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BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS

# Tiansuan Constellation: An Open Research Platform

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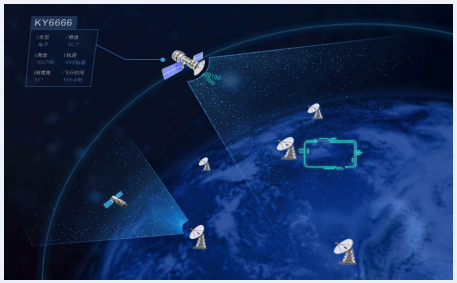
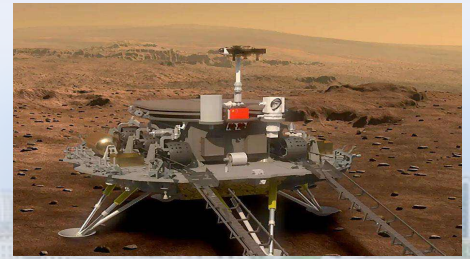
# Background(1)

- The 80% of the world's land and 90% of the world's oceans are not covered by ground Internet
- The 50% of the world's population has difficulty accessing the Internet



- Disaster relief, emergency response, remote sensing and other applications lead to an urgent need for in-orbit satellite computing and in-orbit services



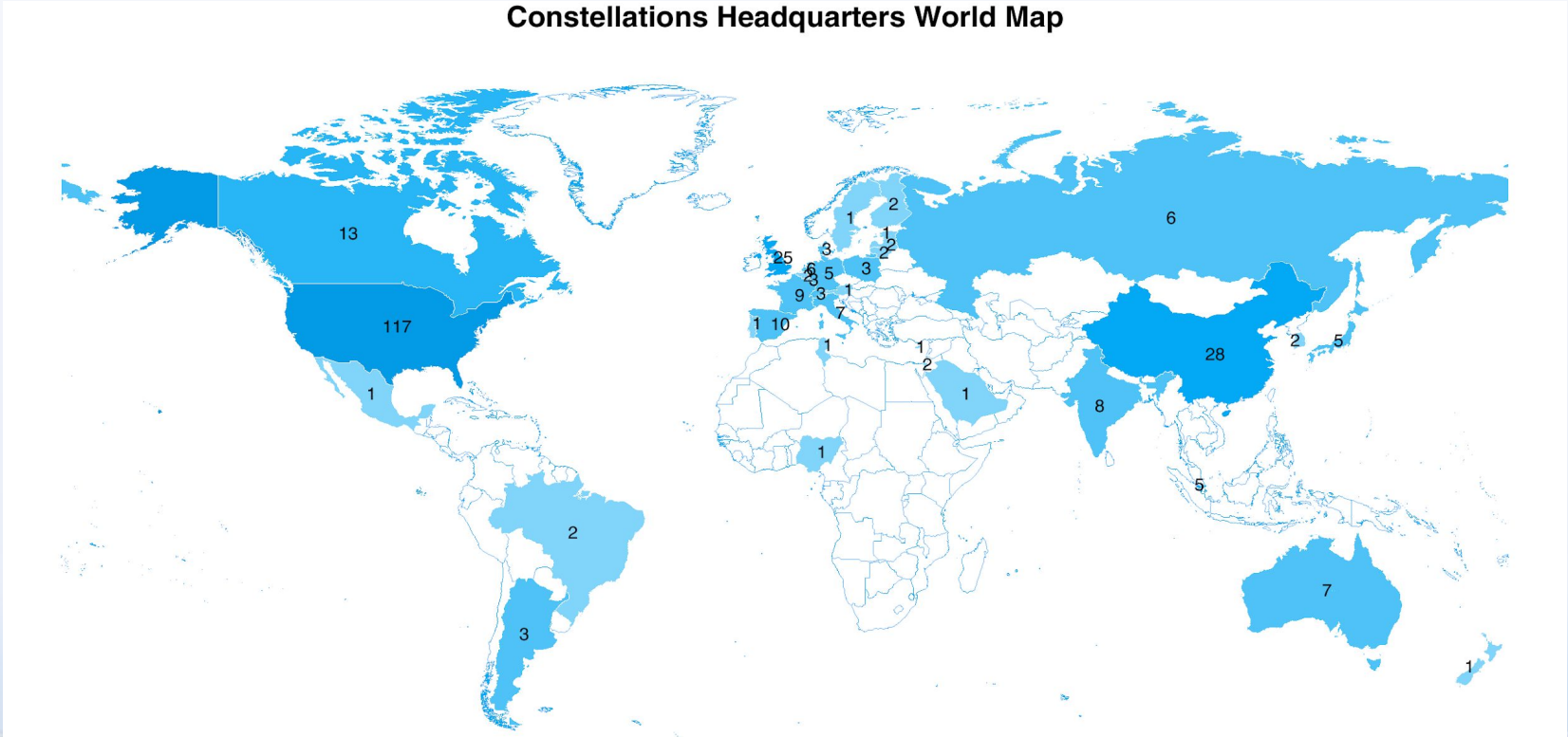
- With the intensification of competition among major powers, frequent disasters and exhaustion of resources, it is necessary to embark on interstellar voyages to expand the living space of mankind

# Background(2)

- Satellite network has become a global hotspot such as Starlink, OneWeb, China Satellite Network and so on.

- Satellite communication is characterized by wide coverage, large communication capacity, low transmission delay, no geographical influence and advantages in global information broadcasting
- Based on the ground network and extending from the space network, it will elevate the human cyberspace to a new dimension

# Background(3)



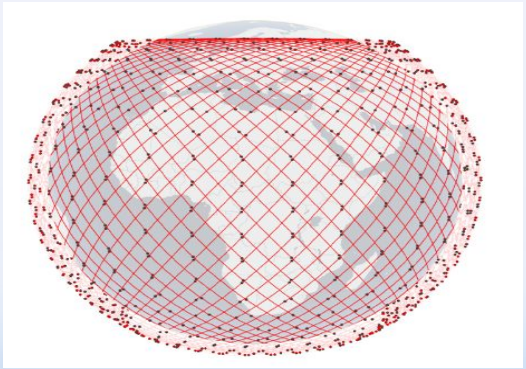
# Background(4)

- Bridge the research gap
- Contribute to the universal connectivity

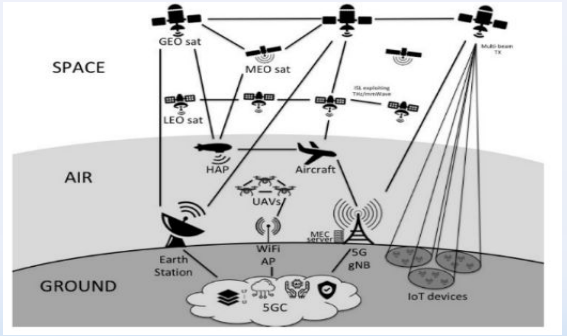
# Our Vision

- Satellites are becoming the next-generation platform for communication and computing
  - After PCs, datacenters, smartphones, edges…
  - Investment on the ground is getting marginal return compared to space

