1. INTRODUCTION

1.1 Scope

This document outlines the way an astronomer will interact with the Herschel observing tool to specify an observation (or set of observations) performed by the SPIRE photometer arrays.

An Astronomical Observation Template is a form which contains all the necessary information to perform an observation. (c.f. AOR- Spitzer, ODF/MSB for JCMT-SCUBA). AOT is a misleading name as there is no physical 'template' in the strictest sense for the astronomer to fill in. The necessary information for the definition of an observation will be handled by the Herschel observing tool and supplied in as yet unspecified format to the Observation Scheduler and the CUS.

In short the AOT provides the information to:

1) Plan an observation via the SPOT system.
2) Schedule an observation
3) Produce the building blocks for the instrument commanding
4) Reduce the resultant data

This note outlines the decision-making process for an observer to plan an observation and investigate the flux sensitivity required to achieve his/her science goal. It is assumed that specific scheduling information (source availability, sizes etc) is provided by the generic Herschel observing tool.

1.2 What SPIRE needs to produce for AOTs

SPIRE is required to provide:

- A decision tree for the PHOT observing modes for HSC to incorporate into Herschel-SPOT
- Ancillary information to HSC for full definition of an observation.
- The necessary logic and tables in order for the observing tool to give a realistic estimate of on-source and overhead times for a given sensitivity.
- A method of converting the completed AOT into CUS language for subsequent insertion into the uplink command chain via the Scheduler.

1.3 Expert/General Astronomer AOTs

There are policy decisions to be made concerning the availability of observing modes to the general astronomer compared to expert user and calibration. On the one hand the SPIRE ICC wants the astronomer to utilise the full capabilities of SPIRE to achieve the key science goals but on the other hand the SPIRE-ICC does not want to hand an extremely complex data set to an observer which may require extensive knowledge of the operating modes and, consequently, a complex reduction procedure. In order to make SPIRE a successful instrument the SPIRE-ICC must provide the **best** observing technique for a given scientific programme. It will
become evident which observing modes are the favoured ones during testing and initial in-flight testing.

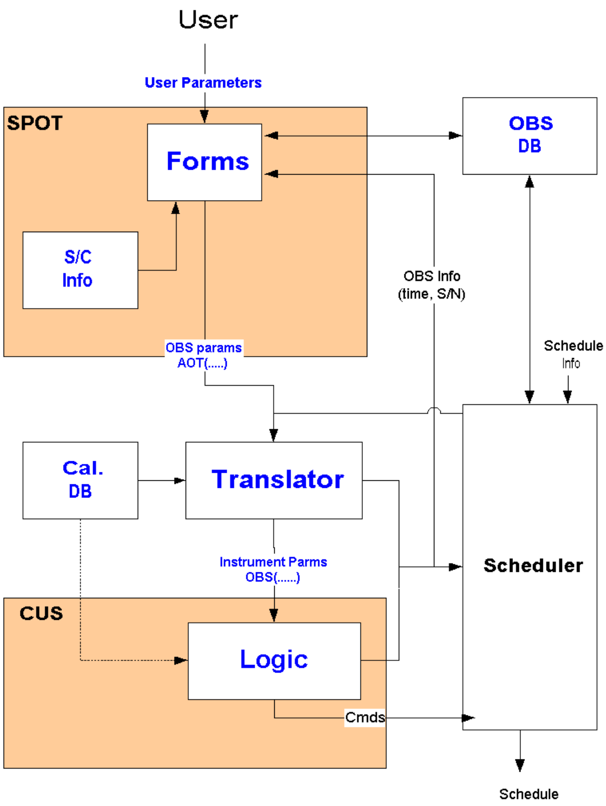

Figure 1: The interconnectivity between SPOT, CUS and the scheduler

There will be a special tool for instrument specialists ("Expert SPOT") for when they want to try out different parameters (and maybe logic) for an AOT. These situations could arise either in PV phase before rubber-stamped AOTs are released, or after PV if they need to be changed or for any special observations with the instrument.

This note as it stands (see date at top of page) provides pseudo-code for HSC to deliver the front-end of the SPOT.

1.4 An AOT as a means to reduce SPIRE-PHOT data

As the AOT contains all the information on how to execute an observation the observer can use this information to correctly reduce his/her resultant data. At the very least the AOT should form the basis of the script for Standard Product Generation. It is therefore necessary for the AOT information to be attached to the data. Keywords from the AOT contained in the data product would be recognised by the SPIRE IA system and the relevant reduction steps performed. The AOT itself will be a small set of keywords and parameters so will not make the data product unduly cumbersome.

