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SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration – missions current and future (3A)

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OVERVIEW OF CHINESE CURRENT EFFORTS FOR MARS PROBE DESIGN

Abstract

Mars exploration activities have gathered scientific data and deepened the current understanding about the Martian evolution process and living environment. As a terrestrial planet, Mars is also an excellent proving ground of some innovative special-purpose aerospace technologies. In the U.S., Soviet Union (Russia), Europe, and India, missions sending spacecraft to explore Mars currently exist, and the first three have landed their spacecrafts on the surface of Mars. China has programmed five Mars landing missions in next 20 years, and some critical technologies for Mars landing mission have been studied beforehand. In this paper, we will report Chinese Mars exploration mission scenario and the latest progress in dynamics study and guidance navigation and control (GNC) system design for Chinese first Mars probe. Some elementary design rules and index will be described according to simulation experiments, analysis and survey. Several new coping strategies will be proposed to be competent for the challenges of the Mars entry descent and landing (EDL) dynamics process. Details of the work, the supporting data and preliminary conclusions of the investigation will be presented. Based on our current efforts, one candidate system configuration architecture of Chinese first Mars probe will be shown and elaborated in the end.

Overview of Chinese Current Efforts for Mars Probe Design

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Abstract

Mars exploration activities have gathered scientific data and deepened the current understanding about the Martian evolution process and living environment. As a terrestrial planet, Mars is also an excellent proving ground of some innovative special-purpose aerospace technologies. In the U.S., Soviet Union (Russia), Europe, and India, missions sending spacecraft to explore Mars currently exist, and the first three have landed their spacecrafts on the surface of Mars. China has programmed five Mars landing missions in next 20 years, and some critical technologies for Mars landing mission have been studied beforehand. In this paper, we will report Chinese Mars exploration mission scenario and the latest progress in dynamics study and guidance navigation and control (GNC) system design for Chinese first Mars probe. Some elementary design rules and index will be described according to simulation experiments, analysis and survey. Several new coping strategies will be proposed to be competent for the challenges of the Mars entry descent and landing (EDL) dynamics process. Details of the work, the supporting data and preliminary conclusions of the investigation will be presented. Based on our current efforts, one candidate system configuration architecture of Chinese first Mars probe will be shown and elaborated in the end.

1. Introduction

As one of Earth's nearest neighbors and preferred target planet of deep space exploration, as well as the natural conditions are similar to Earth, Mars has been much attention for decades. From the 1970s, humans began on Mars landing exploration missions [1]. In 1971, the Soviet Union launched the "Mars-2" which became the first lander reached the surface of Mars (although it crashed on the Martian surface), additionally, the "Mars-3" and "Mars-6" lunched by the Soviet Union in 1971 and 1973 respectively were also reached the Martian surface, but their transmissions soon disappeared after landing [2]. In 1976, the United States launched the "Viking-1" and "Viking-2" which successful landed the surface of Mars [3]. The Mars Entry, descent and landing (EDL) technologies developed by "Viking" series has become a major inherited technologies for the later Mars landing mission of America [4]. On this basis, the United States launched the "Mars Pathfinder (MPF)" [5], "Mars Exploration Rovers number (MER)" (including "Spirit (MER-A)" and "Opportunity (MER-B)") [6], "Phoenix" [7] (its predecessor is the 2001 Mars Surveyor Program [8]), and "Mars Science Laboratory (MSL)/ Curiosity" [9] (its predecessor is the Mars Smart Lander (MSL) [10]) in 1997, 2004, 2008 and 2011 respectively, and their scheduled Mars exploration missions were successfully achieved. In addition, the European Space Agency (ESA) launched the "Mars Express" in 2003, and its carried "Beagle-2" lander is successfully landed on north of the equator of Mars, but it fell silent after landing [11]. India's first Mars orbiter launched and reach Mars orbit successfully in 2014. Future missions including the European ExoMars [12], NASA's Astrobiology Field Laboratory (AFL) [13] and Mars Sample Return (MSR) [14] are pushing the technology limits toward the aforesaid directions to pave the way for human exploration missions. Mars landing exploration missions have become one of the hottest deep space exploration missions in recent years and future.

