A NEXT-GENERATION MAPPING SPECTROMETER

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The following recommendations represent my view of the desirable characteristics for a remote-sensing instrument for aircraft and orbital use, as was discussed at the Multispectral Imaging Science Working Group, Geology Team (Cal Tech, April 20-21, 1982). I make no particular claim to the originality of these ideas, nor can I say that this summary represents the concensus of the entire team. These are my thoughts on the matter, following that very productive meeting.

1) General

The ideal instrument would be based around two-dimensional detector arrays, silicon for the visible and very-near infrared (0.4 to 1.0 microns) and InSb or PbS for the rest of the near-infrared (out to about 2.6 microns). Spectral information would be dispersed along one axis. Thus one exposure or frame would simultaneously record a full spectrum for each pixel in a row perpendicular to the ground track. The instrument should be "smart" and versatile, with extensive pre-processing capability programmable from the ground.

2) Spatial Resolution

The general concensus of the team was that current Landsat resolution (about 80m) was not adequate, but that 30m would be quite acceptable, without leading to a serious data-rate problem. From the standpoint of deconvolving spectral endmembers, as discussed by John Adams, the smaller the pixel, the more successful we are likely to be in applying simple mixing models.

3) Spectral Resolution

Spectral dispersion should be designed so that individual array elements provide a resolution of about 1% ($\frac{\Delta\lambda}{\lambda}$). This resolution has been demonstrated to be useful and/or necessary for identification and discrimination of certain geologically and agriculturally important features. Retention of all spectral elements for each pixel would lead to problems with on-board data storage and transmission. Because the instrument would be computerized, however, data from selected spectral elements could be averaged or deleted, as programmed by the users for specific measurements. It seems likely that a repertoire of "standard" combinations of averages and deletions, optimized for different groups of users, could be developed based on experience from laboratory and field work as well as from hands-on experience with the actual instrument(s).

When used in a mode where only information in certain bandpasses is retained, it would probably prove useful to record a complete spectrum for at least the track directly below the instrument, and possibly also for a track on each side, near the extremes of coverage. This detailed spectral information would help resolve possible ambiguities in regions of abbreviated spectral coverage, and might alert researchers to interesting spectral features which would otherwise have gone unnoticed.

4) Signal-to-Noise and Data Precision

These are really two different issues which were somewhat confused during part of the meeting. Signal-to-noise, or sensitivity, is a property of the detector and its associated analog electronics. My opinion is that we should shoot for a S/N of 100 for surface materials with 10% reflectivity (typical of many basalts, for instance). This corresponds to an uncertainty of only 1.0% of the measured signal, which would provide excellent interpretability of mafic mineralogy. If this goal cannot be met due to engineering realities, 2-3% noise for these dark materials would be servicable. A noise level of 5% (S/N = 20) or worse would seriously compromise our ability to interpret mineralogy or even discriminate among low albedo surface materials.

By "data precision" I refer to the number of bits used to digitize, process, store, and transmit the observed information. Experience with Landsat and various planetary missions has shown that 8 bit (256) or less is not satisfactory for digitilization. A minimum of 10 bits (1024) is required to meet the requirements discussed above, and this only suffices if the signal from a perfectly reflective target is carefully matched to full scale. I would suggest 12 bits (4096) for digitizing the detector signal because it provides reasonable margin for scaling without losing information at either the high or low end. The processing step I envision as serving two purposes: averaging and dumping of channels as discussed above (3), and applying some type of compression scheme to the 12 bit data. While I am not familiar with the details of data compression techniques, the engineers here tell me that a clever scheme might require as little as 8 bits, or at most 10 bits, for onboard data storage and transmission to ground stations.

5) Calibration and Atmospheric Corrections

I am willing to agree with Alex Goetz that absolute calibration of the sensor system is not necessary. We don't really need numbers in units such as watts/square meter. However, knowledge of the response of the various channel relative to each other, and as a function of time, is very important. We need to be able to make direct comparisons between the remotely sensed observations and laboratory and field observations. The great difficulty of calibrating Landsat data to reflectance substantially limits its utility for compositional mapping. I disagree with the opinion put forth at the meeting that it is not worth keeping albedo information. Many people are used to thinking in terms of ratio type analyses primarily because this is required for Landsat data. It would be a shame to not calibrate new instruments well enough to provide albedo measurements.

The first type of calibration required is to look at solar illumination either through a diffusive filter or off of some standard surface. In either case the calibration device should be covered when not in use to reduce deterioration. (This sort of calibration has of course been used on many spacecraft instruments.) The next aspect of calibration is to have an effective computational way of removing atmospheric effects, primarily water absorptions, from the data. A number of groups have come almost simultaneously to the idea that some kind of real-time atmospheric sounding from the spacecraft is highly desirable. It is not clear yet whether data in the visible and near-IR will suffice, or whether there will need to be a few separte channels further in the IR specifically for this purpose.

The last major aspect of calibration is to develop certain areas (or materials) in the observed regions as known calibration standards. Traditionally this is done by sampling and laboratory measurement. Based on our experience comparing laboratory samples to measurements of the same unit in the field, I feel that certain units or areas are to heterogeneous, on a scale of centimeters to meters, to be characterized by laboratory measurements of small samples. For these types of areas field measurements from the ground (ala PFRS) or aircraft, using artificial calibration standards, are likely to be much more useful.

6) Miscellaneous

A number of people at the Geology Team meeting expressed thier frustration at not being able to locate in the field the position of single pixels in Landsat data. It was suggested that a broadband very high spatial resolution data set be obtained concurrently with multispectral observations, preferably using the same optics. This sounds like a desirable feature but I do not have a feel or how difficult it might be to implement.

It was also suggested that topographic information be collected by the new instrument, either through laser ranging or radar. This would allow a fairly accurate removal of photometric and shadowing effects, and therefore would be a great aid during analysis of the multispectral data. Again, I do not know how feasable this might be, but it should certainly be considered.