2. AOT role within the Herschel SPOT, the Scheduler and CUS

The SPIRE-PHOT AOT Meeting (6-7th April) produced a diagram (overleaf) mapping out the interconnectivity between the Herschel-SPOT, the Scheduler and CUS. A translator of the observation parameters to CUS language is required. The translation of the AOT parameters to the

CUS language will reside within the SPOT. The AOT parameters will translate to a number of building blocks. This AOT parameter-CUS building block matrix will be supplied by SPIRE for use within SPOT.

In both the SPOT-tool and the CUS, certain calibration information will be needed. However, whether this is the same file or different version of the same one has yet to be decided. The 'Forms' in this case are the product of the astronomer's interaction with the front end of SPOT. Each decision made i.e. mode , number of integrations, ra, dec etc will be passed to the translator and subsequently the scheduler. The scheduler has two roles; to decide the optimum order of observations and to construct a commanding schedule for uplink. In other words creating microschedules (commanding) within a macroschedule (observation order).

The calibration files required for the SPOT will necessarily have to reside within SPOT and not have a direct link to the HCSS database. These will be updated by SPIRE-ICC as deliveries to the HSC SPOT team. The calibration files required for the CUS will have a direct link to the database as these will involve updates on a much shorter timescale.

3. SPIRE-PHOT DECISION TREES FOR HERSCHEL SPOT

There will be three options for producing a SPIRE PHOT AOT:

1) Point source observation
2) Mapping (jiggle, rastering jiggle and scanning)
3) Parallel Mode with PACS.

In the next three sections there are decision trees for the observing modes. They step through the key decisions the astronomer must make to generate his/her AOT for a SPIRE-PHOT observation. It is envisaged that the SPOT system will point to relevant documentation in order for *informed* decisions be made.

The integration time is the most likely area where the user will play.

The calculation of the integration time will incorporate telescope and instrument overheads as either a percentage of observation time or a fixed value. These values will be contained in the 'Help' and in the documentation accompanying Herschel SPOT. Estimates are provided in Section 2.3. For a given observing mode there will be an option to enter any two of the following criteria in the time estimator which will provide the third: S/N, Time, Source flux (mJy) for all the SPIRE passbands:

Time/sec	Signal/Noise	Source Flux/mJy
	250 microns	
3600	**5**	**7.6**

	350 microns	
3600	**5**	**9.2**

500 microns		
3600	**5**	**10.5**

In this example the astronomer has entered the blue values for time (all overheads included) and r.m.s. flux required and the red values have been calculated by Herschel SPOT. For particularly short observations the astronomer will be aware of step changes in time taken for increments of S/N due to the smallest possible integration time imposed by the jiggle pattern, chop or nod strategy. For example if the astronomer enters a time the estimator will choose the nearest integer number of 'cycles' and show the actual amount of time taken.

3.1 Point Source Observation

The important point to remember is that the observer needs to know how well he/she knows the source position.[1] There are two modes; Single point and 7-point jiggle. The former is a stare at a source using the coincident bolometers. This mode must only be used when the observer is extremely confident of the source position (<1 arcsec) and does not anticipate any flux loss outside of the bolometer. The latter is a small jiggle to ensure all the source flux is gathered in case the source flux is not absolutely falling on a bolometer. This mode does not produce a fully sampled map. It does however provide 7 point jiggle maps at all bolometer positions so it is easy to imagine this mode being used as a sparse mapping technique.
It is worth remembering that even if the astronomer knows the position well he/she may choose the 7-point jiggle. In reality this will be the default point-source observing mode.

Open Issue: What is the difference in time for 7-point and 1-point compared to the total time with overheads?

[1] I find it hard to imagine sources (outside of extremely bright sources) where an observer would be confident to get the source flux contained wholly within the coincident bolometers in all bands (see Operating Modes for SPIRE document for detailed analysis). Even some *calibrators* have centroids dependent on wavelength in the range 350-1000 microns; shifting by a few arcsecs wavelength-to-wavelength. The single pointing mode will be rarely used by general astronomers because of the almost unknown bands which SPIRE is operating at because it is difficult to see an observer risking a 'miss' for the sake of shorter integration time.

