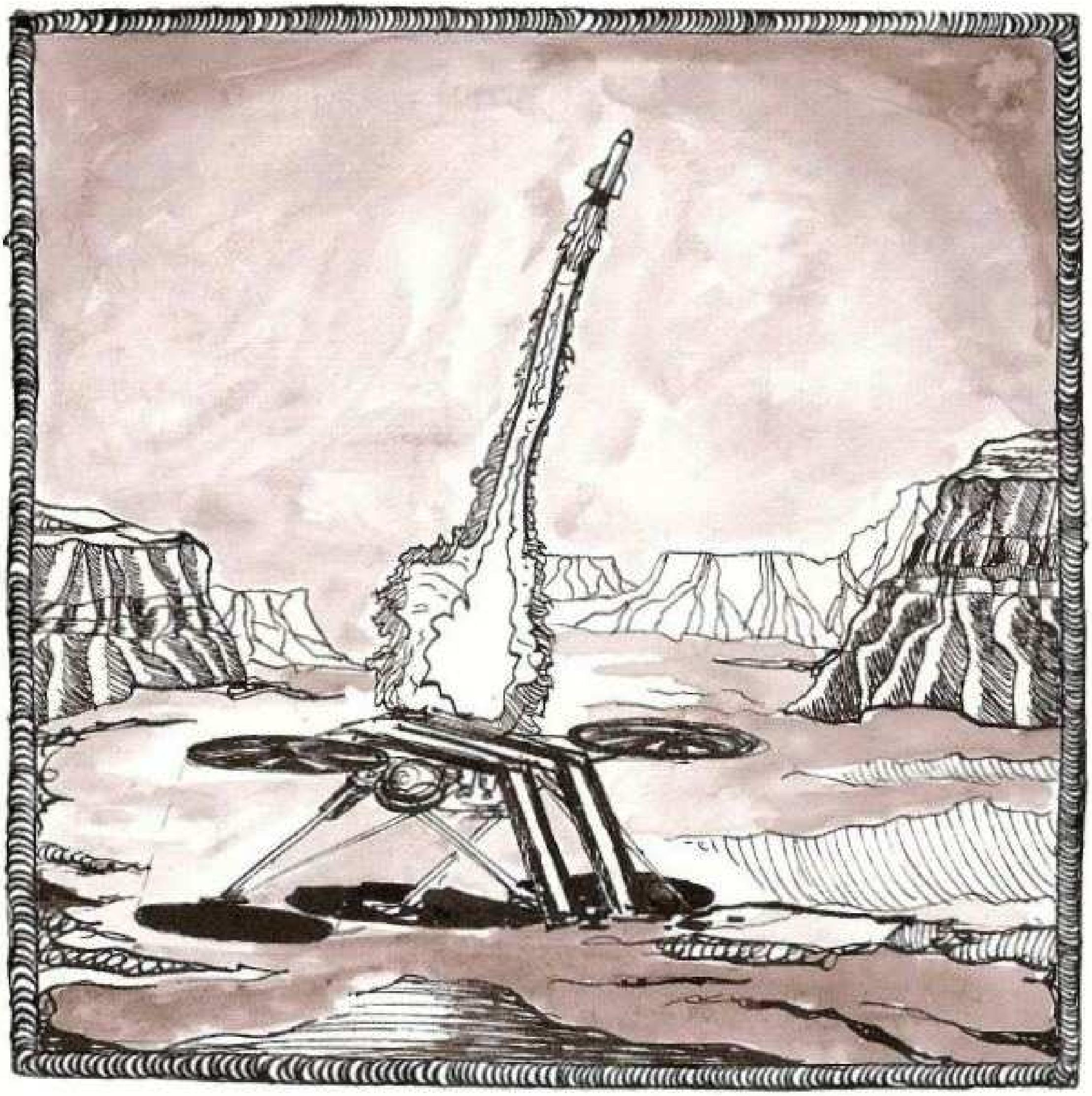
MiniMAV & MultiERV

new components
for MSR mission



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Introduction

The primary target of the Mars Sample Return (MSR) mission is to deliver samples from the Mars surface to Earth. Scientists and general public are thrilled by the search for extraterrestrial life. However to widen our knowledge of Mars we need an opportunity to examine Mars samples with the best available techniques. This has to be done in the terrestrial laboratories.

This paper describes mission architectures of MSR utilizing our proposed new components - **MiniMAV** and **MultiERV**.

