Instrument Science Report WFC3 2003-14

WFC3 UVIS CCD Image Overscan Region Layouts

H. Bushouse
December 19, 2003

ABSTRACT

Wide Field Camera 3 UVIS CCD images can contain up to three different types of overscan pixels: serial physical and virtual overscan, and parallel virtual overscan. The presence and locations of these overscan regions within the CCD images vary according to user-selected readout parameters, including which amplifiers are used to read the image, on-chip binning factor, and full-frame versus subarray modes. This ISR describes and documents the locations of the various overscan regions within UVIS images obtained in all possible readout mode combinations.

1. Introduction

The Wide Field Camera 3 (WFC3) Ultraviolet-Visible (UVIS) channel uses two adjacent 2051x4096 pixel (parallel x serial) CCD chips, creating a combined 4102x4096 pixel array with a small interchip gap of about 50 pixels. This configuration is very similar to that of the Advanced Camera for Surveys (ACS) Wide Field Camera (WFC) channel, however the combination of additional capabilities in detector operations makes the WFC3 UVIS images more complicated in appearance and in data processing. In addition to subarray read out modes, the WFC3 UVIS readouts can also include serial virtual overscan and on-chip binning.

1.1. Subarray Readouts

As with the ACS WFC, observer-defined subarrays may be used to reduce data volume and readout overhead. The instrument Flight Software (FSW) supports one rectangular subarray for the WFC3 UVIS channel, the dimensions and location of which are subject to certain limitations, which are discussed below.

1.2. CCD On-Chip Binning

The WFC3 UVIS channel provides an on-chip binning capability, whereby a small region of neighboring pixels may be read out as a single pixel. The use of binning reduces read-out data volume and improves sensitivity to faint sources, at the cost of lower spatial resolution. The available binning factors for WFC3 are 1x1 (no binning), 2x2, and 3x3. On-chip binning is not allowed in conjunction with subarray readouts to avoid unnecessary complexity.

1.3. Serial Virtual Overscan

The term overscan refers to reading a portion of the detector that was not exposed to any light, which is useful for characterizing detector performance and readout amplifier bias levels. Serial overscan corresponds to a number of unexposed pixels at each end of each amplifier’s serial shift register, while parallel overscan is generated by additional parallel shifting after all of the exposed rows of the detector have been read out. Both serial and parallel overscan can be implemented either as physical or virtual overscan. The extent of physical overscan is a characteristic of the detector hardware, as it is implemented with physical pixels on the CCD chip. Virtual overscan is a software function, and the number of rows and columns of virtual overscan generated with an image is controllable via the readout timing pattern.

As with the ACS WFC detector, the WFC3 UVIS CCD’s have physical overscan pixels located along the edges of the detector in the serial direction only. There are 25 physical overscan columns along each edge, or 50 columns total. Unlike ACS WFC, however, WFC3 has implemented a region of virtual overscan in the serial direction via its timing patterns. Under normal, four-amplifier full-frame readouts, there are 30 columns of serial virtual overscan produced by each of the two amps on each chip, yielding a total of 60 columns of serial virtual overscan. Like the ACS WFC, the WFC3 UVIS detector also employs parallel virtual overscan, which normally provides 19 rows of overscan at one edge of each chip.

Thus there can be as many as three types of overscan regions in WFC3 UVIS images: serial physical overscan, serial virtual overscan, and parallel virtual overscan. All three overscan regions are only present in full-frame readouts. Subarray readouts do not generate the serial and parallel virtual overscan, leaving only the serial physical overscan in these images.

2. Overscan Details

The WFC3 UVIS detector has two amplifiers on each of the two CCD chips, for a total of four amplifiers. The amps are designated by the letter codes A,B,C,D, where amps A and B are located on chip 1, and amps C and D are on chip 2. Under normal operations all four amps are used, in which case each amp reads out one-half of its chip (corresponding to one quadrant of the resulting full-frame image). It is possible to use either of the two amps on a chip by itself to read out the entire chip. Subarray readouts are restricted to using one amp to read out a portion of just one of the chips. Thus there are several different available combinations of amplifier readout modes:

1. Four amp, full-frame readout of both chips, using two amps per chip (amp combination ABCD)
2. Two amp, full-frame readout of both chips, using one amp per chip (amp combinations AC, AD, BC, or BD)
3. One amp, subarray readout of one chip (amp combinations A, B, C, or D)

Each of the two- and four-amp modes may be combined with any on-chip binning mode, while one amp (subarray) readouts may only use 1x1 binning (no binning).

Each of these various combinations of amp and binning modes results in unique overscan region locations and extents. Each mode is discussed in detail in the following sections.

2.1. Four Amp, Full-Frame Readouts

2.1.1. No Binning

Figure 1 shows the image layout for a four-amp, full-frame, unbinned readout of the UVIS detector. There are 2048x2051 “live”, physical pixels on each half of each chip that are exposed to light from the field of view. There are an additional 25 columns of physical overscan on the ends of each serial row. Because these overscan regions are the first to be read out by their amps (i.e. before reading the imaging pixels), they are often referred to as “leading edge” or “prescan” pixels. When each amp is done reading the columns of physical pixels along the serial direction in its half of the chip it is then overclocked for an additional 30 columns of serial virtual overscan pixels. Because these pixels are read out last by their amps, they are often referred to a “trailing edge” overscan. These 60 columns (30 from each amp) appear in the middle of the resulting image. The total image size in the serial direction is therefore 25+2048+30+30+2048+25=4206 pixels.

