master file CAL/007

To: Distribution May 16, 1986
From: Keith Horne, Chris Burrows and Jan Koornneef
Subject: DYNAMIC GENERATION OF THROUGHPUT FUNCTIONS: A UNIFIED APPROACH

Throughput functions are essential in calibrating the various modes of HST. In principle, calculating passbands is not a problem since characteristic curves for all the components in the optical train have been obtained by the IDTs and the OTA-team. In collaboration with the Instrument Scientists, all this material has been collected and forwarded to the STECF in Munich where it is being assembled in a homogeneous format. A pre-release version is now available at the STScI.

Calculating an overall passband function from the individual component characteristic curves requires a 'list' of all the components in the optical train for a particular observing mode. As the combined SIs on HST can be used in a total of over 10^9 modes, an equal number of lists would be needed. We propose instead to generate the required list dynamically by using a set of keywords for each mode to trace a path through a graph description of the HST-observatory. Each entry in the resulting list will correspond to a specified column in a specified Midas table containing the component throughput data, and the multiplication of the various entries to produce the overall passband function is then trivial.

In Section I of the present memo, we provide a somewhat formalized description of the use of graphs for the representation of instrument modes.

Section II describes a working prototype throughput generator that currently includes four of the SIs (FOS, FOC, WF/PC and HSP), uses the Midas tables supplied by the STECF and responds to the keywords given in the instrument handbooks (e.g. FOS BLUE G160L etc.). We include pictorial illustrations of the four instrument graphs that have so far been implemented, and partial listings of the ASCII files that enumerate the individual optical components and define the observatory graph.

In Section III, we discuss how instrument information in the component throughput data-base can be updated with the results of on-orbit calibration observations. The structure chosen for the graph description of an individual SI will ultimately determine the extent to which calibration observations obtained in a given mode will affect the calibration of related modes. Further discussion on this subject as well as on requirements for graph maintenance tools is needed.

[Passbands for the ground-based/pre-launch photometric observations of calibration targets are also needed to generate absolute flux distributions for all photometric and spectrophotometric calibration targets. These bandpasses are being collected from the literature and checked for consistency (e.g. Buser and Horne, in preparation)]

1. Graph Structure for the Representation of Instrument Modes

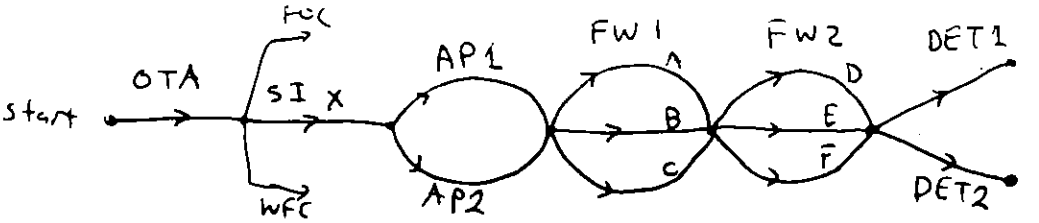
There are more than 10^9 possible observing modes with ST. We need to construct a throughput calibration for each mode. There are two divergent philosophies that could be used to construct such a calibration. The first is to calibrate each mode separately when needed. The second is to somehow calibrate each optical element or group and to combine the elements used in a particular mode. The latter is obviously desirable because of the enormously reduced observing time required [1] and improved instrument understanding that results. The former has received more attention in the past because of its simplicity and, because of two problems that are immediately apparent with the alternative. These problems are discussed below.

The throughput for elements A+B, say is effectively computed from 3 measurements: no elements, A alone and B alone. These measurements lead directly to throughput for the individual components A and B and thus a predicted throughput for the combination. This leads to the first problem: What do you do if the prediction does not agree with a measurement? I am not going to address this problem here because it is very hard. The only point that I would like to make is that if the four calibrations with two elements are carried out independently and disagree the calibration database is inconsistent as a result if the modes are dealt with separately (ie if A+B is treated as a new element C). Thus this problem is fundamental to the process of calibration and must be addressed. The cleanest way to deal with it is to ensure that the database cannot be inconsistent by dealing with the optical path component by component. Any results for combinations of elements need to be understood and used to modify the individual element calibrations somehow.

A second problem is : Given the description of an observation in a science header or proposal, construct a list of the corresponding elements or groups in the optical path. This problem is easy for a scientist familiar with the instrument to answer. The difficulty is in devising a suitably general automatic system that can be easily understood, implemented and maintained. This list can then be used to access the calibration files needed. Thus the input data is a set of keywords; and the output is a list of elements. More than one possible list of keywords can specify one mode. The set of keywords must be checked for consistency and completeness and lack of redundancy.

The SI can be represented as a directed graph, with edges corresponding to elements and vertices corresponding to points in the optical train at which a choice of elements is available. Thus for example, a hypothetical SI consisting of two possible apertures, two filter wheels each carrying three filters, an optional element X (for example a grism) and a choice of two detector modes with differing characteristics would be represented as follows:

[1] 4 filter wheels containing 11 filters and one clear path each (as in the FOC F/94 relay) involve $12^4 = 20736$ separate modes but only 45 separate elementary calibrations.



This type of structure is easily implemented as a relational table with one record for each element and fields giving the node numbers at each end of the corresponding edge. Clearly selecting a list of elements is equivalent to specifying a set of records from this table that traverses the graph. This representation corresponds to our intuitive view of instrument modes. They are a series of possible choices at each stage, not a long unstructured list of possibilities. It also enormously simplifies the problem. Instead of needing to construct one list (of elements) from another (the keywords), all that is now necessary is to be able to chose the right branch from any node given the list of keywords. Then starting at the beginning of the graph (the OTA) we proceed from node to node until we reach a terminal node, keeping track of our path. At the end we can check that all supplied keywords have been used. (This checks for lack of redundancy – A redundant keyword will not be needed) Consistency and completeness are checked by ensuring that the keywords specify one and only one edge from each node.

How do keywords specify the edge to take? This is easy if each edge has one or more keywords associated with it. An edge with no keywords can never be used and therefore can be deleted from the graph. Note that this scheme allows for synonyms amongst the keywords. Also any one keyword can end up being used on more than one edge. If no keyword matches then the program should look to see if the keyword **DEFAULT** occurs on a candidate edge. If so that path should be used and otherwise an error should be flagged.

2. Implementation of the Dynamic Throughput Generator

FORTRAN subroutines have been written implementing the graph structure of instrument modes to generate the throughput function for any observing mode of the HST observatory.

EVALBAND(NWAVE, WAVE, THRU, MODE, ISTAT)

takes as input a wavelength set (NWAVE is the number of wavelengths, WAVE is an array of angstrom values) and a character string MODE containing a list of keywords describing the desired mode. The subroutine returns throughputs for the desired mode at the desired wavelengths in the array THRU, and a status code ISTAT indicating the success or nature of failure of the graph search.

The keywords present in the mode specification are used to find a path through a directed graph representation of the HST in the manner described in the previous section. Possible mode descriptions might be 'FOS BLUE PRISM', 'WF1 F588N POL60', or 'FOC F/96 FIND NUVOP'. The process of tracing through the graph yields a list of the specific optical components that are in the beam for the requested mode. The throughput functions of these individual components are extracted from the appropriate Midas tables or ASCII

files. These component throughput functions are interpolated or extrapolated onto the required wavelength set, and then multiplied together to form the throughput function for the composite mode.

Figures 1-4 depict the graph structure of the FOS, FOC, WF/PC and HSP. The HST graph is specified by two ASCII files that are read by EVALBAND. A listing of the first pages of these files follows the graphs. The file HST.CMP contains a list of all optical components in the HST. Each line in the file gives the unique identification number assigned to a component and the name of the Midas table and column (or ASCII file) in which that component's throughput data is stored. The second file HST.GRF specifies the *links* connecting pairs of nodes in the instrument configuration graph. Each line of the file gives the input node, the output node, the component identification number, and a keyword. The numbers used to identify specific optical components and graph nodes are assigned according to the following conventions:

OTA	1-999	WF/PC	3000-3999
FOS	1000-1999	HSP	4000-4999
FOC	2000-2999	FGS	5000-5999
HRS	6000-6999		

All but the HSP are implemented in the throughput generator with pointers to throughput data stored in the Midas tables that have been delivered by the ST-ECF: the HSP throughput data is taken from ASCII files supplied by Rick White. The FGS and HRS can be implemented as soon as the ST-ECF make their final release of Midas tables.

Perhaps the most important feature of the throughput simulator is that its use of a graph structure allows it to encompass all possible modes of observing with the HST observatory. It can be easily modified by adding a few lines to the two ASCII disk files to add new sets of keywords, to change the structure of the graph, or even to add a new instrument or a new mode of observing with the existing instruments. With a few additional keywords to specify source spectra, the same software would become the core of an instrument simulator or exposure-time calculator. In the next section, we discuss its use in the calibration effort.

3. The Role of the Throughput Generator in Calibration

The throughput generator primed with pre-launch measurements of the throughputs of individual optical components represents our best current information as to the throughput of the ST instruments. We can already calculate sensitivities needed by RSDP for any observing mode that can be named. This tool serves also as the basis for estimating exposure times and planning observational strategies.

In the post-launch era the throughput generator becomes in addition an integral

part of the calibration process. Whenever an observation in a specific mode is made, the passband function is generated for that mode and used to convert the observed count rates to absolute fluxes. The data-base of component throughput functions will be updated as calibration measurements in various observing modes becomes available. These future measurements will include those made during the current thermal-vacuum tests with a calibration source, and measurements of calibration targets from space.

These updates can be accommodated by associating a *corrective component* with each optical component in the observatory graph. The corrective component throughputs are initially unity, and are to be adjusted as new calibration observations are made to ensure that the throughput predictions match the calibration observations.