Reduced Cost



Dense Satellite Mesh



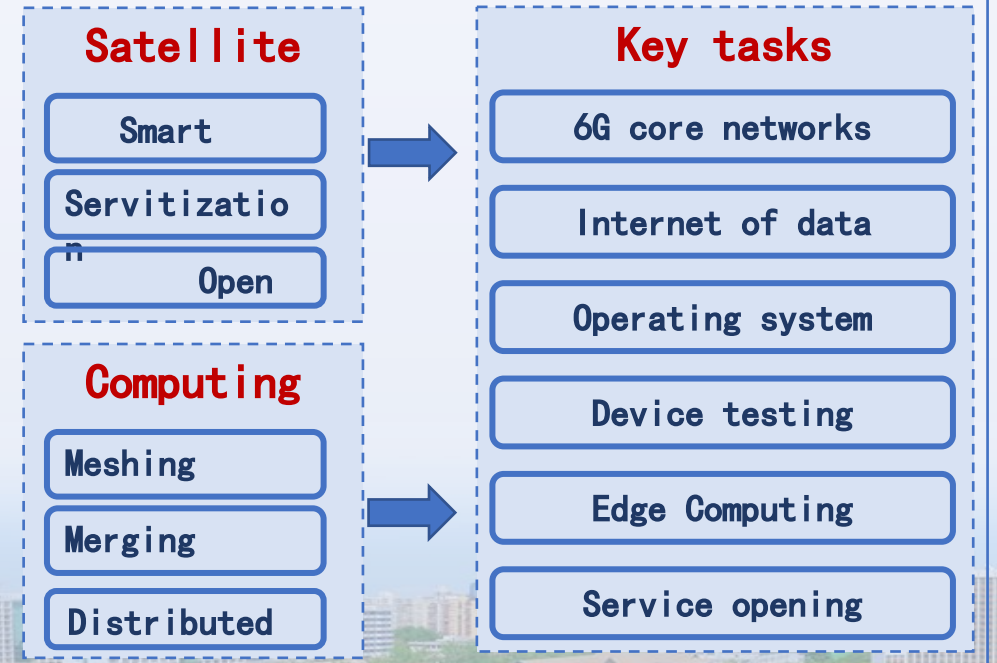

Satellite-terrestrial integrated network

# Our Vision

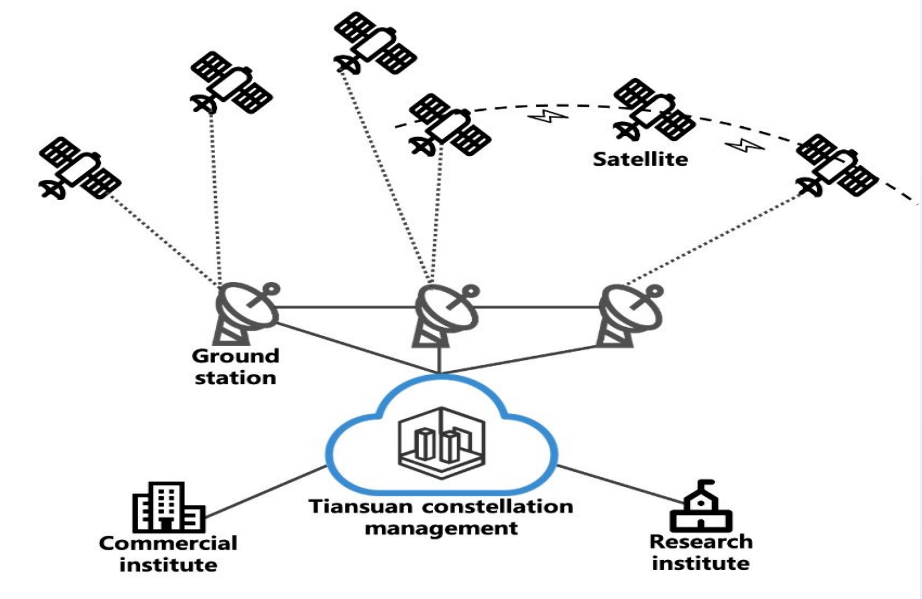
- **SNIC LAB**: established in June 2020 at Shenzhen. Interested in interstellar civilization, interstellar networks, satellite networks, distributed AI computing, etc.
- **Tiansuan constellation（天算星座）**

# Tiansuan (www.tiansuan.org.cn)

**Our Goal:** Building an open research platform facing human needs, based on industry-university-research and application



# Tiansuan (1)

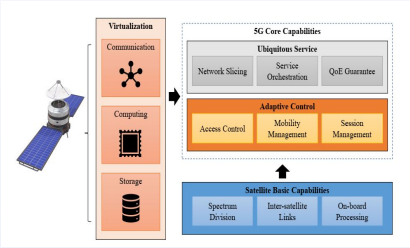



- Communication
- Computing
- Satellite operating system
- Security and reliability
- Hardware testing

Shangguang Wang, Qing Li, Mengwei Xu, Xiao Ma, Ao Zhou, Qibo Sun, Tiansuan Constellation: An Open Research Platform, Proc. IEEE EDGE 2021, Invited Paper.

