THE SOLAR SYSTEM INFORMATION SYSTEM - DESIGN AND APPLICATION

A.C.Cook, F.Trauthan, E.Hauber, N.Bohne, and K.Eichentopf

DLR, Institute of Planetary Exploration,12489 Berlin; Germany

Commission IV, Working Group 5

KEY WORDS: Extraterrestrial, GIS, Raster, Database, Global, Cartography.

ABSTRACT

The Solar System Information System (SOLIS), is a research tool being developed for use by scientists in order to help them to determine the geographical extent, temporal nature, and quality of planetary data, and also for the testing of simple scientific hypotheses against a set of knowledge about a planet. We present an overview of our design to date, describing some important aspects concerning the storage of information about images, and the compact and efficient access to planetary cartographic raster data. We also describe a bibliographic facility. Finally we present two example applications of our system.

1. INTRODUCTION

DLR is involved in the planning of imaging sequences for the Mars 96 spacecraft (Neukum *et al.*, 1995; and see appendix), and in the processing and analysis of spectral and stereo remote sensing data for a variety of planetary objects. These include the Moon, Mars, the moons of Jupiter and Saturn, and the asteroids Ida and Gaspara.

In view of the many different spacecraft and planets involved, it is desirable to have a versatile database system, akin to a Geographical Information System (GIS), which can search, validate, and display graphical information about the planetary remote sensing datasets. Knowledge about each planet is held as logical facts, rules, and look-up tables. The system needs to be capable of handling the huge numbers of records concerning images returned by modern spacecraft. It must also allow for the distorted footprint shapes, moving cameras, and macro-pixels configurations of non-framing spacecraft cameras like those on Mars 96.

In our previous paper (Cook *et al.,* 1994) we reviewed existing planetary data systems, presented a design for SOLIS, and demonstrated simple applications of a development prototype. Here we describe our system in further detail and give additional example applications.

2. OTHER PLANETARY DATA SYSTEMS

Since our last paper (Cook *et al.* 1994), just two years ago, there have been many developments in the availability of planetary data (see table 1) and access to planetary data systems with certain GIS-like characteristics (see table 2). The user interfaces to these make use of hypertext markup language (HTML) and are accessible over the World Wide Web (WWW). We are considering making use of HTML too. However all of these systems still concentrate on just basic information about imagery, or are one-off programs intended for specific missions or planets.

It appears that spacecraft and planetary ephemeris format data is converging to a standard developed by the Jet Propulsion Laboratory (JPL), and this is known as SPICE (Acton, 1995). SPICE is a collection of ancillary planetary ephemeris and spacecraft data files (kernels), software used to produce these files, and software needed by scientists to read the files and calculate derived quantities. We make use of SPICE to generate the database for SOLIS.

It is also interesting to note that GIS techniques are starting to be used by certain sections of the planetary science community, for the geological interpretation of registered planetary remote sensing raster datasets, using commercially available GIS (Brackenridge, 1996; Coombs, C.R., 1996;

Address	Institution
http://blackhole.aas.org/~dps/dps.html	Division of Planetary Sciences (DPS)
http://nssdc.gsfc.nasa.gov/planetary/planetary_home.html	National Space Science Data Center (NSSDC)
http://stardust.jpl.nasa.gov/pds_home.html	Planetary Data System (PDS)
http://cass.jsc.nasa.gov/lpi.html	Lunar and Planetary Institute (LPI)
http://cass.jsc.nasa.gov/RPIF.html	Regional Planetary Image Facilities (RPIF´s)
http://www.dlr.de/dlr_welcome.html	DLR Institutes/sites (under development)

Table 1: Example Starting Point WWW Sites for access to Planetary Data.

Address	Description
http://www.nrl.navy.mil/clementine/clib/	The Clementine Lunar Image Browser (CLIB). Any region of the Moon can be viewed by clicking on a global mosaic. One can select different resolutions and image sizes. Copies of the original images can be retrieved.
http://humbabe.arc.nasa.gov/MarsToday.html)	"Mars Today", by the Center for Mars Exploration at NASA's Ames Research Center depicts: (1) the current orbital positions of Mars and Earth, (2) the apparent size of the martian disc as viewed from Earth and vice versa, (3) a simulated Earth-based image of Mars, (4) a global weather map from the Ames Mars Global Circulation Climate Model.
http://fi-www.arc.nasa.gov/fia/projects/bayes-group/Atlas/Mars/	A browsable, zoomable, scrollable Mars Atlas. It shows the locations of thousands of Viking Orbiter image footprints. The atlas has complete coverage of Mars in the form of greyscale maps at between 1/16° and 1/256° per pixel, and allows downloading of some raw Viking Orbiter images.

