Construction of Integrated Change Monitoring Business System

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Key Words: Integrated space-air-ground-network monitoring network;Integrated change monitoring;One map;One Survey, Multiple Uses

Abstract:

With the gradual deepening of ecological civilization,China has been establishing a categorized regulation mechanism in accordance with the requirements of having unified base map, unified standards, unified planning, and unified platforms, improving the integrated space-air-ground-network monitoring network and accelerating the establishment of a modern eco-environmental monitoring system by full utilization of various modern spacial information technologies . Based on the new positioning of surveying and mapping work, the author analyzed demands for change monitoring services across different departments and redundant construction in natural resources supervision and management, identified that traditional surveying and mapping production process no longer align with current technological advancements or diverse stakeholder requirements. It was imperative to restructure fundamental surveying and mapping production processes using modern informational technology ， establish an integrated solution centered on "change monitoring" technology which achieves simultaneous updates to fundamental geographic information, land cover, and land use data while enables effective supervision and early warning for the illegal and irregular issues in natural resource development and ecological protection， and ultimately realize a "multi-purpose survey" framework. Trough establishing integrated change monitoring business framework,we produced standardized change monitoring outcomes, consolidated the common needs of multiple businesses maximally, integrated production capacity, intensified various production materials,reduced production costs, improved the universality and timeliness of products from the supply-side perspective,achieved

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cross-departmental and cross-level business integration,and enabled infrastructure and data resource sharing ultimately.The scheme was applied and verified in multiple projects such as full-element monitoring, special monitoring, ecological and environmental protection, and arable land protection. As a result, it has achieved the expected goals of cost reduction and efficiency improvement, significantly enhanced the service support capabilities of surveying and mapping work for all tasks related to ecological civilization construction and economic and social development.

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1 Background

With the deepening of China's ecological civilization construction, building a modern environmental governance system has become an inherent requirement for enhancing the modernization of national governance capabilities. Faced with the new characteristics of systematic, complex, and cross-regional ecological and environmental problems, traditional single and fragmented monitoring methods can no longer meet the practical needs of integrated protection and systematic governance of ‘mountains, rivers, forests, farmlands, lakes, grasslands, deserts, and ice.’ In response to such demands, constructing a modern ecological environment monitoring network that achieves full territorial coverage, comprehensive element acquisition, and whole-process perception has become the technological foundation for addressing complex ecological and environmental challenges and supporting precise pollution control and scientific decision-making.

China has clearly stated at the national strategic level the urgency and necessity of constructing an integrated sky-space-ground-sea ecological environment monitoring system,while proposed principles for the coordinated construction of the ecological environment monitoring network, emphasizing ‘establishing and improving classified control mechanisms in accordance with the requirements of a unified base map, unified standards, unified planning, and a unified platform’,calling for ‘adhering to the integrated protection and systematic governance of mountains, rivers, forests, farmlands, lakes, grasslands, and deserts, and building a large-scale protection and governance framework from mountaintops to the ocean,’ as well as ‘accelerating the establishment of a modern ecological environment monitoring system and improving the integrated sky-space-ground-sea monitoring network’.

Multiple departments, including natural resources, water resources, emergency management, development and reform, and agriculture, have successively issued guiding documents within their respective responsibilities. These documents explicitly identify the ‘space-air-ground-network’ integrated monitoring technology system as the primary technical means to achieve dynamic supervision of all elements, processes, and coverage within their

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jurisdictions, thereby providing a solid data foundation for advancing ecological civilization construction.

After integrated into the Ministry of Natural Resources, the functions and responsibilities of geomatics department has been further clarified. As a key element in ensuring the unified allocation of natural resources, geo-information data serves as a core support for fulfilling the ‘two unified responsibilities’ of natural resources.Geomatics technologies and data extensively support the operations of various departments within the natural resources system, such as fundamental surveying and mapping, land resource surveys, monitoring of changes in natural resource elements and boundaries, dynamic monitoring of control boundaries, and the management and public services of fundamental geospatial data. The surveying, mapping, and geographic information departments have been advancing the restructuring of their operational systems, optimizing structural layouts, clarifying functional positioning, prioritizing core functions adapt to local conditions , and further leveraging the advantages of geomatics technologies to provide high-quality services for the advancement of ecological civilization.

