This technical note describes the SPIRE FTS Spectrometer Mechanism scanning parameters needed for running the AOTs. The optimum scanning parameters are determined by the length of the scan needed to reach a certain resolution and the most efficient position to use as the SMEC home point. The main aim of this review is to optimise the observing efficiency for HSpot phase 2 release, and in the final AOT version used in orbit.

Currently in the version of HSpot for phase 1, the following SMEC parameters are used (the definition of each parameter is given in Section 2):

Resolution	$\Delta\sigma$	HOME	ScanSpeed	ScanStart	ScanEnd	ScanTime
LOW	1.0	100	500	6300	9500	6.4
MEDIUM	0.25	100	500	1800	14000	24.4
HIGH	0.04	100	500	6000	39600	67.2

1. Overview of SPIRE FTS AOTs

The sequence of commands and timings for the spectrometer AOTs SOF1 and SOF2 are shown below. The time used to configure the instrument is taken out of the initial telescope slew and so is not charged to the observer.

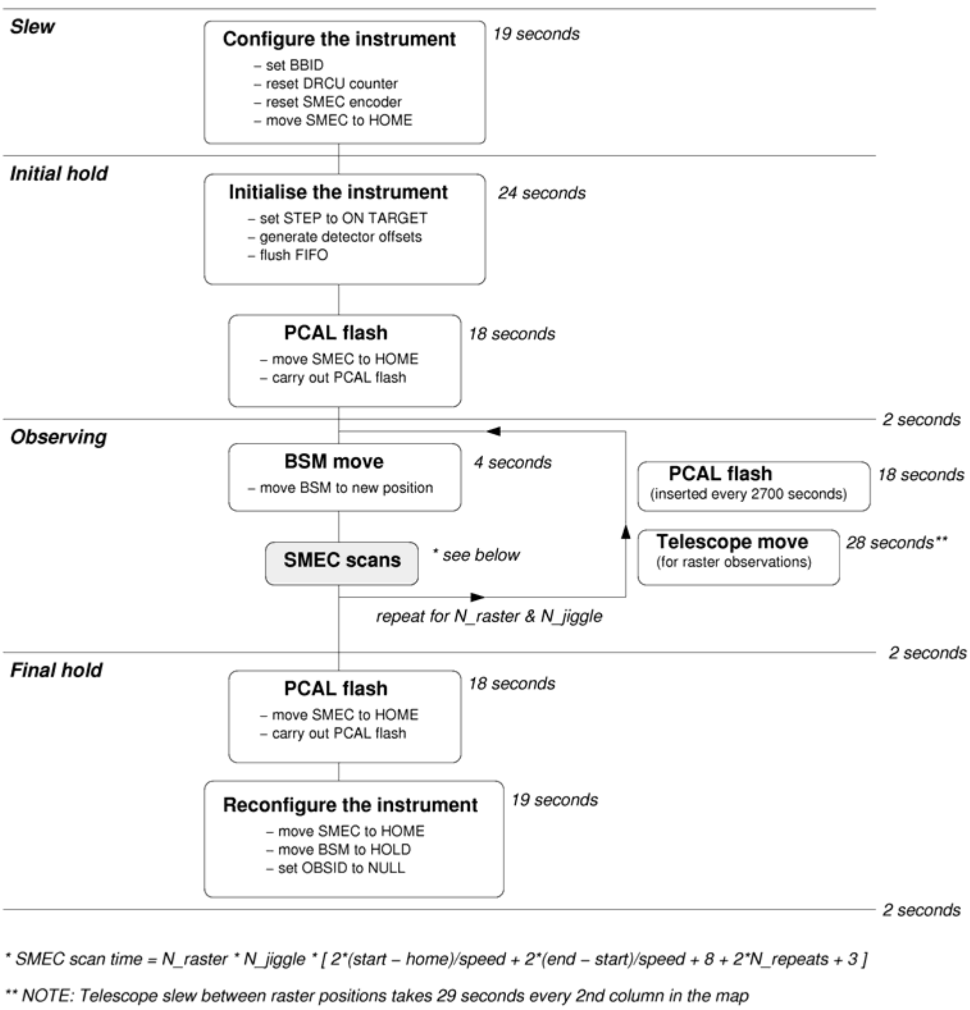

Figure 1: *Sequence used for spectrometer AOTs.*

The detailed procedure within the SMEC scans box in the previous diagram is shown in the following plot (where neither axis is to scale). This plot shows a Low Resolution scan with 3 repetitions. Each repetition consists of a forward and reverse scan.

