

# ELR

## NEWS & ANALYSIS

### Ethical Considerations for Terraforming Mars

by Robert D. Pinson

The colonization of outer space, especially Mars, has become increasingly relevant in recent years. With technological advances and biological discoveries, Mars is perceived as more hospitable to life than previously imagined. Just recently, the Mars Odyssey spacecraft has discovered vast quantities of ice on Mars.<sup>1</sup> As a result, long-term projects like the colonization, or even terraformation, of Mars are becoming less daunting.<sup>2</sup>

This Dialogue addresses novel concerns of environmental ethics and safety as humans begin their expansion beyond earth. The Dialogue then presents an argument for the terraforming of Mars. It is inevitable that humans will live on other moons or planets; it is only a matter of when.

#### An Introduction to Terraforming

##### *What Is Terraforming?*

Terraforming is a word not commonly used in popular culture. It has been familiar, however, to planetary scientists and avid science fiction readers.<sup>3</sup> The most expansive definition in the literature is that used by Martyn J. Fogg:

Terraforming is a process of planetary engineering, specifically directed at enhancing the capacity of an extra-terrestrial planetary environment to support life. The ultimate in terraforming would be to create an unconstrained planetary biosphere emulating all the functions of the biosphere of the earth—one that would be fully habitable for human beings.<sup>4</sup>

More simply put, terraforming is the altering of a planet or moon to be more earth-like.

Obviously, the ultimate goal of terraforming is the expansion of life, especially human life. In order for humans to survive, we need flora and fauna, as well as other terrestrial organisms to support our civilization. Terraforming mainly involves climatic properties such as temperature, pressure, atmospheric gas composition, and availability of liquid wa-

ter.<sup>5</sup> After appropriate adjustments to these properties, along with a little help from earth's biosphere, the entire surface of a planet can be drastically altered to create a suitable home for life.

##### *Popularization of Terraforming*

Biochemist and noted popularizer of science J.B.S. Haldane first speculated about the concept of terraforming; imagining human migration to other worlds after a cosmic accident makes earth uninhabitable.<sup>6</sup> Olaf Stapledon, 1930s science fiction writer, later used this concept in his work *Last and First Men*.<sup>7</sup> Jack Williamson was the first to actually use the word "terraforming."<sup>8</sup> Williamson published a set of short stories that, while not based on terraforming, did use the word and the concept in them.<sup>9</sup>

One of the better-known uses of terraforming in science fiction is by Arthur C. Clarke in his 1951 novel, *The Sounds of Mars*.<sup>10</sup> At that time, terraforming was still considered to be pure science fiction.<sup>11</sup> However, science fiction crossed the threshold into serious research when Carl Sagan began publishing articles on the possibility of terraforming Venus.<sup>12</sup> Within the realm of science fiction, terraforming became more widely used and developed.<sup>13</sup>

The most extraordinary and awe-inspiring literary work on terraforming is the epic poem, *Genesis*, by Frederick Turner.<sup>14</sup> *Genesis* is exactly 10,000 lines of iambic pentameter and is set on a partially terraformed Mars, creating a "prototypical foundation myth for a future planetary civilization."<sup>15</sup>

Robert Pinson grew up in Nashville, Tennessee, where he was an avid fan of science fiction. After earning his B.A. in biology from Oberlin College in Ohio, the author spent two years as a legal assistant in Washington, D.C. He is currently a third-year law student at the University of Tennessee in Knoxville. This Dialogue was inspired by one of his law professors, Glenn Harlan Reynolds.

1. Peter Anderson, CNN.com, *Mars Odyssey Images: "A Lot of Ice"* (Mar. 4, 2002), at <http://www.cnn.com/2002/TECH/space/03/01/mars.odyssey.briefing/index.html>.
2. Even long-term projects such as sending humans to other stars in multigenerational voyages is being discussed in the *New York Times*. See Natalie Angier, *On This Trip, One Lifetime Isn't Enough*, N.Y. TIMES, Mar. 5, 2002, at D1.
3. MARTYN J. FOGG, TERRAFORMING: ENGINEERING PLANETARY ENVIRONMENTS 9 (1995).
4. *Id.* Fogg appears to be the most extensive author on this subject. There are a few other authors who have written on the topic of terraforming and their ideas will be discussed later.

5. Kjetil Gjerde, *Terraforming: The Modern Alchemy—Or Tomorrows Engineering Technology?*, at 2, at <http://www.users.globalnet.co.uk/~mfogg/gjerde.htm> (last visited Sept. 25, 2001).

6. FOGG, *supra* note 3, at 13. Haldane is most notable for his work on evolutionary genetics and the origins of life. *Id.*

7. *Id.* Stapledon gave the first detailed description of terraforming, *id.*, suggesting the use of electrolysis on the Venutian seas in order to create oxygen for humans to breathe. Gjerde, *supra* note 5, at 3.

8. FOGG, *supra* note 3, at 16. Williamson actually used the pseudonym Will Stewart when he published his novelette, *Collision Orbit*. *Id.*

9. *Id.*

10. Gjerde, *supra* note 5, at 3.

11. *Id.*

12. *Id.* Sagan published the first scientific article referring to terraforming in 1961. *Id.* While he never mentioned the word itself, his ideas were based on the concept. *Id.*

13. *Id.* at 19. More recent novels have actually kept up with scientific and ethical developments and have actually won prestigious awards. *Id.* One of these, *The Greening of Mars*, by James Lovelock and Michelle Allaby, has been treated as more of an academic work than science fiction. *Id.* at 19-20. Lovelock, creator of the *Gaia Hypothesis*, and Allaby explore science with the aid of fiction. *Id.* at 20. Their ideas are still the basis of terraforming methods today. *Id.* at 20-21.

14. *Id.* at 22.

15. *Id.*

Terraforming gained even more attention from the scientific community when the National Aeronautics and Space Administration (NASA) published the first large multi-authored study on terraforming.<sup>16</sup> The scientific study of terraforming boomed in the 1970s.<sup>17</sup> Entire papers were written about it; people began to specialize in it.<sup>18</sup> After a dry spell in the 1980s, the pace of terraforming studies picked up in 1989.<sup>19</sup> Through the 1990s, more articles and even whole textbooks were published on the subject.<sup>20</sup>

Early in the 20th century, the concept of humans going to the moon was exclusively the subject of science fiction stories.<sup>21</sup> These days, lunar voyages are a thing of the past.<sup>22</sup> Terraforming may hold the same destiny: from fiction to fact.

