SPACE TELESCOPE SCIENCE INSTITUTE
Operated for NASA by AURA

Instrument Science Report WFC3-2002-10

Wide Field Camera #3 IR and UVIS Filter Wheel Slot Assignments

O. Lupie
June 30, 2002

ABSTRACT

The purpose of this ISR is to document the WFC3 filter slot assignments and the rationale for the slot selections. The wheel assignments were determined by J. Trauger (UVIS filters - JPL) and the author and R. Boucarut (IR Filters - GSFC) and all were reviewed by the WFC3 Scientific Oversight Committee. The as-built locations, the photos and specified diagrams were provided by Jim Sneary and Joe Sullivan from Ball Aerospace. Verification of positioning and orientation will be performed during ground testing.

1. Introduction

Each channel of the dual channel WFC3 has a unique set of optics and a filter wheel assembly. The UVIS channel holds 48 filter slots: 47 filters and 1 UV grism. Of those 47 filters, 5 are composed of four "quad" filters to increase the selection of (mostly) narrow-band filters. The IR channel has a single filter wheel called the Filter Select Mechanism (FSM) and it contains 14 filters, 2 grisms, a long pass "clear" filter for ground optical alignment which can also be used in orbit as a long pass near IR filter, and a "blank" (or opaque) slot. In the absence of a shutter on the IR channel (only), the blank slot is put in place to protect against the bright earth during occultations.

The slot assignments for most of the filters are not random nor based only on availability at the time of bonding, but are based on a careful prioritization of unique filter manufacturing characteristics and/or the science goals of the filter. The UVIS filter placement was designed primarily by John Trauger(JPL) with review and concurrence of the Scientific Oversight Committee, Ball Aerospace Optical Engineers and Goddard and STScI WFC3 scientists. The IR filter placement was designed by the author and R. Boucarut (GSFC) also with concurrence of the SOC and other relevant team members. In the following short sections, the filter placement decisions are reviewed and documented.

A Note on the WFC3 Filter Program

The WFC3 filter program spanned ~ 3 years and included input from community scientists, the SOC, the filter manufacturers (Barr Associates, Omega Optical), and scientists and engineers from JPL, GSFC, and STScI. Filter specifications, procurement, and characterization for the UVIS and IR filters were handled by JPL (John Trauger, Nasrat Raouf) and GSFC (Ray Boucarut, Manuel Quijada) with support from O. Lupie (STScI). Documentation on filter selection, designs may be found in WFC3 ISR 2000-07,08,09. As built transmission curves may found in later ISRs.

2.0 WFC3 UVIS Channel

2.1 The SOFA

The original WFPC1 Selectable Optical Filter Assembly (SOFA) modified with enhancements to mechanical and electrical systems is the flight filter assembly for WFC3. The SOFA is an ingenious design (JPL, J. Westphal) consisting of a stack of 12 wheels with 5 square slots in each wheel as shown in Figure 1. Four filters and an open slot populate each wheel and the size and thicknesses were pre-constrained by the original WFPC1 design. The filters are confocal, thus simplifying the focus mechanism design, i.e., one focus for all filters. The confocality requirements for the UVIS filter set were provided by JPL in the filter specifications document and documented in Ball-SER-OPT-015 (J.Turner-Valle, 1999). As a consequence, only one filter can be in the light path during an observation.

Figure 1 contains a photo and a schematic of the SOFA filter wheel stack and a photo of a single wheel. Figure 2 is a schematic of the 12 wheels (spread out horizontally for ease of viewing), with slot assignments and a color coding of the science priority of each filter. Figure 3 illustrates the numbering scheme of the slots and Figure 4 the labelling scheme of the quad filters. Tables 1 and 2 list the filters and slot assignments for the full-field and quad filters, respectively.

Figure 1: WFC3 UVIS SOFA: photos and drawings courtesy Ball Aerospace.