Table 2: Examples of Planetary Data Systems with certain GIS-like features.

Giguere, *et al.*, 1996). We look forward to seeing further published descriptions about the methods, and whether they are also applicable to the very large global datasets that SOLIS is designed for.

3. DESIGN OF SOLIS

3.1 Overview

SOLIS is a hybrid language system that will make use of the virtues of four languages. SYBASE SQL (Structured Query Language) will be used for handling large tabular datasets, such as those to be generated by the Mars 96 mission. Prolog is being used for database program development and for flexible rule-based queries. The procedural languages Fortran and C are used to perform fast numerical computations and raster image analysis. Currently an interface between Prolog and Fortran/C has been achieved and this is being used as a test-bed to decide upon the types of commands needed to query the database. SQL has already been used to conduct some experiments on querying tabular data for eventual integration into the system (Cook et al., 1994). Below we detail some important points concerning the design of our database.

3.2 Data

Data held within SOLIS fall into seven classes: data about images, cartographic vector and raster data, bibliographic references to images and geographical features, digitized graphs, tables of physical measurements, technical spacecraft data, and small illustrative images/graphics.

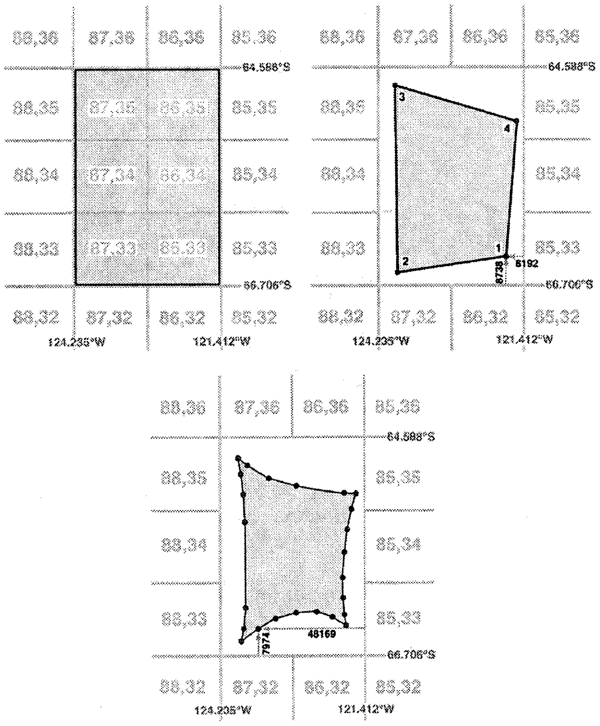

Figure 1: Top left: footprint hierarchy level 1, top right: footprint hierarchy level 2, bottom: footprint hierarchy level 3.

A one-off data-formatting program is required to generate the initial SOLIS database for each planet using, where possible, the best available camera navigation parameters generated from JPL's standard SPICE software and kernel files. Our database design does not require the same precision as SPICE, so can be both more compact, and performs geographical searches faster.

In accordance with Mars 96 requirements, we adopt planetographic longitudes and latitudes to describe spatial positions on the planetary surface, and heights measured with respect to a fitted triaxial ellipsoid reference datum. Time tags applied to SOLIS data are either planet centred ephemeris time (Julian Date) for observational data, or geological age in the case of geological maps.

Field	Format	Field	Format
Image name	Char20	Max. solar alt.*	Byte
Clock count	Double	Min. solar az.*	Byte
Julian Date (days)	Double	Max. solar az.*	Byte
Imager ID	Short	Min. phase angle *	Byte
Min. image lon.	Byte	Max. phase angle *	Byte
Max. image lon.	Byte	Min. spacecraft alt.*	Byte
Min. image lat.	Byte	Max. spacecraft alt.*	Byte
Max. image lat.	Byte	Image centre lon.	Short
Min. pixel size m	Float	Image centre lat.	Short
Max. pixel size m	Float	Image corner 1 lon.	Short
Footprint ID	Long	Image corner 2 lon.	Short
Sub-spacecraft lon.°	Float	Image corner 3 lon.	Short
Sub-spacecraft lat.°	Float	Image corner 4 lon.	Short
Sub-spacecraft rng km	Float	Image corner 1 lat.	Short
Sub-solar lon.°*	Float	Image corner 2 lat.	Short
Sub-solar lat.°*	Float	Image corner 3 lat.	Short
Planets orbital lon.°*	Short	Image corner 4 lat.	Short
Min. solar alt..*	Byte	Image descriptor	Long

* Can be computed to higher precision using Julian Date etc.

