Bioinspired Flight on MARS

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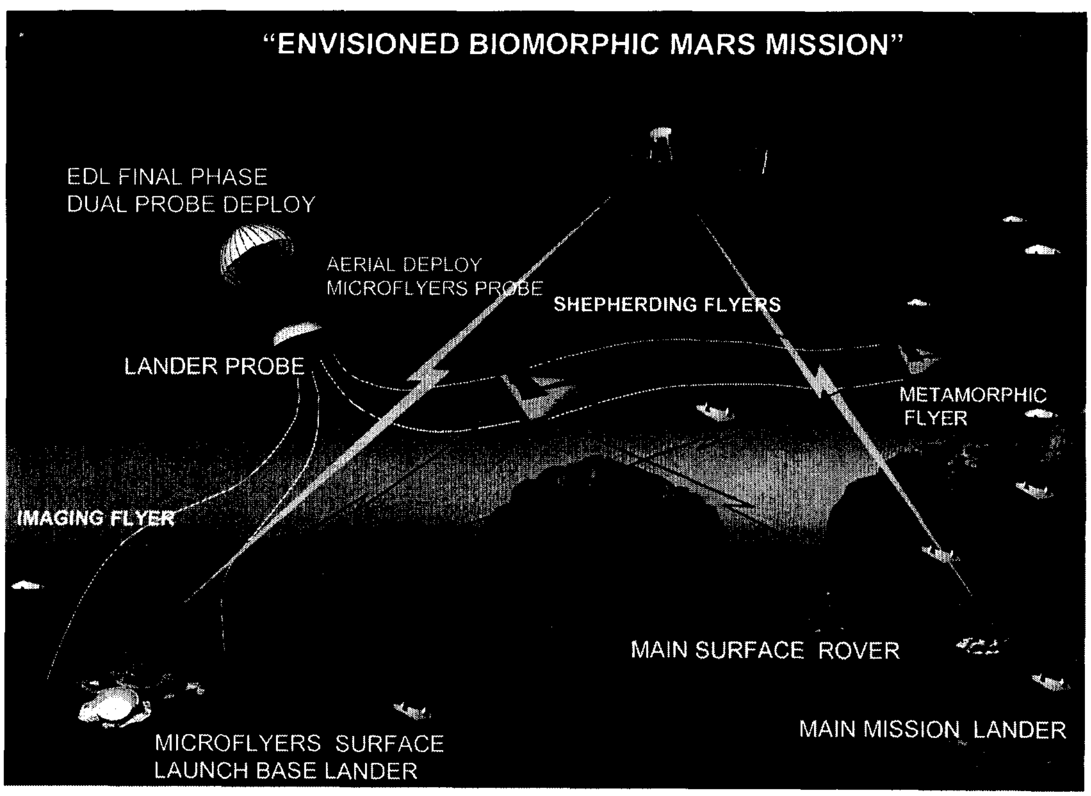
Humanity over the ages has been intrigued by the flight maneuvers of birds and insects. This paper highlights how in just about 100 years since the first successful flight took place at Kitty Hawk, now we are on our way to demonstrating flight capability for MARS exploration using inspiration from biology. Unmanned exploration to date suggests that MARS once had abundant liquid water (considered essential for life as we know it) but it is not clear what went wrong with the Martian climate to have turned it to the desert that it is today. Getting to know closely and understand our sister planet MARS is crucial to learn lessons for preserving and nurturing humanity by avoiding a similar fate for Earth. This apart, of course fundamental scientific curiosity, the lure of mining the many resources on MARS, finding extant or extinct life and perhaps someday establishing a human colony on MARS are other clear motivators. Flight offers a means for covering large spans, several hundred kilometers quickly to provide a close-up birds eye view of the planetary terrain. Exploration that can just be dreamed of today could be a reality if we could engineer a way to fly on MARS and navigate through hard terrain to image/study sites of interest. MARS offers a real challenge to conventional flight, due to several reasons. Its rare atmosphere about a hundredth that on Earth; lack of magnetic compassing for navigation, the limited telecom or navigational infrastructure yet in place, makes it imperative to look at unconventional mission architectures and innovative new technologies to provide autonomous flight for planetary exploration.