### *Why Mars?*

Mars is one of the closest planets to earth as well as the most similar.<sup>23</sup> Compared to earth, Mars has one-ninth the mass, 40% of the gravity, and about 40% of the surface area.<sup>24</sup> Several physical aspects are close enough to those of earth to be acceptable: gravity, rotation rate, axial tilt, and distance from the sun.<sup>25</sup>

The Martian environment is not suitable to support terrestrial life, but of all the planets (and moons) in the solar system, it appears to be the best option for terraforming.<sup>26</sup> Scientists are almost certain that all the elements required for terraforming are present on Mars.<sup>27</sup> Preliminary studies suggest that Mars had a warmer and wetter climate during the early part of its life.<sup>28</sup> When Mars had greater volcanic activity, it is thought that it had a denser atmosphere that supported liquid water.<sup>29</sup> When this volcanic activity slowed down, Mars began to freeze; thus, the gases forming the atmosphere slowly collected in the ground and the water froze.<sup>30</sup> This past and the possible presence of those gases make Mars attractive for terraforming. It may be possible to restore the planet to its past habitable condition.<sup>31</sup> While Mars has a relatively thin atmosphere, many believe that enough carbon dioxide (CO<sub>2</sub>) exists on the planet to make the atmosphere denser.<sup>32</sup> Some of this CO<sub>2</sub> is frozen and makes up at least part of the south polar cap.<sup>33</sup> Additional re-

serves may be trapped in the regolith.<sup>34</sup> The presence of CO<sub>2</sub> and possible presence of water (also in ice form) make Mars an attractive candidate for terraforming.

An alternative to Mars is our true “sister planet,” Venus. The conditions on Venus are inapposite to those on Mars. The high temperature and high pressure on the surface make Venus unsuitable to colonization or terraforming.<sup>35</sup> Earlier in its life, Venus was possibly more earth-like, but now it is extremely hot and dry.<sup>36</sup> Because of its similar mass and gravity, coupled with the prospect of geological activity, Venus is an attractive candidate for terraforming.<sup>37</sup> It is clear, however, that the amount of energy and mass flows required to terraform Venus are several times greater than that of Mars.<sup>38</sup> Other options, such as the moon or Mercury, have been briefly considered, but never seriously discussed.<sup>39</sup>

Unlike the alternatives, Mars has all of the requirements for colonization on-site: “A surface area that can readily be settled, sufficient sunlight for photosynthesis, and both rocky and volatile resources.”<sup>40</sup> Mars has long been, and likely still is, the prime candidate for space colonization.<sup>41</sup> In its current state, however, humans will have to live in enclosed structures<sup>42</sup>; life will be denied the chance to expand.

### *How Terraforming Works*

Life can grow on Mars if we can raise the planet’s surface temperature, thereby increasing its atmospheric pressure and reducing the amount of ultraviolet radiation reaching the surface.<sup>43</sup> While we cannot, and should not, move Mars to a warmer orbit, we can increase its temperature by releasing gases that trap the sun’s radiation—commonly known as the “greenhouse effect.”<sup>44</sup> Recent studies have shown that a small change in temperature at the Martian south pole could spark a runaway greenhouse effect resulting in the evaporation of the polar cap.<sup>45</sup>

As a result of this rise in temperature, the vapor pressure of CO<sub>2</sub> will increase; thus, allowing *more* CO<sub>2</sub> to evaporate into the atmosphere.<sup>46</sup> This runaway process could hope-

16. *Id.* at 27. The study focused on Mars and predicted that it would take approximately 100,000 years to “generate a breathable partial pressure of oxygen.” *Id.*

17. *Id.*

18. *Id.*

19. *Id.* at 29.

20. *Id.* at 30-31; see, e.g., ROBERT ZUBRIN, *THE CASE FOR MARS: THE PLAN TO SETTLE THE RED PLANET AND WHY WE MUST* (1996).

21. ZUBRIN, *supra* note 20, at 247.

22. *Id.*

23. FOGG, *supra* note 3, at 202.

24. *Id.*

25. ZUBRIN, *supra* note 20, at 249.

26. FOGG, *supra* note 3, at 257.

27. *Id.*

28. *Id.*

29. *Id.*

30. *Id.*

31. *Id.*

32. ZUBRIN, *supra* note 20, at 249.

33. *Id.*

34. *Id.* “Regolith” is the loose surface material that overlays a planet; “soil” refers to earth’s regolith. *Id.* at 249-50.

35. FOGG, *supra* note 3, at 397.

36. *Id.*

37. *Id.* at 400.

38. *Id.* at 399.

39. The earth is also not an alternative for terraforming because it already has an atmosphere and any attempts to alter it could have severe consequences for life that exists here. Additionally, since terraforming refers to making something more earth-like, one really can’t make the earth more earth-like.

40. FOGG, *supra* note 3, at 206-07.

41. *Id.*

42. *Id.*

43. Martyn J. Fogg, *A Synergic Approach to Terraforming Mars*, 45 J. BRIT. INTERPLANETARY SOC’Y 315 (1992).

44. ZUBRIN, *supra* note 20, at 250. It would not be wise to attempt to alter a planet’s orbit since we could drastically alter the gravitational, and thus, orbital, stability of our own planet. Additionally, we could cause comets, asteroids, or meteorites to come dangerously close to our own orbit, increasing the chance of planetary annihilation of the human race and all life as we know it.

45. *Id.* at 251.

