FUV Detector Lifetime Estimates for Observation Planning

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1. INTRODUCTION

This TER was motivated by a concern regarding the effects of charge extraction on the detection quantum efficiency of the FUV detector microchannel plates (MCPs) and the number of high signal to noise observations which can be accommodated before the spectrum must be moved to a new position in the cross dispersion direction. This TER provides in a spreadsheet format guidelines for the charge extracted per pixel and the corresponding number of observations than can be acquired assuming a charge extraction limit of 0.01 C/cm^2 as functions of signal to noise. These calculations are neither difficult nor complicated to make. The purpose of this TER is to document in an official format a set of numbers that the Instrument Development Team (IDT) and mission planners can refer to as a baseline.

The charge extraction limit of 0.01 C/cm^2 is based on experimental results at the University of California, Berkeley which found that the plates can support a change in the modal gain of the MCPs per C/cm^2 of 100%/C/cm^2 (COS-11-0012and UCB-COS-006). The specification for MCP lifetime listed in the Statement of Requirements for the HST/FUV Detector (COS-08-0003) states that the "the FUV detector shall be capable of accepting a total flux of $>10^9$ events/mm^2 with <1% degradation in the DQE over the active area of the detector at BOL (beginning of life)." By limiting the charge extraction to <0.01 C/cm^2 we ensure that the loss in DQE will be <1%. Admittedly this is a conservative stance and as more information about the flight MCPs becomes available the charge extraction limit may be raised.

2. THE SPREADSHEET

The attached spreadsheet has four pages. Page 3 is a generalized worksheet that allows an investigator to alter parameters such as the required signal to noise, observed count rate, or resolution element size and evaluate the corresponding change in the total charge extracted and/or required integration times. It also lists certain observational facts such as the number of astrophysical photons, flat field photons, and wavelength calibration photons to be collected per year for comparison purposes. These numbers are *estimates* only with the wavelength calibration numbers being the most suspect.

Pages 4 through 6 are the most useful and consist of a table which lists the charge extracted and number of allowable observations for signal to noises of 10, 30, 70, and 130 per some number of binned pixels. For example, if you want to bin the data into groups of 10 pixels then $2.4X10^{-4}$ C/cm^2 would be extracted in acquiring 900 photons for a signal to noise of 30:1. With this level of binning and signal to noise the MCPs can support 42 observations assuming a maximum charge extraction of 0.01 C/cm^2. As is expected, the number of allowable observations increases with the number of pixels

combined to form a single bin. Given a pixel size of 0.006 X 0.020 mm a typical COS resolution element has 60 pixels (see the shaded row on Page 3). Using a resolution element as a metric we see that the COS FUV MCPs can support about 250 observations at the 30:1 level, 46 observations at the 70:1 level, or 13 observations at the 130:1 level before 0.01C /cm^2 is extracted from the MCPs. Obviously a more realistic scenario for a typical COS year would be some combination of these signal to noise levels which sum to a total of 0.01 C/cm^2 in total extracted charge.

Finally, Page 7 presents in graphical form the number of allowable observations versus binning level for each of the signal to noise ratios.

The formula for calculating the extracted charge per unit area (C/A) is straightforward and is shown below. All the calculations assume a gain of 2x10^7 e$^-$/v.

$$C/A = n_\nu \cdot \frac{2x10^7\, e^- / \nu}{6.242x10^{18}\, e^- / C} \cdot \frac{pixel}{1.2x10^{-6}\, cm^2} \cdot \frac{1}{n_p}$$

n_ν is the number of photons
ν refers to a photon event
n_p is the number of pixels binned

In the event that 0.01C/cm^2 is extracted from the MCPs then the exposed portion of the MCPs will begin to experience a small loss in DQE.