The extent to which calibration measurements in a given mode update the calibration of closely related modes is determined by the structure we choose for the observatory graph and the strategy used to assign the corrective components. It is reasonable to adopt a simple graph structure initially, as has been done in the current graph. However, it may later be necessary to change the architecture of the graph if the calibration data becomes good enough to prove that the simple description is inadequate. Alternatively, we may build a more complicated graph that tries to anticipate places where more realism may be required. For example, the WF/PC's eight CCD detectors each see light that passes through a different part of the filter. The simple graph assumes that the filter throughput is uniform and uses a single corrective component for the filter: a more complicated graph might use eight different corrective components per filter, one for each CCD.

The main advantage of using a simple graph is that fewer calibration observations are necessary since information from calibration observations in one mode propogates to the calibration of closely related modes. For example, suppose that FOC calibration observations with a series of filters indicate throughputs uniformly higher by 10 % than expected. It would then be a good bet to increase the detector's corrective component, and the improved calibration would immediately be transferred to all modes involving that detector.

There will usually be some ambiguity in the way the corrective components are assigned. If the throughput of a particular mode changes, do you attribute that to a change in the filter, the detector, or the OTA ? It is possible to devise automatic schemes for assigning corrections to components throughout the graph in a way that fits the available calibration measurements and at the same time minimizes some measure of the size of the change. Such schemes could be very useful guides since the instruments are complicated enough that it may not always be obvious which components have changed. In any case when discrepancies do occur it will require the thoughtful judgement of a human mind to understand what went wrong.

These are a few of the unsettled issues that require further thought, discussion, and

especially data. Analysis of the thermal-vacuum throughput test data should give us some indication as to how complicated the graph needs to be. Polairzed and extended sources ought also to be treated in the graph framework, although the details need to be worked out.

Unification of Broadband and Spectrophotometric Calibrations

Keith Horne, May 16, 1986

I would like to emphasize the importance of treating throughput calibrations for broadband and spectrophotometric observations in a uniform way throughout the HST. This is the only way to ensure that the results of photometric and spectrophotometric measurements are directly intercomparable. Broadband and spectrophotometric modes both require the determination of a *dimensionless bandpass throughput function*

$$P(\lambda) = \frac{\text{COUNTS OUT}}{\text{PHOTONS IN}}.$$

For the spectroscopic mode the detected count rate in a pixel at wavelength λ covering the wavelength interval $\Delta\lambda$ is given by

$$C(\lambda) = Area P(\lambda) f_\lambda(\lambda) \frac{\lambda}{hc} \Delta\lambda,$$

were $Area$ is the nominal collecting area of the telescope, and the division by $h\nu = hc/\lambda$ converts the energy flux $f_\lambda \Delta\lambda$ to a photon flux as is appropriate for the photon-counting detectors. For a photometric mode the detected count rate through passband P is

$$C(P) = \frac{Area}{hc} \int P(\lambda) f_\lambda(\lambda) \lambda d\lambda.$$

The only difference is that in the spectrophotometric case the star's flux distribution can be considered constant across the narrow bandwidth of each spectroscopic pixel, whereas in the photometric case the integral over wavelength must be performed more carefully.

It is of course true for a photometric mode but not for a spectrophotometric mode that the throughput calibration can be expressed as a single number U giving the conversion between observed count rate and flux density

$$f_\lambda(P) = UC(P).$$

U is the "inverse sensitivity" of the photometric mode, i.e. the flux density required to produce a unit response of 1 count/second. This difference is not a fundamental distinction, however, because the full throughput function is needed for the calibration in both cases. We determine U for a photometric mode by measuring a count rate for a standard star whose spectrum $f_\lambda(\lambda)$ is known. Since f_λ is not uniform over the passband, we have to take a specific average of the star's flux density,

$$f_\lambda(P) = \frac{\int f_\lambda(\lambda) P(\lambda) \lambda d\lambda}{\int P(\lambda) \lambda d\lambda}.$$

Thus the full throughput function is needed to to calibrate the photometric mode. The inverse sensitivity U can be calculated directly from the throughput function.

$$U = \frac{hc}{Area} \int P(\lambda)\lambda d\lambda.$$

The throughput calibration of the HST consists of determining and following the evolution of throughput functions for all modes, both spectroscopic and photometric.

DEMO.CMP

GRAPH DESCRIPTION for a simple PHOTOMETER

```
1        'TELESCOPE.TBL|1'
2        'PINHOLE.TBL|LARGE'
3        'PINHOLE.TBL|SMALL'
4        'FILTER.TBL|U'
5        'FILTER.TBL|B'
6        'FILTER.TBL|V'
7        'DETECTOR.TBL|S20'
8        'DETECTOR.TBL|GaAs'
```

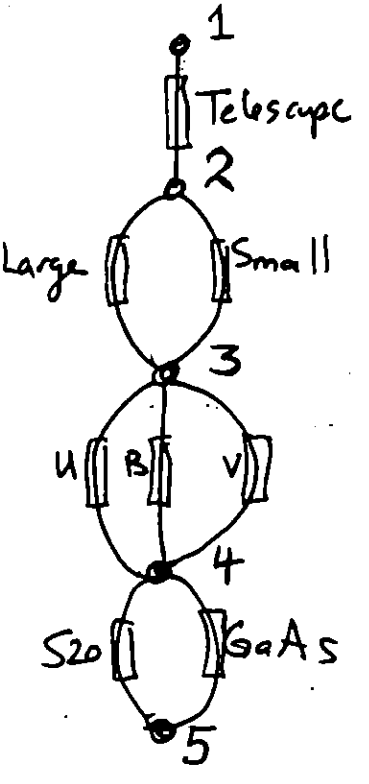
DEMO.GRF

```
IN      OUT     ELEMENT KEYWORD          COMMENTS
1       2       1       'OTA'    photometer configuration graph:
2       3       2       'P1'              1     telescope
2       3       3       'P2'             / \
3       4       4       'F1'             2 3    2 pinholes (large,small)
3       4       5       'F2'             \ /
3       4       6       'F3'             /|\
4       5       7       'D1'             456    3 filters (U,B,V)
4       5       8       'D2'             \|/
2       3       2       'DEFAULT'        / \
3       4       4       'DEFAULT'        7 8    2 detectors (S20,GaAs)
4       5       7       'DEFAULT'

3       4       4       'U'
3       4       5       'B'
3       4       6       'V'

2       3       2       'LARGE'
2       3       3       'SMALL'

4       5       7       'S20'
4       5       8       'GaAs'
```



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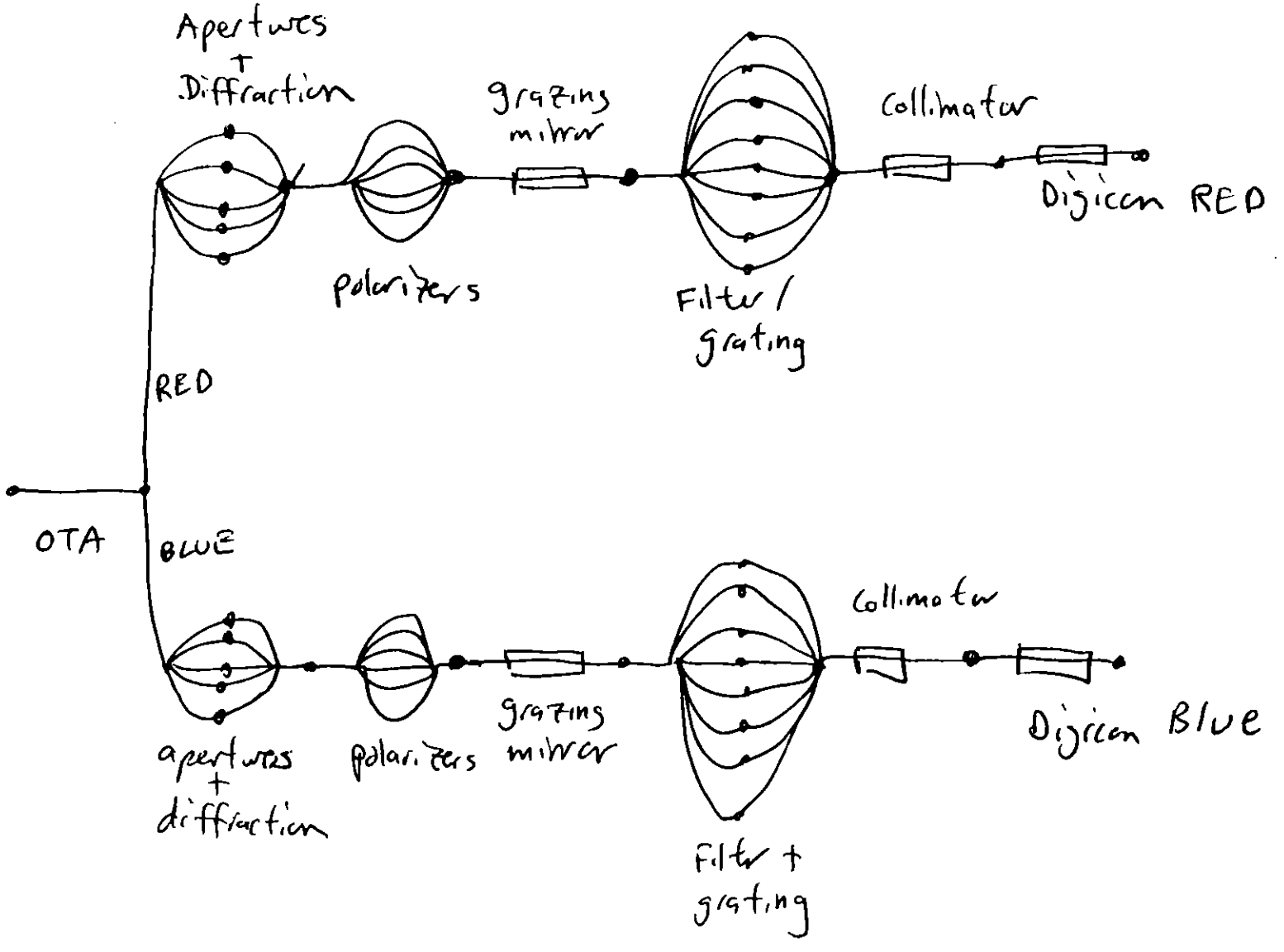
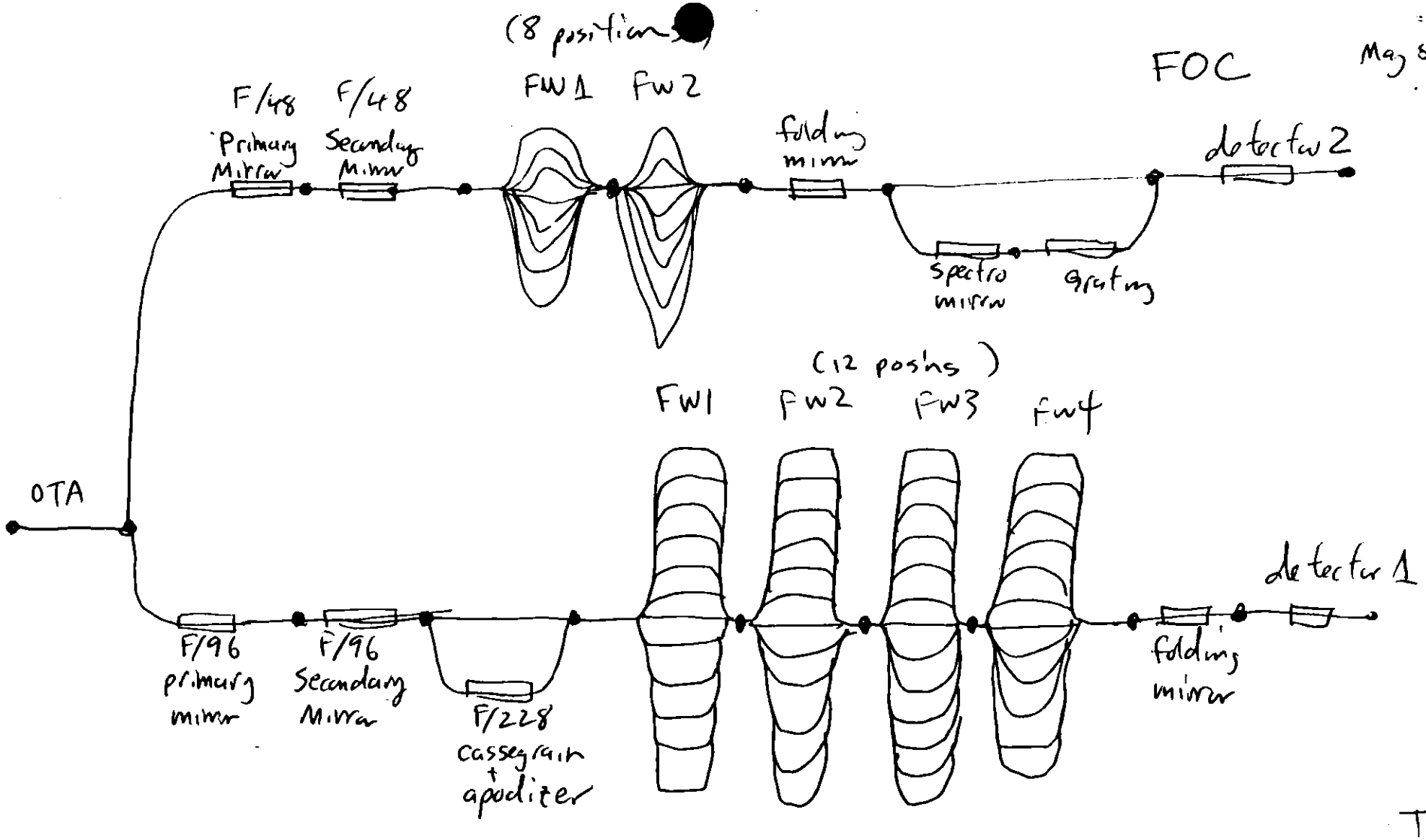
FOS