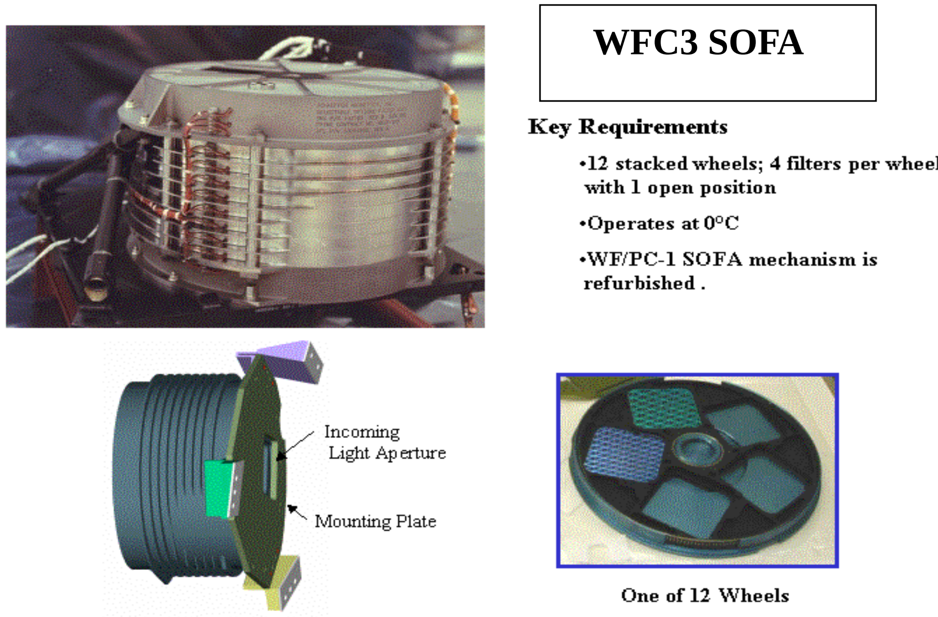


Figure 2: SOFA Wheel Assignments with color-coded science priorities

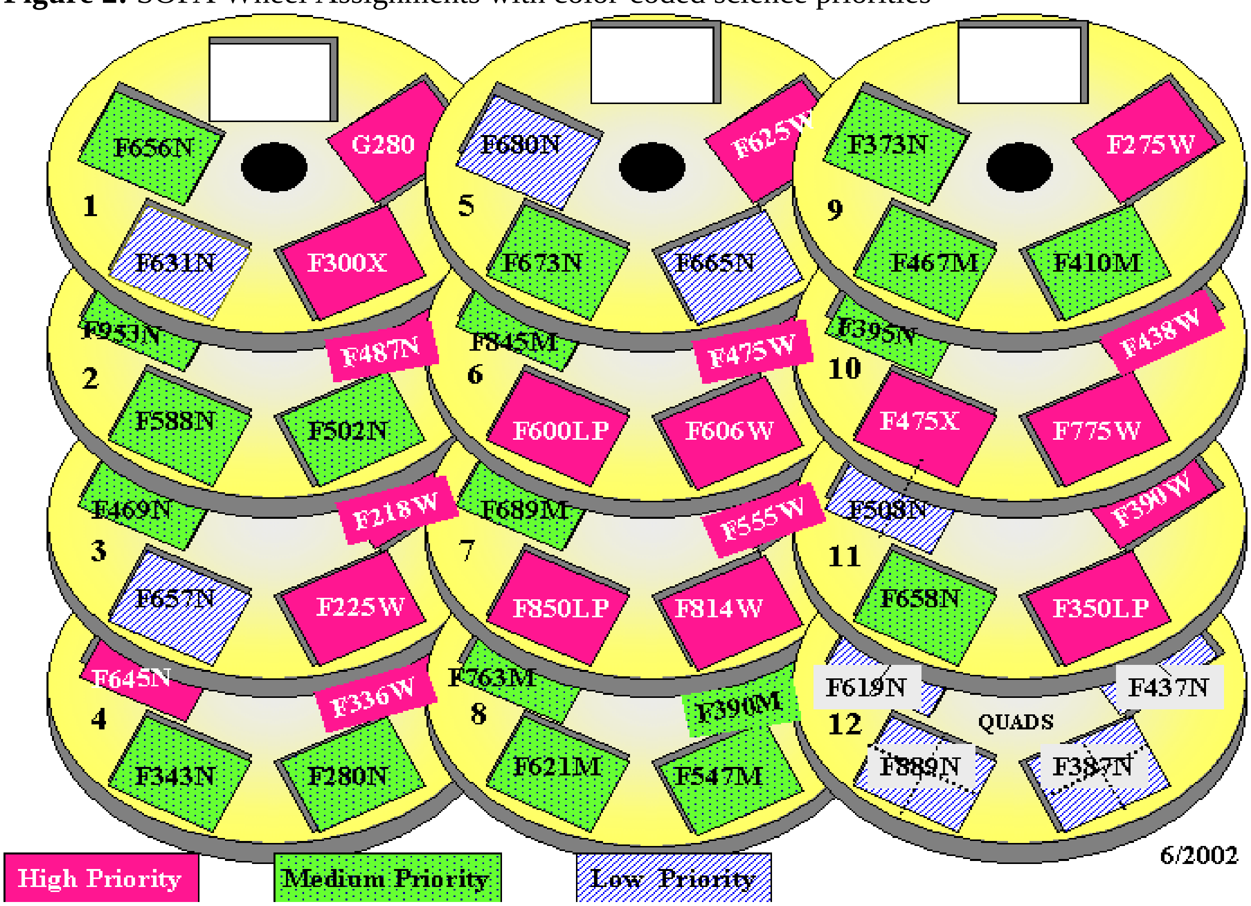


Figure 3: SOFA Wheel Schematic: Slot numbers increase in the clockwise direction from the open slot. In this diagram as in Figure 2, the reader follows the light beam path, i.e., looking into the wheel from the HST OTA to the WFC3 CCD,