Table 1 lists the starting and ending pixel indexes and the total number of pixels contained in each of the serial-direction regions. The serial direction regions are identical for amps A and C, and for amps B and D. The regions read out by amps A and C appear on the left half of the image from their chips, while those from amps B and D are on the right half. Proceeding from left to right across the image, the serial physical prescan (leading edge) pixels from amps A and C appear in image columns 1-25, the imaging pixels in columns 26-2073, the serial virtual (trailing) overscan from amps A and C in columns 2074-2103, the serial virtual (trailing) overscan from amps B and D in columns 2104-2133, imaging pixels in columns 2134-4181, and physical prescan (leading edge) pixels in columns 4182-4206.

In the parallel readout direction each amp is overclocked for an additional 19 rows of virtual overscan. This parallel virtual overscan region appears on one edge of the resulting image from each chip. On chip 1 (amps A/B) it appears at the bottom of the image, while on chip 2 (amps C/D) it appears at the top. In this mode there is a total of 2051+19=2070 rows of pixels along the parallel direction of the image from each chip. In a mosaiced version of the images from both chips, this gives a total of 4140 rows, with the 38 rows (19 from each chip) of parallel virtual overscan showing up in the middle of the image.

Table 2 lists the starting and ending pixel indexes and the total number of pixels contained in each of the parallel-direction regions. The parallel direction regions are identical for amps A and B, and for amps C and D. For amps A and B the parallel virtual overscan pixels are located in image rows 1-19, with the imaging pixels in rows 20-2070. For amps C and D, the imaging pixels are in rows 1-2051, with the parallel virtual overscan pixels in rows 2052-2070.

2.1.2. 2x2 Binning

If on-chip binning is used, the overscan geometry is complicated by the need to truncate "odd" pixels, and each half of an image row (read out by an individual amp) must be considered separately. Because there is an odd number (25) of serial physical prescan pixels on the chips, the last physical overscan pixel is combined with the first exposed pixel in each row, and the last (unbinned) serial virtual overscan pixel in each half of each row is not read out because it occurs on an odd pixel index (in unbinned dimensions). Figure 2 shows the image layouts for four-amp binned images.

Table 1 lists the beginning and ending pixel indexes and sizes of the various serial direction overscan regions for the 2x2 binning mode. Note that the first row in the table for the binned modes lists indexes in units of unbinned pixels, while the second row gives the binned indexes. Proceeding from left to right across the resulting image, physical overscan pixels 1-24 from amps A/C are combined to produce binned columns 1-12, the last physical overscan pixel (25) is combined with the first imaging pixel (26) to produce binned column 13, imaging pixels 27-2072 are binned to produce columns 14-1036, the last imaging pixel (2073) is combined with the first virtual overscan pixel (2074) to produce binned column 1037, and the remaining 28 virtual overscan pixels are combined to produce binned columns 1038-1051. The right half of the image (produced by amps B or D) is then a mirror image of the left half. The resulting image has a total size of 12+1+1023+1+14+14+1+1023+1+12=2102 columns, 1051 from each of the two amps.

In the parallel direction we also end up with some mixed rows, due to the fact that there is an odd number (2051) of unbinned rows on each chip. Thus the last row of imaging pixels gets combined with the first overscan pixel to produce one mixed row on each chip. Referencing Table 2, we see that for amps A and B (chip 1), the first 18 rows of parallel virtual overscan pixels get combined to produced binned image rows 1-9, the last virtual overscan row (19) gets combined with the first exposed image row (20) to produce binned row 10, and the remaining imaging pixels produce binned rows 11-1035, resulting in a binned image with a total of 1035 rows. For amps C and D, where the parallel overscan is at the top of the image, the imaging pixels form binned rows 1-1025, there is one mixed row at 1026, and then virtual overscan in binned rows 1027-1035. The overall 2x2 binned image size is then 2102x1035 pixels per chip, or 2102x2070 pixels total.

2.1.3. 3x3 Binning

Serial direction image information for four-amp, 3x3 binning mode is listed in Table 1. Proceeding from left to right across the image, physical prescan pixels 1-24 get combined to produce binned columns 1-8, the last physical prescan pixel (25) gets combined with the first two imaging pixels (26-27) to produce mixed column 9, the imaging area from amps A and C occurs in binned pixels 10-691, the virtual overscan pixels from amps A and C produce binned columns 692-701, the virtual overscan pixels from amps B and D produce binned columns 702-711, the imaging area from amps B and D occurs in binned pixels 712-1393, the last two imaging pixels (4180-4181) get combined with the first physical overscan pixel (4182) to produce a mixed column at index 1394, and finally the remaining physical overscan pixels from amps B and D get combined to produce binned columns 1395-1402. The resulting image has a total serial direction size of 1402 columns.

Table 2 lists the parallel direction image information for 3x3 binned images. For amps A and B (chip 1), the first 18 rows of parallel virtual overscan pixels get combined to produced binned rows 1-6, followed by one mixed row at index 7, which is made up of one overscan and two imaging rows, and the remaining imaging pixels produce binned rows 8-690. Binned images from amps C and D (chip 2) are simply inverted relative to chip 1 images, with the first 2049 (unbinned) imaging pixels forming binned rows 1-683, followed by one mixed row of imaging and virtual overscan pixels, and then the remaining virtual overscan pixels produce binned rows 685-690. The overall 3x3 binned image size is then 1402x690 pixels per chip, or 1402x1380 pixels total.

