火星营地（北京）教育科技有限公司
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MLP
火星着陆计划
MARS LANDING PROJECT

# TECHNICAL BROCHURE

# 技术手册

**MARS LANDING PROJECT 火星着陆计划**

探索宇宙边缘 你将改变世界

Exploring the edge of the cosmos, you will change the world

# 目 录

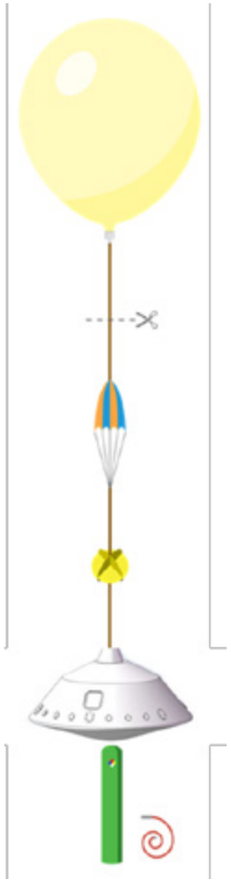




# DIRECTORY

## (一) 项目简介

本项目 采用的参赛装置，实际上是“高空探空气球”，其基本结构如下图所示：



充满氦气的乳胶气球，它提供的静升力可以将着陆舱带到3000米高空（最高可达3万米即30公里）。通过自切割装置，释放着陆舱。然后着陆舱落回到地面。

自我切割装置能人为释放着陆舱，目前这种装置的设计还很初步，自我切割装置的设计和成功运作是本大赛的重心。

着陆舱在高空释放后，将在降落伞的减速作用下，继续飞行，最终在比较低的速度下，比较温和地冲击地面而降落，等待回收。

雷达反射片，让负责空管的民航和军方雷达能掌握气球的行踪。

着陆舱本身是塑料泡沫等轻便结实带有缓冲性能的材料。里面可搭载GPS接收机等基本设备。以及丰富飞行过程的创意设备。

各种地面设备。例如氦气需要用高压钢瓶来运输，需要带有安全阀的管路来充灌。在地面上操作气球需要戴塑胶手套，

气球携带着陆舱升空后，不仅会垂直飞行，也会在气流的作用下横向飞行，在全程1.5到2小时的飞行中，气球可飞过上百公里的距离。

因此，参赛团队所设计的着陆舱功能越复杂多样，整个飞行期间团队对其气球和着陆舱的追踪与遥测结果就越精细，着陆舱能完成的测量和其它创意任务也就越丰富，团队在着陆舱设计和功能运作方面的得分就越高。

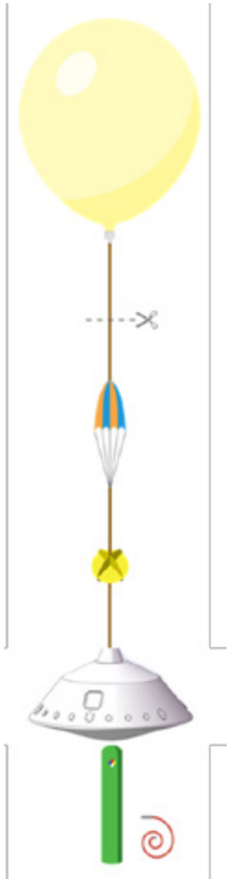
然而另一方面，所需要付出的代价就是，越复杂的着陆舱往往越重，也就需要越大的气球才能飞到比较高的高度，同



## International Mars Landing Design Competition ( MLP ) Technical Manual

## Part One - MLP Profile

MLP adopts an upper-air sounding balloon as the design model. Components of the sounding balloon are showed below:



Latex balloon filled with helium, which can raise the lander to 3 kilometers (with an upper limit of 30 kilometers), and can release the lander to the ground through a self-cutting device

Self-cutting device, which artificially releases the lander and whose design and successful operation are essential in MLP

Parachute, which decelerates the lander in the air, and thus reduces impact force from ground

Rader reflector, which allows air transportation control and government to keep track of the balloon

Lander, composed of light-weighted, sturdy buffer materials such as plastic foam and equipped with necessary devices such as GPS and other devices that enrich flight experiences

Various land-based facilities, such as high-pressure cylinders as helium containers, tubes with safe valves for helium instillation, plastic gloves that protects coating of latex balloon from sweats and thus avoids balloon explosion at high altitude

The rising balloon with lander will travel not only vertically but also horizontally under the influence of horizontal turbulence. The horizontal distance can be up to 100 kilometers during its 1.5 to 2 hours travel.

A well design lander can implement complicated tasks and collect accurate data. The more creative tasks will be implemented and the more accurate data will be collected, the higher score will be earned.

However, the more complicated the lander is, the heavier it is, and thus the larger balloon is required to raise it to destined altitude

时也就需要越大的降落伞才能让落地时速度较低从而保护好设备。而且，更大的气球意味着发射上升段飞行时间更长、更大的降落伞意味着下降段飞行时间更加漫长。更加漫长的飞行过程中，受到气象条件突然干扰的可能性就会大大增加，团队就需要对气球进行更加实时的跟踪，随时调整气球降落地点的预判，才能更准确而及时地赶到降落地点，争取在地面目击和拍摄到降落过程。

## (二) 基本设计原则

1. 一个高水平的着陆舱，可以完成GPS接收/向地面转发、温度-湿度-飞行高度-飞行加速度等遥测功能以及自选创意任务（如鸣警笛、释放纪念物等）；

2. 着陆舱的重量有一定限制，最高重量为500g;

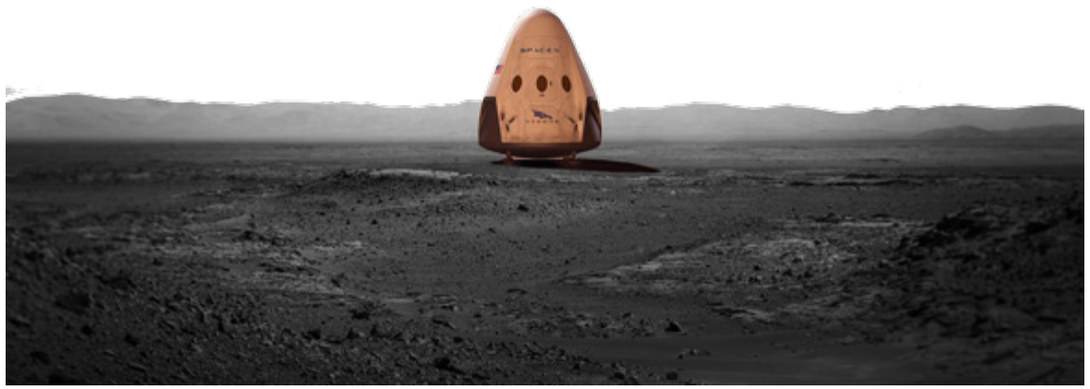
3. 着陆舱内部各种设备的安装、固定和保温措施也处理得很好，能够让各种设备耐受高空低温、低压不良环境，以及飞行中气球爆裂、降落时冲击地面的加速度。

## (三) 高水平团队要求

1. 气球搭载着陆舱上升到3000米高空。

2. 通过地面控制，启动着陆舱上的自我切割装置，释放着陆舱。

3. 能在发射场附近较小范围（例如10公里以内）降落，且获得清晰的高空遥测数据，着陆舱内设备完好可以重复使用、搭载物完好，则这样的团队就是本项目 的高水平团队。





and the bigger parachute is required to decelerate it to a safe landing speed. This also means that longer rising and descending time will be taken, which increases the possibility for lander to be exposed to extreme weather conditions. Therefore, designers should keep lander’ s real-time track more accurately to predict its landing position in order to shoot its landing process in time.

## Part Two - Design Principles

1. A well-designed lander should receive and transmit GPS signals and implement telecontrol, telemetry to collect data of temperature, humidity, real-time altitude, acceleration, etc. and other creative tasks such as siren and souvenir-release.
2. The weight of lander should be limited to 1 kilogram.

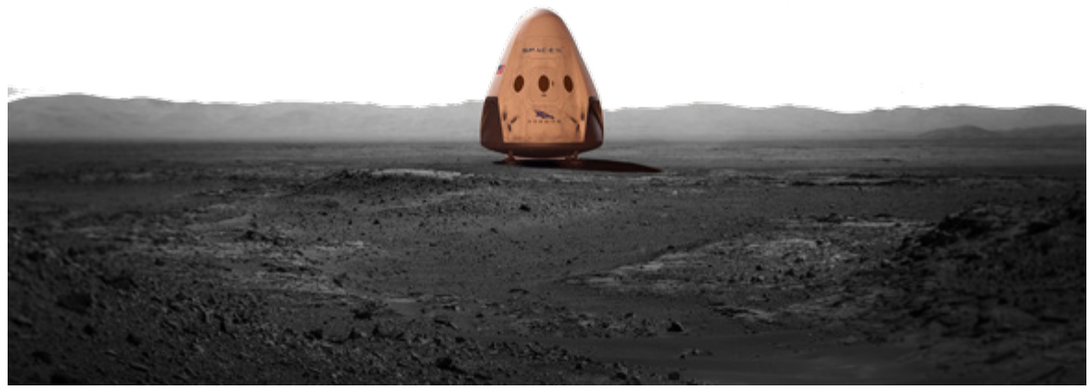
3.Facilities in lander should be well fixed and protected so that they can endure extreme conditions like low temperature and pressure and great impact with ground if the balloon accidentally explodes

## Part Three- Requirements for Excellent Team

1. Balloon can raise the lander up to 3 kilometers above the ground

2. Lander can be released by self-cutting device through telecontrol.

3. The lander can land within a radius of 100 kilometers and collect accurate upper-air data, and facilities in the lander should be well protected for reuse.
Teams that fulfill above requirements are honored with Excellent Team.



## (四) 高空气球飞行环境特点

### 1. 高空环境特点

大气的各种物理性质随高度增加而改变，如下：

| 高度<br>Geo potential Altitude above Sea Level<br>-h-<br>(m) | 气温<br>Temperature<br>-t -<br>(oC) | 气压<br>Absolute Pressure<br>-p -<br>(104N/m2) | 空气密度<br>Density<br>(10-1kg/m3) | 空气动粘滞系数<br>Dynamic Viscosity<br>(10-5N s/m2) |
|---|---|---|---|---|
| -1000 | 21.50 | 11.39 | 13.47 | 1.821 |
| 0 | 15.00 | 10.13 | 12.25 | 1.789 |
| 1000 | 8.50 | 8.988 | 11.12 | 1.758 |
| 2000 | 2.00 | 7.950 | 10.07 | 1.726 |
| 3000 | -4.49 | 7.012 | 9.093 | 1.694 |
| 4000 | -10.98 | 6.166 | 8.194 | 1.661 |
| 5000 | -17.47 | 5.405 | 7.364 | 1.628 |
| 6000 | -23.96 | 4.722 | 6.601 | 1.595 |
| 7000 | -30.45 | 4.111 | 5.900 | 1.561 |
| 8000 | -36.94 | 3.565 | 5.258 | 1.527 |
| 9000 | -43.42 | 3.080 | 4.671 | 1.493 |
| 10000 | -49.90 | 2.650 | 4.135 | 1.458 |
| 15000 | -56.50 | 1.211 | 1.948 | 1.422 |
| 20000 | -56.50 | 0.5529 | 0.8891 | 1.422 |
| 25000 | -51.60 | 0.2549 | 0.4008 | 1.448 |
| 30000 | -46.64 | 0.1197 | 0.1841 | 1.475 |
| 40000 | -22.80 | 0.0287 | 0.03996 | 1.601 |
| 50000 | -2.5 | 0.007978 | 0.01027 | 1.704 |
| 60000 | -26.13 | 0.002196 | 0.003097 | 1.584 |
| 70000 | -53.57 | 0.00052 | 0.0008283 | 1.438 |
| 80000 | -74.51 | 0.00011 | 0.0001846 | 1.321 |



## Part Four – Characteristics of upper-air flight

### 1. Characteristics of upper atmosphere

Physical properties of atmosphere dependent on altitude

| Geo potential Altitude above Sea Level<br>-h-<br>(m) | Temperature<br>-t -<br>(oC) | Absolute Pressure<br>-p -<br>(104N/m2) | Density<br>(10-1kg/m3) | Dynamic Viscosity<br>(10-5N s/m2) |
|---|---|---|---|---|
| -1000 | 21.50 | 11.39 | 13.47 | 1.821 |
| 0 | 15.00 | 10.13 | 12.25 | 1.789 |
| 1000 | 8.50 | 8.988 | 11.12 | 1.758 |
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| 3000 | -4.49 | 7.012 | 9.093 | 1.694 |
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| 80000 | -74.51 | 0.00011 | 0.0001846 | 1.321 |

## 2. 从表中可以总结出于本大赛着陆舱设计相关注意事项

（1）高空低温，两千米以上就会达到零摄氏度，高空气球需要达到3000米（海拔5700米），这一高度气温可接近零下23摄氏度左右，而一般的电池在零下20摄氏度就会失去功能，集成电路在零下40摄氏度就会无法工作。但只要着陆舱注意保温，这些部件工作时自己的产热就足以维持其自身的温度，工作时产热不足的配件，可以给它贴上暖宝宝。

（2）高空低压。

（3）当达到3000米的时候，气球就在70%的大气以上了，需要考虑着陆舱内电路与舱外空气结缘，否则电路有可能会对大气放电，从而破坏着陆舱内的电子设备。

（4）着陆舱内设备的缓冲和着陆舱于降落伞之间缆绳的牢固连接都是不容忽视的设计要点。

## (五) 安全注意事项

### 1. 对航空交通负责

★时刻和当地空管保持联络；
★一定要有雷达反射片；
★着陆舱重量不能太大，上限是500g；
★绳子一定要结实；

### 2. 着陆舱落地安全

★降落伞足够大；
★着陆舱底部要有冲击吸收材料；
★实现预测飞行轨迹，在气球飞行中不断根据实时GPS信息更新预测轨迹；

### 3. 高压气瓶严格按照安全规程使用

★气球不用氢气，用氦气

### 4. 地面电子设备的假设和操作使用安全

★要接地！
★天线工作时可能会很热！不要用手去触碰天线；

### 5. 心理建设：

★发射前后的各个阶段，不要兴奋过度误操作



## 2. Important conclusions from table above

（1）Temperature drops as altitude increases. Temperature will drop under zero Celsius at 2 kilometers. Temperature at the destined altitude, 5.7 kilometers, is close to negative 23 Celsius. Normal batteries will disfunction under 20 Celsius and integrated circuits will disfunction under negative 40 Celsius. However, as long as the temperature in lander is well maintained, the heat produced by working devices will, in turn, keep themselves working, and when the produced heat isn’t enough, several warm pastes can be useful.