FOS GRAPH

HST



FOC GRAPH
Fig 2

WF/PC

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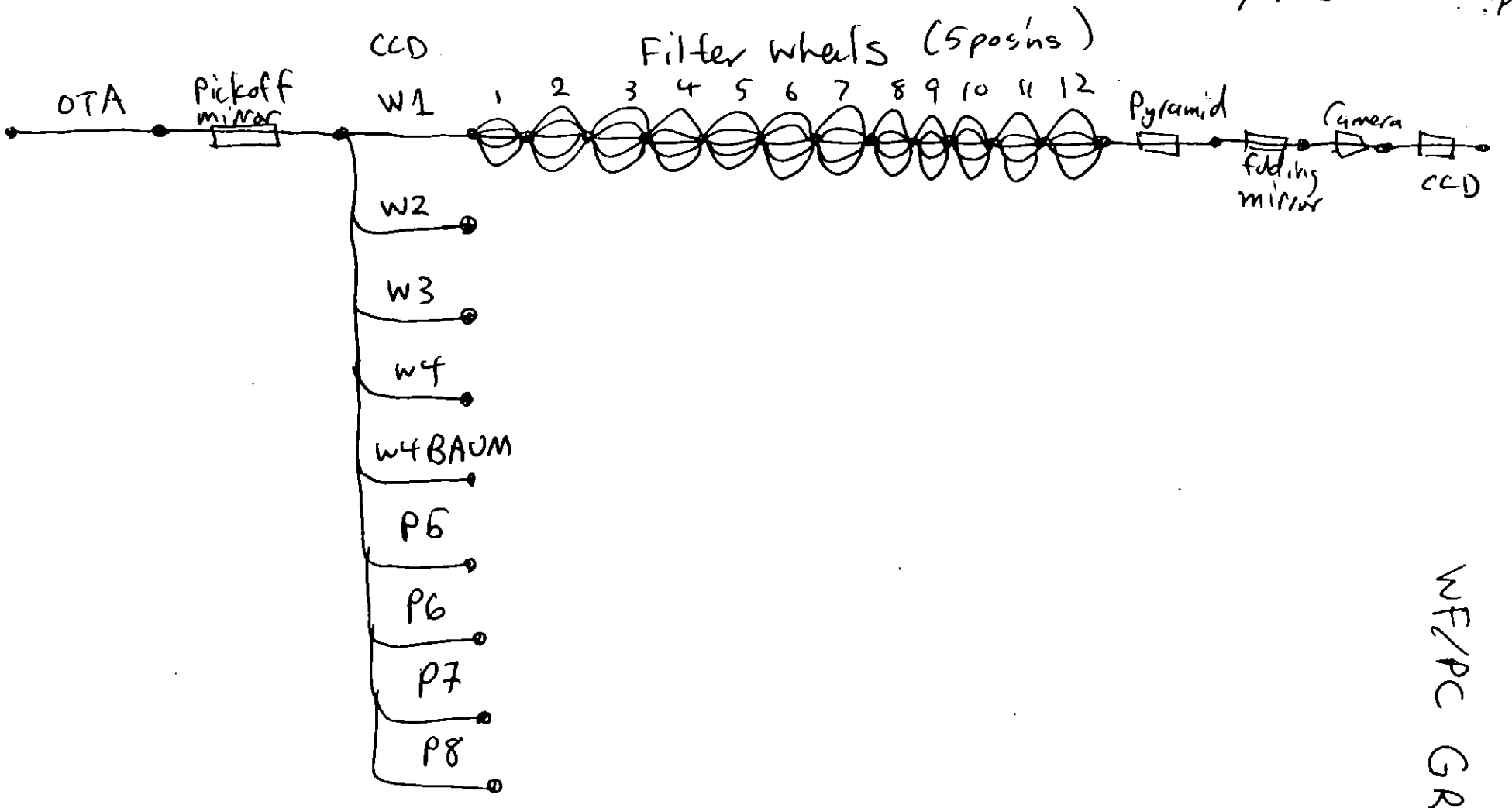

WF/PC GRAPH

Fig 3

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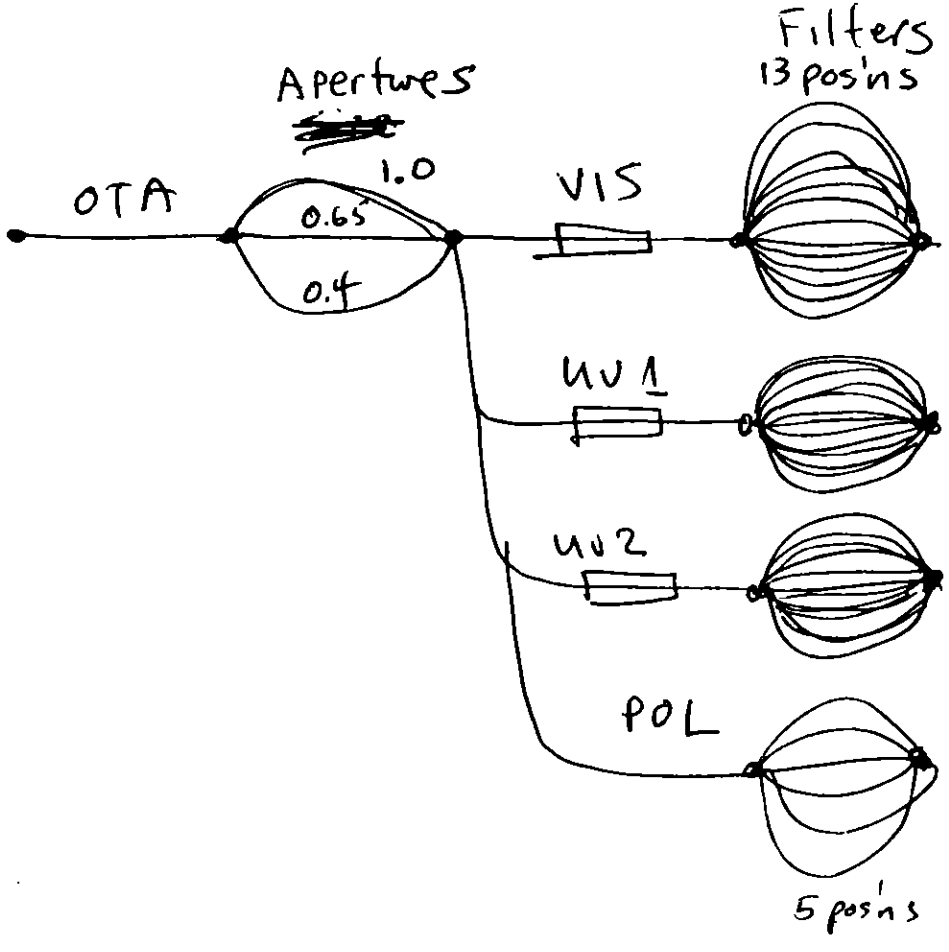
KRi