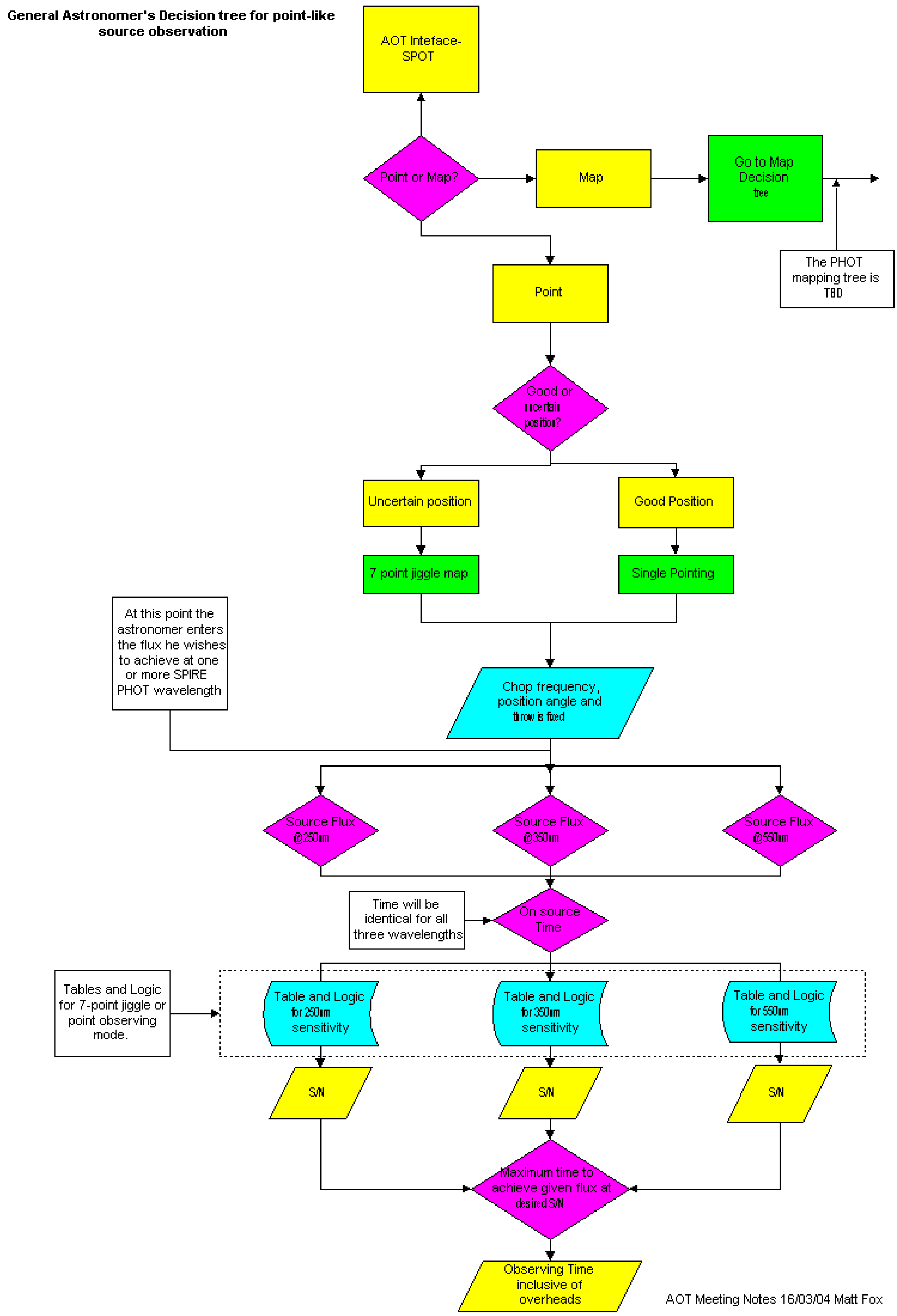

Figure 2: Decision tree for point source observations

3.2 Mapping Observations

When an astronomical source extension is greater than the beamsize (in the wavelength of interest) and the science requirements either demand spatial information or a survey is being conducted then a fully sampled map must be used.
There are three options for the choices of mapping modes;

Small Area	area < 4' x 4'	Jiggle mapping
Large Area	4' x 4' < area < 40' x 40'	Raster jiggle mapping or Scan mapping
Very Large Area	area > 40' x 40'	Scan mapping

Open Issue: It is unclear whether the SPIRE-ICC will make the final decision on the most efficient method for covering area to the depth required by the observer i.e. the use of chopping and/or nodding.