46. *Id.* at 252. Vapor pressure and atmospheric pressure are two different concepts. *Id.* The former is “the tendency for a substance to transform into a gas or vapor” while the latter is “the actual weight of an atmosphere over the surface.” *Id.* As vapor pressure rises at the pole, the atmospheric pressure rises as well. *Id.*

fully cause the entire pole to evaporate.<sup>47</sup> The reserves of CO<sub>2</sub> and water in the regolith then come into play.<sup>48</sup> The CO<sub>2</sub> in the regolith will similarly begin to evaporate into the atmosphere while the water in the permafrost will begin to melt.<sup>49</sup>

The CO<sub>2</sub> at the polar cap will evaporate quickly while that in the regolith will be directly proportional to the rate of the temperature increase.<sup>50</sup> As large portions of the Martian surface rise above the freezing point, large amounts of water should melt.<sup>51</sup> As a result, Mars will have a warmer, wetter climate suitable for certain forms of life. Along with CO<sub>2</sub> and water, the Martian atmosphere would need oxygen and nitrogen to allow for the development of a more habitable environment for humans.<sup>52</sup>

### Methods of Terraforming

As discussed above, the first step in terraforming Mars is to increase its temperature. Various methods have been proposed: space mirrors, albedo reduction, and greenhouse gas production.<sup>53</sup> Additionally, a “synergic” method combining these elements has been proposed and may be the most efficient.<sup>54</sup>

### Orbital Mirrors

This idea involves the construction of a mirror (or mirrors) that would reflect sunlight onto a specified area, such as the south polar region.<sup>55</sup> This increased sunlight would cause an increase in temperature, thereby causing the evaporation of CO<sub>2</sub> in the south polar cap.<sup>56</sup> Because of the total sunlight required to raise the temperature by 4 degrees Kelvin, the mirror will have to be 250 kilometers (km) in diameter.<sup>57</sup> Such a large object would not need to orbit Mars; solar light pressure (solar wind) could balance the planet’s gravity, thus allowing the mirror to float in a static position.<sup>58</sup> Because of its

size, the orbiting mirror would be constructed in space using asteroidal or Martian moon materials.<sup>59</sup>

### Albedo Reduction

An alternative to space mirrors is to increase the amount of solar radiation absorbed by Mars through a reduction of its albedo.<sup>60</sup> This method could be of particular use for warming especially reflective areas, such as the volatile rich polar caps.<sup>61</sup> A reduction in albedo would be best accomplished through the spreading of dark material, such as dirt, or growing dark vegetation over the ice cap.<sup>62</sup>

The use of vegetation is not feasible because no known terrestrial life can survive the present Martian environment.<sup>63</sup> Additionally, the amount of dirt to reduce the albedo sufficiently enough to increase the temperature by 4 degrees Kelvin is too great.<sup>64</sup> The entire surface of Mars would also have to be covered.<sup>65</sup> This option seems ineffective as a means of heating the planet appropriately.

Assuming, however, that not much dirt is needed, what are the methods of spreading the dirt? We cannot just ship it there from earth; that would be too expensive and time-consuming. A proposed method of dispersal is nuclear weapons.<sup>66</sup> The dust created would have to be enough to cover the whole cap. While this may be the cheapest, easiest, and fastest method—we could start today—it would cause some legal as well as ethical problems.<sup>67</sup>

### Greenhouse Gases

Perhaps the most practical approach is the use of super “greenhouse gases.”<sup>68</sup> This process would involve pumping gases such as methane, nitrous oxide, ammonia, and perfluorocarbons (PFCs) into the atmosphere.<sup>69</sup> These

47. *Id.* at 254.

48. *Id.*

49. *Id.* at 256-57.

50. *Id.* at 260.

51. *Id.* at 261.

52. Christopher P. McKay & Margarita M. Marinova, *The Physics, Biology, and Environmental Ethics of Making Mars Habitable*, 1 *ASTROBIOLOGY* 89, 92-93 (2001). Unfortunately, it is not yet known how much of the essential ingredients needed to build a biosphere exist on Mars. *Id.* at 94.

Full terraforming requires substantial modification of the Martian atmosphere:

An increased partial pressure of oxygen so that Martian air becomes breathable and an amount of nitrogen sufficient to control combustion and provides a reservoir for biological nitrogen fixation. A substantial hydrosphere would also be desirable to bury organic carbon sediments . . . and to dampen diurnal and seasonal swings in climate.

Fogg, *supra* note 43, at 315.

53. Fogg, *supra* note 43, at 315-17.

54. *See id.* at 321.

55. ZUBRIN, *supra* note 20, at 263.

56. *Id.*

57. *Id.* Kelvin is the preferred scientific measurement for temperature. It corresponds to degrees Celsius but it starts out at zero (absolute zero) and goes up from there. Because 273 degrees Kelvin equals 0 degrees Celsius, a 4 degree Kelvin rise in temperature is also a 4 degree Celsius rise.

58. *Id.* at 264.

59. *Id.* at 263. The mirror, which could perhaps be made out of an aluminum mylar, would have a mass of 200,000 metric tons; thus, it would be too large and too heavy to launch from earth. *Id.* There are predictions that the mirror may need to be much larger in order to properly heat the planet. Fogg, *supra* note 43, at 316. One projection places the surface area of the mirror as greater than that of Mars itself. *Id.* If this is true, it seems like an unlikely option.

60. *Id.* Albedo is often defined as the “reflectivity over all wavelengths” of a surface. FOGG, *supra* note 3, at 1. Simply put, it is the amount of light that is reflected by a surface. The darker the surface, the less light it reflects; thus, its albedo is lower.

61. Fogg, *supra* note 43, at 316. Sagan originally proposed this idea in 1973. *Id.*

62. *Id.* at 317.

63. *Id.*

64. *Id.*

65. *Id.*

66. Kian Cochran, *Heating Mars* (Feb. 22, 2000), at <http://www.redcolony.com/terraforming/methods.html>. The devices would have to be detonated near the cap and occur once every year for perhaps 40 years to make up for the strong winds on Mars blowing the dirt off the cap. *Id.*

67. *Id.* Not only would it cause political turmoil to detonate a nuclear device on Mars, it would also violate international treaties, such as the Outer Space Treaty of 1967. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2, 410, 610 U.N.T.S. 205. One could write another paper exclusively on this topic; therefore, I will avoid going into further detail.

68. Christopher P. McKay, *Bringing Life to Mars*, *SCI. AM.*, at \*4 (Mar. 1999), available at <http://www.sciam.com/1999/0399space/0399mckay.html>.

69. *Id.*

gases are much more efficient than CO<sub>2</sub>—the most abundant greenhouse gas on Mars—at trapping solar energy.<sup>70</sup> Chlorofluorocarbons (CFCs) are also a recommended tool for heating Mars.<sup>71</sup> However, since CFCs destroy ozone, they need to be replaced with compounds that lack chlorine,<sup>72</sup> such as the already mentioned PFCs.