# Tiansuan (2)

Satellite-Borne Core Network




Service Computing

SBA | Orchestration | Slice

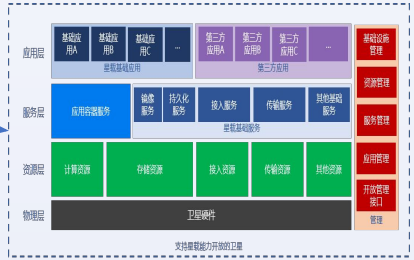
Control Plane

Cognitive service | Policy deployment | Control element

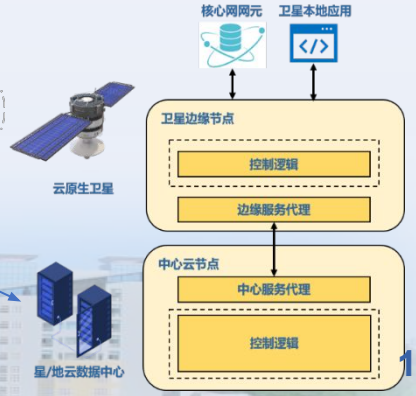
Data Plane

Transponder | Interface | Protocols

Satellite network



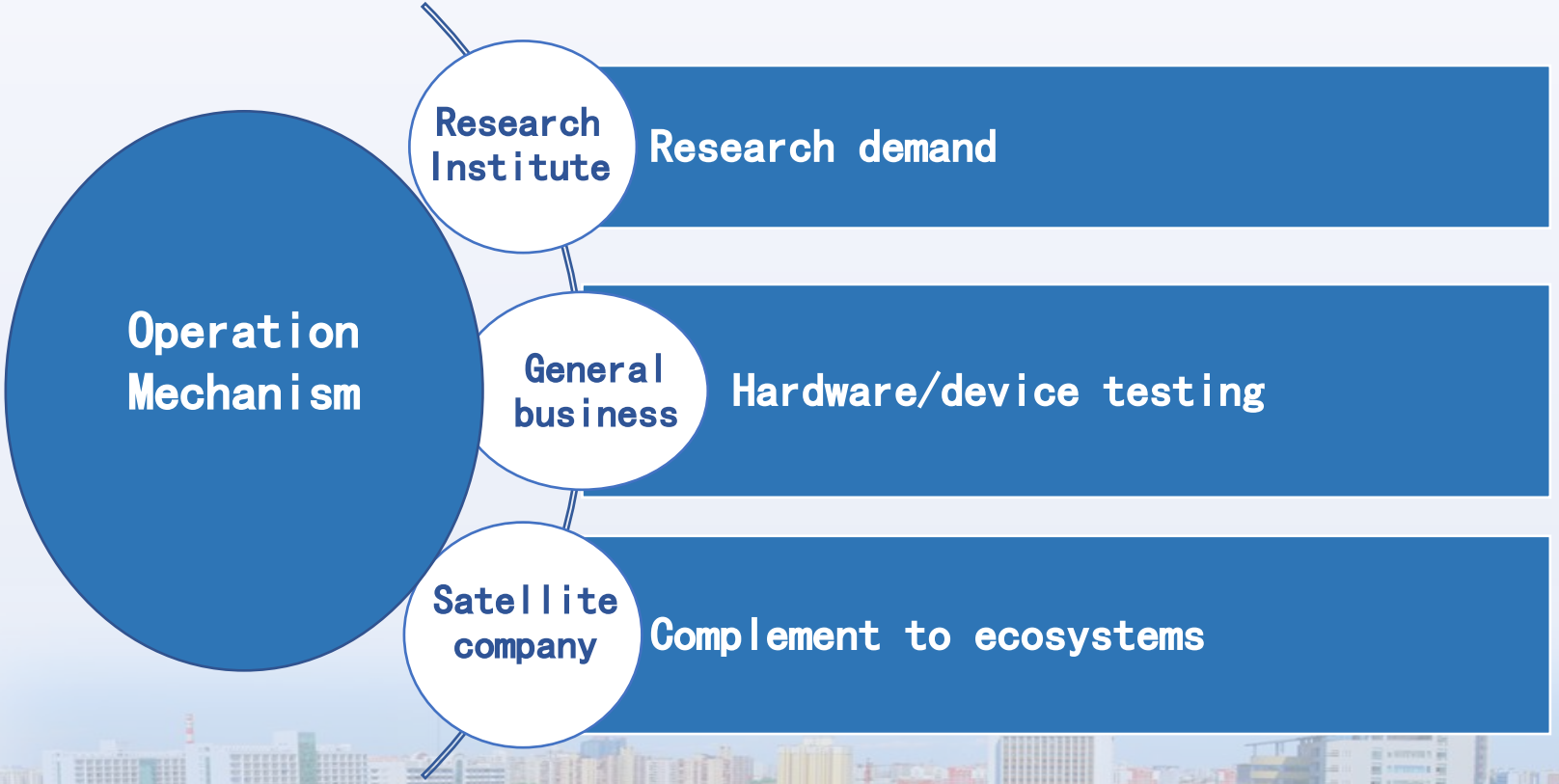

Ground station




terrestrial network

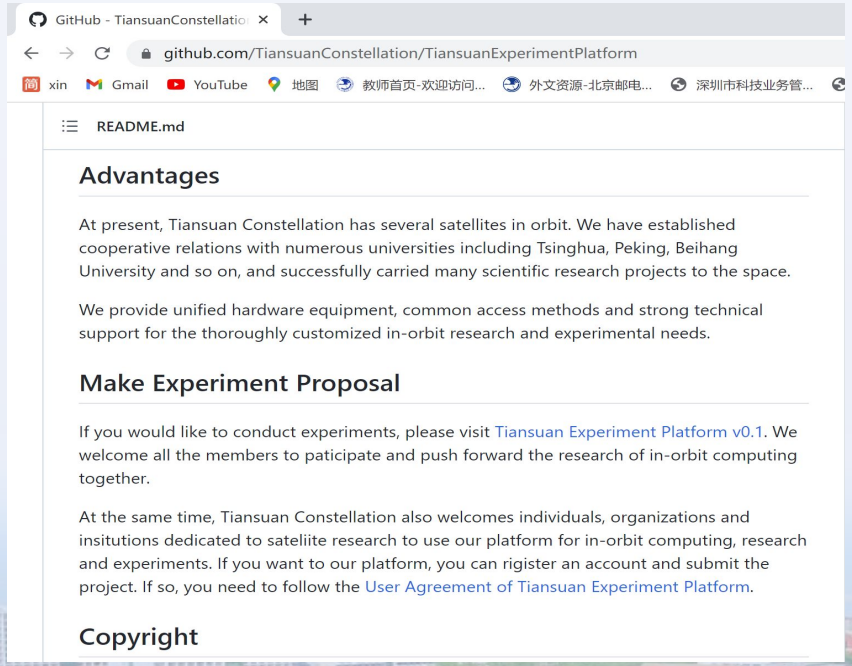
Ground cloud & core network

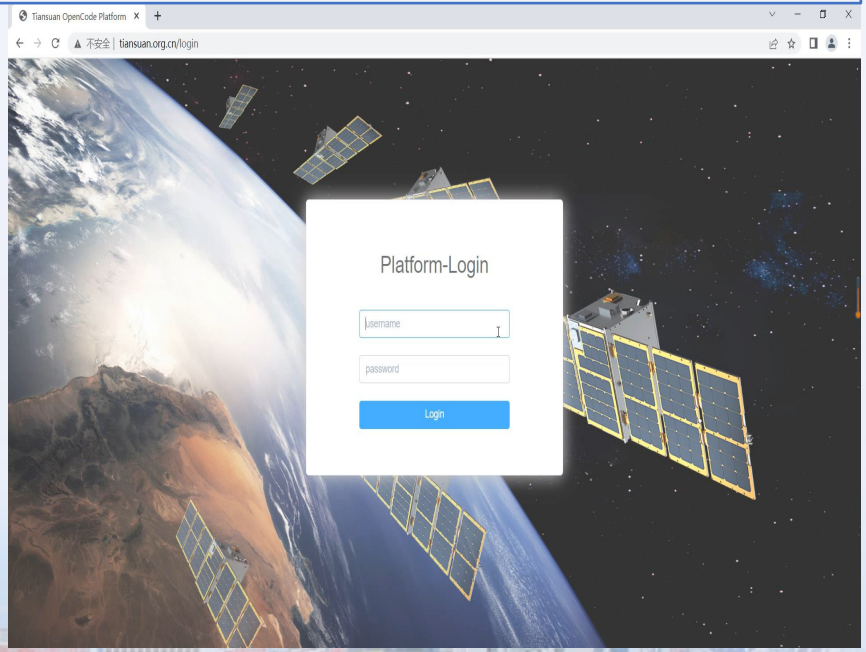
# Tiansuan (3)