China has not formally implemented Mars mission, even though Chinese Lunar Exploration Project and Chinese Manned Space Project have been two major successes. But recently, three to five times Mars landing/sample return missions have already been programmed in next 20 years. This paper will report Chinese current efforts for Mars probe design and preparatory work for Chinese Mars Exploration Project.

2. General Ideas

Chinese Mars Exploration Project (CMEP) is programmed as two main steps in next two decades. The first step contains orbiting, landing and roaming. The second step is to realize Mars sample return. The first step missions have been set up preliminarily.

Scientific goals: (1) Detect and mapping surface topography of Mars and its change; (2) Survey rocks and minerals distribution on the surface of Mars, assess its resources; (3) detect and research the water or water ice in the surface and atmosphere of Mars; (4) Survey Mars physics and Mars atmosphere.

Engineering goals: (1) Break through Mars probe technologies; (2) Realize Mars probe's precision orbit determination and data transmission technology on the distance of 3.5×10^{8} km through the coordinate spacecraft and deep space network system; (3) Preliminary grasp the orbit design for Mars exploration, including the orbit design from launch and interplanetary cruise to the circle orbit of Mars, and deep space operation control technologies.

Based on Chang'e-2 and Chang'e-3 lunar probe platform, Chinese Academy of Space Technology (CAST) proposed a technological scenario of Chinese Mars exploration project, as shown in figure 1, which integrated apply the technologies developed in the first and second phase of Chinese Lunar Exploration Project (CLEP) and Chinese Manned Space Project (CMSP). In the conservative scheme, the launching mass of Chinese Mars probe is about 2350kg, dry mass is about 1040kg, and payload is about 110kg. The launch window is determined in 2020. The entire scenario was roughly described as follows: the Mars probe is to be directly sent into Earth-Mars transfer orbit and flight about 10 months on the orbit. After two to four times midcourse correction, the probe implements Mars orbit injection capture. And then, the probe turns into elliptic orbit of Mars. It will costs 1~2 months to adjust this orbit into the mission orbit. Effective exploration work is planned to last 1~3 years.

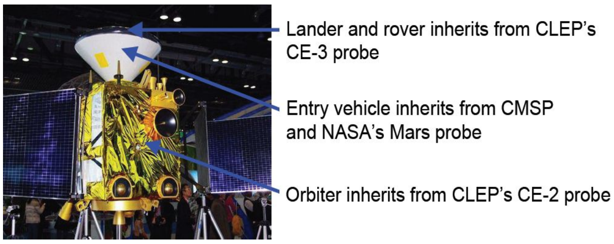


Fig. 1. Preliminary system configuration for CMEP probe (The 10th China international aviation and aerospace exhibition, Zhuhai, China, November 11-16, 2014)

At least seven major problems should be considered and clarified firstly. (1) How to weigh the technological innovation and technological inheriting? (2) How to weigh the independence and international cooperation in the future Mars exploration mission? (3) How to positioning the Mars probe during subsequent operation? (4) How to overcome the difficulties of communication signal attenuation and restricted transmission rate during the implementation of Mars mission? (5) How to overcome the difficulties of the large time delay and real-time monitoring during the implementation of Mars mission? (6) How to ensure accurately Mars capture and mission orbit injection? (7) Key factors in Mars environment, including the gravity field model, Mars heat flow model and Mars atmospheric model.

China's heavy-lift launch vehicles will have the adaptability for multi-mission, large tonnage launching capacity, high reliability and new technologies. For Earth-Mars transfer injection, the CZ-5 launch vehicle can launch Mars exploration payload about 5000kg. The next generation heavy-lift launch vehicles will have low earth orbit (LEO) launching capacity of more than 130 tons; its largest launching mass of Mars exploration payload is about 40 tons.

After the second phase of China's lunar exploration project, three deep space stations had been built in Kashi of Xinjiang province, Jiamusi of northeast

China, and San Diego of South America, respectively. Therefore, China's TT&C coverage for the Mars probe can exceeded 90%. They can also cooperate with the deep space stations of European Space Agency respectively in Australia and Spain to realize long baseline difference one-way distance interferometry (ΔDOR). The capacity of fast accurate measurement and orbit determination of the integrated VLBI (very long baseline interferometry) with TT&C system had been verified and improved through three lunar exploration missions of Chang'e-1, Chang'e-2 and Chang'e-3.