Open Issue: Should the AOT interface provide a method for indicating a preferred observing strategy i.e. how many times should the area be 'painted' by SPIRE-PHOT to reach the depth. One would expect at least two 'coats' would be required for all observations.

Two parts to the decision making process are omitted from the following decision trees; chopping and nodding. Nodding is quoted as being optional in POF2, POF3 and POF4. Chopping is used in POF6 but not in POF5. If these options are to be passed to the general astronomer then it should be made clear in the accompanying documentation the reasons for using these different modes and the impact they will have on the integration time and reduction required. As it is not clear which is the most efficient at this stage for the sake of clarity on the diagrams I have omitted the decision. As it stands the decision is taken within the SPIRE-ICC and is assumed to be hard coded into the SPOT system. **This may change**.
Also the actual coverage for a jiggle map is technically a circle of diameter 2.6' bound by a 4'x4' box in the central portion of the bolometer array[2].

Open Issue: The chop direction and throw can be varied from the default values. There may be circumstances where this is a good idea eg. An observer wanting a long thin field might prefer to chop perpendicular to the y axis rather than parallel. Do we wish to allow changes to a preset chop throw and direction? What implications for reduction and support would there be in allowing this freedom? How flexible should these choices be?

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[2] If raster mode is used the outer portions of the map (outside of the central circle) could be used to build up the S/N between the centre lines of the raster map. In the guidelines by Matt Griffin it seems to discount these out areas without any stategic use of 50% of the SPIRE arrays.

On the accompanying decision trees are the limits to all the observation parameters.