HSP



HSP GRAPH
FIG 4

HST.CMP


```
-----------------------------------------------------------
      components list for hubble space telescope
-----------------------------------------------------------

; default components

        0       'SP:DEFAULT.TBL|2 DARK'          ZERO
        1       'SP:DEFAULT.TBL|3 CLEAR' ONE

; optical telescope assembly

        100     'HSTDIR:HOTOVTR.TBL|2 OTA'        HST optical telescope assembly
-----------------------------------------------------------
; FOS digicon detectors

        1100    'FOSDIR:HFSDTQE.TBL|2 BLUDIG'    blue digicon qe
        1110    'FOSDIR:HFSDTQE.TBL|3 REDDIG'     red digicon qe

; FOS grazing-incidence mirrors

        1101    'FOSDIR:HFSMIRE.TBL|2 GRAZA'       GRAZA
        1111    'FOSDIR:HFSMIRE.TBL|3 GRAZB'       GRAZB

; FOS collimator mirrors

        1102    'FOSDIR:HFSMIRE.TBL|4 COLLA'      COLLA
        1112    'FOSDIR:HFSMIRE.TBL|5 COLLB'      COLLB

; FOS apertures

        1202    'FOSDIR:HFSAPTP.TBL|2 APB2'       0.3
        1203    'FOSDIR:HFSAPTP.TBL|3 APA3'       0.25-PAIR
        1204    'FOSDIR:HFSAPTP.TBL|4 APA4'       0.1-PAIR
        1205    'FOSDIR:HFSAPTP.TBL|5 APB1'       0.5
        1206    'FOSDIR:HFSAPTP.TBL|6 APA2'       0.5-PAIR
        1207    'FOSDIR:HFSAPTP.TBL|7 APC2'       0.25x2.0,C2
        1208    'FOSDIR:HFSAPTP.TBL|8 APC4'       0.7x2.0-BAR,C4

        1210    'FOSDIR:HFSAPDI.TBL|2 APA4FIT'    0.1-PAIR,A4U
        1211    'FOSDIR:HFSAPDI.TBL|3 APA3FIT'    0.25-PAIR,A3U

; FOS gratings

        1302    'FOSDIR:HFSGRRE.TBL|2 H13' G130H
        1303    'FOSDIR:HFSGRRE.TBL|3 H19' G190H
        1304    'FOSDIR:HFSGRRE.TBL|4 H27' G270H
        1305    'FOSDIR:HFSGRRE.TBL|5 H40' G400H
        1306    'FOSDIR:HFSGRRE.TBL|6 H57' G570H
        1307    'FOSDIR:HFSGRRE.TBL|7 H78' G780H
        1308    'FOSDIR:HFSGRRE.TBL|8 L15' G160L
        1309    'FOSDIR:HFSGRRE.TBL|9 L65' G650L
        1310    'FOSDIR:HFSGRRE.TBL|10 PRI' PRISM

; FOS filters

        1312    'FOSDIR:HFSFITR.TBL|2 UVBLK'      UVBLK
        1313    'FOSDIR:HFSFITR.TBL|3 WG305'      WG305
        1314    'FOSDIR:HFSFITR.TBL|4 GG375'      GG375
        1315    'FOSDIR:HFSFITR.TBL|5 OG530'      OG530
```

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; FOS grating fudge factors

1352    'FOSDIR:HFSGRFB.TBL|2 FBH13'      G130H-BLUEFUDGE
1353    'FOSDIR:HFSGRFB.TBL|3 FBH19'      G190H-BLUEFUDGE
1354    'FOSDIR:HFSGRFB.TBL|4 FBH27'      G270H-BLUEFUDGE
1355    'FOSDIR:HFSGRFB.TBL|5 FBH40'      G400H-BLUEFUDGE
1356    'FOSDIR:HFSGRFB.TBL|6 FBH57'      G570H-BLUEFUDGE
1357    'FOSDIR:HFSGRFB.TBL|7 FBH78'      G780H-BLUEFUDGE
1358    'FOSDIR:HFSGRFB.TBL|8 FBL15'      G160L-BLUEFUDGE
1359    'FOSDIR:HFSGRFB.TBL|9 FBL65'      G650L-BLUEFUDGE
1360    'FOSDIR:HFSGRFB.TBL|10 FBPRI'      PRISM-BLUEFUDGE

1372    'FOSDIR:HFSGRFR.TBL|2 FRH13'        G130H-REDFUDGE
1373    'FOSDIR:HFSGRFR.TBL|3 FRH19'        G190H-REDFUDGE
1374    'FOSDIR:HFSGRFR.TBL|4 FRH27'        G270H-REDFUDGE
1375    'FOSDIR:HFSGRFR.TBL|5 FRH40'        G400H-REDFUDGE
1376    'FOSDIR:HFSGRFR.TBL|6 FRH57'        G570H-REDFUDGE
1377    'FOSDIR:HFSGRFR.TBL|7 FRH78'        G780H-REDFUDGE
1378    'FOSDIR:HFSGRFR.TBL|8 FRL15'        G160L-REDFUDGE
1379    'FOSDIR:HFSGRFR.TBL|9 FRL65'        G650L-REDFUDGE
1380    'FOSDIR:HFSGRFR.TBL|10 FRPRI'        PRISM-REDFUDGE

-------------------------------------------------------------

; FOC detector + transfer optics + OTA

2002    'FOCDIR:HFCOVEF.TBL|2 F2EF'      ota+foc efficiency f/228
2003    'FOCDIR:HFCOVEF.TBL|3 F9EF'      ota+foc efficiency f/96
2004    'FOCDIR:HFCOVEF.TBL|4 F4EF'      ota+foc efficiency f/48

; FOC F/96,F/228 filter wheel 1

2101    'SP:DEFAULT.TBL|3 CLEAR' ONE
2102    'FOCDIR:HF9FITR.TBL|02 W1P02'     W1P02   F8ND
2103    'FOCDIR:HF9FITR.TBL|03 W1P03'     W1P03   POL120
2104    'FOCDIR:HF9FITR.TBL|04 W1P04'     W1P04   F2ND
2105    'FOCDIR:HF9FITR.TBL|05 W1P05'     W1P05   F600M
2106    'FOCDIR:HF9FITR.TBL|06 W1P06'     W1P06   F630M
2107    'FOCDIR:HF9FITR.TBL|07 W1P07'     W1P07   POLO
2108    'FOCDIR:HF9FITR.TBL|08 W1P08'     W1P08   F4ND
2109    'FOCDIR:HF9FITR.TBL|09 W1P09'     W1P09   F6ND
2110    'FOCDIR:HF9FITR.TBL|10 W1P10'     W1P10   PRISM2
2111    'FOCDIR:HF9FITR.TBL|11 W1P11'     W1P11   POL60
2112    'FOCDIR:HF9FITR.TBL|12 W1P12'     W1P12   PRISM1

; FOC F/96,F/228 filter wheel 2

2201    'SP:DEFAULT.TBL|3 CLEAR' ONE
2202    'FOCDIR:HF9FITR.TBL|13 W2P02'     W2P02   F370LP
2203    'FOCDIR:HF9FITR.TBL|14 W2P03'     W2P03   F342W
2204    'FOCDIR:HF9FITR.TBL|15 W2P04'     W2P04   F430W
2205    'FOCDIR:HF9FITR.TBL|16 W2P05'     W2P05   F480LP
2206    'FOCDIR:HF9FITR.TBL|17 W2P06'     W2P06   F140W
2207    'FOCDIR:HF9FITR.TBL|18 W2P07'     W2P07   F175W
2208    'FOCDIR:HF9FITR.TBL|19 W2P08'     W2P08   F220W
2209    'FOCDIR:HF9FITR.TBL|20 W2P09'     W2P09   F275W
2210    'FOCDIR:HF9FITR.TBL|21 W2P10'     W2P10   F320W
2211    'FOCDIR:HF9FITR.TBL|22 W2P11'     W2P11   F486N
2212    'FOCDIR:HF9FITR.TBL|23 W2P12'     W2P12   F501N
```

```
; FOC F/96,F/228 filter wheel 3

        2301    'SP:DEFAULT.TBL|3 CLEAR' ONE
        2302    'FOCDIR:HF9FITR.TBL|24 W3P02'     W3P02   F210M
        2303    'FOCDIR:HF9FITR.TBL|25 W3P03'     W3P03   F120M
        2304    'FOCDIR:HF9FITR.TBL|26 W3P04'     W3P04   F152M
        2305    'FOCDIR:HF9FITR.TBL|27 W3P05'     W3P05   F1ND
        2306    'FOCDIR:HF9FITR.TBL|28 W3P06'     W3P06   F130M
        2307    'FOCDIR:HF9FITR.TBL|29 W3P07'     W3P07   F190M
        2308    'FOCDIR:HF9FITR.TBL|30 W3P08'     W3P08   F170M
        2309    'FOCDIR:HF9FITR.TBL|31 W3P09'     W3P09   F140M
        2310    'FOCDIR:HF9FITR.TBL|32 W3P10'     W3P10   F195M
        2311    'FOCDIR:HF9FITR.TBL|33 W3P11'     W3P11   F165M
        2312    'FOCDIR:HF9FITR.TBL|34 W3P12'     W3P12   F231M

