Intelligent remote sensing satellite based on Internet ─ LuoJia03-1 Satellite

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With the development of new technologies such as 5G/6G, cloud computing, the Internet of Things, and artificial intelligence, humanity has entered the era of the interconnection of everything[1]. In order to meet the service needs of the geospatial information industry in the era of Internet of Things, it has become an inevitable trend for remote sensing technology to move from isolated remote sensing satellites to space-based information networks[2-3].

On January 15, 2023, the first Internet intelligent remote sensing scientific experimental satellite-"Luojia03-1 satellite ", was successfully launched in Taiyuan, China. Facing the major needs of national aerospace technology, Luojia03-1 satellite is an important achievement in exploring new theories, technologies, and equipment for aerospace information intelligence services[4]. It has established an open mode experimental verification platform for remote sensing and communication integration, which can demonstrate the entire process of information acquisition, intelligent processing, sparse representation, compression transmission, and real-time distribution of terminals worldwide. Reflect the goal of "fast, accurate, and flexible" remote sensing data application in the spatial information network environment, the satellite provides an open on-orbit experimental verification platform for relevant scientific research institutions, and will also prepare the technology to promote the next step of real-time intelligent services for space-based information under the Internet[4,5].

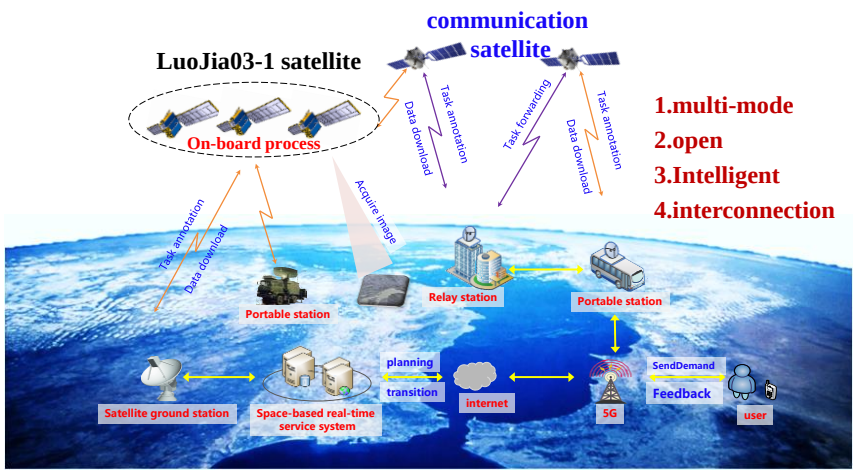


Fig1. Internet Intelligent Remote Sensing Satellite Real Time Service

1. Design of a New Generation Remote Sensing Satellite with Multimode Open Intelligent Interconnection

Luojia03-1 satellite is equipped with multimode optical imaging loads such as video gaze, area array push frame, and area array push scan. It has an on-orbit high-performance processing platform, an open software platform, and supports flexible loading and installation of intelligent processing APP in orbit. It has the following four core features:

(1)Multimode. Light and small remote sensing cameras have the characteristics of high-definition video, multi-angle stereo, and continuous area imaging, which can meet the observation needs of different application scenarios.

(2)Intelligence. A breakthrough has been achieved in satellite on-orbit real-time processing technology. Through intelligent processing units carried on board the satellite, combined with lightweight intelligent processing algorithms, traditional off-satellite processing and analysis tasks have been converted to onboard for the first time, which can effectively improve the intelligence and effectiveness of satellite services.

(3)Interconnection. Innovative integration of satellite to ground links and 5G mobile communications has opened up the two-way link between satellites and mobile phones, enabling global minute level intelligent services from remote sensing data to mobile phones, and supporting the provision of real-time intelligent services for remote sensing information to the general public from the data acquisition end to mobile terminals.

Table1 . Main technical indicators of Luojia03-1 satellite

Item	Technical index
	weight：245kg
	lifetime：1-3years
Payload	image-model：staring-video, push-frame, push-scan
	image-format: bayer
	resolution：0.72m@500km
	frequency：2~12Hz
	region-size：5km*4km(single-cmos imaging), 10km*4km(dual-cmos imaging)
Orbit	type：solar synchronization
	height：500km
	descending intersection time：10:30am
Intelligent platform	processing capacity：500GFlops
	caching capability：4GB
	software interface：open API
Data transfer	X-band:300Mbps
Observe and control	X-band:4Kbps(control),16Kbps(telemetry), 1Mbps(up)
	GNSS：GPS/BD
Sat Service	processing capacity：50MIPS
	onboard autonomous mission planning and generation binary-instructions

(4)Open up. For the first time, an open satellite algorithm platform has been provided, with 9 apps installed on orbit, including target detection, change detection, and image compression. Users can flexibly register, update, and uninstall onboard intelligent app algorithms based on different mission requirements.

