2026 MCM

2026 年 MCM（Mathematical Contest in Modeling，数学建模竞赛）

Problem B: Creating a Moon Colony Using a Space Elevator System

题目 B：利用空间电梯系统建设月球殖民地

Imagine a future where it's possible for anyone to visit space by taking a leisurely and scenic ride from the Equator to Earth's orbit and then catching a routine, safe, and inexpensive rocket flight to the Moon, Mars, or beyond. In this future, we could build lush, green, and beautiful space habitats with artificial gravity, where people would vacation, work, or even live. These habitats would alleviate pressure on Earth's delicate, overworked, and fragile ecosystems. The technology to enable these events would provide humankind with limitless, safe, routine, environmentally friendly, efficient, and global access to space. To achieve these goals, some people envision a Space Elevator System, powered by electricity, offering a scalable infrastructure for interplanetary logistics, commerce, and exploration.

设想这样一个未来：任何人都可以从赤道出发，乘坐一段轻松且风景优美的旅程抵达地球轨道，随后再搭乘一趟常态化、安全且廉价的火箭飞行前往月球、火星乃至更远的深空。在这样的未来里，我们能够建造拥有人工重力、郁郁葱葱且美丽宜居的太空栖居地，人们可以在那里度假、工作，甚至长期居住。这些栖居地将缓解地球脆弱且超负荷运转的生态系统所承受的压力。实现上述愿景所需的技术，将为人类提供几乎无限、安全、常态化、环境友好、高效且面向全球的太空通达能力。为达成这些目标，有人提出构建一套以电力驱动的"空间电梯系统"，为行星际物流、商业与探索提供可扩展的基础设施。

At its final operating configuration, the Space Elevator System would comprise three Galactic Harbours, ideally separated by 120 degrees around the equator. Each Galactic Harbour would include a single Earth port with two 100, 000km -long tethers connected to two apex anchors, with multiple space elevators operating together, each capable of lifting massive payloads daily from Earth to geosynchronous orbit (GEO) and beyond to the apex anchor where they can be loaded on a rocket and delivered anywhere using much less fuel.

在最终运行配置下，空间电梯系统将由三个 Galactic Harbour（可译作"银河港"）构成，理想情况下沿赤道周向相隔 120 度。每个银河港包含一个地面港口（Earth Port），并通过两条长度为 100, 000km 的缆索（tether）分别连接到两个顶点锚（apex anchor）。多个空间电梯将协同运行，每部电梯都能够每天将巨型载荷从地面提升至地球同步轨道（GEO）并继续上行至顶点锚；载荷可在顶点锚处装载到火箭上，并以远低于传统方式所需的燃料消耗运往任意目的地。

The Moon Colony Management (MCM) Agency is preparing to build a Moon Colony with an estimated 100,000 people beginning in the year 2050, after completion of the Space Elevator System. It is estimated that the Moon Colony will need about 100 million metric tons of materials. Additionally, water and supplies will routinely need to be sent to sustain the Moon's population once the colony is complete. To get to the Moon, the Galactic Harbour must send material in two steps: first, from the Earth port to the apex anchor via a space elevator, and second, from the apex anchor to the Moon Colony via a rocket. The MCM Agency anticipates that the Galactic Harbour will provide an advanced lift system capable of moving 179,000 metric tons every year, while generating no atmospheric pollution.

月球殖民地管理机构（Moon Colony Management，MCM）计划在空间电梯系统建成后，自 2050 年起建设一座预计可容纳 100,000 人的月球殖民地。据估计，月球殖民地建设将需要约 1 亿公吨材料。此外，在殖民地建成并投入运行后，还需要持续、常态化地运送水与各类补给以维持月球人口。将物资运抵月球需经由银河港分两步完成：第一步，通过空间电梯将物资从地面港口运至顶点锚；第二步，再由火箭将物资从顶点锚运至月球殖民地。MCM 机构预计，银河港将提供一种先进的提升系统，年运输能力可达 179,000 公吨，同时不产生大气污染。

The agency is also considering using traditional rockets to supply material for construction and supplies to the Moon Colony. The Earth current has ten rocket launch sites: Alaska, California, Texas, Florida, and Virginia (United States), Kazakhstan, French Guiana, Satish Dhawan Space Centre (India), Taiyuan Satellite Launch Center (China), and Mahia Peninsula (New Zealand).

该机构也在考虑采用传统火箭向月球殖民地运送建设材料与补给。地球目前有十个火箭发射场：阿拉斯加、加利福尼亚、得克萨斯、佛罗里达、弗吉尼亚（美国），哈萨克斯坦，法属圭亚那，萨迪什·达万航天中心（印度），太原卫星发射中心（中国），以及马希亚半岛（新西兰）。

题目假设/简化：火箭运载能力统一为100-150t/次

A rocket would require a single step from the rocket launch site on Earth to the Moon Colony. By 2050 it is estimated that rockets will be able to carry 100-150 metric tons of payload to the Moon using advanced Falcon Heavy launches. You may assume perfect conditions for both the Galactic Harbour system (e.g., no swaying of the tether) and rocket launches (e.g., no failed launches). You should consider the cost and timeline to deliver the materials from the surface of the Earth to the Moon Colony site for the different scenarios.

使用火箭时，只需一步即可将载荷从地球发射场直接运至月球殖民地。预计到 2050 年，借助先进的 Falcon Heavy 发射任务，火箭将能够向月球运送 100–150 公吨的有效载荷。你可以假设银河港系统与火箭发射均处于理想条件（例如缆索不发生摆动、发射无失败）。你需要在不同情景下，综合考虑将材料从地球表面运至月球殖民地选址的成本与时间进度。

模型假设：忽略空气阻力，忽略结构重量带来的能量损失

Your Task:

模型假设：不考虑科研成本
、不考虑建设成本、不考虑人力成本，不考虑物理（火箭成本）

你的任务：

Your task is to utilize a mathematical model to determine the cost and associated timeline in order to transport material to build a 100,000 person Moon Colony starting in 2050. You will need to compare the Modern-Day Space Elevator System's three Galactic Harbours to traditional rockets launched from selected rocket bases.

