DESIGN FOR A MICRO-SIZED MARS PROBE. Andreas Stürmer[1]
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In this abstract a design of a new generation of highly efficient Mars probes will be revealed.
As commonly known, what makes space travel so expensive is weight. Therefore, here a way is described how to make a swarm of Mars probes with as low weight as possible.

One problem for Mars probes is the power source. Thermoelectric radioisotope generators are very expensive but provide a constant flow of energy (and heat). Solar panels can power probes, but at night there is no power, and to make matters worse, their batteries need to be heated because they can't handle coldness. Whereas other electronical components such as microcontrollers, resistors, etc. can withstand low temperatures without problems.
Here comes in one new energy accumulator: Green Caps and Gold Caps, respectively, are capacitors with extremely high capacities. They can be discharged totally without taking damage (as opposed to batteries!), and they can operate at cold conditions such as below -40°C (according to datasheets).
Thus, the probe would gain solar power and use most of the electricity to charge the capacitors at day. When the probe faces peak energy use, e.g. while transmitting data, this energy would then be used. When the sun sinks below the horizon, the probe would run out of power, since the capacitor empties, as planned. The next day it would wake up again automatically; when the solar cells deliver electricity again the microcontroller awakens.
The solar cells deliver some 6 Volts, and a Zener diode limits those to 5.4 V for the microcontroller and capacitor. No software for charging/discharging has to be written using capacitors, the input voltage just has to be below the nominal (5,5V) Voltage of the capacitor to avoid damages.

Another very important part of this design is that it uses lightweight and cheap microcontrollers such as AVR's Atmega8. They have a weight as low as about 2 grams. In power down mode, they use just 0.5µA and 3.6 mA when being active. At this low power consumption the capacitor would provide energy for a very long time.
To provide a cheap source of communication, transceiver modules such as RFM12 are available.
Once every few minutes or once an hour, the microcontroller would send the data collected to another probe or a main station (rover, lander).
The design includes a main station that collects all the data from the probes and has a clock onboard. It also has a strong antenna that can transmit data to the Earth. The probes, of course, have no clocks because at night they are powerless and the clock would just stop.
The microchip itself wouldn't even need a power accumulation device, but for transmitting data with 10 to 100 Milliwatts (or higher) a gold cap with 1 Farad would be sufficient. There are also green caps available at 600F weighing only 120 grams but this would be way overkilled.
When the main station receives the data of a probe, it assembles the data from the probe e.g. such as identification number ("probe 1"), temperature, pressure and geological activity, and the local Mars time from its own clock and sends that data package to the Earth.

Illustration: Working prototype of the probe (Size compared to a quarter dollar). Instead of the LCD-display there would be a radio transmission system attached to the probe. On the top right, next to the coin is the Radio Frequency module (for wireless data transmission between the probes) which will be attached.
Measured values: Temperatures in degrees Celsius and voltage supply.

What would also be feasible is that a rover has several microprobes onboard and every 500 meters drops one of them. The first probes would send their data and the others would also serve as data relay stations to the rover.

As an ideal case, the probes' transceiver can use a frequency that is reflected by Mars' ionosphere several times (shorter waves) thus they can travel around the entire globe of Mars. It would have to be evaluated what size of gold cap would be needed to provide power for this. It would make a global communication system possible. For instance, via a rover-to-rover communication, a communication satellite could make contact to one rover and get data from the other rover on the far side of Mars without having sight.

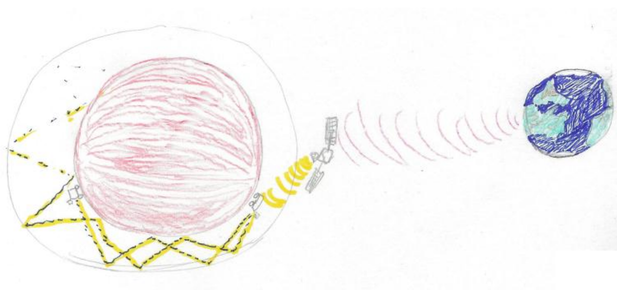

Illustration: Rover-to-Rover or Probe-to-Probe communication, respectively, taking advantage of Mars' ionosphere

Component	Specifications	Weight [grams]
Atmega 8	~2.7 to 5.4V	2
Gold cap	1 F, 5.5V	9
RFM 12	2.2 to 5.4 V power supply, less than 0.3 uA stand-by current,	1
LM135 temperature sensor (or PTC resistor)	~2V to 5V	<1
Stripboard		1
Zener diode	5.4 V	<<1
Solar cell	5 V (Mars: 43% -> 2.15V)	14
Solar cell	9V (Mars: 3.87V), 109 mA	32

Table: weight estimation

Thus, a Micro-Mars probe that just measures the temperature would weight below 15 grams without its solar cells. If pressure sensors and/or geological activity (acceleration measuring) sensors are deployed, you have to add the weight of them.
Solar cells may add roughly 46 grams to the probe. It needs to be said that those solar cells are calculated with commercially available ones, for more money you would surely get ones with lower weight.

A second microcontroller could be added to improve redundancy (adding only 2 grams of mass to the probe), although this won't be essential because the high amount of probes sent at once makes loss of one probe bearable.
Because Mars' solar constant is 43% that of the Earth, a 9V mini-solar cell would produce 3.87V and a 5V one would produce 2.15V.
Together they would produce 6.02V from which 0.62V are burnt by the Zener diode to produce the 5.4V needed. Whenever the solar cells produce a bit less energy because of clouds, the Zener diode would just burn less energy thus still getting 5.4V.

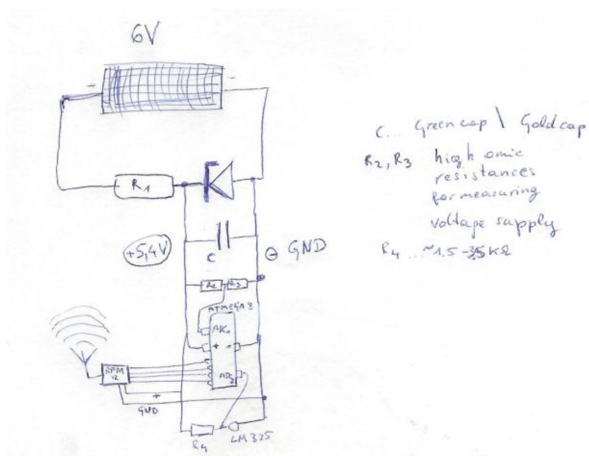

Illustration: circuit diagram of the Micro Mars Probe

In conclusion, one probe weights around 61 grams (on Earth, with standard solar cells). So you can assume about 100 grams per probe if you add other sensors. Assuming the next rover/lander sent to Mars has a secondary payload bay, with one kilogram you can carry along at least 10 micro probes.

A lightweight camera module could also be mounted to the probe, but because of low data transmission it would maybe just have enough capacities for a few pictures per day. It has to be thought twice whether a camera onboard makes sense.

Note: Technically it would also be possible to build a interstellar space probe with a similar design. Changes needed would be a thermoelectric radioisotope generator (1-10 Watts), attachment of a fuel tank (several kilograms) and an ion propulsion device. Because of the low weight it would reach very high velocities consuming very low amounts of fuel.