（2）Pressure drops as altitude increases.

（3）Balloon is above 70% atmosphere at altitude of 3 kilometers, where lander should be isolated from the air, or integrated circuits will discharge to air and thus facilities inside will be destroyed.

（4）Buffer for facilities in lander and connections between lander and parachute are important.

## Part Five – Safety Precautions

### 1. Be responsible for air transportation safety

★Constantly keep contact with local air transportation control
★Equip lander with radar reflector
★Limit weight of lander to 1 kg
★Confirm connections between each components

### 2. Ensure a safety landing

★Make parachute big enough
★Equip bottom of lander with buffer materials
★Predict flight track, and update predicted track according to real-time GPS data

### 3. Follow safety regulations strictly when using high-pressure cylinders

★Instill helium, rather than hydrogen, to balloon

### 4. Follow safety precautions for land-based electronic devices

★Connect devices to the ground
★Don’t touch antenna with naked hand. Antenna could be extremely hot

### 5. Pay attention to psychological problems

★Keep calm in each stage to avoid operational mistake

## (六) 飞行过程与航迹推算


发射升空后的上升阶段，如上图绿色轨迹所示，气球在当地当天风力作用下逐渐上升到最高点而爆裂。经过最高点后，如上图红色轨迹所示，气球又在降落伞逐渐减速下，在当地风力作用下，飞过一段距离后最终落地。

利用在谷歌地球资源的基础上开发的这款软件http://predict.habhub.org/

就可以实时预测全球任意位置，指定重量的着陆舱搭载某种气球，在当地当天风势影响下飞行的大概轨迹。借助这款软件以及许多类似的在线预测软件，就可以合理规划飞行路线，避免让着陆舱降落于湖面、高山中等难以到达的位置。

## (七) 各个组件（建议）排列顺序

### 1. 气球

采用统一规格的乳胶气球。越大的气球，可以承载的着陆舱载重量越大，同时留空时间越长，飞行距离越远。为了保证赛事公平，此次采用统一规格的气球。



## Part Six - Prediction of flight track


During rising time, as indicated by the green area, balloon will rise under the influence of wind to zenith and explode. After that, as indicated by red area, lander will descend under the influence of parachute and wind and finally land.

Use the resources from Google Map  http://predict.habhub.org/

to predict flight track of any object with given weight and location under influence of current wind. With the help from this prediction APP, or any other similar APP, designers can manipulate flight path to avoid landing on unreachable places such as lake and mountain.

## Part Seven – Recommended arrangement of components

### 1. Balloon

MLP  provides standardized latex balloon to ensure fairness of this competition. Larger balloon can load heavier lander, but take longer flight time and greater flight distance.

**操作注意事项：**

★操作气球时注意一定要带手套，防止手上油脂和汗水破坏气球表面涂层。

★不能用手去触摸气球表面，会造成局部的显微伤痕，这样的气球将在升空过程中提早爆裂。

★气球充加氦气时，如何判断气球已经充满?

**首先确保气球已经牢固系留在地面！**

将气球暂时连接到一个水桶上，桶和水的重量已经按照降落伞和着陆舱总重调整好，比它们的总重略大10克左右。然后向气球中充气，直到气球刚刚能将水桶提起来，就可以换上降落伞和着陆舱了。如果想加快上升速度、缩短留空时间，可以多充一些气，但这样会增加气球爆裂的风险。

## 2. 缆绳

降落伞、滑翔伞的缆绳及其配套的挂钩就能充满满足要求，这些缆绳可承受数百公斤的力量，重量也很轻。

## 3. 缆绳切割装置

缆绳切割装置需要从地面发送信号，触发着陆舱中某种机械/机电装置，将缆绳在降落伞以上的位置切断，从而人为、可控地中止飞行。

目前，高空气球还没有开发出普遍适用的自动切割装置，这也成为本项目 的重心。

**缆绳自切装置的原理主要有：**

1) 用电流、电弧熔化缆绳

2) 机械触发式的刀刃直接切割

为了保证自切可靠性，有时需要同时具备两到三种自切机构。



**Tips :**

★Wear gloves when touching balloon to prevent oil and sweat from hands erode surface coating

★Don’t pinch balloon to avoid tiny scratch, or balloon will explode below expected distance.

★How to determine that balloon is fully filled with helium?

First of all, make sure balloon is firmly fixed to the ground. Connect balloon to a bucket with water, whose weight in total is about 10 g greater than lander and parachute. Fill balloon with helium until it can lift the bucket. To increase the rising speed, designers can fill balloon with more helium, which, however, will increase the danger of balloon explosion.

## 2. Cable

Cables and their matching hooks of parachute can completely meet our need. Those light-weighted cables can endure weight more than 100 kg.

## 3. Self-cutting Device

Self-cutting device receives signals from the ground that triggers mechanically or electromechanically device that can cut off cable. This device enables a controllable flight.

Currently, a universally applicable self-cutting device is not yet developed by MLP . Therefore, invention of such device will be core of this competition.

**Potential work principles of a self-cutting device:**

1)melt cable with electric current and electric arc

2)cut off cable with mechanically triggered blades

Note: to increase reliability of self-cutting device, two to three cutting mechanisms are simultaneously required.

## 4. 降落伞

脱离气球后着陆舱开始下坠，降落伞顺势打开，可让着陆舱在减速中水平飞行相当远的距离，最后以不高的着陆速度冲击地面。

在有泡沫塑料等缓冲材料吸收冲击力的情况下，摄像机镜头等贵重配件可以在一定程度上承受较高的接地速度；落地速度最好在3米每秒以下，最高不要超过5米每秒。

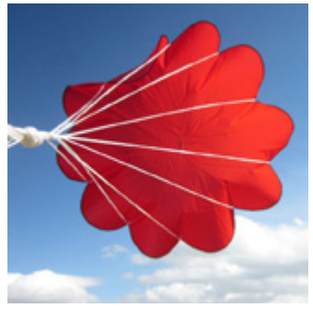
对于总重在一公斤左右的小型着陆舱，只需要直径2米的降落伞即可达到3米以下的着陆速度。而重量更大的着陆舱，如5公斤着陆舱，则需要直径4米的降落伞才能减速到3米以下。

利用以下的在线计算器可以针对所设计的着陆舱重量确定降落伞尺寸：
https://community.balloonchallenge.org/t/parachute-overview/659
跟气球一样，着陆舱越重，降落伞必然越大，着陆舱在脱离气球后的下降段必然留空时间越长。

### 依照降落伞形制的不同，有两种安装方式

1)推荐使用伞顶带有眼环的降落伞，这样可以直接按照气球-降落伞-着陆舱的顺序串联三者，如本手册简介中示意图所示。

2)普通降落伞可将伞绳和气球一并连接到着陆舱顶，发射上升时气流方向会让降落伞无法打开，降落时伞可在气流作用下顺势打开。





## 4. Parachute

Parachute will open once lander starts to descend, and decelerate lander so that it can land in a safely low speed. However, lander will travel a longer horizontal distance due to its deceleration.

With the help of buffering materials such as plastic foam, expensive devices such as camera can bear a relatively high landing speed. Recommended landing speed is 3 m/s or below, and it should no more than 5 m/s.

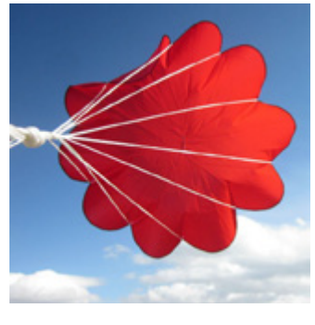
For a small 1kg lander, a parachute with radius of 1 m is adequate to decelerate it to 3 m/s, while, for a big 5kg lander, a parachute with radius of 2 m is required.

Use online calculator below to determine the size of parachute according to weight of lander.
https://community.balloonchallenge.org/t/parachute-overview/659
Similar to balloon, a heavier lander requires a larger parachute, which will definitely increase descending time.

### Two methods to install parachute

1) Parachute with a ring on the top is recommended. With the ring, designers can easily connect balloon, parachute and lander with cables and hooks as indicated by figure 1.

2) Parachute without a ring can be connected with lander together with balloon. During rising time, downward airflow will automatically shut the parachute off, and during descending time, upward airflow will automatically open it.



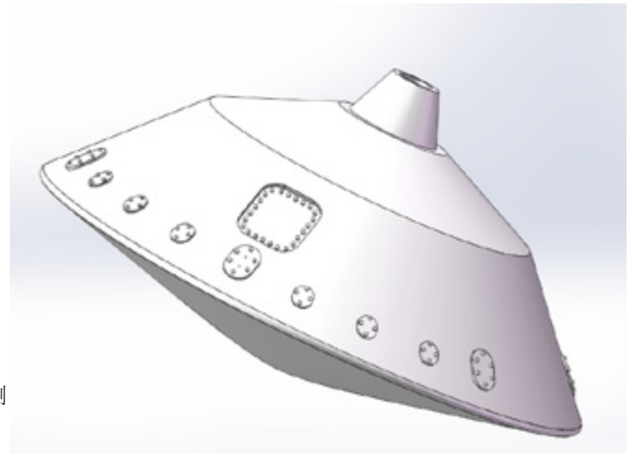
## 5. 雷达反射片

方便空管把握气球的飞行轨迹，可以自制，只需要将铝箔贴在卡纸上，最好制作成如图的多个平板交叉在一起的形态，而不能仅仅只有一个平板，因为这样的话，某些方向发射来的雷达波将无法反射回去。

## 6. 着陆舱设计

着陆舱要能够承担降落时的冲击力，同时重量要尽量轻，而且要能保温绝热。

着陆舱也可能会在高空中意外打开甚至破碎，作为预防措施，所有着陆舱内的配件最好通过不止一条缆绳与气球的主缆绳相连接，这样可以增加设计的可靠性，但也带来额外的重量。



着陆舱中的基础组件包括照相机、电池、嵌入式处理器、GPS等追踪装置；升级组件包括各种遥测装置而自选创意任务组件。

## 7. 电池

推荐使用锂离子电池，可以采用一次性的也可以是可反复使用的。锂离子电池重量轻、能量密度大，温差变化的耐受能力也最强。锂离子电池充电过度会降低其能量存储能力，使用充电式锂离子电池时需要注意。所有电池均不耐低温，低温下电池的内阻会越来越高，以致输出电压越来越低；锂离子电池在0摄氏度性能受到很大影响，-20摄氏度时几乎完全失去功能；电池需要用隔热材料包裹，这样电池工作时自身产热就能够温暖电池；如果需要，还可以贴上暖宝宝。电池供电线、仪器数据线等也需要类似的保温措施。

## 8. 嵌入式处理器

着陆舱的控制核心，依靠电池供电，最基本的功能是将GPS接收信号转换成无线电编码信号，输送给着陆舱上的天线，这样地面人员才能接收到气球的追踪信号。

还可以添加更加复杂的嵌入式操作系统，类似电瓶车和汽车上的系统，从而实现高空气象参数测量等遥感功能，以及一些创意环节，如释放纪念物等等。

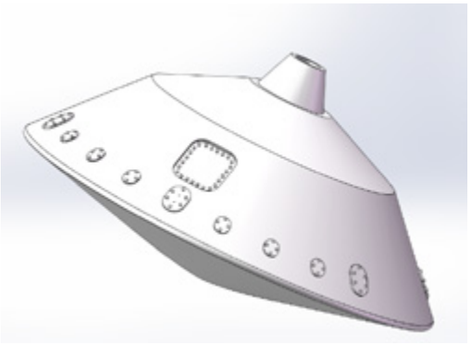


## 5. Radar Reflector

Radar reflector enables air transportation control to track balloon. Designers can make a radar reflector by themselves: cross the plate coated with aluminum foil paper as indicated by picture on the right. A single plate isn’t enough because in this way signals from certain direction will not be reflected.

## 6. Lander

Lander should endure impact from the ground, and be light-weighted and heat-insulated.
Lander could be accidentally disconnected with parachute and balloon at high altitude. Therefore, as a safeguard measure, lander could be connected with other components in multiple ways. However, this measure brings reliability as well as extra weight.



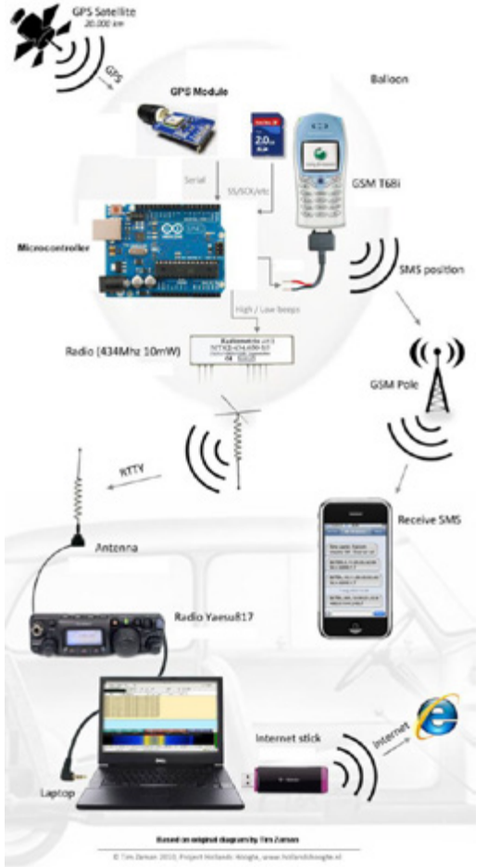
Basic devices in lander include camera, battery, embedded sensors, tracking devices such GPS; extra devices include various telecontrol and telemetry devices and other creative devices.

