商业气象小卫星发展路径研究

Research on the Development Path of Commercial Meteorological Small Satellites

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Foreword

- In 2024, commercial spaceflight was included in the government work report for the first time as a "new growth engine";
- the government work report in 2025 stated, "Promote the safe and healthy development of emerging industries such as commercial spaceflight";
- in 2025, the China Meteorological Administration issued guidance on the development of commercial meteorological small satellites, supporting the promotion of the commercial meteorological small satellite industry;

➢ **The commercial meteorological small satellite industry is developing rapidly,and it has received widespread attention.**

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I. Opportunities and Challenges

1. 发展需求 Development Needs

➢ **增强气象观测时效 Enhance the timeliness of meteorological observations**

■ 现有风云卫星可对全球大气温湿度廓线、海面风场等数值预报所需要素开展综合探测，但对全球数值预报所需的**1小时内全球数据更新能力**存在不足。

➢ **气象灾害协同监测 Collaborative Monitoring of Meteorological Disasters**

■ 需提升面向快时变、小尺度气象灾害的**应急响应效率**，提升面向有云区域、对流低层的温湿度**探测精度**，提升面向暴雨、洪涝、海面大风等灾害的**全天候监测**能力。

I. Opportunities and Challenges

1. 发展需求 Development Needs

➢ **新体制新技术验证 Verification of New Systems and New Technologies**

■ **对前沿的载荷工程及应用技术开展在轨验证，填补关键要素空白。**

➢ **拓展卫星应用深度广度 Expand the depth and breadth of satellite applications.**

■ **发挥商业气象小卫星在时空覆盖性方面的优势，培育更为丰富的应用场景，满足新能源、低空经济、数字经济等新型产业对个性化、精细化气象服务的迫切需求。**

I. Opportunities and Challenges

2. 国内外发展现状 Current Development Status at Home and Abroad

- 美国NEON计划 U.S. NEON Project

■ 以中小型卫星为主，将在2030~2050年为美国提供天气预报、环境观测、气候监测等数据，QuickSounder是该计划的首颗卫星，将配备先进技术微波探测仪（ATMS），采集大气温度和湿度数据，计划2026年后发射。

- 欧美小卫星 Observation of Small Satellite Networks in Europe and America

■ 欧美通过小卫星组网观测，为气象预报提供更多探测数据。典型星座包括掩星星座狐猴Lemur、飓风星座CYGNSS、热带气旋监测星座TROPICS、降水测量星座 Tomorrow.io。

✓ Abroad :The current satge focuses on the construction of experimental satellites, while most of the constellation construction is still in the planning stage.

I. Opportunities and Challenges

2. 国内外发展现状 Current Development Status at Home and Abroad

- **中国小卫星快速发展 China's small satellites achieve rapid development**

- **我国已发射云遥、天目等商业气象小卫星，在轨载荷主要包含GNSS、微波辐射计等。中国气象局推动商业小卫星数据产品在气象部门广泛应用，天目、云遥系列卫星进入中国气象局综合气象观测系统并业务运行。**

- **China: launched commercial meteorological small satellites such as YunYao and TianMu,payloads mainly including GNSS and microwave radiometers.**

I. Opportunities and Challenges

3. 主要挑战 Main Challenges

1 产业定位不清晰 Unclear industry positioning

- 未建立“以市场机制配置资源，以自主盈利为目的”的商业航天运行模式，难以持续发展。

2 研制基础效率低 Low research and development efficiency

- 缺乏**数字化低成本总装集成研制平台**、高效精确的现代化生产线和测试设备，研发和生产周期较长，难以快速迭代和优化产品。

3 产业转化慢 Slow industrial transformation

- **技术研发成果转化不足及缓慢**，创新链与产业链脱节，无法满足各行业精细化气象服务需求。

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II. Development Goals and Key Projects

1. 发展思路 Development Ideas

构建“平台联盟+运营紧耦+资本引导”发展格局，以“协同观测、能力补充、技术验证”为目标，促进卫星遥感在气象领域的融合应用，为气象事业高质量发展提供新动能。

Build a development pattern of "platform alliance + closely coupled operation + capital guidance," with the goals of "collaborative observation, capability supplementation, and technology verification。

构建平台联盟：风云骨干卫星与商业卫星协同发展，通过“技术+资本”双轮驱动

实现运营紧耦：通过精密战略对接和资源深度融合，实现与运营商紧密交织和价值共创。

重视资本引导：引导多元投资，汇聚社会资本，精准锚定商业模式和盈利路径

II. Development Goals and Key Projects

2. 发展目标 Development Goals

构建以风云气象卫星为主、商业气象小卫星为辅的天基气象协同观测体系，充分发挥卫星应用效益，建成需求主导、社会参与、深度协作、产业促进的气象卫星发展新格局。

To build a space-based meteorological collaborative observation system based on Fengyun meteorological satellites, supplemented by commercial meteorological small satellites.