; FOC F/96,F/228 filter wheel 4

        2401    'SP:DEFAULT.TBL|3 CLEAR' ONE
        2402    'FOCDIR:HF9FITR.TBL|35 W4P02'     W4P02   F346M
        2403    'FOCDIR:HF9FITR.TBL|36 W4P03'     W4P03   F410M
        2404    'FOCDIR:HF9FITR.TBL|37 W4P04'     W4P04   F470M
        2405    'FOCDIR:HF9FITR.TBL|38 W4P05'     W4P05   F550M
        2406    'FOCDIR:HF9FITR.TBL|39 W4P06'     W4P06   F372M
        2407    'FOCDIR:HF9FITR.TBL|40 W4P07'     W4P07   F130LP
        2408    'FOCDIR:HF9FITR.TBL|41 W4P08'     W4P08   F502M
        2409    'FOCDIR:HF9FITR.TBL|42 W4P09'     W4P09   F253M
        2410    'FOCDIR:HF9FITR.TBL|43 W4P10'     W4P10   F278M
        2411    'FOCDIR:HF9FITR.TBL|44 W4P11'     W4P11   F307M
        2412    'FOCDIR:HF9FITR.TBL|45 W4P12'     W4P12   F437M

; FOC F/48 filter wheel 1

        2501    'SP:DEFAULT.TBL|3 CLEAR' ONE
        2502    'FOCDIR:HF4FITR.TBL|02 W1P02'     W1P02   FOPCD PRISM3
        2503    'FOCDIR:HF4FITR.TBL|03 W1P03'     W1P03   F150W
        2504    'FOCDIR:HF4FITR.TBL|04 W1P04'     W1P04   F195W
        2505    'FOCDIR:HF4FITR.TBL|05 W1P05'     W1P05   F140W
        2506    'FOCDIR:HF4FITR.TBL|06 W1P06'     W1P06   F175W
        2507    'FOCDIR:HF4FITR.TBL|07 W1P07'     W1P07   F305LP
        2508    'FOCDIR:HF4FITR.TBL|08 W1P08'     W1P08   F220W

; FOC F/48 filter wheel 2

        2601    'SP:DEFAULT.TBL|3 CLEAR' ONE
        2602    'FOCDIR:HF4FITR.TBL|09 W2P02'     W2P02   NUVOP PRISM2
        2603    'FOCDIR:HF4FITR.TBL|10 W2P03'     W2P03   F342W
        2604    'FOCDIR:HF4FITR.TBL|11 W2P04'     W2P04   F430W
        2605    'FOCDIR:HF4FITR.TBL|12 W2P05'     W2P05   F180LP
        2606    'FOCDIR:HF4FITR.TBL|13 W2P06'     W2P06   F275W
        2607    'FOCDIR:HF4FITR.TBL|14 W2P07'     W2P07   F130LP
        2608    'FOCDIR:HF4FITR.TBL|15 W2P08'     W2P08   FUVOP PRISM1

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; WFC CCD detectors

        3501    'WFPCDIR:HWPDTQE.TBL|2 WFDTQE01' W1 CCD ?
        3502    'WFPCDIR:HWPDTQE.TBL|3 WFDTQE02' W2 CCD ?
        3503    'WFPCDIR:HWPDTQE.TBL|4 WFDTQE03' W3 CCD ?
        3504    'WFPCDIR:HWPDTQE.TBL|5 WFDTQE04' W4 CCD ?
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;PC CCD detectors

        3505    'WFPCDIR:HWPDTQE.TBL|6 PCDTQE01' P5 CCD ?
        3506    'WFPCDIR:HWPDTQE.TBL|7 PCDTQE02' P6 CCD ?
        3507    'WFPCDIR:HWPDTQE.TBL|8 PCDTQE03' P7 CCD ?
        3508    'WFPCDIR:HWPDTQE.TBL|2 PCDTQE04' P8 CCD ?

; WF/PC filter wheel 1 (5 positions)

        3010    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3011    'WFPCDIR:HWPFITR.TBL|06 A01'      F225SP
        3012    'WFPCDIR:HWPFITR.TBL|09 B01'      F290SP
        3013    'WFPCDIR:HWPFITR.TBL|04 C01'      G450
        3014    'WFPCDIR:HWPFITR.TBL|05 D01'      G800

; WF/PC filter wheel 2 (5 positions)

        3020    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3021    'WFPCDIR:HWPFITR.TBL|02 A02'      F122M
        3022    'WFPCDIR:HWPFITR.TBL|10 B02'      F336W
        3023    'WFPCDIR:HWPFITR.TBL|15 C02'      F439W
        3024    'WFPCDIR:HWPFITR.TBL|05 D02'      G200

; WF/PC filter wheel 3 (5 positions)

        3030    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3031    'SP:DEFAULT.TBL|3 CLEAR' POL0     *
        3032    'SP:DEFAULT.TBL|3 CLEAR' POL60    *
        3033    'SP:DEFAULT.TBL|3 CLEAR' POL120   *
        3034    'WFPCDIR:HWPFITR.TBL|43 D03'      F1083N

; WF/PC filter wheel 4 (5 positions)

        3040    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3041    'WFPCDIR:HWPFITR.TBL|04 A04'      F157W
        3042    'WFPCDIR:HWPFITR.TBL|05 B04'      F194W
        3043    'WFPCDIR:HWPFITR.TBL|07 C04'      F230W
        3044    'WFPCDIR:HWPFITR.TBL|08 D04'      F284W

; WF/PC filter wheel 5 (5 positions)

        3050    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3051    'WFPCDIR:HWPFITR.TBL|23 A05'      F569W
        3052    'WFPCDIR:HWPFITR.TBL|32 B05'      F675W
        3053    'WFPCDIR:HWPFITR.TBL|37 C05'      F791W
        3054    'WFPCDIR:HWPFITR.TBL|30 D05'      F658N

; WF/PC filter wheel 6 (5 positions)

        3060    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3061    'WFPCDIR:HWPFITR.TBL|27 A06'      F631N
        3062    'WFPCDIR:HWPFITR.TBL|29 B06'      F656N
        3063    'WFPCDIR:HWPFITR.TBL|31 C06'      F664N
        3064    'WFPCDIR:HWPFITR.TBL|33 D06'      F702W

; WF/PC filter wheel 7 (5 positions)

        3070    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3071    'WFPCDIR:HWPFITR.TBL|12 A07'      F375N
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        3072    'WFPCDIR:HWPFITR.TBL|19 B07'      F502N
        3073    'WFPCDIR:HWPFITR.TBL|14 C07'      F437N
        3074    'WFPCDIR:HWPFITR.TBL|24 D07'      F588N

; WF/PC filter wheel 8 (5 positions)

        3080    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3081    'WFPCDIR:HWPFITR.TBL|11 A08'      F368M
        3082    'WFPCDIR:HWPFITR.TBL|13 B08'      F413M
        3083    'WFPCDIR:HWPFITR.TBL|26 C08'      F622W
        3084    'WFPCDIR:HWPFITR.TBL|18 D08'      F492M

; WF/PC filter wheel 9 (5 positions)

        3090    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3091    'WFPCDIR:HWPFITR.TBL|21 A09'      F547M
        3092    'WFPCDIR:HWPFITR.TBL|22 B09'      F555W
        3093    'WFPCDIR:HWPFITR.TBL|28 C09'      F648M
        3094    'WFPCDIR:HWPFITR.TBL|34 D09'      F718M

; WF/PC filter wheel 10 (5 positions)

        3100    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3101    'WFPCDIR:HWPFITR.TBL|38 A10'      F814W
        3102    'WFPCDIR:HWPFITR.TBL|40 B10'      F875M
        3103    'WFPCDIR:HWPFITR.TBL|36 C10'      F785LP
        3104    'WFPCDIR:HWPFITR.TBL|42 D10'      F1042M

; WF/PC filter wheel 11 (5 positions)

        3110    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3111    'WFPCDIR:HWPFITR.TBL|03 A11'      F128LP
        3112    'WFPCDIR:HWPFITR.TBL|16 B11'      F469N
        3113    'WFPCDIR:HWPFITR.TBL|17 C11'      F487N
        3114    'WFPCDIR:HWPFITR.TBL|20 D11'      F517N

; WF/PC filter wheel 12 (5 positions)

        3120    'SP:DEFAULT.TBL|3 CLEAR' ONE
        3121    'WFPCDIR:HWPFITR.TBL|39 A12'      F850LP
        3122    'WFPCDIR:HWPFITR.TBL|25 B12'      F606W
        3123    'WFPCDIR:HWPFITR.TBL|35 C12'      F725LP
        3124    'WFPCDIR:HWPFITR.TBL|41 D12'      F889N
-------------------------------------------------------------

;  HSP Image Dissector Tubes

        4001    'HSPDIR:CSTEIDTQE.DAT'    UV1, UV2
        4002    'HSPDIR:VISIDTQE.DAT'     VIS, POL
        4003    'HSPDIR:PMTQE.DAT'        PMT

;  HSP Apertures

        4004    'SP:DEFAULT.TBL|3 CLEAR' 0.4" round
        4006    'SP:DEFAULT.TBL|3 CLEAR' 0.65" round (POL)
        4010    'SP:DEFAULT.TBL|3 CLEAR' 1.0" round

;  HSP Filters

        4122    'HSPDIR:110383.DAT'       F122M   Lyman alpha
```

```
4135    'HSPDIR:110183.DAT'      F135W   ; 2/prism
4145    'HSPDIR:110783.DAT'      F145M   ; 4/prism
4152    'HSPDIR:033184.DAT'      F152M   2/R2,4/R5
4179    'HSPDIR:080383.DAT'      F179M   4/L2
4184    'HSPDIR:080983.DAT'      F184W   2/L4,4/R2,3/L3
4218    'HSPDIR:082183.DAT'      F218M   2/L5,4/R3
4220    'HSPDIR:081283.DAT'      F220W   2/R3
4240    'HSPDIR:082283.DAT'      F240W   3/L1,3/L2,2/R4    ; 3/prism
4248    'HSPDIR:082783.DAT'      F248M   2/R1,2/L6,4/R4    ; 2/prism
4262    'HSPDIR:011084.DAT'      F262M   4/R1,3/R2 ; 4/prism
4278    'HSPDIR:011284.DAT'      F278N   2/R5,4/L4
4284    'HSPDIR:102783.DAT'      F284M   4/L5
4355    'HSPDIR:011484.DAT'      F355M   3/R4              ; Stromgren u
4419    'HSPDIR:062884B.DAT'     F419N   3/R5              ; Stromgren v
4450    'HSPDIR:BG28.DAT'        F450W   3/L4             ; B
4551    'HSPDIR:072184B.DAT'     F551W   3/R1,3/L5         ; V, 3/prism
4620    'HSPDIR:RG610.DAT'        F620W   3/L6             ; R