MCP Quantities				Units	
	Coulomb	6.242E+18		electrons	
	Charge extraction limit	0.01		C/cm^2	to limit qe degradation to <1%
	MCP gain	2.00E+07		e-/photon	
	photons/cm^2	3.121E+11		photons/cm^2	
Pixel & Resel Quantities		**x**	**y**		
	Pixel (x, y)	0.006	0.02	mm	
	Resel (x, y)	0.04	0.2	mm	
	Area of a Resel	0.00008		cm^2	
	Area of a Pixel	0.0000012		cm^2	
Performance Quantities					
	S/N	70		photons	
	number of photons	4900			
	count rate	2.00E+04		photons/sec	maximum dump while accumulating rate
	area of a flat field	0.85		cm^2	1 mm high X 85 mm long
	# of resels in a flat field	10625		resels	
	# of pixels in a flat field	708333.3333		pixels	
	count rate/resel	1.882352941		events/sec/resel	
	count rate/pixel	0.028235294		events/sec/pixel	
Lifetime Quantities					
	photons/resel	249680		photons/resel	
	Required integration time				
	resels	2603.125	seconds	0.723090278	hours
	pixels	173541.6667	seconds	48.20601852	hours
	Extracted charge / flat field				
	resels	0.000196251		coulombs/cm^2	
	pixels	0.013083413		coulombs/cm^2	
	Allowable # of flat fields				
	resels	50.95510204			
	pixels	0.764326531			

Observational Facts						Area Illuminated
	# astrophysical photons	2.78E+08		per year	5.23E-03	C/cm^2 (0.2cm * 85cm)
	# FF calibration photons	3.12E+08	6	per year	1.18E-03	C/cm^2 (0.5cm * 85cm)
	# wave calibration photons	5.85E+08		per year	1.10E-02	C/cm^2 (0.2cm * 85cm)

Assuming we need signal to noise of 70 at the resel level then we expect to extract the following amount of charge and photons.

1.96E-04	C/cm^2	
5.21E+07	total photons in flat field	

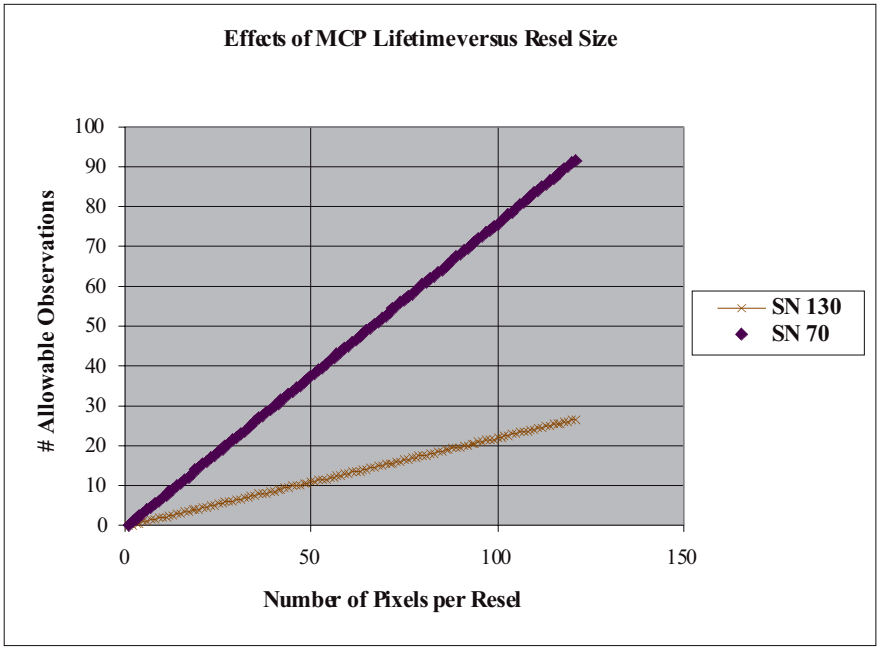
This sheet calculates the total number of observations that can be made for a given signal to noise level and a number of pixels to be summed over. For example, if we assume that we'll flat field at the pixel level at a signal to level of 130, we cannot observe any flat fields without depleting the charge below the 0.01 C/cm^2 limit. However, if we use 120 pixels, which corresponds to 1 spectral resolution element, then we can acquire about 13 flat fields.