2 Problems in current geomatics work

Putting the blueprint into efficient practices still faces severe challenges. In recent years, the geomatics departments have supported and ensured the collection and production of natural resources data. However, in areas such as management, task assignment, raw data acquisition, technical standards, quality control, and result services, the old operational systems continue to be used,which severely constrain the overall efficiency of surveying and mapping data production and urgently need to be resolved through deep technological integration and thorough process reengineering.

(1) **Fragmented Work and Low Efficiency.** Geomatics departments undertook fragmented and compartmentalized tasks from multiple departments of MNR due to multiple directives and individualized demands, that results in significant repetitive work and low production efficiency. Core tasks such as change monitoring have not build a complete and standardized operational system yet ,which lead to insufficient motivation for improving technical processes and the passive and auxiliary service models result in lacking foresight and integration of production organization .

(2) **Redundant Collection of Geo-information.** Because of lacking overall planning and coordination of geo-information acquisition, different industries, departments, and projects collect the same geographic elements within the same region repeatedly, leading to issues such as ‘multiple sources of data’ and ‘redundant data collection’ Inconsistent data classification, coding, and formatting standards create ‘data silos’, severely hindering data sharing and application.

(3) **Redundant construction of spatial information infrastructure.**With economic development, there is an increasing demand for spatial information technologies such as

satellite remote sensing, satellite navigation and positioning, and geographic information systems. Taking satellite remote sensing as an example, many regions, industries, and departments have established remote sensing application centers based on their operational needs. However, although most satellite centers are equipped with personnel and infrastructure, their utilization of satellite data limits to simple data distribution, be lack of the capability to produce high-quality standardized products. The inconsistency in data product standards and varying quality levels make it difficult to share, leading to resource wastage and contradicting the collaborative development and sharing mechanism of the informatization construction principles .

(4)Public geo-information services are unable to meet the demands of current social development and still confined to conventional mapping, with outdated geographic elements. Critical data from other sectors, such as natural resource survey data and control boundaries, has not to be integrated into public geographic information services yet . The factors mentioned above have led to results in disjointed processes across production, service and application.

In response to the above issues, surveying and mapping-related operations within the natural resources system need to deepen integration, break down internal departmental silos, merge similar functions, coordinate common tasks, optimize resource allocation, and promote the establishment of an integrated change monitoring operational system.

To further address the current problems, firstly, it is necessary to clarify the internal logic and supportive relationship between geomatics work and spatial information technologies and products. Geomatics work is the producer and provider of spatial information technologies and products. Using remote sensing data as raw materials and satellite navigation and positioning reference stations as core infrastructure, it produces standardized, interoperable public geographic information products, provides high-precision location services, and offers a spatial foundation for enhancing government governance capabilities and applications across various sectors of society.

Secondly, it is essential to advance the technological and operational upgrades ingeomatics work, maximize the consolidate common demands across multiple departments, integrate production capacity, intensive production resources, reduce production costs, and improve the quality of data supply. This will enable comprehensive and regular monitoring of geospatial elements, generate standardized change monitoring products, enhance the universality and timeliness of surveying and mapping products from the supply-side perspective, promote cross-departmental and cross-level operational integration, and achieve the sharing of infrastructure and data resources.

3 Integrated change monitoring business system

Change monitoring refers to the process of identifying and quantifying changes in surface features by analyzing geospatial data from the same area at different time periods. Definitions from major international organizations vary in focus: ISPRS emphasizes identifying changes in the location, extent, and nature of surface features through remote sensing imagery; FAO focuses on tracking dynamic evolution in natural resources and socio-economic systems; while USGS concentrates on systematic comparison of multi-temporal geographic data to interpret surface changes.