Table 3: "image.tbl".

It is not possible to describe all of this in detail, therefore we highlight some key aspects namely: how we store data about images, the storage and access of digital global mosaic and geological maps, and the "scientists' notebook" facility to be used during the Mars 96 mission, and how this can be extended to include bibliographical references.

3.2.1 Data about Images: Our design must allow for all existing planetary spacecraft camera systems, and also for those likely to be onboard future missions. For each image we need to store information concerning: image identifiers, the image footprint outline, camera position(s), the location of the planet in its orbit, illumination and viewing angle conditions, and a description of the image. However it is also necessary to keep storage requirements low, to be able to handle upto several million image records, and to locate certain records rapidly based primarily upon their geographic location. To achieve the first two goals one main table, "image.tbl" (table 3), has been used and its fields have been selected carefully in terms of precision and number. This results in a stripped down record size of only 108 bytes per image. Compact storage is particularly important for an existing dataset of just under 2 million records, concerning images returned from the lunar Clementine spacecraft. Such a large collection of image records occupies more than 200Mb of disk space in this reduced file format alone.

The first four fields in "image.tbl" are unique identifiers to each image. Images are usually referred to by their name or spacecraft clock count. The Julian Date identifier may also be used for computing illumination conditions and planetary ephemeris data to higher precision, if this is required. The imager ID, points to another table (not given here) which lists combined spacecraft, camera, filter information. Another useful item of data is the location of the planetary object around the Sun; this can yield information about seasons.

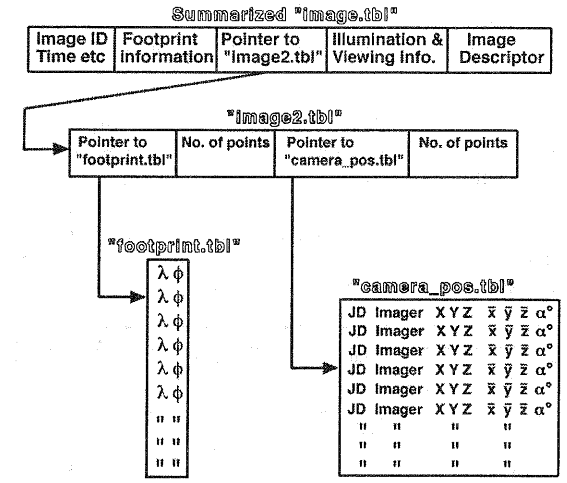

Figure 2: File structure needed to represent distorted footprints and moving camera situations. The last field in "camera_pos.tbl" is used only for rotating scanner cameras.

For the image footprint, minimum and maximum ground pixel size (m) are used to determine if the image is of sufficient resolution. The actual image footprint shape is stored in a three level hierarchy (fig 1) to facilitate rapid search. The planet's surface is divided up into NxM tiles in longitude and latitude directions (where N<256 and M<256, i.e. byte precision). N and M are chosen to optimize footprint storage and access. The minimum and maximum longitude and latitude tiles, stored as bytes, represent the first level of this hierarchy. To find out which images cover a certain area, SOLIS generates initially the corresponding tile IDs, then with the aid of an image-tile geographical index (not described here), it extracts lists of images contained in each tile. This results in a reduced number of image records that need to be searched. The second hierarchy level for the image footprint description, consists of the four corners of a bounding quadrilateral which contains the footprint. The positions of the corners are stored relative to the minimum and maximum longitude and latitude tiles, to unsigned short integer (0-65535) precision. This is sufficient to describe the majority of image footprints.