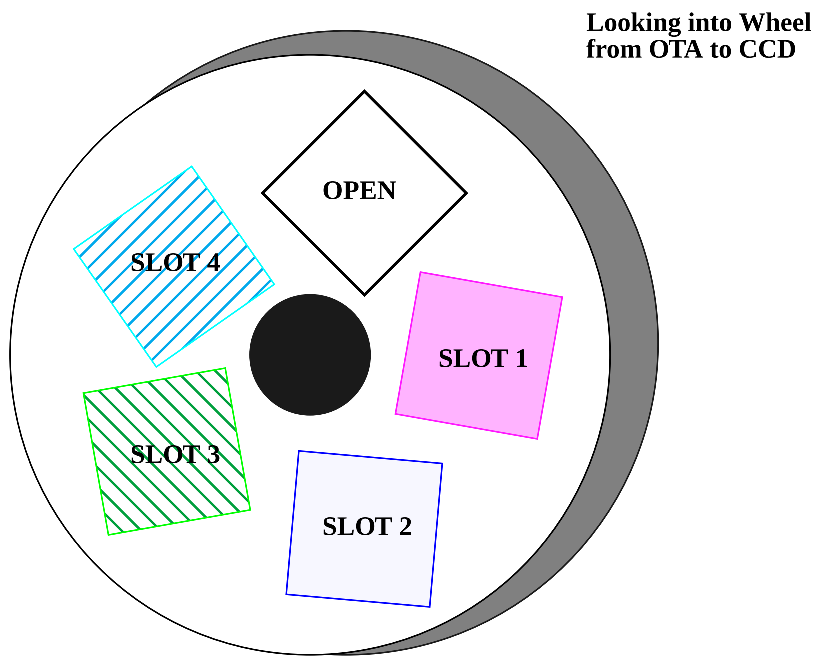


Figure 4: Quad Filters Installation Geometry: The “A” sector is installed nearest the wheel center and the B, C, and D sectors are installed counterclockwise from A.

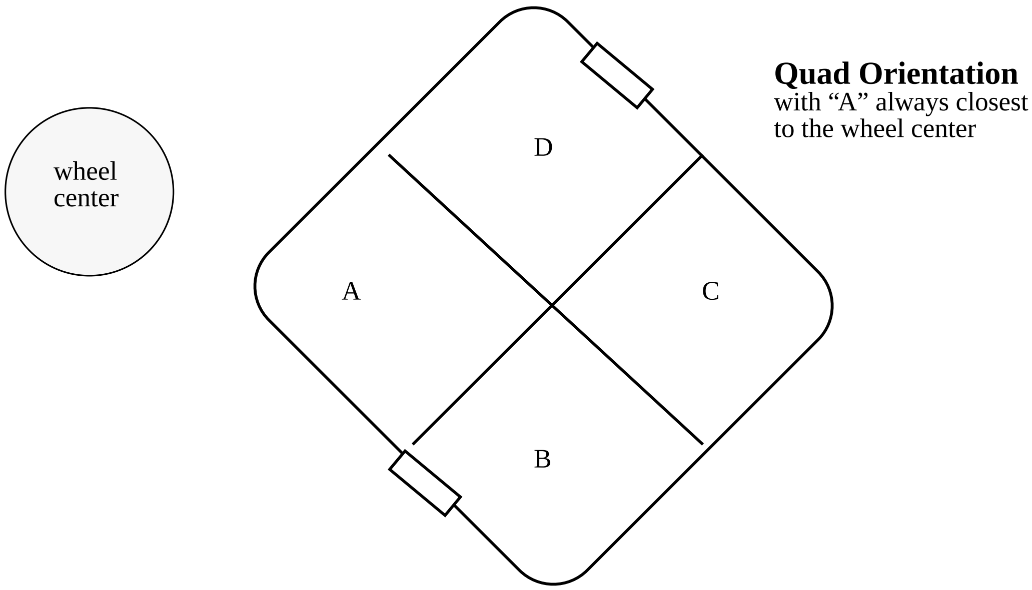


Table 1. WFC3 UVIS Full-field Filters Slot Assignments.

#	Fname	Description	Science Priority	Wheel	Slot *	Wedge Marker	
UVIS 47	G280	UV grism	1	1	1	n/a	
UVIS 15	F300X	very broad	1	1	2	left	
UVIS 34	F631N	[OI] 6300+[SIII]	3	1	3	left	
UVIS 36	F656N	H-a 6563	2	1	4	left	
UVIS 31	F487N	H-b 4861	2	2	1	left	
UVIS 32	F502N	[OIII] 5007	2	2	2	left	
UVIS 33	F588N	HeI	1	2	3	left	
UVIS 41	F953N	[SIII] 9532	2	2	4	left	
UVIS 1	F218W	ISM feature	1	3	1	left	
UVIS 2	F225W	UV	1	3	2	left	
UVIS 48	F657N	Wide Ha+[NIII]	3	3	3	left	
UVIS 30	F469N	HeII 4686	2	3	4		upper
UVIS 4	F336W	U, Stromgren u	1	4	1	left	
UVIS 26	F280N	MgII 2795/ 2802	2	4	2	left	
UVIS 27	F343N	[NeV] 3426	2	4	3		upper
UVIS 35	F645N	Continuum	1	4	4	left	
UVIS 11	F625W	SDSS r	1	5	1	left	
UVIS 38	F665N	z (Ha +[NII])	3	5	2	left	
UVIS 39	F673N	[SII] 6717, 31	2	5	3	left	
UVIS 40	F680N	z (Ha +[NII])	3	5	4	left	
UVIS 10	F475W	SDSS g	1	6	1		upper
UVIS 8	F606W	WFPC2 Wide V	1	6	2		upper
UVIS 17	F600LP	very broad	1	6	3		upper
UVIS 25	F845M	11% fil	2	6	4		upper
UVIS 7	F555W	WFPC2 V	1	7	1		upper
UVIS 9	F814W	WFPC2 Wide I	1	7	2		upper
UVIS 13	F850LP	SDSS z	1	7	3		upper