Basic requirements for proposed MSR mission

Past missions proved that, although challenging, the Mars mission can be highly successful using recent matured technologies.

Mars robotic missions such as Viking, Mars Global Surveyor, Mars Path Finder, Mars Orbiter 2001, Mars Exploration Rovers, Mars Express and Mars Reconnaissance Orbiter have demonstrated most of the critical manoeuvres needed for successful MSR mission.

Basic MSR operations are:

- Launch operations and Earth departure manoeuvre (successful with all above missions)
- Cruising stage en route to Mars (successful with all above missions)
- Mars orbit insertion (MGS, MO2001, MEx and MRO)
- Mars landing (Viking, MPF and MERs)
- Samples acquiring (Viking)
- Mars ascent (not demonstrated yet)
- Complex maneuvers and rendezvous at Low Mars Orbit (not demonstrated yet)
- Trans Earth injection (not demonstrated yet)
- Earth re-entry (demonstrated with Stardust or Luna 16, 20 and 24)

We are proposing to use demonstrated technology for the appropriate MSR mission phases. For not yet demonstrated capabilities - Mars ascent, rendezvous at Low Mars Orbit and Trans Earth injection - we are implementing new components MiniMAV and MultiERV.

MiniMAV is a minimised vehicle for transporting samples from Mars landing site to selected Low Mars Orbit (LMO).

MultiERV is a dexterous vehicle for collecting multiple MiniMAV sample canisters at LMO and delivering them to the Earth.

Mars samples strategy

To get highly diverse and therefore highly valuable samples from Mars we identified a need for delivering around 1 kg sample from several landing sites.

The most promising candidates could be a volcanic terrain (Tharsis), a dry river bed (Valles Marineris) and the edge of polar cap.

Depending on available equipment the samples from several meter depth could be available, but surface samples are valuable too.

Therefore, we set the minimal target to deliver three 1 kg samples from three different sites.

MiniMAV details

Proposed MiniMAV specification is to deliver 1 kg sample into LMO.

The MiniMAV contains these basic components:

- Sample canister
- 2 stage rocket booster with storable liquid propellants
- Navigation through the ascent phase based on the real-time communication with MSR lander and MultiERV

The sample is transported in the lightweight canister containing the photovoltaic panels and radio beacon. The thermoregulation and stabilisation is passive. Based on the CubeSat technology the sample canister could weight less than 3 kg including 1 kg sample.

The two stage rocket booster has total delta V (dV) of 4500 m/s based on ISP of 2500 Ns/kg and gross weight of 60 kg. The first stage has dry weight of 10 kg with 35 kg of propellants and the second stage has 2 kg dry weight with 7 kg of propellants.

The MiniMAV technology hasn't been demonstrated yet, but we believe that this vehicle could be developed and tested as a part of "Centennial Challenge" class competition.

MultiERV details

Proposed MultiERV specification is to perform rendezvous with up to 5 separate sample canisters at LMO and return samples back to Earth.

The Multi ERV contains these basic components:

- Sample return capsule
- Support spacecraft systems for the on orbit operation including communication with the Earth and MiniMAV, navigation, avionics, power generation & management
- Ion Solar Electric Propulsion (SEP) for the high dV manoeuvres
- Storable chemical propellant propulsion for rendezvous, RCS and high thrust manoeuvres
- Rendezvous system for retrieving samples within the sample canister and their ingress to the sample return capsule

The MultiERV is placed en route to Mars by the Earth departure stage of the launch vehicle and enters Mars orbit using an aerobraking technique combined with use of the high and low ISP propulsion.

At Mars orbit the MultiERV provides support for the surface operation and helps navigating the MiniMAVs during ascent to LMO.

Once the sample canisters are in the orbit the MultiERV perform a rendezvous and collects samples into the sample return capsule. With samples from up to five different MiniMAVs the MultiERV performs TEI manoeuvre and delivers samples back to the Earth in the return capsule.

The estimated MultiERV mass is 450 kg where 160 kg is allocated for the dry structure, 40kg for return capsule, 50 kg for high ISP propellant (xenon) and 200 kg for low ISP propellant (hydrazine). Total delta V of MultiERV propulsion system is about 4500 m/s (3000 m/s for SEP and 1500 m/s for chemical propulsion).

The return capsule is designed to return up to 15 kg of cargo to the Earth surface in up to five sample canisters (3 kg each including 1 kg sample).

