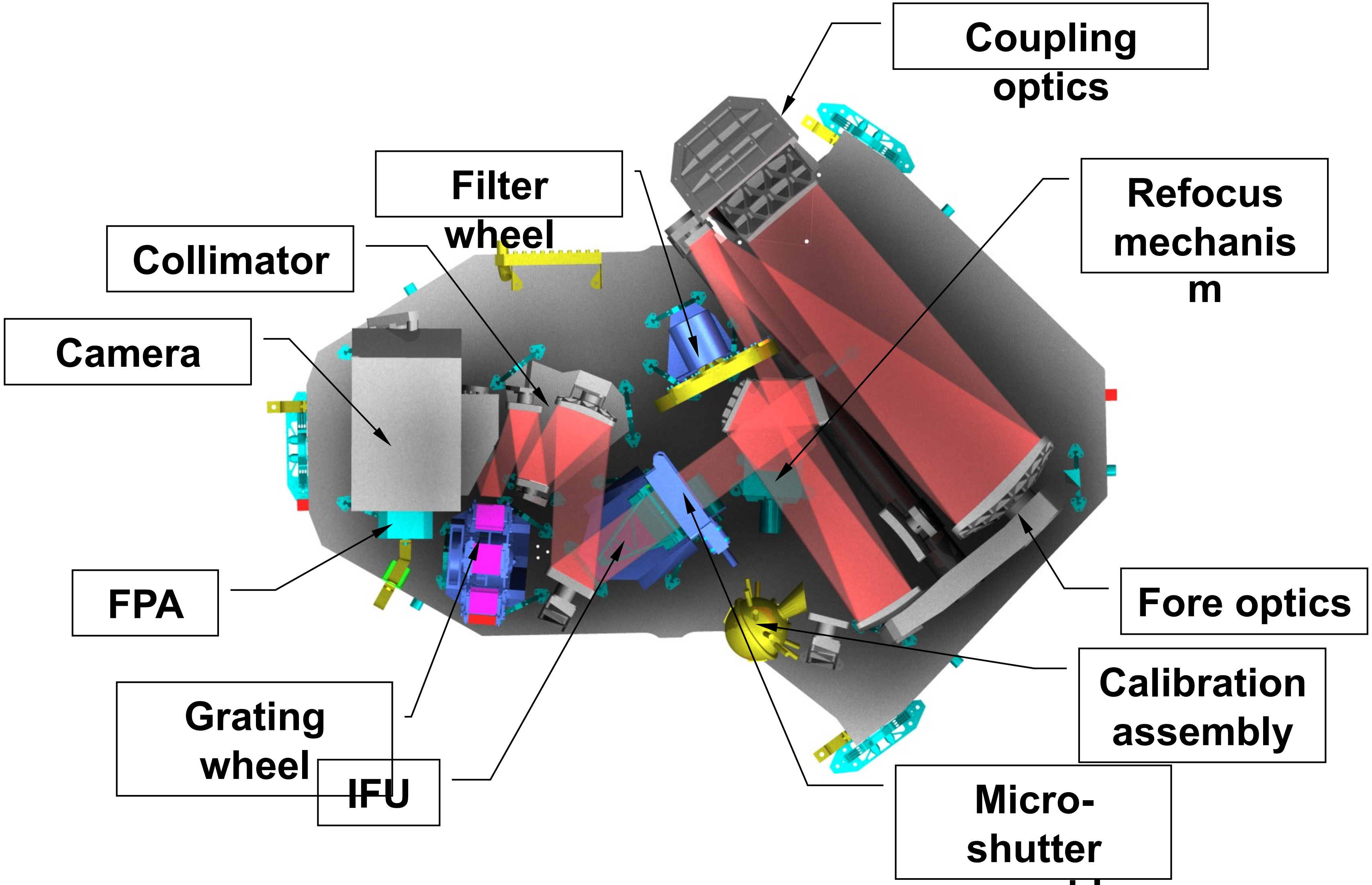
Vibration Test Data Showed Responses That Varied by Quadrant