2.2. Two-Amp, Full-Frame Readouts

Two-amp readouts of the full detector result in the same number of rows and columns in the image as four-amp readouts. Because only one amp is being used to read out each chip, however, the serial virtual overscan pixels appear at the end of each image row, rather than in the middle.

2.2.1. No Binning

Figure 3 and Figure 4 show the image layouts for the two-amp combinations AC and BD, respectively. Two-amp combinations AD and BC are also allowed, but are not shown here because the image layouts are simply the alternate combinations of the upper and lower halves of these figures.

Table 3 lists the serial direction image information for readouts using amps A and C. The parallel direction layout is the same as for four-amp readouts (Table 2). Proceeding from left to right across the images from amps A and C, the first pixels to be read out are the 25 columns of physical prescan, followed by all 4096 columns of imaging pixels, then the second set of 25 columns of physical overscan, and finally the amp is overclocked to produce 60 columns of virtual overscan. The total image size per chip is 4206x2070, which is the same as a four-amp readout.

The image layouts for two-amp read outs using amps B and D are similar, but are simply reversed from left to right across the image (see Figure 4). Table 4 lists the image layout information for amps B and D. In this case, proceeding from left to right across the image, we first encounter the 60 columns of serial virtual overscan, then the trailing physical overscan, the 4096 imaging pixels, and finally the 25 columns of leading edge physical overscan at the far right. The total image size per chip is again 4206x2070 pixels.

2.2.2. 2x2 Binning

Two-amp readouts with binning produce similar effects as in four-amp readouts, with some mixed rows and columns appearing in some modes. The image layouts for two-amp binned images are shown in FiguresFigure 5 andFigure 6. The parallel direction binned image layouts are the same as for four-amp binned readouts, but the serial direction differs. From Table 3 we see that for amps A and C the first 24 columns of serial physical overscan are combined to produced binned columns 1-12, the last physical overscan column (25) is combined with the first exposed imaging column (26) to produce binned column 13, imaging columns 27-4120 are combined into binned columns 14-2060, the last imaging column (4121) is combined with the first physical overscan column (4122) to produce binned column 2061, the remaining physical overscan columns (4123-4146) are combined to produce binned columns 2062-2073, and finally there are 29 binned columns of serial virtual overscan. This yields a total image size per chip of 2102x1035, the same as four-amp 2x2 binned images.

The 2x2 binned image layouts for amps B and D are again the mirror image of this scheme (see Table 4). Binned columns 1-29 contain serial virtual overscan, there are 12 binned columns of trailing physical overscan running from 30-41, there is one mixed column at index 42, binned imaging pixels in columns 43-2089, another mixed column at index 2090, and finally another 12 binned columns of leading edge physical overscan in columns 2091-2102.

2.2.3. 3x3 Binning

Table 3 shows the serial direction image information for 3x3 binning of amps A and C read outs. Starting at the left edge of the image we have 8 binned columns of leading edge physical overscan, followed by one mixed column, 1364 binned columns of image data in columns 10-1373, another mixed column, 8 binned columns of trailing physical overscan in columns 1375-1382, and finally 20 binned columns of virtual overscan in columns 1383-1402. This results in a total image size per chip of 1402x690.

For 3x3 binned images of amp B and D readouts we again have the reverse of the amp AC layout. As listed in Table 4, the images start with serial virtual overscan in columns 1-20, followed by 8 binned columns of trailing physical overscan in columns 21-28, then one mixed column, 1364 binned imaging pixels in columns 30-1393, another mixed column, and finally the 8 binned columns of leading edge physical overscan in columns 1395-1402.

2.3. One Amp, Subarray Readouts

Subarray readouts must be confined to a single CCD chip and may only use one amp on that chip. Due to the way subarray readouts are implemented in the instrument FSW, the edges of the subarray must be at least 1 pixel away from the edges of the chip, except for the edge at the interchip gap, where a subarray may extend to the last row. Furthermore, subarrays must start on an even pixel number (for a zero-indexed numbering scheme) in the serial direction, and the subarray size must be an even number of pixels in the serial direction. Finally, subarray readouts do not include any virtual overscan in either the serial or parallel directions.

The total physical dimensions (i.e. without virtual overscan) of a chip are 4146x2051, so when all of the above restrictions are accounted for we find that the maximum size of a subarray readout is 4142x2050 (serial x parallel). This reduction from the full chip size is due to the loss of 2 columns of serial physical overscan at both ends of each image row, and the loss of 1 row of imaging pixels at the outside edge of each image column. The resulting layout for the largest posible subarray image is shown in Figure 7 and listed in Table 5 and is identical for all four amps. Smaller subarrays may exclude all or some portion of one or both physical overscan regions, depending on the selected size and location of the subarray. It is possible to have subarray images that contain no overscan pixels at all.