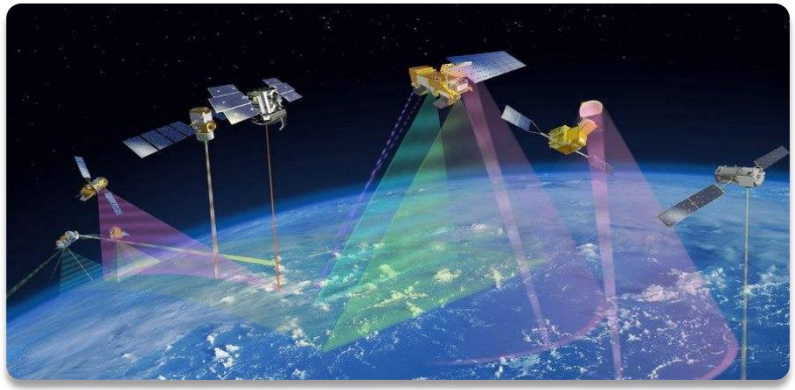
风云骨干体系
Fengyun meteorological satellites

体系中枢 综合观测 国际领先

有力补充
supplemented

商业气象小卫星
commercial meteorological small satellites

协同观测 能力补充 技术验证



Build a space-based meteorological collaborative observation system

II. Development Goals and Key Projects

3. 重点项目 Key Projects

①大气温湿度协同观测星座 Atmospheric Temperature and Humidity Coordinated Observation Constellation

卫星配置小型化微波大气探测仪，对大气温度、湿度、强对流等要素开展高频次观测，补充风云卫星轨道间隙观测数据，提升气象预报精度与时效性。需求迫切，基础较好，建议优先发展。

A mini microwave atmospheric detector is configured on the satellite to conduct high-frequency observations of atmospheric temperature, humidity, and strong convection, supplementing the observation data during gaps in the orbit of the Fengyun satellites, thereby enhancing the accuracy and timeliness of weather forecasting.

✓ The demand is urgent, the foundation is very good, so it is recommended to priority development.

II. Development Goals and Key Projects

3. 重点项目 Key Projects

②中高层大气环境探测星座 Mid- to High-Altitude Atmospheric Environmental Detection Constellation

卫星配置太赫兹临边探测仪，填补中高层大气温度、密度、风场等要素探测能力空白,提升临近空间环境综合保障能力。建议搭载发展。

The satellite is equipped with a terahertz edge detection instrument, which fills the gap in the detection capacity of temperature, density, wind field, and other elements in the middle and upper atmosphere,enhancing the comprehensive support capability for the near-space environment.

- ✓ **The payload is mature, and the economic investment is not very large, we suggest allowing for networking development with other satellites.**

II. Development Goals and Key Projects

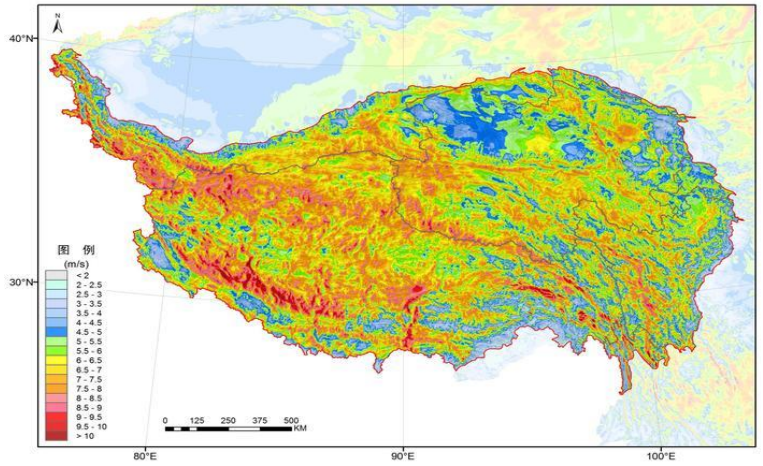
3. 重点项目 Key Projects

③风场协同观测星座 Wind Field Collaborative Observation Constellation

④三维雨探测星座 3D Rain Detection Constellation

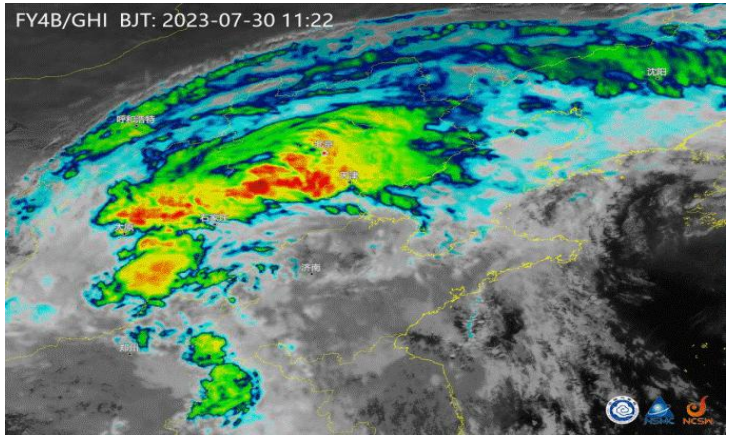
以上两个星座建设需求非常迫切，但载荷小型化攻关还需进一步深化，建议边试边建，与大卫星协同发展。

✓ The construction requirements for the above two constellations are very urgent, but the miniaturization of payloads still needs further deepening. It is recommended to build while testing and to develop in coordination with larger satellites.