## 7. Battery

Lithium-ion battery is recommended, and it can be either reusable or not. Lithium-ion battery is light-weighted with large energy density and excellent endurance to temperature changes. Pay extra attention when using chargeable lithium-ion battery, because overcharge will decrease its capability to store energy. All kinds of batteries will disfunction under low temperature, because their inner resistance will dramatically increase and thus output voltage will dramatically decrease. Lithium-ion battery is greatly influenced under zero Celsius and stops working at negative 20 Celsius. Therefore, battery should be wrapped up with heat-insulated materials, so that heat generated at work will be preserved; if needed, warm pastes can be useful to maintain temperature. Designers should also maintain temperature for supple lines of all kinds of devices.

## 8. Embedded Sensors

Embedded sensors are essential to control system and powered by battery. Their basic function is to convert GPS signals to coded radio signals and then transmit these signals to antenna of lander so that ground crew can receive them.
Designers can use more complicated combinations of embedded sensors , like those on the motorbikes and cars, to implement creative tasks, such as collection of weather parameters and release of souvenirs.




## 9. 追踪和遥感

使用GPS或者本地的无线电地面基站，可以对气球整个飞行过程的部分阶段，进行追踪。原则上GPS定位可以一直使用到接近两万米的高度。如果采用本地无线电基站、甚至自制无线电天线/基站来接收GPS信号，则能够达到全程追踪。其架构略图如下：
追踪技术可实现对着陆舱设备的单向控制甚至双向反馈控制，即遥测遥感。

例如可以在着陆舱中携带温度计、湿度计、气压计等高空气象测量设备，用遥感指令激活设备并将测量数据发送回。

此外，还可以增加创意环节，例如指令着陆舱鸣响警笛、释放压载物加快上升速度、放出小飞机等。

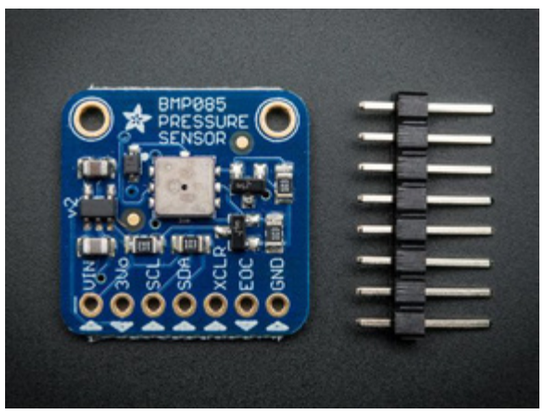
## 10. 着陆舱传感器

着陆舱可以携带各类高空测量仪器，丰富此次探空飞行所能采集的数据。

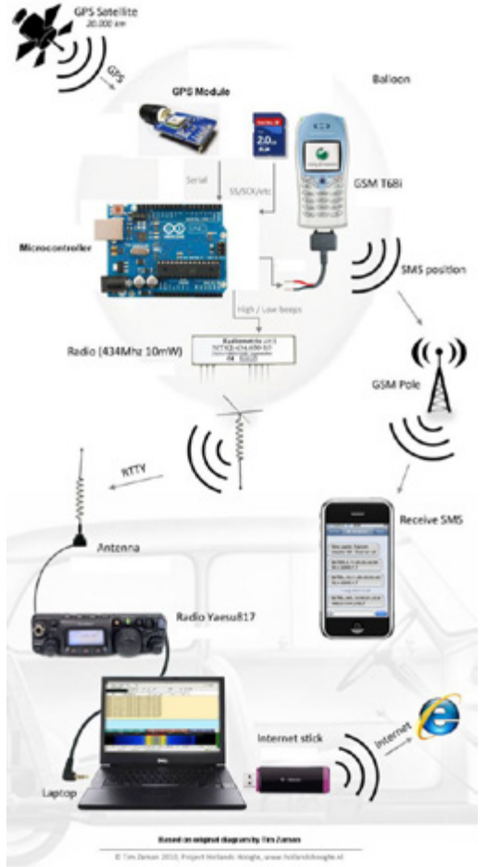
除了常见的温度、湿度计之外。还有：

### 气压计

其读数可转化为高度数据，跟GPS即无线电测高等数据彼此参照。






## 9. Tracking and Remote Sensing

GPS or local ground-based radio station enables designers to keep track of balloon in every stage of flight. Theoretically, GPS will keep working until balloon rises to 20 km. However, a local ground-based radio station, or even a hand-made antenna, allows designers to receive GPS signal and track balloon regardless its altitude. Its principle of work is shown left.

Tracking technology allows both an unilateral control and an interactive feedback control, namely telemetry and telecontrol. For example, designers can activate devices in lander such as thermometer, hygrometer and barometer, and commend them to send collected data back at any time of flight.

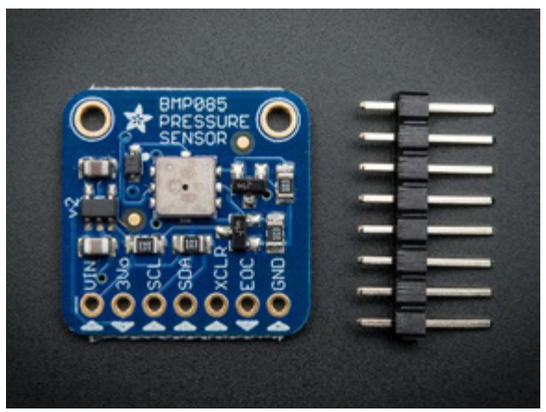
In addition, creative tasks, such as siren, accelerating balloon by releasing masses and releasing tiny airplane, can also be implemented.

## 10. Sensors in lander

Lander can carry various sensors, collecting abundant data in one flight. Besides thermometers and hygrometers, other possible sensors are listed below.

### Barometer

Atmospheric pressure is a good indicator of altitude.



**加速度计**

把加速度计固定在气球-降落伞的主缆上，可测算出底舱上升、气球爆裂和降落过程中所受力的大小以及所受气流冲击的作用强弱。

**地磁计**

把地磁计固定在气球-降落伞的主缆上，可当做指南针使用，实时测量着陆舱飞行的水平方向。

**整个探空气球各个子系统相互依赖关系，如下图：**




**Accelerometer**

Fix accelerometer on cable that connects parachute and balloon to collect data necessary to calculate force exerted on lander in rising time, descending time and at the moment of balloon explosion and impact force exerted by airflow.

**Magnetometer**

Fix magnetometer on cable connecting parachute and balloon to use it as a compass that indicates horizontal flight direction.

**Relationship between each subsystem of sounding balloon is shown below**

## (八) 发射准备与实施的（建议）流程

### 1. 发射前一周的准备工作

#### 1) 列出配件清单，对照检查

| 配件自查清单 | |
|---|---|
| 名称 | 数量 |
| GPS | 2 |
| 气球 | 2 |
| 降落伞 | 1 |
| 雷达反射片 | 1 |
| 电池 | 8 |
| 氦气充灌管 | 1 |
| 缆绳和固定抓钩 | 若干 |
| 剪刀 | 1 |
| 扳手 | 1 |
| 其他工具 | |

#### 2) 团队分工明确

★电子设备测试
★硬件材料准备
★航迹预测
★发射步骤安排
发射前一周应当保证GPS，无线电和接收基站以及相机等所有设备正常运转。

### 2. 发射前一天

确保电子和硬件设备的状况良好
进行航迹预测
确定并列出发射步骤
（发射日心情激动的情况下可以按照步骤安排逐项进行）



## Part Eight – Recommended Preparations For Launch

### 1. Preparations for one week before launch

#### 1) Make a list of needed components and check your stuffs according to it

| List for Self-check | |
|---|---|
| Name | Quantity |
| GPS | 2 |
| Balloon | 2 |
| Parachute | 1 |
| Radar Reflector | 1 |
| Battery | 8 |
| Helium Instillation Tube | 1 |
| Cable and Hook | several |
| Scissor | 1 |
| Wrench | 1 |
| Other Tool | |

#### 2) Specify and clarify work for each member in team. Some possible specifications are listed below

★Test electronic devices
★Prepare hardware
★Predict flight track
★Arrange and organize final launch
Note: make sure devices, especially GPS, antenna, and camera, work well

### 2. Preparations for one day before launch

-Make sure all electronic devices work well
-Predict flight track
-Finalize and clarify procedures for launch
-Keep calm to follow these procedures carefully

**步骤表举例**

| 日期2018/x/x | 地点 | 事项 |
|---|---|---|
| 8:30 | 冷湖营地 | 装好各种设备材料 |
| 9:00 | 路上 | 出发 |
| 10:30 | 发射场 | 发射准备 |
| 11:00 | 发射场 | 发射！ |
| 11:15 | 路上 | 追踪 |
| 1:10 | 降落场 | 目击着陆 |
| 1:45 | 降落场 | 回收 |

### 3. 发射日

按照上表程序行事，到达发射场后

**1) 再次预测航迹**

**2) 测试GPS/无线电工作情况**

**3) 组装着陆舱，用缆绳与氦气球连接**

### 4. 发射后追踪气球

发射后按照推算的航迹追踪气球，至少需要两人协同：
驾驶员专心按照航迹驾驶，同时注意导航员的修正指令
导航员通过GPS/无线电来实时更新实际航迹
有些GPS可能存在限高，往往只能在上升和降落阶段使用。
首先，发射后用实时GPS数据更新航迹预测，朝预测降落点行驶
着陆舱开始降落后，用接收到的GPS数据再次更新航迹预测。

### 5. 着陆舱回收

着陆舱无动力，落地后一般也不会移位，因此记住，安全第一。

## (九) 禁止使用的辅助设备

禁止使用无人机观测气球飞行状态，因为可以利用无人机蓄意干扰其他参赛队的地面信号接收，甚至可以直接用无人机恶意攻击其他参赛队的气球。



**Schedule of launching day**

| Time | Location | Event / work |
|---|---|---|
| 8:30 | Cool Lake camp | Prepare all necessary stuffs |
| 9:00 | / | Set out to launching field |
| 10:30 | Launching field | Prepare for final launch |
| 11:00 | Launching field | Launch |
| 11:15 | / | Track balloon |
| 1:10 | Landing field | Witness landing |
| 1:45 | Landing field | Recover lander |

### 3. Preparations and work on day of launch

Follow the schedule above. Preparations after arriving at launching field are listed below:

**1)Predict flight track**

**2)Test GPS and antenna**

**3)Assemble lander and connect each component with cable**

### 4. Track balloon after launch

This task requires at least two people to cooperate:
Driver is responsible for driving according to instructions from navigator. Navigator is responsible for updating the driving routine for driver according to real-time data from GPS.
Some GPSs have altitude limit and only work in some stages of rising and descending. Therefore, navigator need to predict landing location according to collected data, and once receiving descending data, correct driving routine.

### 5. Recover lander

Lander has no motor, so it won’t move once landing. Put your safety to the first place.

## Part Nine – Not Permitted Devices

Unmanned aerial vehicle is not permitted, because unmanned aerial vehicle can be used to observe balloon in flight and disturb other teams’ balloon and signal receiver.

## (十) 着陆系统各个部分设计要求

### 1. 着陆舱

着陆舱是承载所以载荷的关键子系统，包含：底部、碗状流线外壳、设备舱、载荷舱。底部主要起缓冲、保护作用；碗状流线外壳设计以流线外形为主，主要为了减少除底部以外的其他部位与空气摩擦。

**着陆舱设计需要考虑：**

★造型设计如何科学，合理?
★着陆舱的气密性如何保证?
★着陆舱如何实现隔热?
★整体重量是否超标?
★整个体积是否超标?
★如何保证着陆舱的能源供应？以及如何实现能源设施的保温?

### 2. 辅助减速装置

辅助减速装置是保证着陆舱安全降落的重要子系统，通常使用降落伞。

**辅助减速装置设计需要考虑：**

★通常采用的减速辅助装置有哪些？发挥功能的阶段?
★如何实现对低温的适应性?
★如何实现对低气压的适应性?
★如何控制减速辅助装置的重量?

### 3. 测控系统

测控系统是整个着陆系统的控制中枢，此次赛事中主要采用开源平台Arduino实现对各个部分的控制，同时实时获取高度、温度、气压等数据，并且能在着陆舱落地后发送定位。



## Part Ten – Requirements for subsystems of landing system

### 1. Lander

Lander is an important subsystem and includes a bottom base, a bowl-shaped streamlined shield, an equipment bay and a payload capsule. The bottom base has protective function for landing, the bowl shaped streamline shield is to reduce the air resistance.

**Factors to consider when designing a lander:**

★How to design an appropriate shape?
★How to promise air tightness of lander?
★How to make lander heat-insulated?
★Whether weight of lander is appropriate?
★Whether volume of lander is appropriate?
★How to promise energy supply? How to maintain temperature for energy suppliers?

### 2. Auxiliary Decelerating Devices

Auxiliary decelerating device is an important subsystem to promise safety of lander, and generally consists of a parachute.

**Factors to consider when designing decelerating device:**

★What are common decelerators?
★How to deal with influence of low temperature?
★How to deal with influence of low pressure?
★How to limit weight of this device?

### 3. Monitor and Control System

Monitor and control system is an important subsystem to control landing system. In MLP , Arduino is used to control each component as well as collect data such as altitude, temperature and pressure, and finally send landing location.

