STIS Capabilities for Cycle 7 - A Discussion Document

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ABSTRACT
We define a core set of capabilities for STIS which should be developed and supported for Cycle 7. This core set enables the overwhelming majority of scientific uses of STIS while providing a great simplification to the interface to the GO, to the needed ground systems, including TRANS, PDB, and command development, to the calibration and PDB table requirements, and to the calibration software. Perhaps more importantly, by focusing our efforts on this core set, we assure that we will provide robust support for the capabilities of STIS which are needed to conduct >95% of the science. At the same time, all of the capabilities of STIS which are supported by the hardware and flight and ground software and for which the necessary PDB files are produced by the IDT can be made available as Engineering Only modes. They can subsequently be developed and brought on for GO use in subsequent cycles if there is scientific need.

1. Introduction

STIS is a versatile and complex instrument. Development and testing of its full set of capabilities prior to Cycle 7; production, verification and maintenance of the necessary calibration/commanding software and calibration/PDB files for that full set and presentation of that full set to the GO in a way that does not complicate use of the primary capabilities of STIS, is unrealistic and risks the robust development of STIS's primary capabilities. Fortunately, it is possible to define a core set of STIS capabilities for GO use and first priority development prior to Cycle 7 which encompasses the overwhelming majority of scientific uses of STIS. Access to the remaining capabilities can be provided as Engineering Only modes, pending the necessary flight and ground software development and production of concomitant PDB and calibration files, and brought on as GO modes for subsequent cycles if there is scientific need.

In this document we define the core set of STIS capabilities we recommend be developed for Cycle 7 GO use. This set is both the minimum set which must be developed to enable STIS's scientific capability (i.e., must be ready for Cycle 7, SMOV, and GTO Science) and the full set we recommend be made available for GO use in for Cycle 7.

The remainder of this document is organized as follows. In Section 2, we present the core capabilities and describe the overall benefits from adopting this approach. In Section 3, we explain in detail for each of the science capabilities and how we have arrived at this recommendation; we describe each recommendation in detail, the gain achieved by adopting the recommendation, and the science loss, as applicable.

2. Recommended Cycle 7 Science Capabilities

We recommend providing the following set of core STIS capabilities for GO use in Cycle 7:

- all 15 science modes plus two backup modes which facilitate near-uv first order spectroscopy. A mode is a grating/detector combination; the backup modes were designed to provide redundancy in case of detector failure.
- 103 Mode Select Mechanism (MSM) positions. The MSM is STIS's nutating grating wheel. It houses the first order gratings, cross dispersers, and camera mirrors. For those gratings where the spectroscopic format is larger than the detector, the tilt of the optical element can be adjusted to move a different segment of the spectral format onto the detector. The MSM tilt can also be adjusted to project different parts of large apertures onto the detector (e.g., for MAMA coronographic observations). The 103 core MSM positions include those needed to fully sample the full spectral range of all the STIS gratings, with 10% overlap between adjacent spectra, and the MSM positions required for target acquisition and imaging.
- a subset of the apertures including 9 echelle slits, 4 long slits, 2 planetary slits, 9 uv imaging filters, 1 FPSPLIT aperture, all target acquisition filters, all CCD coronographic apertures and those MAMA coronographic apertures which are imaged directly on the detector without additional Mode Select Mechanism (MSM) motions[1] .
- user selection of a single subarray. The subarray width is fixed at the full width of the detector. The user specifies the height of the subarray and the y location (order number for echelles, distance along slit for first order modes) of the subarray center.
- MAMA exposures binned on board to produce 1024 x 1024 format images (`lowres`)
- all wavecals taken as full format images rather than as subarrays.

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1. The coronographic apertures were sized for the CCD field of view which is roughly twice that of the MAMAs, so MSM motions are needed to project some of the coronographic apertures onto the MAMA detectors.

- no GO selection of repeller voltage status (off or on) for the far uv MAMA (MAMA1).
- the primary science operating modes, ACCUMULATE and TIME TAG
- CCD Point Source, CCD Bright Object, CCD Peakup, MAMA Peakup, CCD Diffuse Source and CCD Planetary Acquisitions.

As described in detail in Section 2, this core set of capabilities encompasses the overwhelming majority of scientific uses of STIS. However, it provides a great simplification to the interface to the GO, to the needed ground system TRANS, PDB, and command development, to the calibration and PDB table requirements, and to the calibration software. Perhaps more importantly by focusing our efforts on this core set, we assure that we will provide robust support for the capabilities of STIS which are needed to conduct >95% of the science. At the same time, all of the additional capabilities of STIS which are supported by the ground software, hardware, flight software and for which the necessary PDB files are produced by the IDT to allow commanding, will still be available as Engineering Only modes. The Cycle 7 pipeline will calibrate those data taken using Engineering Only configurations which do not require additional calibration reference files or software logic (e.g., *highres* 2048 x 2048 MAMA images, or subarray images). However, the Cycle 7 pipeline will not calibrate data taken in Engineering Only configurations for which additional calibration reference files or logic are required (e.g., repeller in non-standard configuration, non-standard MSM positions); those data will be passed through generic conversion and then archived as uncalibrated FITS images. Observers will be required to taken any needed calibration observations for these configurations as part of their observing time.