2. Multimodal imaging for diverse user's needs

2.1 High resolution continuous area imaging

Luojia03-1 satellite is equipped with a small and lightweight sub meter resolution Bayer color area array camera, which can obtain images with a resolution of better than 0.72 meters at subsatellite points on a 500 km orbit. At the same time, it can perform area array push frame or linear array push scan continuous area imaging, with a maximum imaging time of 10 minutes and an amplitude width of more than 10 kilometers.

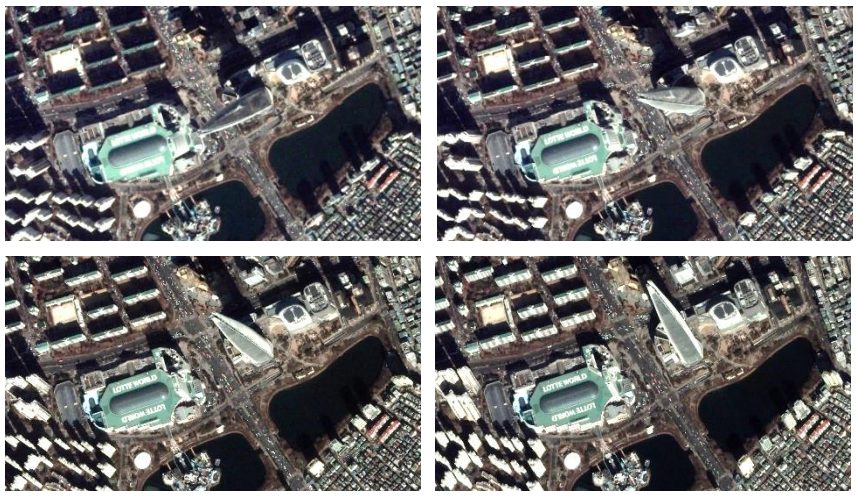
Note：imaged at Ferrari Theme Park in the United Arab Emirates On March 17, 2022.

Fig 2. High resolution continuous area imaging local image

2.2 High definition video real-time imaging

Satellite video gaze imaging and transmission is a key issue in the multimode and intelligent technology of Luojia03-1 satellite. The effectiveness of video gaze requires that the camera accurately point to the

target area during high-speed motion of the satellite. At the same time, the large amount of video gaze imaging data and the time-consuming satellite to ground transmission pose challenges for intelligent transmission. Luojia No.3 01 satellite uses on-orbit high magnification compression and transmission technology independently developed by Wuhan University, with a maximum transmission speed of 2Gb/min, effectively solving the transmission delay problem caused by bandwidth constraints. Satellite video gaze imaging data can serve target monitoring tasks with high time sensitivity requirements, such as port ships, highway vehicle flow, and airborne moving target tracking and monitoring tasks.

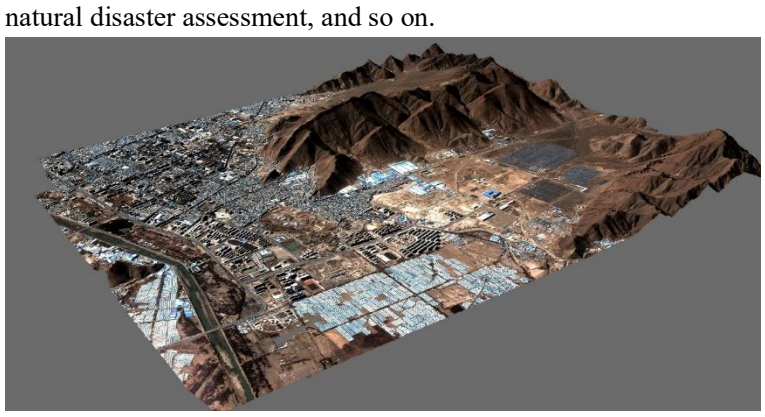


Note：imaged at Lotte World Building, Seoul, South Korea On February 21, 2023.

Figure 3 Staring video data at different imaging angles

2.3 Multi-angle 3D imaging

The multi-angle imaging data obtained from Luojia03-1 satellite can be processed through sensor correction, stereo image matching, dense matching and reconstruction to obtain high-quality three-dimensional terrain data, and build three-dimensional models of buildings or specific targets. This will play an important role in multiple fields such as urban planning and management, natural disaster assessment, and so on.

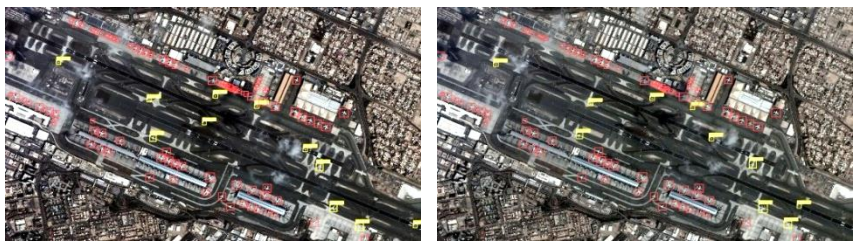


Note：Shigatse Region, Tibet, China, February 14, 2023.