3. TT&C and Pulsar Navigation

China has already set up the Mars exploration project, and the Chinese VLBI network (CVN) will take on the measurements of the related satellite orbit and position. The CVN has tracked the Mars Express (MEX), a Martian satellite of the European Space Agency (ESA), for several times in order to train, test and improve the software and hardware systems. Based on the positioning reduction software developed during the Chang'e-1 lunar exploration project, the tracking data of CVN has been processed to determine the coordinates of MEX satellite in Chinese TT&C network system [15]. In order to improve the positioning accuracy of the Martian satellite, it is has also actively practice the differential VLBI, same beam VLBI and so on, to further reduce the systematic errors and to compress the noise level of observations.

Because of pulsar's very long distance to the solar system, its stable pulse period and precise direction vector can provide navigation for interplanetary exploration. Autonomous navigation technology based on X-ray pulsar can be well qualified for the autonomous navigation task of Mars probe in interplanetary cruise and part of entry phase, so as to make up for the lack of ground tracking system (including the VLBI, ΔDOR and ΔDOD) and ranging technology, especially when the probe out of the observation of ground TT&C system [16]. Combining the advantages of both onboard autonomous navigation and ground tracking system is also the important effort direction of the future Mars probe autonomous navigation. In addition, for potential international cooperation, UHF (Ultra High Frequency) relay technique and UHF device as well as the space link protocol series of Consultative Committee for Space Data System (CCSDS) should also be taken into account.

4. Mars Capture Mode

Mars capture strategy has a direct impact on the overall design of the probe and mission planning. For example, the selection of target parameters for midcourse corrections, fuel consumption for Mars capture, and target orbit determination after capture. Moreover, limited fuel and various constraints of capture should also be taken into account for analyzing various potential Mars capture schemes and fuel consumption. Optimizing the capture mode is significant for Mars capture orbit design and subsequent exploration activities.

The preliminary parameters of capture are assumed as follows. Probe mass is 2350 kg, capture thrust is 490 N, specific impulse is 312 s, height of periareon of target orbit is 600km, height of apoareon of target orbit is 100000 km, remaining velocity is 3.55 km/s.

The capture problem of Mars probe with finite-thrust has been analyzed and handled by using three different strategies. They are fuel-optimal capture, constant turn rate capture, and constant directional capture, respectively [17]. The optimal control and particle swarm optimization algorithm are used to solve the different capture strategies. It is indicated that the optimum solution of minimum fuel consumption is bang-bang control and the thrust direction is nearly anti-parallel to the velocity vector, but it is too hard for the attitude control system. Capture process with a constant directional capture maneuver is easy to implement, but the gravity loss is more serious. Fuel consumption of the capture strategy with a constant turn rate capture maneuver is between the fuel optimum solution and the capture strategy with a constant direction capture maneuver, but it is easy of execution in the practical implementation. Therefore it has more important practical value in engineering.

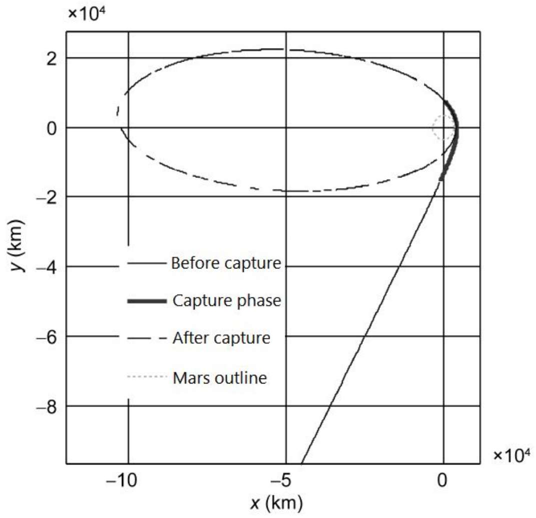


Fig. 2. Trajectory of constant turn rate capture [17]

The trajectory of constant turn rate capture is shown as figure 2. The parameters of this capture mode are listed as Table 1. The constant turn rate of Mars probe is 2.2427×10^{-4} rad/s. The radius of periareon of hyperbola orbit is 4887.68 km, the lowest height during Mars capture is about 650 km. There is sufficient margin to ensure that the probe would not uncontrollable or knock on Mars as the cause of the error in the capture process.

