"HOW GOOD IS 'GOOD ENOUGH'?": ANALYSIS OF COST/QUALITY TRADE-OFFS IN PLANETARY REMOTE SENSING FOR BOTH RESEARCH AND EDUCATION.

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Introduction: Subtle, but diagnostic, topographic features are associated with many landforms common to Earth and Mars. Finding and identifying such features is a critical part of image interpretation. However, as is true in so many walks of life, there is a severe trade-off between image quality (spatial and vertical resolution, in most cases) and the cost of image acquisition/processing. Understanding the minimum requirements for data quality in meeting interpretation requirements is essential in ensuring proper landform identification at minimum cost.

Ground surveys in the vicinity of a landed space probe have similar minimum resolution needs. How precise must such a survey be in order to detect adequately diagnostic features? Could such a survey be completely automated? Would the judgement of an astronaut in the selection of an interesting survey site and in the set up and troubleshooting of such a survey be required? Answering these questions is of critical importance in designing remote sensing systems for spacecraft. Further, posing and answering such questions make an engaging and educational inquiry-based activity useful for supplementing both formal and informal educational curricula.

The authors have recently been awarded a Mars Fundamental Research Program grant to perform detailed surveys of pluvial and aeolian features in the Mojave and Lahontan Deserts of the western United States, with supplemental funding from both NASA HEDS and NASA OSS E/PO, to address the questions above and to create educational activities for use in the National Air and Space Museum; this is a report on our plans for carrying out the work.

Description of proposed fieldwork: Detailed topographic surveys will be conducted in April, 2003 of subtle features associated with pluvial Lake Lahontan in western Nevada and aeolian structures in Nevada and southern California. Two separate techniques will be used: detailed 3-D profiling using Differential Global Positioning System (DGPS) and an Electronic Distance Measuring (EDM) central station survey.

The DGPS survey will provide a "ground truth" baseline against which comparisons can be made. The dataset can be artificially "coarsened" to assess the "How good is good enough?" question by determining the minimum resolutions necessary to identify the features diagnostic of a particular landform.

The details of planetary surveying from orbit and/or the surface are particularly germane at this time because of the aggressive Mars exploration program presently underway over the next decade. The MOC instrument aboard the Mars Global Surveyor spacecraft produces images in visible light with resolutions as good as 1.5 meters/pixel in some cases. THEMIS, aboard the Mars Odyssey spacecraft also in operation in Mars orbit, has a visible light imager that produces images of slightly lower resolution (~18 meters/pixel; better than all but the very best Viking orbiter images) and a thermal infrared imager that operates at 100 meters/pixel; outstanding for the thermal infrared part of the spectrum and greatly superior to any sesnsor flown previously. The MOLA aboard MGS produces detailed topographic data at ~180 meters/pixel spatial resolution. Of course, nobody will refuse a higher resolution capability if it were available without cost, but understanding the qualitative needs for effective remote sensing interpretation is becoming very important for Mars exploration and mission planning.

The EDM survey, utilizing a central location EDM and measurements of radial distance, azimuth, and elevation to a movable (roving) stadia rod/reflector is a more realistic analog to the types of surveys that could be conducted by a spacecraft lander/rover combination, since a DGPS survey requires a satellite network infrastructure not present at Mars or elsewhere in the solar system. However, what kinds of errors might crop up in making such a survey? Do those errors limit the range over which such a survey is sufficiently accurate to allow the identification of diagnostic features? Comparison of the datasets produced by the complementary surveys proposed should allow those questions to be answered.

Formal/Informal Education Opportunity: Many museums sell pin box toys of the type shown in the figure below, and many museum visitors and students everywhere have either played with them personally or have seen them somewhere before. One is marketed under the "PinPressions" label; there are other manufacturers. A series of pins is held in an open-bottom frame in such a way that their shanks are parallel and their heads are in a closely packed arrangement. When the pin box is placed atop an object, the configuration of the pinheads mimic the shape of the object beneath.