Bits	Description	Value
1	Image contains the whole planet?	0 or 1
2	Image contains a planetary limb?	0 or 1
3	Image used for control point nets?	0 or 1
4	Image used for topographic maps?	0 or 1
5	Image used for geological maps?	0 or 1
6	Image referenced in publication?	0 or 1
7	Image entirely blank?	0 or 1
8	Image contains saturated pixels?	0 or 1
9	Lossy compression used on image?	0 or 1
10-12	Contrast: unknown	000
10-12	Contrast: excellent ($255<4\sigma_{DN}$)	001
10-12	Contrast: good ($150<4\sigma_{DN}\leq255$)	010
10-12	Contrast: ok ($80<4\sigma_{DN}\leq150$)	011
10-12	Contrast: moderate ($40<4\sigma_{DN}\leq80$)	100
10-12	Contrast: poor ($20<4\sigma_{DN}\leq40$)	101
10-12	Contrast: bad ($10<4\sigma_{DN}\leq20$)	110
10-12	Contrast: terrible ($4\sigma_{DN}\leq10$)	111
13-15	Noise: unknown	000
13-15	Noise: excellent (256<S/N)	001
13-15	Noise: good (128<S/N≤256)	010
13-15	Noise: ok (50<S/N≤128)	011
13-15	Noise: moderate (12<S/N≤24)	100
13-15	Noise: poor (6<S/N≤12)	101
13-15	Noise: bad (3<S/N≤6)	110
13-15	Noise: terrible (S/N≤3)	111
16-17	Sharpness: unknown	00
16-17	Sharpness: good (<1.5 pixels)	01
16-17	Sharpness: moderate (1.5-3 pixels)	10
16-17	Sharpness: poor (>3 pixels)	11
18-32	To be decided	

Table 4: The image descriptor field.

If an image is not completely covered by the level 2 footprint hierarchy, because the footprint is distorted (fig 1 lower), then normalized two byte offsets are used to describe a more detailed footprint. These offset points are stored in a separate file "footprint.tbl" (see fig 2).

The final field in "image.tbl" is an image descriptor, consisting of a 4 byte integer (see table 4). Here, bits can signify a positive answer (bit=1) as to whether the image contains some attribute of the planet, or has been used in a cartographic process, or in a publication. A negative answer (bit=0) can indicate either a "no", or an "unknown". In addition, groups of bits are used to describe the image contrast, noise and sharpness. Additional bits are available for future use, for example whether an image contains a duststorm etc.

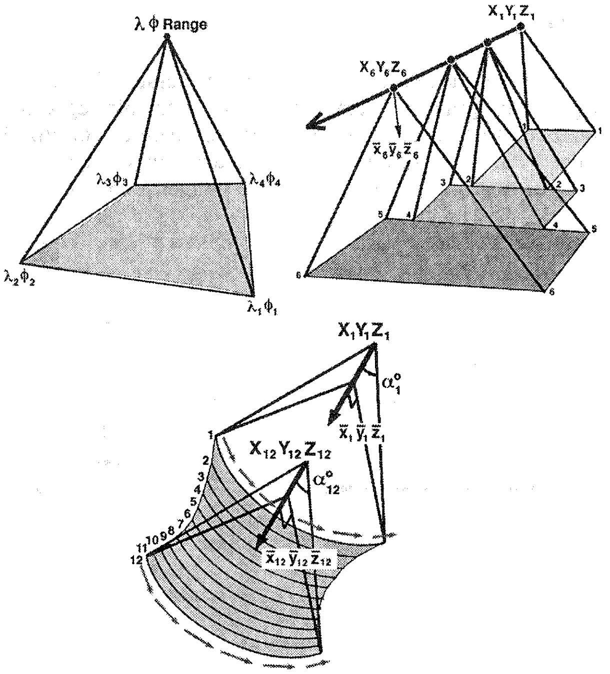

Figure 3: Top left: framing camera geometry, top right: push broom camera geometry, lower: rotating scanner camera geometry.

Lastly, for stereo and photometric analyses, it is necessary to know the location of the camera with respect to the planetary surface. For a framing camera (fig 3 top left) "image.tbl" gives this, but for a pushbroom camera (fig 3 top right), or for a rotating point source scanner camera (fig 3 lower), the camera is moving during imaging. In figure 2 we present a simple file structure which can be used to describe these, "camera_pos.tbl". Only positions and orientations are stored when there has been significant change in position and orientation. To obtain position and orientation in between these points, interpolation is used. Planet centred XYZ coordinates are used for these moving camera systems because they are easier to handle in geometric calculations involving motion.