Our intent is to <u>distill</u> the principles found in successful, nature-tested navigation mechanisms for example to implement such specific functions that are hard to accomplish by conventional methods on MARS, and thus enabling a reach to new exploration sites for much sought for science endeavors. The intent is not just to mimic operational mechanisms found in a specific biological organism but also to imbibe the salient principles from a variety of diverse bio-organisms for a specific function. There by we can build explorer systems that have specific capabilities endowed beyond nature, as they will possess a mix of the best nature tested mechanisms for that particular function.

As a test of the validity of this premise, we have selected a few bioinspired technologies for development to enable specific science goals of exploring new currently hard to reach sites of interest on MARS. We plan to do a demo of "Bio-inspired Engineering of Exploration Systems for MARS" (BEES for MARS) at a MARS analog site on Earth. A variety of biologically-inspired flyers (biomorphic flyers) are released or launched each containing biologically inspired technologies capable of, for example, autonomous navigation, visual search, selective feature detection, intelligent flight control, image enhancement by sensory data fusion, etc.

The mission architecture to be utilized, deals with the challenge of rare atmosphere on MARS by using surface launched biomorphic flyers essentially like payload carrying darts with an extended powered glide. Launch energy could be provided by single or multiple solid rocket boosts, pneumatic thrust, compressed *in-situ* resource gas launch, a spring launch, electrically powered launch or a mechanism combining two or more of the stated techniques. Either a lander or rover could be used as the surface launch base for such biomorphic flyers.

Two kinds of biomorphic flyers are in development. First, small (< 1 Kg) imaging explorers with less than ~ 15 minute flight duration during which the camera will acquire and transmit motion imagery data in real time. The second kind of flyers will serve the **dual role of imaging explorers and a telecom relay** (mass ~ 5 Kg, flight duration ~ 45 min). The lander/rover lands in the site of interest roughly 10-500 Km from an area of potential scientific significance. A launching mechanism is used to launch the biomorphic flyer from the lander/rover towards the target site specifying a flight heading. The communication range depending on the science goal could be line of sight to the lander/rover base to a few hundred kilometers by using additional telecom bases. The larger flyer is sent out first as a **shepherding** flyer telecom local relay to provide an intermediate relay node when the smaller imaging flyers go survey sites beyond the line of sight of the lander. Surface imagery is obtained using miniature camera systems on the flyers. The flyer relays imagery/meteorological data to the lander and after landing conducts/deploys a surface experiment and acts as a radio beacon to indicate the selected site. The lander receives the images and beacon signals transmitted by the flyers and relays them to the science team and mission planners on Earth via the orbiter. Another way of using the dual role flyers is to land them at a relatively high spot (~ 500m or higher) and remain stationed there as a **metamorphic flyer** which is now in its telecom role permanently for the duration of the mission. The imagery data will be broadcast both to the primary lander and to the nearby dual role flyer (shepherding and /or metamorphic) intermediate relays for guaranteed science data storage and eventual return to an orbiting telecommunications relay. By providing redundant receiving stations, communications link uncertainties related to signal blockage and multipath interference are mitigated.



This mission illustrated in Fig 1 offers the most robust telecom architecture and the longest range for exploration with two landers being available as main local relays in addition to an ephemeral aerial probe local relay and the shepherding or metamorphic planes in their dual role as local relays and storage nodes. The placement of the landing site for the Core MARS Lander wrt the Surface Launching Lander/Rover Base can allow coverage of extremely large ranges and/or exhaustive survey of the area of interest.

Insects (for example honey bees and dragonflies) cope remarkably well with their world, despite possessing a brain that carries less than 0.01% as many neurons as ours does. Although most insects have immobile eyes, fixed focus optics (no range info) and lack stereo vision, they use a number of ingenious strategies for perceiving their world in three dimensions and navigating successfully in it. We are distilling some of these insect inspired strategies to obtain unique solutions to navigation, altitude hold, stable flight, terrain following and smooth deployment of payload. Recent results on exploring the feasibility of incorporating these success strategies of bioinspired navigation into our biomorphic flyers for future missions will be described.