Tab.1. Orbital elements of constant turn rate capture strategy[17]

Parameters	Value
Thrust time	6069.21 s
Attitude direction function	0.00022427×*t* -0.38383 rad
Lowest height during capture	650.1 km
Semi-major axis *a* before capture	3290.965 km
Eccentricity ratio *e* before capture	2.485
Radius of periareon of hyperbola orbit	4887.684 km
Semi-major axis *a* after capture	43695 km
Eccentricity ratio *e* after capture	0.90857
Radius of periareon of captured orbit	3995.000 km

5. Mars Entry Descent and Landing Scenario

5.1. Description of Probe during Mars EDL

On the interface of Mars atmosphere (elevation ~120km), the maximum relative velocity of the entry descent capsule is 5.827km/s, various constraints should be considered as follows during atmospheric entry. (1) heat flux < 650kw/m^2, (2) heat load < 40 MJ/m^2, (3) load < 10.5 g, (4) inflatable load of parachute < 73.5kN, (5) landing accuracy < 50km. According to these five factors, Mars atmospheric change (e.g. density, wind field), and characteristics of the entry descent capsule (e.g. mass, aerodynamics), the entry corridor can be assessed and the entry angle is required to exceed 1.1°. Because the distribution of entry interface points is within ±0.3°, the entry flight path angle of the entry descent capsule is about -12.4°.

After the entry from hyperbola orbit, disk-gap-band parachute would be deployed within 1.8~2.1 Mach. Forebody heat shield separates after stable deceleration. The Doppler radar and Navcam start to work, combined with the IMU, the multi-information fusion tri-axial navigation data could be obtained though GNC computer. Once the probe reach a certain height above the surface (height ~1400m, velocity ~80m/s), the afterbady with parachute would be separated with the lander of the entry descent capsule, and the lander starts to work during powered descent.

During the powered descent, the lander will slow down and descent by using several monopropellant rocket engines. And finally, all thrusters will be turned off at 1.5m above the Martian surface, at the same time, both vertical and horizontal velocity are reduced to zero. Then, the lander free touches down on the surface.

At the moment of landing, buffer honeycomb sandwich structure is adopted to further decrease landing impact load. The compression energy absorption structure is light-weight, small size, simple and reliable, low cost; as well as the lander can reach a very small distance to the surface of Mars after landing. A lot of sensors are desired to be installed on the entry descent capsule, but their total mass is limited within 8kg. Their main function is to provide effective engineering data for reconstruct the EDL trajectory after landing, and improve the beforehand models.

5.2. Aerodynamics Configuration of Entry Vehicle

The aerodynamic configuration study is one of the key issues for Mars probe design. Based on the deep understanding of the aerodynamic configuration of both Mars entry probe and Earth reentry capsule, the main aerodynamic characteristics of Mars probe were investigated in the aspects of atmosphere environment and configuration pattern. The influences of atmosphere environment and configuration pattern on the hypersonic lift and drag characteristics, trimming characteristics and static stability were then discussed by means of engineering computation. Calculated results showed that the changes of atmosphere may alter gas thermal properties and hypersonic surface pressure, as shown in figure 3.

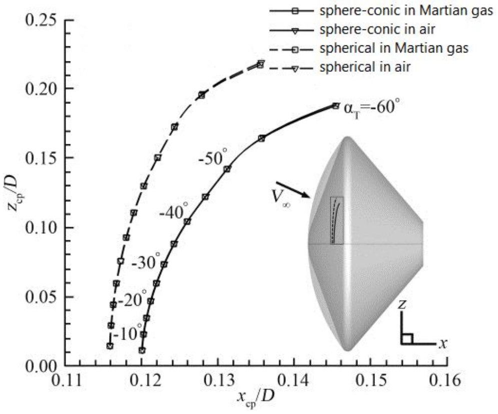


Fig. 3. The centers of pressure for the sphere-conic and spherical heat shield in the Martian gas and the air [18]