As a crucial technical method in geomatics work, change monitoring permeates various aspects of ecological environment monitoring. It represents one of the most urgently needed components in the daily operations of natural resource management and application departments.

The traditional surveying and mapping workflow can no longer accommodate modern technological advancements or meet diverse demands. With the ultimate goal of sharing infrastructure, sharing data resources, co-building service platforms, and restructuring common services, by reconstructing fundamental surveying and mapping production processes based on modern information technology, an integrated solution centered on change monitoring technology is emerging. This approach not only enables synchronous updates of fundamental geographic information alongside land cover and land use data, but also effectively monitors and provides timely warnings regarding illegal activities in natural resource development and ecological protection - thereby achieving the 'once survey multi-use' principle.

3.1 Integrated change Monitoring Technology System

An integrated 'space-air-ground-network' monitoring technology system has been established, combining various technical means such as satellite remote sensing, aerial remote sensing, drones, the Internet of Things, and ground-based monitoring station networks. This system achieves a multidimensional monitoring capability that integrates broad coverage with detailed perception. Leveraging functions like time-series analysis, text mining, and graph neural networks in big data technology, it identifies spatial change clues and extract spatial change information quickly. Using the visual understanding and analytical capabilities of large remote sensing models and various sample libraries and model libraries, tasks such as feature classification, target detection, and change detection, are accomplished rapidly and accurately, providing core technical support for change monitoring.

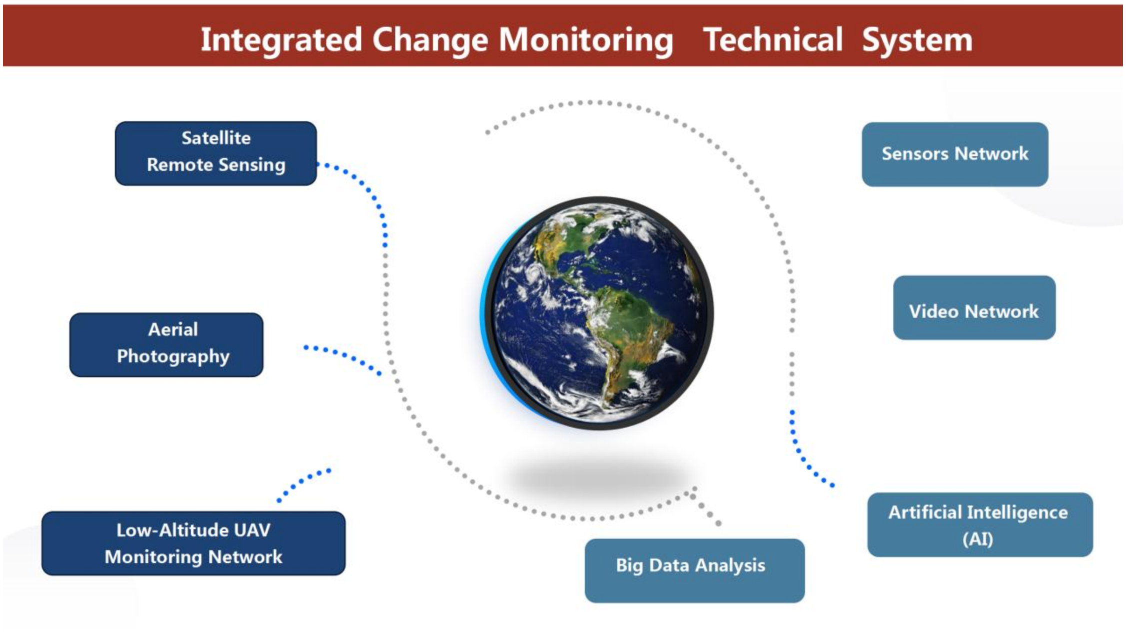

Fig. 1: Integrated Change Monitoring Technology System Diagram

3.2 Integrated change monitoring business system

3.2.1 'One Map': the data foundation

Fundamental geospatial data is the core content of 'One Map' for natural resource management, which includes the basic geographic information data produced by traditional surveying and mapping departments, natural resource survey data, change monitoring data, and control boundaries. It serves as the critical data foundation for the integrated change monitoring business system.