One suggestion is to use bacteria to synthesize water and CO<sub>2</sub> into methane.<sup>73</sup> Some bacteria can metabolize nitrogen and water to produce ammonia.<sup>74</sup> These bacteria, however, will need to be used subsequent to an initial greenhouse condition, possibly with orbital mirrors or PFC production.<sup>75</sup> Additionally, since methane and ammonia will be constantly destroyed by certain wavelengths of solar radiation, the supplies will need to be constantly replenished.<sup>76</sup> These initial greenhouse gases would have to be produced on Mars itself.<sup>77</sup> The best option proposes distributing hundreds of small PFC factories on the Martian surface.<sup>78</sup> Powered by the sun, each of these machines would generate the PFCs using elements from the Martian soil.<sup>79</sup>

Another method of introducing greenhouse gases on Mars is moving ammonia asteroids. It is possible that large amounts of ammonia, frozen as in asteroids, exist.<sup>80</sup> The best way to deliver the ammonia is to impact the asteroids into Mars, thus releasing the ammonia and melting the water in the regolith as well.<sup>81</sup> For this project to work, however, multiple asteroids, perhaps 50, would be needed.<sup>82</sup> Three factors prohibit this method from being feasible: First, it is unknown if these types of asteroids really exist.<sup>83</sup> Second, the repeated impacts would be incompatible with the objective of settling Mars.<sup>84</sup> Third, the chance of missing Mars and hitting earth is too great a risk to take, especially since there are other options available.

### Synergic Approach

This combination of other methods is the creation of the earlier mentioned Fogg. Fogg notes that current engineering schemes, such as “positive feedback” methods, may not be realistic.<sup>85</sup> He proposes a “technocentric approach favoring more active and energetic intervention.”<sup>86</sup> The need to mine CO<sub>2</sub>, nitrogen, oxygen, and water exists and will require a large industrial effort on the Martian surface.<sup>87</sup> This combi-

nation of the techniques is promising and may allow the complete terraforming of Mars in less than 10,000 years.<sup>88</sup> Fogg predicts that Mars will be predominantly dry with the flora and fauna consisting mostly of temperate and continental species.<sup>89</sup> While terraformed, Mars will still be the same “exotic and alien world providing a new and unique stage for the dramas of life and civilization.”<sup>90</sup>

### Other Alternatives

A few more alternatives should be discussed. One such alternative is the concept of “paraterraforming.” Paraterraforming involves the creation of global scale “contained” biospheres.<sup>91</sup> Essentially, this involves enclosing some or all of the Martian surface and creating a stable atmosphere within the enclosure; decreasing the amount of terraforming required since only a small portion of the atmosphere—up to 3 km—needs to be altered.<sup>92</sup> While ambitious, the sheer monstrosity of the project and the materials it requires prevent the “worldhouse” from becoming reality.<sup>93</sup> Additionally, the roof would be so susceptible to cosmic impact that it would fail to achieve proper containment.<sup>94</sup>

Other “lesser planets” may be available to terraform; but with the dearth of information on these bodies, they cannot be viable options.<sup>95</sup> Similarly, the concept of planet shifting is so grandiose and energy-intensive that it is not a feasible alternative.<sup>96</sup>

### How to Start

The problem with terraforming is that it will take so long to accomplish. No human project has ever lasted as long as 10,000 years. The biggest obstacle is politics.<sup>97</sup> Before we terraform Mars, we must study it and research which methods are most applicable. In order to study Mars, we must first put humans on the surface. Robert Zubrin proposes three models on how a “humans-to-Mars program” could be accomplished: the J.F.K. model, the Sagan model, and what Zubrin calls the Newt Gingrich model.<sup>98</sup>

The J.F.K. model is based on the late president’s challenge to send humans to the moon.<sup>99</sup> Under this model, the president calls upon the nation to meet the challenge of the future just as President John F. Kennedy did when he stated: “We choose to go to the Moon in this decade and do the other things not because they are easy but because they are hard . . . .”<sup>100</sup> Instead of sneaking his program through the political process, President Kennedy boldly stated his inten-

70. *Id.*

71. ZUBRIN, *supra* note 20, at 264.

72. *Id.*

73. *Id.* at 266.

74. *Id.*

75. *Id.*

76. *Id.* at 267.

77. McKay, *supra* note 68, at \*4.

78. *Id.*

79. *Id.* These machines would only be about the size of a Volkswagon, *id.*, and would probably be maintained by colonists.

80. Robert M. Zubrin & Christopher McKay, *Technological Requirements for Terraforming Mars*, at \*8, at <http://www.users.globalnet.co.uk/~mfogg/zubrin.htm> (last visited Sept. 25, 2001).

81. *Id.* at \*9.

82. *Id.*

83. *Id.*

84. *Id.*

85. FOGG, *supra* note 3, at 326.

86. *Id.*

87. *Id.* These materials are necessary for life to exist on Mars.

88. *Id.* at 327.

89. *Id.*

90. *Id.*

91. *Id.* at 406.

92. *Id.* at 407-08. On a global scale, the enclosure is called a “worldhouse.” *Id.*

93. *Id.* at 413.

94. *Id.*

95. *See id.* at 415.

96. *See id.* at 447-48.

97. ZUBRIN, *supra* note 20, at 273.

98. *Id.* at 277. The last model is named after the former Speaker of the House because Zubrin and Gingrich came up with the basic idea together. *Id.* at 282-83.

99. *Id.* at 277.

100. *Id.* (emphasis in original).

tions to the U.S. Congress and to the world.<sup>101</sup> The money spent sending humans to Mars would not be a waste.<sup>102</sup> That money would create jobs, pay for innovations and inventions, and pay for raw materials.<sup>103</sup> Additionally, and most importantly, the money would pay for “an invitation to every youth in the nation to join in a great adventure by developing their minds—the true source of our future wealth.”<sup>104</sup> Not only will this project demonstrate America’s great spirit, it could serve to promote international cooperation by involving other interested nations.<sup>105</sup>

The next model is that proposed by Sagan. Sagan proposes a joint collaboration between the United States and the (former) Soviet Union.<sup>106</sup> The cooperation would call for a sharing of both technology and cost.<sup>107</sup> The United States lacks a heavy-lift launch vehicle with the requisite power to send a manned spacecraft to Mars; Russia possesses such a rocket in the Energia.<sup>108</sup> With the fall of the Soviet Union, this model appears to be outdated. A new possibility exists, however, for U.S.-Russian collaboration.<sup>109</sup> Instead of soothing relations between foes, the project could be used to “stabilize a nation that is trying to be a friend.”<sup>110</sup> While the Sagan model remains sound, it still runs the risk of the Mars project becoming hostage to Russian stability.<sup>111</sup>