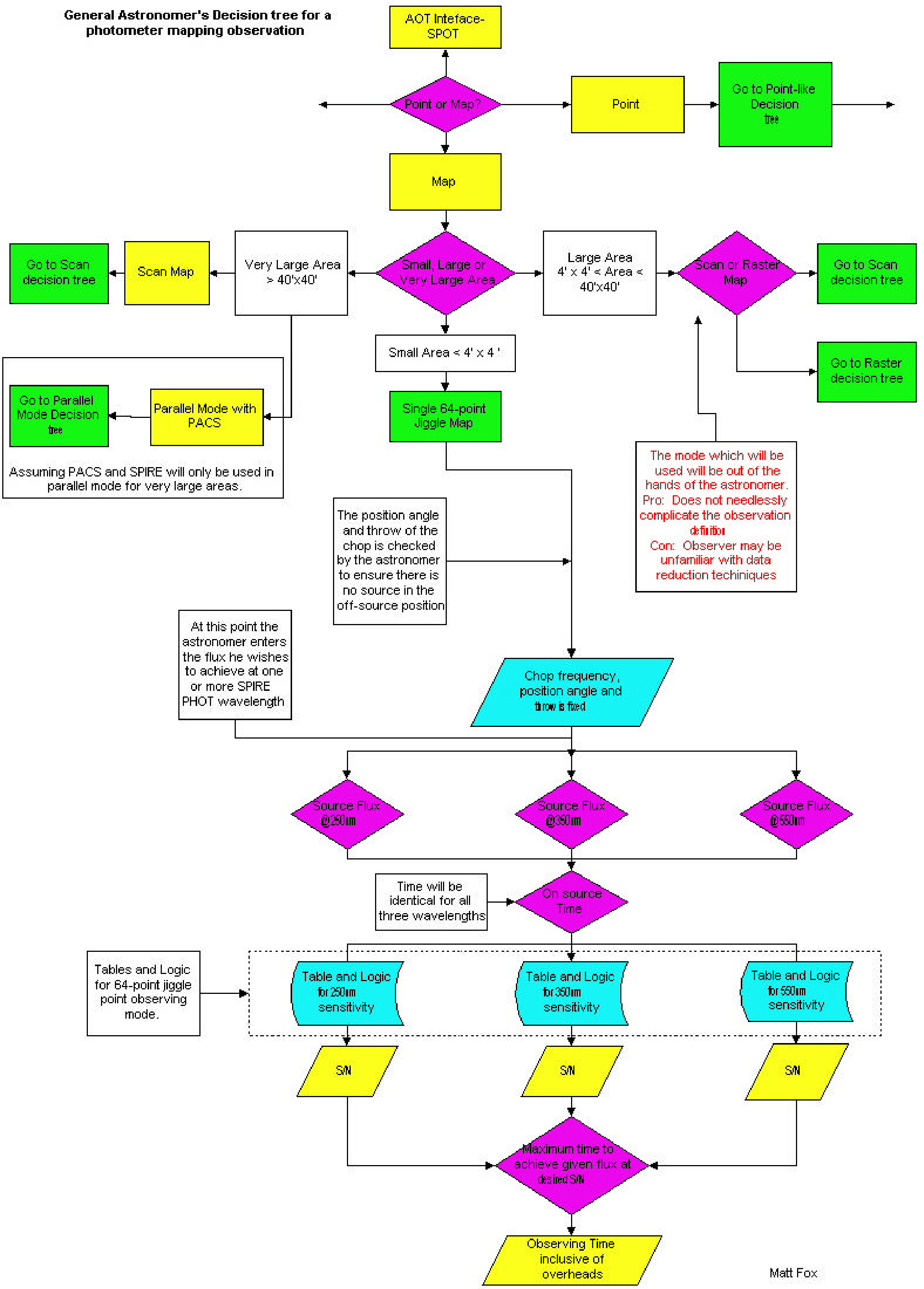

Figure 3: Mapping decision tree

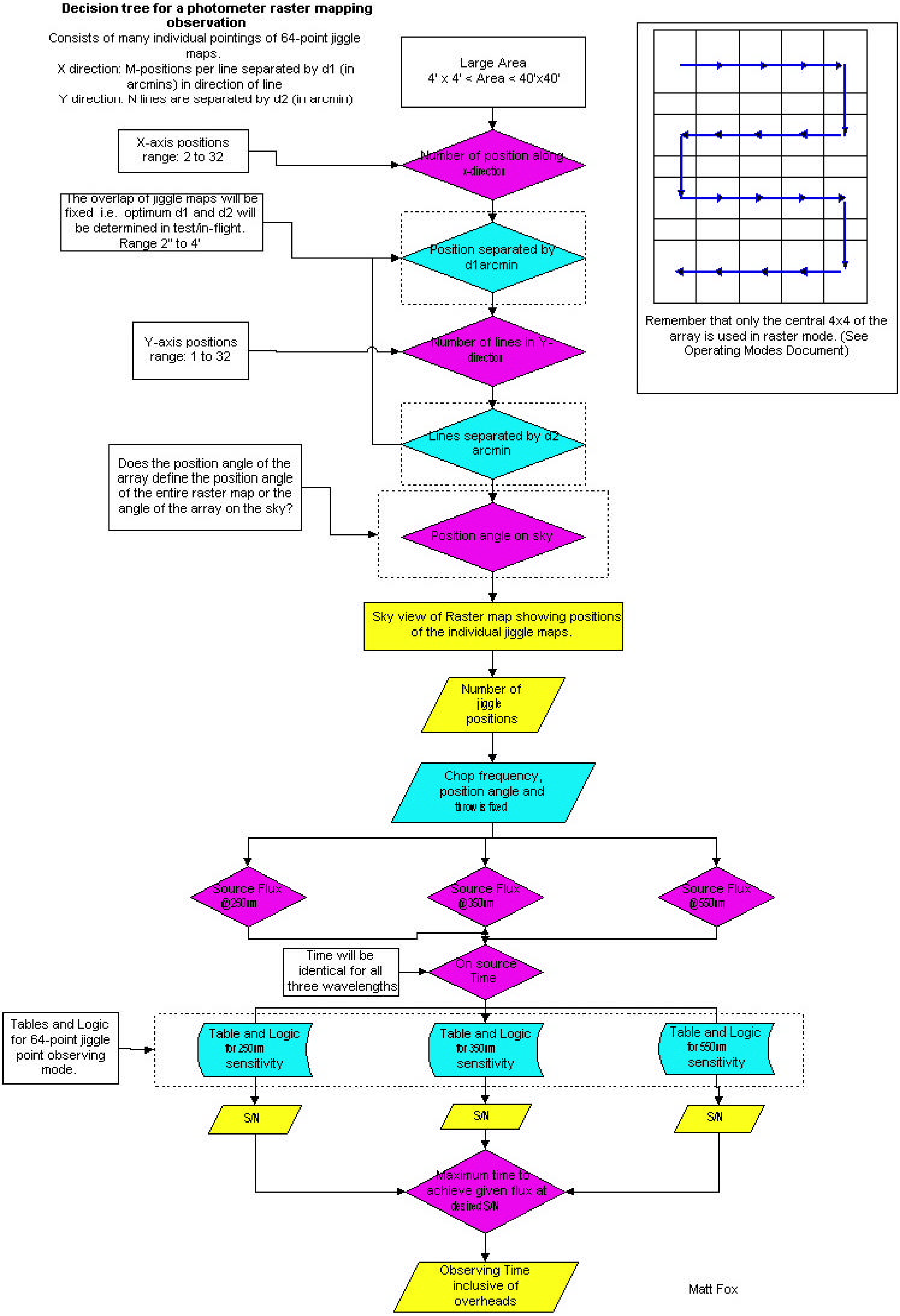

Figure 4: Raster mapping tree

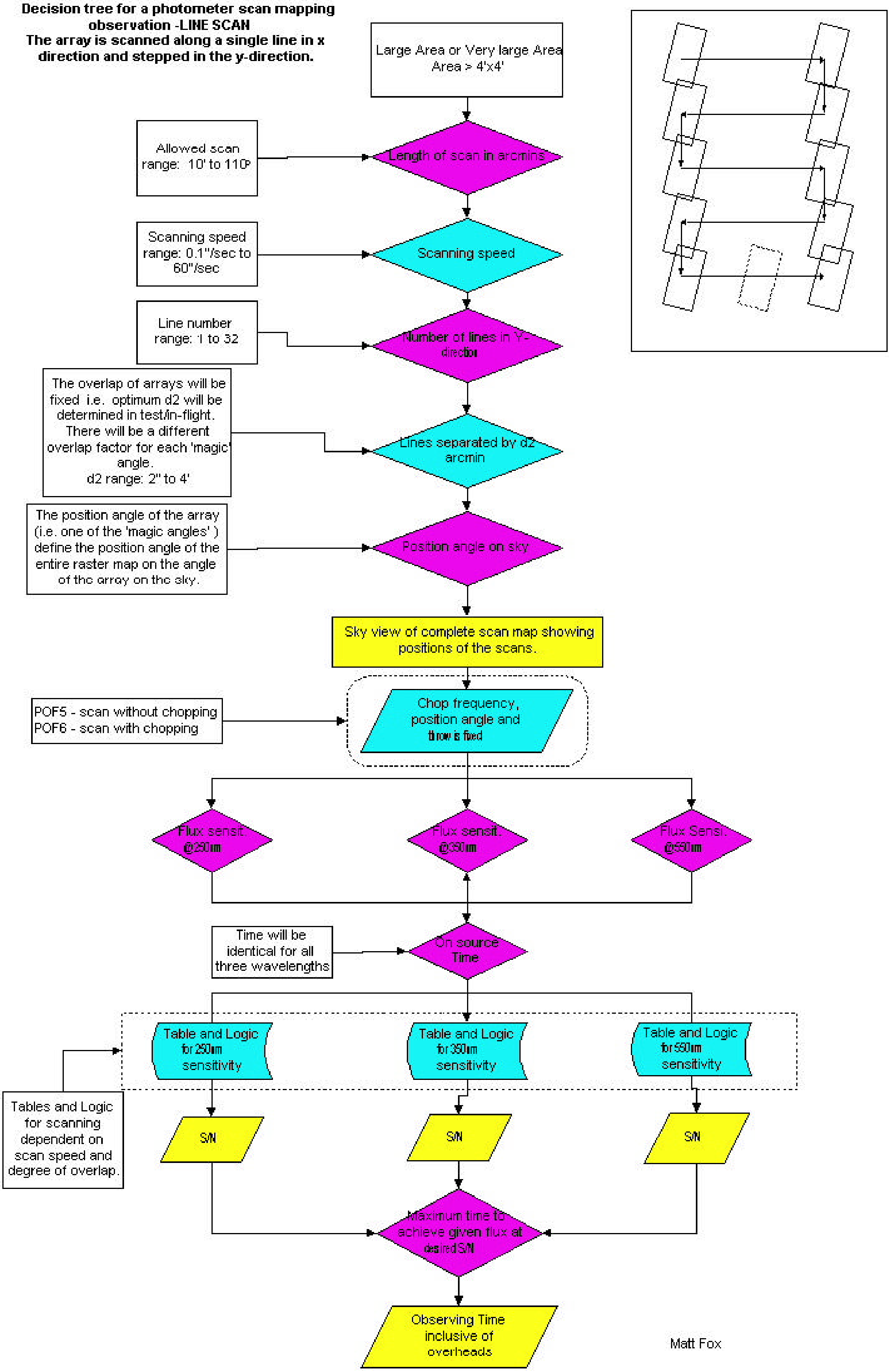

Figure 5: Scanning decision tree

3.3 Parallel Observations

For the largest surveys an obvious option would be using SPIRE and PACS in parallel to obtain multiwavelength coverage simultaneously. Certain restrictions would be imposed on the observations. This would be reflected in the SPOT.

As the instruments are offset in the focal plane by several arcmins on the sky the total area of a parallel survey would have to be very large i.e. > 1 sq.degree, to make this mode viable. Close coordination with PACS is required to ensure this mode is successfully executed and the resultant data manageable. The first impact on SPIRE is the high data rate for PACS observing. Consequently, SPIRE will have to operate at lower the nominal data rate. Turning off the peripheral bolometers, one entire array, or two arrays may be sufficient to reduce the data rate to acceptable levels but the optimum combination will have to be found before flight. Indeed, it may be that different programs would have different ideal solutions. Such a mode of observation would also require further restrictions on SPIRE. The BSM action may affect PACS observations (still TBD) and we would be restricted to scanning as this is the most efficient mode for very large areas. The scan speed is also critical to obtain a good compromise in data collection for PACS and SPIRE. Practicalities such as the number, separation and length