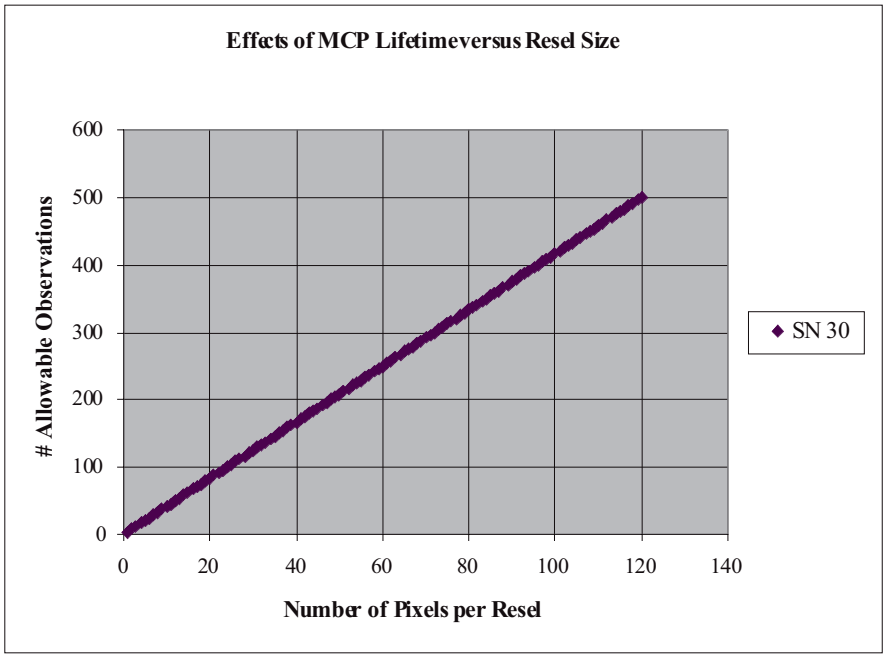
Total MCP Life 0.01 C/cm^2

	Extracted Charge in C/cm^2				# Allowable Observations			
# Pixels	SN 10	SN 30	SN 70	SN 130	SN 10	SN 30	SN 70	SN 130
1	2.67E-04	2.40E-03	1.31E-02	4.51E-02	3.75E+01	4.16E+00	7.64E-01	2.22E-01
2	1.34E-04	1.20E-03	6.54E-03	2.26E-02	7.49E+01	8.32E+00	1.53E+00	4.43E-01
3	8.90E-05	8.01E-04	4.36E-03	1.50E-02	1.12E+02	1.25E+01	2.29E+00	6.65E-01
4	6.68E-05	6.01E-04	3.27E-03	1.13E-02	1.50E+02	1.66E+01	3.06E+00	8.86E-01
5	5.34E-05	4.81E-04	2.62E-03	9.02E-03	1.87E+02	2.08E+01	3.82E+00	1.11E+00
6	4.45E-05	4.01E-04	2.18E-03	7.52E-03	2.25E+02	2.50E+01	4.59E+00	1.33E+00
7	3.81E-05	3.43E-04	1.87E-03	6.45E-03	2.62E+02	2.91E+01	5.35E+00	1.55E+00
8	3.34E-05	3.00E-04	1.64E-03	5.64E-03	3.00E+02	3.33E+01	6.11E+00	1.77E+00
9	2.97E-05	2.67E-04	1.45E-03	5.01E-03	3.37E+02	3.75E+01	6.88E+00	1.99E+00
10	2.67E-05	2.40E-04	1.31E-03	4.51E-03	3.75E+02	4.16E+01	7.64E+00	2.22E+00
11	2.43E-05	2.18E-04	1.19E-03	4.10E-03	4.12E+02	4.58E+01	8.41E+00	2.44E+00
12	2.23E-05	2.00E-04	1.09E-03	3.76E-03	4.49E+02	4.99E+01	9.17E+00	2.66E+00
13	2.05E-05	1.85E-04	1.01E-03	3.47E-03	4.87E+02	5.41E+01	9.94E+00	2.88E+00
14	1.91E-05	1.72E-04	9.35E-04	3.22E-03	5.24E+02	5.83E+01	1.07E+01	3.10E+00
15	1.78E-05	1.60E-04	8.72E-04	3.01E-03	5.62E+02	6.24E+01	1.15E+01	3.32E+00
16	1.67E-05	1.50E-04	8.18E-04	2.82E-03	5.99E+02	6.66E+01	1.22E+01	3.55E+00
