Space Mining Application for South African Mining Robotics

Neale, A.M.

Mining Engineer
Hatch Africa
Johannesburg, South Africa
mneale@hatch.co.za

President
South African Space Resources Association
Pretoria, South Africa
president@sasra.co.za

***Abstract*— The concept of mining in space in not new, but the topic has been getting more attention in recent years. Many authors agree that mining space resources and the settlement of space would require extensive use of robotics. This paper explores the notion that future South African mining robotics could make the country a key player in the space mining industry. South Africa has fairly unique ultra-deep narrow tabular gold deposits, which lends itself to mechanization/automation for a number of reasons. The challenges to overcome before successfully implementing robotics in these deposits are similar to some of the robotics challenges in mining space resources. This paper discusses these challenges as applied to both the SA gold deposits and in space mining. This overlap can be mutually beneficial. There are a number of ways, suggested in this paper, in which the SA mining robotics industry could benefit from co-operating with the space mining industry.**

Keywords- space, mining, robotics, South Africa

I. INTRODUCTION

Space mining discussions started even before the first lunar landings [1]. Back then, it was thought that the lunar landings would be the first step towards mining resources and eventually settlement of the moon. 40 years later it is obvious that these plans did not realise, though space mining is again getting increasing attention. Examples of the increased attention are:

- the Google Lunar X-prize [2], to develop more affordable lunar launches
- the International Lunar Research park [3], phase 1 opening in November 2011 to develop a robotic lunar base
- the increased probing of the moon [4][5], aimed at, amongst other things, mapping of minerals and potential mission sites
- NASA's RESOLVE probe [6], to assay potential resource sites in more detail and demonstrate resource utilization capabilities

A number of authors [7][8][9] agree that returning to the moon, with the intention of eventual settlement, would require robotics, and specifically a high level of automation. The author believes that the mining robotics required for lunar mining is similar to what is being developed in South Africa for ultra-deep narrow tabular gold deposits; which means South Africa can, and should, be one of the key players in the first lunar mines.

II. THE NEED FOR ROBOTS IN SOUTH AFRICAN GOLD MINES

South Africa has some of the world's deepest gold deposits. These deposits are very narrow and spread out (tabular), and could benefit from robotic mining for the reasons that follow.

A. Safety

In 2008, South African mining industry leaders agreed to the Tripartite Action Plan on Health and Safety [10]. This plan aims to reduce the fatality frequency rate in South African mines to international standards. The yearly improvement goal, together with the actual achievement, for both gold and non-gold mines can be seen in Figure 1 and Figure 2. When looking at these figures it is evident that: 1) the South African mining industry is struggling to achieve its safety goals, and 2) the problem is worse in the gold mining industry.

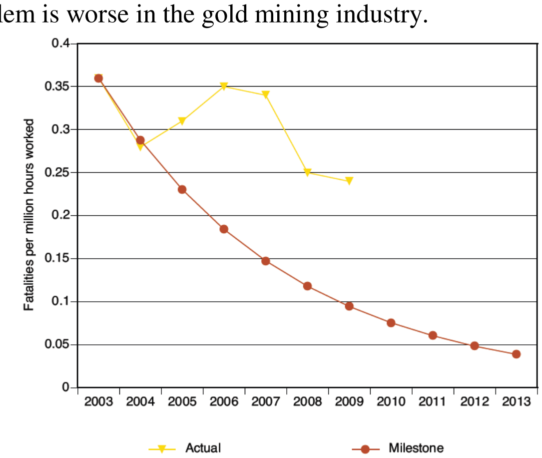

Figure 1: Gold Mines Fatality Frequency Rates [10]

Presented at the 4th Robotics and Mechatronics Conference of South Africa (ROBMECH 2011)
23-25 November 2011, CSIR Pretoria South Africa.

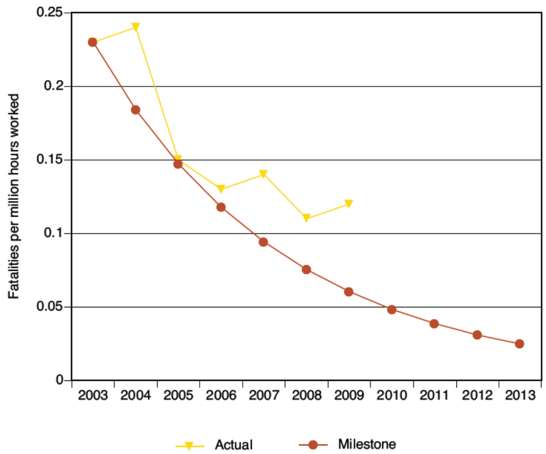

Figure 2: Non-Gold Mines Fatality Frequency Rates [10]

Having robotics (not just mechanisation) in gold mines will remove people from the dangerous areas and improve the overall safety [11][12][13]

B. Working conditions

Apart from the safety issue, gold mines are known to have more adverse working conditions than other mines. The conditions in the deep South African gold mines are said to be "*… the most severe in the world…*"*[14]* Examples of such conditions are: narrow stopes and thus severely confined working areas, long trips to face, extreme heat and humidity, and the amount of manual labour required.