Table 1. Serial Direction Image Layouts for a Four-Amp Readout

	Amps A/C								**Amps B/D**							
Bin Mode	Physical Prescan		Mixed Cols	Imaging Pixels		Mixed Cols	Virtual Overscan		Virtual Overscan		Mixed Cols	Imaging Pixels		Mixed Cols	Physical Prescan	
1x1	1	25		26	2073		2074	2103	2104	2133		2134	4181		4182	4206
Totals		25			2048			30		30			2048			25
								2103								4206
2x2	1 +2	23 +24	25 +26	27 +28	2071 +2072	2073 +2074	2075 +2076	2101 +2102	2103 +2104	2129 +2130	2131 +2132	2133 +2134	4177 +4178	4179 +4180	4181 +4182	4203 +4204
	1	12	13	14	1036	1037	1038	1051	1052	1065	1066	1067	2089	2090	2091	2102
Totals		12	1		1023	1		14		14	1		1023	1		12
								1051								2102
3x3	1 +2 +3	22 +23 +24	25 +26 +27	28 +29 +30	2071 +2072 +2073		2074 +2075 +2076	2101 +2102 +2103	2104 +2105 +2106	2131 +2132 +2133		2134 +2135 +2136	4177 +4178 +4179	4180 +4181 +4182	4183 +4184 +4185	4204 +4205 +4206
	1	8	9	10	691		692	701	702	711		712	1393	1394	1395	1402
Totals		8	1		682			10		10			682	1		8
								701								1402

Table 2. Parallel Direction Image Layouts for Two- and Four-Amp Readout

	Amps A/B					**Amps C/D**				
Bin Mode	Virtual Overscan		Mixed Rows	Imaging Pixels		Imaging Pixels		Mixed Rows	Virtual Overscan	
1x1	1	19		20	2070	1	2051		2052	2070
Totals		19			2051		2051			19
					2070					2070
2x2	1+2	17+18	19+20	21+22	2069+ 2070	1+2	2049+ 2050	2051+ 2052	2053+ 2054	2069+ 2070
	1	9	10	11	1035	1	1025	1026	1027	1035
Totals		9	1		1025		1025	1		9
					1035					1035
3x3	1+2+3	16+17 +18	19+20 +21	22+23 +24	2068+ 2069+ 2070	1+2+3	2047+ 2048+ 2049	2050+ 2051+ 2052	2053+ 2054+ 2055	2068+ 2069+ 2070
	1	6	7	8	690	1	683	684	685	690
Totals		6	1		683		683	1		6
					690					690

Table 3. Serial Direction Image Layouts for a Two-Amp Readout (Amps AC)

	Amps A/C									
Bin Mode	Physical Prescan		Mixed Cols	Imaging Pixels		Mixed Cols	Physical Overscan		Virtual Overscan	
1x1	1	25		26	4121		4122	4146	4147	4206
Totals		25			4096			25		60
										4206
2x2	1 +2	23 +24	25 +26	27 +28	4119 +4120	4121 +4122	4123 +4124	4145 +4146	4147 +4148	4203 +4204
	1	12	13	14	2060	2061	2062	2073	2074	2102
Totals		12	1		2047	1		12		29
										2102
3x3	1 +2 +3	22 +23 +24	25 +26 +27	28 +29 +30	4117 +4118 +4119	4120 +4121 +4122	4123 +4124 +4125	4144 +4145 +4146	4147 +4148 +4149	4204 +4205 +4206
	1	8	9	10	1373	1374	1375	1382	1383	1402
Totals		8	1		1364	1		8		20
										1402

Table 4. Serial Direction Image Layouts for a Two-Amp Readout (Amps BD)

	Amps B/D									
Bin Mode	Virtual Overscan		Physical Overscan		Mixed Cols	Imaging Pixels		Mixed Cols	Physical Prescan	
1x1	1	60	61	85		86	4181		4182	4206
Totals		60		25			4096			25
										4206
2x2	3 +4	59 +60	61 +62	83 +84	85 +86	87 +88	4179 +4180	4181 +4182	4183 +4184	4205 +4206
	1	29	30	41	42	43	2089	2090	2091	2102
Totals		29		12	1		2047	1		12
										2102
3x3	1 +2 +3	58 +59 +60	61 +62 +63	82 +83 +84	85 +86 +87	88 +89 +90	4177 +4178 +4179	4180 +4181 +4182	4183 +4184 +4185	4204 +4205 +4206
	1	20	21	28	29	30	1393	1394	1395	1402
Totals		20		8	1		1364	1		8
										1402

Table 5. Serial Direction Layout for One Amp (Subarray) Readout

	Amps A/B/C/D					
Bin Mode	Physical Overscan		Imaging Pixels		Physical Overscan	
1x1	1	23	24	4119	4120	4142
Totals		23		4096		23
						4142