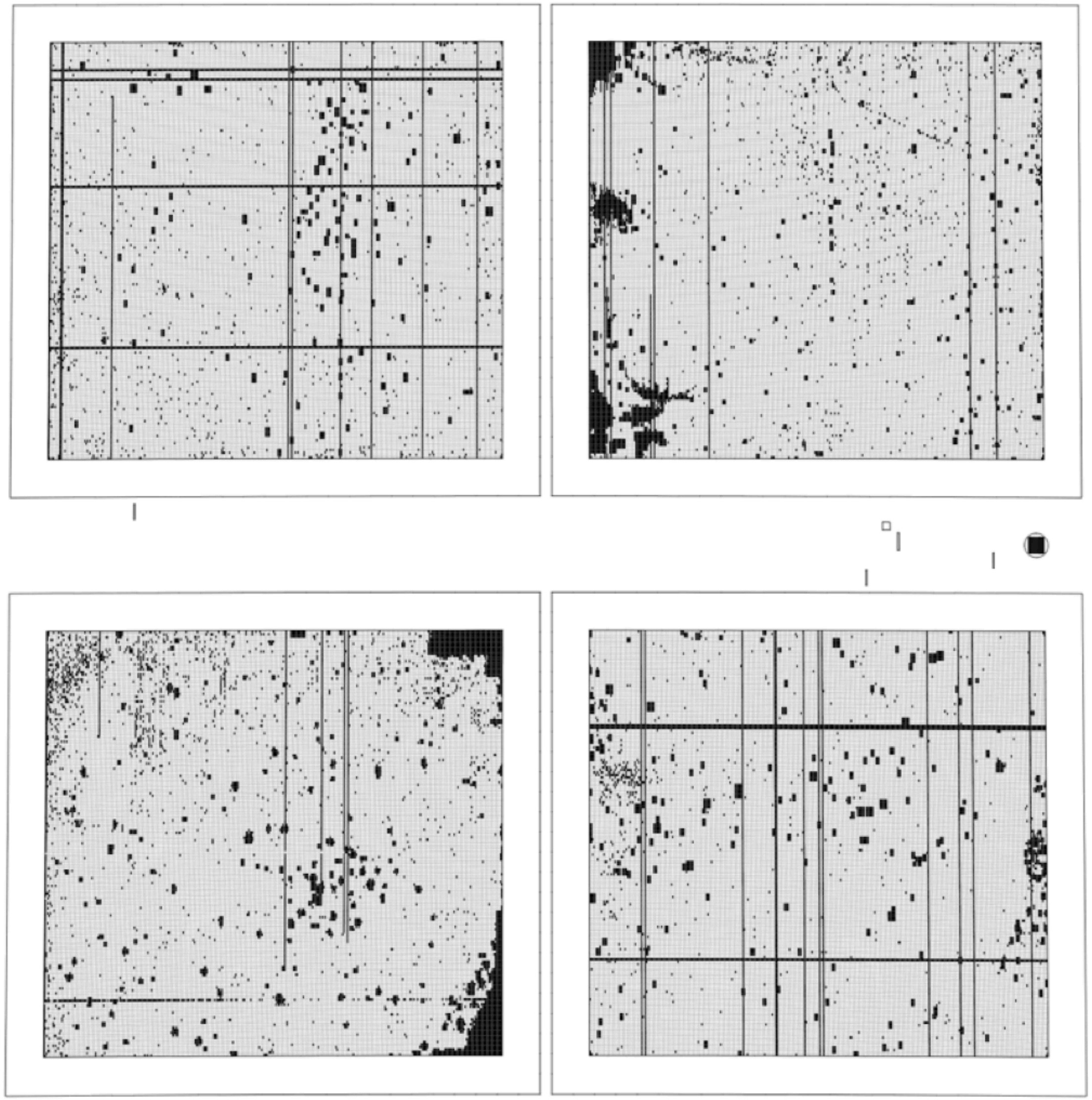
Accels shown in the picture correspond to the location of the accels during quadrant qual testing.

"Accels" drawn on the picture (red boxes) correspond to location of the accels for SM testing