Any capabilities within the Engineering Only modes which are deemed scientifically needed can be brought on as fully supported GO modes in subsequent cycles.

3. Detailed Explanation of the Core Capabilities

In this section we describe, for each of the core capabilities, the rationale behind the selection of the core set. We discuss the gains and the losses associated with restricting Cycle 7 GO use to this core set. Table 1 contains a summary of the information presented below. Table 2 through Table 6 present a summary of the science uses of STIS with this core set.

Table 1. Summary of Recommendations

Science Capability	Recommendation	Engineering Only[a]	Gain	Loss
Apertures	9 echelle slits 4 long slits 2 planetary slits 1 fpsplit slit filtered and target acq apertures coronographic apertures	remaining apertures for which the necessary geometrical information is available from ground work	Robust calibration of apertures Increased uniformity of data. Calibration and PDB Overhead reduced by 70% for aperture-dependent files.	Loss of flexibility of aperture specification. Chosen apertures do include slits sized for photometry and throughput, spectral resolution, planetary work, and coronography.
Modes (detector/ grating combinations)	Support All Primary modes plus 2.1B and 2.2B for Science.	Cross dispersed first order modes (.7 modes).	2.1B and 2.2B allow increased sensitivity in the 2500-3100 Angstrom range	None
MSM Central Wavelengths	103 positions including ~89 to cover full spectral range with 10% overlap in adjacent MSM positions, plus positions for non-slit apertures and coronography.	5 times subsampled MSM positions totalling ~500 (or continuous wavelength selection) as supported by flight software and calibrated during thermal vac.	Robust calibration and commanding of GO central wavelengths. Reduced PDB overhead for subarray commanding. Reduced effort developing and testing MSM encoder position model.	GO may need to take 2 integrations at adjacent MSM positions to cover desired wavelengths where one optimally centered spectrum would have sufficed. Flexible line centering for slitless spectroscopy of extended sources at non-zero redshift lost.
Subarrays	1 subarray allowed; width fixed at full detector, placement and height specifiable	1 flexible subarray, specified as xcorner and ycorner pixel coordinates for MAMA and for the CCD	simplification of user interface, vast simplification to TRANS and PDB, simplification to data products	Echelle observers with lines on orders at opposite ends doing 5-15 second variability work will need to use the Engineering parameters.
MAMA `lowres` (1024 x 1024)	1024 x 1024 (*lowres*) images default	*highres* (2048 x 2048) available as Engineering mode	data volume management, uniformity of flats, calibration overhead to reach fixed signal to noise, facilitates taking full frame wavecals.	*highres* available as Engineering mode- provides 5-9% improvement in resolution at price of fixed pattern noise and flat field variability.
Wavecals	automatic full frame wavecals, and user specifiable full frame wavecals.	flexible subarray available in Engineering mode, using xcorner and ycorner parameters	Simplification to TRANS, reduction of PDB overhead, robustness of pipeline calibration of MSM-induced offsets.	2 minute price for data buffer management of wavecals for 2048 x 2048 *highres* MAMA exposures.
fuv-MAMA repeller	non-selectable	selectable	calibration overhead reduction uniformity of data	unclear at this time
Science Operating Modes	ACCUMULATE, TIME-TAG		no work on development of commanding and pipeline calibration for CCD PSD mode	CCD PSD, unsupported. Short time scale optical and near-uv variability work impacted.
Target Acquisitions	`CCD Point Source, Bright Object and Peakup, Diffuse and Planetary, MAMA Peakup`		command development and in orbit verification work reduced	CCD Crowded, MAMA Point Source, Diffuse, Crowded, Planet, Bright Object- unsupported.

a. The availability of Engineering Only modes for science useage is contingent on the completion of the commanding software to support them, the flight software to support them, and their calibration during thermal vacuum testing.

Table 2. Near IR to Optical Red Spectroscopy (5000 to 10000 A)

optical element	λ range (Å)	resolving power	detector	Å/ EXP	λ_c's[a]	grating type	recommended science slits[b]	operating modes	Science Usage
G750L	5500-10000	425-680	CCD	4500	1	first order	length 51”	ACCUMULATE	optical red, low resolution, long slit spectroscopy
mode 4.1							widths 0.1, 0.2		
G750M	5500-10000	3760-6220	CCD	572	9	first order	length 51”	ACCUMULATE	optical, red, intermediate resolution, long slit spectroscopy
mode 4.2							widths 0.1, 0.2		

a. Number of exposures at unique MSM positions to cover free spectral range of grating. A/EXP denotes the spectral range of a single exposure.
b. Lists slits recommended for majority of science uses in this configuration. 45 degree planetary slits available for planetary observations as well. See Table 7 for full list of supported slits/apertures.

