The Martian

Andy Weir

Broadway Books, 2014, $15.00 (369 pp)
ISBN 978-0-553-41802-6
eBook ISBN 978-0-8041-3903-8

Reviewed by Gary L. Bennett

For millennia the reddish point of light in the sky has attracted humans. The Greeks and the Romans associated the bloody red object with their god of war (Ares and Mars respectively). The Arabs named Cairo for the planet (Al Najm Al Qahir) which was rising on the day the city was founded in 972 CE.

Science fiction writers have long seen Mars as a destination. Most famously, of course, was Edgar Rice Burroughs' Martian series with its swashbuckling heroes and damsels in distress acting out on the kind of dying Mars popularized by Percival Lowell. In the middle of the 20th century, Ray Bradbury brought in themes that echoed the Cold War as his protagonists emigrated to Mars. By the 1960s, with the first spacecraft having flown by Mars, stories about going there began to change, more recently with Kim Stanley Robinson's 1990s Mars trilogy about colonizing and terraforming a hostile planet.

With *The Martian*, first-time novelist Andy Weir has jumped into that large pool of novels about human voyages to Mars. He has written a *Robinson Crusoe on Mars* story about human perseverance and ingenuity in one of the most hostile environments humans have dreamed of exploring. (Those who have not read the novel or seen the movie should be aware that I am going to disclose some of the story.)

The Martian is a "page-turner" with a steady stream of challenging problems and ingenuous solutions. This novel is positive about NASA and its team approach to missions and solving problems (think Apollo 13). That is a nice bit of reality that is a welcome relief from the NASA-bashing that sometimes passes for plotting. (Full disclosure requires me to reveal that I have both worked for NASA and on programs in support of NASA missions.)

The Martian (and the newly released movie of the same name) could give NASA a boost to its Mars exploration program. Now if only Congress and the White House would get onboard …

In reading *The Martian*, imagine a place colder than Antarctica, drier than the Sahara and with less air than at the top of Mount Everest and you have a beginning appreciation for what awaits the first humans who travel to the Red Planet.

The Martian begins with astronaut/botanist Mark Watney trapped on Mars in the third (Ares 3) human mission to that planet. With a raging Martian sandstorm tearing at them, Watney's five companions have been forced to leave Mars quickly. Watney is left for dead, his flight spacesuit sensors giving the crew no life signs, thanks in part to Watney having been stabbed by a piece of antenna.

It was at this point that *The Martian* started to go off the rails (off the trajectory?).

Weir posits the clotting ("gunky residue") of Watney's blood with sealing the hole in Watney's spacesuit. With essentially one atmosphere of oxygen in the suit and essentially zero outside, I suspect that spacesuit could depressurize so rapidly that the blood won't have time to seal the hole. But let's invoke the willing suspension of disbelief here.

Watney is unable to communicate with Earth because the sandstorm has conveniently ripped off the main communication dish which in turn conveniently crashed into the reception antenna array. So, at this point, Watney is (to use his technical term) "fucked" until he travels to (spoiler alert!) the landing site of Mars Pathfinder, NASA's 1997 mission to Mars. Pathfinder consisted of a lander (since renamed the Carl Sagan Memorial Station) and a small rover named Sojourner.

[One can question how severely a Martian sandstorm would damage the Ares 3 Mars Habitation Unit or "Hab" and the Mars Ascent Vehicle (MAV). In a moving fluid such as the Martian air, the pressure exerted by the moving fluid is proportional to the product of the density of the fluid and the square of its velocity. Weir describes a 175-kph (kilometer per hour) sandstorm, a velocity that on Earth would be equivalent to wind speeds in a Category Two hurricane; however, on Mars the effect may not be that severe because the Martian atmospheric pressure is only about one percent that of Earth's. In short, the Ares 3 crew would see a lot of "not much" hitting them. Granted the sand could gunk up equipment.]

Mars Pathfinder went silent on 27 September 1997, less than three months after landing (the lander's battery lifetime was initially projected to be about 30 days). The lander's silver-zinc battery may have totally discharged which probably drove all the electronic equipment (e.g., computer) settings to "zero". Even though Watney retrieves Pathfinder, both the lander and the rover, and hooks the lander up to Hab power in all likelihood he could not use it to communicate with Earth.

