

Turning Dust to Gold: Building a Future on the Moon

By Haym Benaroya
Springer-Verlag, 2010
ISBN: 978-1-4419-0870-4
Pages: 402

Rutgers University Professor of Engineering Haym Benaroya set for himself no small challenge in writing this intriguing, ambitious, although ultimately unsatisfactory “history” of human space flight, as written by hypothetical “chief executive” Yerah Timoshenko around the time of the 200th anniversary of the Apollo landings on the Moon. The book’s conceit is that a trove of missing documents from the early century of human exploration has been discovered in the late 22nd Century. These documents fill in gaps in the historical record of lunar settlement. Thus, future scholars are able to reconstruct humanity’s faltering steps in exploring beyond the Earth. Writing to us from his lunar home in 2169, Timoshenko summarizes the political, engineering, management, and financial hurdles faced by advocates of human space flight a century and a half earlier. And, from that future perspective, extensive human settlement on the Moon, with a foothold on Mars, was made possible by humanity’s desire to expand beyond the Earth and commercial development of putative lunar resources, hence the title of the book.

The most obvious challenge that Benaroya faced in choosing such a curious structure is that history begins to unfold – and unfold very differently – as soon as he hits the last *return* on his word processor. Thus, the Augustine Committee’s recommendations and the Obama Administration’s priorities in human space flight are only briefly noted, not surprising for a book written in 2009. It may be unfair to criticize a book that from the start makes it clear to the reader that it is a “history” written 150 years in the future. Not many readers of *Quest* begrudge the occasional historical howlers in episodes of *Star Trek*. However, Professor Benaroya is not writing science fiction, but attempting a hard science and engineering summary of major issues in contemporary human space flight. Thus, from the perspective of a reviewer in early 2012, it is a bit disconcerting to read about a “history” that includes, for example, fulfilling President Bush’s 2004 *Vision for Space Exploration*.

There is much value in the book, which might have been more successful if organized differently and the “future history” excised. I found interesting the numerous interviews with individuals with disparate experiences in human space flight. And, to Professor Benaroya’s credit, he included interviewees who unambiguously disagree with his unalloyed enthusiasm for lunar settlements and commercial development. In addition, although they can be easily found elsewhere, the texts of historically important speeches by Presidents Kennedy and George W. Bush were valuable entries to read again. In addition, the author correctly and repeatedly emphasizes three of the core limitations to human space exploration: (1)

lack of commercial motivation, (2) the expense of Earth-to-orbit transportation, and (3) the dangers of radiation.

And with those three, the book's weaknesses become apparent. Although it is reasonable to expect that techniques for mitigating the risks of space radiation will advance significantly over the next century and a half, Professor Benaroya describes most lunar habitats buried underground or covered in a few meters of regolith. Nevertheless, many of the book's fanciful – and well-reproduced – images show hotels and sports arenas above ground, often with stunning, unimpeded views of the sky. And, apparently, unimpeded exposure to solar particle radiation and galactic cosmic rays. It was jarring to this reviewer to follow the detailed engineering of buried lunar living huts and protection by living within lava tubes not many pages away from an image of a vast sports complex beneath a transparent dome. [One of the author's suggested sources of commercial money-making is sports on the lunar surface, notwithstanding the questionable economics of today's Olympics.]

Professor Benaroya argues that lunar tourism will contribute about a third of the necessary commercial value of the Moon, with thousands of tourists per year paying around \$5 M per trip (2005 dollars). The author compares this favorably with the \$20 M charged not long ago by the Russians for a several-day trip to the ISS. Apparently, a major reason for the profound difference is that the author adopts an orders-of-magnitude reduction in the future in the cost of importation to the Moon: he estimates about \$2000 per kilogram. However, this issue is far too lightly discussed in the book. Instead, reference is given to a pair of computer simulation models developed at the Berlin Institute of Technology, which consists of “nearly one thousand parameters and more than one hundred nonlinear equations.” This reviewer was impressed – nearly one thousand parameters! – although not persuaded without additional discussion in the book, which was lacking. The author seems to clearly favor the “space elevator” as the essential engineering breakthrough to make possible low-cost access to space, although it is (fairly briefly) discussed only after 300 pages of text, which suggests that the book would have benefited from a different structure.

Professor Benaroya's enthusiasm for “commercial activities” that would pay for future lunar settlement is apparent in a long, largely unexamined list, many items of which already today are carried out relatively inexpensively via other platforms. The author claims, for example, that reduced costs of lunar operations will lead to transfer of Earth resource surveys, climate monitoring, and weather satellite operations to the lunar surface in the coming century. Even more implausibly, monitoring the Solar System for potential human settlement sites is carried out in the late-22nd Century by telescopes on the lunar surface, rather than by *in situ* robotic scouts. [I wonder how many sites for future human settlement in the Solar System will still be awaiting discovery by the end of the next 150 years?] Astronomy from the lunar surface appears scattered through the book, although years before Professor Benaroya completed his book, the majority of astronomers understood that, with a few exceptions, observatories operating in free space were vastly

preferable to those on the lunar surface. [Full disclosure: for more than a decade, this reviewer has been actively involved in developing concepts for human operations, usually at libration points, as additional or alternative venues to the deep gravitational well of the Moon.]

Predictably, He-3 mined from the lunar regolith as the fuel source of the future figures prominently as a justification for settlement and commercial development. By 2169, when the book was “written,” the profound technical challenges had been solved of mining 100 million kilograms of regolith to obtain each kilogram of He-3 to be shipped inexpensively to Earth for use in fusion reactors that today we have only vague concepts how to build. The solutions to these challenges are treated far too lightly. Thus, to this reviewer in 2012, the book’s treatment of He-3 as an enabling enterprise for lunar settlement is too much like the famous Sidney Harris cartoon of the pair of scientists staring at a blackboard of complex equations, which are solved by, “Then a miracle occurs.”

Finally, there is remarkably little speculation about the evolution of robotics over the next 150 years, which in this reviewer’s opinion is likely to have the most profound impact on every aspect of human life, certainly including space exploration. Whether for good or ill, robots of various designs will likely be humanity’s intimate partners in future decades; they are all but absent in Professor Benaroya’s “history” of the future.

To conclude, there is more than a hint of hasty preparation in the book. I have already noted, for example, that the descriptions in the text of avoiding space radiation by being buried beneath meters of regolith directly conflicts with many of the illustrations. In addition, although it was valuable once again to read the complete texts of a pair of Presidential speeches, these are readily available elsewhere and added little that was new to the book other than increasing the number of pages. Finally, the thin two-page index is next to useless.

Harley Thronson
Science and Exploration Directorate
NASA Goddard Space Flight Center
Greenbelt, MD