; HSP long-pass filters

4160    'HSPDIR:SUPSILCUT.DAT'   F160LP  4/L3,3/R3,3/R6,3/P,1/A
4140    'HSPDIR:CRYQCUT.DAT'      F140LP  2/R6,4/R6
4400    'HSPDIR:GG395.DAT'       F400LP  3/L7

; HSP PMT filter

4695    'HSPDIR:RG695.DAT'        F695LP  PMT              ; PMT filter

; HSP polarimetry filters

4216    'HSPDIR:071784.DAT'      F216M   1/E
4237    'HSPDIR:071184.DAT'      F237M   1/D
4277    'HSPDIR:080384.DAT'      F277M   1/C
4327    'HSPDIR:081584.DAT'      F327M   1/B

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;  FGS detectors

5001    'HSTDIR:DEFAULT.TBL|3'
5002    'HSTDIR:DEFAULT.TBL|3'
5003    'HSTDIR:DEFAULT.TBL|3'
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;  HRS

6001    'HSTDIR:DEFAULT.TBL|3'
```

HST.GRF


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-----------------------------------------------------------
        instrument description graph for the hubble space telescope
-----------------------------------------------------------
        IN      OUT     ELEM    KEYWORD         COMMENTS

; OTA   (nodes and components 0-999)
; Optical Telescope Assembly

        1       2       100     'OTA'
        1       2       100     'DEFAULT'

; FOS   (nodes and components 1000-1999)
; Faint Object Spectrograph

        1       1000    100     'FOS'
        1       1000    100     'RED'
        1       1000    100     'BLUE'

; FOC   (nodes and components 2000-2999)
; Faint Object Camera

        1       2000    1       'FOC'   (foc graph includes ota)
        1       2000    1       'F/96'  (foc graph includes ota)
        1       2000    1       'F/48'  (foc graph includes ota)
        1       2000    1       'F/228' (foc graph includes ota)

; WF/PC (nodes and components 3000-3999)

        1       3000    100     'WF/PC'
        1       3000    100     'WFPC'
        1       3000    100     'WFC'
        1       3000    100     'PC'
        1       3000    100     'W1'
        1       3000    100     'W2'
        1       3000    100     'W3'
        1       3000    100     'W4'
        1       3000    100     'BAUM'
        1       3000    100     'P5'
        1       3000    100     'P6'
        1       3000    100     'P7'
        1       3000    100     'P8'

; HSP   (nodes and components 4000-4999)

        1       4000    100     'HSP'
        1       4000    100     'VIS'
        1       4000    100     'UV1'
        1       4000    100     'UV2'
        1       4000    100     'PMT'

; FGS   (nodes and components 5000-5999)

        1       5000    100     'FGS'

; HRS    (nodes and components 6000-6999)

        1       6000    100     'HRS'

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FOS-BLU IN      OUT     ELEM    KEYWORD         COMMENTS
```

```
; FOS BLUE (odd numbered nodes)

        1000    1011    1       'BLUE'

; FOS BLUE apertures

        1011    1013    1204    '0.1-PAIR'
        1011    1013    1204    'A4U'
        1013    1015    1210    '0.1-PAIR'
        1013    1015    1210    'A4U'

        1011    1013    1203    '0.25-PAIR'
        1011    1013    1203    'A3U'
        1013    1015    1211    '0.25-PAIR'
        1013    1015    1211    'A3U'

        1011    1015    1206    '0.5-PAIR'
        1011    1015    1206    'A2U'

        1011    1015    1       '1.0-PAIR'
        1011    1015    1       'C1U'

        1011    1015    1206    'FailsafeU'

        1011    1013    1204    '0.1-PAIR'
        1011    1013    1204    'A4L'
        1013    1015    1210    '0.1-PAIR'
        1013    1015    1210    'A4L'

        1011    1013    1203    '0.25-PAIR'
        1011    1013    1203    'A3L'
        1013    1015    1211    '0.25-PAIR'
        1013    1015    1211    'A3L'

        1011    1015    1206    '0.5-PAIR'
        1011    1015    1206    'A2L'
        1011    1015    1       '1.0-PAIR'
        1011    1015    1       'C1L'
        1011    1015    1       'FailsafeL'

        1011    1015    1202    '0.3'
        1011    1015    1202    'B2'
        1011    1015    1205    '0.5'
        1011    1015    1205    'B1'
        1011    1015    1       '1.0'
        1011    1015    1       'B3'
        1011    1015    1207    '0.25x2.0'
        1011    1015    1207    'C2'
        1011    1015    1208    '0.7x2.0-BAR'
        1011    1015    1208    'C4'
        1011    1015    1       '2.0-BAR'
        1011    1015    1       '4.3'
        1011    1015    1       'A1'
        1011    1015    0       'BLANK'

        1011    1015    1       'DEFAULT'

; FOS BLUE polarizers   (* set to clear)
```

```
1015    1017    1       'POL0-A'
1015    1017    1       'POL22.5-A'
1015    1017    1       'POL45-A'
1015    1017    1       'POL67.5-A'
1015    1017    1       'POL90-A'
1015    1017    1       'POL112.5-A'
1015    1017    1       'POL135-A'
1015    1017    1       'POL157.5-A'
1015    1017    1       'POL180-A'
1015    1017    1       'POL202.5-A'
1015    1017    1       'POL235-A'
1015    1017    1       'POL257.5-A'
1015    1017    1       'POL270-A'
1015    1017    1       'POL292.5-A'
1015    1017    1       'POL315-A'
1015    1017    1       'POL337.5-A'

1015    1017    1       'POL0-B'
1015    1017    1       'POL22.5-B'
1015    1017    1       'POL45-B'
1015    1017    1       'POL67.5-B'
1015    1017    1       'POL90-B'
1015    1017    1       'POL112.5-B'
1015    1017    1       'POL135-B'
1015    1017    1       'POL157.5-B'
1015    1017    1       'POL180-B'
1015    1017    1       'POL202.5-B'
1015    1017    1       'POL235-B'
1015    1017    1       'POL257.5-B'
1015    1017    1       'POL270-B'
1015    1017    1       'POL292.5-B'
1015    1017    1       'POL315-B'
1015    1017    1       'POL337.5-B'

1015    1017    1       ''DEFAULT'

; FOS BLUE grazing incidence mirror

1017    1019    1111    'GRAZB'

; FOS BLUE filter/disperser wheel (9 positions)

1019    1023    1302    'G130H'
1023    1025    1352    'G130H' BLUEFUDGE

1019    1023    1303    'G190H'
1023    1025    1353    'G190H' BLUEFUDGE

1019    1021    1312    'G270H' UVBLK
1021    1023    1304    'G270H'
1023    1025    1354    'G270H' BLUEFUDGE

1019    1021    1313    'G400H' WG305
1021    1023    1305    'G400H'
1023    1025    1355    'G400H' BLUEFUDGE

1019    1021    1314    'G570H' GG375
1021    1023    1306    'G570H'
1023    1025    1356    'G570H' BLUEFUDGE
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        1019    1021    1315    'G780H' OG530
        1021    1023    1307    'G780H'
        1023    1025    1357    'G780H' BLUEFUDGE

        1019    1023    1308    'G160L'
        1023    1025    1358    'G160L' BLUEFUDGE

        1019    1023    1309    'G650L'
        1023    1025    1359    'G650L' BLUEFUDGE

        1019    1023    1310    'PRISM'
        1023    1025    1360    'PRISM'  BLUEFUDGE

; FOS BLUE camera mirror

        1019    1025    1       'MIRROR'   DEFAULT
        1019    1025    1       'DEFAULT'

; FOS BLUE collimator mirror

        1025    1027    1112    'COLLB'
        1025    1027    1112    'BLUE'

; FOS BLUE digicon detector

        1027    1029    1100    'BLUE'  DIGICON QE

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FOS-RED  IN      OUT     ELEM    KEYWORD  COMMENTS

; FOS RED (even numbered nodes)

        1000    1012    1       'RED'

; FOS RED apertures

        1012    1014    1204    '0.1-PAIR'
        1012    1014    1204    'A4U'
        1014    1016    1210    '0.1-PAIR'
        1014    1016    1210    'A4U'

        1012    1014    1203    '0.25-PAIR'
        1012    1014    1203    'A3U'
        1014    1016    1211    '0.25-PAIR'
        1014    1016    1211    'A3U'

        1012    1016    1206    '0.5-PAIR'
        1012    1016    1206    'A2U'
        1012    1016    1       '1.0-PAIR'
        1012    1016    1       'C1U'
        1012    1016    1206    'FailsafeU'

        1012    1014    1204    '0.1-PAIR'
        1012    1014    1204    'A4L'
        1014    1016    1210    '0.1-PAIR'
        1014    1016    1210    'A4L'

        1012    1014    1203    '0.25-PAIR'
        1012    1014    1203    'A3L'
```

```
1014    1016    1211    '0.25-PAIR'
1014    1016    1211    'A3L'

1012    1016    1206    '0.5-PAIR'
1012    1016    1206    'A2L'
1012    1016    1       '1.0-PAIR'
1012    1016    1       'C1L'
1012    1016    1       'FailsafeL'

1012    1016    1202    '0.3'
1012    1016    1202    'B2'
1012    1016    1205    '0.5'
1012    1016    1205    'B1'
1012    1016    1       '1.0'
1012    1016    1       'B3'
1012    1016    1207    '0.25x2.0'
1012    1016    1207    'C2'
1012    1016    1208    '0.7x2.0-BAR'
1012    1016    1208    'C4'
1012    1016    1       '2.0-BAR'
1012    1016    1       '4.3'
1012    1016    1       'A1'
1012    1016    0       'BLANK'

1012    1016    1       'DEFAULT'

; FOS RED polarizers     (* set to clear)

1016    1018    1       'POL0-A'
1016    1018    1       'POL22.5-A'
1016    1018    1       'POL45-A'