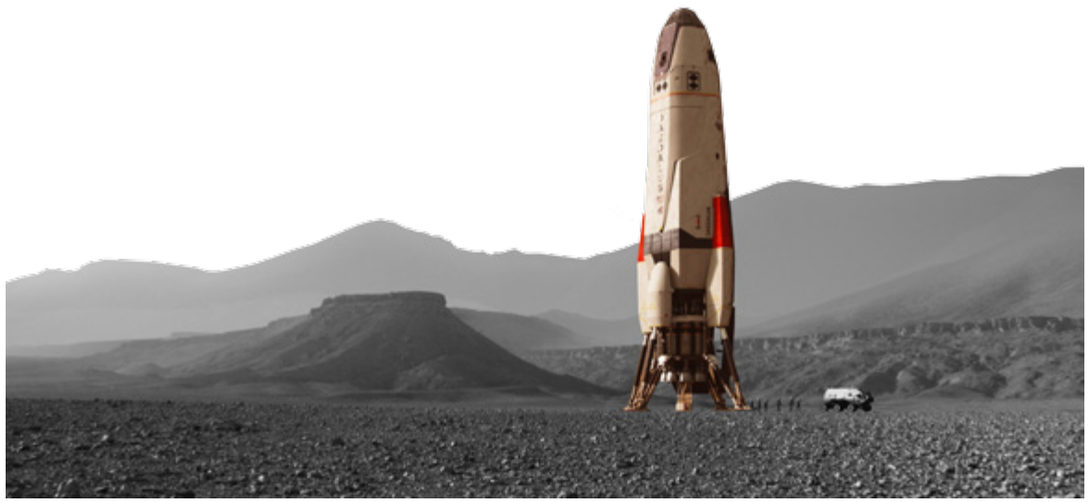
**辅助减速装置设计需要考虑：**

★完成此次任务需要用到的载荷有哪些？如何让这些载荷良好工作?
★到达指定高度后，如何确保启动脱离气球的指令?
★如何顺利启动减速装置系统?
★如何实现对低温、低气压的适应性?
★如何实现实时传输数据?
★如何确保数据的可靠性?

## (十一) 评分细则

### 1. 城市初赛

城市初赛阶段重点展示各个队伍的设计方案以及模型，交付内容为：学术海报+物理模型。大赛组委会提供材料套件，参赛队伍可使用套件材料，也可在约束条件内采用其他材料自行设计。





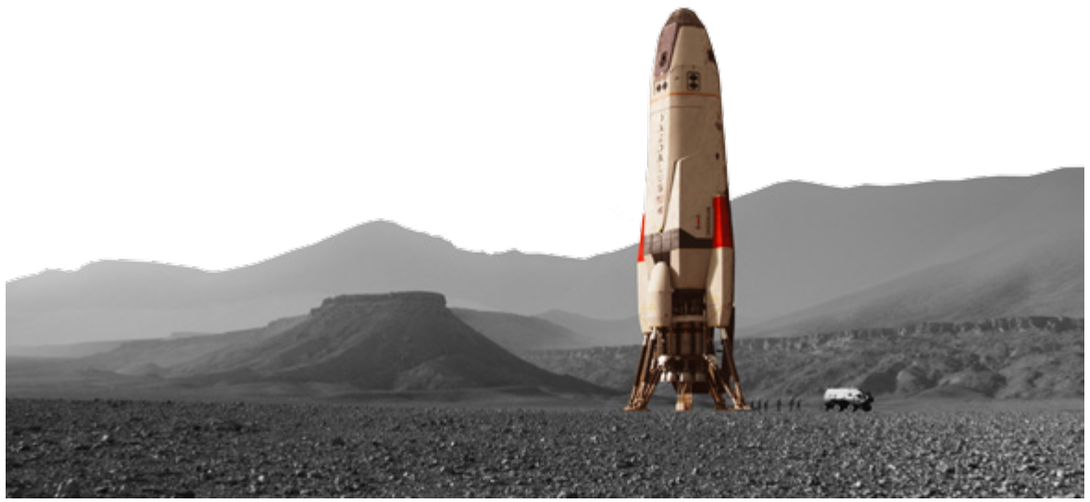
**Factors to consider when designing monitor and control system:**

★What modules are required for this task? How to make them work well?
★How to commend to cut off balloon once reaching destined altitude?
★How to successfully turn on decelerating device?
★How to deal with influence of low temperature and pressure?
★How to transmit data?
★How to improve the reliability of collected data?

## Part Eleven – Grading Rules

### 1. Regional Preliminary Competition

This round focuses on design and solid model. Participants need to submit an academic poster and a solid model. MLP committee will provide material pack, but participants can also use their own materials that are permitted.



## 城市初赛评分细则

| 交付内容 | 评分细则 | | 分值 |
|---|---|---|---|
| 学术海报（65分） | 海报内容 | 着陆舱：3D设计图样，设计合理<br>辅助减速装置：以文字或是图表的形式说明减速辅助装置类型，有清晰的设计图纸和工作原理说明方框图，设计合理。<br>测控系统：以图表或是文字形式说明工作原理、设计要点并且设计合理。<br>着陆系统：以文字或者方框图的形式，说明着陆系统工作原理、设计要点。 | 40 |
| | 呈现方式 | 方案和设计有创新性、科学性、可行性 | 10 |
| | | 美观性：海报具有良好的视觉呈现效果，图文并茂 | 5 |
| | | 范性：<br>海报支持统一使用A1大小<br>示意图清晰<br>无错别字 | 5 |
| | | 可读性：图文展示清晰，突出设计要点。 | 5 |
| 物理模型（35分） | 物理模型 | 模型美观、设计合理 | 10 |
| | | 视频符合时长要求，并有清晰简短的说明 | 10 |
| | | 视频中演示着陆舱与气球顺利脱离 | 15 |
| 合计 | | | 100 |



## Grading Guide

| Submitted Materials | Detailed Grading Guide | | Score (point) |
|---|---|---|---|
| Academic Poster (65pt) | contents | Lander: 3D diagram, reasonable design<br>Auxiliary decelerating device: text or graphical description of its type, clear design diagram and block diagram of its work principles<br>Monitor and control system: text or graphical description of its work principles, reasonable design<br>Landing system: text or block diagram of its work principles | 40 |
| | Appearance | Creative, reasonable, and practical | 10 |
| | | Aesthetics: aesthetically good | 5 |
| | | Regularity:<br>A1 size<br>Clear and informative diagram<br>No misspelled word | 5 |
| | | Readability: clear arrangement of text and diagram | 5 |
| Solid Model (35pt) | Solid Model | Aesthetically good and scientifically reasonable | 10 |
| | | Within time limit, brief and instructive | 10 |
| | | Successful departure of lander from balloon shown in video | 15 |
| Total | | | 100 |

## 2.大区复赛

大区复赛通过现场演讲展示、专家答辩、实际演示等环节评选出优秀队伍。

| 大区复赛评分细则 | | |
|---|---|---|
| **内容** | **评分细则** | **分值** |
| 模型展示（100分） | 模型美观、设计合理 | 20分 |
| | 着陆舱载荷功能 | 20分 |
| | 着陆系统重量：上限为500g；每减少5g，加5分，最高分值为30分 | 10-30分 |
| | 现场成功实现着陆舱与气球脱离 | 10分 |
| | 实时传输数据（含高度、温度等） | 20分 |
| 演讲展示（50分） | 着陆系统整体设计科学、合理 | 15分 |
| | 语言表达流畅、逻辑清晰；阐明设计原理、突出设计要点 | 15分 |
| | PPT制作精美 | 10分 |
| | 现场答辩流畅 | 10分 |
| 合计 | | 150分 |

## 3. 决赛

决赛只有手动阶段，在指定时间内于规定场地内，完成要求获得相应分数。

| 决赛评分细则 | | |
|---|---|---|
| **内容** | **评分标准** | **分值** |
| 物理模型 | 模型美观、设计合理 | 10 |
| | 着陆舱载荷功能 | 10 |
| | 着陆系统重量：上限为500g；每减少5g，加5分，最高分值为30分 | 10-30分 |



## 2. Regional Semi-final Competition

This round selects outstanding teams by oral presentation, expert assessment, etc.

| Grading Guide | | |
|---|---|---|
| **Submitted Materials** | **Detailed Grading Guide** | **Score (point)** |
| Model Presentation (100pt) | Aesthetically good and scientifically reasonable | 20 |
| | Lander’s loading capability | 20 |
| | Weight of landing system:Upper limit is 1kg. Every reduced 5 g earns 5 points. Highest score is 30 points. | 10-30 |
| | Successful departure of lander from balloon on the spot | 10 |
| | Real-time data transmission, including altitude, temperature, etc. | 20 |
| Oral Presentation (50pt) | Overall scientifically reasonable | 15 |
| | Fluent speech, clear logic, brief explanation of design principles | 15 |
| | Elegant PPT | 10 |
| | Fluent conversation with experts | 10 |
| Total | | 150 |

## 3. Final Competition

Final round only requires hands-on operation. Participants need finish following tasks to acquire points in competition field in limited time.

| Grading Guide | | |
|---|---|---|
| **Contents** | **Detailed Grading Guide** | **Score (Point)** |
| Solid Model | Aesthetically good and scientifically reasonable | 10 |
| | Lander’s loading capability | 10 |
| | Weight of landing system:<br>Upper limit is 1kg. Every reduced 5 g earns 5 points. Highest score is 30 points. | 10-30分 |

| 决赛评分细则 | | |
|---|---|---|
| **内容** | **评分标准** | **分值** |
| 实际测试 | 上升高度到3000米 | 15 |
| | 实时数据传输，获得确定的最高点温度、气压等数据 | 15 |
| | 着陆舱成功脱离气球 | 10 |
| | 返回地面时的加速度 | 10 |
| | 落地后登陆器的完好程度 | 50 |
| | 取回登陆器的时间 | 50 |
| 合计 | | 200分 |

## (十二) 奖项设置

证书：参赛队伍均可获得相应级别的证书；
大区复赛优胜队伍（96支）：可获得奖杯，以及奖金1000元/队；
决赛冠军队伍：获得冠军奖杯，以及奖金5000元/队。

## 4. 资料包

### (一) 火星着陆的基本方法和火星着陆器的基本构造

从20世纪60年代到今天，人类已经陆陆续续尝试了近20次向火星释放着陆器，在这个过程中逐渐发展出了一套由“防热大底”（Heat Shield）、降落伞（Parachute）、气囊（Airbag）和“反推火箭”（Retro Rocket）组成的完整火星着陆器设计方案。

**图1. 2011年美国航天局“火星科学实验室”项目中向火星释放的“好奇”号火星车正在火星着陆的最后阶段**



| Grading Guide | | |
|---|---|---|
| **Contents** | **Detailed Grading Guide** | **Score (Point)** |
| Field Test | Rise to 3 km | 15 |
| | Real-time data transmission, including altitude, temperature, etc. at zenith | 15 |
| | Successful departure of lander from balloon | 10 |
| | Landing speed / acceleration | 10 |
| | Completeness of lander after landing | 50 |
| | Time to fetch lander | 50 |
| Total | | 200分 |

## Part Twelve – Awards

-Certification:
Each participating team is honored with a certification.
-Outstanding Teams in regional semi-final competition:
Each team is awarded with a trophy and 1000 RMB.
-Outstanding Teams in final competition:
Each team is awarded with a trophy and 5000 RMB.

## 4. Information Pack

### Part One – Method of landing on Mars and structure of Mars lander

From 1960s to now, human have tried to land on Mars for about twenty times and developed a relatively satisfactory design of Mars lander that mainly consists of heat-insulated shield, parachute, airbag and retro rocket.

**Figure 1. Final stage of landing of the Curiosity launched by Mars Science Laboratory of NASA in 2011**

The Curiosity has the same size of a normal car, weights 900 kg, and is heaviest detector that human have successfully sent on Mars. Therefore, landing system of the Curiosity is currently most advanced landing system. Following passage will use it as an example to introduce a method to land on Mars.

**图2. “好奇”号火星车的着陆器外形**

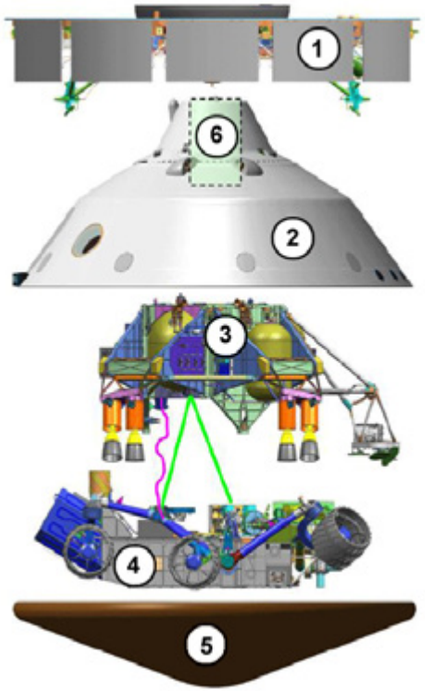



**图3. “好奇”号火星车着陆器构造图解**

“好奇”号的着陆器好像用一只倒扣的碗把火星车罩住，下面又有一个锥形的深色大底。整个着陆器上任务最重的组件，就是构造图上标号为5、位于着陆器最底下的这个浅锥形大底。它是使用绝热材料制成的，作用是防止着陆器被火星大气烧毁——着陆器进入火星大气以后，速度仍然接近每秒六千米，这就造成了着陆器和大气之间剧烈的摩擦，霎时间绝热大底会变成炼钢高炉里面铁水那样的颜色，如下图：

**图4. 火星着陆器进入火星大气后，暂时呈红热状态**





**Figure 2. Appearance of the Curiosity**

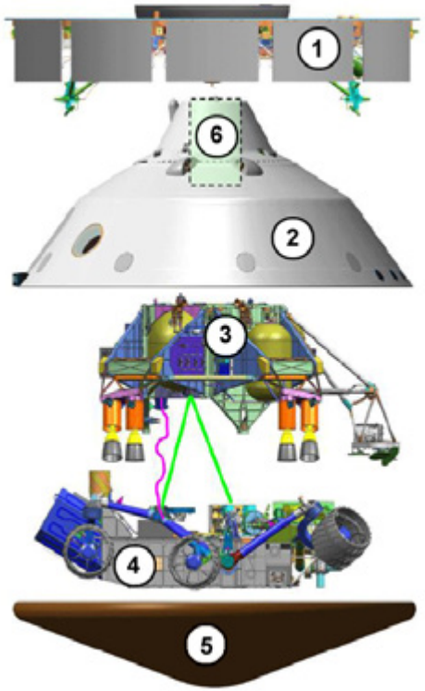



**Figure 3. Structure of lander of the Curiosity**

Lander of the Curiosity is like an upset bowl protecting the Mars rover inside. Its bottom is cone-shaped as shown in Figure 3 num. 5, which undertakes important responsibility. It is made of heat-insulated material to prevent burning in other parts: after entering the Mars atmosphere, lander still travels in a speed of 6 km/s and thus experiences a great air resistance. The bottom will immediately turn red, as shown below.