3.2.2 Cartographic Raster Data - Overview: There are three types of cartographic raster data: scaled physical parameters, thematic maps, and background maps e.g. respectively: gravity maps, geologic maps, and global image mosaics. We store scaled physical parameter raster data as binary images, without compression to preserve numeric accuracy. For background maps, which are to be used for display purposes only, we store these as tiles and compress them by approximately 20 times using JPEG (Joint Photographic Experts Group) compression. In this way it is possible to store the best currently available global image mosaic of the whole of the surface of Mars (231m per pixel or 1/256th of a degree, 2.5Gb in Sinusoidal projection; Batson, 1986) in only 130Mb. The storage of thematic map data has special requirements, namely it must be compact, it must be easy to portray at any scale (generalization), and it must be possible to perform rapid geographical searches.

3.2.2.1 Storage of Geological Maps using Quadtrees: For our test data we used a digital geological map of Mars (Tanaka, 1988). We processed this as a longitude-latitude cylindrical projection. It is thus straightforward to locate points on this for a given longitude and latitude. However it has the disadvantage that the scale (m/pixel) in the longitude direction becomes distorted as a function of $\cos(\phi)$, and it is not easy to portray at low resolutions without either: performing averaging processes over several pixels on the original map, or storing multiple resolution versions of the map with the consequential increase in storage space.

Therefore to solve these problems we convert digital geological maps into quadtrees (Cromley, 1992). These allow both multiple resolution and compact data storage. The quadtree algorithm that we have used is based upon the following approach: if a coloured image region with a size of $2^n * 2^n$ contains different coloured pixels (geological units), then it is declared inhomogeneous, and the algorithm splits it into four square sub-regions each $2^{n-1} * 2^{n-1}$ in size. Fig 4 shows a geological map of Mars which has started to undergo this process. This procedure continues recursively until all sub-regions are homogeneous.

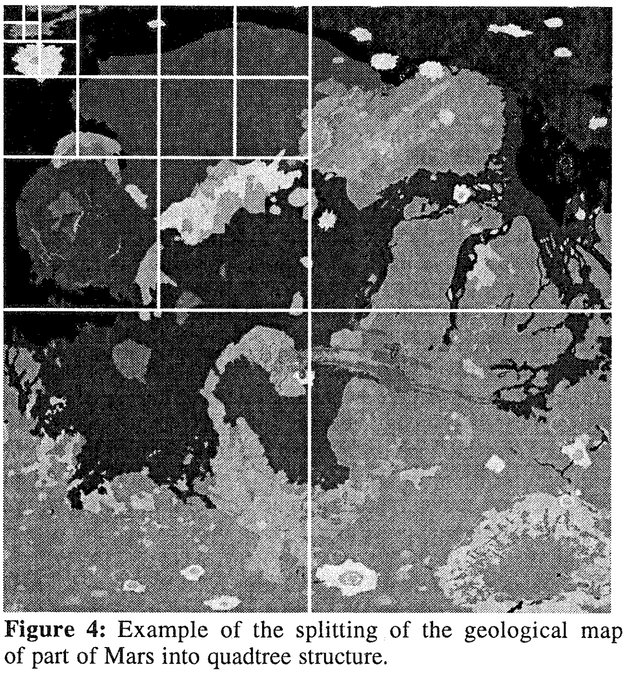

Figure 4: Example of the splitting of the geological map of part of Mars into quadtree structure.

In our quadtree structure the east and the west hemispheres are treated as separate quadtrees. The first quad level covers a whole hemisphere. This then divides into four 90° longitude and latitude quadrants, and so on. Figure 5 shows the coverage of quadtrees down to different levels of resolution. The dark lines are regions where the colour information is still inhomogeneous at these respective levels. This actually high-lights the boundaries between different geological units quite well.

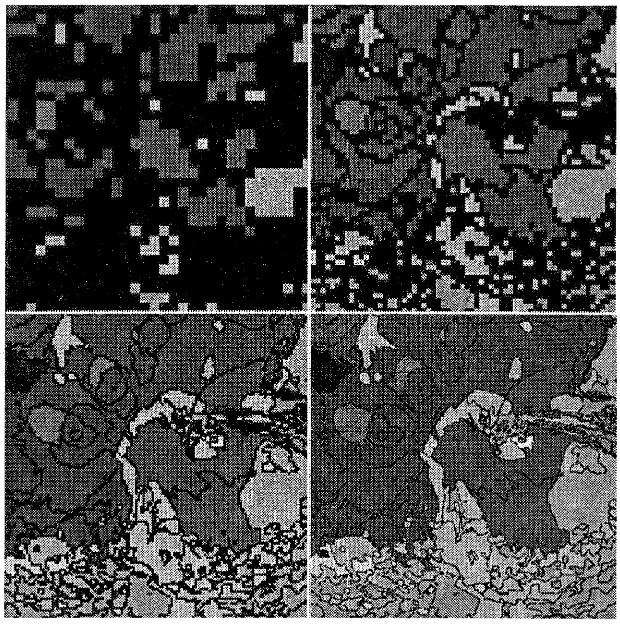

Figure 5: Part of the geological map of Mars represented at different quadtree resolutions: top left 16x16 pixels, top right 8x8 pixels, lower left 4x4 pixels, lower right 2x2 pixels.