1016    1018    1       'POL67.5-A'
1016    1018    1       'POL90-A'
1016    1018    1       'POL112.5-A'
1016    1018    1       'POL135-A'
1016    1018    1       'POL157.5-A'
1016    1018    1       'POL180-A'
1016    1018    1       'POL202.5-A'
1016    1018    1       'POL235-A'
1016    1018    1       'POL257.5-A'
1016    1018    1       'POL270-A'
1016    1018    1       'POL292.5-A'
1016    1018    1       'POL315-A'
1016    1018    1       'POL337.5-A'

1016    1018    1       'POL0-B'
1016    1018    1       'POL22.5-B'
1016    1018    1       'POL45-B'
1016    1018    1       'POL67.5-B'
1016    1018    1       'POL90-B'
1016    1018    1       'POL112.5-B'
1016    1018    1       'POL135-B'
1016    1018    1       'POL157.5-B'
1016    1018    1       'POL180-B'
1016    1018    1       'POL202.5-B'
1016    1018    1       'POL235-B'
1016    1018    1       'POL257.5-B'
1016    1018    1       'POL270-B'
1016    1018    1       'POL292.5-B'
1016    1018    1       'POL315-B'
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        1016    1018    1       'POL337.5-B'

        1016    1018    1       ''DEFAULT'

; FOS RED grazing incidence mirror

        1018    1020    1101    'GRAZA'

; FOS RED filter/disperser wheel (9 positions)

        1020    1024    1302    'G130H'
        1024    1026    1372    'G130H' REDFUDGE

        1020    1024    1303    'G190H'
        1024    1026    1373    'G190H' REDFUDGE

        1020    1022    1312    'G270H' UVBLK
        1022    1024    1304    'G270H'
        1024    1026    1374    'G270H' REDFUDGE

        1020    1022    1313    'G400H' WG305
        1022    1024    1305    'G400H'
        1024    1026    1375    'G400H' REDFUDGE

        1020    1022    1314    'G570H' GG375
        1022    1024    1306    'G570H'
        1024    1026    1376    'G570H' REDFUDGE

        1020    1022    1315    'G780H' OG530
        1022    1024    1307    'G780H'
        1024    1026    1377    'G780H' REDFUDGE

        1020    1024    1308    'G160L'
        1024    1026    1378    'G160L' REDFUDGE

        1020    1024    1309    'G650L'
        1024    1026    1379    'G650L' REDFUDGE

        1020    1024    1310    'PRISM'
        1024    1026    1380    'PRISM'  REDFUDGE

; FOS RED camera mirror

        1020    1024    1       'MIRROR'
        1020    1024    1       'DEFAULT'

; FOS RED collimator mirror

        1026    1028    1102    'COLLA'
        1026    1028    1102    'RED'

; FOS RED digicon detector

        1028    1030    1110    'RED'    DIGICON QE
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FOC     IN      OUT     ELEM    KEYWORD  COMMENTS

;  FOC -- OTA + transfer optics + detector efficiency

        2000    2010    2002    'F/228' ota+foc efficiency f/228
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2000    2010    2003    'F/96'  ota+foc efficiency f/96
2000    2100    2004    'F/48'  ota+foc efficiency f/48

; FOC f/96,f/228 filter wheel 1 (12 positions)

2010    2020    2101    'W1P01' CLEAR
2010    2020    2102    'W1P02' F8ND
2010    2020    2103    'W1P03' POL120
2010    2020    2104    'W1P04' F2ND
2010    2020    2105    'W1P05' F600M
2010    2020    2106    'W1P06' F630M
2010    2020    2107    'W1P07' POLO
2010    2020    2108    'W1P08' F4ND
2010    2020    2109    'W1P09' F6ND
2010    2020    2110    'W1P10' PRISM2 NUVOP
2010    2020    2111    'W1P11' POL60
2010    2020    2112    'W1P12' PRISM1 FUVOP

2010    2020    2101    'DEFAULT' CLEAR
2010    2020    2102    'F8ND'
2010    2020    2103    'POL120'
2010    2020    2104    'F2ND'
2010    2020    2105    'F600M'
2010    2020    2106    'F630M'
2010    2020    2107    'POLO'
2010    2020    2108    'F4ND'
2010    2020    2109    'F6ND'
2010    2020    2110    'PRISM2'
2010    2020    2110    'NUVOP'
2010    2020    2111    'POL60'
2010    2020    2112    'PRISM1'
2010    2020    2112    'FUVOP'

; FOC f/96,f/228 filter wheel 2 (12 positions)

2020    2030    2201    'W2P01' CLEAR
2020    2030    2202    'W2P02' F370LP
2020    2030    2203    'W2P03' F342W   U
2020    2030    2204    'W2P04' F430W   B
2020    2030    2205    'W2P05' F480LP  V
2020    2030    2206    'W2P06' F140W
2020    2030    2207    'W2P07' F175W
2020    2030    2208    'W2P08' F220W
2020    2030    2209    'W2P09' F275W
2020    2030    2210    'W2P10' F320W
2020    2030    2211    'W2P11' F486N
2020    2030    2212    'W2P12' F501N

2020    2030    2201    'DEFAULT'       CLEAR
2020    2030    2202    'F370LP'
2020    2030    2203    'F342W'
2020    2030    2203    'U'
2020    2030    2204    'F430W'
2020    2030    2204    'B'
2020    2030    2205    'F480LP'
2020    2030    2205    'V'
2020    2030    2206    'F140W'
2020    2030    2207    'F175W'
2020    2030    2208    'F220W'
2020    2030    2209    'F275W'
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2020    2030    2210    'F320W'
2020    2030    2211    'F486N'
2020    2030    2212    'F501N'

; FOC f/96,f/228 filter wheel 3 (12 positions)

2030    2040    2301    'W3P01' CLEAR
2030    2040    2302    'W3P02' F210M
2030    2040    2303    'W3P03' F120M
2030    2040    2304    'W3P04' F152M
2030    2040    2305    'W3P05' F1ND
2030    2040    2306    'W3P06' F130M
2030    2040    2307    'W3P07' F190M
2030    2040    2308    'W3P08' F170M
2030    2040    2309    'W3P09' F140M
2030    2040    2310    'W3P10' F195M
2030    2040    2311    'W3P11' F165M
2030    2040    2312    'W3P12' F231M

2030    2040    2301    'DEFAULT'       CLEAR
2030    2040    2302    'F210M'
2030    2040    2303    'F120M'
2030    2040    2304    'F152M'
2030    2040    2305    'F1ND'
2030    2040    2306    'F130M'
2030    2040    2307    'F190M'
2030    2040    2308    'F170M'
2030    2040    2309    'F140M'
2030    2040    2310    'F195M'
2030    2040    2311    'F165M'
2030    2040    2312    'F231M'

; FOC f/96,f/228 filter wheel 4 (12 positions)

2040    2050    2401    'W4P01' CLEAR
2040    2050    2402    'W4P02' F346M
2040    2050    2403    'W4P03' F410M
2040    2050    2404    'W4P04' F470M
2040    2050    2405    'W4P05' F550M
2040    2050    2406    'W4P06' F372M
2040    2050    2407    'W4P07' F130LP
2040    2050    2408    'W4P08' F502M
2040    2050    2409    'W4P09' F253M
2040    2050    2410    'W4P10' F278M
2040    2050    2411    'W4P11' F307M
2040    2050    2412    'W4P12' F437M

2040    2050    2401    'DEFAULT'       CLEAR
2040    2050    2402    'F346M'
2040    2050    2403    'F410M'
2040    2050    2404    'F470M'
2040    2050    2405    'F550M'
2040    2050    2406    'F372M'
2040    2050    2407    'F130LP'
2040    2050    2408    'F502M'
2040    2050    2409    'F253M'
2040    2050    2410    'F278M'
2040    2050    2411    'F307M'
2040    2050    2412    'F437M'
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; FOC f/48 filter wheel 1 (8 positions)

        2100    2110    2501    'W1P01' CLEAR
        2100    2110    2502    'W1P02' FOPCD PRISM3
        2100    2110    2503    'W1P03' F150W
        2100    2110    2504    'W1P04' F195W
        2100    2110    2505    'W1P05' F140W
        2100    2110    2506    'W1P06' F175W
        2100    2110    2507    'W1P07' F305LP
        2100    2110    2508    'W1P08' F220W

        2100    2110    2501    'DEFAULT' CLEAR
        2100    2110    2502    'PRISM3'
        2100    2110    2502    'FOPCD' PRISM3
        2100    2110    2503    'F150W'
        2100    2110    2504    'F195W'
        2100    2110    2505    'F140W'
        2100    2110    2506    'F175W'
        2100    2110    2507    'F305LP'
        2100    2110    2508    'F220W'

; FOC f/48 filter wheel 2 (8 positions)

        2110    2120    2601    'W2P01' CLEAR
        2110    2120    2602    'W2P02' NUVOP   PRISM2
        2110    2120    2603    'W2P03' F342W   U
        2110    2120    2604    'W2P04' F430W   B
        2110    2120    2605    'W2P05' F180LP
        2110    2120    2606    'W2P06' F275W
        2110    2120    2607    'W2P07' F130LP
        2110    2120    2608    'W2P08' FUVOP   PRISM1

        2110    2120    2601    'DEFAULT'       CLEAR
        2110    2120    2602    'PRISM2'
        2110    2120    2602    'NUVOP' PRISM2
        2110    2120    2603    'F342W'
        2110    2120    2603    'U'
        2110    2120    2604    'F430W'
        2110    2120    2604    'B'
        2110    2120    2605    'F180LP'
        2110    2120    2606    'F275W'
        2110    2120    2607    'F130LP'
        2110    2120    2608    'PRISM1'
        2110    2120    2608    'FUVOP' PRISM1
-----------------------------------------------------
WFPC    IN      OUT     ELEM    KEYWORD  COMMENTS

; WFC CCD detectors

        3000    3100    3501    'DEFAULT'
        3000    3100    3501    'WFC'
        3000    3100    3501    'W1'
        3000    3100    3502    'W2'
        3000    3100    3503    'W3'
        3000    3100    3504    'W4'

; PC CCD detectors