of scans to fully cover the sky will have to be taken on a case-by-case basis. The PACS and SPIRE arrays are different sizes so merely stepping by the amounts required for SPIRE alone is not acceptable. Additionally, SPIRE is restricted to its ‘magic’ angles when scanning, and the effects of this on PACS must be considered.

For AOT purposes if parallel mode is offered there will be a need to choose a 'prime' instrument for calculation of integration times, sky coverage etc., and then the astronomer will assess the restrictions which are imposed on the other instrument performance and assess feasibility.

In the final analysis, parallel mode brings a wide range of difficulties in observational and support complexity. It might be a powerfully efficient way of operating large surveys in spite of the necessary compromises, but it might equally be a complex waste of time if, for example, the BSM causes problems for PACS. We will have to think very carefully about offering parallel mode to the general observers, or to experts on key programme teams.

There are thus many issues associated with parallel observations. The subject will be revisited at a later date.

Open Issues:
Which bolometers (array(s)?) will be turned off to accommodate the PACS data?
Will it be scanning or raster mapping or both?
Need to know the focal plane offset of SPIRE and PACS.
Will this be 'expert' mode only?
Array overlaps on scans will be dependent on the prime instrument FOV, how will the sky view be realised?

4. TABLES AND LOGIC FOR CALCULATING OBSERVING TIME