#	Fname	Description	Science Priority	Wheel	Slot *	Wedge Marker	
UVIS 23	F689M	11% fil	2	7	4	left	
UVIS 18	F390M		2	8	1		upper
UVIS 21	F547M	Stromgren y	2	8	2		upper
UVIS 22	F621M	11%	2	8	3		upper
UVIS 24	F763M	11%	2	8	4		upper
UVIS 3	F275W	UV broad	1	9	1	left	
UVIS 19	F410M	Stromgren v	2	9	2	left	
UVIS 20	F467M	Stromgren b	2	9	3	left	
UVIS 28	F373N	[OII] 3726/29	2	9	4		upper
UVIS 6	F438W	WFPC2 B	1	10	1		upper
UVIS 12	F775W	SDSS i	1	10	2		upper
UVIS 16	F475X	very broad	1	10	3	left	
UVIS 29	F395N	CaII H&K	2	10	4		upper
UVIS 5	F390W	Washington C	1	11	1	left	
UVIS 14	F350LP	very broad	1	11	2		upper
UVIS 37	F658N	[NII]6583	2	11	3		upper

(Table 1. Continued)

Table 2. UVIS Quad Filter Slot Assignments

#	Fname	Description	Science Priority	Wheel	Slot
UVIS 44a	FQ508N	z ([OIII] 5007)	3	11	4-A
UVIS 44b	FQ575N	[NII] 5755	3	11	4-B
UVIS 44c	FQ672N	[SII] 6717	3	11	4-C
UVIS 44d	FQ674N	[SII] 6731	3	11	4-D
UVIS 42a	FQ437N	[OIII]	3	12	1_A
UVIS 42b	FQ232N	CII] 2326	3	12	1-B
UVIS 42c	FQ243N	[NeIV] 2425	3	12	1-C
UVIS 42d	FQ378N	z ([OII] 3727)	3	12	1-D
UVIS 43a	FQ387N	[NeIII] 3869	3	12	2-A
UVIS 43b	FQ422M	continuum	3	12	2-B
UVIS 43c	FQ436N	[OIII] 4363+H g	3	12	2-C
UVIS 43d	FQ492N	z (H-b)	3	12	2-D
UVIS 45a	FQ889N	25/km-agt	3	12	3-A
UVIS 45b	FQ906N	2.5/km-agt	3	12	3-B
UVIS 45c	FQ924N	0.25/km-agt	3	12	3-C
UVIS 45d	FQ937N	0.025/km-agt	3	12	3-D
UVIS 46a	FQ619N	CH4 6194	3	12	4-A
UVIS 46b	FQ634N	6194 cont.+	3	12	4-B
UVIS 46c	FQ727N	CH4 7270	3	12	4-C
UVIS 46d	FQ750N	7270 cont.	3	12	4-D

2.2 SOFA Slot Assignment Considerations

Filter Wheel Usage

If all other considerations were equal, the correct strategy for placement of all but the quads would be to distribute heavily used and highest priority filters among the 12 wheels so that 1) no single wheel would experience excessive rotations, and 2) a single wheel failure would not catastrophically “take out” the highest priority science filters. This strategy was adopted when other considerations, described herein, were not judged as higher priority.

