TELE-ANALYSIS OF RETURNED MARS SAMPLES: AN OPPORTUNITY FOR NASA? D.F. Blake[1] and L.F. Allard[2], [1]Exobiology Branch, MS 239-4, NASA Ames Research Center, Moffett Field, CA 94035, david.blake@nasa.gov, [2]Materials Science & Technology Division, Oak Ridge National Laboratory, 1 Bethel Valley Rd., MS 6064, Oak Ridge, TN, allardlfjr@ornl.gov

Introduction: Returned samples from Mars will be the most valuable scientific materials ever obtained, eclipsing by far the lunar soil and rocks returned during the Apollo program. In addition to the inestimable value of returned samples from Mars, there will be other reasons why scientifically, politically and socially its curation, accessibility and analysis will be unique in the history of science:

- The sample is from another planet which could have harbored life, and there will be legitimate concerns about public health and safety. How will we satisfy public fears of back-contamination - an "Andromeda Strain" event?
- A principal research interest in the sample involves whether extant life, remnants of extinct life, or pre-biotic organic compounds are contained within it. Because the Earth is teeming with life and its byproducts, the samples will require special protection from the Earth environment.
- A Mars sample return mission in the current (and forseeable) fiscal climate will be of necessity an international collaboration. Shared cost carries with it the expectation of shared reward in the form of equal access to samples.
- The gold standard of empirical science is repeatability. An analytical result reported by a single research team (especially an observation pertaining to extraterrestrial life) must be validated by another research group in the same or an equivalent sample. How can a one-in-a-million discovery be repeated if you have fewer than a million samples?
- The instruments used for analyzing returned samples will have to be upgraded and modified to a degree we have not experienced before (contamination free, parsimonious with sample material).
- Sample handling and sample preparation will be unique for each type of sample and each technique. How will samples be prepared to minimize waste and redundancy?

Telescopes, Microscopes and Mars Rovers: "Tele-astronomy" "Tele-microscopy" and "Tele-robotics," are methods of "instrument" control that are already in use within some areas of NASA and DOE, and are being adopted by the private sector as well. For example, tele-robotic operation is a requirement when the instrument is a rover operating on Mars. Beginning with the Mars Exploration Rovers *Spirit* and *Opportunity*, remote operations have become increasingly more user-friendly, to the point where Payload Uplink and Downlink commands can be accomplished using a laptop computer virtually anywhere in the world (although the actual spacecraft commands are still uplinked by controllers at JPL).

Major earth-based research telescopes are fully staffed and automated to optimize instrument usage and availability via tele-astronomy methods. Astronomers who wish to have observing time write peer-reviewed proposals and when observing time is granted, operate the telescopes from control rooms far from the mountain tops where the instruments are located. Data are collected in real time and analyzed offline.

For characterization of returned Mars materials, the concept of tele-analysis via methods such as tele-microscopy is a logical extension of NASA's experience with tele-robotics and tele-astronomy. Tele-microscopy methods were pioneered by the Department of Energy through the Materials Microcharacterization Collaboratory project among national laboratory (Oak Ridge, Argonne and Lawrence Berkeley National Laboratories) and university (Univ. of Illinois) partners in the 1990's. Microanalytical methods require a wide array of instruments for specimen preparation and data collection, and represent the most operator-intense scientific processes that will be involved with analysis of Mars materials. Much of the hardware and software required for the remote operation of state-of-the-art Analytical Electron Microscopes (AEMs) is routinely adapted to modern microscopes by the manufacturers. Modern AEMs cost in the neighborhood of ~$2-5M, require >$100K in annual maintenance contracts, and need technicians and specialized sample preparation equipment for optimal use. The most advanced instruments require specialized buildings to provide the quiet environment needed to routinely achieve their specified operation levels.

How Should Sample Return Science be Accomplished? Returned samples must be handled in such a way that the public health is protected. Returned sample science should be available equally among the international science community, and samples should be analyzed in a way that false positives and false negatives are minimized or eliminated and so that important observations can be repeated.

The Curatorial Facility. The curatorial facility should be permanently staffed, and contain all of the instruments and infrastructure necessary for sample curation, sample preparation and sample analysis. The facility should be built to P-4 or whatever biohazard level is deemed sufficient to prevent forward or back-contamination of the sample. Once returned samples are put in the curatorial facility, they will never (or rarely) be removed.

The International User Community. The scientific community with access to the returned samples would include anyone who has written a successful peer-reviewed proposal. The only required equipment at the PI's location should be a computer and a fast data link.

Returned Samples and their Analysis. Samples should be prepared in the curatorial facility by the permanent technical staff, and loaded into and removed from the analytical instruments by them. Data from the analyses are downlinked to the PI as the observations are made, as well as kept in an archive at the curatorial facility. Should the same observation be proposed by another researcher (either for another purpose or for validation of an earlier analysis), that researcher could reacquire the same location on the sample and perform the same analysis with the same equipment. Each set of observations obtained by a researcher should be covered by "Rules of the Road" document which allows priority to that researcher for those data for a set period of time (e.g., six months). Returned sample science could be performed by individual researchers with only a few $K of investment in a computer and data analysis software.

What Are the Benefits for NASA? NASA engineers and scientists will work together to create new robotic technologies and applications for science. This will have a variety of benefits: Scientists will become more familiar with their instruments and the measurements they make. This will have the effect of improving the technology, and creating more links between the engineering community and the scientific community, something that is relatively rare at the present time. The specialized sample handling and sample preparation techniques that will be necessary for returned samples will be tested and in place when the samples return. Scientific – technical collaborations will benefit spaceflight instrument development, and produce spinoff applications in the private sector. In the long run, there will be more accessibility of science and research to institutions that have been traditionally left behind as a result of the high cost of research facilities. Early adoption of tele-analytical science will forge collaborations between scientists of different countries and institutions and will establish trust among NASA, European Space Agency and other funding partners that science return will be shared equally.

The tele-microscopy will be shown as an example of what is already being done in DOE labs such as Oak Ridge National Laboratory. The Materials Microcharacterization Collaboratory project could be used as a starting point for designing and developing the infrastructure for Mars returned sample science.