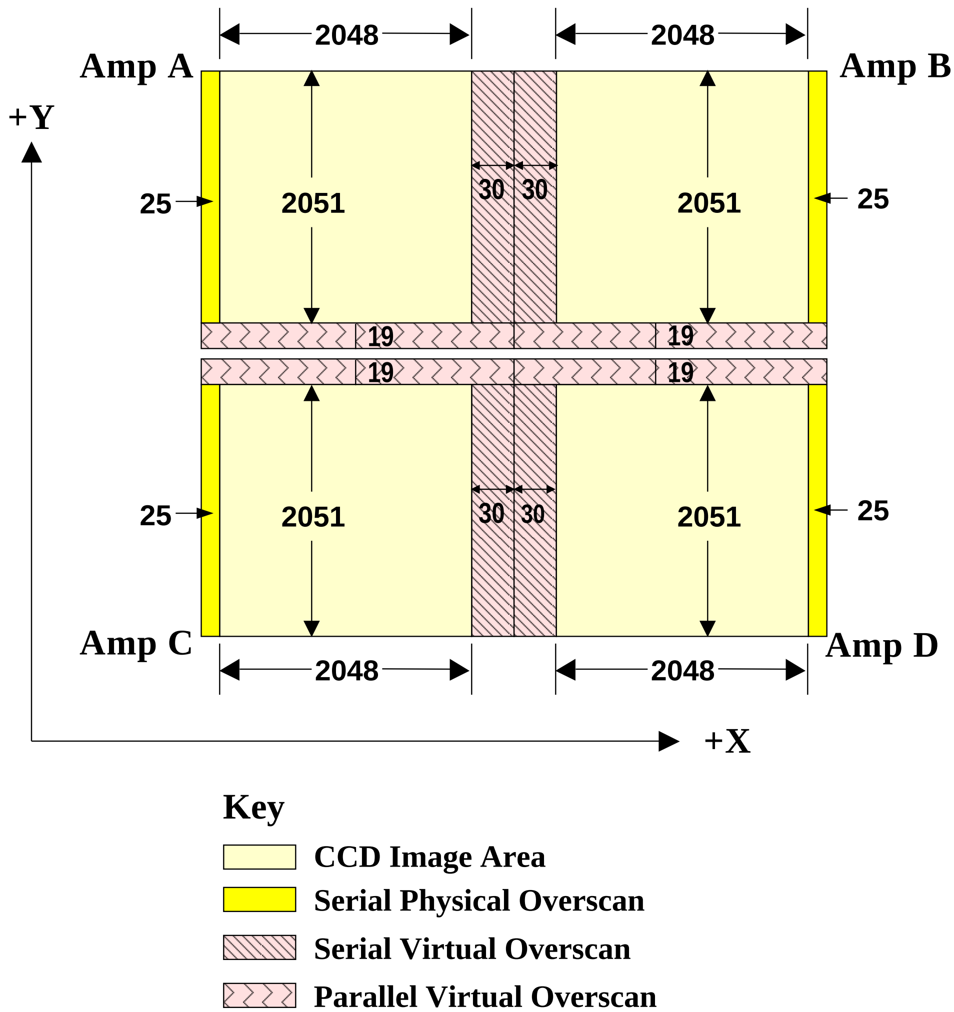

Figure 1: WFC3 UVIS Four-Amp Unbinned Readout (Amps ABCD)