Fig 4. Realistic 3D scene reconstruction data

3.Mission Driven High Precision On-Orbit Positioning and Intelligent Processing Technology

Luojia03-1 satellite has achieved a breakthrough in actively discovering and identifying interested targets. Satellites can perform cloud detection, target detection, moving target tracking, scene classification, change detection, etc. in orbit. Compared to the traditional mode of "transmission before analysis" for existing remote sensing satellites, satellite onrbit target detection accuracy and moving target tracking accuracy can meet most real-time intelligent analysis application requirements. At the same time, the intelligent processing unit carried by Luojia03-1 satellite also provides an important computing platform for deep learning model reasoning. Combining deep learning algorithms, it makes the satellite more intelligent, providing an important guarantee for real-time intelligent services of remote sensing information.



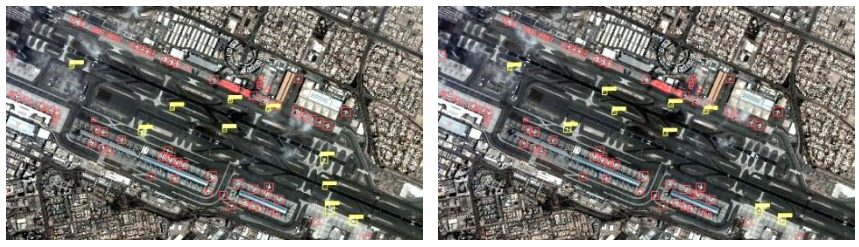


Fig5. Moving Target Tracking Results

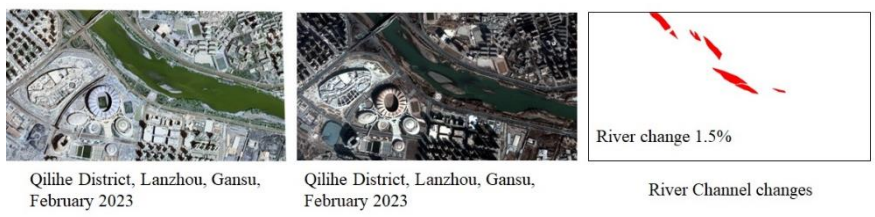


Fig6. Surface Change Detection Results

4. A New Mode of Internet Intelligent Remote Sensing Satellite Real Time Service

The on-orbit processing and real-time transmission characteristics of the Luojia03-1 satellite have broken the traditional satellite remote sensing data service model, creating a new B2C model for the Internet intelligent remote sensing satellite on-orbit processing and real-time transmission service for ground mobile terminals, shortening the time for satellite data acquisition, processing, transmission, and distribution, and meeting the "fast, accurate, and flexible" real-time information service requirements for remote sensing information, It can effectively improve the dynamic emergency response efficiency of emergencies and provide strong support for the popularization of remote sensing data mobile terminal services.

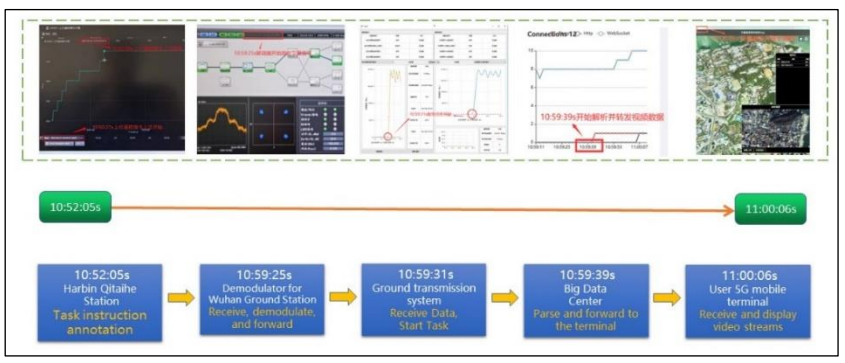


Fig7. On-orbit verification of minute level remote sensing information real-time intelligent service

On-orbit scientific experiments and tests have shown that it takes only about 8 minutes from acquiring data from the satellite terminal to receiving and displaying satellite video data on the user's mobile terminal, achieving a minute level real-time intelligent service for remote sensing information.

5. Summary and prospect

Focusing on the significant demand for "fast, accurate, and flexible" remote sensing information services, Luojia03-1 satellite has built a verification platform for the full link from data acquisition to real-time information intelligent services for intelligent remote sensing satellites in a large-scale network environment. In the future, it will provide a real-time verification platform for on-orbit functional software related to scientific research, and provide intelligent remote sensing services based on mobile phone apps to the public, promoting the leapfrog development of satellite remote sensing technology from traditional professional data services to popular, intelligent, and real-time remote sensing information services.

Acknowledgments

The author would like to express sincere thanks to the personnel involved in the development and experiment of Lujia03-1 satellite. Thanks to the reviewers and editors for their valuable comments.

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