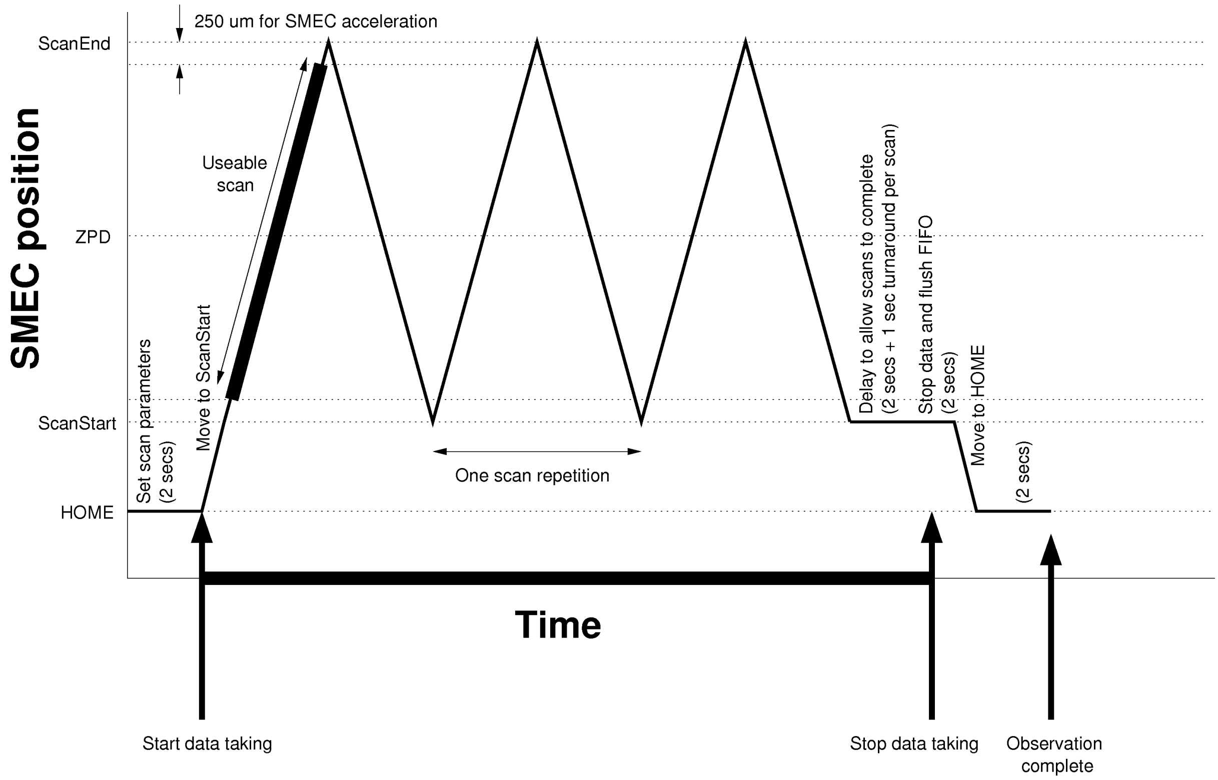

Figure 2: *Details of SMEC scan for Low Resolution mode.*

The initial location of the SMEC before starting scanning is assumed to be the HOME position. It is returned to the HOME position at the end of the scans. Data taking starts just before moving from HOME to the ScanStart position and ends when scanning has finished but before moving back to HOME.

2. SMEC SCANNING PARAMETERS

The SMEC scanning parameters required are

- HOME: Reference position for the SMEC used for PCAL flashes and for the hold between spectrometer observations.
- ScanStart: Start position of SMEC scan, including extra distance to allow the SMEC to accelerate to constant speed.
- ScanEnd: End position of SMEC scan, including extra distance to allow the SMEC to accelerate to constant speed.
- ScanSpeed: Speed of the SMEC
- ScanTime: Length of time needed for the SMEC to travel from ScanStart to ScanEnd.

ScanStart and ScanEnd are calculated from the final required spectral resolution using the following method. This assumes SMEC parameters based on PFM4 observations.

Assume that the position for zero path difference (ZPD) is at 7860 μm, with a maximum recommended travel of 39600 μm from cold stop (based on PFM4 observations).

Compute the start and end positions of the SMEC for the three resolutions,

HIGH: $\Delta\sigma$ = 0.04 cm^{-1}
MED: $\Delta\sigma$ = 0.25 cm^{-1}
LOW: $\Delta\sigma$ = 1.0 cm^{-1}

These values are defined as the distance from the peak of the instrumental sinc function to the first zero crossing point (the full width at half maximum is given by 1.207$\Delta\sigma$).

