The Band 1 pixel design exhibits the best performance across the 4 PV3 SCAs tested in the DCL and exceeds the milestone requirements by a significant margin.

- Other bands (3, 4) also show good performance; preliminary recommendation of band 1 folds in yield considerations as well as performance

- PV3 shows significant improvement in persistence (roughly 0.1% after 180sec vs 0.3% for PV2a)
• Detector development plan (reminder)
• PV3 results summary
• Details of PV3 detector array test results
DETECTOR DEVELOPMENT PLAN
Notional Detector Performance Targets

- Detailed flowdown of scientific requirements is in progress, including important simulations using the planned observation strategies.
- Until these detailed requirements are completed, a notional set of performance targets are used.
- Operating temperature is still an open trade, but is expected to be in the 80-100K range for a 2.5um detector cutoff wavelength.

- Dark Current: < 0.05 e-/sec
- CDS Readout Noise: < 20 e- rms
- Total Noise: < 5 e- rms (in 180 sec)
- Quantum Efficiency: > 70%
- Persistence: < 0.01% (after 180 sec)
- Inter-Pixel Crosstalk: < 8% (total)
<table>
<thead>
<tr>
<th>MS #</th>
<th>Milestone</th>
<th>Milestone Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Produce, test, and analyze <strong>2 candidate passivation techniques</strong> (PV1 and PV2) in <strong>banded arrays</strong> to document baseline performance, inter-pixel capacitance, and shall meet the following derived requirements: dark current less than 0.1 e-/pixel/sec, CDS noise less than 20 e-, and QE greater than 60% (over the bandpass of the WFI channel) at nominal operating temperature.</td>
<td>7/31/14</td>
</tr>
<tr>
<td>2</td>
<td>Produce, test, and analyze <strong>1 additional candidate passivation technique</strong> (PV3) in <strong>banded arrays</strong> to document baseline performance, inter-pixel capacitance, and shall meet the following derived requirements: dark current less than 0.1 e-/pixel/sec, CDS noise less than 20 e-, and QE greater than 60% (over the bandpass of the WFI channel) at nominal operating temperature.</td>
<td>12/30/14</td>
</tr>
<tr>
<td>3</td>
<td>Produce, test, and analyze <strong>full arrays with operability &gt; 95%</strong> and shall meet the following derived requirements: dark current less than 0.1 e-/pixel/sec, CDS noise less than 20 e-, QE greater than 60% (over the bandpass of the WFI channel), inter-pixel capacitance ≤3% in nearest-neighbor pixels at nominal operating temperature.</td>
<td>9/15/15</td>
</tr>
<tr>
<td>4</td>
<td>Produce, test, and analyze final selected recipe in <strong>full arrays demonstrating a yield of &gt; 20% with operability &gt; 95%</strong> and shall meet the following derived requirements: dark current less than 0.1 e-/pixel/sec, CDS noise less than 20 e-, QE greater than 60% (over the bandpass of the WFI channel), inter-pixel capacitance ≤3% in nearest-neighbor pixels, persistence less than 0.1% of full well illumination after 150 sec at nominal operating temperature.</td>
<td>9/15/16</td>
</tr>
<tr>
<td>5</td>
<td><strong>Complete environmental testing</strong> (vibration, radiation, thermal cycling) of one SCA sample part, as per NASA test standards.</td>
<td>12/1/16</td>
</tr>
</tbody>
</table>
PV3 RESULTS SUMMARY
Bands were evaluated to be either
- Green (good)
- Orange (fair)
- Red (poor)

A combined map was made
- Showing worst color of all tests
- Including slope noise and persistence only

Only SCAs 17631-634 were included in the evaluation
- 630 and 635 were poor SCAs due to other factors

Best bands:
1B
3A
4A

Band behavior is more consistent than in previous run (PV1/PV2)
• Based solely on overall performance, the best bands are:
  – 1B, 3A, and 4A
• The “twin” band for each of these is of orange rank
• Band 4A has shown manufacturing challenges in the PV1 and PV2 SCAs
• Band 1B and 3A are very similar: C1 vs B1
  – Only small difference is one of diode size; same contact
• Band 1 was used for the PV2 full array mask
• Recommendation:
  – Band 1 (commonality with PV2)
  – Band 3 as second choice
## Comparison of PV2A and PV3 Performance

<table>
<thead>
<tr>
<th>Detector</th>
<th>Dark Current (e-/sec)</th>
<th>CDS Noise (e- rms)</th>
<th>Total Noise (e- rms)</th>
<th>Persistence (% first 180s)</th>
<th>Mean QE (%)</th>
<th>Cross-talk (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>457</td>
<td>0.003</td>
<td>12.9</td>
<td>4.6</td>
<td>0.12</td>
<td>100</td>
<td>2.06</td>
</tr>
<tr>
<td>530</td>
<td>0.002</td>
<td>14.7</td>
<td>5.1</td>
<td>0.08</td>
<td>99</td>
<td>2.05</td>
</tr>
<tr>
<td>532</td>
<td>0.001</td>
<td>8.3</td>
<td>4</td>
<td>0.61</td>
<td>93</td>
<td>1.77</td>
</tr>
<tr>
<td>PV2A Mean</td>
<td>0.002</td>
<td>12</td>
<td>4.6</td>
<td>0.27</td>
<td>97</td>
<td>1.96</td>
</tr>
<tr>
<td>631</td>
<td>0.006</td>
<td>17.6</td>
<td>5.8</td>
<td>0.11</td>
<td>111</td>
<td>1.93</td>
</tr>
<tr>
<td>632</td>
<td>0.008</td>
<td>18.4</td>
<td>5.9</td>
<td>0.12</td>
<td>112</td>
<td>2.05</td>
</tr>
<tr>
<td>633</td>
<td>0.004</td>
<td>15.4</td>
<td>4.9</td>
<td>0.1</td>
<td>95</td>
<td>1.6</td>
</tr>
<tr>
<td>634</td>
<td>0.009</td>
<td>16.3</td>
<td>6.9</td>
<td>0.18</td>
<td>98</td>
<td>1.94</td>
</tr>
<tr>
<td>PV3 Mean</td>
<td>0.007</td>
<td>16.9</td>
<td>5.9</td>
<td>0.13</td>
<td>104</td>
<td>1.88</td>
</tr>
</tbody>
</table>