Natural resources geospatial big database comprises a unified data standard system, an integrated database and service platform, centralized data management of fundamental surveying and mapping products, real-scene 3D models, resource surveys, various spatial boundaries, and marine surveying and mapping data , shared services and in-depth applications, which will ultimately form the structure of 'one base map, one set of data, and one platform', provide a unified spatial information data foundation for the construction of ecological civilization.

3.2.2 Construction of standardized system for monitoring products

By reviewing survey and monitoring task information and extracting requirements within the natural resources system, using the 'Classification of Land Change Survey Work' as a unified foundational framework, a new unified change classification system is constructed in accordance with design principles such as 'systematicness, completeness, scalability'. This system integrates business attribute extension codes and specialized rule libraries, while accommodating multidimensional application needs, including fundamental surveying and mapping, law enforcement and supervision, natural resources inspection, arable land protection, forest-grassland-wetland monitoring, and ecological conservation. It achieves dual identification of "land category attributes + management attributes" for change parcels.

3.2.3 Production models optimization

Traditional surveying and mapping production organization methods are inadequate to meet current production demands, restricting the efficiency improvement of modern technologies.In the construction of an integrated change monitoring technology system, emphasis is placed on using technical logic to refine production models and management logic, thereby optimizing and upgrading the original surveying and mapping production methods.

3.2.3.1 ‘Grid-based, Responsibility System’ Production Organization Method

Geospatial data production grids are delineated based on administrative boundaries, natural geographical boundaries (such as mountains and water systems), and the "three control lines." These grids are then assigned to responsible units and personnel, clearly defining ‘responsibility zones’ and ‘grid staff’. The advantages of the ‘grid-based and responsibility system’ production organization model are as follows: First, it ensures clear responsibilities and facilitates product traceability. Second, it enhances production efficiency. With the accumulation of work experience, production units and specific operators have become increasingly familiar with the topography and land cover of their designated areas, enabling them to promptly identify changes.Third, shifting from passively identifying to proactively detecting changes facilitates the establishment of standardized operational procedures.

3.2.3.2 Bottom-Up Workflow

After delineating grids and determining designated responsibility areas, the primary operational tasks for responsible units, departments, and personnel at each grid level are to conduct change monitoring. Starting from the smallest grid unit, a standardized integrated change monitoring business system is established, centered on the process of ‘change detection, change extraction, classification and qualitative evaluation, change verification, product assembly, and result dissemination’, by comparing the differences between the latest remote sensing images and fundamental geospatial data (natural resource and geospatial data) within the responsibility area.

（1）Change Detection

Using fundamental geospatial data, resource surveys, and control boundaries as background data, high-resolution satellite remote sensing is employed for periodic change monitoring across the entire area, with the cycle based on the time of full image coverage. Customized satellite or aerial remote sensing images are used for specialized monitoring in key local areas, while drone remote sensing is deployed for verification in critical regions. Ground-based fixed intelligent sensor monitoring and field surveys serve as supplementary methods.

（2）Change Collection

Newly observed data are promptly distributed to staff responsible for data production of the specific grid. They compare the data with the background data, collect all changes, and compile a comprehensive set of periodic changes in fundamental geospatial information.

（3）Change Classification and Characterization

Comparing various supporting materials, the type and nature of changes are determined. Changes are categorized as follows: changes in geographic features (e.g., newly added roads, buildings); changes in surface cover and land use boundaries (e.g., boundaries of farmland, forest land); and changes suspected to transcend various legal boundaries (e.g., newly constructed buildings within natural reserve).

（4）Change Verification

For changes that cannot be determined or accurately classified in internal work, necessary field verification is conducted. For illegal and unauthorized cross-boundary development, relevant documents should be verified.