C. Reserves

Reference [12] describes how having small mining robots in gold mines can improve the South African gold reserves. In short, to fit humans and current machinery into the working areas, miners need to take out much more rock than just the desired gold bearing layers. The cost of this constraint result in cut-off reef thicknesses, smaller than which cannot be mined economically. If a concept like the "Nederburg miner" [13] can be employed, these narrower reefs have a chance of being mined.

Reference [14] believes that South African gold mines will soon go even deeper than they are now. An increase in depth is coupled with increased risks and costs, as well as further deterioration in working conditions. The Nederburg miner concept can increase the national reserves currently excluded based on depth.

III. Comparison of Robotic Mining Challenges in SA Gold Mines and on the Moon

The author believes that, by developing the robotic abilities for ultra-deep narrow gold mines, South Africa will unknowingly be developing abilities for lunar mining. To support this, the following gold mining robotics challenges [12][13] are compared to lunar mining robotic challenges [7][8][9].

A. Localization without GPS

Localization is an important aspect of coordinating operations, especially robotics. On the Earth surface, localization is tremendously aided by GPS. In underground mines, GPS does not work and robotics would require an alternative method of localization.

Similarly, there are currently no positioning satellites around the moon. Such infrastructure will be put in place eventually, but the first robotic mines on the moon would definitely benefit from non-GPS localization.

B. Small

The base idea of the Nederburg Miner is that it must be small. The robots should fit into <50cm stopes, and will thus be inherently light weight (compared to traditional mining equipment). One of the key drivers for any lunar development is that it must be light weight due to the expensive launch costs. One example is the NASA Lunabotics Competition [15] which imposes an 80kg limit on lunar excavators. For terrestrial application, excavators that are considered miniature weigh over 1.5t [16].

C. Autonomous

The Nederburg miner will go where man can't, and thus needs to be remote controlled and as autonomous as possible. With the 3 second communication delay between Earth and the Moon, and the expense of having people on the moon, lunar robots will need to be tele-operated as a prerequisite, and the more automation, the better.

D. Swarming

With small mining robots, it will be necessary to have a number of robots with different functions, swarming to meet the production targets. Developing the logistics and intelligent systems to control the interaction of agents are essential for filling a stope with robots. Similarly, operations on the moon will require multiple robots interacting and cooperating. An example of this is the "Musketeer" lunar excavators tested at Mauna Kea in 2010 [17].

E. Rock breaking

Breaking rock with small robots will be a challenge. Small robots will struggle to drill the length of rounds which the gold mines are used to, and it won't be able to efficiently carry the weight of the explosives required. A proposed method being researched for this purpose is the electric discharge rock drill. This technology will be useful for lunar mining, because the robots will have similar weight carrying constraints. Also, launching heavy drill steels or bulk explosives is expensive and potentially dangerous.

F. Power

Reference [12] hopes for battery technology which will enable the mining robots to not require power supply cables. Freedom from a stationary power supply is an obvious advantage for lunar mining as well. Self-powered robots are critically important for operation during the 2 week long lunar night (where solar power would be cut off).

G. Data communication

AziSA is the current data communication architecture being developed for robotic mining operations. This architecture is designed for environments where there is “limited power and communications infrastructure”. Power constraints and limited communications infrastructure would be characteristic of an early lunar mine and the same architecture would be applicable (possibly with a few adjustments).

IV. Opportunities

The success of the Nederburg miner concept would benefit space mining development, but the reverse is also true: mining robotics can benefit from the current work in space mining. The potential for mutual benefit should be realized early on and resource and work share should be considered. Following are a few of the opportunities identified.

A. SASRA

The South African Space Resources Association has the vision of having South Africa involved when space mining is established [18]. SASRA could be seen as an umbrella opportunity for contact with and information on the space mining industry.

B. Space Mining Robotics

A number of people are doing technical research on lunar mining robotics [17][19][20]. Each of these endeavours represents potential for collaboration, lessons learnt and technology share to the advantage of mining robotics.

C. NASA Lunabotics

The NASA Lunabotics competition is a yearly event where engineering students design and build an excavator to dig lunar soil [15]. The students compete against each other in partially simulated lunar environments to see who can excavate the most regolith.

South Africa has a robotics competition entitled the “Mobile Robot Competition” [21]. The CSIR’s Centre for Mining Innovation recently became involved in the competition and now it has a mining theme.

The author proposes that the aim for the next Mobile Robot Competition should be to simulate mucking and cleaning in a gold mine. The robots of the two respective competitions could then be similar enough that the South African winner may enter the NASA Lunabotics with but a few adjustments. This could mean publicity, exposure and added support for the South African mining robotics industry.

D. ILRP

Phase 1 of the International Lunar Research Park is a terrestrial prototype of a robotic lunar base [3]. The facility is to open in November 2011. One of the functions of the ILRP is lunar resource development and mining.

South Africa could get involved in the mining robotics aspect of the ILRP, which will develop useful capabilities for ultra-deep narrow tabular gold deposits.