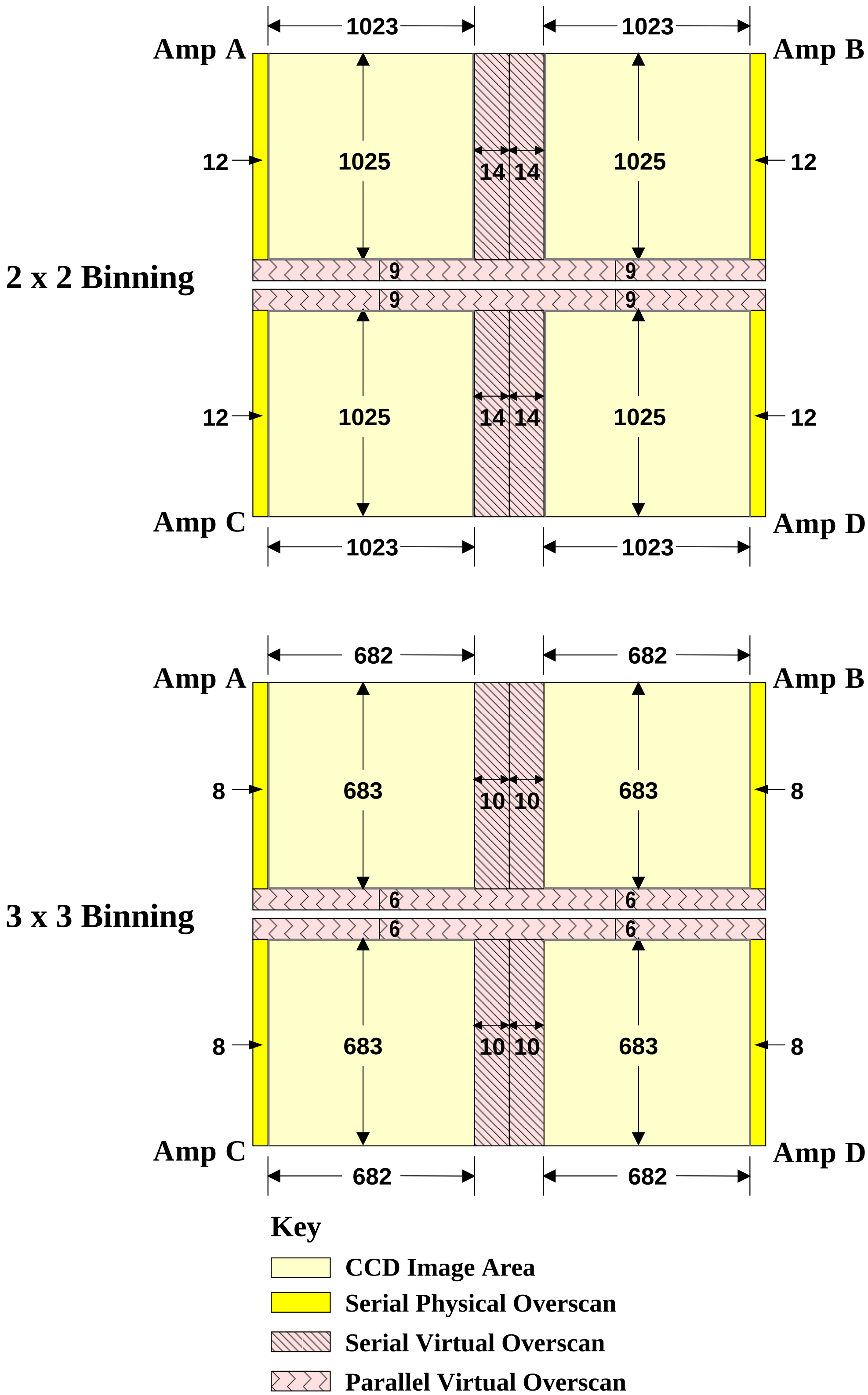

Figure 2: WFC3 UVIS Four-Amp Binned Readouts (Amps ABCD). Indicated pixel ranges exclude mixed rows and columns.

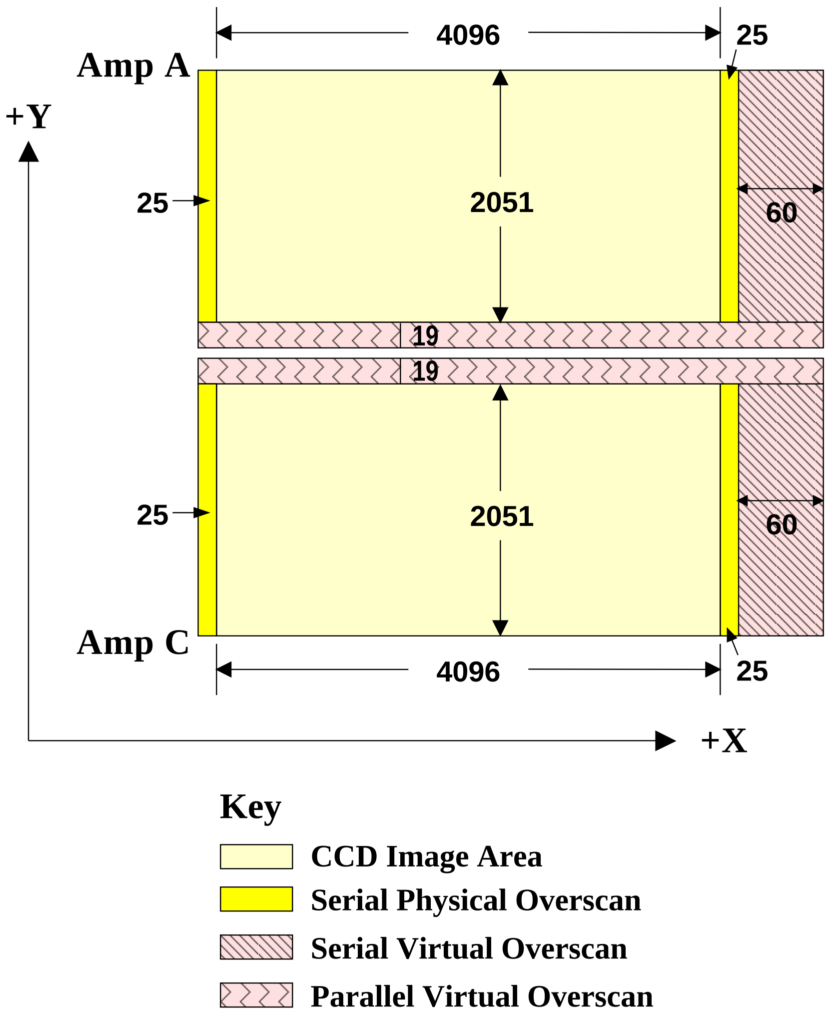

Figure 3: WFC3 UVIS Two-Amp AC Unbinned Readout.

