Mole_1999

TERRAFORMING MARS
WITH FOUR WAR-SURPLUS BOMBS

Robert Alan Mole*

Four, 100kg fusion warheads, launched from a Mars orbiter, can throw into the air, enough dust to cover Mars' South Polar Cap, darken it, and cause it to sublime through increased solar heating. The added atmospheric pressure will set off a runaway advection effect and partially terraform the planet. We have the warheads and the orbiters. We can start whenever we like.

INTRODUCTION

There is a standard scenario in which Mars is "terraformed" as follows: 24mb of CO2 is vaporized from the South Residual Cap, and this thickens the atmosphere enough that greenhouse warming plus increased advection from the tropics warms the higher latitudes. Due to the warming, the rest of the cap is vaporized and CO2 adsorbed in the regolith is liberated, resulting in a CO2 atmosphere thick enough that liquid water can exist, people can walk around without spacesuits (but with breathers) and plants may possibly grow in the open. (McKay, Toon & Kasting, 1991) This environment is called "terraformed" because it is far more earthlike than present conditions, though without free oxygen it is not fully terraformed. The scenario has its critics and variations. There may not be enough CO2 at the pole. Speculations vary from very little (Fanale et al, 1982) to "between 50 and 150 mb" (Zubrin & McKay, 1993.) There may not be enough in the regolith. About 250mb is required for humans to doff spacesuits, and speculation varies from "60 to 600 mb" (Fanale et al, 1982) to "300 to 600 mb" (Zubrin & Mckay, 1993.) And the regolithic CO2 may be too tightly bound to be freed by just the CO2 from the cap; it may be necessary to add other greenhouse gasses as well. (Ibid.) But all this is speculation, and no one will know until Mars is fully explored -- or until the terraforming plan is tried, and by its success or failure shows whether the gas is there or not. In any event, the scenario is widely discussed, and this paper will assume it is workable.

The real difficulty with the plan is vaporizing the initial 24mb to trigger the process. To do so directly would require the energy of ten million one-megaton H-bombs, a clearly impractical proposition (McKay, in Oberg, 1981.) Carl Sagan considered covering the cap with a 1-mm layer of carbon black, thereby darkening it so it absorbed more solar energy and vaporized. But the cap is 350 km in diameter, and he found that at least 0.1km^3 of material, weighing 2 x10^11 kg, would be required, another wildly unlikely figure. "This is about 10^8 times our present capability to land payloads on Mars...It is probably all to the good: it is obviously unwise to perform a major alteration on a planetary environment before that planet has been thoroughly explored." He also considered bringing a 0.3km radius asteroid to Mars and

* 1441 Mariposa Ave, Boulder, CO, USA, email: ramole@aol.com

pulverizing it, which he found equally unlikely. (Sagan, 1973) Other proposals include using aircraft to scatter dark Martian dust (requires millions of flights), using 200,000 tonne mirrors to increase insolation, and making 8x10^6 tonnes per year of halocarbon greenhouse gases in factories on the Martian surface. (Zubrin & McKay, 1993) None of these ideas seem immediately practical.

In this paper I propose a method which is immediately practical: simply use a penetrator to carry a small fusion warhead deep into a dust drift near the cap; explode it and cause a huge dust cloud which drifts over the cap and darkens it exactly as the Mt. St. Helens eruption dusted much of North America in 1980. Repeat the process three times as condensation covers the dark material each winter. Solar energy absorption will then vaporize the 24mb "trigger" in just seven years, advection will sublime the rest in a few decades, and we'll have a second planet able to support life within our own lifetimes. The total mass of each bomb and penetrator is about 100kg.

I will also point out research that shows that the covering needed to darken the ice is only one three-hundredth the volume that Sagan assumed.

THE MT. ST. HELENS EXAMPLE

The 1980 eruption of Mt. St. Helens shows clearly just how widespread dust fallout can be. Figure 1 shows the pattern from the blast of May 18. Noticeable dust fallout covered the entire shaded area, some twenty times larger than the small circle representing the South Residual Cap. The author recalls clearly how the albedo of his white Oldsmobile in Boulder Colorado, 1500 km from the mountain, was lowered dramatically to that of gray dust a day or two after the blast. Mars' atmosphere is thinner, so the dust might not go as far, but the atmosphere does support dust storms and adequate coverage is likely. Mt. St. Helens' energy release was equivalent to about a 7 megaton H-bomb (Kieffer, 1981.) To cover a twentieth the area, about a twentieth the energy, 0.35 mt, is required -- or even less, as will be shown shortly.

