HOW DO YOU ANSWER THE LIFE ON MARS QUESTION? USE MULTIPLE SMALL LANDERS LIKE BEAGLE 2

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To address one of the most important questions in planetary science "Is there life on Mars"? The scientific community must turn to less costly means of exploring the surface of the Red Planet. The United Kingdom's Beagle 2 Mars lander concept was a small meter-size lander with a scientific payload constituting a large proportion of the flown mass designed to supply answers to the question about life on Mars. A possible reason why Beagle 2 did not send any data was that it was a one-off attempt to land. As Steve Squyres said at the time: "It's difficult to land on Mars - if you want to succeed you have to send two of everything".

A new approach utilizing the Beagle 2 small lander design would be to use a spacecraft carrier for transporting extensively tested multiple Beagle 2-like landers to Mars and target selective sites of high science priority. Cooperative work between the U.S. and the UK team that conceived the Beagle 2 lander should begin to examine the potential of using multiple Beagle 2 landers on a common carrier for Mars Exploration. Multiple surface landers could be deployed and the probability of successfully landing at several sites on the surface would have a great scientific return. The loss of a couple of the landers would not be a major loss to the overall mission's scientific and technical goals.

Beagle 2 as launched on Mars Express in 2003 was a 68 kg probe with a 33 kg lander carrying an 11 kg science payload. It was designed, developed and built in the United Kingdom with some contributions from US based companies. Beagle 2 was intended to deliver to the martian surface a payload which had the highest percentage of science instruments to landed spacecraft mass of any planetary mission launched to date. Beagle 2 was launched on June 2nd with Mars Express on a Soyuz-Fregat rocket from the Baikonur Cosmodrome in Kazakhstan. It was targeted to land on Mars on December 25th in Isidis Planitia (~11.5^{o}N and 275^{o}W), a large sedimentary basin that overlies the boundary between ancient highlands and northern plains. Isidis Planitia, the third largest basin on Mars, which is possibly filled with sediment deposited at the bottom of long-standing lakes or seas, offers an ideal environment for preserving traces of life. However, Beagle 2 had as its focus the goals of establishing whether evidence for life exists now or in the past on Mars and whether conditions there were ever suitable to support life and could be appropriate to many other target landing sites.

Beagle 2 was developed to search for organic material and other volatiles on and below the surface of Mars in addition to studying the inorganic chemistry and mineralogy. Important for life detection experiments, it included a mechanical Mole to obtain samples from below the surface and under rocks places which might be protected from harsh oxidizing conditions. To sample the interior of rock and consider past life on Mars a corer/grinder was included. A pair of stereo cameras could image the landing site and a microscope was available for the examination of cleaned/ground rock surfaces. Solid samples were to be chemically analyzed using chemical X-ray and mineralogical Mossbauer spectrometers. A gas analysis package (GAP, 5.5 kg) was included for organics and other light element species (e.g. carbonates and water) and measurement of their isotopic compositions for solids, liquids and the atmosphere. The sample extraction process, stepped combustion, had been extensively evaluated with laboratory meteorite specimens and is capable of detecting every atom of carbon (and nitrogen) in all its chemical forms. Other methods of chemically converting light elements into the species most appropriate (e.g. splitting water into the component elements) for determining geologically precision isotope ratios were available in the gas-processing package.

A multiple degrees of freedom mechanical arm and PAW (position adjustable workbench) could be used for science operations along with sample acquisition. Instruments attached to the PAW included: stereo cameras, Mossbauer and X-ray fluorescence instruments, micro-scope, environmental sensors, the rock corer/grinder, a spoon, mirror, brushes, an illumination device (torch) and facilities to deploy and retrieve the Mole for acquisition of subsurface at depths of 1 to 2 meters. The camera had 14 filters for mineral composition, dust and water vapor detection. The microscope's camera was designed for viewing the size (down to 4 microns) and shape of dust particles, rock surfaces, microfossils and the characteristics of the samples prior to introduction into the GAP. The camera featured 4 color capability (red, green, blue and UV fluorescence), a depth of focus of 40 micrometers and translation stage of $\pm$3 millimeters.