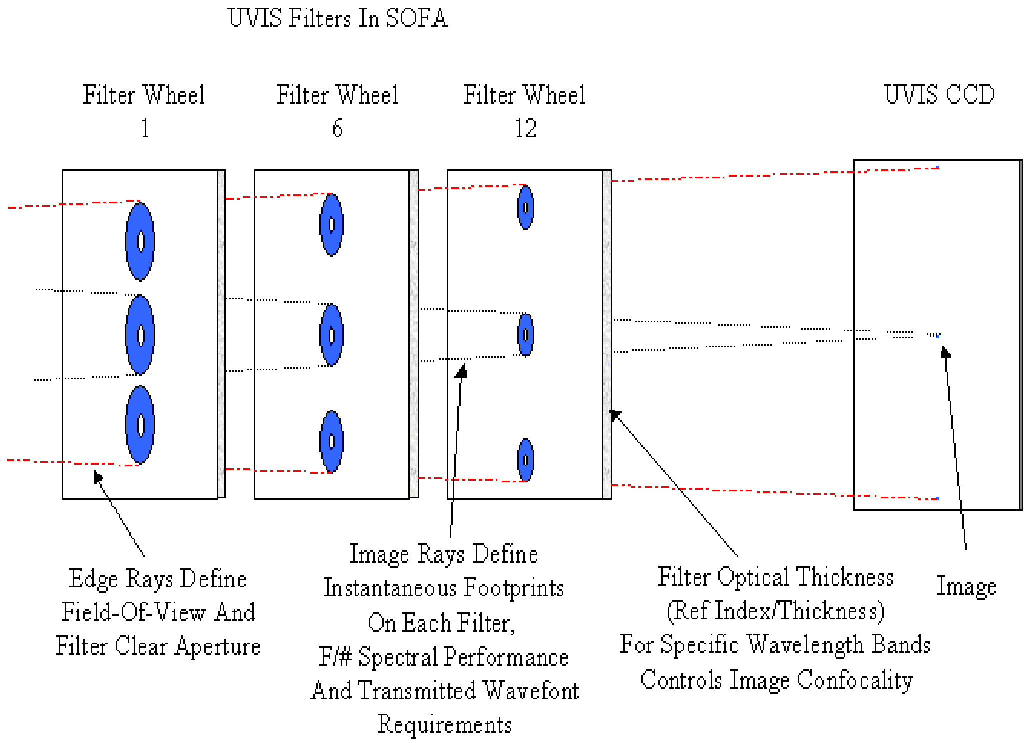
SOFA Placement in the Optical Chain

The wheels are numbered such that wheel 1 is farthest from the UVIS focal plane and wheel 12 is the closest to the CCD. Wheel #12 is 289.344 mm from the CCD. The angle of incidence of the F/31 cone on the filters range from -3 to +3 degrees over the full field of view (Turner-Valle, 1999: Ball SER OPT -019). Figure 5 illustrates 1) the full field footprints, defined as the light beam footprint from the entire FOV, and 2) the instantaneous footprint defined as the light beam footprint from a single point source in the FOV. The edge rays spread out from wheel 1 to wheel 12 and the instantaneous footprint decreases in radius. The Code V optical model output from J. Turner-Valle may be found in the Ball SER-0PT 019. Table 3 summarizes the UVIS beam dimensions at the first and last wheel.

Table 3. UVIS Filter Wheel Optical Footprints (from Ball-SER-OPT 019)

Wheel	Instantaneous Footprint Dimensions	Full Field Footprint Dimensions
1	13mm	45mm
12	10mm	49.5mm

Figure 5: UVIS SOFA: Edge and Image Rays



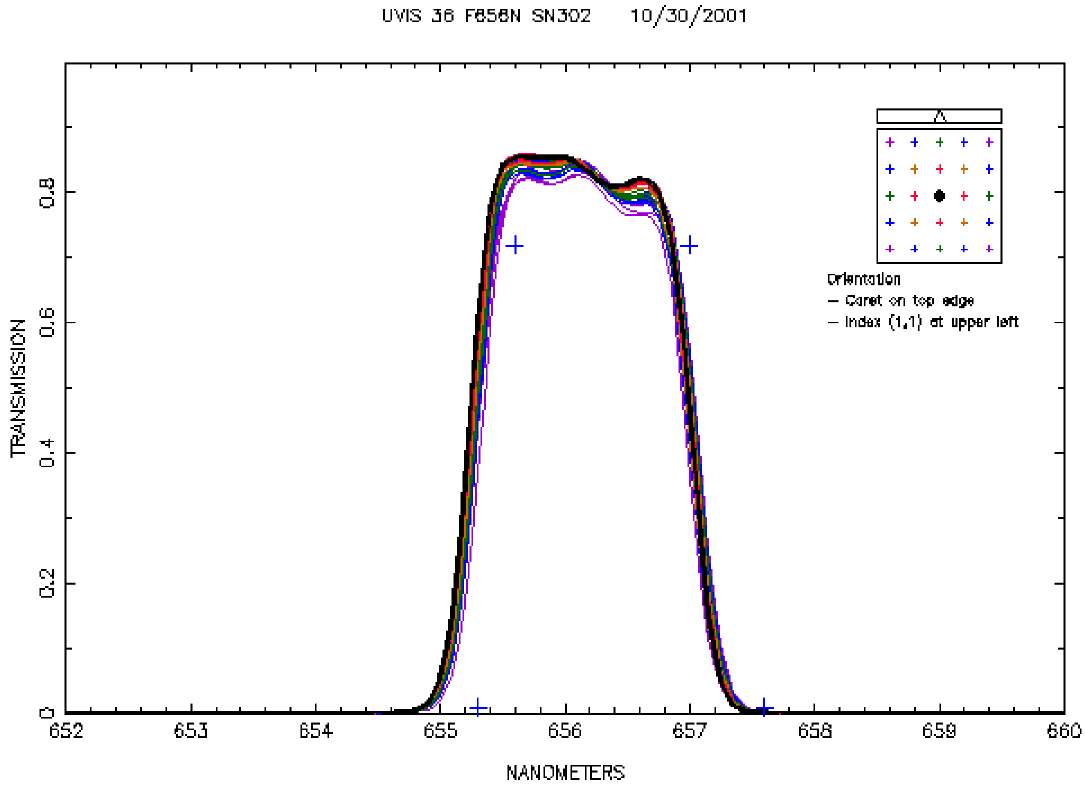
The Beam Footprint and Placement Strategies

The difference in size of the instantaneous footprint between wheels 1 and 12 (and varying linearly in between) suggests strategies for the placement of certain filters:

- Wheels closer to the focal lane (with the smaller instantaneous footprint) are better suited for the "quad" apertures where four filters are positioned in a single slot.
- To achieve the greatest dispersion, the grism g280 is best suited for wheel 1.
- Filters with blemishes or pinholes (from the manufacturing process) are best positioned in a filter with a large instaneous beam footprint - to smear out the effect.