Operation Mechanism
Research Institute
Research demand
General business
Hardware/device testing
Satellite company
Complement to ecosystems

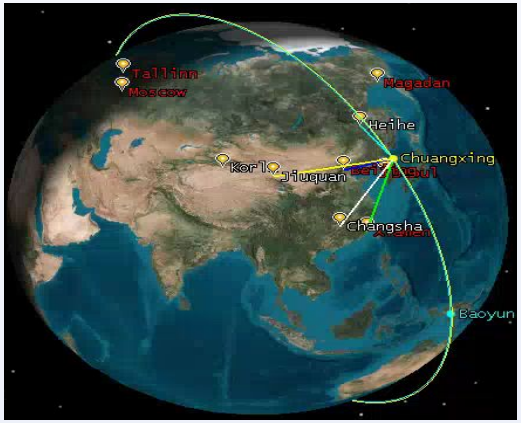
# Tiansuan (4)

- **Tiansuan Experiment Platform v0.1**
- https://github.com/TiansuanConstellation/TiansuanExperimentPlatform



# Current work：Launch two satellites




- 5G Core Network with 5G gNB software
- Cognitive Service Architecture for 6G Core Network
- Cloud-native Satellite
- Quic Protocol
- Network measurement

2021.12.7
Tiansuan1（baoyun）

2022.02.27
Tiansuan2（innovation Raytheon）

# Case Study: Satellite 5G Core Network

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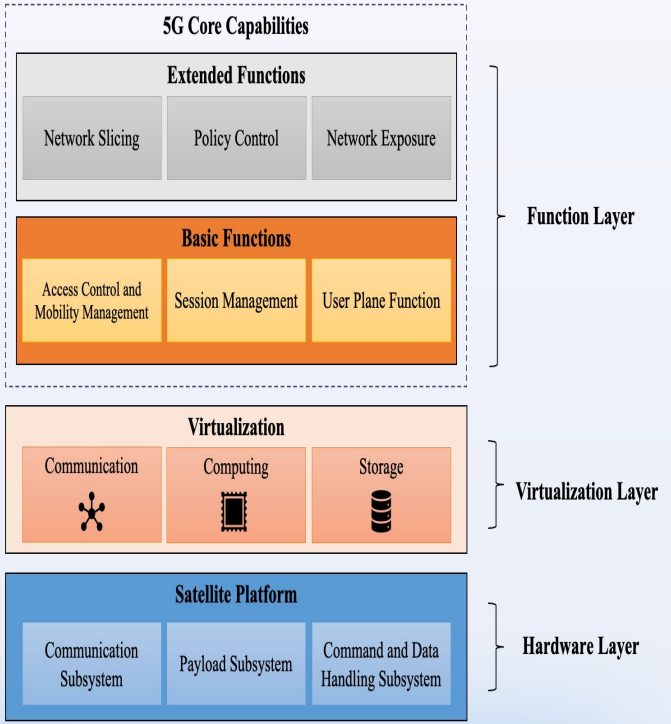
## Motivations

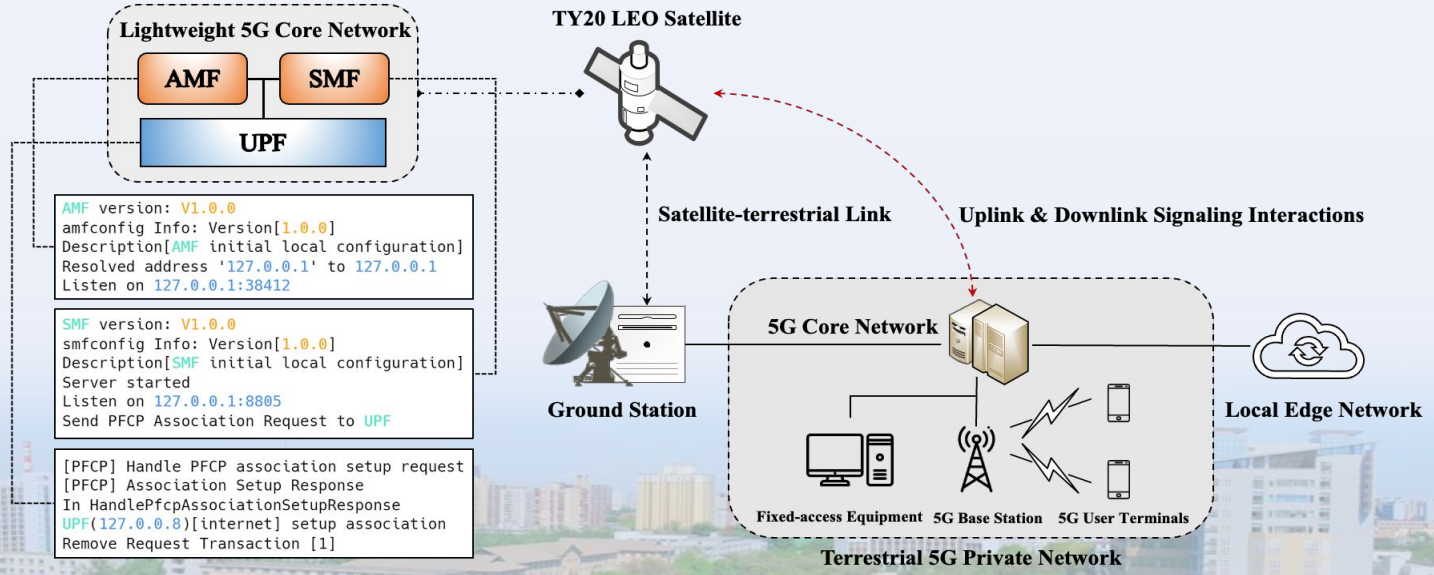
- **It supports LEO Satellites as Base Stations** and can integrate with future access networks which are made up of large-scale LEO satellite constellations
- **It has Potential Performance Gain**, and will reduce the control plane signaling interaction delay and speed up the user access procedures.
- **It benefits Onboard Services,** mobile users can access the satellite services more conveniently