**Figure 4. Mars lander turns red once entering Mars atmosphere**

如果整个火星着陆器都与火星大气高速摩擦，那么着陆器就会烧毁。不过着陆器会在飞进火星大气的时候，选择大底朝前的飞行方式，就像上图一样。这样一来，就只有大底逐渐被火星大气烧蚀，从而保护了里面的火星车。

倒扣在大底上面的碗状外壳可以给整个着陆器以流线外形，减少着陆器大底之外的部分和火星空气的摩擦。

碗状外壳顶端藏着降落伞（图3. 6号），在合适的时候可以打开来，让着陆器进一步减速。

着陆器最上面是一个环形的装置（图3. 1号），它的作用是领着着陆器到达火星大气层的顶层，以正确的姿态飞入火星大气层。

着陆器的碗状流线外壳和绝热大底之间装着火星车（图3. 4号）和带有反推火箭的“空中吊机”（图3. 3号）。

绝热大底、降落伞、空中吊机，这三个关键组件，在着陆器的整个火星着陆过程中，依次发挥作用。

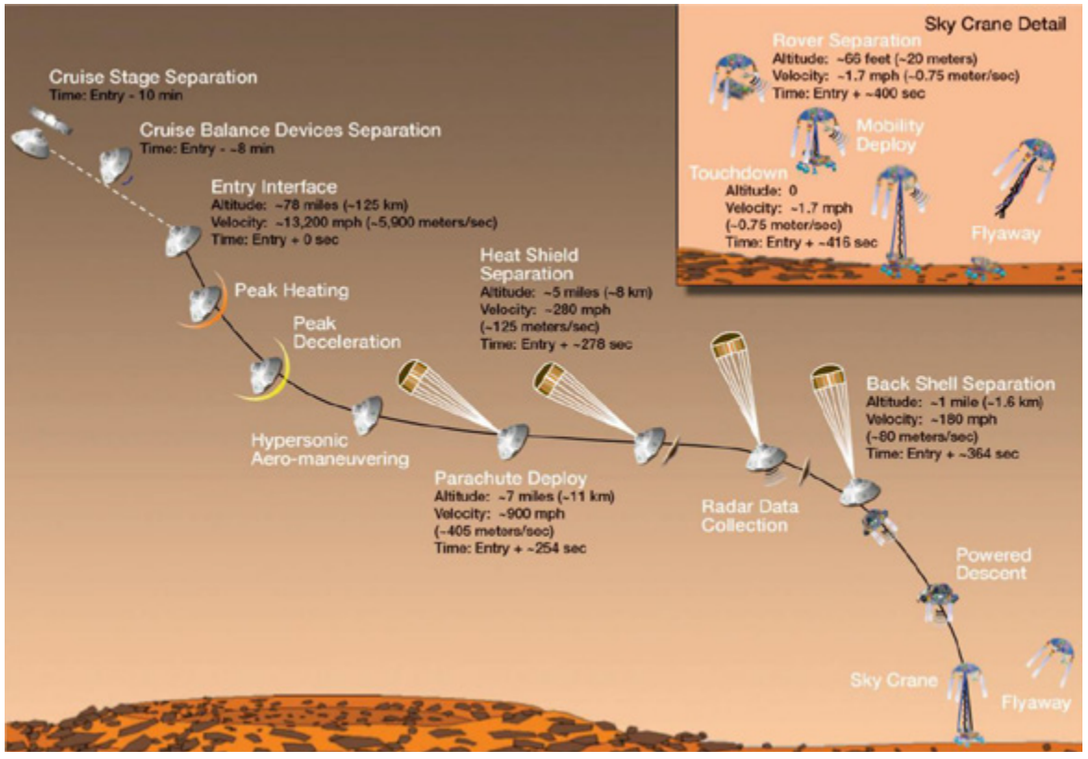



**图5. “好奇”号火星着陆过程图解**



If the whole lander rubs with atmosphere, it will be immediately burnt. However, Mars lander will travel with bottom in the front, as shown in figure 4, and, in this way, only the bottom will be burnt and thus protect rover inside.

The bowl-shaped shield reduces air resistance and minimizes friction of parts besides bottom. Parachute (Figure 3, num. 6) on the top of bowl-shaped shield will open at appropriate moment, and further decelerate lander. The ring on the top of lander (Figure3, num.1) will guide it enter the Mars in correct direction. Mars rover (Figure 3, num. 4) and retro rocket (Figure 3 num.3) are between bowl-shaped shield and heat-insulated bottom.

Heat-insulated bottom, parachute and sky crane are the most essential components.

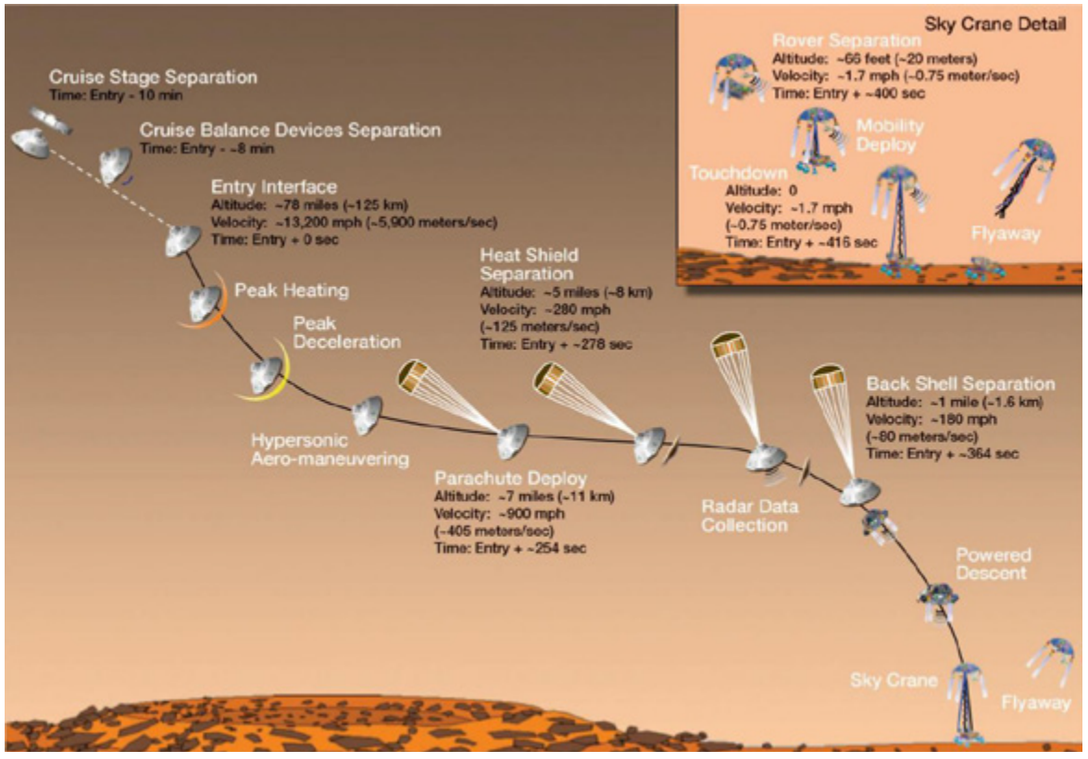



**Figure 5. Landing procedure of Curiosity**

根据上图，首先由着陆器顶端的圆环型推进装置控制着陆器到达火星大气层的顶端，该装置就和着陆器分离了，这时着陆器抛掉配重，绝热大底朝前下方冲入火星大气层，进入火星大气层的速度高达5900米每秒。

于是绝热大底开始发挥作用，通过它自身的逐渐烧蚀、蒸发，带走热量，从而保护着陆器不被烧毁。

大底摩擦烧蚀的阶段，着陆器快速刹车，当速度下降至405米每秒的时候，降落伞打开，开始发挥减速作用。

当降落伞将速度降低到125米每秒的时候，抛弃绝热大底，火星车和“空中吊机”一起吊在白色的碗型流线罩下面。当速度进一步降低到80米每秒的时候，带有降落伞的流线罩和“空中吊机”相分离。

从图1看得出来，空中吊机带有朝四个方向的四组反推火箭，这些火箭开始工作，靠一组缆绳把“好奇”号吊在下面，最后以不到一米每秒的速度让“好奇”号平稳落地，然后吊机自己飞离“好奇”号并最终坠毁。

可见，火星着陆器除了一个包住所有载荷的外壳，其它必不可少的组件，包括【1】一个绝热大底，大底既能保护着陆器不被烧毁，又能迅速刹车减速；【2】一副降落伞，用于着陆器的进一步减速。【3】反推火箭，可以直接安装在固定式探测器的底部，也可以安装在着陆器的外壳上，如果着陆器里搭载的是重型火星车，那么就需要一台安装反推火箭的“空中吊机”来保证火星车上珍贵精密的科学设备最后能以极慢的速度平稳落地。

如果探测器重量较轻，可以像上图一样，将火星车装在一个四面体里，然后周围的气囊充气，在自由落体撞击地面时，提供缓冲。

**图6. “火星探路者”项目中使用的缓冲气囊**

## (二) 人类历次登陆火星的着陆器名称以及特点

无人探测器着陆火星的计划，已经实施过近20次，但成功的只有7次。

1971年苏联向火星发射的“火星2号”、“火星3号”探测器是无人探测器登陆火星的最早尝试，这两个探测器释放的登陆器都在着陆的时候坠毁而失效。

**图7. “火星3号”着陆器模型**



According to Figure 5, once driving lander to upper Mars atmosphere, the top ring departs from other parts. Once taking off the heavy mass on the top, Mars lander enters Mars with bottom in the front in speed of 5.9 km/s. The heat-insulated bottom protect rover from burning by burning itself. In this stage, speed of lander decreases dramatically, and when speed reaches 405 m/s, parachute opens and further decelerates it. When speed reaches 125 m/s, bottom departs from the lander, and Mars rover and sky crane are hung and protected in bowl-shaped shield. When speed reaches 80 m/s, the shield, together with parachute, departs from rover and sky crane. As shown in Figure 1, four retro rockets are installed on sky crane, and start to work in this stage, decelerating lander to land in speed of 1 m/s. After the Curiosity lands, sky crane flies away and destroy itself.

Therefore, we can conclude that, besides a protective shield, a lander should consist of [1] a heat-insulated bottom that protects lander from burning and impact, [2] a parachute that further decelerates lander, [3] retro rockets that can be fixed on either bottom of rover or shield of lander. If the rover is heavy enough, a sky crane with retro rockets is required to protect expansive scientific instrument in the rover.

Rover can be also protected in tetrahedron with filled airbags on each side, if it is light enough. Those airbags will buffer free-falling rover.

**Figure 6. Airbags used for the Curiosity**

## Part Two – Names and Characteristics of Successful Mars Landers

Mars landing plan was implemented for near 20 times, but only 7 of them are successful.

Russian sent Mars 2 and Mars 3 to Mars in 1971. They were the earliest attempts to land on the Mars, but both ended up with failure.

**Figure 7. Model of Mars 3**

从该着陆器设计来看，它虽然有绝热大底和降落伞，但着陆依靠反推火箭的反推力，而没有任何缓冲气囊设备，应当是缓冲火箭工况异常而导致了着陆在最后阶段失败。

1976年，美国成功向火星释放了两个互为备份的“北欧海盗”（Viking）探测器即“海盗1号”和“海盗2号”，两个探测器都成功实现软着陆。

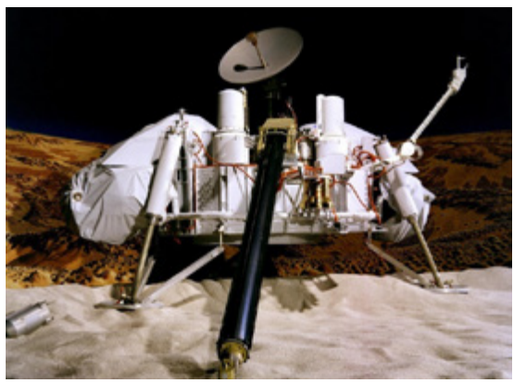


**图8. “海盗”号探测器模型图**　　**图9. “火星探路者”探测器**

“海盗”号探测器和失败的苏联“火星”号探测器都不是火星车，只能在降落地点固定不动，它们的着陆方式也是先用绝热大底减速，然后再打开降落伞减速，最后，和“好奇”号火星车通过“空中吊车”上的反推火箭实现软着陆不同，“海盗”号探测器本身底部的反推火箭让它成功实现软着陆，因为它不需要移动。

1997年，美国将“火星探路者”（Mars Pathfinder）探测器成功释放到火星表面。

这个探测器呈可以打开的四面体，三个“花瓣”可以用太阳能为探测器充电，探测器着陆时使用了缓冲气囊，而且探测器还携带一架小型火星车，能够探索探测器着陆地点周围的环境。

实际上，整个90年代美国航天局开战了5、6个火星探测项目，只成功了两个，其中就包括这里的探路者探测器，同一时期，日本和俄罗斯的火星登陆计划也没能成功。

2003年，欧洲航天局“火星快车”（Mars Express）项目的“鹰”（Eagle）2号着陆探测器在着陆后失联，2015年美国从轨道照片上定位到失联的该探测器。

同年，美国航天局先后发射了两架互为备份的火星车，它们先后于次年成功降落在火星上，即“勇气”（Spirit）号和“机遇”（Opportunity）号



From figure 7, we can see that although Mars 3 are equipped with heat-insulated bottom and parachute, they land by retro rockets without any airbags, which probably leads to failure.