Table 3. Optical Blue Spectroscopy (3050-5550 A)

optical element	λ range (Å)	resolving power	detector	Å/ EXP	λ_c's	grating type	recommended science slits[a]	operating modes	Science Usage
G430L	3050-5550	445-770	CCD	2500	1	first order	length 51”	ACCUMULATE	optical, blue, low resolution, long slit spectroscopy
mode 3.1							widths: 0.1, 0.2		
G430M	3050-5550	4340-7730	CCD	286	10	first order	length 51”	ACCUMULATE	optical, blue, intermediate resolution, long slit spectroscopy
mode 3.2							widths 0.1, 0.2		

a. 45 degree planetary slits available for planetary observations.

Table 4. Near Ultraviolet Spectroscopy (1650-3100 A)

optical element	λ range (Å)	resolving power	detector	Å/ EXP	λ_c's	grating type	recommended science slits[a]	operating modes	Science Usage
G230L	1650-3100	415-730	Cs_2Te MAMA	1616	1	first order	.length 51” (28” on detec- tor)	ACCUMULATE	near uv, low resolution, long slit spectroscopy
mode 2.1							widths 0.05, 0.1, 0.2	TIME TAG	
G230LB	2000-3070	495-910	CCD	1380	1	first order	length 51”	ACCUMULATE	near uv, high throughput, low resolution long slit spectroscopy
mode 2.1B							widths: 0.1, 0.2		in the 2500-3100 A range.
G230M	1650-3100	7500- 13900	Cs_2Te MAMA	90	18	first order	length 51” (28” on detector)	ACCUMULATE	near uv, intermediate resolution, long slit spectroscopy
mode 2.2							widths 0.05, 0.1, 0.2	TIME TAG	
G230MB	2000-3100	4370-8230	CCD	150	11	first order	length 51”	ACCUMULATE	near uv, high throughput, intermediate resolution long
mode 2.2B							widths 0.1, 0.2		slit spectroscopy, in the 2500-3100 A range.
E230M	1650-3100	23500	Cs_2Te MAMA	800	2	echelle,	length 0.2	ACCUMULATE	near uv, m edium resolution echelle ,
mode 2.3						+X230M	widths 0.063, 0.2	TIME TAG	short slit only, to prevent order overlap
E230H	1650-3100	100000	Cs_2Te MAMA	267	6	echelle,	length 0.1	ACCUMULATE	near uv, high resolution echelle ,
mode 2.4						**+X230H**	widths 0.063, 0.2	TIME TAG	short slit only to prevent order overlap
PRISM	1200-3100	1000-26	Cs_2Te MAMA	1950	1	objective prism	28 x28 “ clear aperture	ACCUMULATE	near uv objective prism, 29 x 29” field of view
mode 2.5								TIME TAG	

a. 45 degree planetary slits available for first order modes, FPSPLIT aperture for high signal to noise echelle observations.

Table 5. Far Ultraviolet Spectroscopy (1150-1700 A)

optical element	λ range (Å)	resolving power	detector	Å/ EXP	λ_c's	grating type	recommended science slits[a]	operating modes	Science Usage
G140L	1150-1700	770-1130	CsI MAMA	611	1	first order	length 51" (28" on detector)	ACCUMULATE	far uv, low resolution, long slit spectroscopy
mode 1.1							widths 0.05, 0.1, 0.2	TIME TAG	
G140M	1150-1700	8600-12800	CsI MAMA	55	11	first order	length 51" (28" on detector)	ACCUMULATE	far uv, intermediate resolution, long slit spectroscopy
mode 1.2							widths 0.05, 0.1, 0.2	TIME TAG	
E140M	1150-1700	24000	CsI MAMA	600	1	echelle,	length 0.33	ACCUMULATE	far uv, medium resolution echelle,
mode 1.3						+X140M	widths 0.063, 0.2	TIME TAG	short slit only o prevent order overlap
E140H	1150-1700	100000	CsI MAMA	210	3	echelle,	length 0.2	ACCUMULATE	far uv, high resolution echelle,
mode 1.4						+X140H	widths 0.063, 0.2	TIME TAG	short slit only to prevent order overlap

a. 45 degree planetary slits available for first order modes, FPSPLIT aperture for high signal to noise echelle observations.

Table 6. Imaging with STIS (1150-10000 A)

optical element	λ range (Å)	resolving power	detector	Å/ EXP	λ_c's	grating type	apertures	operating modes	Science Usage
mirror	1150-1700		CsI MAMA		1	filtered imaging	Lyα, Quartz, 182nm, CIII], MgII, SrF_2, clear, 270nm	ACCUMULATE	Far-ultraviolet Imaging, 25 x 25 " fov
mode 1.6								TIME TAG	
mirror	1150-3100		Cs_2Te MAMA		1	filtered imaging	Lya, Quartz, 182nm, CIII], MgII, SrF_2, clear, 270nm	ACCUMULATE	Near-ultraviolet Imaging, 25 x 25" fov
mode 2.6								TIME TAG	
mirror	3050-10000		CCD		1	filtered imaging	50.0CORON, occulting bars	ACCUMULATE	near-ir/optical imaging
modes 3.6&4.6							[OIII], [OII], longpass, clear		28 x 51" for filtered apertures,
									51 x 51" fov for clear apertures and coronography