- The comparison of the performance of the PV2A SCAs against the PV3 SCAs includes data for band 1 only.
- The results show that PV3 demonstrates better persistence, while PV2A exhibits better noise.
- These conclusions should be considered preliminary as they are based on a small sample of detectors.
- The full array lots are expected to provide more definitive results on which we can base our down-select to the flight detector design.
DETAILS OF PV3 DETECTOR ARRAY
RESULTS
WFIRST PV3 Preliminary Results
(631, 632, 633, 634)

November, 2014
• The photon transfer method of measuring gain was found to be unreliable in some of the PV3 detectors
  – It is expected that gain correction of flat field reduces differences between bands
  – It is expected that photon transfer gain is correlated to relative gain measured by X-ray method
• Two PV3 detectors (633 and 634) show agreement between different gain estimators. Photon transfer gain has been used for their test results.
• Two PV3 detectors (631 and 632) show good correlation between gain estimators for certain bands. We used detector averaged photon transfer gain and flat field pattern to produce per-band gain.
• Two detectors (630 and 635) showed poor correlation between gain estimators. Test results are not included in detector comparisons.
H4RG-630 Gain Comparison

Gain (counts/electron)

Band Number

- Photon Transfer Gain 1a-8a
- Fe55 Gain 1a-8a
- Photon Transfer Gain 1b-8b
- Fe55 Gain 1b-8b
H4RG-631 Gain Comparison

Gain (counts/electron)

Band Number

- Photon Transfer Gain 1a-8a
- Fe55 Gain 1a-8a
- Photon Transfer Gain 1b-8b
- Fe55 Gain 1b-8b
H4RG-635 Gain Comparison

Gain (counts/electron) vs Band Number

- Fe55 Gain 1a-8a
- Photon Transfer Gain 1a-8a
- Fe55 Gain 1b-8b
- Photon Transfer Gain 1b-8b
Gain 630, 634 and flat fields

- It is expected that gain correction would make flat field ‘flat’
• Teledyne (TIS) screens quality of HgCdTe material for detector fabrication by measuring density of defects and minority carrier free path.

• TIS screening results have excellent correlation to DCL test results
  – Detectors 17630 and 17635 had high defect density and short free length path – they showed the worst performance in DCL testing
  – Detectors 17633 and 17634 had fair screening results – they showed reasonable performance in DCL testing
  – Previously manufactured H2RG detectors with PV3 passivation, H2RG-16114 and H2RG-16116, had very good screening results – they had the best performance in DCL testing

• Excellent correlation of performance with screening data makes vendor confident to select proper material for good PV3 detectors
• The PV3 SCAs show some interconnect operability issues in the corners and in some cases along the edges of the devices.

• Teledyne is gradually learning how to improve the interconnect performance on the H4RG devices.
  – Going to a 10µm pixel requires smaller indium bumps

• As part of this effort, one of our SCAs is undergoing a DPA to examine the interconnect regions.
We report on the following tests:

• Photon Transfer Gain
• Crosstalk
  ✓ Dark Current
  ✓ CDS and Total (Slope) Noise
  ✓ Quantum Efficiency (QE)
• Persistence

• We first summarize results for each parameter, then give detailed results for each parameter
Photon Transfer Gain Summary

- Two PV3 detectors (633 and 634) show good agreement between different gain estimators. Photon transfer gain has been used for their test results.

- For two PV3 detectors (631 and 632) we have used detector averaged photon transfer gain and flat field pattern to produce per-band gain.

- Images on the following slide are gain-corrected flat field images at 1400nm.
Crosstalk Summary

- From Fe55 X-ray data
- Images are in linear scale: Black < 0%, White > 3%
Crosstalk From $^{55}$Fe X-ray Data
Dark Current Summary

- Uncertainty: 0.003 e-/s
- The dark current floor is set to be 0.001 e-/s in summary section, i.e. any values below 0.001 e-/s or negative are set to be 0.001 in the plots
- All plotted dark current numbers are median values.
- Images are in log scale [black = 0.005 e-/s, white = 0.1 e-/s]
Dark Current
Summary at 100K

Dark Current (e/s)

H631 H632 H633 H634

29
CDS Noise Summary

- All plotted CDS noise numbers are median values
- Images are in linear scale: Black=0, White=30e-
CDS Noise Summary at 100K

Graph showing CDS Noise values for different chips:
- Chip 631
- Chip 632
- Chip 633
- Chip 634

Graph indicates variations in CDS Noise values across different bands.

Graphs for individual chips with data points for each band.
Slope Noise Summary

- Total noise computed as a mean value per band
- Images are in linear scale: Black < 0e-, White > 20e-
QE Summary

- Plotted values are the averaged QE from 800nm to 2350nm
- Images are flat field images at 1400nm in linear scale: [0.9-1.1]
- All plots are IPC corrected
- The DCL has started a collaborative effort with NIST in order to address issues with absolute QE calibration and QE measurement methodology

PV3 QE is work in progress...