Because these are i*nterference filters,* the +/- 3 degree variation of the angle of incidence across a filter introduces small wavelength shifts from the center to the edge of the filter. The effect is negligible for wide and medium band filters and in most applications is not a problem for most of the narrowband filters. However, trade-offs in the manufacturing process introduced wavelength shifts from center to edge of some of the narrow band filters. When the direction of the shifts from edge to center is blueward, an opposite shift is realized by placing the filter in a wheel where the wavelength shift due to the angle of incidence is comparable. As an example, Figure 6, a transmission plot of F656N (H-alpha), shows a blueward shift from edge to center (colored curves correspond to location in upper right box on plot). The central wavelength shifts as a function of wheel position for the narrowband filters are calculated in Table 4 (provided by J. Trauger, JPL) where the optimal range of central wavelengths shifts at a 1.0 inch radius from the filter center are given for wheel 12 and wheel 1 (varying linearly in between). An effective space index of 1.90 was used for the calculation.

Figure 6: F656N: wavelength shift from filter center to edge (edge shifted redward).Cal



* Data provided by J. Trauger (JPL).

Table 4. Central wavelength shifts for narrowbands (provided by J. Trauger, JPL)

#	Fname	Description	Wheel	Slot	Central-Wave	Shifts (Ang)
					Wheel 12 (FPA)	**Wheel 1 (OTA)***
UVIS 26	F280N	MgII 2795/ 2802	4	2	0.9	1.6
UVIS 27	F343N	[NeV] 3426	4	3	1.1	1.9
UVIS 28	F373N	[OII] 3726/29	9	4	1.3	2.1
UVIS 29	F395N	CaII H&K	10	4	1.3	2.2
UVIS 30	F469N	HeII 4686	3	4	1.6	2.6
UVIS 31	F487N	H-b 4861	2	1	1.6	2.7
UVIS 32	F502N	[OIII] 5007	2	2	1.7	2.8
UVIS 33	F588N	HeI	2	3	2.0	3.3
UVIS 34	F631N	[OI] 6300+[SIII]	1	3	2.1	3.5
UVIS 35	F645N	Continuum	4	4	2.2	3.6

#	Fname	Description	Wheel	Slot	Central-Wave	Shifts (Ang)
					Wheel 12 (FPA)	**Wheel 1 (OTA)***
UVIS 36	F656N	H-a 6563	1	4	2.2	3.7
UVIS 37	F658N	[NII] 6583	11	3	2.2	3.7
UVIS 38	F665N	z (Ha +[NII])	5	2	2.2	3.7
UVIS 39	F673N	[SII] 6717, 31	5	3	2.3	3.8
UVIS 40	F680N	z (Ha +[NII])	5	4	2.3	3.9
UVIS 41	F953N	[SIII] 9532	2	4	3.2	5.3
UVIS 42a	F437N	[OIII]	12	1	1.5	2.4
UVIS 42b	F232N	CII] 2326	12	1	0.8	1.3
UVIS 42c	F243N	[NeIV] 2425	12	1	0.8	1.4
UVIS 42d	F378N	z ([OII] 3727)	12	1	1.3	2.1
UVIS 43a	F387N	[NeIII] 3869	12	2	1.3	2.2
UVIS 43b	F422M	continuum	12	2	1.4	2.4
UVIS 43c	F436N	[OIII] 4363+H g	12	2	1.5	2.4
UVIS 43d	F492N	z (H-b)	12	2	1.6	2.8
UVIS 44a	F508N	z ([OIII] 5007)	11	4	1.7	2.9
UVIS 44b	F575N	[NII] 5755	11	4	1.9	3.2
UVIS 44c	F672N	[SII] 6717	11	4	2.2	3.8
UVIS 44d	F674N	[SII] 6731	11	4	2.3	3.8
UVIS 45a	F889N	25/km-agt	12	3	3.0	5.0
UVIS 45b	F906N	2.5/km-agt	12	3	3.0	5.1
UVIS 45c	F924N	0.25/km-agt	12	3	3.1	5.2
UVIS 45d	F937N	0.025/km-agt	12	3	3.1	5.3
UVIS 46a	F619N	CH4 6194	12	4	2.1	3.5
UVIS 46b	F634N	6194 cont.+	12	4	2.1	3.6
UVIS 46c	F727N	CH4 7270	12	4	2.4	4.1
UVIS 46d	F750N	7270 cont.	12	4	2.5	4.2
UVIS 48	F657N	Wide Ha+[NIII]	3	3	2.2	3.7