# Case Study: Satellite 5G Core Network

## Architecture

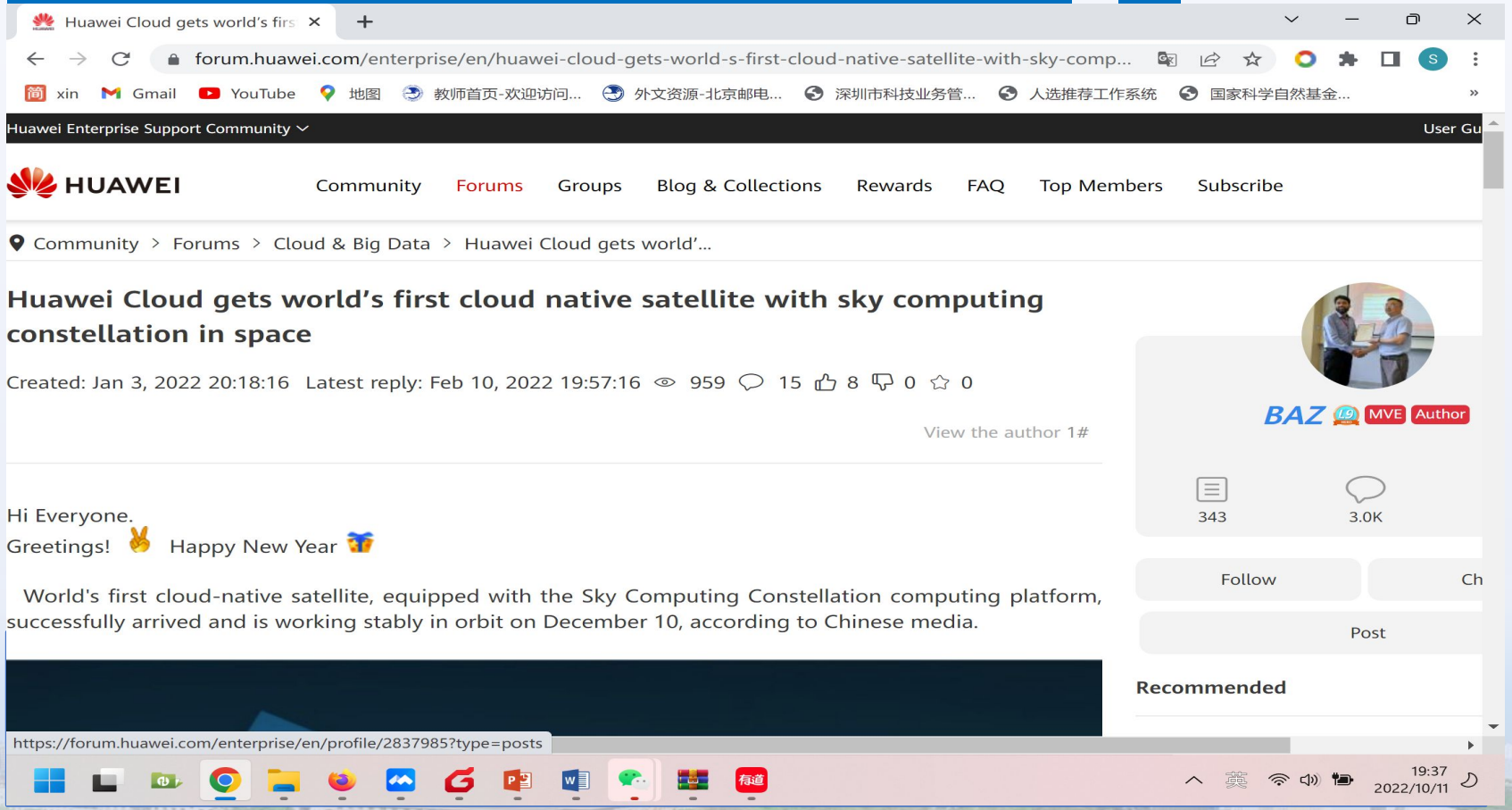
- It enables **Cloud-Native Networks in Space**, and build network functions like web apps
- It complements **Terrestrial 5G Networks**, and units the Space-Ground network from a Mobile Network perspective



# Case Study: Satellite 5G Core Network

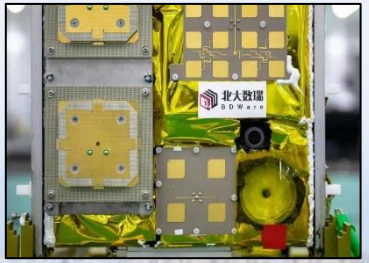
Ruolin Xing, Xiao Ma, Ao Zhou, Schahram Dustdar, Shangguang Wang, From Earth to Space: A First Deployment of 5G Core Network on Satellite, China Communications, https://arxiv.org/abs/2210.05405