In a more realistic scenario, Watney wouldn't have to spend 20 days retrieving Pathfinder. As safety and reliability conscious as NASA is and as expensive as the human Mars program will be (trillion-plus dollars spent on development) there will be antennae everywhere.

For example, as I was reading *The Martian*, the September 2015 issue of *NASA Tech Briefs* arrived and in it were two technologies that could solve Watney's communication problem.

The first is the intriguing "Mars Relay CubeSat". With current Mars orbiting spacecraft aging, Sami W. Asmar of Caltech has proposed that each mission to Mars take along a number of CubeSats to act as relays for landers. (If the future NASA can provide 17 satellites orbiting Mars, as Weir has written, then it can provide all the rovers and habitats with good communications to Earth.)

The second technology uses printed antenna arrays which Neil F. Chamberlain of Caltech and colleagues have proposed be placed on Mars rovers to allow direct-to-Earth (DTE) communication.

Thus, a "real" Mark Watney would have a range of options to enable him to communicate with Earth. The postulated loss of an antenna or two wouldn't stop him.

But being able to talk to mission control should not detract from the basic story of survival alone on inhospitable Mars (again think Apollo 13).

Weir had me turning the first hundred pages, eager to see what new challenges awaited Watney and to learn the clever ways he addressed them. And Watney's acerbic comments sounded genuine. But after that the novel took on a kind of "Perils of Pauline on Mars" tone (with a touch of *MacGyver*). Another chapter, another problem, another *Mission Impossible* solution.

Someone in Watney's space boots would no doubt face a host of problems but they would probably be of a different type from those described in the novel. For example, the Martian dust may damage the EVA suit. In December 2007, while serving on a National Research Council committee to review NASA's (then) Exploration Technology Development Program (ETDP), I learned that the Apollo spacesuits were seriously damaged by lunar dust even with their limited EVAs. Mars dust may be worse – in addition to mechanical abrasion, the soil may be chemically abrasive, too.

Dava Newman of MIT and colleagues have been working on a "BioSuit" that may allow greater freedom of movement on Mars along with ease of repair should there be a puncture of the sort Watney experienced. Stay tuned, space cadets!

Watney jaunts around Mars in a rover which Weir rightly recognizes will be limited by the available power. (A former colleague patented a clever way around the limitations of solar-and-battery-powered rovers but I'll save that neat trick in case I ever write a *Robinson Crusoe on Mars* novel!) A more likely problem with a rover would be a frozen or locked wheel (or wheels) as happened to Spirit, a Mars Exploration Rover.

The Mars Habitat Unit ("Hab") is described as being constructed of some kind of canvas-like material. While inflatable structures seem to be the rage with those advocating economy-class travel to Mars, the more likely scenario is something sturdier and more impenetrable than an inflatable.

Which brings up another issue. Weir describes the canvas-like Hab as having the capability to shield Watney from space radiation because the canvas is laced with material that cancels out the radiation. This might work if the radiation were electromagnetic but the radiation of concern for astronauts on Mars is particulate, such as solar proton events (SPEs) and galactic cosmic rays (GCRs), essentially atomic nuclei that have been stripped of their electrons. Such space radiation is potentially dangerous but there are "fixes". Long-term stays on Mars may require serious radiation shielding such as burying the Hab or piling Martian sand all over it.

Another radiation issue is associated with nuclear power sources. Like Geoffrey Landis's explorers in his somewhat similar novel, *Mars Crossing* (2000), Weir has Watney use a radioisotope power source – in this case a 1500-thermal-watt radioisotope thermoelectric generator (RTG). The RTG is a great power source – so far, the U.S. has launched 45 RTGs on 26 space systems. An RTG basically consists of two elements: (1) the radioisotope heat source and (2) the thermoelectric converter which converts the heat from the natural decay of the radioisotope into useful electrical power. The converter also rejects any unused ("waste") heat away.