For the Martian gas, both the lift and drag coefficients increased, and thus the lift-to-drag ratio and trimming characteristics held, and there exited much stable domain compared with the air. For the configuration pattern, the sphere-conic heat shield will make bigger drag force than the spherical one, which is beneficial to descending deceleration. Moreover, a small radial offset will meet the trimming requirement for the given angle of attack and the sphere-conic capsule is not so sensitive for static pitch stability in the axial direction, both of which arc the reasons why to use the sphere-conic heat shield in the successful missions. The aerodynamics prediction technique and the aerodynamic analysis method can be the foundation of China Mars probe design. As shown in figure 4, the inflatable entry vehicle is also tested and developed for future China's large-mass Mars landing missions [19].

Fig. 4. Test of inflatable deployed structure [19]

5.3. Navigation for Descent and Landing

The first effective approach is to correct the inertial basis and drift using external measurement. To this end, the Mars orbiter or cruise stage can be used to support integrated navigation. Recent research shows that the ionizing plasma around the entry vehicle has little effect on ultra-high frequency (UHF) band (300~3000 MHz) radio communication and radio measurement, which can be utilized in real-time to significantly improve the on board state knowledge during the Mars atmospheric entry [20]. For Chinese Mars exploration, the radio measurements from orbiter and the range and velocity measurements from radars are candidates to correct the IMU for integrated navigation of descent and landing phase, as shown in figure 5 [21,22].

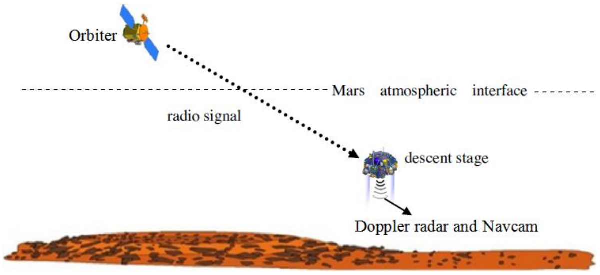


Fig.5. Candidate navigation scheme for descent and landing [22]

In addition, the satellite map and terrain map of Martian surface obtained by the orbiter can be utilized for landing navigation by matching the descent image obtained by the lander. Landmarks on the surface of Mars can be obtained by matching the descent image and digital elevation map of the landing area. Based on the landmark images given by navigation camera to obtain line-of-sight vectors combined with the position data of the landmarks and the output of IMU, the probe's position, velocity and attitude can be estimated [23].

5.4. Telecommunication System

Communication types of EDL process mainly includes direct and relay communication. Because the communication distance between the probe and the earth is farther than the distance between the two probes (lander and orbiter), the communication speed between the two probes is 2~3 orders of magnitude faster than the communication speed between the probe and the earth. The communication link between the probe and the earth can be used for the transmission of the small amount of data such as the key event. The relay communication link can be used to transmit the data of the probe's health, working status, exploration data and so on. Two kinds of links can be used to form a heterogeneous backup, and improve the reliability of communication system [24].

One-way communication mode is planned to be used during the EDL process. The Mars soft-landing probe only sends the remote sensing data to the ground station or the Mars orbiter, without to use upward or forward link. First of all, the time delay and the time cost of sending the instruction is far greater than that of the EDL process. Secondly, there is a wide range of signal power, frequency and other large fluctuations in the process of EDL, such as the blackout of hypersonic entry, the parachute deployment and swing.

Communication support covers the whole process of EDL. Firstly, monitor probe’s working state and improve the exhibition of mission. Secondly, signal strength, Doppler frequency shift and other wireless signal characteristics can be taken full use of to deduce the relevant data of EDL process as a reference for the subsequent missions. Thirdly, it can support the analysis afterwards, especially for the failure in the mission.

Wide beam and low gain antenna is selected as antenna applied in EDL. In order to adapt to larger attitude change during the EDL, ensure visibility of communication, and improve reliability, the antenna with wide beam characteristics is required. But wider beam antenna has a lower gain, which causes a performance loss of the link; therefore, it needs to be weighed and balanced.

