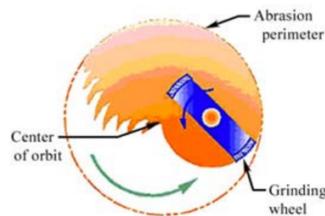


**SUMMARY OF ROCK ABRASION TOOL ACTIVITY FOR THE MARS EXPLORATION ROVERS.** S. J. Indyk,<sup>1</sup> J. W. Spring,<sup>1</sup> G. L. Paulsen,<sup>1</sup> and K. Zacny,<sup>1</sup> Honeybee Robotics, Pasadena, CA, 91103, U.S.A. (sjindyk@honeybeerobotics.com)

**Introduction:** The Rock Abrasion Tool (RAT) was developed specifically for the Mars Exploration Rovers (MER) Athena Science Payload [1]. Similar in function to a geologist's rock hammer, the RAT's primary function was to expose fresh rock surfaces to the other science instruments through abrading and brushing. Rock physical properties were also evaluated at each ground rock target by calculating the energy used per grind hole and the calculated amount of rock removed. This was called the Specific Grind Energy (SGE) and was catalogued for both Spirit and Opportunity for the duration of the mission.

**Mechanism:** The RAT consisted of three actuators. The grind motor, which spins a grinding bit with diamond grain embedded phenolic resin pads at 3000 RPM. Opposite the grinding wheel was a stainless-steel brush also rotated by the grind actuator through a gear train by the grind motor. The revolve motor, which nominally operated at about 3 RPM to spin the grinding axis, this provided a 45 mm diameter grind area with minimal surface roughness. (Fig 1) The last motor is the Z-stage, which extends the mechanism to locate and abrade the rock surface. Mounted to the end of the robotic arm of the rover, the RAT would be preloaded against the target rock surface between 10 and 100 N for grind or brush activities. [2]



**Fig 1:** Diagram of the grinding wheel path

**Grinds and Brushes:** During the course of the MER mission, 52 RAT grinds were performed by Opportunity and 15 by Spirit. A representative grind hole of 3 mm depth is seen in Fig 2, typical grind depths ranged between 3-6 mm. SGE were calculated for all grind targets, generally rocks ground by Spirit had significantly higher SGE values than Opportunity grind targets. The final RAT grind took place on sol 5036, by Opportunity at the target Aguas Calientes in Perseverance Valley.

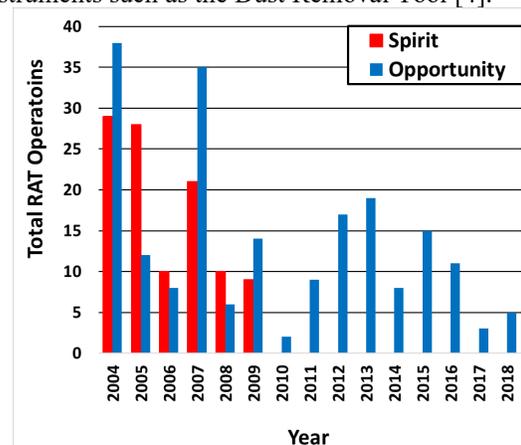
The RAT was especially useful for sweeping clear the surfaces of rocks in the dusty Martian environ-

ment. Over 160 brushes were performed by the RAT, 72 on Opportunity and 92 on Spirit.



**Fig 2:** Baltra RAT Grind hole on sol 893, Opportunity

**Legacy:** The Rock Abrasion Tools have exhibited exceptional performance and endurance in such a difficult environment as the Martian surface. (Fig 3) Due to its excellent performance, the RAT has become the baseline for extraplanetary grinding tools [3] and has influenced other contact science flight instruments such as the Dust Removal Tool [4].



**Fig 3:** Cumulative annual RAT activities

**References:** [1] Gorevan, S. P., et al. (2003), JGR, doi:10.1029/2003JE002061. [2] Myrick, T. M., Davis, K. and Wilson, J. (2004), 37th Aerospace Mechanism Symposium, 277-290. [3] Bar-Cohen, Y. & Zacny, K.. (2009). ISBN: 978-3-527-40852-8. 10.1002/9783527626625. [4] Davis, K., et al. (2016), 43rd Aerospace Mechanism Symposium, 279-292.