17	1.57E-05	1.41E-04	7.70E-04	2.65E-03	6.37E+02	7.07E+01	1.30E+01	3.77E+00
18	1.48E-05	1.34E-04	7.27E-04	2.51E-03	6.74E+02	7.49E+01	1.38E+01	3.99E+00
19	1.41E-05	1.26E-04	6.89E-04	2.37E-03	7.12E+02	7.91E+01	1.45E+01	4.21E+00
20	1.34E-05	1.20E-04	6.54E-04	2.26E-03	7.49E+02	8.32E+01	1.53E+01	4.43E+00
21	1.27E-05	1.14E-04	6.23E-04	2.15E-03	7.86E+02	8.74E+01	1.61E+01	4.65E+00
22	1.21E-05	1.09E-04	5.95E-04	2.05E-03	8.24E+02	9.15E+01	1.68E+01	4.88E+00
23	1.16E-05	1.04E-04	5.69E-04	1.96E-03	8.61E+02	9.57E+01	1.76E+01	5.10E+00
24	1.11E-05	1.00E-04	5.45E-04	1.88E-03	8.99E+02	9.99E+01	1.83E+01	5.32E+00
25	1.07E-05	9.61E-05	5.23E-04	1.80E-03	9.36E+02	1.04E+02	1.91E+01	5.54E+00
26	1.03E-05	9.24E-05	5.03E-04	1.74E-03	9.74E+02	1.08E+02	1.99E+01	5.76E+00
27	9.89E-06	8.90E-05	4.85E-04	1.67E-03	1.01E+03	1.12E+02	2.06E+01	5.98E+00
28	9.54E-06	8.58E-05	4.67E-04	1.61E-03	1.05E+03	1.17E+02	2.14E+01	6.21E+00
29	9.21E-06	8.29E-05	4.51E-04	1.56E-03	1.09E+03	1.21E+02	2.22E+01	6.43E+00
30	8.90E-06	8.01E-05	4.36E-04	1.50E-03	1.12E+03	1.25E+02	2.29E+01	6.65E+00
31	8.61E-06	7.75E-05	4.22E-04	1.46E-03	1.16E+03	1.29E+02	2.37E+01	6.87E+00
32	8.34E-06	7.51E-05	4.09E-04	1.41E-03	1.20E+03	1.33E+02	2.45E+01	7.09E+00
33	8.09E-06	7.28E-05	3.96E-04	1.37E-03	1.24E+03	1.37E+02	2.52E+01	7.31E+00
34	7.85E-06	7.07E-05	3.85E-04	1.33E-03	1.27E+03	1.41E+02	2.60E+01	7.53E+00
35	7.63E-06	6.87E-05	3.74E-04	1.29E-03	1.31E+03	1.46E+02	2.68E+01	7.76E+00