ISPP

We haven't included the In-Situ Propellant Production (ISPP) capability in our architecture, since we don't recognize any benefit for achieving the main MSR objective. Our analysis shows that an architecture relying on ISPP is more complex and expensive with less probability of success.

There is still a possibility of including ISPP demonstration to the MSR mission but our architecture is independent from any ISPP.

Dedicated multi MSR Mission architecture

Our preferred mission architecture is to launch one MultiERV and up to three MiniMAVs during the single launch to the Mars bound trajectory. Each MiniMAV would be attached to standard Mars Lander similar to one used for the Mars Pathfinder mission.

The whole multi MSR stack has a total mass as follows:

MultiERV	450 kg
3 x Lander/MiniMAV	3 x 500 kg
Vehicle interface	150 kg
Total	**2100 kg**

After Trans Mars Injection (TMI), provided by launch vehicle, is the MultiERV used for guidance, energy supply & distribution and midcourse trajectory corrections for the whole stack up to Mars arrival.

At this point Mars Landers containing MiniMAVs separates from the vehicle interface and lands each independently on the Mars surface (in different areas). All Mars Landers performs their separate missions collecting samples and supporting MiniMAVs stay on the Mars surface until they are prepared for the sample return.

Meanwhile the MultiERV separates from the vehicle interface and performs the Mars Orbit Insertion (MOI) manoeuvre. From the selected generic Low Mars Orbit the MultiERV helps to provide guidance for MiniMAVs during their ascent to LMO. The MultiERV performs a rendezvous with each MiniMAV (upon their Mars ascent) collecting the sample canisters.

With all sample canisters safely placed inside the return capsule the MultiERV uses both high and low ISP propulsion systems to place itself onto the trans-Earth trajectory. When the MultiERV enters the Earth atmosphere the return capsule separates and delivers samples to the Earth surface.

Piggyback MSR Mission architecture

The alternative approach is to use already planned Mars missions to deliver MiniMAVs on the Mars surface. Thanks to the low mass of the MiniMAV this would be an ideal candidate to be carried as a piggyback package on the existing missions. This would enable a high sample efficiency choosing the most promising specimen already analysed by the primary mission. The MiniMAV could be built in bigger series increasing probability of successful sample return.

MultiERV can be launched as part of another Mars Orbiter mission, or optionally can be launched later, when MiniMAV's sample canisters are safely delivered into proper LMO.

New Technology

As stated before, our mission architecture takes advantage from the previously demonstrated technology. However, there are certain mission phases requiring never before demonstrated techniques. These were entirely concentrated in MiniMAV and MultiERV vehicles and include:

- miniaturized rocket systems for MiniMAV
- Mars based real-time assisted ascent navigation
- Rendezvous and sample canisters collecting at LMO
- LMO departure

These mission phases are critical for a successful MSR mission and have to be demonstrated before the mission itself.

We have identified that the MiniMAV subsystems could be demonstrated during a competition similar to the "Centennial Challenge".

Although the key subsystems have to be extremely miniaturised and are subjected to the wide scale of environmental conditions, their low mass and relative low cost make it ideal candidate for such type of competition.

The critical manoeuvre for the MultiERV is the rendezvous and sample canister collection. This can be demonstrated in LEO using MultiERV vehicle platform derived from SMART or Hayabusa space probes. Although substantially more complex than mentioned vehicles it is possible to refine these manoeuvres long before the actual MSR mission.

Conclusions

We are proposing two main ideas:

- make MAV so small and so lightweight to be added to the standard Mars Lander/Rover missions (=> MiniMAV)
- make ERV so dexterous to be capable to pick up multiple sample canisters at LMO and deliver them to the Earth all at once (=> MultiERV)

Presented MSR architecture is based on the currently available technology wherever possible. The existing technology and techniques are used to deploy the architecture subsystems to the Mars surface and the Mars Low Orbit.

A transport of the collected samples from the Mars surface to the Earth is where the challenge begins. Two new vehicles were envisaged to perform these tasks. The MiniMAV and MultiERV. We believe that both vehicles can be developed competitively and extensively tested on the Earth or LEO to decrease the inherent risk of the MSR mission. The clear advantage is that the system weight and cost is minimised while enabling delivery of significant volume of samples from different landing sites.

Presented architecture ensures that the single MiniMAV failure doesn't mean failure of the entire MSR mission. The more costly and complex MultiERV doesn't go to the Mars surface but stays at the Mars orbit where it can support several MiniMAVs bringing the samples back from the Mars surface. The MSR mission efficiency and scientific value is therefore maximised.

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