Calculate the length of travel either side of ZPD as,

$$L = \frac{1}{2\Delta\sigma}$$

where L is given in cm in optical path difference (OPD).

The length is then converted to mechanical path difference (MPD, a factor of 4 lower than OPD due to the nature of the Mach-Zender FTS), and a correction added to each end of the scan to account for the time needed for the SMEC to accelerate to constant speed. This correction should be 0.5 seconds. Assuming a SMEC speed of 500 μm/s, this means 250 μm should be added to the distance.

For example, for Low Resolution mode,

$\Delta\sigma$ = 1.0 cm^{-1}
L_{OPD} = 0.5 cm = 5000 μm
L_{MPD} = 1250 μm

Final scan length in MPD = 1250 + 250
= 1500 μm

The final scan limits are given by ZPD ± scan length.

This results in:

ScanStart = 7860 - 1500 μm = 6360 μm → 6300 μm to get a nicer round number
ScanEnd = 7860 + 1500 μm = 9360 μm → 9500 μm to get a nicer round number

The final parameters for each resolution are:

Resolution	$\Delta\sigma$	*Final* L_{MPD}	*Max. ScanStart*	*Min. ScanEnd*	**ScanStart**	**ScanEnd**	**ScanTime**
LOW	**1.0**	*1500*	*6360*	*9360*	**6300**	**9500**	**6.4**
MEDIUM	**0.25**	*5250*	*2610*	*13110*	**1800**	**14000**	**24.4**
HIGH	**0.04**	*31500*	*	*39360*	**6300***	**39600**	**66.6**

* The scan for HIGH resolution is not symmetrical about ZPD, and is set to start at the same position as the LOW resolution scan.

The scans for Low and Medium resolution mode are double sided and symmetrical about ZPD. However, High resolution mode is not symmetrical and has a short length on the low side of ZPD. The start position for High resolution mode is set to the same value as Low resolution mode as this makes it easier to do direct comparisons between the two, whilst still allowing sufficient coverage of the double sided portion of the interferogram to give a good reconstruction of the spectrum. It is also an advantage to have the starting position for Low and High resolution scans the same because it allows easier commanding in the "Low+High" mode (see later).

3. Determination of HOME position

The position of SMEC HOME is used for PCAL flash measurements and as a hold position between observations.

The best position for HOME for making PCAL flash measurements should be in the quiet part of the interferogram away from fringes and large amplitude variations. This is to remove as much possible variation between measurements so that the response of the detectors can be accurately traced from one flash to the next.

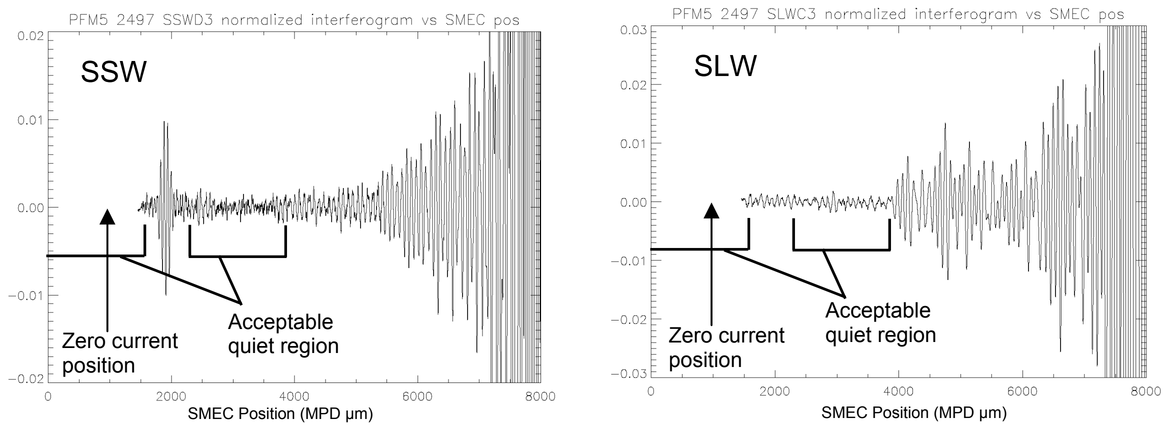

Figure 3: Normalised interferograms for SSW and SLW from PFM5, showing the zero current region and acceptable quiet regions of the interferogram.

Figure 3 shows normalised interferograms from PFM5, with the SMEC position requiring zero current (1000 µm – see Fig. 4) and the quiet region where the modulated signal is at an acceptable level for PCAL flash measurements.