Modes

A STIS *mode* is a grating - detector combination. We propose to fully support all of the science (primary) modes as well as the two backup modes 2.1B and 2.2B. The backup modes are designed to allow use of gratings with alternate detectors to provide contingency in case of detector failure. The 2.1B and 2.2B, however (where the B indicates this was originally a backup mode) have been moved to science modes; they allow use of the first order gratings for the near-uv with the CCD, to provide enhanced quantum efficiency in the 2500-3100 Angstrom range. Table 2 through Table 6 summarize the full set of modes we recommend supporting. As can be seen, the full range of science capabilities of the instrument are covered. Only the backup modes, 1.1B, 1.2B, 1.3B, and 1.4B, which will not be available even in Engineering Only mode, and the cross disperser modes (0.7 modes) whose primary usage is for calibration will not be available for GO use.

Consideration can be given to bringing on the 1.7x4 mode for Cycle **8** science as it facilitates intermediate resolute (R=3000) far-uv science with a relatively large free spectral range. However, the cross disperser modes requires special slits and produce a spectrum which is oriented perpendicular to all the remaining modes, with dispersion running along the x detector direction; thus there is considerable work (for the proposal instructions/ TRANS and for the calibration pipeline) to bring these modes on for GOs in a robust and reliable manner. No science is lost by not providing these modes, as the R=10000 G140M grating can be used and the data smoothed a factor of 3 to achieve R=3000; for those wishing to cover the full spectral range of the grating they will have to take 3 separate exposures.

Apertures

STIS has 65 physical apertures housed in its slit wheel (including the 47 spectroscopic slits, the target acquisition apertures and the uv imaging filters). Defined on those physical apertures are roughly 100 observing apertures in the PDB (with sub-locations on the physical apertures supported for things such as target centering behind bars, different quadrants on the neutral density filters). Maintaining accurate calibration both for the pipeline (throughput versus wavelength versus slit location) and for the PDB to support all these sub-apertures is a large task.

We propose a subset of the total apertures be made available for GO science use in Cycle 7. Our suggestions are summarized in Table 7.

Table 7: Apertures Recommended for GO Use in Cycle 7[1]

Aperture Type	Apertures[a]	Use[b]
First Order Spectroscopic	52 x 2.0 (photometric calibration) 52 x 0.2 52 x 0.1 52 x 0.05 including subapertures	high throughput compromise between throughput and resolution maximum resolution, **CCD** long slit maximum resolution. **MAMA** long slit

Aperture Type	Apertures[a]	Use[b]
Echelle[c]	**E140M (0.3 gives order separation)**	**E140H**
	0.3 x 0.2	high throughput
	0.3 x 0.09	compromise throughput and resolution
	0.3 x 0.063	maximum resolution
	E230M, E140H (0.2 gives order separation)	**E230M, E140H**
	0.2 x 0.2	high throughput
	0.2 x 0.09	compromise throughput and resolution
	0.2 x 0.063	maximum resolution
	E230H (0.1 gives order separation)	**E230H**
	0.1 x 0.2	high throughput
	0.1 x 0.09	compromise throughput and resolution
	0.1 x 0.063	maximum resolution
	All Echelle Modes	**All Echelle Modes**
	0.06FPSPLIT (is 5 physical apertures)	High Signal to Noise
Planetary	35.7 x 0.6 (+45 deg) 35.7 x 0.6 (-45 deg)	facilitates planetary observations
UV Imaging Filters	Ly-alpha,Quartz, 182nm,CIII,MgII,SrF_2, clear, 270nm cont.	UV imaging
Coronographic Apertures	50.0CORON (support all positions for CCD, those not requiring MSM motion for MAMA) occulting bars on long slits (slits as above)	coronography
Target Acquisition Filters	UV Quad, ND5, ND6, [OIII],[OII], Longpass, clear	target acquisitions
Calibration Apertures	ALL	WAVECAL ONLY, not for GO Science

a. sizes given are arcseconds
b. maximum resolution is for slit width which project to two detector pixels to give fully sampled lsf.
c. neutral density filled apertures available under Engineering Mode for very bright targets.

The philosophy adopted is to provide a range of slit sizes to cover science needs (accurate photometry, maximum spectral resolution, or a compromise between the two) without overburdening the system. We have made available 20 out of the 46 physical spectroscopic slits (we anticipate encouraging use predominantly of 9 of these for the bulk of STIS spectroscopic work, see Table 2 through Table 5) and all the target acquisitions and filtered apertures. Obviously, some flexibility in exact specification of slit dimension for a given observation is lost by restricting access in this way. However, there are both scientific benefits and resource benefits from adopting this approach.

The primary gains in adopting this set are:

- reduction in precise aperture definition work

1. Choice of specific designated apertures may change between now and the date when they must be firmed up (Cycle 7 Call for Proposals) as we learn more about the apertures in ground test- however the philosophy employed in their selection will not change. The IDT has stated that 3 long slit and 3 echelle slits for the trhee echelle mode formats will be fully characterized in Thermal Vac testing.