The engaging quality of the pin box toy is the close correlation between object and pinhead surface made possible by the use of many small pinheads in close formation. The size and spacing of the pinheads is a direct analog to spatial resolution of an image, and the vertical displacement of the pinheads corresponds to vertical resolution of a 3-D dataset.

Pin box toy placed over a human hand. At this resolution, details such as the ring being worn, are readily visible.

Pin boxes at the National Air and Space Museum (NASM): To help visitors visualize the effect of spatial resolution on image interpretability, we will use a set of four pin boxes at our "WHAT are You Looking At?" Discovery Station (a mobile interpretative exhibit that supports image interpretation in the NASM "Looking at Earth" Gallery). One will be a conventional pin box like the one shown above, the other three will use progressively larger and more widely spaced pins, to show the effects of degrading the resolution of the dataset. Each box will have a "price" associated with it based on the number of pins it contains, to make the visitor aware of the trade-off between resolution and cost. The "coarsest" resolution pin box will have a single large-head pin; if something is under the box, the pin will be up, if nothing is under the box the pin will be down. The amusement generated by such a blatantly "binary" device will help cement the general learning message, as well as to teach the distinction between ***detection*** and ***identification*** in remote sensing analysis.

The terrain models to be used in the pin boxes could be derived from molded 3-D topographic maps cut to fit. A more exciting possibility would be the use of terrain models of key topographic features of Mars, Earth, and other planetary bodies being developed at the Goddard Spaceflight Center.

The terrain models and pin boxes are also a powerful teaching tool for use with visually-impaired visitors/students. The Goddard terrain models were originally designed for that purpose and undergone initial testing to rave reviews. The pin boxes would also work well in this context. Pin boxes normally have fixed tops made of plexiglass, to prevent the pins from falling from the frame if the box is inverted. We would modify the box tops to mount magnetically, making them easy to remove when the box is placed atop the terrain model under study. This would allow the visitor to feel the array of pinheads and to determine the effect of resolution on interpretability without resorting to having to see the pins, another advantage to the differently-enabled visitor.

Pin boxes on-line: Discovery Stations at NASM serve thousands of visitors annually, but since the NASM website gets *millions* of hits monthly, we have at our disposal a powerful lever that would allow expansion of this education activity to reach many more students on-line than is possible with museum-based presentations. We have a grant proposal pending that would allow us to construct a web-based "cyber pin box" for the NASM Exploring the Planets Cyber-Center website (cybercenter.si.edu/planets/index.htm). The cyber-visitor can select (but not see) a landform to be placed beneath the cyber pin box, then cause the pins to be lowered. The pin heads will change color depending on the distance they drop to the surface of the landform beneath them. The farther the drop, the "cooler" the color, resulting in a color-coded physiographic map akin to the type commonly found in most classrooms. The activity will start at a low spatial and vertical resolutions; the student can "purchase" better vertical resolution and larger numbers of smaller pinheads, until they reach the point where they can conclusively identify the terrain type in question.

Alignment with formal education standards: The pin box activity works very well at NASM and could be used in a variety of museum and other informal education settings. Teachers wishing to use the on-line version of the pin box activity in their classrooms can use it to supplement their lesson plans. For example, a middle school teacher could augment a lesson on National Science Education Standard A (Science as Inquiry): Use appropriate tools and techniques to gather, analyze, and interpret data or NSES Standard E (Abilities of Technical Design): Design a solution or product. "(Students) must consider constraints – such as cost, time, trade-offs, and materials needed…."[1]. A high school teacher could augment a lesson concerning NSES Standard A (Abilities Necessary to do Scientific Inquiry), Understandings about scientific inquiry section, "Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advancement of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used." [2]

References: [1] National Research Council (1996), *National Science Education Standards*, Washington DC: National Academy Press, page 165. [2] *ibid.*, page 176.