United States successfully send the Vikings, Viking 1 and Viking 2, to Mars.

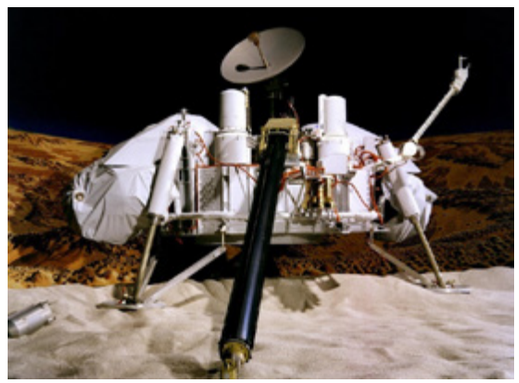


**Figure 8. Model of the Viking**　　**Figure 9. Model of the Mars Pathfinder**

However, both the Viking and the Mars are not rovers: they can’t move once landing. Similarly, they both were decelerated first by insulated bottom and then by parachute. Different from the Curiosity, the Vikings finish their final landing by retro rockets installed on themselves rather than on sky crane, because they don’t need to move around after landing.

After that, United States successfully sent the Mars Pathfinder to Mars in 1997. It is like an openable tetrahedron. Three sides of it can provide power with solar energy, and airbags are used as buffer for landing. It also carries three rovers that explore its surroundings.

However, NASA made approximate five attempts to land on Mars in 1990s, but only two attempts were successful, and one of them is the Mars Pathfinder. At the same time, Japan and Russian made no successful landing.

In 2003, Eagle 2 of NASA’s Mars Express project was out of contact after landing, but was again tracked in 2015 from pictures taken at orbit of the Mars.

In the same year, NASA successfully sent two Mars rovers, the Spirit and Opportunity, to Mars.

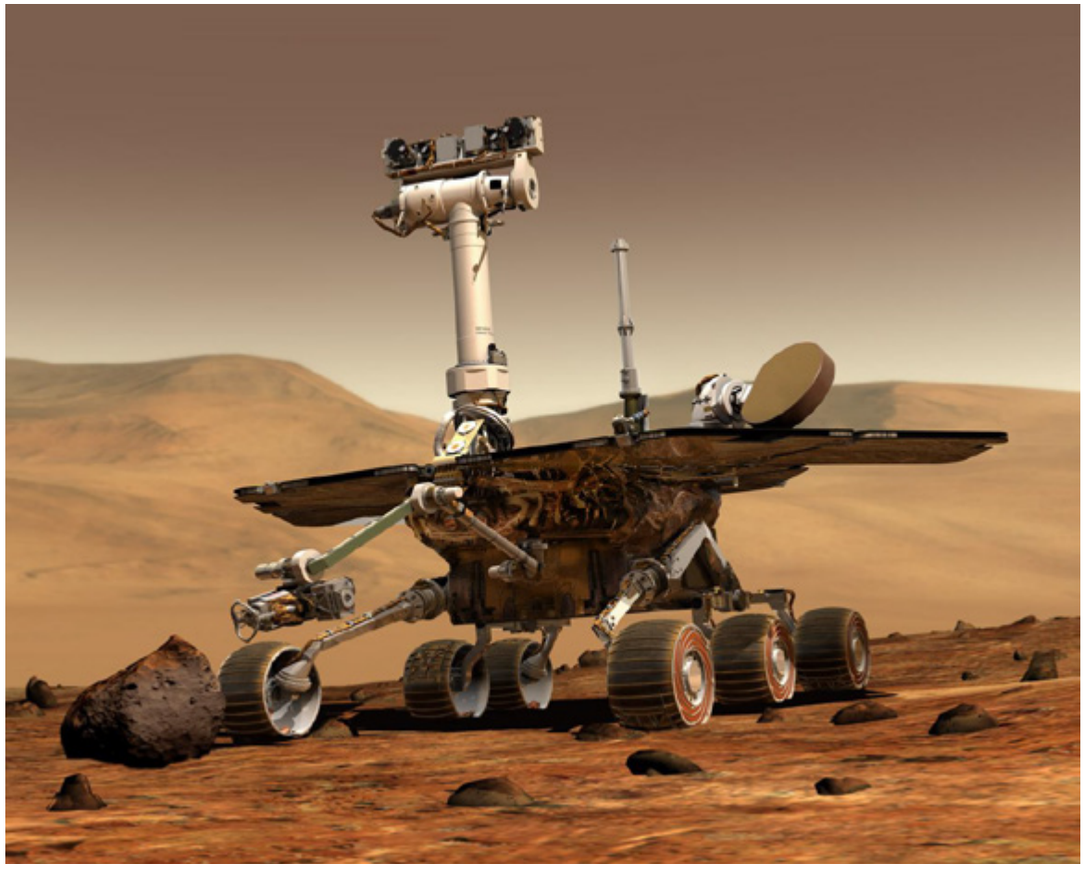


**图10. “机遇”号火星车**

这两个火星车都采用了之前“火星探路者”的成功登陆模式，在绝热大底、降落伞、反推火箭的一系列减速之后，最后还是依靠缓冲气囊来最终实现软着陆。

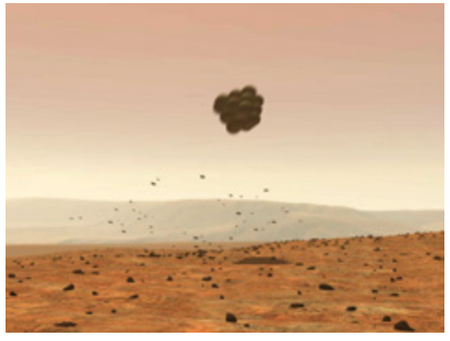


**图11. 装有“机遇”号火星车的四面体型着陆器弹跳着陆**



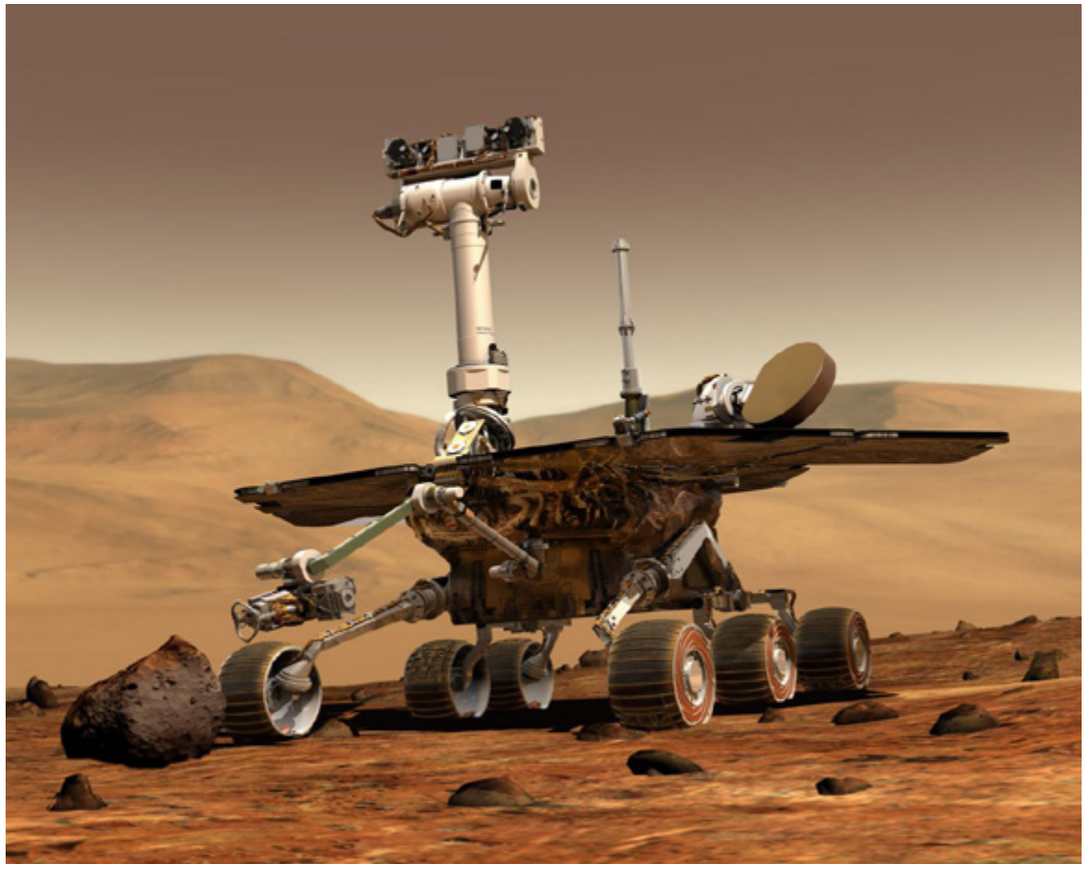


**Figure 10. The Opportunity**

These two rovers land in the same way as Mars Pathfinder does with heat-insulated bottom, parachute, retro rockets and airbags.

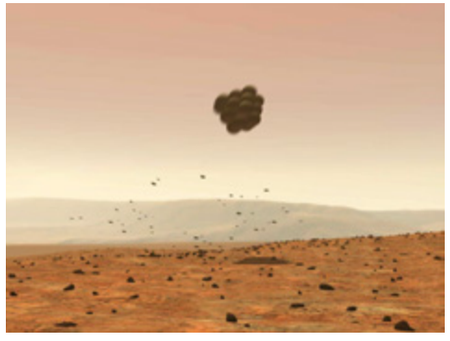
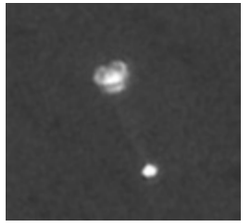


**Figure 11. The Opportunity in tetrahedron airbags lands with bouncing**

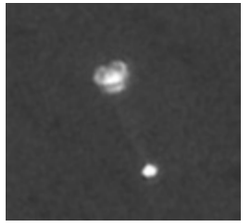


2007年，美国航天局发射了“凤凰”号探测器，这是在降落过程中首次被探测器的无人轨道飞船抓拍到的探测器。

**图12. “凤凰”号探测器打开降落伞下降**

**图13. “凤凰”号探测器软着陆**





In 2007, NASA launched the Phoenix and it’s human’s first time to shot the whole landing process by spacecraft on orbit of the Mars.

**Figure 12. the Phoenix descending with parachute**

**Figure 13. Final landing of the Phoenix**

该探测器为固定式，因此在绝热大底和降落伞减速后，就依靠探测器底部的反推火箭实现软着陆。

2011年发射的“好奇”号火星车采用带反推火箭的“空中吊机”，成功软着陆。

这就是迄今为止成功着陆的7个火星探测器，均为美国发射的，其中有4架火星车。

2018年美国航天局又发射了“InSight”火星地址探测器，已于今年5月发射，需要经过半年的轨道飞行，才能抵达火星引力场。

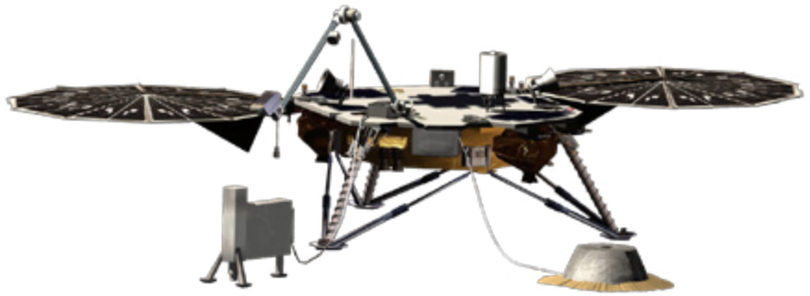


**图14. “InSight”探测器也是固定不动的，使用反推火箭软着陆，然后可以通过它的起重臂，在地面上安放一个地震仪（左）和一个地下温度计（右）**

在以上的火星探测历史中，可以发现，并不是每年都能随意向火星发射探测器，只有当火星和地球之间的相对位置满足一定关系的时候，才能用目前可以接受的发射成本来发射一架火星探测器。从上文大约可以看出，每隔5~7年会有这样的一次发射机会，这种机会称为“发射窗口”（Launch Window），再发射窗口之外发射，如果想要让探测器抵达火星，那么要么所需的火箭的价格达到闻所未闻的天价，要么人类目前的科技水平还不能制造出这样高性能的火箭发动机。

目前实际抵达火星的都是无人探测器，对于未来，人们也在构想载人的火星登陆计划，由于火星拥有大气，载人火星登陆器可以像航天飞机一样带有机翼，这样就可以节省宝贵的火箭燃料，增强登陆器的机动能力。

最基本的火星登陆器将类似于之前的无人登陆器，也主要由绝热大底、降落伞和反推火箭来提供减速，但这些都应该能够重复使用，让着陆器再次起飞，回到火星轨道上。

**图15. 衍生自无人火星探测器的未来载人火星着陆器**



The Phoenix can’t move after landing, so after decelerated by heat-insulated bottom and parachute, it lands with retro rockets on its own bottom.