- minimal set of apertures supported, allowing good job to be done in transferring calibration from wide slit to smaller slits, and assuring robust calibration for GO.
- savings in the work required to populate and calibrate pipeline databases for processing of science data
- uniformity of data taken with STIS, facilitating inter-observation comparisons (similar to the TAC request that WFPC2 observers use a subset of the filters).

Spectroscopic slit apertures which are not supported for GO use will be maintained in the PDB and their geometric properties will be maintained in calibration reference files. It is expected that the bulk of the aperture locations in the PDB will be extrapolated from the relative slit positions measured during ground-based calibration and absolute measurement of a few apertures during SMOV.

If the need for additional, or alternative, slits evolves they can be added during subsequent cycles. In orbit photometric calibration will use observations of spectrophotometric standards through the core set of GO slits. For the non-maintained slits, the pipeline will have to extrapolate calibrations from larger slits used in the measurement of spectrophotometric via a geometric correction. If a slit/aperture is to brought on in a subsequent cycle, then clearly, detailed geometric measurements of that slit must have been completed during ground testing so that we can support calibration for that given slit. We anticipate that the imaging apertures will be calibrated using spectrophotometric standards at a frequency of ~2-3 times per year.

MSM Central Wavelengths

The STIS first order and echelle gratings are scannable, through tilting of the grating (first order) or the cross dispersers (echelle) by the Mode Select Mechanism. This tilting effectively shifts the spectrum, moving the central wavelength or order which falls on the detector across the detector. In the case of the echelles, the only motion enabled is in the order direction. Selection of a specific central wavelength is equivalent to selecting a set of MSM encoder positions for that optical element. For many modes of STIS, the full spectral range producing by the grating does not fall on the detector at any one time; the grating *must* be scanned to cover the full wavelength range, with an exposure taken at each scan position. A set of 89 *core central wavelengths* for the dispersive elements have been defined which allow full coverage of the free spectral range, with 10% overlap between spectra taken at adjacent settings. An additional 14 MSM positions have been identified to support imaging, target acquisitions and coronography for the GO supported apertures. We recommend supporting this set of 103 (=89+14) MSM positions for Cycle 7 GO science.[1]

Various suggestions have been made to use the scanning capability to increase the flexibility of central wavelength selection, from allowing full flexibility (choice of any central wavelength) to allowing GO specification of one of ~500 central wavelength settings. This kind of *supersampling* of wavelength selection space is desirable, in that it obviates the need to take two exposures to cover a fixed wavelength range when a single might do if the central wavelength could be shifted. If continuous wavelength selection is possible, it opens the possibility of doing efficient FPSPLIT observations by selection slightly different central wavelengths, thereby shifting the spectrum in wavelength space, while keeping it in place in the space direction. Clearly, there will be insufficient time to calibrate (either in thermal vac or in flight) the supersampled wavelength settings. Thus, in all cases, the values for the supersampled wavelength settings (beyond the core set) will be interpolated from those at the core wavelengths. In some cases interpolation may be appropriate and straightforward; however, for others it may well not be. There is a very large overhead involved with supporting supersampled or continuously selectable central wavelengths either in terms of the maintenance of a large number of calibration reference files for the pipeline and PDB or of software to interpolate among files in real time. In addition, ground test time is required to determine and verify the full set of MSM positions which are provided. To allow fine or continuous wavelength sampling an accurate model of the relationship between the three MSM encoder positions and the central wavelength projected on the detector is required. It is currently unclear if such models can be accurately developed.

To summarize, expanding from ~100 to ~500 MSM or continuous settings incurs considerable additional complexity and reliability risks. It facilitates science by allowing flexibility; at the same time it greatly increases the heterogeneity of the set of spectroscopic data taken by HST (particularly if interpolation turns out not to be robust), complicating inter-observation comparisons. Therefore, we recommend enabling for Cycle 7 GO use the choice of only the core central MSM wavelengths. If the IDT provides the necessary PDB and calibration files from ground test to allow utilization of the supersampled wavelengths or provision of continuous wavelength selection, then we can support *some* IDT use of these supersampled wavelengths in Engineering Only mode in Cycle 7, with a view to bringing on supersampling (or continuous sampling) in future cycles if it is deemed robust and reliable to do so.

1.It may be necessary to define the MSM settings to assure that key emission lines (e.g., [OII], [OIII], etc) have settings which place them in the center of the detector at zero redshift (to facilitate slitless spectroscopy at zero redshift) and that key sets of stellar emission lines for far-uv echelle spectroscopy are optimally covered in single settings. We recommend adding a small number of additional MSM positions for this purpose (<20), as deemed necessary.

Subarrays

The MAMAs and the CCD have the capability of reading out up to 8 subarrays of equal size. The subarray capability is used for both the MAMAs and the CCD to limit the data volume. Subarrays can also be used with the CCD to limit the read time. The `xcorneri` and `ycorneri` Engineering Only optional parameters in conjunction with the `xsize` and `ysize` optional parameters allow specification of the dimension and location of 8 subarrays in detector pixel coordinates. These 8 subarrays have been instituted in the ground and flight software for the MAMAs but not for the CCDs.

