POTENTIAL WATER RESOURCE DEPOSITS ON MARS: LOCATION AND SPATIAL RELATIONSHIPS TO REGIONS OF HIGH INTEREST FOR ASTROBIOLOGY AND SAFE SPACECRAFT OPERATIONS Beaty, David W.[1], Abby Allwood[1], Deborah Bass[1], Jim Head[2], Jen Heldmann[3], Scott Murchie[4], and Jerry Sanders[5], [1]Jet Propulsion Laboratory, NASA/California Institute of Technology, USA, [2]Brown University, USA, [3]NASA Ames Research Center, [4]Johns Hopkins University, Applied Physics Laboratory, USA, [5]NASA Johnson Space Center, USA.

Introduction: Water is the single most important location-dependent resource for a potential future human mission to Mars. Therefore, an important consideration for planning the future exploration of Mars is understanding the location of these deposits, and their relationship to the regions of high scientific interest. The areas of overlap constitute valuable targets for potential robotic exploration in the near term and possible eventual human exploration in the longer term. Consideration of these locations can provide guidance to mission planners and technology developers for key mission parameters like elevation, latitude, terrain roughness, etc.

The Potential Significance of Water-based ISRU: Using the resources at the site of exploration for making mission critical consumables and products could significantly reduce the cost, mass, and risk of the future human exploration of Mars. The ability to manufacture propellants on Mars for crew ascent to orbit is considered mission-enabling. The last NASA human Mars Design Reference Architecture (DRA) 5.0 study concluded that making oxygen for ascent propulsion from carbon dioxide acquired and processed from the Mars' atmosphere could reduce the lander mass by over 30% (or >25 MT). The availability of water on Mars, along with atmospheric carbon dioxide, may be game-changing for potential human exploration of the Mars surface. With water, not only might it be possible to produce oxygen life support and propulsion, but also water for the crew's needs, for radiation shielding, and and for fuels such as methane. Production of both oxygen and methane propellants could futher reduce the mass of Mars landers. To be considered a viable resource for processing, the water would need to be accessible, and the energy and mass of the hardware to acquire/process the water would need to be much less than just bringing hydrogen or fuel from Earth.

Water Resource Potential on Mars: We are currently aware of three broad classes of water-containing resource deposits of interest to the potential human exploration of Mars:

1. Shallow ice (occurring in several different geologic settings)
2. Surficial deposits of hydrated minerals
3. Potential liquid water in Recurring Slope Lineae (RSL) and possibly gully deposits

Surface Ice: Although the dominant reservoir of water ice is currently the north and south polar layered deposits (PLD), there is evidence that the spin axis-orbital parameters have changed over geologic time, and that variations in obliquity have mobilized polar ice causing it to be redeposited at low latitudes. Evidence for ancient non-polar, ice-rich deposits includes relatively young latitude-dependent mantles, and older pedestal craters, lobate debris aprons, lineated valley fill, and lobate deposits interpreted as tropical mountain glaciers. Remote sensing (neutron/gamma ray spectrometer and shallow radar) and geological observations of superposed craters provide evidence that tens to hundreds of meters of ice-rich material remains in the substrate and accessible in significant quantities at least down to mid-latitudes.

Surficial Deposits of hydrated minerals: The neutron spectrometer survey (Mars Odyssey, launched 2001) discovered large low-latitude regions with enhanced hydrogen concentration. These have subsequently been shown by the OMEGA and CRISM spectrometers on MEX and MRO to originate in hydrated minerals, which are interpreted to have formed in liquid water environments. These mineral deposits include phyllosilicates, sulfates, and carbonates, and may contain enhanced water contents of up to ~13%. The mineral deposits are exposed in low-latitude areas lacking an ice-rich mantle. They are present at the surface, and thus could potentially be mined without need for removal of overburden. Concentrations of hydrated minerals occur at scientifically interesting sites where exploration of deposits possibly recording ancient habitats would be enabled by humans.