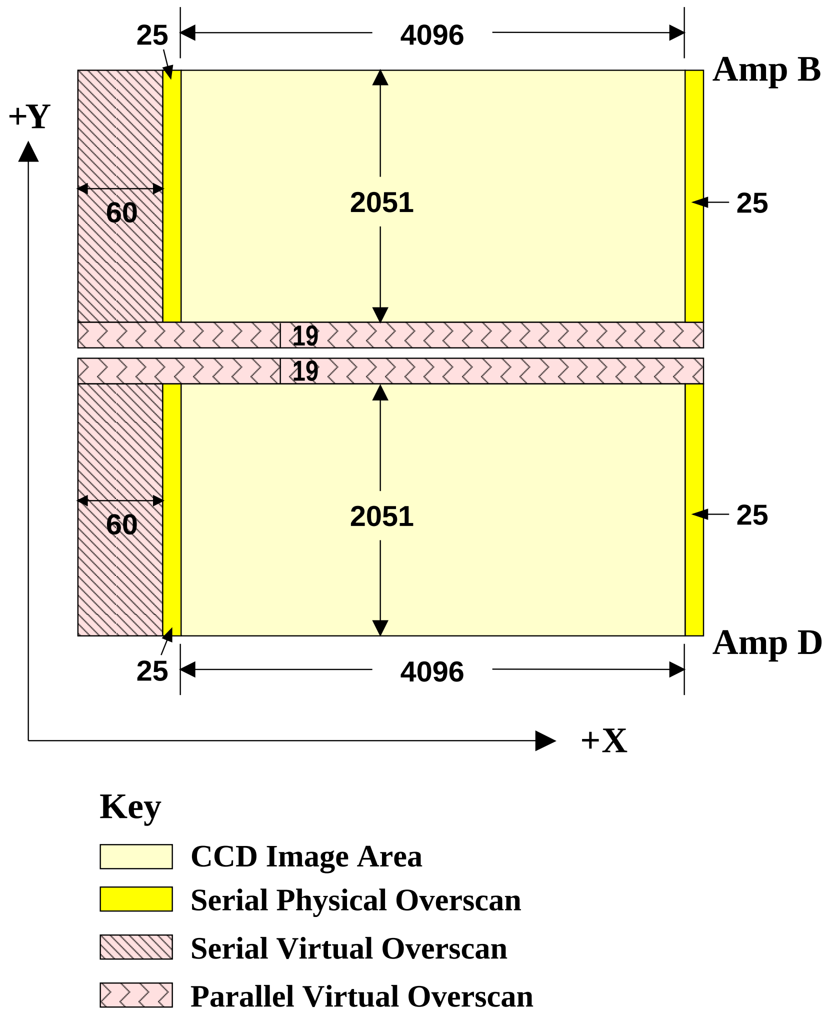

Figure 4: WFC3 UVIS Two-Amp BD Unbinned Readout.

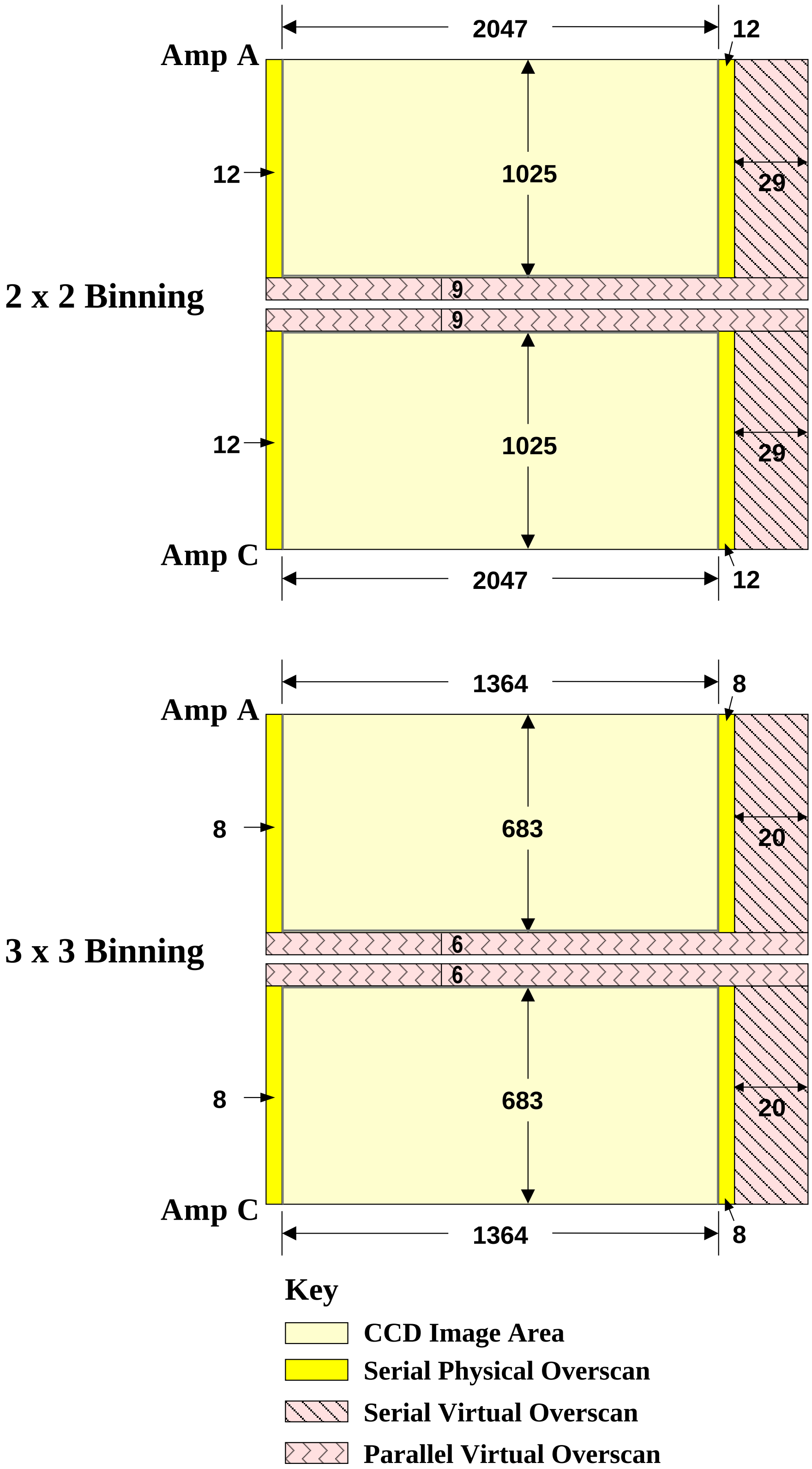

Figure 5: WFC3 UVIS Two-Amp AC Binned Readouts. Indicated pixel ranges exclude mixed rows and columns.