THE FLUFF FACTOR

In 1984, Wells, Ververka and Thomas reported experiments to simulate fine-grained dust covering the Martian surface. (Wells et al, 1984.) Where Sagan had assumed 1mm of solid material, they found that just 0.16 mm of extremely fluffy "fairy castle structure" dust was required to darken a white surface to nearly the albedo of solid dust. Fluffed dust was about a fiftieth the density of solid material. From this I calculate that the volume of solid material would be a three-hundredth of what Sagan assumed. The area of the South Cap is 96,000km^2. To cover it 0.16mm deep requires .016km^3 of fluffy matter, or just a fiftieth as much solid matter, 0.00033km^3. Assuming that three quarters of the dust falls into or near the crater, four times as much is needed, or 0.0013km^3.

The St. Helens blast scattered 0.2km^3 (compacted) as dustfall (Sarna-Wojcicki et al 1981). The 0.0013km^3 we need is just 0.65% as much, and will require a proportionally smaller explosion -- 0.05mt, compared to 7 mt for St. Helens. (Still less with a more efficient explosion, as will be shown.)

Wells also answers the question of why frequent dust storms have not blackened the pole already. "Pollack et al (1979) estimate an average annual loading of the Mars atmosphere by dust storms of ~ 2 x 10^-3 g/cm^3. Even allowing that a significant fraction may be lost to polar deposition (by no means certain) our results demonstrate that an even distribution of dust would completely remove surface contrast on Mars. Observations show that this is not the case, even immediately after dust storms (Sagan et al, 1973). Processes of uneven deposition that concentrate much of the dust in small fractions of the surface area, would allow retention of albedo features and recycling of dust in the next storm." (Wells et al, 1984)

In other words, we can tell by looking at the cap that it does not naturally get much dust, because it always looks white. In the same way, some parts of North America have sand dunes and others do not. But the unusual eruption of St. Helens dusted a whole region equally, and a sudden, unusual dust blast on Mars can cover the pole, even though this normally does not happen.

The question has been raised, does not some dust from the storms ever cover even a little of the cap? The first paper to discuss the runaway was Gierasch and Toon in 1973, and it showed that only a minimum of about 6% of the cap need be covered to trigger the process. Why then does not the cap frequently evaporate? Gieresch and Toon answered this question in the same paper. For 6% coverage, the time constant for the process, the complete sublimation of the cap due to greater solar absorption plus increasing advection, is about 75 [Earth] years. [So] "the system is not unstable to short time scale events, such as albedo changes due to a single dust storm, so long as they are limited to a time on the order of a few years." I think that if we use a bomb to cover 60% instead of the minimum 6%, then the time should drop to seven years. If precipitation rewhitens the cap each Martian winter (every 1.8 Earth years), then we will have to re-dust it three times, requiring four bombs in all.

It is of course necessary to wait for the right wind pattern. During dust storms, dust clouds are blown over the pole, so clearly the wind does blow that way at times. Computer simulations show that in dust storms, near-surface winds blow poleward at about 70km per hour for six-hour stretches, which will carry the dust 420km, a bit more than the 350km required. (Kondrazev and Hunt, 1981.) Presumably, propitious winds blow frequently, and can be detected by instruments on the orbiter. Only then will the penetrator be launched and fired.

PENETRATORS

Penetrators are heavy, pointed, rod shaped vehicles that strike soil at high speed (up to 1 to 2 km/s) and penetrate far beneath the surface. Based on experiments at Sandia Laboratories (Young, 1972), a heavy penetrator striking very dry, loose topsoil at 838m/s can penetrate 426m, or 96m in sand. Deceleration would be 490g, maximum, in sand, or 109g in soil. Penetrators can probably stand about 2000g, so if the dunes were more solid we could hit faster, stand the deceleration, and still get deep enough. I will show we need about 97m for a small warhead, and this seems attainable. In the event, we might want even less depth for the best dust production. At any rate, adequate penetration appears possible.