你的任务是建立并运用数学模型，确定自 2050 年起为建设一座可容纳 100,000 人的月球殖民地所需的物资运输成本及相应时间进度。你需要比较"现代空间电梯系统"的三座银河港与从选定火箭发射基地发射的传统火箭方案。

Your model should include:

你的模型应包含：

时间线甘特图、成本对比图、Pareto前沿

1. Consideration of three different scenarios for how the 100 million metric tons of materials will be delivered to build the 100,000-person Moon Colony;

   考虑用于向月球殖民地交付 1 亿公吨材料（以建设可容纳 100,000 人的月球殖民地）的三种不同情景；

   a. using the Space Elevator System's three Galactic Harbor's alone,
   仅使用空间电梯系统的三座银河港；

   b. traditional rocket launches from existing bases alone (you may choose which facilities to use), or,
   仅使用现有发射场的传统火箭发射（你可自行选择使用哪些设施）；或

   c. some combination of the two methods. 两种方式的某种组合。

2. To what extent does your solution(s) change if the transportation systems are not in perfect working order (e.g, swaying of the tether, rockets fail, elevators break, etc.).?

   如果运输系统并非完美运行（例如缆索摆动、火箭发射失败、电梯故障等），你的解（或多种解）在多大程度上会发生变化？

3. Investigate the water needs for a one-year period once the 100,000-person Moon Colony is fully operational. Use your delivery model to understand the additional cost and timeline needed to ensure the colony has sufficient water for one full year after the Moon Colony is inhabited.

   当 100,000 人规模的月球殖民地全面投入运行后，研究其一年期的用水需求。运用你的交付模型分析：为确保殖民地在开始有人居住后的一整年内有充足用水所需的额外成本与时间进度。

假设：忽略工业用水原因：无人居住跟有人居住无区别，为基础建设成本

4. Discuss the impact on the Earth's environment for achieving the 100,000-person Moon Colony under the different scenarios. How would you adjust your model to minimize the environmental impact?

   讨论在不同情景下实现 100,000 人月球殖民地对地球环境的影响。你将如何调整模型以尽量降低环境影响?

5. Write a one-page letter recommending a course of action to the fictional MCM Agency to build and sustain a 100,000-person Moon Colony.

   撰写一封一页的建议信，向虚构的 MCM 机构推荐建设并维持一座可容纳 100,000 人的月球殖民地的行动方案。

Your PDF solution of no more than 25 total pages should include:

你的 PDF 解答（总页数不超过 25 页）应包括：

- One-page Summary Sheet.
  1 页摘要页（Summary Sheet）。
- Table of Contents.
  目录。
- Your complete solution.
  完整解答。
- One-page letter to MCM Agency
  致 MCM 机构的一页建议信。
- References list.
  参考文献列表。
- AI Use Report (If used does not count toward the 25-page limit.)
  AI 使用报告（如使用；不计入 25 页总页数限制。）

Note: There is no specific required minimum page length for a complete MCM submission. You may use up to 25 total pages for all your solution work and any additional information you want to include (for example: drawings, diagrams, calculations, tables). Partial solutions are accepted. We permit the careful use of AI such as ChatGPT, although it is not necessary to create a solution to this problem. If you choose to utilize a generative AI, you must follow the COMAP AI use policy. This will result in an additional AI use report that you must add to the end of your PDF solution file and does not count toward the 25 total page limit for your solution.

注：完整的 MCM 提交稿没有规定最低页数要求。你的全部解题内容及任何补充信息（例如：图示、示意图、计算、表格）最多可使用 25 页。允许提交部分解答。竞赛允许谨慎使用 ChatGPT 等 AI 工具，但完成本题并不依赖 AI。如你选择使用生成式 AI，必须遵循 COMAP 的 AI 使用政策；这将要求你在 PDF 解答文件末尾附加一份 AI 使用报告，该报告不计入 25 页总页数限制。

Glossary

术语表

Space Elevator System is comprised of three Galactic Harbours plus additional support facilities.

空间电梯系统：由三座银河港及其他配套支撑设施组成。

Galactic Harbour is comprised of two apex anchors each connected by two tethers to a single Earth Port.

银河港（Galactic Harbour）：由两个顶点锚组成；每个顶点锚通过两条缆索连接到同一个地面港口（Earth Port）。

Earth Port is the location on the Earth that provides surface support for the Galactic Harbour.

地面港口（Earth Port）：在地球表面为银河港提供地面支撑与保障的地点。

Tethers are 100,000km long graphene material that links the Earth port and apex anchors in the Space Elevator System.

缆索（tether）：空间电梯系统中连接地面港口与顶点锚的石墨烯材料缆索，长度为 100,000km。

Apex Anchor is the counterweight in space at the end of the 100,000km tether.

顶点锚（apex anchor）：位于 100,000km 缆索末端、在太空中起配重作用的结构。

Geosynchronous orbit (GEO) is approximately 35,786km above the surface of the Earth where the orbital period to circle Earth is 24 hours, matching Earth's rotation so it stays over the same longitude each day.

地球同步轨道（GEO，geosynchronous orbit）：距离地球表面约 35,786km 的轨道；其绕地周期为 24 小时，与地球自转周期一致，因此每天可保持位于同一经度上空。

Moon Colony is a habitat on the moon with the capacity to support 100,000-persons.

月球殖民地（Moon Colony）：位于月球、可支持 100,000 人居住与生活的栖居地。