In 2011, the Curiosity successfully landed by its sky crane with retro rockets.

Those are seven successful Mars detectors and four of them are rovers. All of them are launched by NASA.

In May of 2018, NASA launched the Insight, and it will spend about half year to reach the Mars.

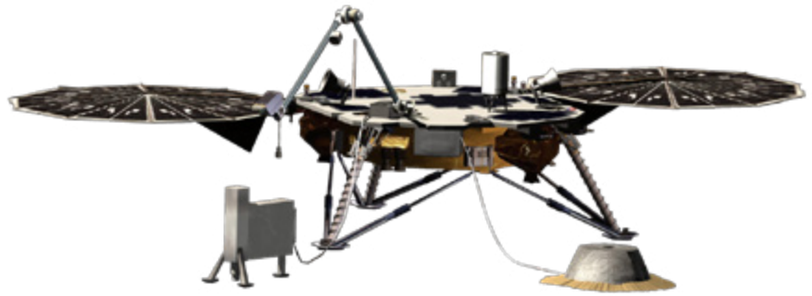


**Figure 14. The Insight is a rover, and lands by retro rockets. It can fix a seismometer (left) and thermometer (right) on the ground with its own booms.**

From history of Mars exploration, we can conclude that we can only launch Mars detectors with acceptable cost when the Mars and the Earth are in appropriate relative position. Such opportunities come every five to seven years and are called Launch Window. Launching Mars detectors not in Launch Window will have unimaginably high cost, or probably human have not developed advanced technology to construct such a rocket.

Currently, all Mars landers are unmanned, but human are conceiving a manned lander. Such lander will probably have wings like airplane to save fuel because atmosphere on Mars is thick enough, and the saved fuel can be used to increase lander’s power. The other part of it should be similar to those unmanned lander consisting of heat-insulated bottom, parachute and retro rockets that are reusable to launch lander back to orbit of the Mars.

**Figure 15. Conceived manned lander according to unmanned landers**

在对火星环境有了更进一步了解的基础上，通过三角翼滑翔机形态的着陆器来节省燃料，就构成一个很好的思路。

**图16. 波音曾提出的“火星滑翔机”计划**

当然，在未来科技进步、资本充裕的情况下，可能会出现可重复使用的大型载人登陆器

**图17. 组图：洛克希德•马丁设想的未来火星航天飞机，当然其“机翼”主要起安定作用，似乎不能产生推力，本质上是一台可以重复使用并且能单级入轨的运载火箭，今天，人类科技水平和它的距离还很远**



With more comprehend knowledge of environment on the Mars, a lander like a delta-wing glider that saves fuel will be also a good idea.

**Figure 16. Mars glider conceived by Boeing**

Certainly, with development of technology and growth of capital, making reusable large manned landers will be possible.

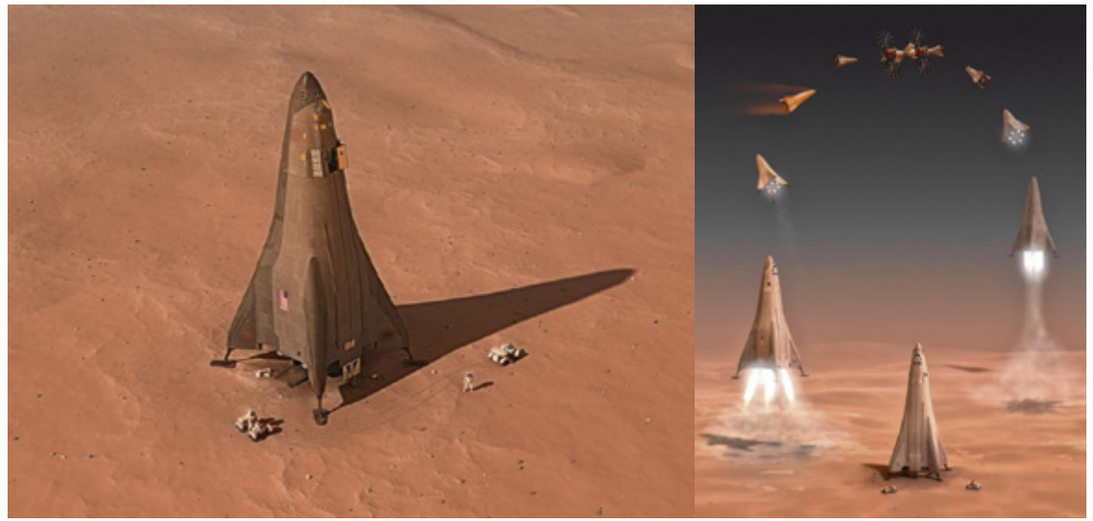


**Figure 17. Large manned Mars airplane conceived by Lockheed Martin. The wings only have supportive function but supply no driving force. This airplane is basically a reusable single-stage-to-orbit rocket. However, human still need to make a great progress to construct it.**

## (三) Aruduino特点以及介绍

Arduino是一款便捷灵活、方便上手的开源电子原型平台。包含硬件（各种型号的Arduino板）和软件（Arduino IDE)。由一个欧洲开发团队于2005年冬季开发。

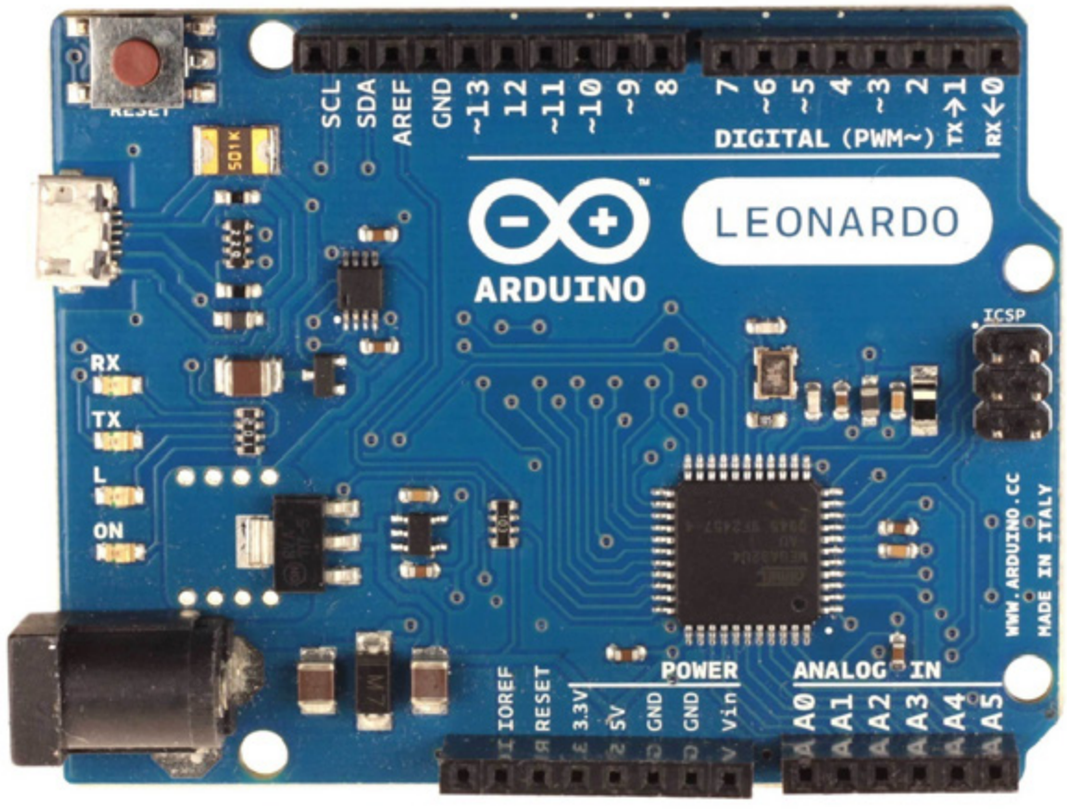



**图18.最常见的Arduino控制板**



## Part Three – Introduction to Arduino

Arduino is an open-source electronics platform and includes hardware (Arduino board) and software (Arduino IDE). It is developed by a European team in winter of 2005.

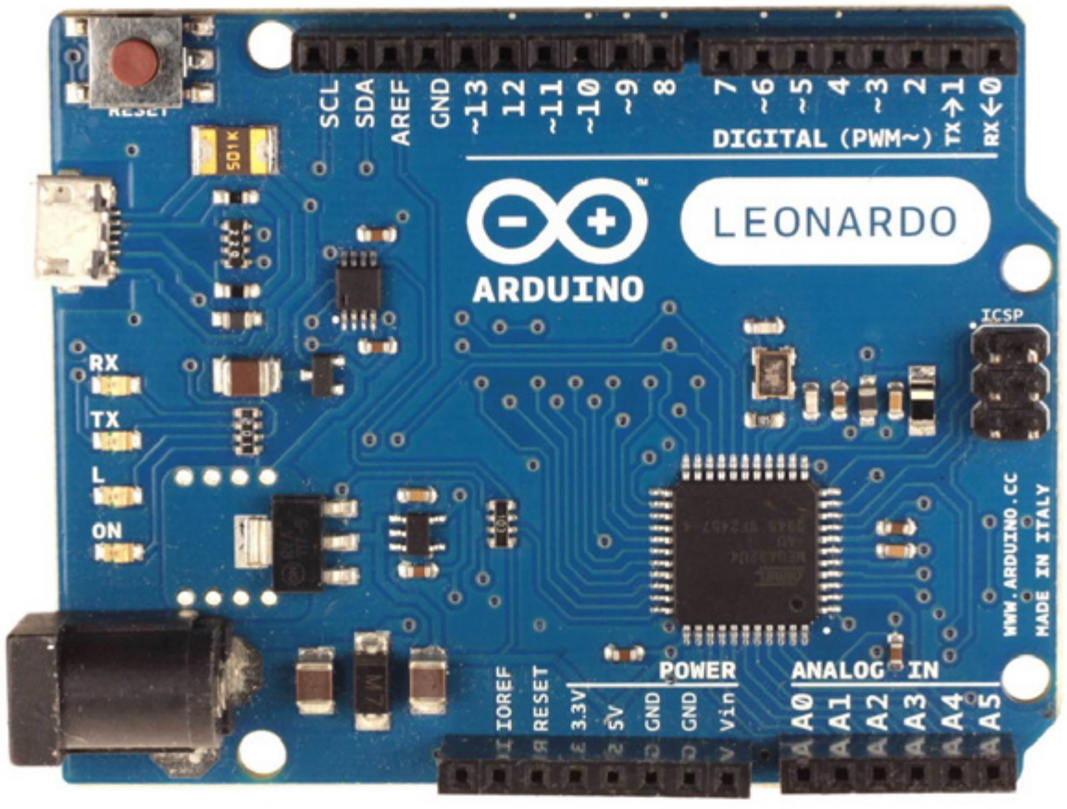



**Figure 18. Common Arduino board**

## Arduino具有以下特点：

### 1) 开放性

Arduino是起步比较早的开源硬件项目。各种开源项目目前已经得到广泛的认可和大范围的应用。它的硬件电路和软件开发环境都是完全公开的，在不从事商业用途的情况下，任何人都可以使用、修改和分发它。这样不但可以使用户更好地理解Arduino的电路原理，更可以根据自己的需要进行修改，比如由于空间的限制，需要设计异形的电路板，或是将自己的扩展电路与主控制电路设计到一起。

### 2) 易用性

Arduino IDE基于processing IDE开发。对于初学者来说，极易掌握，同时有着足够的灵活性。Arduino语言基于wiring语言开发，是对 avr-gcc库的二次封装，不需要太多的单片机基础、编程基础，简单学习后，你也可以快速的进行开发。

### 3) 发展迅速

Arduino不仅仅是全球最流行的开源硬件，也是一个优秀的硬件开发平台，更是硬件开发的趋势。Arduino简单的开发方式使得开发者更关注创意与实现，更快的完成自己的项目开发，大大节约了学习的成本，缩短了开发的周期。

因为Arduino的种种优势，越来越多的专业硬件开发者已经或开始使用Arduino来开发他们的项目、产品；越来越多的软件开发者使用Arduino进入硬件、物联网等开发领域；大学里，自动化、软件，甚至艺术专业，也纷纷开展了Arduino相关课程。

在这次赛事中，Arduino将作为中央处理器，通过Arduino控制各个传感器以及完成各种操作。

## (四) 测控系统各种模块

### 1. 无线传输模块（推荐2.4G），2.4G频段的相关特性

2.4G无线模块工作在全球免申请ISM频道2400M-2483M范围内，实现开机自动扫频功能，共有50个工作信道，可以同时供50个用户在同一场合同时工作，无需使用者人工协调、配置信道。同时，可以根据成本考虑，选择50米内、150米、600 米多种类型无线模块。接收单元和遥控器单元具有1键自动对码功能，数字地址编码，容量大，避免地址重复。

### 1) 应用领域

无线数据传输广泛地运用在车辆监控、遥控、遥测、小型无线网络、无线抄表、门禁系统、小区传呼、工业数据采集系统、无线标签、身份识别、非接触RF智能卡、小型无线数据终端、安全防火系统、无线遥控系统、生物信号采集、水文气象监控、机器人控制、无线232数据通信、无线485/422数据通信、数字音频、数字图像传输等领域中。

### 2) 模块分类



## Characteristics of Arduino

### 1) Openness

Arduino is an early-developed, open-source and broadly approved program. Circuit of its board and development environment of its software are completely open. People can use, change and distribute it for any noncommercial use. In this way, people can better understand Arduino circuit and are flexible to change it according to their own demands. For example, people can change it to a special shaped circuit due to space limit, or connect expander circuit with main control circuit.

