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Exploring the Martian Surface: Lessons Learned from Thirteen Rover-Years on Mars
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The two Mars Exploration Rovers, Spirit and Opportunity, touched down on Mars in January 2004 and have been conducting extensive observations with the Athena science payload. Together the two rovers have traversed about 35 km. Spirit, located on the floor of Gusev crater, has investigated basaltic plains, as well as older materials in the Columbia Hills. The rocks of the Columbia Hills are granular in nature and have undergone significant alteration by water. They appear to be largely a mixture of altered impact ejecta and explosive volcanic materials. Spirit has discovered silica-rich deposits that may have formed in a hot spring or volcanic fumarole environment, as well as massive carbonate-rich rocks. Opportunity has carried out the first outcrop-scale investigation of ancient sedimentary rocks on Mars. The rocks are sandstones formed by wind and water erosion and re-deposition of ”dirty evaporite” materials rich in sulfate salts. The stratigraphic section observed to date is dominated by wind-blown bedforms, with water-formed current ripples exposed locally near the top of the section. While liquid water was present at Meridiani below and occasionally at the surface, the ancient environmental conditions recorded there are dominantly arid, acidic and oxidizing, and would have posed some significant challenges to life.

In carrying out the rovers’ mission, many lessons have been learned regarding the operation of robotic vehicles on the surface of Mars. These cover topics including flight system and mission design, traverse planning, science payload selection, flight software and autonomy, and team selection and training. Among the most important flight system capabilities are mobility, particularly in steep and rugged terrain, and a power system design that allows long mission life. Traverse planning benefits greatly from high resolution orbital imaging, and should take full advantage of topographic features, like impact craters, that provide access to important geologic materials. Important payload elements include instruments that can detect subtle compositional differences both remotely and in situ, and tools for getting below rock and soil surfaces. The most important flight software capabilities are ones that save time on the martian surface. Similarly, it is important to invest in the tools and team training necessary to minimize the duration of the uplink planning process.
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