Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System (B)
Technology for Planetary Exploration (B0.3)

AUTOMATION AND AI TECHNOLOGY DEVELOPMENT FOR PLANETARY DRILLING

Brian Glass, brian.glass@nasa.gov
NASA Ames Research Center, Moffett Field, California, United States
Thomas Stucky, thomas.stucky@nasa.gov
COSATS CO., Ltd, NASA Ames Research Center, Moffett Field, California, United States
Terry Stevenson, terry.h.stevenson@nasa.gov
NASA Ames Research Center, Moffett Field, California, United States
Sarah Boelter, boelt072@umn.edu
University of Minnesota, Minneapolis, Minnesota, United States
Dean Bergman, dxbergman@honeybeerobotics.com
Honeybee Robotics Spacecraft Mechanisms Corporation, Altadena, California, United States
Carol Stoker, carol.r.stoker@nasa.gov
NASA Ames Research Center, Moffett Field, California, United States

Future human and precursor exploration will require a rapid, but thorough, initial survey of any localities on Mars to determine the spatial distribution, quantity, and quality (e.g., salt/mineral/organic content) of any discovered water, as well as to evaluate any signs of extant or extinct life. If our ultimate goal is finding biosignatures or resources at or below the surface, drilling will likely be the primary means of accessing these. Past technologies have required manual operation of these tools to acquire samples. Contact delay with devices on the moon is approximately five seconds. In contrast, contacting devices on Mars will take 7-20 minutes with lightspeed time delays. If we plan to drill beyond our local earthly orbit, time delays from Earth to further reaches of our solar system prevent manual teleoperation. Beyond the Moon, in-situ deeper robotic subsurface drilling and sampling in missions like Icebreaker [1] or Mars Life Explorer [2] will require a high level of automation.

For the past two decades, NASA subsurface automation and Artificial Intelligence (AI) technology development has examined drilling autonomy issues, starting with observing how humans do these tasks in terrestrial exploration, and (from an AI perspective) looking for ways to replicate or mimic the perceptive and decision-making processes exhibited by terrestrial drillers. In oil and gas drilling, “automation” and “remote control” generally mean being able to watch values and open/close valves with a mouse click in a control room, rather than by sending out a human with a wrench – i.e., teleoperation, whether onsite nearby or from an onshore control room.

Beyond Earth, drilling automation is challenging: oftentimes drilling largely blind without prior surveys, in a highly uncertain environment, with limited number of measurements possible be-

fore committing to a given target. While in progress, penetration performance is dependent on local strata, whose variations lead to dynamically-varying downhole environments. In our software approach, we began with several internal agents with defined roles, trying to pattern these after our understanding of human operators and their preferred parameters of interest. One agent addressed quick reactions, implementing heuristics, while a second compared incoming drilling telemetry to a parallel model of drill behavior using model-based reasoning, and a third used simple machine learning to identify drill state changes from shifts in shaft frequency and vibrational modes [3]. Finally, an encompassing autonomous executive executed nominal and fault-recovery scripts and plans. This was later extended to integrate sample transfer robotics and instrument controls [4].

Our fielded drilling autonomy approach has evolved in laboratory testing and in tests at remote analog drilling sites in the Arctic, Antarctic, Spain and Chile's Atacama Desert. In recent years (2016-19) the Atacama Rover Astrobiology Drilling Studies (ARADS) drilling life-detection rover added sample transfer robotics and addressed planetary protection/contamination issues [5]. In the summer of 2023, recent analog-site tests in the USA western desert (Bishop, CA) tested drilling performance in cuttings-impermeable fine-grained layers, and tests in the Canadian Arctic (Haughton Crater) addressed software automation and drilling performance in icy-impactites similar mechanically to regolith-volatile targets [6], relevant to the upcoming VIPER lunar polar mission and the proposed Mars in-situ biosignature missions. Future directions will look at software and hardware performance in massive ice and impactites, as well as multi-platform prospecting architectures.

References: [1] McKay, C.P., et al., *Astrobiology* 13(4):334-353, 2013. [2] Natl. Academies Press, 2022. [3] Statham, S. et al., *AIAA Journal*, 50(12), 2670-2681. [4] Stucky, T. et al., *ASCE Earth and Space 2018.* [5] Glass, B., et al., *Astrobiology* 23(12): 1245-1258, 2023. [6] Glass, B., et al., *ASCE Earth and Space 2024.*