However, the GO cannot easily use the xcorner and ycorner parameters, because to do so requires a detailed understanding the projection of the 2-D spectrum on to the detector for each configuration, where here a configuration is a *detector/aperture/grating/MSM central wavelength* combination. For the GO, therefore, we need to provide an astronomer friendly interface which allows him/her to specify their subarray location in wavelength/order and arcseconds space. This necessitates the maintenance of a set of 2-D dispersion relations for the different modes in the PDB and the maintenance of a file for the mapping from arcseconds along the slit to detector coordinates (space mapping). The former is dependent on the detector/aperture/grating/central MSM wavelength combination, the latter is dependent on the apertures/slits only. (Note here that increasing the number of available MSM positions from 100-500 would result in an increase by a factor of 80% in the complexity of these PDB files and/or the software which accesses them if we chose to do the interpolation in real time).

As stated above, subarrays serve two scientific purposes: they reduce data volume and they speed up read time for CCD observations. Since use of a subarray means loss of data, users will only use them when forced to by one of these two constraints. The instances when they are needed should be minimal as described below.

Data volume constraints have been substantially reduced with the advent of the solid state recorder; the vast majority of GO science (~97%, see STIS Instrument Science Report 95-02) should be conducted by reading out a full image. Data volume/buffer management constraints allow users to take a full frame ACCUM mode CCD or MAMA 1024 x 1024 image every 15 seconds. ACCUM mode exposures are limited to one every ~3-5 seconds due to overhead with setting up the exposure. Thus the window where subarrays can be effectively used to manage data volume is for observations which monitor variability on the 5-15 second timescale. MAMA Time Tag mode covers shorter timescale variability uv science.

For the CCD, it is in fact the read time, expected to be ~27 seconds for the full frame, which limits the exposure rate. Through use of subarrays which are short in the parallel-direction, the read time can be reduced substantially since it allows fast clocking over the portion of the chip not included in the subarray. Subarrays which are short in the serial direction do not substantially alleviate read time considerations, since the full register must be clocked out in any case.

We recommend providing for the GO the option of using a single subarray which runs the full length of the detector in y (the dispersion direction for the vast majority of STIS modes) for the CCDs and for the MAMAs. For the CCDs this assures that the subarray will include the overscan region to allow debiasing and reaps the benefit of the rapid read (since the y axis or dispersion direction is along the serial direction). For the MAMAs requiring use of a full detector width subarray provides a substantial simplification to the ground system translation of astronomer inputs to the detector pixel `xcorneri` and `ycorneri` coordinates which are commanded to the instrument. The user will only specify the order number of the subarray for echelle modes, and the PDB need only need maintain a translation between order number and detector y pixel for each allowed MSM position.

This recommendation has three principal effects:

- it maintains the scientific benefit of shortening the read time for CCD observations and overcoming data volume limitations for variability work on the tens of second timescale for both CCD and MAMA observations,
- it considerably simplifies the proposal instructions for the GO,
- it considerably simplifies the PDB files/software needed to map from GO input parameters to `xcorneri` and `ycorneri`
- it simplifies the data products for the GO and the archive.

The only scientific areas which may suffer from this simplification are the cases of high time resolution echelle observations where lines on different orders widely spaced along the detectors are of interest and rapid images of planetary system where the GO might wish to place a single subarray along the x detector axis to trace the full spatial extent of a given emission line as the planet rotates. We anticipate that <1% of GO observations should require more than a single subarray such as recommended here; those can be satisfied using the Engineering mode `xcorneri` and `ycorneri` parameters with the assistance and approval of an instrument scientist; thus no science is precluded. Data taken in engineering only mode subarrays will be calibrated by the Cycle 7 Pipeline.

`Lowres` (1024 x 1024) MAMA Images

The MAMA detectors have 1024 x 1024 pixels. However each pixel is defined by 3 electrodes, so the ratio of charge distribution between the 3 electrodes can be used to centroid the incident charge cloud to sub-pixel resolutions. The MAMA detector processing electronics are hard-wired to always read out as 2048 x 2048 images, which can be binned on board to produced 1024 x 1024 images with pixels of size equal to the original detector pixels (so called *lowres* or `binx=2 biny=2` mode). The gain of the *highres* 2048 x 2048 mode is some moderate increase in resolution at the price of increased fixed pattern noise arising from the statistics of charge partition between the electrodes and flat field irreproducibility.

Don Linder has conducted an analysis of tests conducted to measure the resolution of *highres* versus *lowres* mode on the far-uv MAMA (MAMA 1). The test was conducted by stepping an illuminated 10 micron wide slit across the detector in increments of 0.1 Lo-Res pixels = ~3 microns, and taking images at each scan step. 30 scan steps were done. A profile was produced for each row which was scanned by integrating along the row in the direction perpendicular to the scan and plotting the counts versus scan step (microns). This experiment was conducted for different repeller voltages. A FWHM was determined from the raw data and from Gaussian fits to the data. The results were similar in all cases: *high-res* provided a 25% increase in resolution for the stepped slit. The *highres* gaussian was ~20 microns FWHM at the nominal operating voltage, and the *lowres* gaussian was 26 microns FWHM.