        3000    3100    3505    'PC'
        3000    3100    3505    'P5'
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3000    3100    3506    'P6'
3000    3100    3507    'P7'
3000    3100    3508    'P8'

; WF/PC filter wheel 1 (5 positions)

3100    3101    3010    'DEFAULT'       CLEAR
3100    3101    3011    'A01'   F225SP
3100    3101    3012    'B01'   F290SP
3100    3101    3013    'C01'   G450
3100    3101    3014    'D01'   G800
3100    3101    3011    'F225SP'
3100    3101    3012    'F290SP'
3100    3101    3013    'G450'
3100    3101    3014    'G800'

; WF/PC filter wheel 2 (5 positions)

3101    3102    3020    'DEFAULT'       CLEAR
3101    3102    3021    'A02'   F122M
3101    3102    3022    'B02'   F336W
3101    3102    3023    'C02'   F439W
3101    3102    3024    'D02'   G200
3101    3102    3021    'F122M'
3101    3102    3022    'F336W'
3101    3102    3023    'F439W'
3101    3102    3024    'G200'

; WF/PC filter wheel 3 (5 positions)

3102    3103    3030    'DEFAULT'       CLEAR
3102    3103    3031    'A03'   POL0
3102    3103    3032    'B03'   POL60
3102    3103    3033    'C03'   POL120
3102    3103    3034    'D03'   F1083N
3102    3103    3031    'POL0'
3102    3103    3032    'POL60'
3102    3103    3033    'POL120'
3102    3103    3034    'F1083N'

; WF/PC filter wheel 4 (5 positions)

3103    3104    3040    'DEFAULT'       CLEAR
3103    3104    3041    'A04'   F157W
3103    3104    3042    'B04'   F194W
3103    3104    3043    'C04'   F230W
3103    3104    3044    'D04'   F284W
3103    3104    3041    'F157W'
3103    3104    3042    'F194W'
3103    3104    3043    'F230W'
3103    3104    3044    'F284W'

; WF/PC filter wheel 5 (5 positions)

3104    3105    3050    'DEFAULT'       CLEAR
3104    3105    3051    'A05'   F569W
3104    3105    3052    'B05'   F675W
3104    3105    3053    'C05'   F791W
3104    3105    3054    'D05'   F658N
3104    3105    3051    'F569W'
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3104    3105    3052    'F675W'
3104    3105    3053    'F791W'
3104    3105    3054    'F658N'

; WF/PC filter wheel 6 (5 positions)

3105    3106    3060    'DEFAULT'       CLEAR
3105    3106    3061    'A06'   F631N
3105    3106    3062    'B06'   F656N
3105    3106    3063    'C06'   F664N
3105    3106    3064    'D06'   F702W
3105    3106    3061    'F631N'
3105    3106    3062    'F656N'
3105    3106    3063    'F664N'
3105    3106    3064    'F702W'

; WF/PC filter wheel 7 (5 positions)

3106    3107    3070    'DEFAULT'       CLEAR
3106    3107    3071    'A07'   F375N
3106    3107    3072    'B07'   F502N
3106    3107    3073    'C07'   F437N
3106    3107    3074    'D07'   F588N
3106    3107    3071    'F375N'
3106    3107    3072    'F502N'
3106    3107    3073    'F437N'
3106    3107    3074    'F588N'

; WF/PC filter wheel 8 (5 positions)

3107    3108    3080    'DEFAULT'       CLEAR
3107    3108    3081    'A08'   F368M
3107    3108    3082    'B08'   F413M
3107    3108    3083    'C08'   F622W
3107    3108    3084    'D08'   F492M
3107    3108    3081    'F368M'
3107    3108    3082    'F413M'
3107    3108    3083    'F622W'
3107    3108    3084    'F492M'

; WF/PC filter wheel 9 (5 positions)

3108    3109    3090    'DEFAULT'       CLEAR
3108    3109    3091    'A09'   F547M
3108    3109    3092    'B09'   F555W
3108    3109    3093    'C09'   F648M
3108    3109    3094    'D09'   F718M
3108    3109    3091    'F547M'
3108    3109    3092    'F555W'
3108    3109    3093    'F648M'
3108    3109    3094    'F718M'

; WF/PC filter wheel 10 (5 positions)

3109    3110    3100    'DEFAULT'       CLEAR
3109    3110    3101    'A10'   F814W
3109    3110    3102    'B10'   F875M
3109    3110    3103    'C10'   F785LP
3109    3110    3104    'D10'   F1042M
3109    3110    3101    'F814W'
```

```
        3109    3110    3102    'F875M'
        3109    3110    3103    'F785LP'
        3109    3110    3104    'F1042M'

; WF/PC filter wheel 11 (5 positions)

        3110    3111    3110    'DEFAULT'       CLEAR
        3110    3111    3111    'A11'   F128LP
        3110    3111    3112    'B11'   F469N
        3110    3111    3113    'C11'   F487N
        3110    3111    3114    'D11'   F517N
        3110    3111    3111    'F128LP'
        3110    3111    3112    'F469N'
        3110    3111    3113    'F487N'
        3110    3111    3114    'F517N'

; WF/PC filter wheel 12 (5 positions)

        3111    3112    3120    'DEFAULT'       CLEAR
        3111    3112    3121    'A12'   F850LP
        3111    3112    3122    'B12'   F606W
        3111    3112    3123    'C12'   F725LP
        3111    3112    3124    'D12'   F889N
        3111    3112    3121    'F850LP'
        3111    3112    3122    'F606W'
        3111    3112    3123    'F725LP'
        3111    3112    3124    'F889N'
-----------------------------------------------------------------
HSP     IN      OUT     ELEM    KEYWORD         COMMENTS
;
; HSP Apertures
;
        4000    4100    4010    '1.0'
        4000    4100    4004    '0.4'
        4000    4100    4006    '0.65'
        4000    4100    1       'ACQ'
        4000    4100    4010    'DEFAULT'
        4000    4100    4010    'PRISM'
        4000    4100    4010    'PMT'
        4000    4100    4006    'POL'
;
;  HSP Image Dissector Tubes
;
        4100    4200    4002    'VIS'
        4100    4500    4002    'POL'
        4100    4300    4001    'UV1'
        4100    4300    4001    'UV2'
        4100    4400    4003    'PMT'
;
;  HSP Filters for VIS IDT
;
        4200    4201    4551    'F551W'         3/R1    V PRISM
        4200    4202    4262    'F262M'         3/R2
        4200    4203    4160    'F160LP'        3/R3
        4200    4204    4355    'F355M'         3/R4    Stromgren u
        4200    4205    4419    'F419N'         3/R5    Stromgren v
        4200    4206    4160    'F160LP'        3/R6    SUPSILCUT

        4200    4216    4160    'PMT'           3/R6    SUPSILCUT
        4216    4217    4620    'PMT'           3/L6    RG610
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HST.GRF
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        4200    4207    4240    'F240W'         3/L1    PRISM
        4200    4208    4240    'F240W'         3/L2
        4200    4209    4184    'F184W'         3/L3
        4200    4210    4450    'F450W'         3/L4    B
        4200    4210    4450    'B'             3/L4    B
        4200    4211    4551    'F551W'         3/L5    V
        4200    4211    4551    'V'             3/L5    V
        4200    4212    4620    'F620W'         3/L6    R
        4200    4212    4620    'RG610'          3/L6    R
        4200    4212    4620    'R'              3/L6    R
        4200    4213    4400    'F400LP'        3/L7    GG395
        4200    4213    4400    'GG395'         3/L7
;
;  HSP Filters for UV1 IDT
;
        4300    4301    4248    'F248M'         2/R1     PRISM
        4300    4302    4152    'F152M'         2/R2
        4300    4303    4220    'F220W'         2/R3
        4300    4304    4240    'F240W'         2/R4
        4300    4305    4278    'F278N'         2/R5
        4300    4306    4140    'F140LP'        2/R6     CRYQCUT

        4300    4307    4135    'F135W'         2/L1    PRISM
        4300    4308    4135    'F135W'         2/L2
        4300    4309    4145    'F145M'         2/L3
        4300    4310    4184    'F184W'         2/L4
        4300    4311    4218    'F218M'         2/L5
        4300    4312    4248    'F248M'         2/L6
        4300    4313    4122    'F122M'         2/L7    Lyman alpha
;
;  HSP Filters for UV2 IDT
;
        4400    4401    4262    'F262M'         4/R1     PRISM
        4400    4402    4184    'F184W'         4/R2
        4400    4403    4218    'F218M'         4/R3
        4400    4404    4248    'F248M'         4/R4
        4400    4405    4152    'F152M'         4/R5
        4400    4406    4140    'F140LP'        4/R6     ; CRYQCUT

        4400    4407    4145    'F145M'         4/L1    PRISM
        4400    4408    4179    'F179M'         4/L2
        4400    4409    4160    'F160LP'        4/L3    SUPSILCUT
        4400    4410    4278    'F278N'         4/L4
        4400    4411    4284    'F284M'         4/L5
        4400    4412    4145    'F145M'         4/L6
        4400    4413    4122    'F122M'         4/L7    Lyman alpha
;
;  HSP Filters for POL IDT
;
        4500    4550    4160    'F160LP'        1/A     SUPSILCUT
        4500    4550    4327    'F327M'         1/B
        4500    4550    4277    'F277M'         1/C
        4500    4550    4237    'F237M'         1/D
        4500    4550    4216    'F216M'         1/E
-------------------------------------------------------------
FGS     IN      OUT     ELEM    KEYWORD         COMMENTS

        5000    5001    1       'DEFAULT'
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HRS	IN	OUT	ELEM	KEYWORD	COMMENTS
	6000	6001	1	'DEFAULT'	