风资源普查
Wind Resource Survey

海上平台保障
Offshore Platform Support



短临天气预警
Short-term Weather Warning

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III. Key Technologies

1. 低成本高可靠设计技术 Low-cost and high-reliability design technology

坚持“低成本是设计出来”的理念，应对成本控制面临的新形势，提升成本管控优势。

Adhere to the principle that "low cost is designed," respond to the new situation of cost control, and enhance the advantages of cost management.

措施	主要内容
建立商业航天成本管控体系	通过组织建立战略成本、成本方针和目标，并通过实际实施过程中的改进和纠偏，实现成本目标的指挥和控制。
建立任务分类管理体系	参照NASA有效载荷风险分类的定义，对任务进行风险等级区分并分类管理，实现成本降低。
建立低成本元器件选用体系	重点研究宇航级、军用级、宽温商业级以及商业级等不同级别的器件，依据任务的关键性和环境/生命周期矩阵选取最合适的器件。
引入“白痴指数”评估体系	使用SpaceX公司首席执行官马斯克提出的“白痴指数”作为自研和外购的判断标准，评估产品制造成本，识别降本对象。
开展卫星模块化设计	将卫星系统分解为多个独立的模块，每个模块都具有明确的功能，可以独立设计、测试、集成和维护，提高卫星研制效率、降低成本、增强灵活性。
发展仿真验证技术	通过仿真手段开展试验验证，代替实物的试验，节约成本。

KEY POINT

- Product Cost
- Supply Chain
- Production Efficiency

III. Key Technologies

2. 载荷平台一体化电子架构技术 Integrated Electronic Architecture Technology for Load Platforms

商业卫星整星信息流融合、功能集成度较高，必须打破传统卫星系统分工界面，实现系统架构高度一体化集成设计。

The information flow of the entire satellite is integrated, and the degree of functional integration is high. It is essential to break through the traditional interface divisions of satellite systems and achieve a highly integrated and unified architectural design.

措施	主要内容
开展信息融合型一体化架构设计	整合传统卫星载荷、数管、姿轨控、存储、通信等不同系统和功能，优化整星信息流设计，打造八院商业版信息系统架构，实现功能模块高度集成；基于处理器+操作系统形态实现软硬件在轨软件定义，功能可配置、任务可重构、平台可升级。
实施产品化组批研制模式	面对商业卫星研制特点，切实探索相适应的产品敏捷研制流程，实现八院商业卫星型谱产品货架，完善全级次供应链体系，去平台化、去型号化，聚焦核心产品组批次投产，全面做好用户对接、积极引导总体选用。
推进自主微系统设计	梳理产品功能和指标技术状态，根据最大化兼容原则，研制管理控制、数据处理、驱动执行等不同类型自主微系统器件，从而进一步降低系统设计开销，减少系统复杂度，提升信息效能和功能密度，实现商业卫星核心产品升级换代。

KEY POINT

- Integrated Design
- Information Fusion
- Mass Production

III. Key Technologies

3. 低成本载荷技术 Low-cost payload technology

面向商业应用，载荷以够用、实用、好用为目标，综合考虑SWaP-C（Size Weight and Power-Cost），即尺寸、重量、功耗以及成本，寻求应用效能的最大化。

Aimed at commercial applications, the payload targets adequacy, practicality, and usability, taking into account SWaP-C (Size, Weight, Power, and Cost), which refers to dimensions, weight, power consumption, and cost, in order to maximize application efficiency.

措施	主要内容
发展综合射频一体化技术	以电磁场统一为总路，实现射频综合一体从综合显控、联合处理，向通道一体、孔径一体、信号一体纵深发展，实现用频系统在任意时间、任意位置、任意频段、任意功能的按需自由灵活重构。
发展载荷平台一体化技术	对于小型载荷，实现数字、射频一体化的模块化设计，实现结构、电源、接口等资源的共享公用，通过统一的软件构架设计，实现平台、载荷的统一高效管理。