# Case Study: Cloud-native satellite

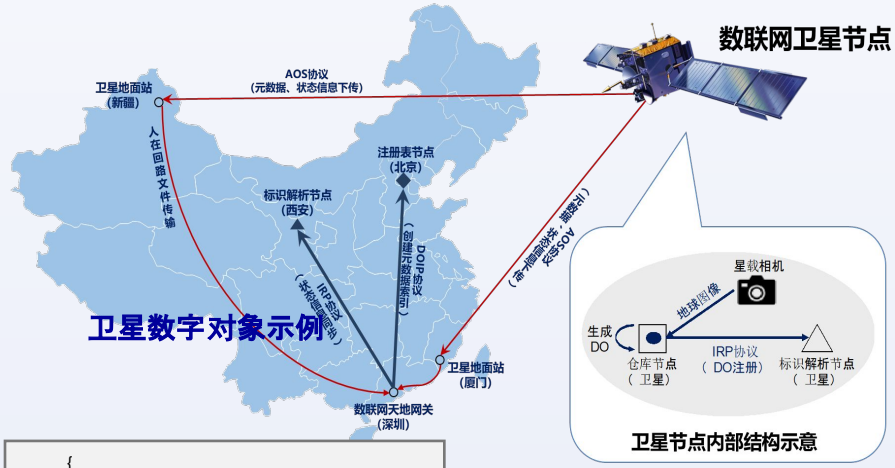


# Case Study: DOI satellite node

2021.12.7 Gushenxing1 Rocket



Data of Internet satellite node

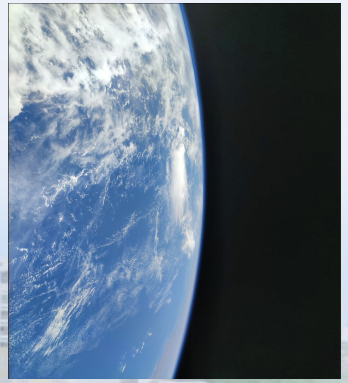



Marking

Metadata

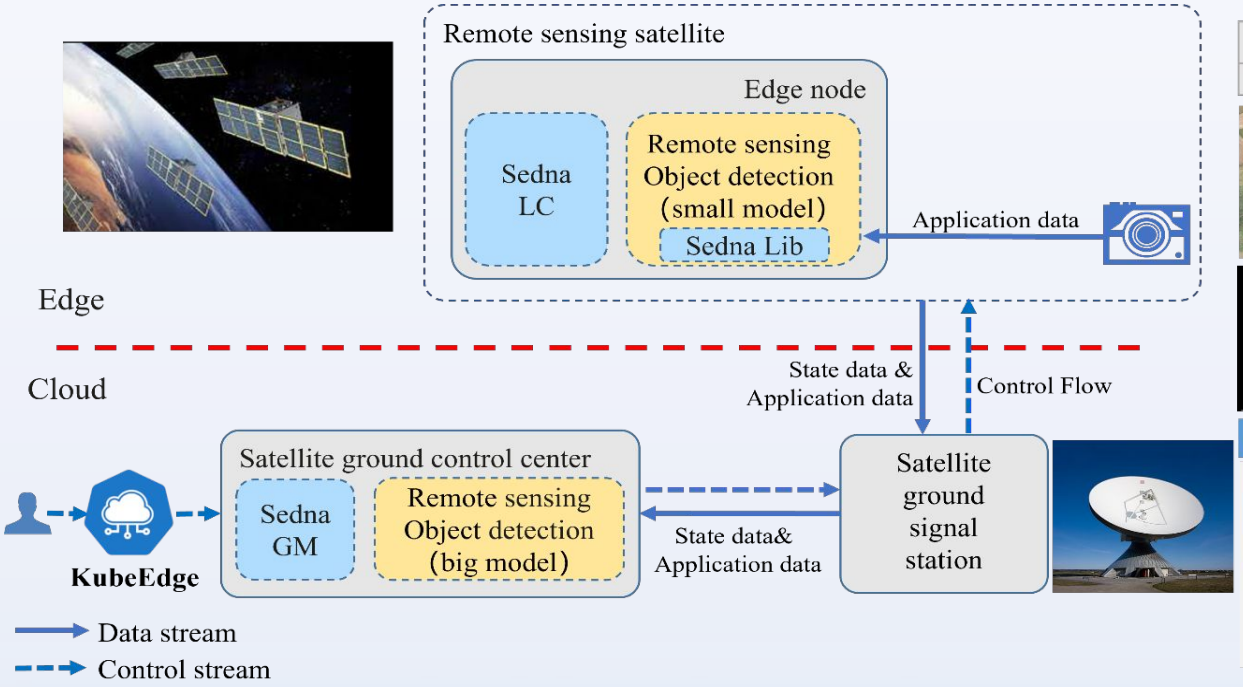
Entity

```
{
 "id":"86.5000.470/do.aSn44HqaO7_bdw",
  "type":"0.Type/DO",
 "attributes":{
   “name”: ”2wd89a41wd.jpg”,
   “from”: “satellite”,
   “desc”: ”photos by xiaomi”,
   ”date”:”20220301”
 },
 "elements":[{
  "attributes":{
    “size”: ”17.6MB”,
    “format”: ”jpeg”
  },
  "data":{ }
  }]
}
```



# Case Study: Satellite-ground computing






| Accuracy rate | Recall rate |
|---|---|
| 99.13% | 99.07% |

**The benefits**

- Improve the accuracy of area statistics
- Reduce satellite energy consumption
- Slow down the satellite-earth traffic
- Reduce transmission costs

- The cooperative AI inference between satellite and ground station is realized. In remote sensing scenarios, the identification accuracy of ground targets in orbit is improved by more than 50% through in-orbit cloud detection.
- Through in-orbit calculation, the amount of data returned by the satellite is reduced by 90%

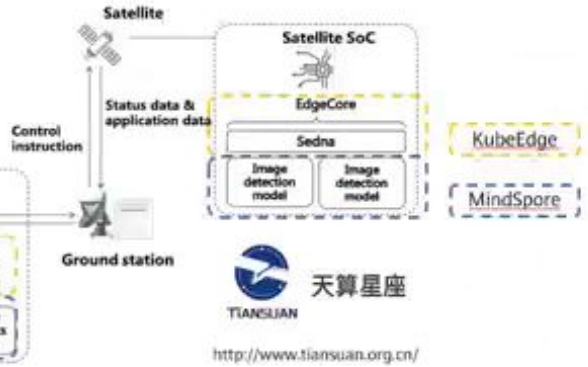
# Case Study: Satellite-ground computing

Huawei showed the work on the KubeCon and CloudNativeCon Europe 2022

## Cloud Native + AI For Space

KubeCon | CloudNativeCon Europe 2022

| Number | Orbital Altitude | Mass | Battery Capacity | Spectrum | Uplink Rate | Downlink Rate | ISLs | Processors |
|---|---|---|---|---|---|---|---|---|
| 1 | 500±50km | < 50kg | 110Wh - 230Wh | X-band | 0.1Mbps - 1Mbps | 100Mbps - 600Mbps | NO | CPU/SPU |
| 2 | 500±50km | < 50kg | 110Wh - 230Wh | X-band | 0.1Mbps - 1Mbps | 100Mbps - 600Mbps | NO | CPU/SPU |
| 3 | 500±50km | < 50kg | 110Wh - 230Wh | X-band | 0.1Mbps - 1Mbps | 100Mbps - 600Mbps | NO | CPU/SPU |
| 4 | > 500km | > 50kg | > 360Wh | X, Ku, Ka bands | ≥ 200Mbps | ≥ 1Gbps | YES | CPU/NPU/GPU |
| 5 | > 500km | > 50kg | > 360Wh | X, Ku, Ka bands | ≥ 200Mbps | ≥ 1Gbps | YES | CPU/NPU/GPU |
| 6 | > 500km | > 50kg | > 360Wh | X, Ku, Ka bands | ≥ 200Mbps | ≥ 1Gbps | YES | CPU/NPU/GPU |




- Working with BUPT, PKU, CMCC on the **Tiansuan Constellation** with Tiansuan-1 launched in Sep 2021;
- Shipped with CNCF KubeEdge and MindSpore to address the challeneges of :
  - **On-orbit computation** to minimize orbit-earth communication for better life span
  - Edge-cloud real time inference and **Incremental deep learning for SAR type task**