WFC3 IR Channel

The IR channel has a single wheel, called the Filter Selection Mechanism (FSM) and the slot assignment procedure is straightforward. The following considerations were addressed when assigning filter locations in the slots:

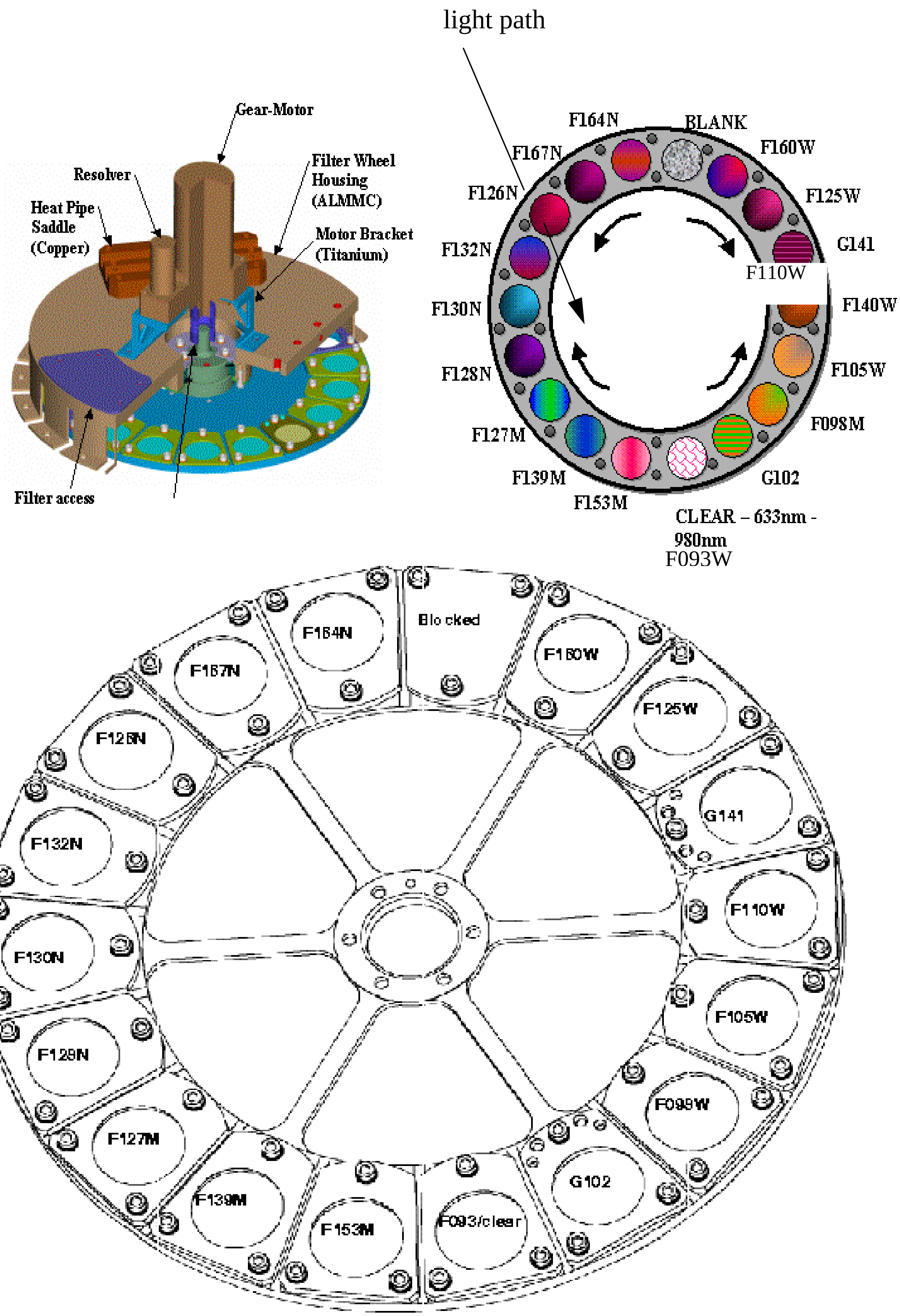
- The FSM moves in either direction and the command logic uses a “shortest distance” algorithm.
- A blocked slot is included in the wheel and is to be used for bright earth.
- A “clear” long-pass visible filter is included in the wheel for ground alignment calibrations. The alignment setup includes lasers that emit 633nm light. The actual filter can be used for science as a short-end wide IR filter, however the blue edge will be defined by the detector qe cutoff.
- At the beginning of each occultation, the wheel moves to the blocked slot.
- Large angle rotations should be minimized where feasible, according to the mechanical engineering experts at Ball Aerospace (from a conversation with R. Martinez 2001). Hence, it is advantageous to place “partner filters” side by side, e.g., line and continuum filters. Lubricant damming from short motions does not appear to be a problem.
- Mechanism lifetime projections suggest caution and minimization of wheel motion within reason.