### 2) Easy to Master

Arduino IDE is developed based on processing IDE. For beginners, it’s easy to master and quite flexible. Arduino language is developed based on wiring language and is a second encapsulation of avr-gcc library. It requires minimized knowledge of single chip and programming. People can master it after short learning.

### 3) Rapidly Developing

Arduino is not only the most popular open-source hardware platform but also an excellent platform for hardware development, and represents general trend of hardware development. Arduino enables people to focus on creativity, accelerates development of project and saves costs of learning.

Benefit from Arduino, increasing number of hardware developers select Arduino for their programs and products and increasing number of software developers select Arduino to start their work in hardware and field of internet of things. In universities, majors of automation, software, and even art require students to take courses related to Arduino.

In MLP , Arduino will be used as central processing unit to control sensors and motors.

## Part Four – Components of Monitor and Control System

### 1.Wireless Transmitting Module and Characteristics of 433M Module (Recommended)

433M wireless module works at frequency from 2400M to 2483M in global application-free channel ISM and has function of automatic frequency sweep once started up. 50 channels are available, which means 50 modules can simultaneously work at the same place without any manual coordination. In addition, people can select modules with different working distances, 50m, 150 m or 600 m, according to their budget. Receptor and remote controller can pair their code automatically by digital address. The large number of digital address avoids address error.

### 1) Applications

Wireless transmission is widely used in vehicle monitoring, remote control, telemetry, small wireless network, wireless meter reading, access control system, community pager, industrial data acquisition system, wireless label, identity recognition, contactless RF smart card, small wireless data terminal, safety and fire protection system, wireless remote control system, biological signal acquisition, hydrometeorological monitoring, robot control, 232 data communication, wireless 485/422 data communication, digital audio, digital image transmission and other fields.

### 2) Data Sheet

## ★ 2.4G无线发射模块JF24D-TX

| JF24D-RX（2.4G无线接收模块）性能参数 | |
|---|---|
| ★工作频率：2.4G | ★输出状态：锁存/非锁存 |
| ★工作电压：2.5-3.6V | ★输出电平：0-高电平 |
| ★接收电流：23mA | ★编码形式：学习码，自动识别遥控器地址及数据 |
| ★接收灵敏度：-85dBm | ★天线形式：PCB天线 |
| ★调制方式：GFSK | ★参考距离：50米(无障碍) |
| 数据通道：6路 | 模块尺寸：25X13X2mm（长X宽X厚） |

## ★ 2.4G无线收发模块JF24D

| JF24D（2.4G无线收发模块）性能参数 | |
|---|---|
| 频率范围：2397-2483Mhz | 工作电压：2.8-3.6V |
| 可编程输出功率：-25/-15/-5/0/3(dbM) | 调制方式：GFSK/FSK |
| 发射电流：14mA (0dBm) | 最大速率：1M |
| 接收电流：21mA (1Mbps) | 接收灵敏度：-85dBm |
| 休眠电流：3.5uA | 最大距离：100米(遥控）20米（数传） |
| 待机电流：410uA | 编程接口：SPI数字接口 |
| 天线形式：PCB天线 | 模块尺寸：21X12.5X2mm（长X宽X厚） |



## ★ 433M Wireless Transmitting Module JF24D-TX

| JF24D-TX（Wireless Transmitting Module）Performance Parameters | |
|---|---|
| Working Frequency：2.4G | Maximum Rate：1M |
| Working Voltage：2.5-3.6V | Console Port：6路按键输入 |
| Emission Current：0-15mA | Coding Form：Study Code |
| Output Power：5db | Antenna Form：PCB antenna |
| Static Current：3.5uA | Reference Distance：50 m without block |
| Modulation Mode：GFSK | Module Size：25 x13 x 2 mm（Length x Width x Height） |

## ★ 433M Wireless Receiver Module JF24D-RX

| JF24D-RX（2.4 G Wireless Receiver Module）Performance Parameter | |
|---|---|
| Working Frequency：2.4G | Output Status：Latch / Unlatch |
| Working Voltage：2.5-3.6V | Output Level：0 – High level |
| Reception Current：23mA | Coding Form：Study Code |
| Receiving Sensitivity：-85dBm | Antenna Form：PCB antenna |
| Modulation Mode：GFSK | Reference Distance：50 m without block |
| Data Chanel：6 ways | Module Size：25 x 13 x 2mm（Length x Width x Height） |
| | |

## ★ 2.4G无线收发模块JF24D

| JF24D（2.4G无线收发模块）性能参数 | |
|---|---|
| 频率范围：2397-2483Mhz | 工作电压：2.8-3.6V |
| 可编程输出功率：-25/-15/-5/0/3(dbM) | 调制方式：GFSK/FSK |
| 发射电流：14mA (0dBm) | 最大速率：1M |
| 接收电流：21mA (1Mbps) | 接收灵敏度：-85dBm |
| 休眠电流：3.5uA | 最大距离：100米(遥控）20米（数传） |
| 待机电流：410uA | 编程接口：SPI数字接口 |
| 天线形式：PCB天线 | 模块尺寸：21X12.5X2mm（长X宽X厚） |

## 2. 传感器介绍

### 1) GPS

赛事中使用GPS可以对气球整个飞行过程的部分阶段，进行追踪。

### 2) 气压传感器

气压传感器主要用来测量气体的压强大小，以及高度。

### 3) 温度传感器

温度传感器是指能感受温度并转换成可用输出信号的传感器。此次赛事中用于时刻获得高空温度数据。

## 3. 执行机构，脱离装置

缆绳切割装置需要从地面发送信号，触发着陆舱中某种机械/机电装置，将缆绳在降落伞以上的位置切断，从而人为、可控地中止飞行。

缆绳自切装置的原理主要有：



## ★ 433M Wireless Transceiver Module JF24D

| JF24D ( 2.4G Wireless Transceiver Module ) Performance Parameter | |
|---|---|
| Frequency Range：2397-2483Mhz | Working Voltage：2.8-3.6V |
| Programmable Output Power：-25 / -15 / -5 / 0 / 3 (dbM) | Modulation Mode：GFSK/FSK |
| Emission Current：14mA (0dBm) | Maximum Rate：1M |
| Reception Current：21mA (1Mbps) | Reception Sensitivity：-85dBm |
| Static Current：3.5uA | Maximum Distance：100 m (Remote control) 20 m（Data transmission） |
| Standby Current：410uA | Application Programming Interface：SPI digital interface |
| Antenna Form：PCB antenna | Module Size：21X12.5X2mm（Length x Width x Height） |

## 2. Introduction to Sensors

### 1) GPS

GPS is used to track balloon.

### 2) Baroceptor

Baroceptor is used to measure atmospheric pressure and altitude.

### 3) Temperature Sensor

Temperature sensor can convert temperature to exportable electrical signal and is used to measure temperature.

## 3. Self-cutting System

Self-cutting device receives signals from the ground, which triggers mechanical or electromechanical devices in lander that cut off cable. This device enables an artificially controllable flight.

Potential Work Principles of Self-cutting System：

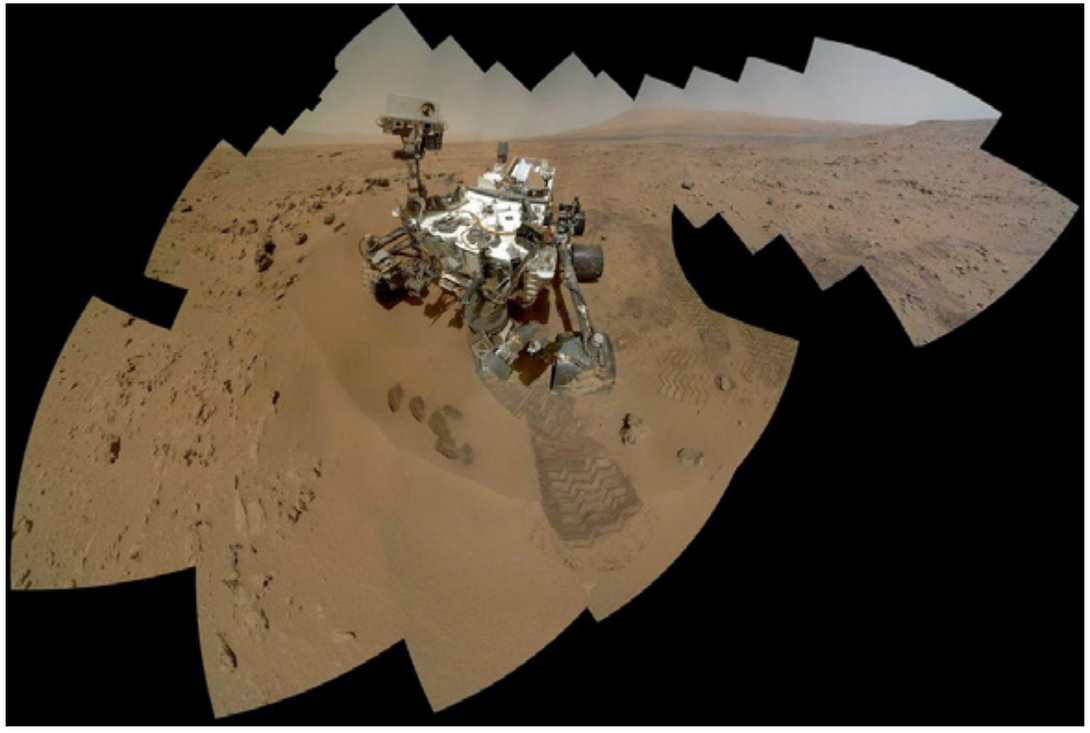
**3) 用电流、电弧熔化缆绳**

**4) 机械触发式的刀刃直接切割**

为了保证自切可靠性，有时需要同时具备两到三种自切机构。

## 4. 电源系统

赛事中整个电源系统需要满足4h以上供电。推荐使用锂离子电池，可以采用一次性的也可以是可反复使用的。锂离子电池重量轻、能量密度大，温差变化的耐受能力也最强。锂离子电池充电过度会降低其能量存储能力，使用充电式锂离子电池时需要注意。所有电池均不耐低温，低温下电池的内阻会越来越高，以致输出电压越来越低；锂离子电池在0摄氏度性能受到很大影响，-20摄氏度时几乎完全失去功能；电池需要用隔热材料包裹，这样电池工作时自身产热就能够温暖电池；如果需要，还可以贴上暖宝宝。电池供电线、仪器数据线等也需要类似的保温措施。





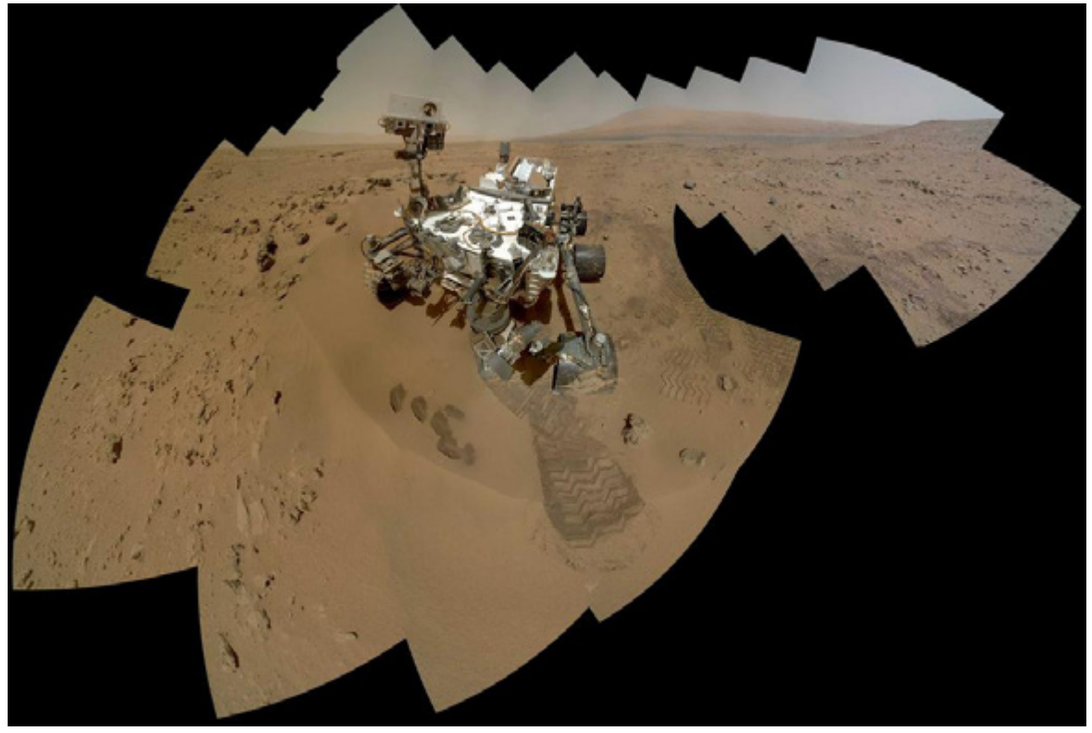
1) melt cable with electric current and arc

2) scut off cable with mechanically triggered blades

Note: to increase reliability of self-cutting device, two to three cutting mechanisms are simultaneously required

## 4. Power Supply

In MLP , batteries need to supply energy for more than four hours. Lithium-ion battery is highly recommended, and can be either reusable or not. Lithium-ion battery is light-weighted with large energy density and excellent endurance to temperature changes. Pay extra attention when using chargeable lithium-ion battery, because overcharge will decrease its capability to store energy. All kinds of batteries will disfunction under low temperature, because their inner resistance will dramatically increase and thus output voltage will dramatically decrease. Lithium-ion battery is greatly influenced under zero Celsius and stops working at negative 20 Celsius. Therefore, battery should be wrapped up with heat-insulated materials, so that heat generated at work will be preserved; if needed, warm pastes can be useful to maintain temperature. Designers should also maintain temperature for supple lines of all kinds of devices.



MLP
火星着陆计划
MARS LANDING PROJECT

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