	Extracted Charge in C/cm^2				# Allowable Observations			
# Pixels	SN 10	SN 30	SN 70	SN 130	SN 10	SN 30	SN 70	SN 130
36	7.42E-06	6.68E-05	3.63E-04	1.25E-03	1.35E+03	1.50E+02	2.75E+01	7.98E+00
37	7.22E-06	6.49E-05	3.54E-04	1.22E-03	1.39E+03	1.54E+02	2.83E+01	8.20E+00
38	7.03E-06	6.32E-05	3.44E-04	1.19E-03	1.42E+03	1.58E+02	2.90E+01	8.42E+00
39	6.85E-06	6.16E-05	3.35E-04	1.16E-03	1.46E+03	1.62E+02	2.98E+01	8.64E+00
40	6.68E-06	6.01E-05	3.27E-04	1.13E-03	1.50E+03	1.66E+02	3.06E+01	8.86E+00
41	6.51E-06	5.86E-05	3.19E-04	1.10E-03	1.54E+03	1.71E+02	3.13E+01	9.09E+00
42	6.36E-06	5.72E-05	3.12E-04	1.07E-03	1.57E+03	1.75E+02	3.21E+01	9.31E+00
43	6.21E-06	5.59E-05	3.04E-04	1.05E-03	1.61E+03	1.79E+02	3.29E+01	9.53E+00
44	6.07E-06	5.46E-05	2.97E-04	1.03E-03	1.65E+03	1.83E+02	3.36E+01	9.75E+00
45	5.93E-06	5.34E-05	2.91E-04	1.00E-03	1.69E+03	1.87E+02	3.44E+01	9.97E+00
46	5.80E-06	5.22E-05	2.84E-04	9.81E-04	1.72E+03	1.91E+02	3.52E+01	1.02E+01
47	5.68E-06	5.11E-05	2.78E-04	9.60E-04	1.76E+03	1.96E+02	3.59E+01	1.04E+01
48	5.56E-06	5.01E-05	2.73E-04	9.40E-04	1.80E+03	2.00E+02	3.67E+01	1.06E+01
49	5.45E-06	4.90E-05	2.67E-04	9.21E-04	1.84E+03	2.04E+02	3.75E+01	1.09E+01
50	5.34E-06	4.81E-05	2.62E-04	9.02E-04	1.87E+03	2.08E+02	3.82E+01	1.11E+01
51	5.24E-06	4.71E-05	2.57E-04	8.85E-04	1.91E+03	2.12E+02	3.90E+01	1.13E+01
52	5.13E-06	4.62E-05	2.52E-04	8.68E-04	1.95E+03	2.16E+02	3.97E+01	1.15E+01
53	5.04E-06	4.53E-05	2.47E-04	8.51E-04	1.98E+03	2.21E+02	4.05E+01	1.17E+01
54	4.94E-06	4.45E-05	2.42E-04	8.36E-04	2.02E+03	2.25E+02	4.13E+01	1.20E+01
55	4.85E-06	4.37E-05	2.38E-04	8.20E-04	2.06E+03	2.29E+02	4.20E+01	1.22E+01
56	4.77E-06	4.29E-05	2.34E-04	8.06E-04	2.10E+03	2.33E+02	4.28E+01	1.24E+01
57	4.68E-06	4.22E-05	2.30E-04	7.92E-04	2.13E+03	2.37E+02	4.36E+01	1.26E+01