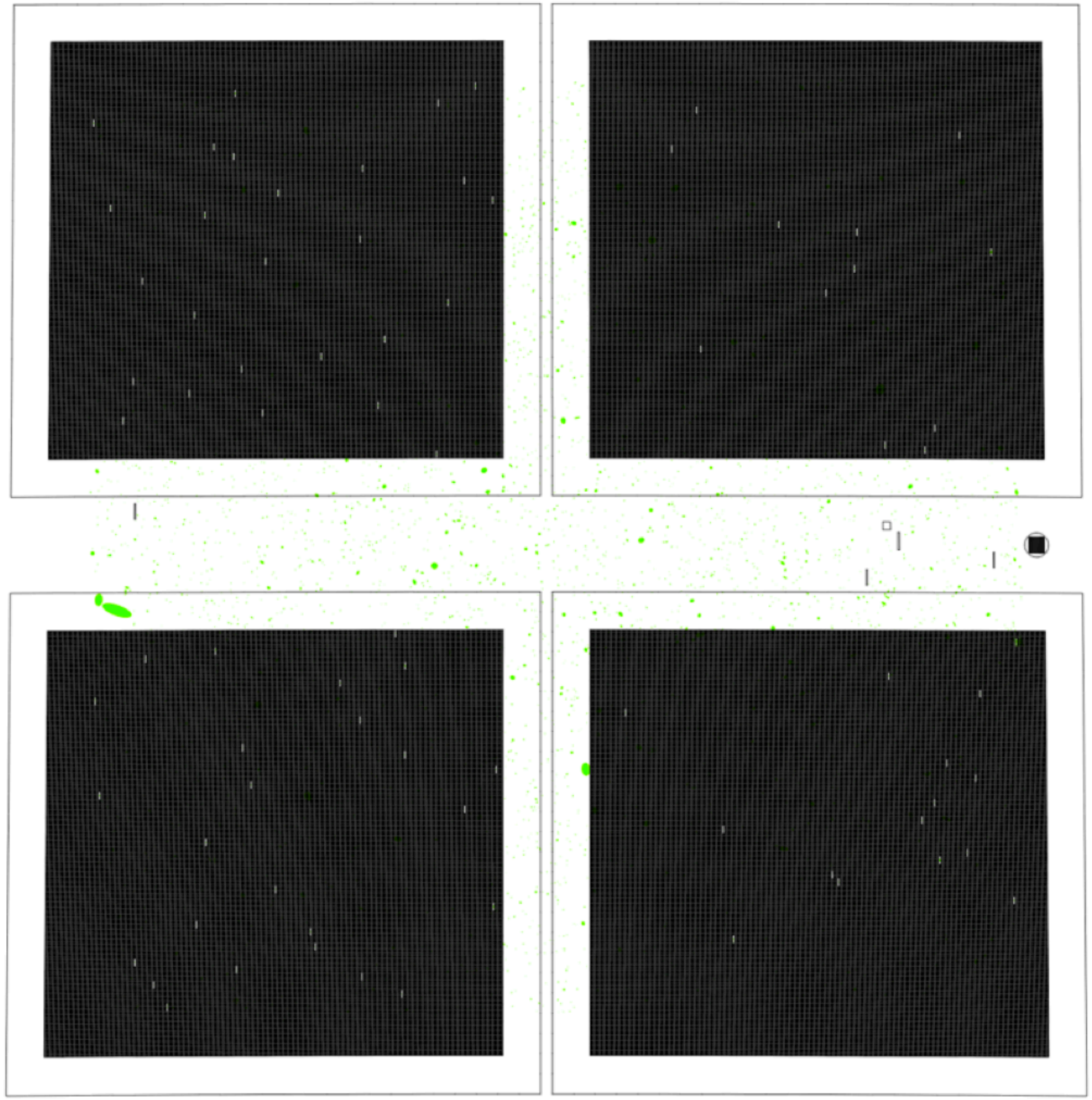
NIRSpec Instrument Layout



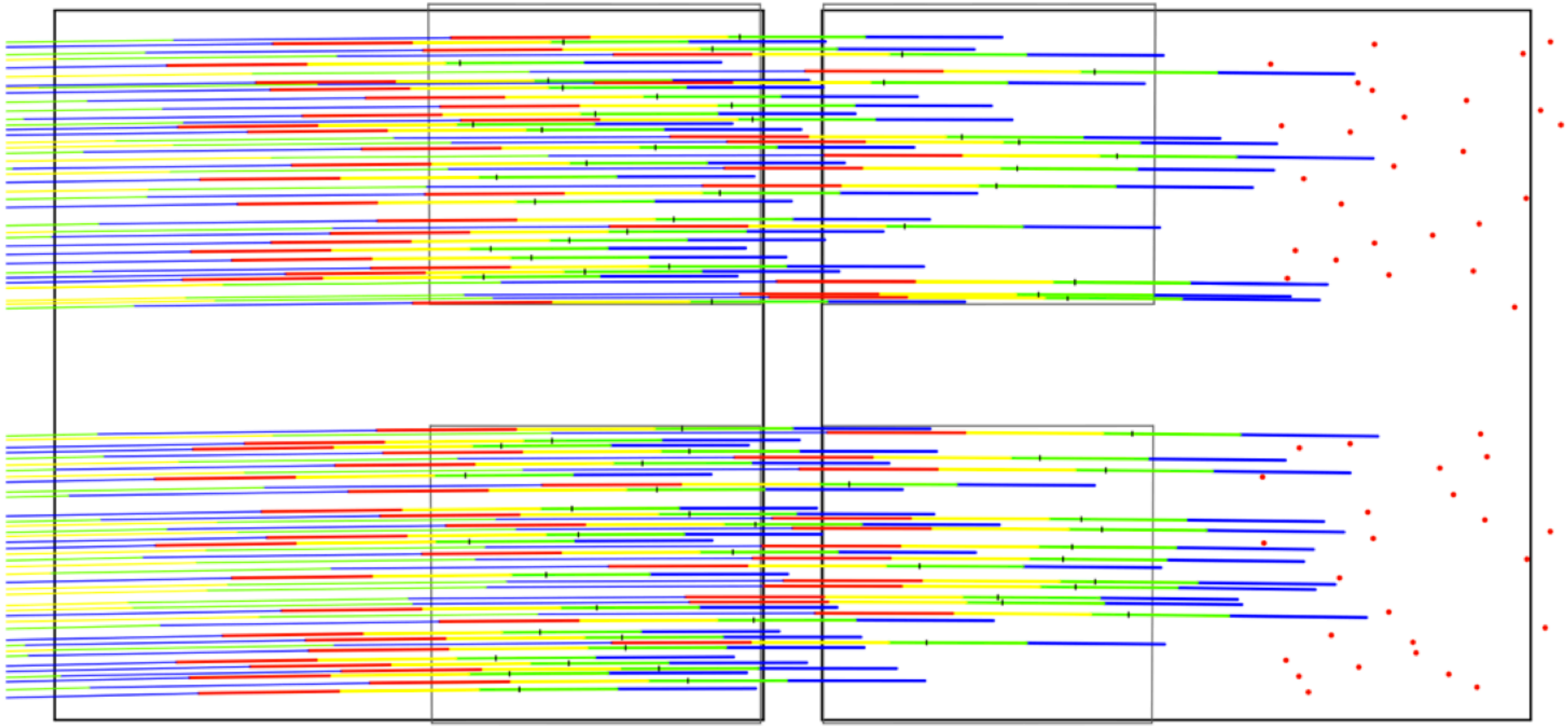
MSA Opens



Observing Configuration



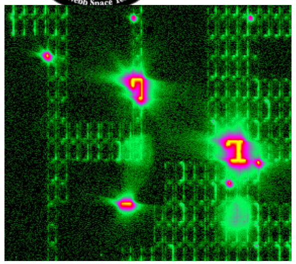
Lots of Spectra