The final model is the Gingrich approach that involves a project called “Mars Prize.”<sup>112</sup> The U.S. government would post an award, say \$20 billion, to be given to the first private company to successfully land a crew on Mars and return them safely to earth.<sup>113</sup> In addition, several prizes of a few billion dollars for various milestones would be given along the way.<sup>114</sup> Many such prizes were offered in aviation’s early years; Charles Lindbergh flew across the Atlantic, not as a part of a government program, but in pursuit of a privately posted prize.<sup>115</sup> This approach removes the chance of cost overruns because there is no incentive to run up costs; the government will spend no money until the desired result is achieved.<sup>116</sup> Zubrin estimates that the total project should cost between \$4 billion and \$6 billion.<sup>117</sup> With about \$15 billion in profit at stake, it should be easy to mobilize the required capital from the private sector.<sup>118</sup> Not only is the pri-

mate sector more innovative because a consensus is not required, but the private sector will undoubtedly subcontract expertise in particular areas from various NASA centers.<sup>119</sup>

With the above scenarios in mind, it appears that the Gingrich approach may be the ideal choice. Once the project is accomplished, we will be able to perform studies on Mars to determine the feasibility of the various methods for terraforming. All of this has still not taken into account the next big question: *Should we terraform Mars?*

## Ethical Considerations

Ethics is a branch of philosophy dealing with issues of good versus evil behavior.<sup>120</sup> Ethics has a lot to do with our decisions on whether we should or should not do something. Only in the last century have our ethics expanded to include human interactions with nature.<sup>121</sup> As a new century begins, environmental ethics have become a “thriving discipline” with a strong influence on politics.<sup>122</sup> On earth, there is no distinction between life and nature.<sup>123</sup> When one looks outside of earth’s atmosphere, worlds apparently devoid of life exist all around us.<sup>124</sup> Therefore, a distinction between life and nature becomes necessary when considering the environmental ethics of terraforming Mars.<sup>125</sup>

### *Fundamental Axioms of Environmental Ethics*

Any system of environmental ethics is based on three fundamental axioms: anti-humanism, wise stewardship, and intrinsic worth.<sup>126</sup>

#### Anti-Humanism

Anti-humanism holds that humans should not use their technology to alter the environment.<sup>127</sup> This view is based on the belief that humans are merely an equal part of nature and should not change the ecology of the planet.<sup>128</sup> An essential component of this view is that the passive contemplation of nature is the ultimate goal for mankind because the world ecological system is too complex for us to truly understand.<sup>129</sup> Since we cannot understand our own planet’s systems, we cannot understand those of Mars; therefore, anti-humanism would argue against terraforming Mars.<sup>130</sup> An argument could be made, however, that terraforming will not only spread human civilization, but also terrestrial life. In order for humans to live on a terraformed Mars, we will need flora and fauna to support our colonies. This ex-

101. *Id.* at 278.

102. *Id.*

103. *Id.* at 278-79.

104. *Id.* at 279.

105. *Id.*

106. *Id.* Sagan saw this project as a way to bind the two adversaries together. *Id.*

107. *Id.* at 280.

108. *Id.* Energia is the most powerful rocket on the planet. *Id.*

109. *Id.* at 281.

110. *Id.* Since it is in the best interests of the United States to have a stabilized Russia, this provides new vigor to the model. *Id.* at 282.

111. *Id.*

112. *Id.* at 283.

113. *Id.* Companies could do this on their own or they could form coalitions to work together and share in the prize money.

114. *Id.*

115. *Id.*

116. *Id.* at 283-84. Since no or little red tape will be involved, the process will be more efficient. Additionally, since the company’s profits will be the prize minus their costs, they will have every reason to drive down costs. *Id.* at 284.

117. *Id.* at 285.

118. *Id.* at 286.

119. *Id.* This should calm fears that the Mars prize will hurt NASA. *Id.*

120. Martyn J. Fogg, *The Ethical Dimensions of Space Settlement*, 16 *SPACE POL’Y* 205, 206 (2000).

121. *Id.*

122. *Id.*

123. McKay & Marinova, *supra* note 52, at 105.

124. *Id.* On earth, it is difficult to find a place devoid of life. *Id.*

125. *Id.*

126. *Id.* at 106

127. *Id.* This view also can easily be expanded to the cosmos.

128. Christopher P. McKay, *Does Mars Have Rights? An Approach to the Environmental Ethics of Planetary Engineering*, in *MORAL EXPERTISE: STUDIES IN PRACTICAL AND PROFESSIONAL ETHICS* 184, 188 (Don McMillen ed., 1990).

129. *Id.*

130. McKay & Marinova, *supra* note 52, at 106.

pansion of life and nature seems to be in the best interests of the anti-humanism view because if there is no life on Mars, then there is no nature. This interdependency of life and nature in the anti-humanism belief is the key fallacy to its exclusive application to a non-earth environment such as Mars. However, if it is truly human nature to mess everything up, this view then becomes extremely relevant if we wish to conserve resources and limit our impact on the environment.

### Wise Stewardship

Wise stewardship, also known as utilitarianism, holds that humans can use and alter natural systems but must do so wisely and to the long-term benefit of humanity.<sup>131</sup> This view is the most prevalent in environmental ethics.<sup>132</sup> Many good economic reasons exist for preserving a diverse and stable biota that makes wise stewardship the most universally appealing.<sup>133</sup> This view assumes that humans can indeed be “wise” and take the appropriate steps to achieve balance in a biosphere. Wise stewardship would argue that a terraformed Mars, seen as a restoration to a biological state, would be acceptable and proper because it would help us “develop a scientific understanding of how biospheres work as well as provid[e] aesthetic and educational advantages.”<sup>134</sup>