BOMB CRATERS, BURY DEPTH, AND THE WEIGHT OF H-BOMBS

In the 1960's, the United States considered the use of nuclear explosives for digging harbors and canals. Project Plowshare tests exploded bombs at various depths in sundry materials, and developed formulas for proper bury depth and resulting crater size. The Sudan test used a 0.1mt bomb at 195m to make a crater 365m in diameter and 97m deep, approximate volume 0.01km^3 (Teller et al, 1968.)

This is about eight times the volume we need, so we could get by with 0.013 mt. (This is even less than the .05 mt estimated from the St. Helens analogy, which is a reasonable check, since so much of St Helens' energy release was in the form of 316C lava cooling to ambient, and so little as kinetic energy, whereas the Sedan blast was more efficient.)

Desirable bury depth is proportional to the cube root of the energy release, and for an eighth the bomb size is half the depth, or 97m. As we have seen, penetrators can go 96 to 426m, so this depth seems feasible.

Moreover, there are several factors that might increase the size of the hole on Mars. First, about half the material fell back into the Sedan crater, but with Mars' lower gravity, less will fall into the Mars crater. Second, the dunes near the cap are ideally constituted to convert heat into kinetic energy. They are composed of dust interlaced with layers of dry ice near the vaporization temperature. "The minimum thickness of the deposits has been estimated at 1-2 km. The layered deposits are believed to be accumulations of volatiles and dust."(Carr, 1981.) Practically all the heat from the nuclear reaction will go to vaporize nearby CO2 into high-pressure gas just above the vaporization temperature. Hotter gas and dust will be blasted into cooler regions, where radiation will transfer more energy to new dry ice, creating still more gas. Thus most of the energy will go to the vaporization of CO2, an explosive process, and little will be lost in the form of high-temperature material lying on the ground radiating to the sky.

Third, Plowshare blasts were designed to make a large hole while containing the fireball to minimize radiation escape, but we want to maximize dust and are not concerned about fallout. So we may use shallower blasts and let the fireball escape. Finally, Sedan and Mt. St. Helens threw out a lot of house-size boulders, gravel, rocks and sand that could not possibly remain airborne. But we may expect to produce pure dust, because that is what the drifts are made from -- they consist entirely of dust particles carried there by the wind in the first place, and so able to be wind-borne again.

H-bombs are fairly light. The Titan II carried a 9mt warhead of 2700kg. (May, 1989) Ratioing, a 0.1mt warhead should be only 30kg (say 100kg to allow for a fusion trigger of approximately constant mass, and the penetrator structure.) How much less a 0.013mt device might weigh is speculation, but it might be just as well to use a 0.1mt device and get an eight times safety factor for a few extra kilograms. The Mars Observer spacecraft was 2600kg, and 100kg are only 4% of that, so the mass requirement is hardly exorbitant.

There are around 10,000 fusion warheads that must be disposed of under terms of the SALT II nuclear treaty, so the bomb should be free and the transportation quite reasonable.

Another question that has been raised is whether the Martian atmosphere is thick enough for a Mt. St. Helens' type of airborne transport of enough dust to darken the cap. I believe so. As quoted above, the entire atmosphere carries more than enough dust in an average year to darken the whole planet, and carries it for months at a time. Therefore the atmosphere should be able to carry enough for a few hours to darken the cap, even though the mushroom cloud itself will be much more concentrated for a short time while the dust spreads. However, if we assume no atmosphere and require that the dust be distributed ballistically, then bombs of about 20mt are needed. (Personal communication, Robert Zubrin, 1995.) This represents a conservative upper bound, yet it would still be feasible.

RADIATION

Plowshare craters were dangerously radioactive right after the blast, but the radiation decayed so rapidly that the rims were safe for construction work just three weeks later. (Teller et al, 1968)

On Mars there will be no one on the crater rim. Anyone on the planet at all will be thousands of kilometers away, and by the time the fallout gets to them it will be harmless thousands of times over because:

a. It will take so long to get there that by the time it does, even the crater rims will be safe.

b. Only a little dust will reach the latitude of the landing sites - most will fall out along the way.

c. What does arrive will be dispersed over millions of square kilometers.

d. The astronauts spend no time outdoors in their shirtsleeves. They live mainly indoors in domes covered with soil to protect them from Mars' naturally high background radiation. That is, they already live in fallout shelters that would protect them from Armageddon.

e. In earthbound bomb tests the main concern was for large farm populations living fifty miles away. Long lived Cesium and Strontium isotopes fell on the grass; cows ate the grass; children drank the milk; and the isotopes lodged in their growing bones. On Mars will be neither grass, nor cows, nor growing children.