During PFM testing in the lab, a SMEC position of 1000 µm was used for HOME. In order to maintain consistency between ground tests and observations in space, it could be an advantage to keep the lab value of HOME. However, this need not be the one used for PFM testing at RAL because once the instrument is integrated into the spacecraft, the response to PCAL will change anyway (ie. with the final optics rather than those for the lab tests). PCAL testing will be redone during IST and the new value of HOME can be used there.

As the SMEC HOME position is used as the reference at which the SMEC is held between observations and between scanning, it is important to consider the power required to maintain it at the proposed position. Figure 4 shows the power dissipation and the SMEC position for a SMEC scan observation during PFM5. This shows that the position with zero current and zero power dissipation is at 1000 µm. For a HOME position at the higher end of the acceptable region from Fig. 3, at 3500 µm, the power dissipated is ~0.1 mW.

Even though the SMEC is kept at HOME position between spectrometer observations, it is only switched on during spectrometer operations. This means that the extra power dissipated for HOME positions greater than 1000 µm will not affect the operation of the photometer.

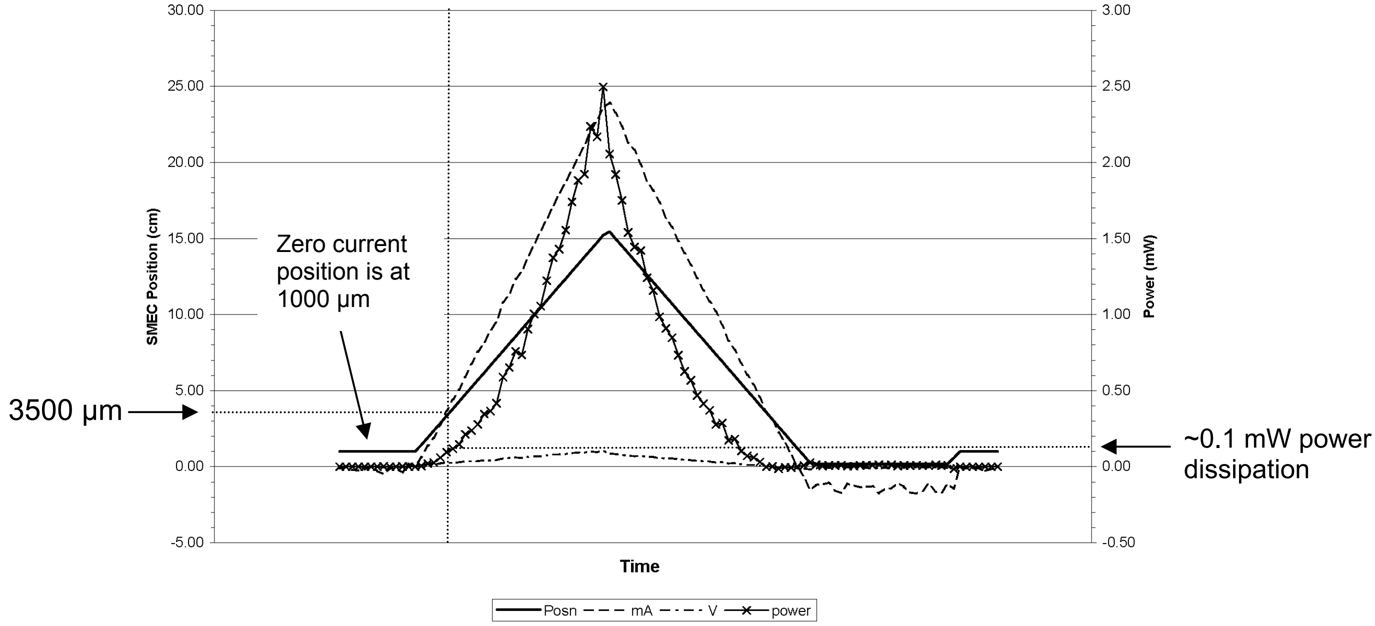

Figure 4: SMEC position, current, voltage and power from an example observation in PFM5.

The final consideration for the position of HOME is the efficiency of the observation. In order to minimise the time taken for the SMEC to travel between HOME and ScanStart, the HOME position should be located between the start positions for Medium and High/Low resolution. This would indicate a position in the region of 4000 µm. This is just at the edge of the region highlighted in Fig. 3, and so taking both factors into account would indicate the best position for HOME to be 3500 µm. The effect of this position related to the zero current position at 1000 µm is investigated in the next section.