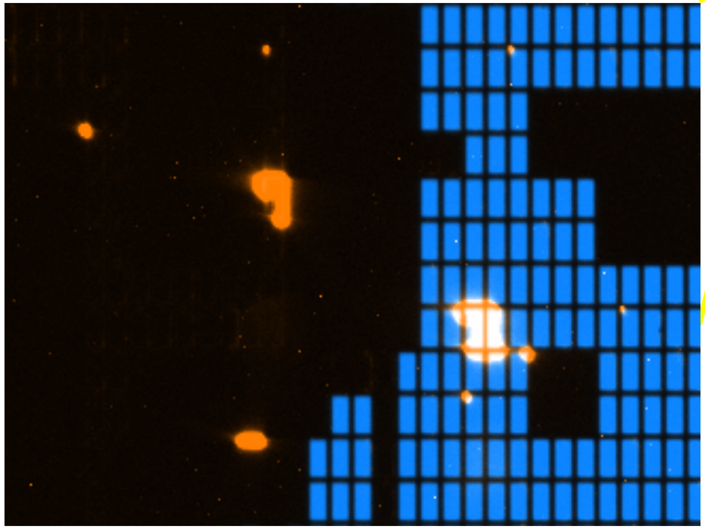


Failed Opens
Light Shield Leakage

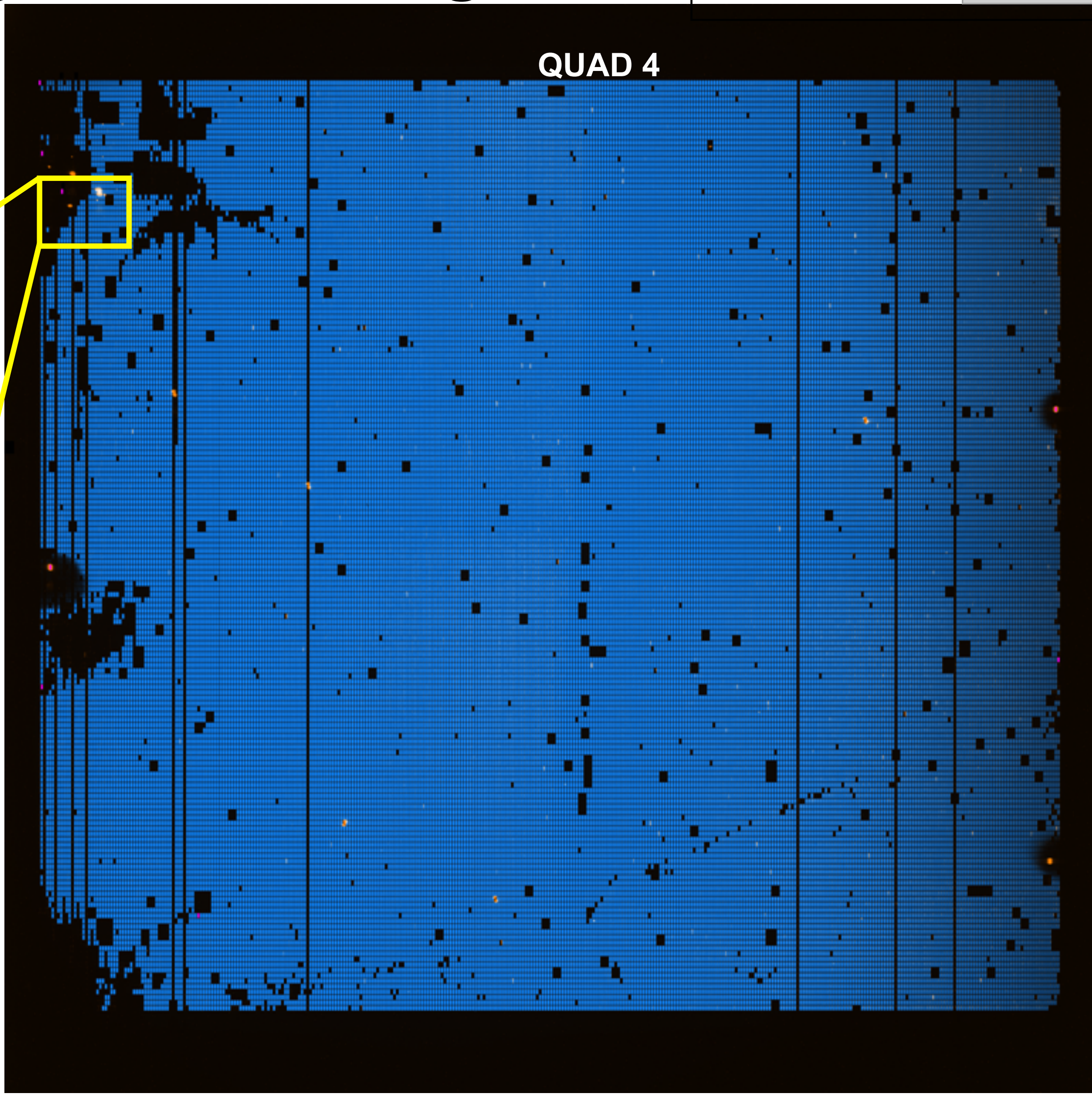
Failure Count

Dec.			Apr.	
0	0	→	0	0
0	8		0	8





- Very Low Contrast (<500)
- Localized to 14 shutters on 8 rows within enlarged area
- Masked during contrast test & escaped 2nd plugging
- Unchanged since last array test prior to MSA integration



Q4: Blue for Open Shutters. Black for Failed Closed Shutters. Orange & White for light leaks.