For the display of quadtree infomation as a map, at a given resolution, this boundary information needs to be filled in using a generalization method. This is achieved in the following order. If, in the next level down, the tree contains a majority of one colour (geological unit) over another, then this is used to fill in the gap. If this is not possible, then the geological unit present with the highest rank (rank pre-assigned to geological units according to the percentage area coverage of each unit on the surface of the planet) is used. If this fails then dithering of geological units is applied to fill in the gap.

Raw image (2048 x 2048) - no header	Quadtree storage for colour + x,y position	Quadtree storage for colour only
4.19MB	3.08MB	0.51MB

Tabel 5: Comparison of storage for a 2048 x 2048 pixel geological map of part of the western hemisphere of Mars.

3.2.3 Bibliographical References: During the Mars 96 mission, it is planned for co-investigators to have a "scientists note-book" facility whereby they can submit an email to the SYBASE SQL database system administrator, concerning an image taken by the spacecraft. Keywords describing the Mars 96 image, are then added to the database. This facility could be extended to include books, journals, and conference proceedings, whereby certain images, named cartographic features, and geographical regions can be included. Such a bibliographic list held within the database is unlikely to become fully comprehensive, however it will be of enormous benefit to scientists who wish to find out whether there are some publications which describe an area, or an image, that they are interested in.

We plan to hold this infomation in SYBASE SQL, but for now we have been prototyping the database using Prolog. Here are the Prolog facts that we are currently using; these are all tied together by specific unique reference identifiers e.g. Ref_id= "batson_1986":

<u>This would form the main reference table</u>
general_ref(*Ref_id,Author_list,Title,Year, Pub_type,Page_start,Page_end,Keyword_list*).

where "Pub_type" is one of: journal, book, proceedings

<u>The following are sub-reference tables for specific types of publications</u>
journal_ref(*Ref_id,Journal,Vol,No*).

book_ref(*Ref_id,Title,Edition,Publisher,Isbn_no,City, Pages*).
proceedings_ref(*Ref_id,Conference,Vol,Part*).

<u>Finally, for specific examples of images, features, locations, and regions, that have been mentioned in publications:</u>
image_ref(*Ref_id,Keyword_list,Spacecraft,Image, Clock_count,Photo_no,Page*).

feature_ref(*Ref_id,Keyword_list,Feature,Page*).

location_ref(*Ref_id,Keyword_list,Lon,Lat,Page*).

region_ref(*Ref_id,Keyword_list,Lon_w,Lon_e, Lat_n,Lat_s,Page*).

4. APPLICATIONS

4.1 Image Footprints

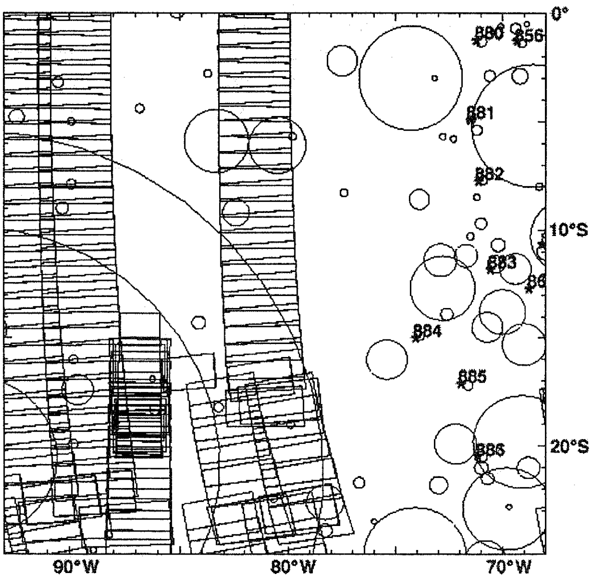

Figure 6: Clementine UVVIS C filter image footprints with respect to control points, and named crater outlines on the north-east of the Mare Orientale region of the Moon.