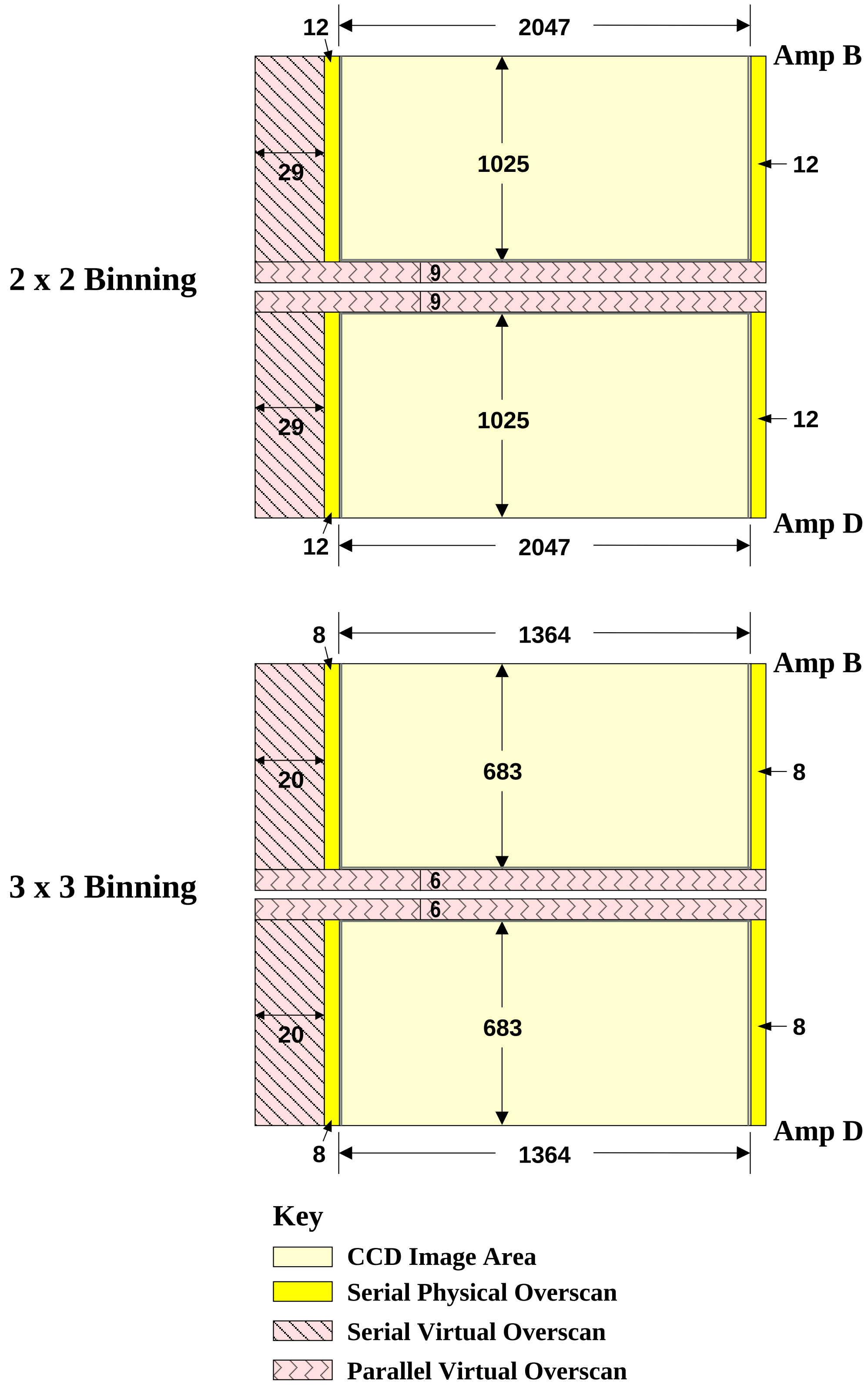

Figure 6: WFC3 UVIS Two-Amp BD Binned Readouts. Indicated pixel ranges exclude mixed rows and columns.

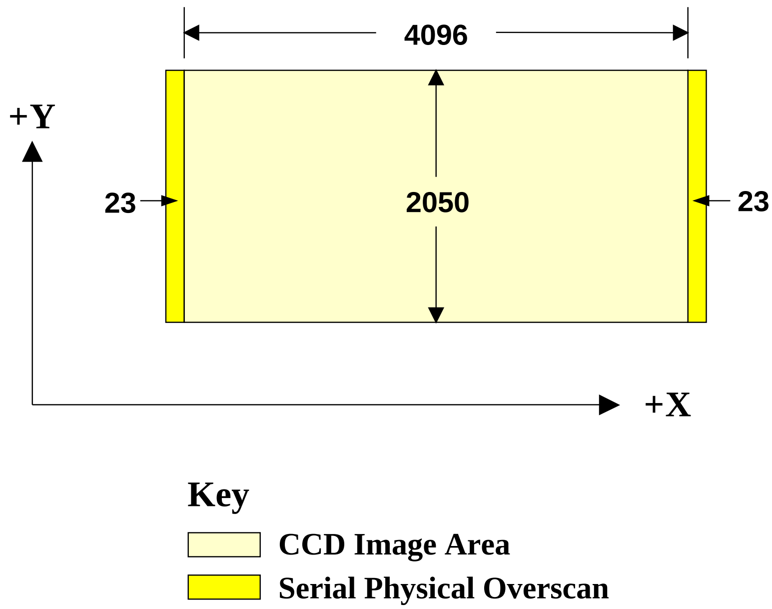

Figure 7: WFC3 UVIS One Amp (Subarray) Readout. This is the maximum possible size for a subarray image.