58	4.60E-06	4.14E-05	2.26E-04	7.78E-04	2.17E+03	2.41E+02	4.43E+01	1.29E+01
59	4.53E-06	4.07E-05	2.22E-04	7.65E-04	2.21E+03	2.46E+02	4.51E+01	1.31E+01
60	4.45E-06	4.01E-05	2.18E-04	7.52E-04	2.25E+03	2.50E+02	4.59E+01	1.33E+01
61	4.38E-06	3.94E-05	2.14E-04	7.40E-04	2.28E+03	2.54E+02	4.66E+01	1.35E+01
62	4.31E-06	3.88E-05	2.11E-04	7.28E-04	2.32E+03	2.58E+02	4.74E+01	1.37E+01
63	4.24E-06	3.81E-05	2.08E-04	7.16E-04	2.36E+03	2.62E+02	4.82E+01	1.40E+01
64	4.17E-06	3.75E-05	2.04E-04	7.05E-04	2.40E+03	2.66E+02	4.89E+01	1.42E+01
65	4.11E-06	3.70E-05	2.01E-04	6.94E-04	2.43E+03	2.70E+02	4.97E+01	1.44E+01
66	4.05E-06	3.64E-05	1.98E-04	6.84E-04	2.47E+03	2.75E+02	5.04E+01	1.46E+01
67	3.99E-06	3.59E-05	1.95E-04	6.73E-04	2.51E+03	2.79E+02	5.12E+01	1.48E+01
68	3.93E-06	3.53E-05	1.92E-04	6.64E-04	2.55E+03	2.83E+02	5.20E+01	1.51E+01
69	3.87E-06	3.48E-05	1.90E-04	6.54E-04	2.58E+03	2.87E+02	5.27E+01	1.53E+01
70	3.81E-06	3.43E-05	1.87E-04	6.45E-04	2.62E+03	2.91E+02	5.35E+01	1.55E+01
71	3.76E-06	3.38E-05	1.84E-04	6.36E-04	2.66E+03	2.95E+02	5.43E+01	1.57E+01
72	3.71E-06	3.34E-05	1.82E-04	6.27E-04	2.70E+03	3.00E+02	5.50E+01	1.60E+01
73	3.66E-06	3.29E-05	1.79E-04	6.18E-04	2.73E+03	3.04E+02	5.58E+01	1.62E+01
74	3.61E-06	3.25E-05	1.77E-04	6.10E-04	2.77E+03	3.08E+02	5.66E+01	1.64E+01
75	3.56E-06	3.20E-05	1.74E-04	6.02E-04	2.81E+03	3.12E+02	5.73E+01	1.66E+01
76	3.51E-06	3.16E-05	1.72E-04	5.94E-04	2.85E+03	3.16E+02	5.81E+01	1.68E+01
77	3.47E-06	3.12E-05	1.70E-04	5.86E-04	2.88E+03	3.20E+02	5.89E+01	1.71E+01
78	3.42E-06	3.08E-05	1.68E-04	5.79E-04	2.92E+03	3.25E+02	5.96E+01	1.73E+01
79	3.38E-06	3.04E-05	1.66E-04	5.71E-04	2.96E+03	3.29E+02	6.04E+01	1.75E+01
80	3.34E-06	3.00E-05	1.64E-04	5.64E-04	3.00E+03	3.33E+02	6.11E+01	1.77E+01
81	3.30E-06	2.97E-05	1.62E-04	5.57E-04	3.03E+03	3.37E+02	6.19E+01	1.80E+01