So by a whole series of large factors, radiation from fallout will not be a problem.

CONCLUSION

The production of dust clouds by explosive blasts is neither speculative nor visionary; instead it is well understood and within the personal physical experience of tens of millions of people in North America and throughout the world. We know this method will work, because we've seen it dust half a continent.

If there is enough CO_2 available on Mars to make the standard scenario feasible, and then it can be released quickly and cheaply in this way.

And if it were desirable to explore Mars before changing it, then we should hurry, for it appears that we can make dramatic changes whenever we want to and at little expense.

ADDENDUM:

This paper originally appeared four years ago. Since then readers have expressed two concerns I would like to address here.

1. Timing. I contend we *can* begin this process tomorrow, but that does not mean we *should*. The polar cap contains much Martian history in its layers, so of course we should explore it, take cores etc., before we evaporate it. I would suppose we might arrive at Mars in twenty years, and spend another ten or twenty studying its present state, and only then begin to terraform. But in any event it will not be my call -- this decision will be up to the scientists and all the people of earth.

2. Environmentalists are very deeply concerned over radiation and polluting the surface of Mars. But in reality the situation is different from what might at first be thought:

   There is an immediate tendency to condemn radiation from a bomb blast because it damages life, but this applies only on earth.

   In space there is no life, and there is a great deal of radiation. But the radiation is a natural and a neutral thing, sometimes good, sometimes bad, but generally ignored as irrelevant. The sun, for example, is good. (I approve of the sun!) Yet it is a giant fusion fireball, the equivalent of a billion H-bombs exploding every second. Naturally it is a radiation holocaust, but because it is harmless to life on earth, no one protests. Without it life would quickly freeze in the dark.

   The sun emits enough ultraviolet radiation to sterilize the surface of earth, and every year or two sends out a solar storm of radiation of around 3,000 rems, enough to kill an unprotected human six times over. Yet this radiation is harmless to life on earth because we are protected by an atmosphere.

But Mars has for practical purposes no atmosphere, and it is not protected. No known form of life on earth could survive the UV on its surface, and most of the solar storm radiation, thousands of rems, gets through. Plus it gets 25 rems from cosmic rays every year.

My proposal will dust the whole surface with less than *one* rem *one* time. And create an atmosphere that stops much of the UV and *thousands* of rems per year ***forever***. It will destroy no life. Instead it will protect life from the ghastly levels of radiation that now prevail, and thereby make life possible.

It will change a radiation inferno into a garden and not the other way around.

3. I have found I made minor metrication errors. The penetrator depths achievable should be 96-425 feet, not meters, or 33-125 meters. The lesser penetration, 33m in packed sand type material, is less than the optimum Plowshare depth of 97m. But this is unimportant -- we may be able to strike at a higher speed and get the optimum depth. In any event, Plowshare depths were intended to make a large hole by creating a cavity that collapsed, without throwing explosion debris all over the landscape, while we want to throw out as much material as possible, to create a maximum sized cloud. So our optimum depth will be less. (How much less I do not know. Plowshare data only give us the rough upper limit of 97m, and we should be able to get that much or near it.)

   The .01 cubic *km* plowshare crater is only about twice the needed .0013 cubic *mile* size we need, not eight times as reported. So using a Plowshare size 0.1Mt bomb gives us a two times safety factor, not eight times.

   Neither error requires any change to the plan.

   No one else that I know of has found errors nor raised technical objections nor proposed reasons it would not work.

   After four years it appears to remain feasible.

REFERENCES

1. McKay,C.P., Toon,O.B., Kasting, J.F., Making Mars Habitable, Nature, vol. 355, pp. 489-496, Aug 1991.
2. Fanale, F.P.; Salvale, J.R.; Banerdt, W.B. and Saunders, R.S.; Mars: The Regolith Atmosphere Cap System and Climate Change; Icarus 50 381-407, 1982.