In order to ensure the smooth implementation of EDL communication scheme, communication visible arc is posed as an important prerequisite for EDL process design. It introduces several constraints on the overall design level of the mission, such as the entry opportunity, entry mode, and the orbiter’s position during the EDL process.

6. Mars Rover

The Mars rover navigation system consists of a pair of panoramic camera, a pair of navigation camera, two pairs of obstacle avoidance camera, inertial measurement unit, digital sun sensor and photoelectric encoder [25]. Their arrangement and field of view are shown as figure 6.

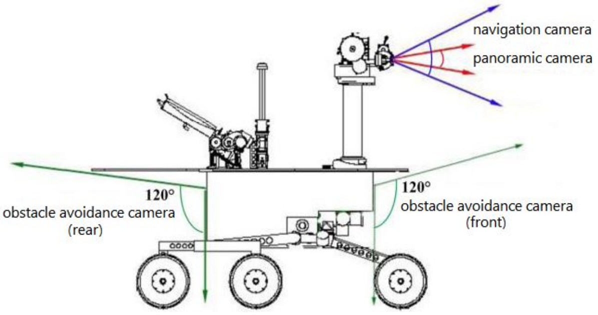


Fig. 6. Sensors configuration of Mars rover [25]

Field of view of navigation camera is 45°. It is setup on the mast of Mars rover, and about 1.6m above the Martian surface. It adopts 20cm baseline and parallel axis, the mast can horizontal rotate 360°, and the installation can vertical rotate 90°.

A pair of navigation camera formed a passive stereo vision system to detect potential terrain hazard. It can provide local or panoramic terrain images within a range of 100 meters for Mars rover path planning. It can also be cooperatively used with the obstacle avoidance camera for Mars rover autonomous navigation. The visual odometry is used to calculate the mileage in a relatively short running distance (<10m) based on continuous stereo vision image of navigation camera.

Field of view of panoramic camera is 14°, installed on the mast. It is used to omnidirectional imaging the surrounding terrain of Mars rover. The panorama is useful for morphological, atmospheric and geological research, and for describing the three-dimensional scene and providing assistance to autonomous navigation of Mars rover. The 30cm baseline and the parallel axis are adopted, one is a medium resolution camera, and another is a high resolution camera. The panoramic camera with a higher resolution than the navigation camera would be used for a remote path planning.

Two pairs of obstacle avoidance camera are respectively installed on the front and rear of the rover, about 50cm above the surface of Mars, and 50° to the horizontal direction; as well as 10cm baseline and the parallel axis are adopted. The obstacle avoidance camera is used for hazard detection, precise positioning during the moving process, and clear near imaging the surface of Mars. It provides the main basis for a short path planning and assisting deployment of scientific experiment instruments.

The inertial measurement unit is mainly used for static angle measurement and dynamic attitude estimation. Digital sun sensor is mainly used for determining the yaw (azimuth) of the rover. The photoelectric encoder is a sensor that converts mechanical displacement to a pulse or digital quantity through photoelectric conversion. The data flow of navigation and path planning of Mars rover is depicted by figure 7 [25].

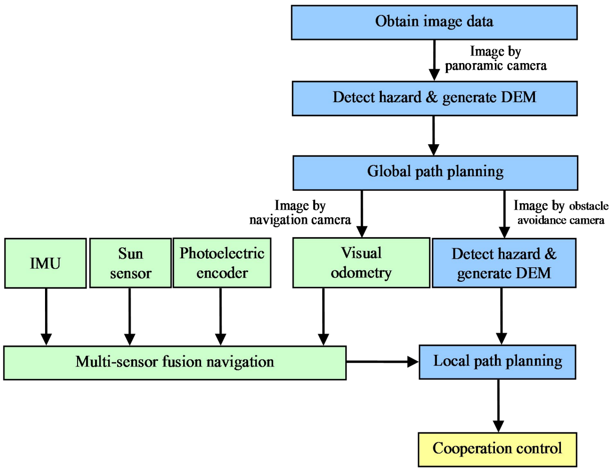
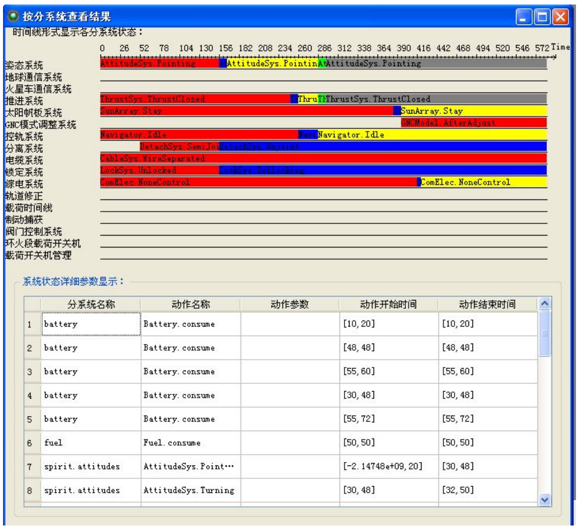