Quad History Summary

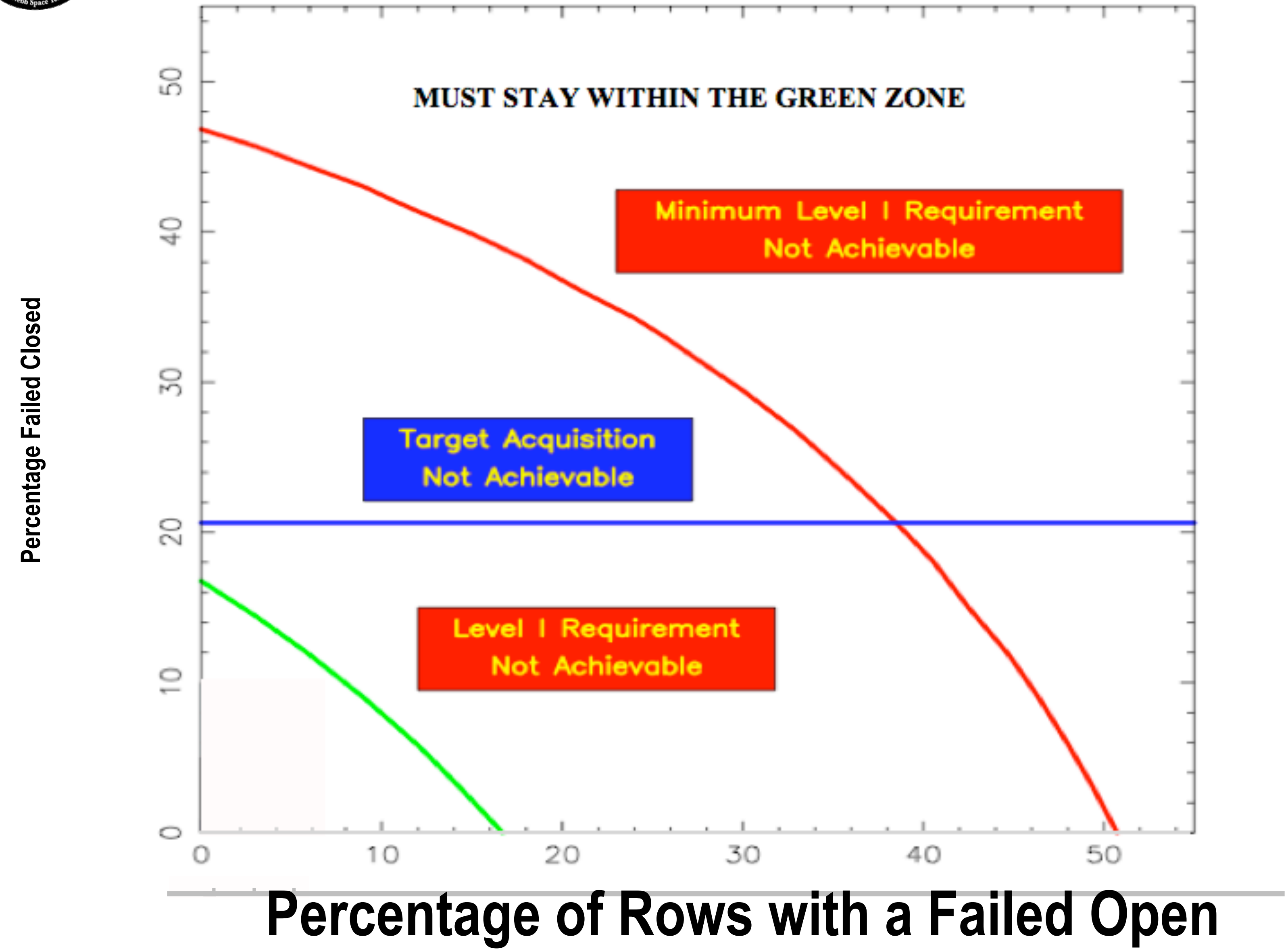
Quad ID	Q1-52-102	Q2-42-128	Q3-26-106	Q4-55-116
Intermittent	0	1	5	3
Contrast < 500	0	1	0	9
500 < Contrast < 2K	0	1	0	5
Total F/O	0	3	5	17
# of F/O Columns Int. & Contrast	0	3	5	15
# of F/O Columns Contrast < 2000	0	2	0	12
# of F/O Columns Contrast < 500	0	1	0	8