Given these considerations, the guidelines for slot assignment are prioritized as follows:

1. Large angle rotations should be minimized where feasible --> the most-used filters will be placed closest to the blocked slot.
2. Assume that small angle rotations are acceptable without limitation --> line and continuum filters, related medium band filters, and grism and grism reference filters will be placed side by side or nearby.
3. Assume that detector persistence will not be long-lived or a major concern --> a target that is “bright” through a medium-band filter will not persist in subsequent exposures when the wheel rotates through a wide band filter.
4. Assume that the detector persistence will be substantial (but not a safety issue) for a “narrow-band-bright” object passing across a wide band filter. Select the relative placement of wide and narrowbands to minimize such cases.

These guidelines were used to place the filters in the slot as shown in Figure 7. The wheel mechanism is drawn at the left (provided by Ball Aerospace) and a schematic of the slot assignments is shown at the right and expanded below. Note that the light path direction is into the page.

Figure 7: The IR Filter Wheel Mechanism and slot assignments. Note that the light path is down w/r to the housing figure in the upper left (courtesy Ball Aerospace) and into the page w/r to the drawings of the wheel.



The IR filters, operational names, and associated slots on the wheel are listed in Table 5.

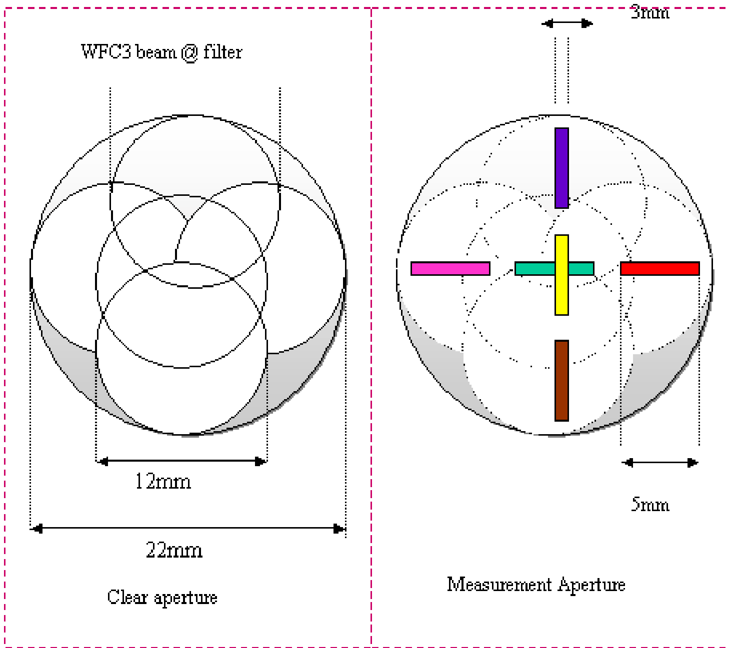
The instantaneous beam footprint at the position of the filter wheel and the full clear aperture is shown in Figure 8. The beam footprint is much larger relative to the clear aperture than the relative sizes in the UVIS channel.

Table 5. WFC3 IR Filter Slot Assignments.

Number	Fname	Description	Central Wave (design) microns	FWHM (design) microns	Wheel Slot (as built)[1]
1	F160W	H_at_1.69 microns	1.545	0.2900	1
2	F125W	Broad J	1.250	0.3000	2
3	G141	"""Red"" Low Res Grism	"NA	0.6000	3
6	F127M	Water/CH_4 continuum	1.270	0.0700	11
7	F139M	Water/CH_4 line	1.385	0.0700	10
8	G102	"""Blue"" High Res Grating	"NA	0.2500	7
17	F098M	"""Blue"" Blue Grism Ref *	"0.985	0.1700	6
10	F164N	[FeII]	1.646	0.0165	17
11	F167N	[FeII] - continuum	1.668	0.0167	16
12	F153M	H_20 and NH_3	1.530	0.0700	9
13	F128N	Paschen Beta	1.284	0.0128	12
14	F130N	Paschen Beta continuum	1.301	0.0130	13
15	F126N	[FeII]	1.259	0.0126	15
16	F132N	Paschen Beta (red-shifted)	1.320	0.0132	14
18	F105W	"Wide FAT ""z	"""1.050	0.3000	5
19	F110W	Wide J	1.150	0.5000	4
20	F093W	Clear	0.900	0.3200	8

[1]Wheel slot assignments are made starting with the 'blank' as number 00 and counting clockwise around the wheel (as seen looking into the wheel in the same direction as the beam).

Figure 8: IR Instantaneous Beam Footprint at the positions of the filters.



Acknowledgements

John Trauger (JPL), Ray Boucarut (GSFC) and Joe Sullivan (Ball Aerospace) were instrumental in discussions of slot assignments. Wayne Baggett (STScI) gratiously provided comments on this document.

Bibliography

Ball SER OPT-071 “UVIS Filters Installation Orientation”, 2002. Sneary, J., Ball Aerospace.
Ball SER OPT-015 “Optical Filter Requirements”, 1999. Turner-Valle, J., Ball Aerospace.
Ball SER OPT-010 “UVIS Filter Focus Shift and CCD Window”, 1999. Turner Valle, J., Ball Aerospace.
Trauger, J. (JPL) private communication.
WFC3 ISR 2000-07,08,09 (Series on WFC3 Filter Design and Selection), Lupie, O.