4. ANALYSIS OF OVERHEADS IN SPECTROMETER AOTS

The efficiency of spectrometer observations depends critically on how much time is spent moving the SMEC between its HOME position (required for PCAL flashes) and the scan starting position.

For greatest efficiency the HOME position should be placed as close to the scan start position as possible. In addition, the number of times the SMEC must move between the two positions should be minimised.

The best way to minimise the number of times the SMEC is required to move from HOME to scan start is to only travel to HOME when absolutely necessary – ie. for PCAL flashes and at the end of the observation.

This indicates that not only should the SMEC scanning parameters be optimised, but that the whole sequence of the AOT (Fig. 1) could be reorganised to minimise movements between HOME and ScanStart positions. The following is a 2 stage proposal to increase efficiency.

1) **Adjust the position of HOME to be 3500 μm.**
The reasons for the location of HOME are given in the previous section.

2) **Reorganise the AOT so that the SMEC only goes to HOME for PCAL flashes.**
This involves moving the SMEC to the scan start position during configuration. Scan start would then become the reference position that each step of the AOT leaves the SMEC at. PCAL building blocks would need to move from scan start to HOME and back. Reconfiguration would need to move to HOME at the end (actually, it already allows for this movement).

The proposed reorganisation of the AOT would change the sequence in Fig. 1 to be as shown in Fig. 5.