Weir has Watney worry about a release of the plutonium-238 that fuels the RTG. That's not very likely. The U.S. Department of Energy (DOE) and its laboratories and contractors have gone to great lengths to ensure the containment and/or immobilization of the Pu-238. (By the way, the Pu-238 fuel does not "get red hot all by itself". It takes insulating the Pu-238 so that it can't reject heat for it to glow (and then you may need to turn off the lights to see the glow)).

While the RTG does contain the Pu-238 and the alpha particles that are the primary radiation emitted by Pu-238 are easily absorbed within the radioisotope heat source, there are neutrons and gamma rays emitted that could be of concern to an astronaut. For example, spending about ten 24-hour days within a meter of the RTG described in *The Martian* would give an astronaut the allowable radiation worker dose for a year. In the context of the much higher radiation dose an astronaut on Mars would receive from naturally occurring solar and galactic cosmic radiation, this may not be much, but it is something that an astronaut would have to consider in transporting an RTG around Mars.

Watney survives for over 500 sols (Martian days) thanks to growing potatoes in soil Watney creates by mixing Martian sand with his feces (Watney's technical term is "shit"). While I do live in the "potato state", I don't know anything about growing potatoes but I do recall one town where I lived making its waste available to farmers only after it had been spread out in sunlight for a year. Maybe what Watney produces at one end can go into the other end in less than 80 days but is it kosher?

Weir's choice of a propulsion system (VASIMR – Variable Specific Impulse Magnetoplasma Rocket), a kind of nuclear electric propulsion (NEP) system, is sporty; in the absence of a multi-megawatt nuclear reactor power source that option may not be available anytime soon. Studies dating back to the 1960s have shown that the preferred method of sending humans to Mars and returning them is the nuclear rocket, a technology which the U.S. almost brought to fruition before abandoning it in 1971.

I am an advocate of both NEP and nuclear rockets. Nuclear electric propulsion (NEP) can, in principle, get humans to and from Mars though it comes with some additional complications. As Weir rightly notes, electric propulsion provides a low thrust, but it's steady and after a while it can drive a spacecraft to large velocities (comparable to those of more impulsive systems like chemical rockets and nuclear rockets). However, it's that early phase of long-duration spiraling from Earth when the mission gets tricky. There's a potentially risky barrier called the Van Allen radiation belts that a Mars-bound NEP spacecraft must pass through.

One option proposed for human NEP missions is to send the NEP vehicle (what Weir calls "Hermes") on its way first. Then when the NEP vehicle has cleared the radiation belts, the human crew will be launched on a high-speed rendezvous using chemical propulsion. The return NEP spaceship would do a sort of reverse of this maneuver.

This is a long-winded (and roundabout) way of saying that Weir's Hermes rescue mission is going to be a bit more complicated than described.

As in Greg Benford's *The Martian Race*, it's the Chinese who save the day for castaway Watney. (One is also reminded of Martin Caidin's 1964 novel and the 1969 movie *Marooned* in which the Russians conveniently save the day for American astronauts.) Where would trapped heroes be without *deus ex machina* (hey – it worked regularly for that other Martian, John Carter!)?

The issues highlighted in novels like *The Martian*, *Mars Crossing* and *The Martian Race* reinforce Wernher von Braun's 1956 humans-to-Mars proposal: send two spaceships, each with the capability to back up the other in an emergency.

By the end Watney pulls it off by stripping Mars Ascent Vehicle 4 (MAV 4) a la the astronauts in the 1950 movie *Destination Moon* (thank you, Robert A. Heinlein!). Even

Hermes astronaut Chris Beck's use of the Manned Maneuvering Unit, MMU, as the propulsive force to rescue Watney reminded me of one of the astronauts using an oxygen tank as a thruster to rescue another astronaut in *Destination Moon*.

In the final analysis, forget the technical comments and sit back and enjoy "high adventure in the wild vast reaches" of Mars. (Take a bow, *Space Patrol*!) If *The Martian* can get us moving toward sending humans to Mars that alone justifies it. (And I'm looking forward to seeing the movie and wondering if it will replace *Conquest of Space* as my favorite movie about traveling to Mars.)

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