In actuality, for astronomical observations, the optical psf is expected to be 1.4 detector pixels (35 microns, ~0.03") Gaussian FWHM. For the narrowest slits the slit width projects to roughly 1.3 detector pixels. For astronomical observations, of course, the image (lines) of interest are not stepped across the detector as for the test, but illuminate the detector pixels in a fixed pattern, so that more generally to achieve the benefit of the resolution (i.e., for Nyquist sampling) 2 independent pixels across the psf are required (~2 detector pixels, or 50 microns).

To estimate the real improvement in resolution for astronomical observations from using *highres* mode we therefore have to take into account the optical psf in conjunction with the detector psf. While accurate simulations should be conducted, for the purpose of this exercise we can get an approximate answer by adding the PSF contributions from the detector and from the optics in quadrature. We first deconvolve the 10 micron slit width for the slit-stepped observations and find a detector PSF of ~ 17 microns FWHM for *high-res*, and 24 microns FWHM for *lowres*. Then, using a 1.4 detector pixel optical PSF, we find that the total resultant psf realized for astronomical observations in *highres* is ~39 microns and for *lowres* is ~42.5 microns, and the result is a ~9 % increase in resolution. This is the _best_ case scenario as we have not fully sampled the PSF; for the case of a fully sampled PSF, the improvement is ~5%. This small increase in resolution is accompanied by high price to pay in the pixel to pixel uniformity of the flat field (adjacent pixels vary by ~30% in an off/on pattern; variability of the pattern is yet to be fully established but appears to be substantial on day timescales, and it appears that the flats in highres mode are *rate dependent*), by the charge partition noise, and by the inherently lower signal to noise in the full resolution flat field/image (~25/1 maximally). All of these suggest that the benefit in resolution will be difficult to realize. Note that this discussion is really primarily relevant for the far-uv MAMA (MAMA 1); the detector PSF on the near-uv

MAMA (MAMA 2) has much broader wings and the benefit of *highres* is expected to be even less.

The use of *highres* as a typical GO mode has substantial operational consequences. The data volume is four times that from *lowres* mode, the pipeline processing time is increased by at least a factor of four (more in cases where internal memory is insufficient to work with 2048 x 2048 images), the data buffer management is more complex, automatic wavecal observations (taken to correct for wavelength and space uncertainties introduced by the MSM see below) must be done in subarray format to avoid paying a 2 minute price to dump the internal buffer prior to initiating a science observation. For the GO and the archive the volume of the data is 4 times as large. Scientifically, there is a small improvement in resolution, which must be offweighted by the uncertainty in the reliability of the flat field, the reduced signal to noise in the flat field and the added fixed patter noise. While it is certainly true that the GO can always bin their data to 1024 x 1024 on the ground, as we expect that the vast majority of GOs will want to do so (~95%), it seems prudent to do so in the instrument, and so not pay the price of managing the larger data volumes, either in the commanding or ground system or by the GO and the archive.

We therefore recommend only providing *lowres* (`binx`=2 and `biny`=2) for GO use with the MAMAs for full frame readouts. *Highres* (`binx`=1 and `biny`=1) would be available as Engineering parameters. We anticipate its scientific usage would be limited to astronomers seeking the highest possible spectroscopic resolution in echelle observations at high signal.[1] Dithering the telescope across exposures (i.e., scanning subsequent exposures across the lowres pixels) is likely to prove a more robust way of achieving the highest possible spatial resolution for first order modes and imaging.

Wavecals

An automatic wavecal will be taken following each move of the MSM and then associated with the subsequent science exposures for processing in the pipeline. The wavecal allows (1) determination of the zeropoint of the wavelength scale and (2) determination of the zeropoint of the astrometric scale (i.e., location of the aperture center in pixel coordinates). The former is important to allow knowledge of the absolute velocities, the latter to allow comparison of exposures taken at different MSM positions for line ratio and kinematic work on extended sources. We recommend that all automatic wavecals be taken as full frame, using the same set up of slit, grating, MSM position, and X and Y binning, as

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1. An alternate possibility worth considering is to take all first order science far-uv MAMA1 and all near-uv MAMA2 data in lowres, and taking far-uv MAMA 1 Echelle data in 1024 x 2048 mode (binned only in the space direction, providing the maximum spectroscopic resolution). This is a viable option which maintains the science benefit of *highres* for just that science for which it is most appropriate, however given the current understanding of the flat fielding properties of *highres*, it is not clear what the benefits would be.

the science exposures with which they are associated (or the first science exposure with which they are associated in the case of ambiguity).