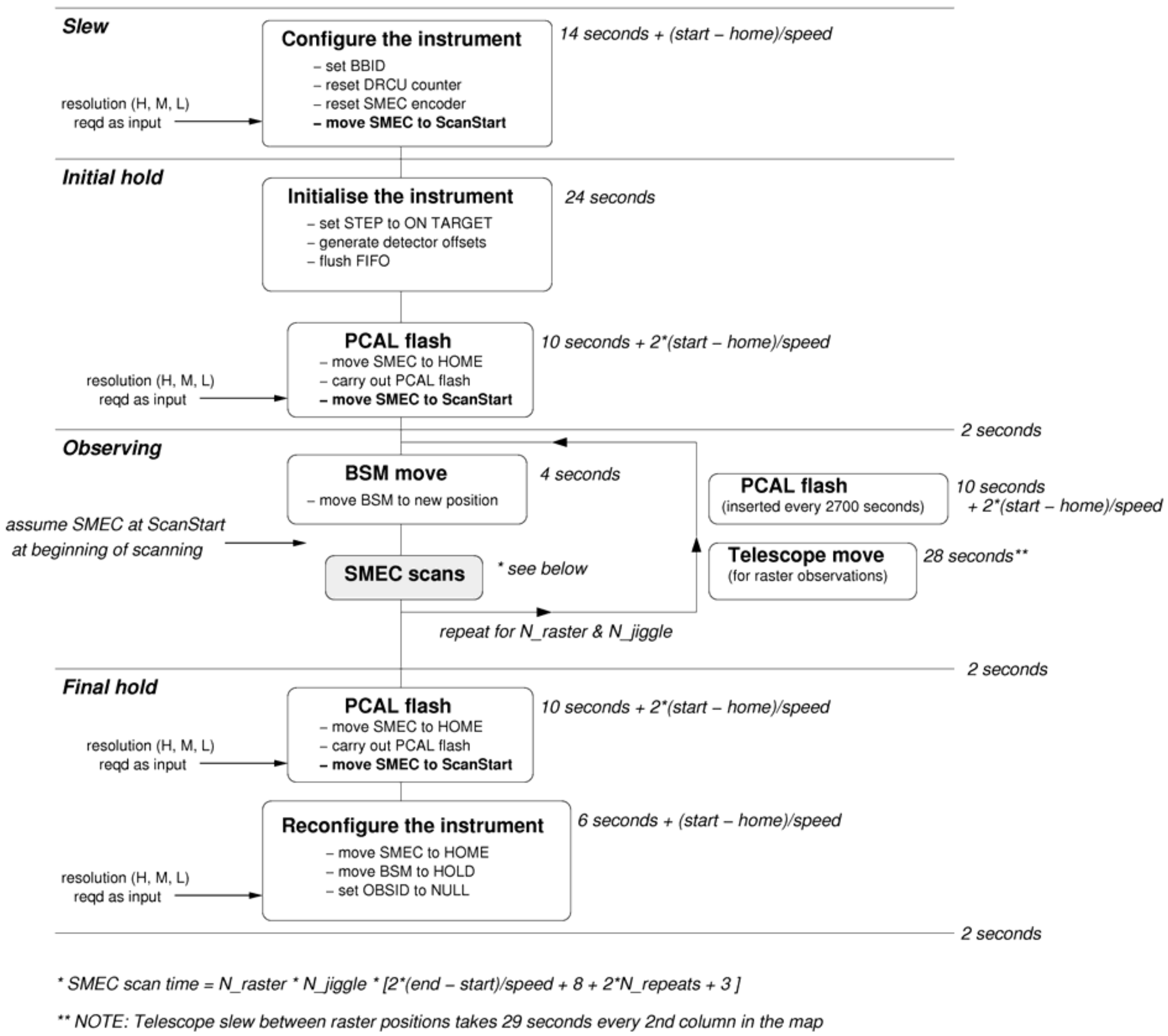

Figure 5: Sequence for spectrometer AOTs after reorganisation.

The effect of these two proposals on the observing efficiency is shown in the following plots. The corresponding efficiency for a HOME position at 1000 μm (zero current) is also shown. The efficiency is calculated ignoring the 180 second observatory slew tax.

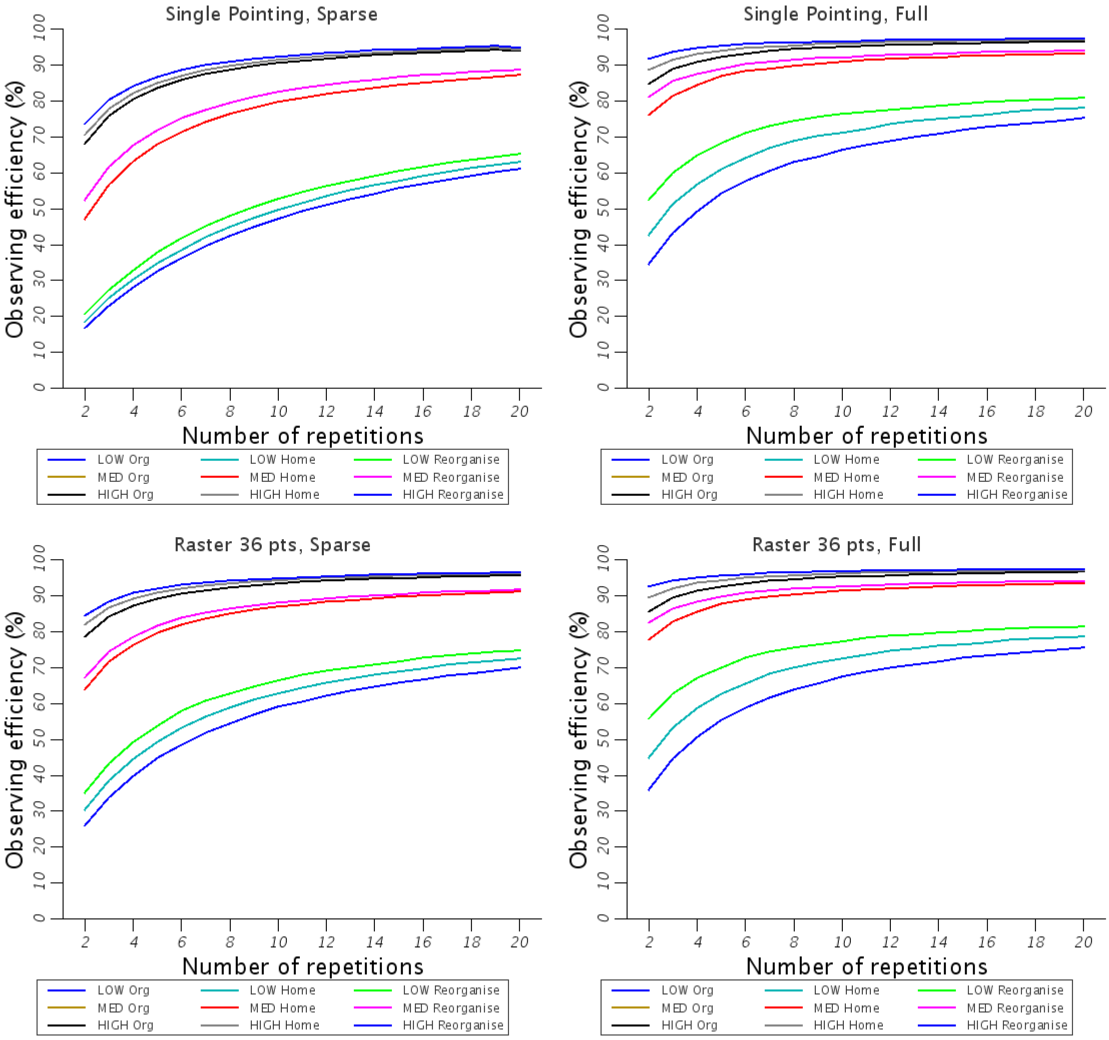

Figure 6: *Efficiency of low, medium and high resolution modes with different numbers of repetitions for the current HSpot case (Org), change of HOME to 3500, and reorganisation of the AOT.*