# Case Study: Space service computing

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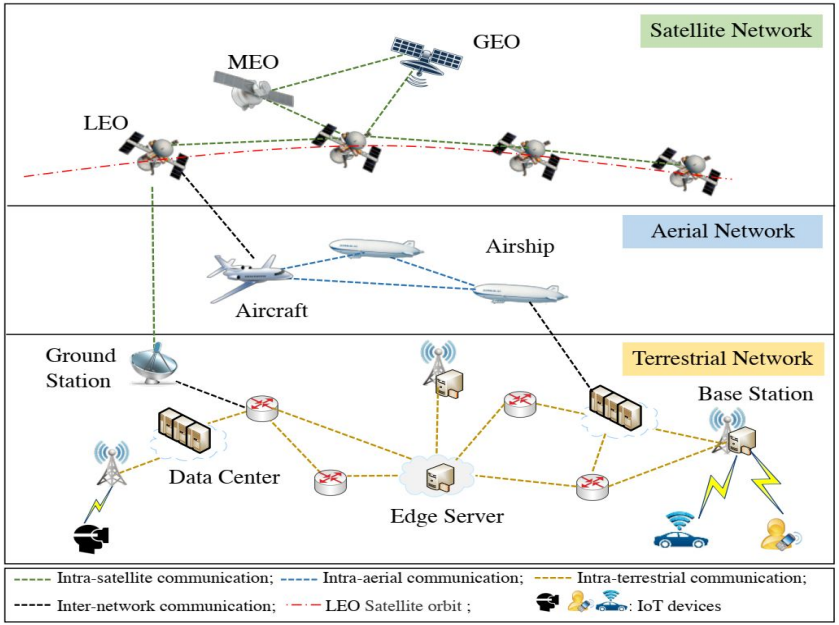
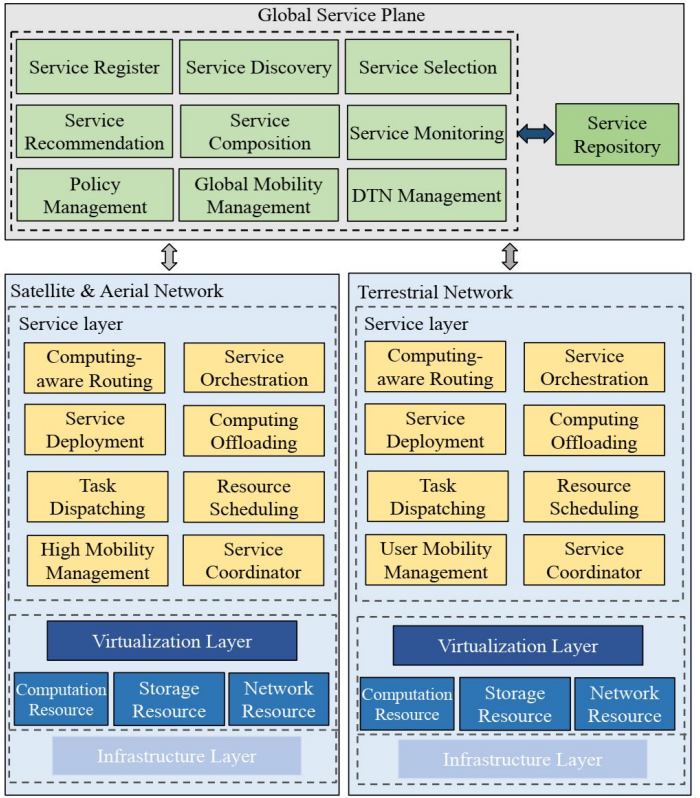
## Challenges:

- Space-time regional restricted connectivity
- Multi-dimensional complexity of resources
- Diversified user needs



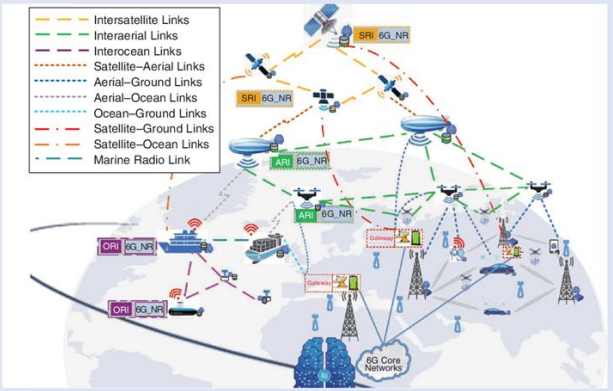




Yan Guo, Shangguang Wang, Challenges and Opportunities in Space Service Computing, In Proc. SCC 2021

# Research plan

## 6G exploration (2023 – )

- 6G space edge core network
- Service continuity guarantee
- Space-air-ground deterministic latency guarantee
- Space-air-ground service offloading and coordination
- Security and reliability

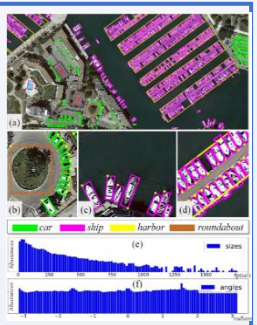


**The first paper about 6G core networks:** Y. Li, J. Huang, T. Sun, S. Wang, Cognitive Service Architecture for 6G Core Network, IEEE TII, 2021

# Research plan

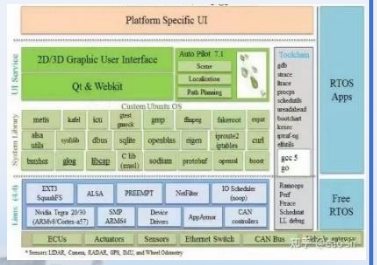
## Satellite-distributed AI (2022 – )

- Space-ground coordinated prediction
- Cross-satellite federated learning for data privacy
- Hardware acceleration for resource-efficient ML




## Satellite Operating System (2023 – )

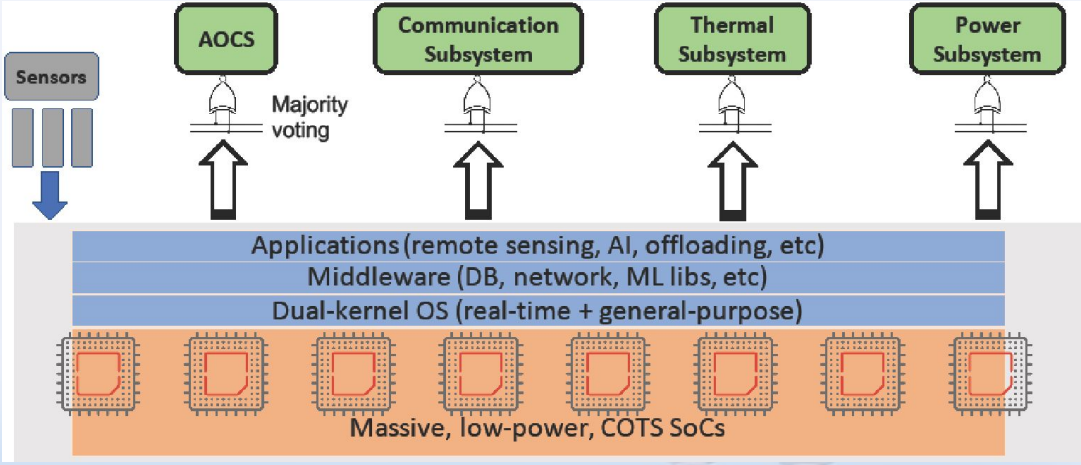
- Better performance and security
- Dual-kernel (RTOS + Linux)
- Rust-based