E. SANSA

SANSA is mandated to develop space engineering, something which South Africa currently does not have much of [22]. Though the space engineering currently envisioned is aimed at satellites, developing mining robotics for the NASA Lunabotics or the ILRP is arguably also space engineering. By this argument, it should be possible to get additional governmental support through SANSA for mining robotics development.

V. Conclusion

Developing mining robotics is the natural way forward for the mining industry, especially when looking at the ultra-deep narrow tabular gold deposits of South Africa. Some of the mining robotics challenges foreseen are: localization without GPS, miniaturisation, autonomy, swarming, rock breaking, power supply and data communication. Similar challenges are foreseen for the space mining industry and solving it in the one industry would benefit the other. The overlap between these industries should be explored early on to identify synergetic opportunities, like those mentioned in this paper. Making the most of such opportunities could make South Africa a key player in robotic mining, both on earth and in space.

Acknowledgment

The author would like to express his gratitude to the members of the South African Space Resources Association (SASRA), for giving up their personal time for the space mining cause, and to Hatch, for supporting employees with out-of-the-ordinary ideas.

References

[1] Delinois, S. L. (1966). The Challenge of the 70's... Mining on the Moon. *Mining Engineering*, 63-69

[2] Google Lunar X-Prize. (2011). *Home*. Retrieved September 1, 2011, from Google Lunar X-Prize: http://www.googlelunarxprize.org/

[3] ILRP. (2011). *Home*. Retrieved September 1, 2011, from International Lunar Research Park: https://sites.google.com/site/internationallunarresearchpark/home

[4] Bhandari, N. (2005). Chandrayaan-1: Science goals. *Earth and Environmental Science*, 701-709.

[5] Chin, G., Brylow, S., Foote, M., Garvin, J., Kasper, J., Keller, J., et al. (2007). Lunar Reconnaissance Orbiter Overview: The Instrument Suite and Mission. *Space Science Reviews*, 391-419.

[6] NASA. (2008). *NASA Team Demonstrates Robot Technology For Moon Exploration*. Retrieved September 1, 2011, from NASA: http://www.nasa.gov/home/hqnews/2008/feb/HQ_08067_lunar_robot_prt.htm

[7] Eckart, P. (2006). The Lunar Base Handbook: An Introduction to Lunar Base Design, Development and Operations. Boston: McGraw-Hill Companies.

[8] Lewis, J. (1997). *Mining the Sky: untold riches from the asteroids, comets and planets.* New York: Basic Books.

[9] Schrunk, D., Sharpe, B., Cooper, B., & Thangavelu, M. (2008). *The Moon: Resources , Future Development, and Settlement.* Chichester: Praxis Publishing.

[10] Chamber of Mines (2010). *Annual Report 2009-2010.* Chamber of Mines of South Africa.

[11] Green, J., Bosscha, P., Candy, L., Hlope, K., Coetzee, S., & Brink, S. (2010). Can a Robot Improve Mine Safety? *25th International Conference of CAD/CAM.* Pretoria.

[12] Green, J., & Vogt, D. (2009). A Robot Miner for Low Grade Narrow Tabular Ore Bodies: The Potential and Challenges. *3rd Robotics and Mechatronics Symposium*, (p. 6). Pretoria.

[13] Harper, G. (2008). Nederburg Miner. *Narrow Vein and Reef.* SAIMM.

[14] van der Merwe, J. (2011). Presidential Address: Future of the South African mining industry and the roles of the SAIMM and the Universities. *Journal of the Southern African Institute of Mining and Metallurgy*, 582-592

[15] NASA. (2011). *Lunabotics Mining Competition*. Retrieved September 18 2011, from NASA: http://www.nasa.gov/offices/education/centers/kennedy/technology/lunabotics.html

[16] HE Services. (n.d.). *Mini Diggers*. Retrieved September 1, 2011, from HE Services: http://www.heservices.co.uk/mini-diggers/

[17] Frenzel, F., Fu, T., Gammel, J., Grouchy, P., Law, K., Earon, J., et al. (2010). Robotic Lessons from Mauna Kea. *1st Joint Meeting Between the Space Resources Roundtable and the Planetary and Terrestrial Mining Sciences Symposium.* Golden.

[18] SASRA. (2011). *About SASRA*. Retrieved June 1, 2011, from SASRA: http://www.sasra.co.za/about/sasra

[19] Halbach, E. (2011). The Future Worksite Demonstrator: A Hardware Infrastructure for Testing Automated Earthmoving for Planetary Applications. *The 2nd Joint Meeting between the Planetary and Terrestrial Sciences Symposium and the Space Resources Roundtable.* Ottawa

[20] Norcat. (n.d.). *Innovation: Space exploration*. Retrieved September 1, 2011, from Norcat: http://www.norcat.org/Innovation-space.aspx

[21] Green, J., & Plumb, S. (2011). Mobile Robotics Competition: a Challenging Appication in Mobile Robotics. *AFRICON'11 - Special Sessino on robotics and Artificial Intelligence in Africa.* Livingstone: IEE Xplore.

[22] SANSA. (2010). *Space Engineering*. Retrieved September 1, 2011, from SANSA: http://www.sansa.org.za/space-engineering.aspx