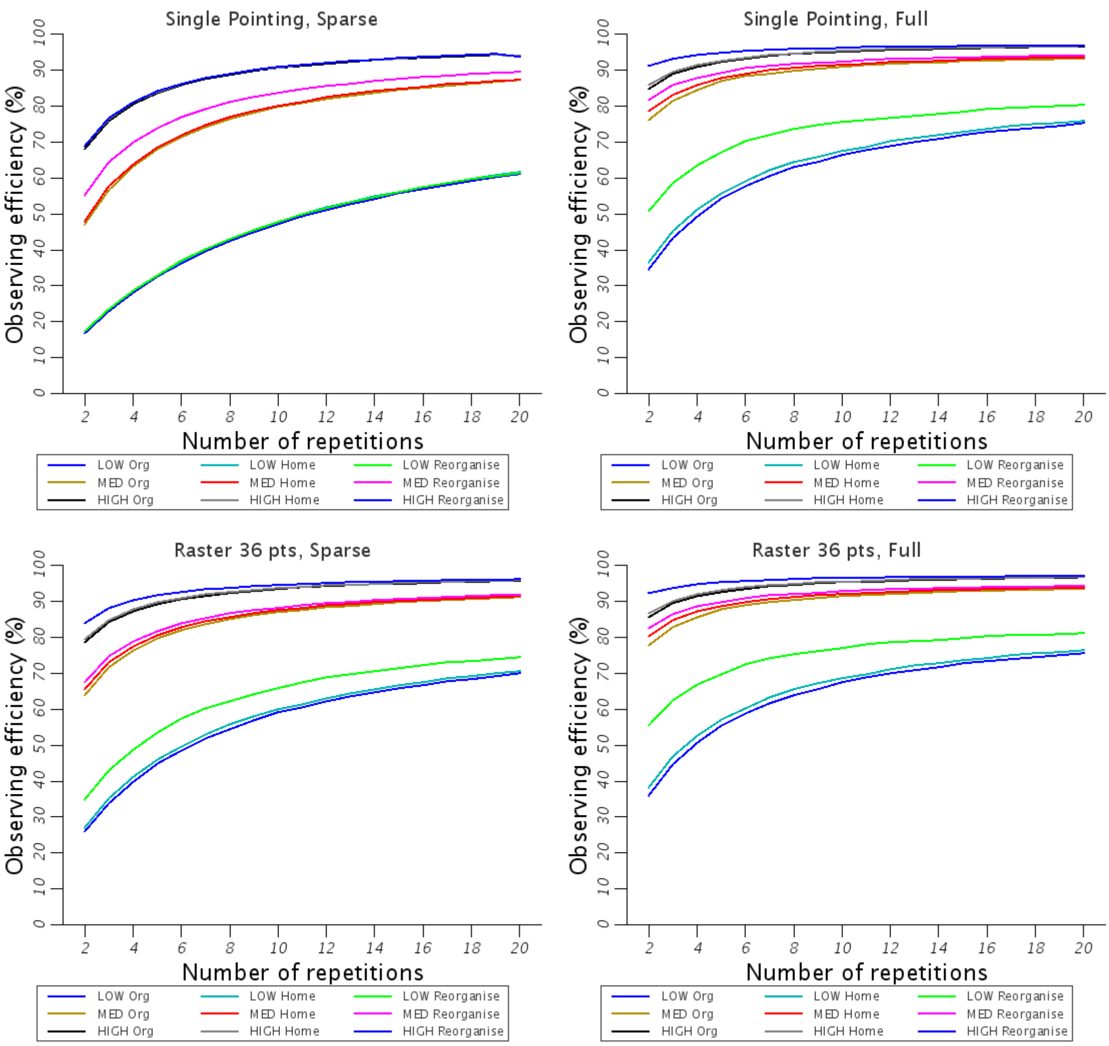

Figure 7: *Efficiency of low, medium and high resolution modes with different numbers of repetitions for the current HSpot case (Org), change of HOME to 1000, and reorganisation of the AOT.*

It is clear that the efficiency of the low resolution mode can be significantly improved by adopting both of the two proposals, particularly for jiggled or raster observations. However, if only the first proposal to change the HOME position can be implemented, it is clearly better to use the value of 3500 rather than the zero current position at 1000.