（5）Product Assembly

Change results are classified and aggregated step by step, forming change monitoring outcomes for grids at each level.

（6）Result dissemination

If the changes are lawful and compliant, they are used to update fundamental geospatial data and resource survey data. If they are suspected to be unlawful or non-compliant, the change results are categorized and submitted to relevant departments for tasks such as natural resource supervision and law enforcement, cultivated land protection, oversight of spatial planning implementation, Special Campaigns and related tasks. Figure 2 illustrates the principle of the integrated change monitoring business system.

Fig.2： Principle of the of Integrated Change Monitoring Business System

The establishment of the change monitoring business system has not only improved the efficiency of surveying and mapping work， but also boosted the comprehensive enhancement of natural resource supervision capacity and efficiency. In emergency surveying and mapping support work, standardized change monitoring business can also significantly improve work efficiency.

3.3 'One Survey, Multiple Uses' geographic information data production system

Change monitoring can promptly detect and collect the boundaries of changed geographic features and newly added surface objects. This enables the timely updating of fundamental surveying and mapping achievements and land and resource survey results (including change surveys), and also provides a novel method for updating all fundamental geospatial data.

3.3.1 Coordination of 3 tasks

Surveying and mapping production within the natural resources system can be summarized as three primary tasks: fundamental surveying and mapping, resource surveys, and change monitoring. Fundamental surveying and mapping and resource surveys require dynamic updates, and the update processes are similar to the change monitoring workflow. Therefore, change monitoring can be taken as the main focus to coordinate the three tasks, effectively integrating them in terms of production processes and technical standards, and addressing public and overlapping elements. This ensures that in the same area, fundamental surveying and mapping updates and resource change surveys are conducted simultaneously. The results of change monitoring can not only support various tasks in natural resource supervision but also be used to update basic surveying and mapping and resource survey outcomes, thereby achieving 'one survey, multiple uses'

.3.2.2、production organization optimization

The traditional production organization model is project-driven, with tasks assigned from the top down. Production units decompose these tasks layer by layer, eventually deploying them to specific staff. staff complete tasks according to project requirements, and the units then aggregate and perform quality inspection before submitting the final results . The new production model centers on changes within responsibility areas, where the responsible units independently carry out data production. The distribution of remote sensing data is distributed to fourth-level grid-based operators at the first, ensuring the timeliness of change monitoring. Operators, using remote sensing image updates as their work cycle, follow the change monitoring business process to assemble products level by level from the bottom up and proactively push the results to meet the needs of multiple applications.