There have been suggestions that the wavecals be taken as a series of 8 subarrays in order to reduce data volume and ease buffer management problems. However, there is a large overhead involved with taking wavecals as subarrays. Specifically, the location of the lines (hence subarrays) will change with the setting of the MSM as will the location of the features in the slits which allows identification of the aperture center on the detector (these are the slit edges or occulting bars). That is, the PDB must maintain tables identifying the subarray `xcorneri` and `ycorneri` locations for each combination of detector, grating, and central MSM wavelength in addition to a set of offsets to those locations for each aperture. Determination of the subarrays, assurance that there is enough slop in the sizes and locations of the subarrays so that spectral lines desired for the cross correlation will not be missed, all come into play. By using full frame wavecals, these problems are avoided. In addition, it considerably simplifies the task in the calibration pipeline of identifying spectral line and aperture features to determine the wavelength and space offsets and assures the robustness of these procedures.

The only downside of taking full frame wavecals comes for full frame *highres* MAMA science. There, the 2048 x 2048 image must be transferred out of the internal memory buffer to the tape recorder immediately after it is taken. This adds an additional 2 minutes to the wavecal time, which will range from ~tens of seconds to several minutes in duration, depending on the mode and whether shuttering is required. However, this penalty is only felt for 2048 x 2048 MAMA exposures; (1) we expect such *highres* exposures to be inherently long to achieve the necessary signal to noise to benefit from the higher resolution in face of the fixed pattern noise, (2) we expect *highres* to be rarely used (See “`Lowres` (1024 x 1024) MAMA Images” on page 12.).

Repeller

The faruv (Band 1) MAMA, has a *repeller* voltage which can be commanded on or off. By turning the repeller voltage on, photoelectrons which are moving in directions other than into the microchannel plate (MCP) are driven into the MCP. This produces a substantial increase in the quantum efficiency of the faruv MAMA. However, the photo-electrons have their own random velocities - they may travel some lateral distance before falling into the microchannels, thereby increasing the detector PSF (dPSF). At this time it is unclear what the affect on the detector PSF is from having the repeller voltage on - it appears as if there may be a 20% increase in the signal in the wings of the PSF at ~8 pixels.

Careful tests and data analysis will have to be conducted to determine the trade off between the benefits of having the repeller off or on. However, it is clear that the calibration overhead will be *greatly* increased if both options are available to the GO. Throughput versus wavelength and flat field calibration observations will have to be conducted separately for the fuv-MAMA with the repeller on and the fuv-MAMA and the repeller off (they are essentially then two separate detectors). It seems unlikely that the repeller voltage configuration will affect the geometric properties of the detectors; if there was a dependence on repeller configuration, then separate dispersion solutions would have be maintained for the two configurations. Since each fuv-MAMA flat field must be ~10 hours long to obtain a signal to noise of 100:1 for *lowres* (the long duration is due to the need to maintain the global count rate across the detector below the non-linear regime), there is a substantial overhead here to the calibration program both in orbit and during ground test.

We therefore recommend that the repeller voltage configuration (off or on) not be selectable by the GO. [1]

Science Operating Modes

STIS supports three science operating modes. ACCUMULATE mode for the MAMA and CCD produces an image of counts accumulated at each pixel. ACCUM is the fundamental science mode of STIS which the vast majority of science observations will utilize (>95%). TIMETAG mode for the MAMAs, which passes a x,y, time tagged stream of photon events, facilitates rapid variability work in the ultraviolet. Despite the fact that TIMETAG mode will compromise a small fraction of GO science, it facilitates an important scientific niche which otherwise is not available, and hence should be supported.

PSD (parallel scan and dwell) for the CCD enables time variable CCD work. However, we expect PSD mode to be used extremely rarely. Time variable work in the optical can also be performed from the ground though there may be some improvement in time resolution in space due to the lack of atmospheric affects. The ability of the CCD to achieve high throughput in the 2500-3100A range also suggests that CCD PSD will enable time variable work in the near uv. Development of CCD PSD mode is, however, clearly of lower priority that the other science operating modes and we do not recommend that it be developed for Cycle 7.

Target Acquisition Modes

Twelve target acquisition modes have been defined for STIS. Of these, six are essential to facilitate STIS science and should be developed and supported for Cycle 7. These are:

- CCD `Point Source Acquisition`
- CCD `Bright Object Acquisition`, needed to allow point source acquisitions on bright stars as well as for coronography

1.This recommendation may need to be reviewed if strong scientific need for both configurations is established.

- CCD `acq/peakup`
- MAMA `acq/peakup`
- CCD `diffuse acquisition`
- CCD `planetary acquisition.`

Unless the CCD fails, it is anticipated that all acquisitions will be conducted with the CCD; peakups for MAMA observations will be conducted with the MAMA and those for CCD observations with the CCD. Diffuse and planetary acquisitions are needed to allow acquisition of planets and extended objects, when suitable offsets from point sources are not available.

Of lower priority are CCD crowded field acquisitions, MAMA Point Source, Diffuse, Crowded, Planet, and Bright Object Acquisitions. We recommend not developing them for Cycle 7 science - they should be enabled as scientific need for them develops.