In fig. 6 we present a plot of C-filter (900nm) Clementine spacecraft image footprints, where the UVVIS (ultraviolet-visible) camera was tilted more than 5° off-nadir, during the third month of operation. These overlap with nadir pointing images that were taken, to produce a global image mosaic, during the previous two months. Although SOLIS has a more systematic method of determining good stereo pairs (Cook *et al.*, 1996), this plot clearly illustrates where the user might expect to find areas with strong stereo coverage.

Displacements between control points (stars) and crater centres, infer a systematic offset between the coordinate systems used for these two datasets (Anderson and Whitaker, 1987; Davies *et al.*, 1994). This illustrates one way in which SOLIS can be used for cartographic verification. The plot also shows that the region in the vicinity of Mare Orientale does not have good control point coverage. This may be due to the lack of former spacecraft stereo coverage in this area.

4.2 Phase Angle Coverage

For photometric studies of planetary surfaces (Hapke, 1993), it is important to have as many images as possible available, taken under different phase angle conditions. Here we present a map (Cook *et al.*, 1996) of the region covering Reiner Gamma (left) and Kepler (right of centre) on the Moon's surface illustrating the variety of different phase angle images, by the number of 5° phase bins covered. These two features, indicated by dark grey, have been imaged at many different phase angles, and hence are suitable regions on which to perform photometric studies.

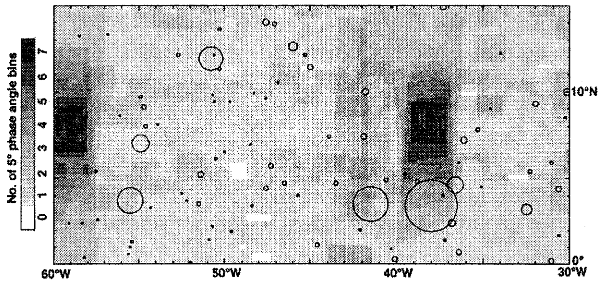

Figure 7: Multiple phase angle coverage map of the lunar region 60°W-30°W, 0°N-15°N.

5. SUMMARY AND FUTURE WORK

Although SOLIS is still under development, it has been applied successfully to tasks involving Clementine mission imagery (Oberst *et al.*, 1996). In particular it has been used to produce minimum ground pixel size, stereo, minimum phase angle, and multiple phase angle coverage, maps of the Moon (Cook, *et al.*, 1996), and for the location of image footprints with respect to craters and control points. Furthermore it has proven capable of handling datasets with up to 2 million image records. The design of our raster cartographic database is efficient, compact, and allows for the multi-scale retrieval of thematic maps. We have found that even greater compression can be achieved on a global Mars image mosaic using JPEG.

It is planned to output raster data in four formats: VICAR, GIF, JPEG, and raw binary format (no header). Tabular data are currently output in ASCII format, though we are also considering JPL IBIS format. Graphical output, at the time of writing, is either written to the X11 screen or to a postscript file for hardcopy output using the PGPLOT graphics library. We will output maps using polar, mercator, cylindrical, and sinusoidal projections. The user interface to SOLIS is still being investigated, but will probably make use of HTML for input/output to SQL/Prolog/F77/C programs that access the database.

We plan to start making use of registered remote sensing datasets for geological studies, rather than using the system for just photometric image selection, and cartographic purposes. For the testing of simple scientific hypotheses against knowledge about a planet, this will be achieved with the aid of Prolog logical facts and rules, and access to registered datasets held within the database.

Acknowledgements
The authors would like to thank: Thomas Duxbury and Chuck Acton (JPL) for providing additional information about the Clementine imagery, and the use of the SPICE data and software. We would also like to thank Randy Kirk for the use of United States Geological Survey (USGS) data, and Mert Davies of the RAND corporation for supplying the control point data.

6. REFERENCES

Acton, C., The Clementine SPICE archive, 1995. In: 26th Lunar and Planetary Science Conference. Houston, Texas, USA. Vol 1, pp. 1.

Andersson, L.E., and E.A.Whitaker, 1987. NASA Catalogue of Lunar Nomenclature. NASA Reference Publication 1097.

Batson, R.M., 1986. A digital image model of Mars. In: Reports of planetary geology and geophysics program - 1985, NASA TM-88383, Washington DC, USA, pp577-579.