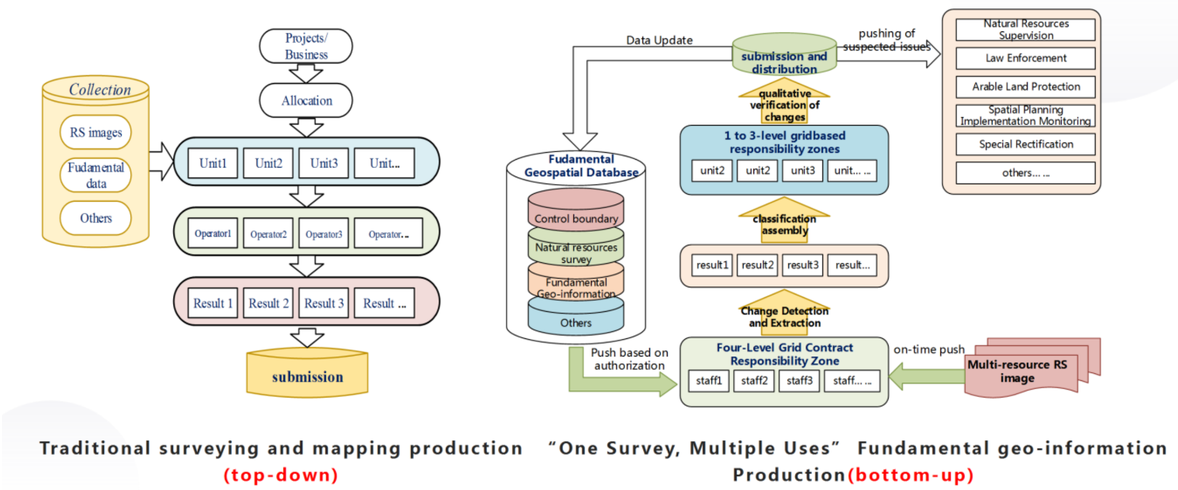

Fig. 3 Comparison of the traditional and new production organization mode

Change monitoring results can be used to support various tasks in natural resource supervision and to update fundamental surveying and mapping as well as resource survey outcomes. This facilitates the intensive utilization of resources, thereby achieving the goal of "one survey, multiple uses."

4. Validation and Analysis

To further validate the feasibility, accuracy and usability of the integrated change monitoring business system, data from three county-level regions in Shaanxi Province—Northern Shaanxi, Guanzhong, and Southern Shaanxi—were selected for experiments on integrated change monitoring data production. These experiments also verified ‘grid-based, responsibility system ’management models. The total area of the test regions amounted to 961.5 km², involving six surveying, mapping and geographic information projects, tasks such as change collection, data storage, and product assembly were carried out. Analysis shows that the traditional production model requires extracting 15,600 change patches to complete six projects, whereas integrated change monitoring only requires extracting 4,546 change patches, resulting in a 3.4 times increase in work efficiency.

	integrated change monitoring	remote sensing monitoring		forest-grassland-wetland monitoring		law enforcement		illegal occupation of cultivated land in rural areas		arable Land Protection		supervision and inspection	
Fuping	**2601**	**2519**	**97%**	**865**	**33%**	**1970**	**76%**	**172**	**7%**	**1776**	**68%**	**1813**	**70%**
Wuqi	**1183**	**1166**	**99%**	**947**	**80%**	**842**	**71%**	**145**	**12%**	**320**	**27%**	**331**	**28%**
Danfeng	**762**	**729**	**96%**	**447**	**59%**	**680**	**89%**	**112**	**15%**	**384**	**50%**	**382**	**50%**

Statistics of Reused Patches in Fuping						
Repeat count	1	2	3	4	5	6
No. of patches	10%	24%	9%	44%	11%	2%
Statistics of Reused Patches in Wuqi						
Repeat count	1	2	3	4	5	6
No. of patches	4%	34%	43%	1%	13%	5%
Statistics of Reused Patches in Danfeng						
Repeat count	1	2	3	4	5	6
No. of patches	2%	31%	27%	10%	27%	2%

Fig. 4: Statistics of Reused Patches of Product Assembly

Meanwhile, in key areas ecological protection projects and arable land protection, the application of the integrated ‘space-air-ground-network’ monitoring model has achieved remarkable results which deeply integrates multi-dimensional technological means such as satellite remote sensing, drones, video surveillance, and grid-based personnel verification, enabling comprehensive supervision from the macro to the micro level. As a result, it provides real-time, precise, and scientific decision-making support for government administration.

5. Conclusion

The systematic integration and coordinated governance of geospatial data resources across key dimensions—including data standardization systems, public service platform architecture, integrated change monitoring mechanisms, and sustainable update models—form the logical foundation and fundamental support for building the foundational platform of the ‘One Map’ for natural resources. Therefore, strengthening the integration of data resources and business convergence within the natural resources system, redefining the content of data element supply for surveying and mapping departments in the new era based on fundamental geospatial data, and constructing an integrated change monitoring business system is an innovative exploration that maximizes the integration of public demands for multiple businesses, consolidates production capacity, intensifies various production factors, reduces production costs, and enhances the universality and timeliness of products from the supply-side perspective. This not only addresses the issues of improving production efficiency and service capabilities but also further clarifies the main responsibilities of surveying and mapping work. These will inevitably lead to a series of changes, including functional adjustments of various business departments and units within the natural resources department, restructuring of the business system, transformation of project management methods, and revision of data standards.