### Intrinsic Worth

Intrinsic worth holds that sets of objects have intrinsic worth,<sup>135</sup> or are valued as they exist. There are two main subjects within this view: all life, and life as well as inanimate objects.<sup>136</sup> With regards to the set of living organisms, it is obvious that human life has value. Intrinsic worth seeks to establish that non-human life has equal value to humans.<sup>137</sup> If no indigenous life exists on Mars, then this aspect of intrinsic worth does not exclude the possibility of terraforming. If life exists, however, intrinsic worth would oppose terraforming. In that case, we may have a moral *duty* to maximize the potential of that life.<sup>138</sup> Thus, if life on Mars is genetically related to life on earth or if no life exists, then a Mars teaming with terrestrial life is the best alternative because a “biologically rich and diverse Mars is of more value than the beautiful, but virtually dead, world we explore today.”<sup>139</sup>

A different result occurs under the view that all objects, animate and inanimate, have intrinsic worth. If indigenous Martian life exists, we cannot encourage the development of

that life at the expense of the rocks and regolith.<sup>140</sup> We also cannot introduce life to a lifeless Mars because “life has no precedence over non-life.”<sup>141</sup> This view essentially demands that we leave Mars, and all other planetary bodies, alone. This view takes intrinsic worth to the extreme and is hopefully not followed by many. Of course, it would be preferable to leave “X” as it is if our adaptations would completely ruin or alter “X” without increasing its value to life. However, if there is no life to begin with, what is the harm in trying?

As for the first view, a good contrary argument is that the life on Mars, if any exists, is likely to become extinct; thus, introducing new life would be performed because the world will be dead soon anyway. If Mars is lifeless, then there is nothing to intrinsic worth that prevents terraforming; in fact, it may fully support it.

### Traditional Ethical Approaches

Fogg proposes that current environmental ethics currently follow a “geocentric” viewpoint.<sup>142</sup> This view sees earth as a sealed box; space simply lies beyond moral consideration.<sup>143</sup> The only environmental problem involving space that involves this view is the escalating problem of orbital space debris around earth.<sup>144</sup> Within this geocentrism, there are three central ethical perspectives: anthropocentrism, zoocentrism, and ecocentrism.<sup>145</sup>

### Anthropocentrism

Anthropocentrism, also known as homocentrism, holds that only humans have rights; the basis of intrinsic value is the ability to think rationally and act morally.<sup>146</sup> Through this perspective, the rest of nature is amoral and has no moral standing.<sup>147</sup> While nature is seen as valuable because it contributes to human welfare, all other life and the ecosystems in which it exists, as well as inorganic matter, have no rights other than those assigned by humans.<sup>148</sup>

Since the earth and its ecosystems support humans and develop our minds, we have a real obligation toward nature.<sup>149</sup> Humans should balance exploitation with preservation under anthropocentrism.<sup>150</sup> This view largely adopts the wise stewardship standard that we must wisely control nature for the long-term benefit of mankind. Anthropocentrism clearly would not oppose terraforming Mars.<sup>151</sup> In fact, if it could be shown that terraforming would benefit humanity, this view would undoubtedly support it. Essentially, if Mars is better as another home than as it is, terraforming would be a moral cause.<sup>152</sup>

131. *Id.*

132. McKay, *supra* note 128, at 189.

133. *Id.*

134. McKay & Marinova, *supra* note 52, at 106. Once again, since wise stewardship allows for the alteration of nature for its own good, terraforming Mars would be appropriate. Additionally, since life itself would be spread to a new world, wise stewardship would most likely endorse terraforming.

135. McKay, *supra* note 128, at 188.

136. *Id.* at 191.

137. *Id.* at 190.

138. *Id.* at 191. If that means leaving it alone, then colonizing Mars may be out of the question.

139. McKay & Marinova, *supra* note 52, at 106.

140. McKay, *supra* note 128, at 191.

141. *Id.* at 191-92.

142. Fogg, *supra* note 120, at 206.

143. *Id.*

144. *Id.* This problem is perceived as a threat to “personnel and hardware safety” and does not involve ethical consideration. *Id.*

145. *Id.* at 207-08.

146. *Id.* at 207.

147. *Id.*

148. *Id.*

149. *Id.*

150. *Id.*

151. *Id.*

152. *Id.*

## Zoocentrism

Zoocentrism involves an expansion of moral rights beyond humans.<sup>153</sup> This view holds that not only humans, but also animals considered sentient, would have moral standing; thus, animals would be treated more like humans.<sup>154</sup> As a result, exploiting animals for “food, medicine, science or degrading entertainment would be immoral and we would have to strive to uphold animal as well as purely human welfare.”<sup>155</sup> Therefore, if terraforming Mars were shown to benefit conscious existence, then it would be a right and proper thing to do.<sup>156</sup> This seems to be the predominant view among environmentalists. While this view may have merit when applied to earth because there is life all around us, it is less applicable to areas beyond earth because there is only a small *chance* of life being present.

## Ecocentrism

Ecocentrism, also known as biocentrism, holds that “all life is sacred and has the right to exist and flourish.”<sup>157</sup> Humans are not a superior species, but are an equal part of a greater whole.<sup>158</sup> Proponents of this view urge that we dismantle our technologically advanced society and adopt a simpler lifestyle in harmony with nature.<sup>159</sup> This view is inapposite to anthropocentrism since there is quasi-equality between man and nature.<sup>160</sup>

Ecocentrism adopts life as the basis of value: “Planets and the rocks they are made of provide an instrumental stage within which life can play out its destiny.”<sup>161</sup> Thus, terraforming may not necessarily be immoral since maximizing diversity is one of ecocentrism’s principles.<sup>162</sup> If life exists on Mars, then it would be assigned intrinsic value and we would have to further its interests.<sup>163</sup> As long as Mars is truly lifeless, we can terraform.<sup>164</sup>

The problem with ecocentrism is that it is too restricted to earth. It demands that we get rid of much of our technology; therefore, we will not be able to terraform Mars. At some point, humanity’s need to survive will force us to go to other planets, thus requiring technology. Additionally, ecocen-

trism, while ideal, faces many of the same problems that zoocentrism faces. If we get rid of our technology, we will be unable to treat disease and hunger because our medical capabilities will be limited. Ultimately, our life-spans will decrease and mortality rates, especially those of infants, will increase. Our civilization will undoubtedly be averse to the consequences of this view.

## New Ethical Approaches

The applications of geocentric theories of environmental ethics to space do not necessarily view terraforming as wrong and immoral.<sup>165</sup> There are a few proposed environmental ethics that might apply to space-faring humans.

