SELECTION OF THE GEOLOGICAL FILTERS ON THE EXOMARS PANCAM INSTRUMENT. C. R. Cousins[1], A. D. Griffiths[1], I. A. Crawford[1], B. J. Prosser[2], A. J. Coates[1], [1]Centre for Planetary Sciences at UCL/Birkbeck, London, UK, c.cousins@ucl.ac.uk. [2]Department of Computer Science, Queen Mary College, University of London, London, UK.

Introduction: The ExoMars rover - due to launch in 2018 - aims to uncover evidence of past or present life via a drill that can reach up to 2m depth into the subsurface. The rover will be equipped with a multi-purpose Panoramic Camera (PanCam), which will provide wide-angle multispectral images of the rover's surroundings, as well as high resolution images [1]. This multispectral imaging capability is achived by utilizing a set of filters with pre-determined wavelengths and bandwidths. The ExoMars PanCam will have a total of 22 filters (11 per eye), with 12 of these dedicated to providing narrowband multispectral data of the surrounding geological terrain. These observations will be used to help identify lithological diversity, mineralogy, and broad geochemistry of rocks, soils, and stratigraphy proximal to the rover. The importance of a multispectral panoramic camera for rover exploration has been demonstrated by the Mars Exploration Rovers [2] and ExoMars will be no exception. In particular, ExoMars PanCam data will be crucial in identifying suitable sites for drilling and subsequent analysis. As such, the geological filters for PanCam need to be carefully designed to achieve this goal.

PanCam filters are required to fall within the 440 - 1000nm wavelength region, constrained by the detection limits of the CCD detector. Whilst the geological filters have undoubtedly been highly effective on the MER pancams, their wavelengths have not been changed since first devised for Mars Pathfinder. These filters were originally designed with the aim to detect iron oxides and determine silicate mineralogy [3], and this filter set was largely adopted for the MER Pancam with the same aim in mind, as well as to provide a direct comparison to Pathfinder results [4]. Likewise the Beagle2 PanCam also adopted these same wavelengths. However, both remote and in-situ exploration of the Martian surface has since revealed highly varied mineral terrains. Lithologies containing hydrated minerals in particular are of significant importance for the astrobiological objectives of ExoMars, and the geological filters for the ExoMars PanCam will be revised to account for this [5].

Methods: Six new alternative filter sets were devised based on hydrated mineral, iron oxide, and mafic silicate reflectance spectral data from the USGS [6], JPL [7], and RELAB [8] online mineral spectral databases. Four of these filter sets were optimized to detect specific mineral groups (phyllosilicates, sulphates, iron oxides, mafic silicates), whilst two sets were optimized to detect absorption features within the PanCam spectral range (Fe^{2+}/Fe^{3+}, and weak hydration bands), regardless of mineral group (Table 1). Carbonates were not used for the selection of filters due a lack of any significant absorption or spectral features within the Pancam detection range. These filter sets were then tested on heterogeneous, unprocessed rock samples.

Group	Mineral	Filter set
Sulphates	Gypsum	SULPH, HYDRA
	Alunite	SULPH, HYDRA
	Jarosite	SULPH, All Fe
	Copiatite	SULPH, All Fe
	Magnesium Sulphate	SULPH, HYDRA
Phyllosilicates	Chlorite	PHYL, All Fe
	Nontronite	PHYL, All Fe
	Montmorillonite	PHYL, HYDRA
	Saponite	PHYL. HYDRA
Mafic silicates	Olivine	MAFIC, All Fe
	Augite	MAFIC, All Fe
	Diopside	MAFIC, All Fe
	Bronzite	MAFIC, All Fe
	Enstatite	MAFIC, All Fe
	Albite	MAFIC
Iron oxides	Haematite	FERRIC, All Fe
	Goethite	FERRIC, All Fe
	Magnetite	FERRIC, All Fe
	Ferrihydrite	FERRIC

Table 1: Mineral data used to select potential new filter sets for the geological filters on the ExoMars PanCam.

Filter wavelength selection: the 12 optimal wavelengths were calculated based on the method outlined in [5]. This method selects the 12 best filters (with two filters fixed at 440 and 1000nm) for a given mineral dataset by calculating the error between the original spectrum and the filter-generated 'PanCam' spectrum.

Test rock samples: Geological samples containing a variety of sulphates, phyllosilicates, carbonates, opaline silica, mafic silicates, and iron oxides were used to test the filter sets. Samples were left untreated and unprocessed so to effectively mimick a natural outcrop or rock surface.

Testing filter sets: Rock samples were imaged multispectrally using a Foculus FO432SB camera (1024 x 1024 pixel CCD detection of 400 - 1000nm wavelengths) interfaced with one of two CRI Varispec liquid crystal tunable filters covering the visible and infrared. Imaging was conducted at a resolution of 10nm, and this data was subsampled to match the respective filter sets. Relative reflectance spectra were calculated by dividing the brightness values for a region of interest (ROI) by those measured from an optical grade Spectralon calibration target placed in the background of each image. Filter sets were tested using several criteria:

1. Simple hitting/missing of spectral features.
2. Measured error between the filter-generated 'PanCam' spectrum and the actual original rock ROI spectrum.
3. Statistical clustering of rock ROI's into spectrally-similar groups.
4. Discrimination of rock ROI's into geologically/mineralogically sensible groups.

The filter set that produces the best results based on these criteria will be selected for the ExoMars PanCam.

PHYL	SULPH	FERRIC	MAFIC	All Fe	HYDRA
440	440	440	440	400	440
510	470	500	470	490	500
560	500	530	520	520	550
590	560	570	560	570	590
650	610	610	640	650	630
680	660	670	690	700	710
730	700	740	740	740	760
770	730	780	800	780	810
810	820	840	850	840	890
900	890	900	900	890	940
960	950	950	950	950	970
1000	1000	1000	1000	1000	1000

Table 2: Filter wavelengths (in nm) for the 6 new filter sets based upon minerals belonging to the phyllosilicates ("PHYL"), sulphates ("SULPH"), iron oxides ("FERRIC"), mafic silicates ("MAFIC") and a combination of those minerals that contain ferric and ferrous iron absorptions ("All Fe") and hydration features ("HYDRA").

Results: Initial results demonstrate a significant difference in ability and accuracy of the filter sets in both capturing spectral features in mineral data sets, and also recreating rock ROI spectra. In particular, the "FERRIC" filter set has the lowest error when recreating rock ROI spectra, and also captures the most number of spectral features within mineral data sets. However, filter sets "PHYL" and "All Fe" also perform well, and further multi-parameter analysis will help identify the best filters, not just in re-creating mineral spectra, but also for distinguishing between broad mineral groups.

References: [1] Griffiths, A. D. et al. (2006) *IJA, 5,* 269-275. [2] Farrand, W. H. et al. (2007) *JGR, 112,* doi:10.1029/2006JE002773. [3] Smith, P. H. (1997) *JGR, 102,* 4003-4025. [4] Bell, J. F. (2003) *JGR, 108,* doi:10.1029/2003JE002070. [5] Cousins, C. R. et al. (2010) *Astrobiology,10,* 933-951. [6] Clark, R. N. et al. (2007) *U.S. Geological Survey, Digital Data Series 231.* [7] Baldridge, A. M. et al. (2009) *Remote Sensing of Environment, 113,* 711–715. [8] NASA RELAB facility at Brown University.