# Research plan

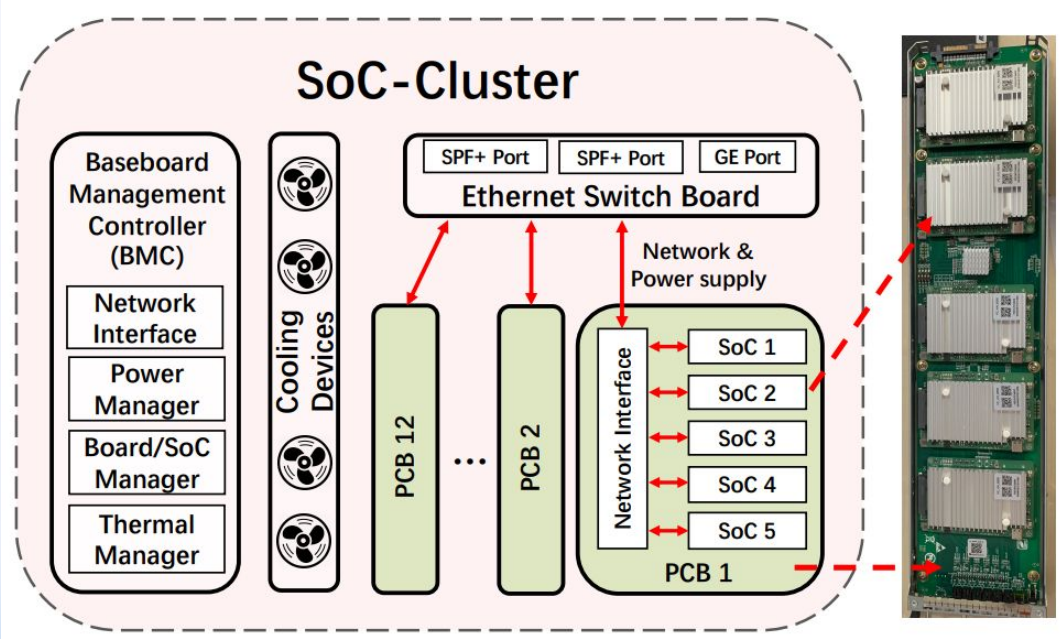
## In-space Computing Server (2022 – )

- A satellite-borne server design with massive ARM SoCs
- High computing density, high reliability, and high energy efficiency



# Research plan

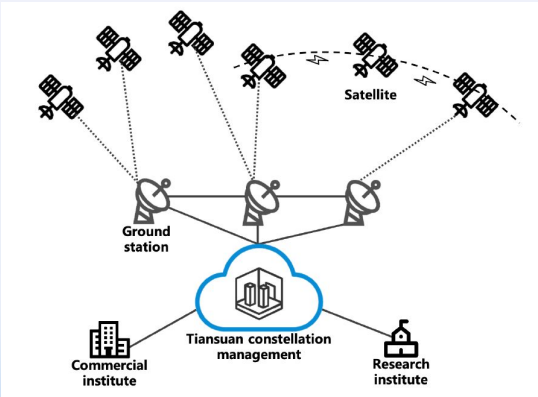
## In-space Computing Server (2022 – )



# Research plan

## Open Platform (2022 – )

- A public, web-based, unified platform that provides services to third-party researchers and practitioners
- = Satellites + ground stations + super-computing data centers

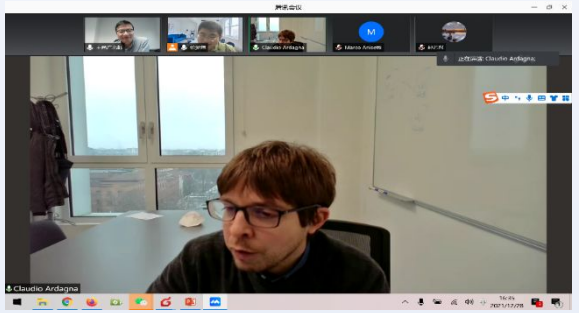


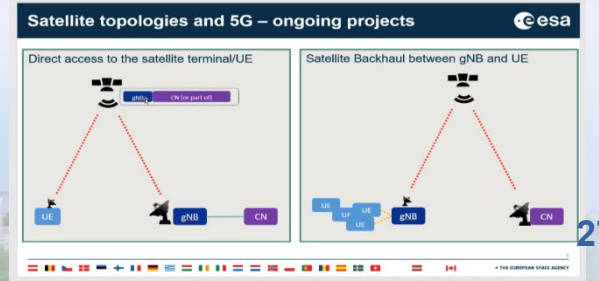

Existing partners:

- University of Milan, Italy
- Vienna University of Technology, Austria
- Peking University, China
- Chinese Academy of Sciences, China
- etc…

The blueprint paper about Tiansuan Constellation: S. Wang, Q. Li, M. Xu, X. Ma, A. Zhou, Q. Sun, Tiansuan Constellation: An Open Research Platform, IEEE EDGE, 2022

# International cooperation



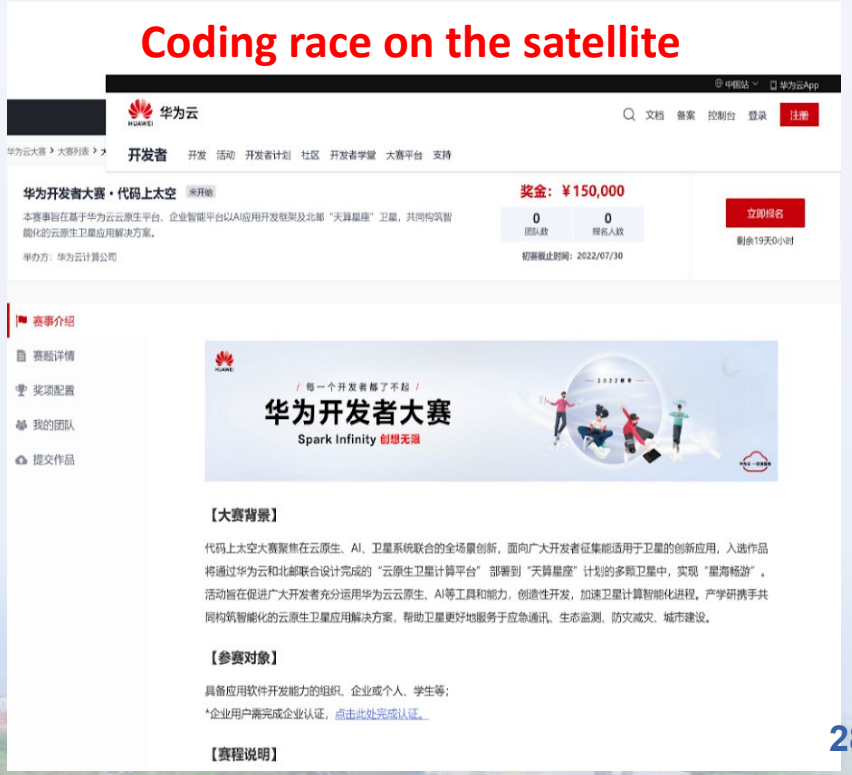


# International cooperation

http://ieee-satellite.org/

https://competition.huaweicloud.com

## Coding race on the satellite



# Future work

- Launch Tisansun3（望齐州号）, 2022. 11.6
- Launch BUPT1(北邮一号), 2022.12.10
- Launch other 2 satellite, about 2023.2

**A web-based, easy-to-use platform that allows any registered users to submit their code directly to real satellites!**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# Conclusion

- Introduce an open research platform, Tiansuan constellation
- Present the goal and key design and state how various institutes can benefit
- Discuss many potential research topics
- Give several case studies

# Thanks

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# Thanks & Questions!

Shangguang Wang

http://www.tiansuan.org.cn/