KEY POINT

- Sufficient
- Practical
- easy to use

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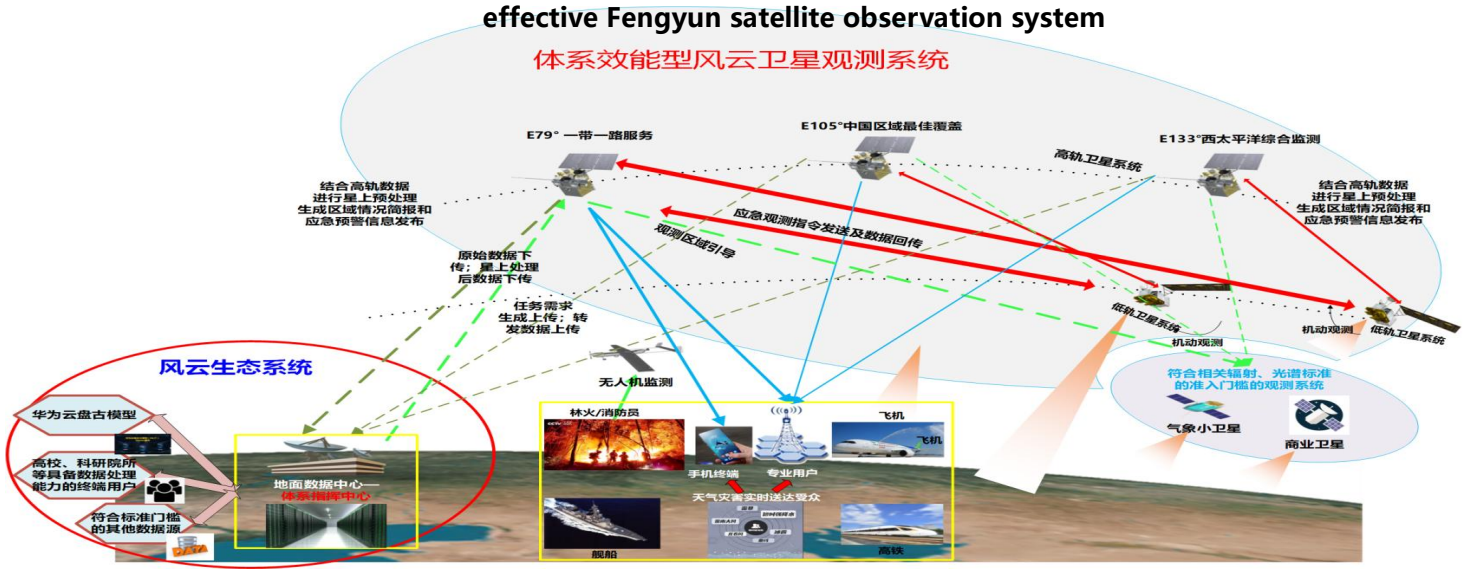
1. 体系设想 System Concept

到2035年，商业气象小卫星对骨干卫星系统形成有力补充，建设以互联、智能、开放、标准为特征的体系效能型风云卫星观测系统，建成国际先进的天地一体风云生态。

By 2035, commercial meteorological small satellites will form a strong supplement to the backbone satellite system, establishing an effective Fengyun satellite observation system characterized by interconnection, intelligence, openness, and standards, and creating an internationally leading integrated space-ground Fengyun ecosystem.

- Backbone Satellite: Space-based Hub
  (骨干卫星：天基枢纽)
- Small Satellite: Strong Supplement
  (小卫星：有力补充)
- Ground: System Center
  (地面：体系中心)