Once both proposals are implemented, the position of HOME (1000 or 3500) does not make a significant difference.

The only exception is low resolution, single pointed sparse observations which would benefit from a HOME position as close as possible to the scan start of 6300. The effect of increasing HOME to 5000 is shown below in Fig. 8.

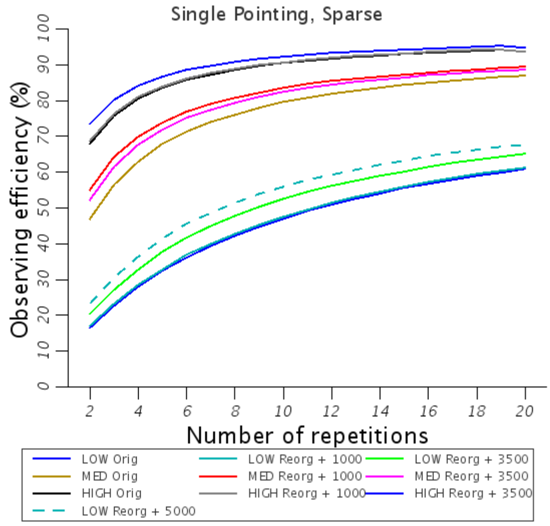

Figure 8: *Comparison of the effect of changing HOME to either 1000 or 3500 and implementing the reorganisation of the AOT for single pointing, sparse. For other jiggled and raster modes there is no significant difference in efficiency between HOME of 1000 and 3500. The dashed line shows the effect of increasing HOME to 5000 for low resolution mode.*

5. FEATURES ACTUALLY IMPLEMENTED FOR HSPOT PHASE 2

The release of HSpot for phase 2 will contain the following modifications for spectrometer AOTs compared to the phase 1 release:

- HOME position changed from 100 to 3500
- ScanStart for High resolution changed from 6000 to 6300

The direct effect of these changes on 4 example observations (2 are real observations proposed in the GT) are shown below.

Example	Description	On source time	Total time phase 1	Total time phase 2	Saving
Standard low res	Low res Single point sparse 2 repetitions	25.6 sec	334 sec	320 sec	14 sec 0.004 hrs
Standard high res fully sampled	High res Single point full 2 repetitions	2150 sec	5259 sec	5019 sec	240 sec 0.07 hrs
SAG 4	High + Low res Single point full 2 repetitions	4710 sec	6317 sec	5853 sec	464 sec 0.13 hrs
SAG 6 10'x10' raster	Low res 6 FOV x 6 FOV intermediate 2 repetitions	1843 sec	11253 sec	9219 sec	2034 sec 0.57 hrs

The above examples show that although the changes may not make a huge saving on standard low and high resolution examples, they do start to make a real difference to the total observing time for actual observations that have been proposed as part of the guaranteed time SAGs.

6. FEATURES STILL TO IMPLEMENT BEFORE LAUNCH

There are several features that must still be implemented in spectrometer observations before launch.

6.1 SPIRE SPR-0591: *SMEC scan does not begin at SCANSTART position*

The most important is to fix a bug that was found during PFM4 AOT testing. This causes the SMEC scanning to start from the HOME position rather than ScanStart. Now that HOME has been changed to 3500 μm, this will mean that Medium resolution scans will miss data between ScanStart (1800 μm) and HOME. The reason for this problem is most likely that there is no specific command sent to the SMEC to move from HOME to ScanStart. There is only a single 'move' command sent to start the scanning sequence and this does not move the SMEC backwards to ScanStart first.

6.2 HCSS SCR-3057: *Reorganisation of Spectrometer observations to reduce overheads*

This SCR relates to the second stage of the proposal in Section 4.

If the proposal was implemented as described in Section 4, the savings in time for the 4 example observations described in Section 5 over HSpot phase 1 would be:

Example	Description	On source time	Total time phase 1	Total time reorganised	Saving
Standard low res	Low res Single point sparse 2 repetitions	25.6 sec	334 sec	306 sec	28 sec 0.008 hrs
Standard high res fully sampled	High res Single point full 2 repetitions	2150 sec	5259 sec	4843 sec	416 sec 0.12 hrs
SAG 4	High + Low res Single point full 2 repetitions	4710 sec	6317 sec	5482 sec	835 sec 0.23 hrs
SAG 6 10'x10' raster	Low res 6 FOV x 6 FOV intermediate 2 repetitions	1843 sec	11253 sec	7620 sec	3633 sec 1.01 hrs