Fig.7. Flow chart of navigation & path planning of Mars rover[25]

7. Mars Mission Planning System

The autonomous mission planning is the core of the autonomous management of the Mars probe, which is based on the current state of the probe and the mission objectives to plan a set of feasible action sequences. The mission planning and simulation system platform for Mars probe has been built to deal with the problem of autonomous mission planning [26]. Based on the characteristics of Mars mission, the time line based representation method is adopted to build the planning model; the time series backtracking algorithm, time constrained grid, and maximum flow based resource processing method are used to generate the action sequence and allocate reasonable time and resources for each action. Through the simulation experiment of the orbiter-EDC (entry descent capsule) separation task of Mars exploration, it is verified that the system can be used to produce the feasible action sequences, and the planning efficiency can preliminary meet the requirements of the actual work.



	分系统名称	动作名称	动作参数	动作开始时间	动作结束时间
1	battery	Battery.consume		[10,20]	[10,20]
2	battery	Battery.consume		[48,48]	[48,48]
3	battery	Battery.consume		[55,60]	[55,60]
4	battery	Battery.consume		[30,48]	[30,48]
5	battery	Battery.consume		[55,72]	[55,72]
6	fuel	Fuel.consume		[50,50]	[50,50]
7	spirit.attitudes	AttitudeSys.Point···		[-2.14748e+09,20]	[30,48]
8	spirit.attitudes	AttitudeSys.Turning		[30,48]	[32,50]

Fig.8. Interface of mission planning system for Mars probe [26]

8. Candidate Probe Scheme for CMEP

Many disciplines and subsystems are included in the Mars probe design, to ensure success of the whole mission, the overall performance of system level and the local performance of subsystem should be balanced and optimized, just like the idea of figure 9.

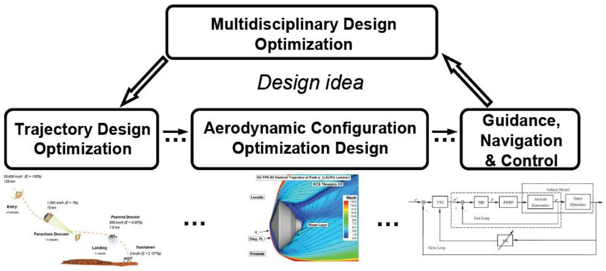
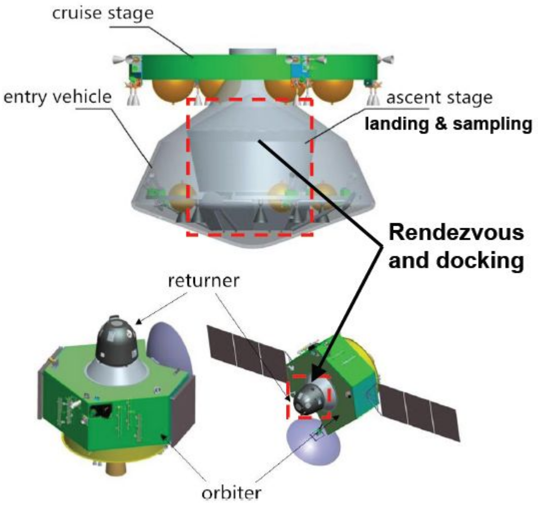