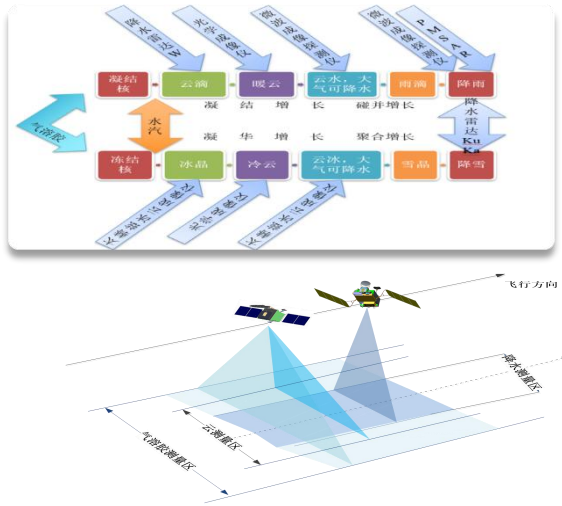


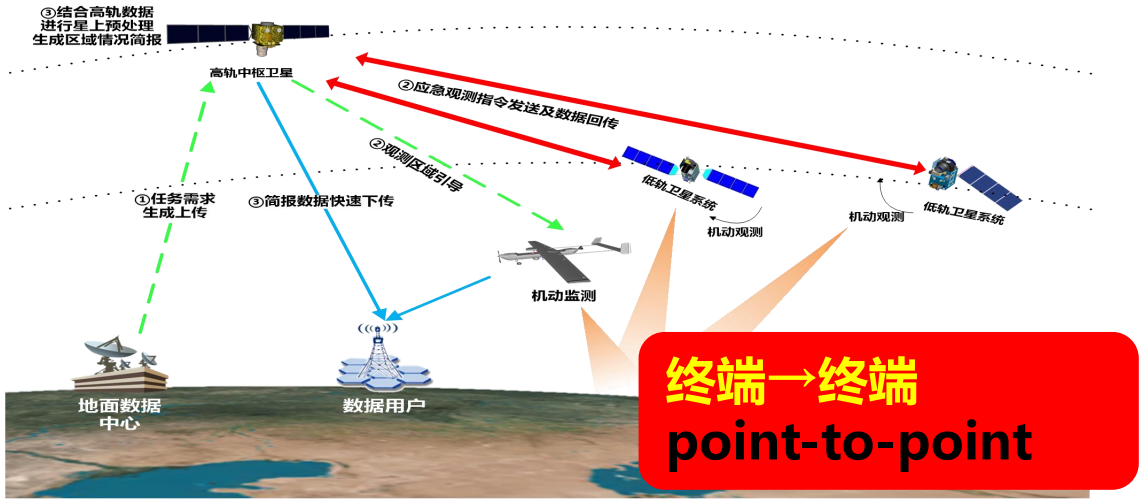
IV. Development Outlook

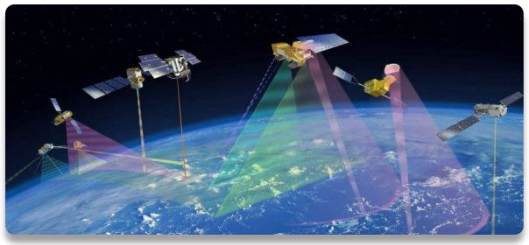
1. 体系设想 System Concept

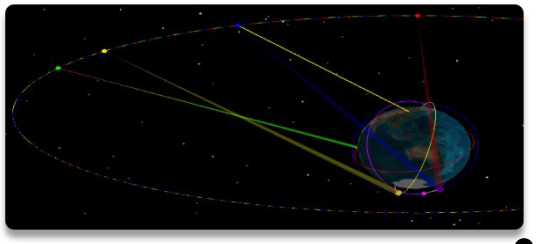
互联：星间互联、星地互联
Interconnection: Inter-stellar interconnection, inter-ground interconnection

- **构建紧耦合的卫星体系：风云卫星将提供高通量、高可靠的星间数据互联服务，数据广播服务可定制，实现点对点友好服务。**
- **Building a tightly coupled satellite system:enabling point-to-point friendly services.**









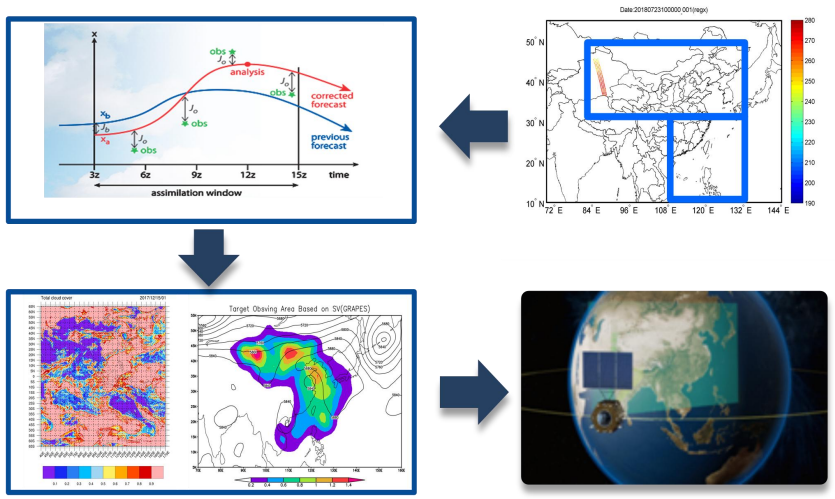
IV. Development Outlook

1. 体系设想 System Concept

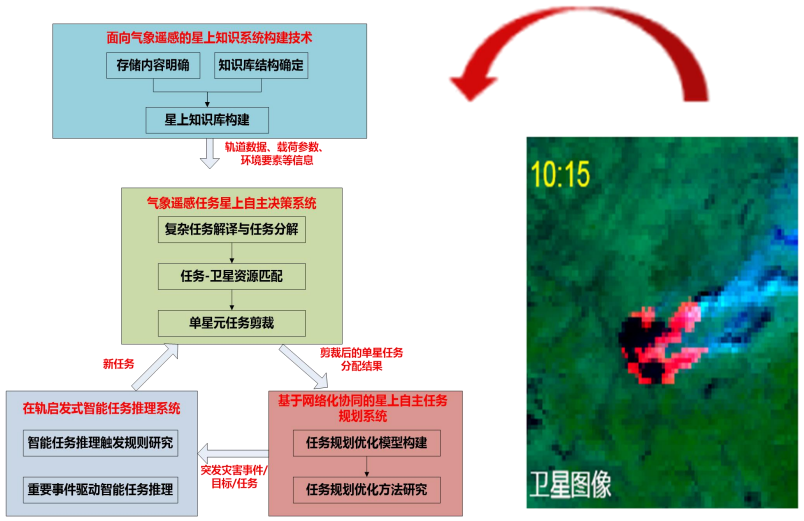
智能：自主运行、智能处理、智能决策、智能响应
Intelligence: autonomous operation, intelligent processing, intelligent decision-making, intelligent response