At the heart of the life detection package was a mass spectrometer with collectors at fixed masses for precise isotopic ratio measurements and voltage scanning for spectral analysis. Primary aim of the GAP was to search for the presence of bulk constituents, individual species and isotopic fractionations for both extinct and extent life along with studying the low-temperature geochemical cycles of the hydrogen, carbon, nitrogen and oxygen components. The mass spectrometer was a magnetic sector instrument (mass range of 1 to 140 amu) which could be operated in both the static and dynamic modes. Triple Faraday collector arrays were used for C, N and O ratios along with a double Faraday array for H/D. Pulse counting electron multiplier was employed for noble gases and some other species. Detection limits were at the picomole level (ppm from milligram samples) for static operation and high precision isotopic measurements made in the dynamic mode. Sample processing and preparation system consisted of 10 reaction vessels along blanks with reference gases. Sample ovens attached to the manifold were capable of being heated to >1000^{o}C during sample combustion. Surface, subsurface materials and interior rock specimens could be combusted in pure oxygen gas at various temperature intervals in a stepped fashion to release organic matter and volatiles according to speciation. A chemical processing system was capable of a variety of conversion reactions. Gases could be manipulated either by cryogenic or gas/solid reversible reactions and passed through the vacuum system. There were three modes of operation: qualitative and quantitative analysis and precise isotopic measurements.

Four main types of analysis could be carried out by the GAP: (1) search for organic matter, (2) stepped combustion for total light element content and speciation, (3) atmospheric analysis and (4) K/Ar age determinations. Isotopic measurement of H/D, $^{13}C/^{12}C$, $^{15}N/^{14}N$ and $^{18}O/^{16}O$ was possible. A search for trace quantities of biogenic methane within the martian atmosphere could be achieved by pre-concentration of samples. The procedures would have been feasible at the levels of methane currently estimated (<100 ppb) for Mars. The mass spectrometer could be operated in the static mode for the CH_4 detection at the highest sensitivities. Since the half-life of methane against oxidation in the atmosphere of Mars is believed to be <300 years any methane would presumably have been from a biogenic source (i.e. methanogenic bacteria) possibly confirmable from isotopic measurements. An environmental sensor system for surface temperatures, atmospheric pressures, wind speed and direction accompanied atmospheric sampling and was to be used for operations. Additional sensors such as salinity and pH along with the "life-detection" on a chip may be considered for future addition to the payload.

Elsewhere the lander had calibation target and radiation environment, (total dose and rate) monitors were included. UV flux at the lander would be measured at various wavelengths longer than 200nm, information relevant for understanding survival of organics. A dust sensor package would have provided information pertinent to future human exploration.

The high sensitivity isotopic analysis strategy of Beagle 2 made no assumptions about the biochemistry on Mars but would provide clues to past life as inferred from the isotopic fractionation of organic carbon species relative to inorganic forms of the element (carbonates/atmospheric CO_2). All measurements would be made directly on Mars thereby avoiding criticisms concerning contamination on Earth leveled at meteorite studies. The Beagle 2 systems and its science payload were built under conditions to meet COSPAR level IV Planetary Protection protocols in an aseptic assembly facility after sterilization.

No specific reason could be found as to why Beagle 2 did not communicate with Earth after landing. The Beagle 2 teams "Lessons Learned" document reached the conclusion that every part of the program except the actual landing on Mars (that was tested during the mission) couldn't have or shouldn't have worked. However there is no doubt that the martian atmospheric conditions near to the end of the dust storm season were not the most favorable for a direct entry trajectory and parachute/gas-bag landing. Such difficulties would be avoidable for a multi-probe mission flown on an orbiter.

A number of studies following on from the Beagle 2 concept have been made: (i) Beagle 2007, a rapid reuse of the technology in more favorable conditions, (ii) Beagle 2e (evolution) a lander redesign to ensure a greater chance of survival through elimination of possible failure modes and (iii) BeagleNet, a multiple lander mission including small roving vehicles and geophysical sensors. Others have considered missions involving six Beagle 2-type landers (ARTEMIS, PI-David Paige) or one having the gas analysis package/mass spectrometer of Beagle 2 as a part of their multiple lander system design (MARGE, Mars Autonomous Rovers for Geoscience Exploration, PI Mike Malin).

Beagle 2 was not only a low resource (mass and power) mission but it was also built at an incredibly low cost, estimates put the budget at below £50M ($80M, 2003 prices) for a single lander. The low-cost approach offers great science for minimal financial outlay. The possibility of using the Beagle 2 design for further exploration activities with spacecraft orbiting Mars, asteroids, etc. that could place multiple Beagle 2-like landers on planetary surfaces must be considered as one of the low-cost, international partner options for future Mars Exploration.