## Cosmic Preservationism

Cosmic preservationism holds that the cosmos has its own values and has a right to exist without the interference of humans.<sup>166</sup> Ideally, terrestrial life, especially humans, would stay on earth and merely observe the universe from this location.<sup>167</sup> In essence, this view is the ultimate extreme of intrinsic worth: everything has a right to be as it is.

A similar view is called the “exploration ethic.”<sup>168</sup> This view is essentially anti-humanistic and object-centered.<sup>169</sup> The basic rules of exploration ethics as proposed by Holmes Ralston III are:

1. Respect any natural place spontaneously worthy of a proper name.
2. Respect exotic extremes in natural objects.
3. Respect places of historical value.
4. Respect places of active and potential creativity.
5. Respect places of aesthetic value.<sup>170</sup>

Since almost any part of the universe could be included in one or all of these rules, terraforming would be immoral under exploration ethics.<sup>171</sup>

While these factors should be considered, preservationism and exploration ethics are less than ideal and are likely to be accepted by only a small number of individuals.

## Restorationism

Restorationism, as proposed by Richard Miller, mainly adopts the ethical axiom of wise stewardship. According to this view, humans must maintain natural systems and must wisely and ethically manipulate the environment.<sup>172</sup> The restoration is utilitarian in means but preservationist in intent.<sup>173</sup> Restorationism would support terraforming because it would restore life to a place we believe it once existed, and

153. *Id.* at 208. Animal rights activists and vegetarian groups have used this view for many years. *Id.*

154. *Id.*

155. *Id.*

156. *Id.* Zoocentrism suffers from a few weaknesses. The inability to properly define “sentient” makes this view unattractive. Obviously, lower life forms are not included, but where is the line drawn between sentient and not sentient? Additionally, the inability to communicate with animals provides a barrier to our ability to treat them as humans. When dealing with humans, we ask them what they want. If we cannot ask animals what they want, how can we assume to know what is best for them, especially if they are to be treated as equals?

157. *Id.* This viewpoint is claimed to be the first true environmental ethic because of its base in holistic principles. *Id.* This view is closely tied to the intrinsic worth of all life concept discussed above.

158. *Id.*

159. *Id.*

160. *Id.* Under ecocentrism, “the survival needs of humans outweigh the survival needs of non-humans, but the survival needs of non-humans outweigh the non-survival needs of humans.” *Id.*

161. *Id.*

162. *Id.*

163. *Id.*

164. *Id.*

165. *Id.*

166. *Id.*

167. *Id.* at 209.

168. Richard W. Miller, *Terraforming: An Ethical Perspective*, in *THE CASE FOR MARS VI: MAKING MARS AN AFFORDABLE DESTINATION* 407, 430 (Kelly R. McMillen ed., 2000).

169. *Id.*

170. *Id.*

171. *Id.*

172. *Id.* at 433.

173. *Id.* Humans must learn to live on and cultivate the land, not exploit it. *Id.* This view furthers the idea that humans must “be one with the land,” but also allows for technology.

we can become attuned to ourselves as well as to nature.<sup>174</sup> Like wise stewardship, this view assumes that humans are capable of being “wise” and able to correctly predict the effects of our influences. However, if we never took risks then we would never go anywhere; we would squalor in mediocrity and monotony.

### Inventionism

Inventionism uses humanity’s thirst for knowledge as a means of finding purpose in our own existence.<sup>175</sup> Since humans cannot exist without a biosphere, plants and animals must be able to live on Mars if we are to live there.<sup>176</sup> We must also take responsibility to protect the environment,<sup>177</sup> not unlike wise stewardship.

Inventionism allows for the development of ideas and technology as long as their application does not disturb nature.<sup>178</sup> While we are the most important aspect of this ideology, nature still has significant value to us and must always be considered. This view supports terraforming as long as no indigenous life exists; if it did, we would have to develop that life with, perhaps, some help from terrestrial organisms. Besides pure anthropocentrism, inventionism is the most conducive to terraforming.

### Summary

Besides the technical obstacles to terraforming Mars, ethical issues also exist. Some new environmental ethics have been proposed, most of which are merely extensions of traditional forms. The ethics of terraforming should be considered now so we will be better prepared to decide when the time comes. While considering the appropriate ethical arguments for and against terraforming, we may learn something about ourselves and how, where, and why we place value.

### Why Must We Terraform Mars?

There are two simple answers to this question: (1) because we can; and (2) because life is precious. The arguments, however, are not so simple.

#### *Because We Can*

Mars is a frontier. It is both similar and dissimilar to the old frontier of America. It has many of the same challenges, but it also has new challenges, such as lack of air, food, and water. The domination of that frontier is what makes America so great.<sup>179</sup> A frontier provides the opportunity to begin anew, to make up for past mistakes.<sup>180</sup> With it new ideas develop and the chance to improve upon the past. New challenges will provide new answers and new ways of thinking.

Our society is losing its vigor as evidenced by the following: “Increasing fixity of the power structure and bureaucra-

tization of all levels of life; impotence of political institutions to carry off great projects; the proliferation of regulations . . . ; the spread of irrationalism; the banalization of popular culture . . . ; economic stagnation and decline . . . .”<sup>181</sup> Without a new frontier to breathe new life into our culture, our progressive spirit will fade along with our dreams and ideals.<sup>182</sup> Mars is the frontier to reignite the flame. This flame was the feeling that “America was not something one simply lived in—it was a place one helped to build.”<sup>183</sup> We need that feeling once more.

Those who colonize Mars will feel like they are, and actually will be, building a “New World.” Additionally, people on earth will also be invigorated by a much-needed boost of hope: “Democracy in America and elsewhere in Western civilization needs a shot in the arm. That boost can only come from the example of a frontier people whose civilization incorporates the ethos that breathed spirit into democracy in America in the first place.”<sup>184</sup> Like the changes in the “Old World” that America started, this “New World” will substantially change the way we think here on earth. A sense of a global community should emerge, much like it has since the events of September 11, 2001.