Brackenridge, G.R., 1996. Relative Age Determination from 1:1.5 Million geological Mapping, Sapas Mons FMAP, Venus. In: 27th Lunar and Planetary Science Conference, Houston, Texas, USA, pp. 151-152.

Coombs, C.R., 1996. Using GIS (Geographic Information System) technology to assess the resource potential of lunar pyroclastic deposits. In: 27th Lunar and Planetary Science Conference, Houston, Texas, USA, pp. 251-252.

Cromley, R.G., 1992. Digital Cartography. Prentice Hall, Englewood Cliffs, New Jersey, USA, 317 pages.

Cook, A.C., T.Day, J-P. Muller, J.C.Iliffe, D.A.Rothery, G.D.Thornhill and J.B.Murray, 1992. A Prolog-based Mars Information System. In: International Archives of Photogrammetry and Remote Sensing, Vol. 29, B4, pp.788-794.

Cook, A.C., E.Hauber, R.Pischel, K,Eichentopf, and G.Neukum, 1994. A Versatile geographic information system for use in planetary science. In: International Archives of Photogrammetry and Remote Sensing, Athens, Georgia, USA, Vol. 30, Part 4, pp. 556-563.

Cook, A.C., J.Oberst, T.Roatsch, R.Jaumann, and C.Acton, 1996. Clementine Imagery: Selenographic Coverage for Cartographic and Scientific Use. Planetary and Space Science Journal, in press.

Davies, M.E., T.R.Colvin, D.L.Meyer, and S.Nelson, 1994. The unified lunar control network: 1994 version. J.Geophys. Res., 99E, pp.23211-23214.

Giguere, D.T., D.T.Blewett, P.G.Lucey, G.J.Taylor, and B.R.Hawke, 1996. Adding dimensions to the lunar geological map using GIS. In: 27th Lunar and Planetary Science Conference, Houston, Texas, USA, pp. 411-412.

Hapke, B., 1993. Theory of reflectance and emittance spectroscopy. Cambridge University Press, Cambridge, UK. 455 pages.

Neukum, G., J.Oberst, G.Schwarz, J.Flohrer, I.Sebastian, R.Jaumann, H.Hoffmann, U.Carsenty, K.Eichentopf. and R.Pischel, 1995. The Multiple Line Scanner Camera Experiment for the Russian Mars 96 Mission: Status Report and Prospects for the Future. In: Photogrammetric Week '95, Stuttgart, Germany, pp45-61.

Oberst, J., T.Roatsch, W.Zhang, A.C.Cook, R.Jaumann, T.Duxbury, F.Wewel, R.Uebbing, R.F.Scholten, and J.Albertz, 1996. Photogrammetric analysis of Clementine multi-look-angle images obtained near Mare Orientale. Planetary and Space Science Journal, in press.

Tanaka, K.L., N.K.Isbell, D.H. Scott, R.Greeley and J.E.Guest, 1988. The resurfacing history of Mars: A synthesis of digitized, Viking-based geology. In: 18th Lunar and Planetary Science Conference, Houston, Texas, USA, pp. 665-687.

7. APPENDIX

In November 1996, Russian Mars 96 spacecraft will be launched towards the planet Mars. Two German multiple line scanners are on board: HRSC (High Resolution Stereo Camera) and WAOSS (Wide Angle Optoelectronic Stereo Scanner). Upon arrival in December 1997 the spacecraft will enter a highly elliptical orbit around Mars, and the cameras will obtain multiphase, colour, stereo images. During the nominal mission (two Earth years), the expected planned imaging of the surface by HRSC will be both global (at least 150m/pixel), and regional (50% of the surface at better than 60m/pixel, and 20% at better than 15 m/pixel) in resolution. Global imagery will also be taken by WAOSS to monitor temporal changes in the appearance of surface and atmosphere.

It is expected that 20 GByte of raw compressed telemetry data will be received from both cameras and the final processed data products are likely to amount to 3.4 TByte in size. All Mars 96 data will be archived under the management of the SYBASE database system. Data formats of the Mars 96 data will follow PDS (Planetary Data System) standards in terms of logical and physical data structures, documentation, and file naming conventions. It is planned that scientists will be able to access an HRSC/WAOSS data catalog remotely via a query program to view information, and to request data of interest from the Regional Planetary Image Facility located at the DLR Institute of Planetary Exploration, Berlin.