Recurring Slope Lineae Deposits – Possible Evidence for Melting Ice: Mid-latitude recurring slope lineae (RSL) in equator-facing darker areas identified in HiRISE images have a seasonal dependence—they appear and systematically grow in a downslope direction in the summer and fade in the winter. Dozens of known and candidate occurrences all occur between 30°-50° latitude. They occur on sunward-facing slopes and are active during the warmest season. Their form and behavior are consistent with overland brine flows, and they are hypothesized to form from the melting of shallow mid-latitude ice. The RSLs have been intensely studied by MRO; besides marking potential shallow ice they are among the most likely current surface habitats for life.

Relationship to areas of scientific interest:

A primary driver for the scientific exploration of Mars is the search for the signs of life, either extinct or extant. The sites of interest to these two options are somewhat different.

Regions of interest to the search for extinct life:

To first order, the presence of water-laid sedimentary rocks serves as a proxy for areas of potential interest in the search for evidence of past life. It is possible to infer the distribution of sedimentary rocks in general from observations of stratified rocks in HiRISE and MOC images, and to identify the subset formed in water from OMEGA and CRISM spectral signatures of aqueous minerals. The depositional environments of many apparently aqueous sedimentary rocks is still uncertain, but their presence serves as a first-pass filter for potential astrobiological interest.

In addition, a number of potentially interesting locations were studied in detail as part of the site selection process for MSL. The science objectives of MSL led to a focus on sites that are potentially very relevant to the search for past life, so the MSL candidate sites represent a relatively small selection of specific sites that are much better understood in terms of their relevance for the search for evidence of past life on Mars.

A map of MSL candidate sites plus sedimentary rock outcrops inferred from current orbital data was constructed. Although this set of sites may not be a complete representation of regions of interest for the search for ancient life, it is sufficient to identify many regions where a mission might access suitable rocks in the search for ancient biosignatures.

Regions of interest to the search for extant life: The search for extant life on Mars focuses on regions where liquid water may exist to support the existence of martian biota. Three classes of features on Mars with the highest potential for hosting extant life include 1) gullies, 2) ice, and 3) RSLs. Geologically young martian gullies are primarily found at mid-latitudes and some may have formed by liquid water flowing on the martian surface. Although which were formed by water is debated, some gullies may nonetheless provide a habitable niche for martian life. Ground ice represents another possible martian habitat, particularly where the ice may have been recently warmed to provide meltwater and/or thin films of water to support life. The RSL features are one location where ongoing melting may occur, resulting in possible briny flow features during the warmest parts of the martian year. If this interpretation is correct, then RSLs may be a premier target of interest for extant life.

Planetary Protection Implications: There are important potential relationships between some of these types of resource deposits and planetary protection that may affect when and how they may be accessed by possible future human explorers. In terms of protecting Mars and possible native biota, we need to understand which environmental niches could be occupied by hitch-hiking terrestrial organisms. Of the kinds of deposits mentioned above, current understandings are:

- Terrestrial organisms cannot live in hydrated minerals.
- We do not know of terrestrial organisms that could reproduce in martian ice at martian temperatures. However, they might be able to do so in melted ice, which might result with spacecraft heat/power sources in close proximity.
- The biological significance of the RSLs is currently almost completely unknown.

Summary and Conclusions: For robotic missions to the martian surface with lifetimes of one Mars year or longer (like MSL), we currently are focused on sites that are within the latitude range 30°S to 30°N (because of thermal design issues associated with surviving the winter), at elevations of -1.0 km or lower (to minimize EDL risk), and that have a relatively smooth, flat place >20 km across in which to land (again related to EDL risk). There are also going to be comparable considerations for the potential future human exploration of Mars.

It is clear from this analysis that there is considerable overlap between regions of interest to the scientific exploration of Mars and the potential sites of future water resources for human exploration. Some of these resources lie within the current latitude and elevation constraints described above. However, many regions of potentially high interest are also located outside these limits. The portfolio of sites for future human exploration would be significantly expanded if technologists developing both ISRU and mission system technologies made these systems viable at expanded latitude limits of 40°S to 40°N, an elevation limit of at least +1 km (crucial to accessing southern latitudes), and at landing sites that have topographic hazards internal to the landing error ellipse. It is also clear that information on the types, distribution, and character of potential water resource deposits needs to be collected to inform future PP policy decisions.