Fig.9. Sketch of multidisciplinary optimization design

In the candidate scheme of Chinese Mars exploration mission, the probe consists of orbiter-returner combination and landing-ascent combination. As shown in figure 10 [27]. Landing-ascent vehicle contains cruise vehicle, entry vehicle, and ascent vehicle. Cruise vehicle provides power, communication, and environmental protection to the landing-ascent vehicle before atmospheric entry. Entry vehicle will separate from cruise vehicle when they near Mars or predesigned landing area. The entry vehicle carries a lander or landing-ascent vehicle to entry Mars atmosphere, and land a rover or landing-ascent vehicle on the surface of Mars. And then, under the support of ground TT&C, exploration or sampling/encapsulation is executed on the surface of Mars.



Mass redistribution

Items		Mass redistribution (kg)
① Lander-ascent combination	Cruise stage (dry weight)	280
	Cruise stage (wet weight)	600
	Ascent stage	800
	Lander, rover, heat shield	1100
	Total	2500
② Orbiter-returner combination	Orbiter (dry weight)	1200
	Orbiter (wet weight)	3470
	Returner	330
	Total	5000

Note: ① for first step missions.
①+② for second step missions.

Fig. 10. A candidate probe scheme for CMEP [27]

Ascent vehicle carry the sample capsule re-launch from Martian surface, and enter a circle orbit of Mars with the height of 400~500km. Ascent vehicle rendezvous and docking with the orbiter-returner combination, and the sample capsule will be captured by the latter while. After that, the ascent vehicle will separate with the orbiter-returner combination, and orbiting the Mars. The orbiter-returner combination will wait a proper window to carry the sample capsule return the earth. The obiter and returner will separate when they near the earth, and the returner will carry the sample capsule reentry and landing on the earth.

The main deltaV should be considered as follows: (1) Earth-Mars transfer. Orbiter-returner combination reaches the orbit of Mars to support surface exploration and telecommunication relay. Its mission orbit is a circle with the height of 500km. Its total deltaV needed is traditionally no more than 2400m/s. The total deltaV can be reduced to 1km/s only if aerodynamic deceleration strategy adopts. (2) Mars-Earth transfer. When orbiter-returner combination reaches the window of Mars-Earth transfer, it is required deltaV of ~2000m/s for injection. (3) Re-launch and ascent. According to the simulation of ascent trajectory, the deltaV of re-launch and ascent is required no more than 4.4km/s. (4) Rendezvous and orbit maintain. The deltaV of rendezvous on the orbit of Mars is predicted as about 100m/s, the orbit maintain needs about 50m/s totally.

Tab. 2. Preliminary index of Mars sample return mission[27]

Item	Preliminary performance index
Exploration type	Landing and surface exploration + sample return
Launch opportunity	2028, backup 2031
Launch window	Continuous 20 days, window width 5 minutes
Launch mass	Landing ascent vehicle: 2500kg (cruise stage 600kg) Obiter returner vehicle: 5000kg
Sample mass	1kg
Mission period	1~3 years
Mars entry mode	Ballistic-lifting guided entry
Deceleration mode	Aerodynamic shape + parachute + anti-propulsion + buffer
Ascent mode	> 4km/s, two stages injection
Sample transfer	Approach + release + capture
Earth re-entry mode	14km/s, skip re-entry

The main index of Mars sample return is addressed in table 2. For further reduce the mass of vehicle for Mars sample return. An effective candidate is to use local resource for replenishment. For example: Mars atmosphere is rich in carbon dioxide; its content is as high as 95%. Astronauts or robot can produce oxygen and hydrogen by electrolysis of water. The hydrogen and carbon dioxide in the atmosphere of Mars can be used to produce methane and water. Methane and oxygen can be used as rocket fuel to support Mars probe return to the earth.

9. Conclusions

Chinese Mars Exploration Project (CMEP) has been programmed as two major steps in next 20 years, Mars probe is urgent to be designed. This paper reported the progress in Chinese Mars probe design, including system level and subsystem level.

Some candidate scenarios, technical schemes, design ideas, and preliminary index were addressed and presented; while many more key and innovative technologies should continued to be developed.

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