A recent paradigm struggling for recognition in environmental law is the “precautionary principle.” The precautionary principle itself states that “[w]here an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public[,] bears the burden of proof.”<sup>185</sup> The precautionary principle developed because scientific certainty would often come after proper responses to environmental threats lost their effectiveness.<sup>186</sup> As a result, there is an international trend toward preventative, rather than remedial, policies that could become standard in international law.<sup>187</sup>

While I am sure there are many valid reasons for and against the precautionary principle, it is inapplicable and irrelevant to Mars. The precautionary principle’s chief goal is to preserve life as it exists as well as human civilization; it prevents some country from doing something terribly stupid, in theory. However, for a place where no life exists, no need exists to take precautions because there is nothing to protect. While it is important to continue research to see if life *does exist* on Mars, I believe humanity as a whole would suffer from a conservative approach to such a large-scale project like terraforming. We must be aggressive and act now, for every year counts.

Humans strive to achieve the impossible. We must be constantly challenged; no problem exists, at least in our minds, which we cannot overcome. Terraforming Mars is just another obstacle to overcome. If we do not do it out of

174. *Id.* Although many would consider it excessively idealistic, this view does have some merit.

175. *See id.* at 434.

176. *Id.*

177. *Id.*

178. *See id.*

179. *See* ZUBRIN, *supra* note 20, at 295-97.

180. *See id.*

181. *Id.* at 296-97.

182. *Id.* at 297.

183. *Id.* at 299.

184. *Id.* at 303.

185. Urban Governance, *Wingspread Statement on the Precautionary Principle* (Jan. 1998), at <http://www.gdrc.org/u-gov/precaution-3.html> (last visited Mar. 11, 2002).

186. Paul C. Lin-Easton, *It’s Time for Environmentalists to Think Small—Real Small: A Call for the Involvement of Environmental Lawyers in Developing Precautionary Policies for Molecular Nanotechnology*, 14 GEO. INT’L ENVTL. L. REV. 107, 120 (2001).

187. *Id.* at 120-21.

necessity, we will do it because we think we can. On earth, no mountain is too tall to climb; no ocean too deep to explore. Mars is our next mountain and we will climb it. The possibility exists that humans will mess up; we have done it before and we will do it again. However, the result may not be what our society needs. Perhaps the adventure itself is what is good for us. Knowing that we tried and failed is better than to not try at all and never know if we could be successful.

### *Life Is Precious*

Earth may be the only place in the universe where life has developed. If this is true, then it is imperative that we ensure life's survival. Life will have a better chance of surviving if it exists on a broader scale; one planet is too small. A stray comet or asteroid could annihilate the work of billions of years of evolution in a single moment. More is needed to "allow the preservation and continued generation of the diversity needed not just to keep life interesting, but to assure the survival of the human race."<sup>188</sup>

Perhaps humans are the next step in evolution: serving as the vehicle for the expansion of life. The purpose of our existence and the technology we develop could be to disperse life throughout the solar system, the galaxy, maybe even the universe. In expanding ourselves, we will also expand life as we know it; for we are dependant upon the biota and the biosphere it forms.

Life is a wonderful phenomenon almost four billion years old with no end in sight.<sup>189</sup> Our solar system, however, is middle aged and the sun will eventually consume the earth in a fiery senescence.<sup>190</sup> Therefore, total annihilation of all terrestrial life can only be avoided by expanding beyond our original planet.<sup>191</sup> Our attempts to spread life to Mars may prove a disaster and even fatal to life on earth. We may create a new bacteria or virus that would kill all humans and maybe even most life. In the face of imminent destruction by the growth of the sun, this seems to still be the better option. We must at least try; to not do so will definitely result in failure.

So should we terraform Mars? It is required of us. There must be a reason why we have been allowed to develop the ability to accomplish this task.<sup>192</sup> All things have a reason; perhaps a hidden agenda exists, unknown to us, that requires us to terraform Mars.<sup>193</sup> We cannot know unless we try. Of course, many will see this as "playing God," and perhaps it is. But if we had stopped throughout history when scientists were accused of "playing God," we probably would not

have medicine to treat disease and the ability to grow enough food to feed most of the world. Many are just scared of the unknown; we all should be. But our fear must not be allowed to stop us from furthering life and ourselves along with it.

### **Conclusion**

Does Mars have rights? Not really. It is beautiful and has its use in its present form, but it also has no life, at least that we know of. We will certainly research to see if life does in fact exist on Mars. But to a certain extent, even if it does, the good of all life should outweigh the good of a naturally soon-to-be extinct form of life. On earth, many would allow the killing of one animal for the good of the whole population or species. In nature, the good of the many indeed outweighs the good of the few (or the one). Planets must be vehicles for life in this universe; they are perfectly designed for it. Mars will not lose its uniqueness; earth certainly has not. In fact, it may be the life that grows on a planet that makes it truly unique. Life on Mars will evolve and adapt differently than life on earth. This difference will simultaneously make Mars unique, ensure the survival of life through diversification, and provide a wonderful opportunity to watch and learn.

If there is life on Mars, does it have rights? The answer to that is yes and no. Many believe that we should nurture indigenous life on Mars. I believe we should let natural selection decide. Let us expose terrestrial life to the Martian environment and watch what develops. Perhaps there will be genetic blending among the groups and life will become enhanced in beauty and diversification. Just because some bacteria may exist on Mars should not mean that all life on earth must stop expanding. Perhaps the bacteria are there by accident; perhaps they are the ancestors to life on earth. Certainly we should study any indigenous life on Mars, but we should not put its interests ahead of our own.<sup>194</sup> A possibility exists that we will create new life that could destroy life as we know it. However, the possibility of this occurrence is so much smaller than the possibility of success that we must try.

The most applicable environmental ethic to terraforming Mars is anthropocentrism. It puts our interests at the forefront while still ensuring the existence of all life. It seems obvious that we should give ourselves the highest level of intrinsic worth since we are the ones placing the value.<sup>195</sup> Life, of course, has the ultimate intrinsic worth, but we are a part of that life. It is in our best interest to preserve and expand life. What better way than by changing a planet that is currently unable to sustain life into one that can. Not only will we enrich our lives but also the life around us. We cannot, of course, begin terraforming today, but we can research and plan for the future.

188. *Id.* at 300.

189. Fogg, *supra* note 120, at 209.

190. *Id.*

191. *Id.*

192. On a religious note, why would God have allowed us to develop the ability to terraform a planet if he did not want it done?

193. The intended result could be a terraformed Mars or it could be something a billion years from now—who knows?

194. We have never done this for any other bacteria; usually we try to kill them.

195. I don't see animals giving us due consideration when they are threatened or we accidentally come between a baby and its mother.