- **发挥风云卫星天基中枢作用：实现突发事件快速响应与自主规划，引导多卫星多体制协同观测，星上信息处理与融合。Play a critical role in the space-based central command of the Fengyun satellite: achieve rapid response and autonomous planning for emergencies**

数据模型本地化
Data Model Localization



目标识别芯片化
Target recognition chipization

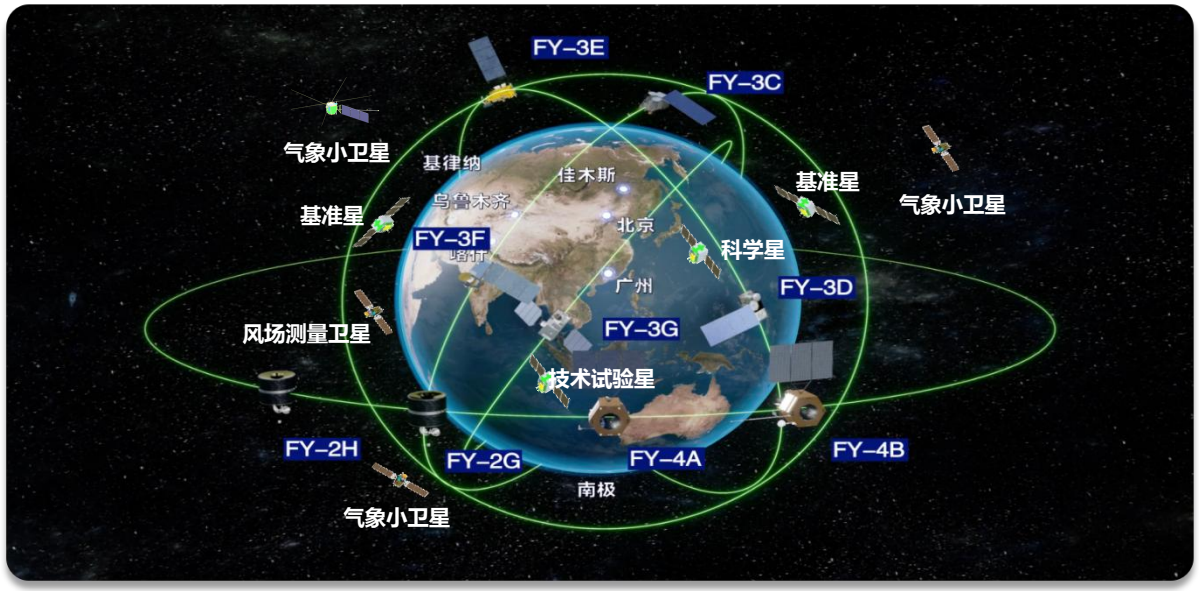


IV. Development Outlook

1. 体系设想 System Concept

开放：支持轨道多类、卫星多型、观测要素多样
Open: Support for multiple types of tracks, various types of satellites, and diverse observational elements.

- **促进天基资源整合：卫星类型包括综合星、专用星、验证星，大卫星、小卫星；观测要素涵盖气象、空间天气、极地、海洋等，提升体系整体效能。**
- **Promote the integration of space-based resources: to enhance the overall efficiency of the system.**