	Extracted Charge in C/cm^2				# Allowable Observations			
# Pixels	SN 10	SN 30	SN 70	SN 130	SN 10	SN 30	SN 70	SN 130
82	3.26E-06	2.93E-05	1.60E-04	5.50E-04	3.07E+03	3.41E+02	6.27E+01	1.82E+01
83	3.22E-06	2.90E-05	1.58E-04	5.44E-04	3.11E+03	3.45E+02	6.34E+01	1.84E+01
84	3.18E-06	2.86E-05	1.56E-04	5.37E-04	3.15E+03	3.50E+02	6.42E+01	1.86E+01
85	3.14E-06	2.83E-05	1.54E-04	5.31E-04	3.18E+03	3.54E+02	6.50E+01	1.88E+01
86	3.10E-06	2.79E-05	1.52E-04	5.25E-04	3.22E+03	3.58E+02	6.57E+01	1.91E+01
87	3.07E-06	2.76E-05	1.50E-04	5.19E-04	3.26E+03	3.62E+02	6.65E+01	1.93E+01
88	3.03E-06	2.73E-05	1.49E-04	5.13E-04	3.30E+03	3.66E+02	6.73E+01	1.95E+01
89	3.00E-06	2.70E-05	1.47E-04	5.07E-04	3.33E+03	3.70E+02	6.80E+01	1.97E+01
90	2.97E-06	2.67E-05	1.45E-04	5.01E-04	3.37E+03	3.75E+02	6.88E+01	1.99E+01
91	2.93E-06	2.64E-05	1.44E-04	4.96E-04	3.41E+03	3.79E+02	6.96E+01	2.02E+01
92	2.90E-06	2.61E-05	1.42E-04	4.90E-04	3.45E+03	3.83E+02	7.03E+01	2.04E+01
93	2.87E-06	2.58E-05	1.41E-04	4.85E-04	3.48E+03	3.87E+02	7.11E+01	2.06E+01
94	2.84E-06	2.56E-05	1.39E-04	4.80E-04	3.52E+03	3.91E+02	7.18E+01	2.08E+01
95	2.81E-06	2.53E-05	1.38E-04	4.75E-04	3.56E+03	3.95E+02	7.26E+01	2.11E+01
96	2.78E-06	2.50E-05	1.36E-04	4.70E-04	3.60E+03	3.99E+02	7.34E+01	2.13E+01
97	2.75E-06	2.48E-05	1.35E-04	4.65E-04	3.63E+03	4.04E+02	7.41E+01	2.15E+01
98	2.72E-06	2.45E-05	1.34E-04	4.60E-04	3.67E+03	4.08E+02	7.49E+01	2.17E+01
99	2.70E-06	2.43E-05	1.32E-04	4.56E-04	3.71E+03	4.12E+02	7.57E+01	2.19E+01
100	2.67E-06	2.40E-05	1.31E-04	4.51E-04	3.75E+03	4.16E+02	7.64E+01	2.22E+01
101	2.64E-06	2.38E-05	1.30E-04	4.47E-04	3.78E+03	4.20E+02	7.72E+01	2.24E+01
102	2.62E-06	2.36E-05	1.28E-04	4.42E-04	3.82E+03	4.24E+02	7.80E+01	2.26E+01
103	2.59E-06	2.33E-05	1.27E-04	4.38E-04	3.86E+03	4.29E+02	7.87E+01	2.28E+01
104	2.57E-06	2.31E-05	1.26E-04	4.34E-04	3.90E+03	4.33E+02	7.95E+01	2.30E+01
105	2.54E-06	2.29E-05	1.25E-04	4.30E-04	3.93E+03	4.37E+02	8.03E+01	2.33E+01
106	2.52E-06	2.27E-05	1.23E-04	4.26E-04	3.97E+03	4.41E+02	8.10E+01	2.35E+01
107	2.50E-06	2.25E-05	1.22E-04	4.22E-04	4.01E+03	4.45E+02	8.18E+01	2.37E+01
108	2.47E-06	2.23E-05	1.21E-04	4.18E-04	4.04E+03	4.49E+02	8.25E+01	2.39E+01
109	2.45E-06	2.20E-05	1.20E-04	4.14E-04	4.08E+03	4.54E+02	8.33E+01	2.42E+01
110	2.43E-06	2.18E-05	1.19E-04	4.10E-04	4.12E+03	4.58E+02	8.41E+01	2.44E+01
111	2.41E-06	2.16E-05	1.18E-04	4.07E-04	4.16E+03	4.62E+02	8.48E+01	2.46E+01
112	2.38E-06	2.15E-05	1.17E-04	4.03E-04	4.19E+03	4.66E+02	8.56E+01	2.48E+01
113	2.36E-06	2.13E-05	1.16E-04	3.99E-04	4.23E+03	4.70E+02	8.64E+01	2.50E+01
114	2.34E-06	2.11E-05	1.15E-04	3.96E-04	4.27E+03	4.74E+02	8.71E+01	2.53E+01
115	2.32E-06	2.09E-05	1.14E-04	3.92E-04	4.31E+03	4.79E+02	8.79E+01	2.55E+01
116	2.30E-06	2.07E-05	1.13E-04	3.89E-04	4.34E+03	4.83E+02	8.87E+01	2.57E+01
117	2.28E-06	2.05E-05	1.12E-04	3.86E-04	4.38E+03	4.87E+02	8.94E+01	2.59E+01
118	2.26E-06	2.04E-05	1.11E-04	3.82E-04	4.42E+03	4.91E+02	9.02E+01	2.61E+01
119	2.24E-06	2.02E-05	1.10E-04	3.79E-04	4.46E+03	4.95E+02	9.10E+01	2.64E+01
120	2.23E-06	2.00E-05	1.09E-04	3.76E-04	4.49E+03	4.99E+02	9.17E+01	2.66E+01


Effects of MCP Lifetimeversus Resel Size
Allowable Observations
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
Number of Pixels per Resel
SN 130
SN 70


Effects of MCP Lifetimeversus Resel Size
Allowable Observations
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
Number of Pixels per Resel
SN 30