The simple table to be provided for use within SPOT can be translated from the guidelines provided by Matt Griffin in December 2003. These guidelines give the approximate integration times for a given sensitivity and are inclusive of telescope and instrument overheads. See that document for the necessary disclaimers about uncertainties in telescope emissivity and instrument performance. The increase in sensitivity for longer (or shorter) observing time is obtained merely by use of vt scalings. Needless to say this is not a wholly accurate extrapolation! Of course for the multiple jiggle maps of Raster mapping and scan mapping the times need to be multiplied to allow for the area to be covered. As an example the typical coverage of 1 square degree is given in days.

Band		**250um**	**350um**	**500um**
?S (1-s; 3600s) mJy	7-point	0.54	0.7	0.84
	4’x4’ jiggle map	1.9	2.3	2.64
	4’x8’ jiggle map	1.52	1.84	2.1

For example these are the sources & field sensitivities in 1 hr observations:

Band		**250um**	**350um**	**500um**
?S (5-s; 3600s) mJy	7-point	2.7	3.5	4.2
	4’x4’ jiggle map	9.5	11.5	13.2
	4’x8’ jiggle map	7.6	9.2	10.5
Days to map 1 sq. deg to 3mJy 1-s		2.06	3.01	3.92

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As well as the basic instrument sensitivities, we will also need some way of dealing with the confusion limit. This could be achieved by a simple flag that appears when observations are likely to be affected by confusion, expected to be at around the 20mJy level in the three SPIRE bands. Further information on the impact of confusion noise would need to be given in the user documentation.