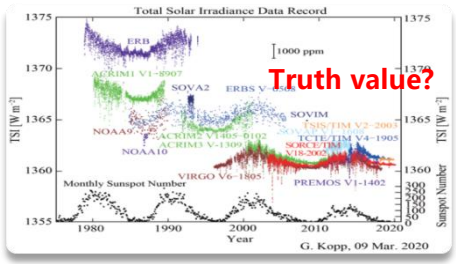


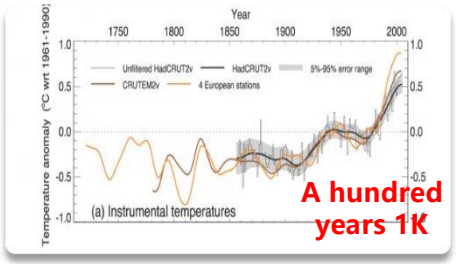
IV. Development Outlook

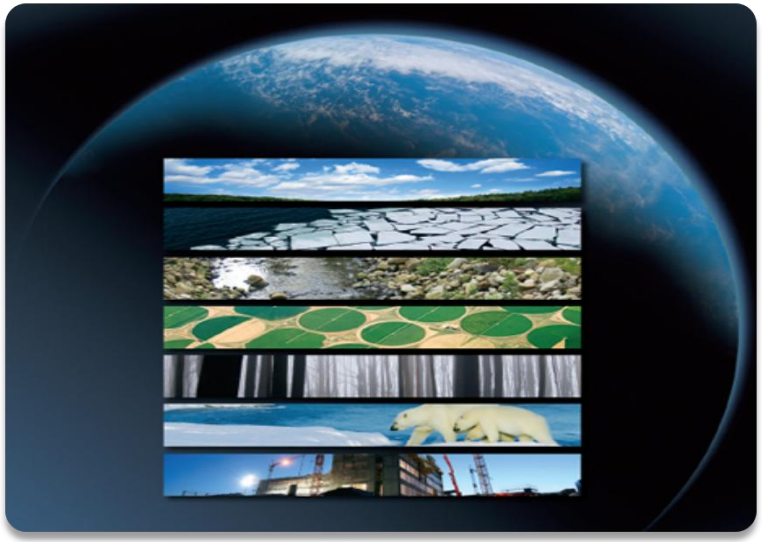
1. 体系设想 System Concept

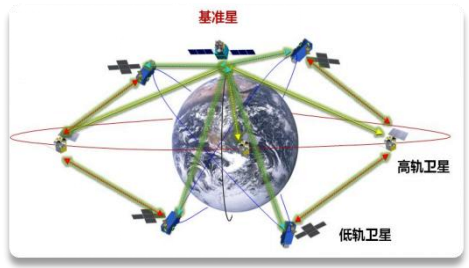
标准：标准化，数据标准、辐射标准、光谱标准
Standards: Standardization, Data Standards, Radia Standards, Spectral Standards

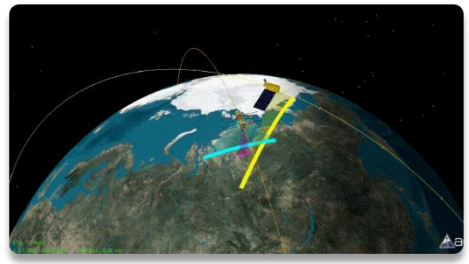
- **保证卫星数据质量，满足气象业务要求：实现各类卫星的快速接入与按需接入，统一空间辐射、 光谱基准，作为纳入体系的必要特征。**
- **Ensure the quality of satellite data to meet meteorological business requirements: unify spatial radiation and spectral baselines。**