Total F/C	6274	6,103	11,519	5,399

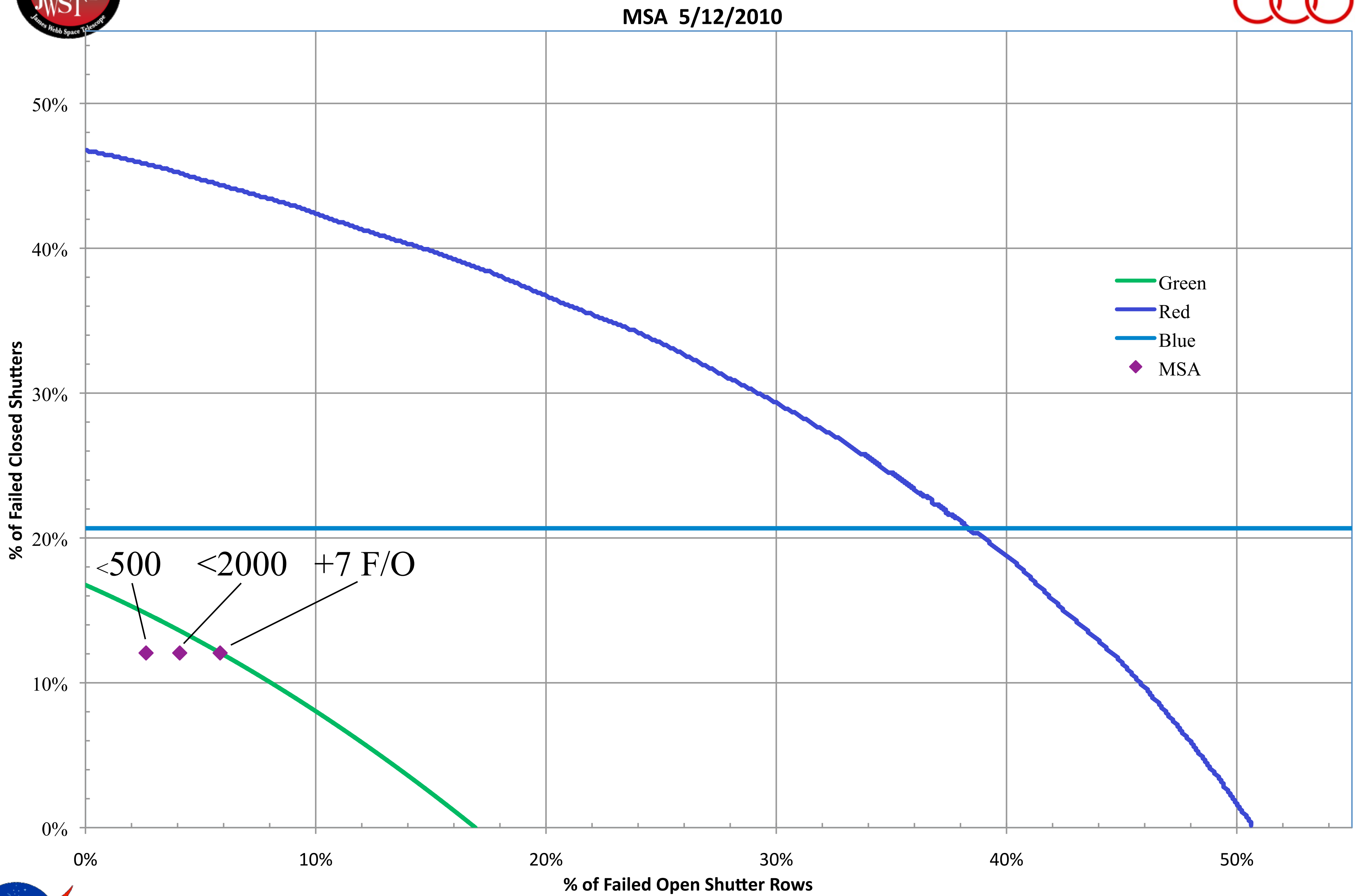
Avg. Visible Contrast	42,458	78,000	120,000	71,000
H Band IR	13,439	13,000	16,600	7,627

All Values in blue are from Quad Testing Lab

The Jakobsen Chart



Failed Open-Failed Closed Requirements



The Present

- **Flight Unit is assembled and is in performance testing**
- **Delivery of the system to Astrium is in the near future – JWST project says it come on June 17, no matter what.**
- **The most frightening part of the project is ahead – waiting for 5 years with only limited test opportunities**
- **If we can maintain the present performance during this time, NIRSpec, with its microshutters, will be a remarkable and unprecedented tool for science.**

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