3. Zubrin, R.M. and McKay, C.P.; Technological Requirements for Terraforming Mars; AIAA 93-2005, American Institute for Aeronautics and Astronautics, Washington, DC, 1993.

4. Oberg, J.E., NEW EARTHS Terraforming Other Planets for Humanity, Stackpole Books, Harrisburg,
PA, 1981.

5. Sagan, C., Planetary Engineering on Mars, Icarus 20 513-514 (1973).

6. Kieffer, S.W., Blast Dynamics on Mt. St. Helens on May 18, 1980, Nature 291, (June 18, 1981)

7. Wells, E.N., Ververka, J and Thomas, P., MARS: Experimental Study of Albedo Changes Caused by Dust Fallout, Icarus 58 331-338 (1984).

8. Sarna-Wojcicki, A.M.; Waitt, R.B., Jr.; Wood, S.H.; Shipley, S.; Dzurisin, D.; Areal Distribution, Thickness, Mass, Volume, and Grain Size of Air Fall Ash from Six Major Eruptions of 1980. In Lipman, P.W. and Mullineaux, Editors, The 1980 Eruptions of Mt.St.Helens, U.S. Government Printing Office, Washington, D.C. (1981).

9. Kondratzev, K.Y. and Hunt, G.E., Weather and Climate on Planets, Pergamon Press, Oxford, 1982.

10. Young, C.W., Empirical Equations for Predicting Penetrometer Performance in Layered Earth Materials for Complex Penetrometer Configurations, SC-DR-72-0523, Sandia Laboratories (1972).

11. Teller, E.; Wilson, K.; Higgins, G. and Johnson, G.W.; The Constructive Use of Nuclear Explosives, (Pg. 185) McGraw Hill, New York, 1968.

12. Carr, M.H., The Surface of Mars, Yale University (The Murray Printing Company, Westford Mass.), 1981.

13. May, J., The Greenpeace Book of the Nuclear Age, Victor Gollancz Ltd., London, 1989.

14. Gierasch, Peter B. and Toon, Owen B., Atmospheric Pressure Variation and the Climate of Mars, Journal of the Atmospheric Sciences, vol. 30 pp. 1502-1508, November, 1973.

Terraforming Mars - GIGA Expansion - [Ares, Pathfinder, Betterments, Rob Antilles, The Moon, Venus Phase 2, Nuclear, Ides of Mars, Solaris, Postlude, High Orbit]. by OmegaUba Wed Oct 16, 2019 3:04 am [Page 1,2,3...17,18,19]. 471.Â 10. It all started with two plus some new cards. by Dabluesheep Sat Feb 13, 2021 8:51 pm. 9. Terraforming Mars with Four War-Surplus Bombs, Robert Alan Mole 134. The Value of Rust, Sam Burbank 137. A Study of Mars Global Surveyor (MGS) Mars Orbital Camera (MOC) Images of Probable Water Seepages - Are They Dust Slides as NASA Claims Or Proof of Water on Mars?, Efrain Palermo, Jill England and Harry Moore 139.Â Social and Ethical Considerations of Humans on Mars. Do Indigenous Martian Bacteria have Precedence over Human Exploration?, Christopher P. McKay; Robert Zubrin 177. Several Theological Considerations Concerning Plans for Terraforming Mars, The Rev. James D. Heiser, M.Div. 182. Official Site: Terraforming Mars official page. Created by: Jacob Fryxelius, Daniel Fryxelius, Isaac Fryxelius. Published by: FryxGames, REBEL.pl, Schwerkraft-Verlag.Â To be able to increase immigration from Earth, Mars needs to be terraformed by altering its environment until humans can live there without expensive protective gear, and without even minor accidents becoming lethal. Therefore the World Government has decided to support any organization that contributes to this vast undertaking. The terraforming of Mars or the terraformation of Mars is a hypothetical procedure that would consist of a planetary engineering project or concurrent projects, with the goal of transforming the planet from one hostile to terrestrial life to one that can sustainably host humans and other lifeforms free of protection or mediation. The process would presumably involve the rehabilitation of the planet's extant climate, atmosphere, and surface through a variety of resource-intensive initiatives, and the