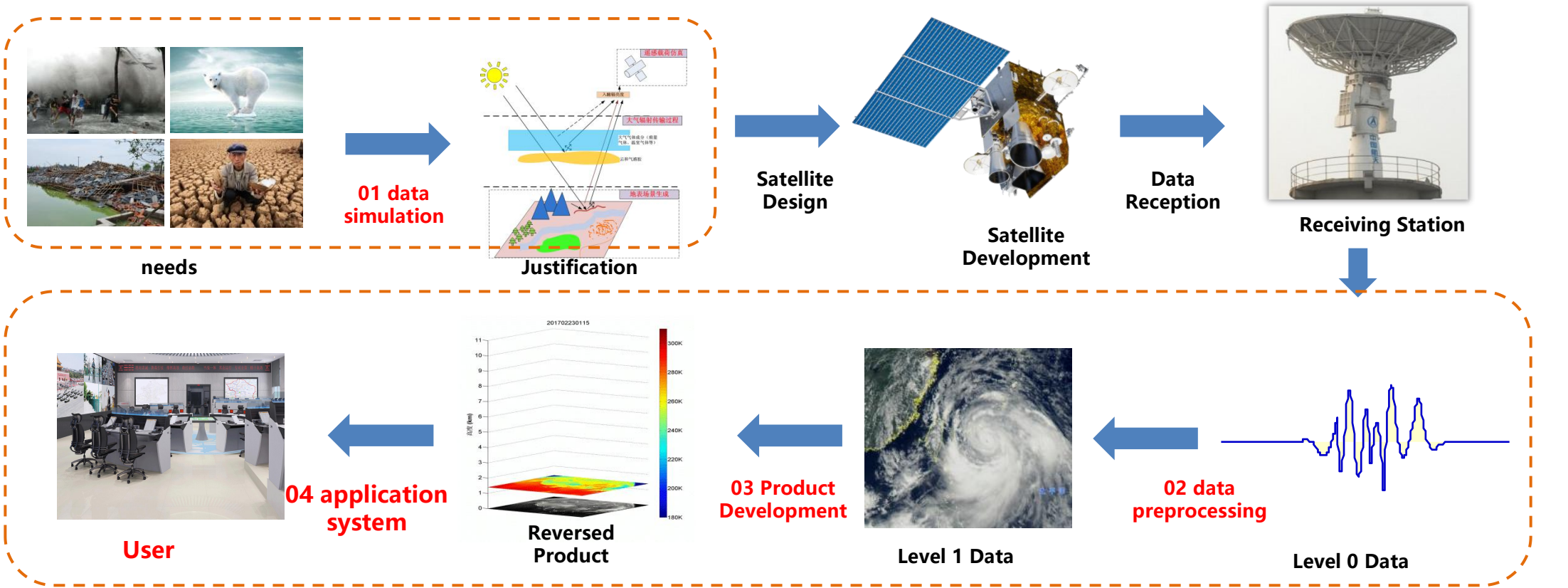


IV. Development Outlook

2. 气象卫星体系应用 Application of Meteorological Satellite Systems

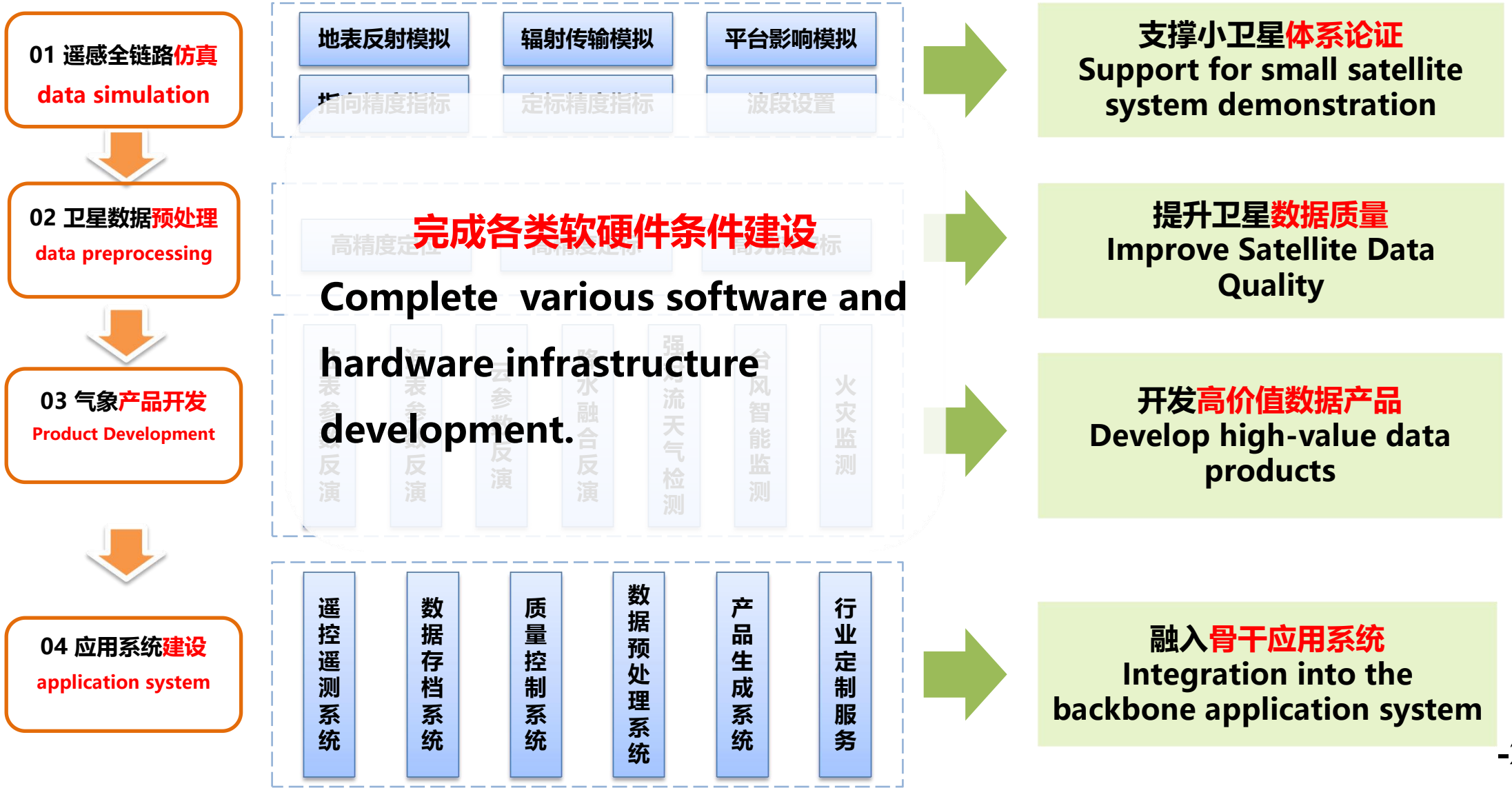
以提高卫星数据质量、提供更好的服务、支撑气象高质量发展为宗旨，攻关遥感数据仿真、数据预处理、典型产品算法、地面应用系统建设等技术，实现“全链条服务”。

Focus on tackling technical challenges such as remote sensing data simulation, data preprocessing, typical product algorithms, and ground application system construction, to achieve "full-chain services."



IV. Development Outlook

2. 气象卫星体系应用 Application of Meteorological Satellite Systems



Conclusion

The development of commercial aerospace requires a dual drive of policy guidance and technological breakthroughs, as well as a deep integration of the upstream and downstream of the industrial chain. Standing at the critical juncture of high-quality meteorological development, let us embrace commercial aerospace, create a new pattern for meteorological satellite development, and embark on a new chapter in the modernization of meteorology.

商业航天发展需要政策引导与技术突破双轮驱动，更需要产业链上下游深度融合，站在气象高质量发展的关键节点，让我们拥抱商业航天、创建气象卫星发展新格局，开启气象现代化建设的新篇章。

谢 谢

Thanks