Development and Application of Photogrammetry and Remote Sensing in Disaster Prevention and Mitigation in China

Prof. Jixian Zhang

National Administration of Surveying, Mapping and Geo-information

2016.05

Outline

1. National Emergency Mapping System
2. Status of its Development and Application
3. Challenges of its Development and Application
4. National Emergency Geospatial Information Project
5. Conclusion and Suggestions

China suffered from natural disasters
中国是自然灾害多发的国家

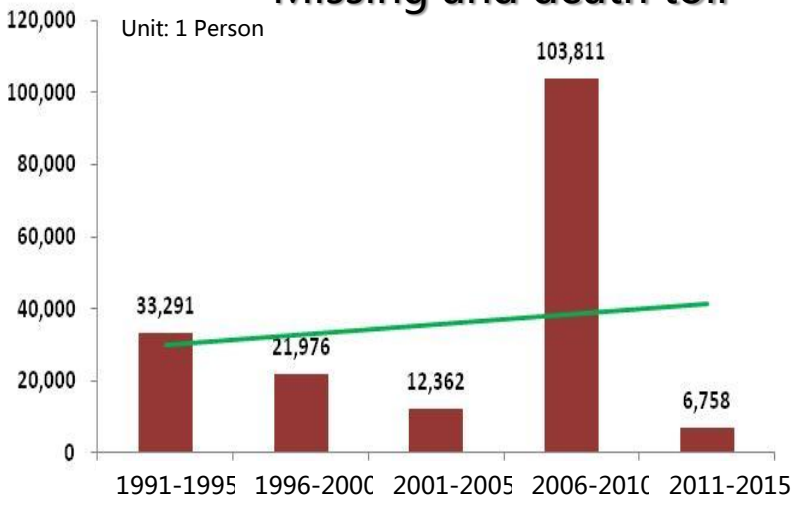
Emergency 突发事件

- Natural disaster 自然灾害
- Accident disaster 事故灾难
- Public health incident 公共卫生事件
- Social security incident社会安全事件

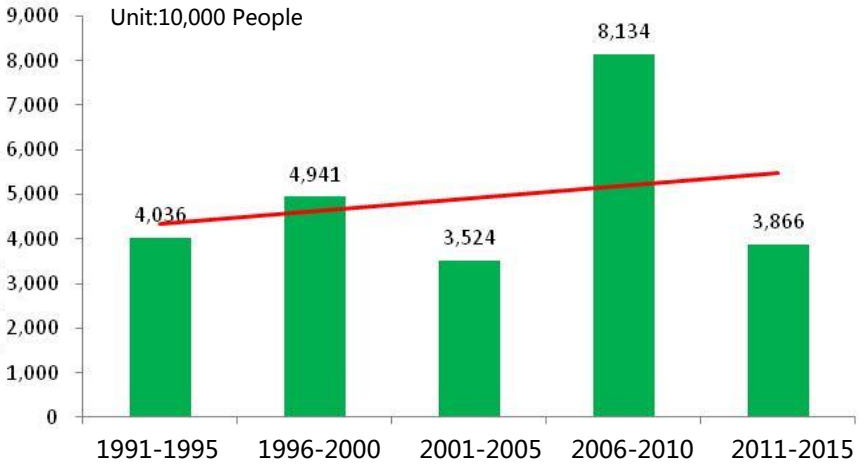
- Meteorological disaster 气象灾害
- Marine disasters 海洋灾害
- Flooding 洪水灾害
- Geological disasters 地质灾害
- Earthquakes 地震灾害
- Biological disasters 农林生物灾害
- Forest and grassland fires 森林草原火灾

Statistics of disaster damages in China
灾害影响统计数据

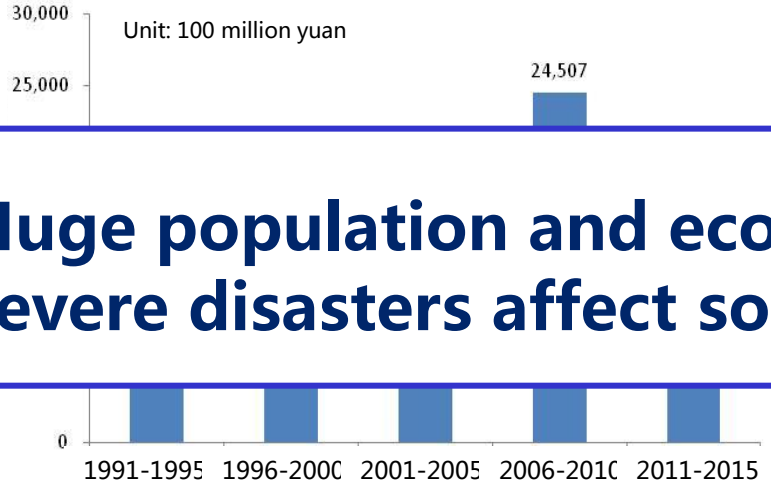
Missing and death toll



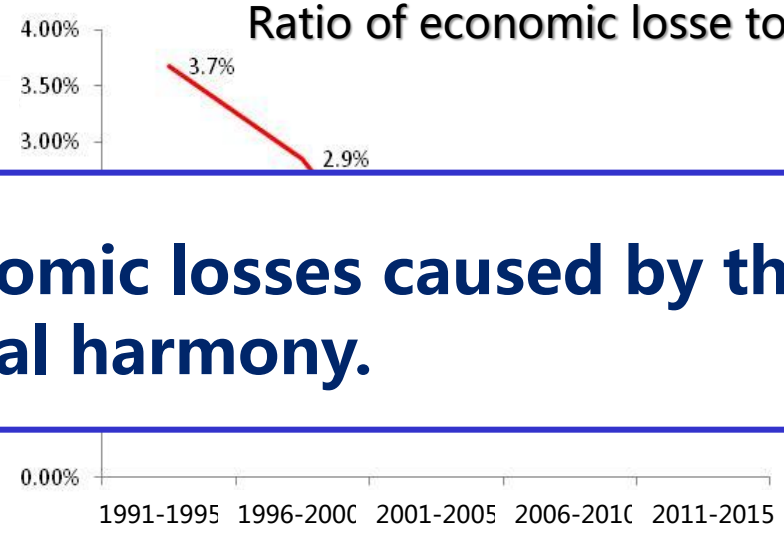
Emergency relocation of population



Direct economic loss

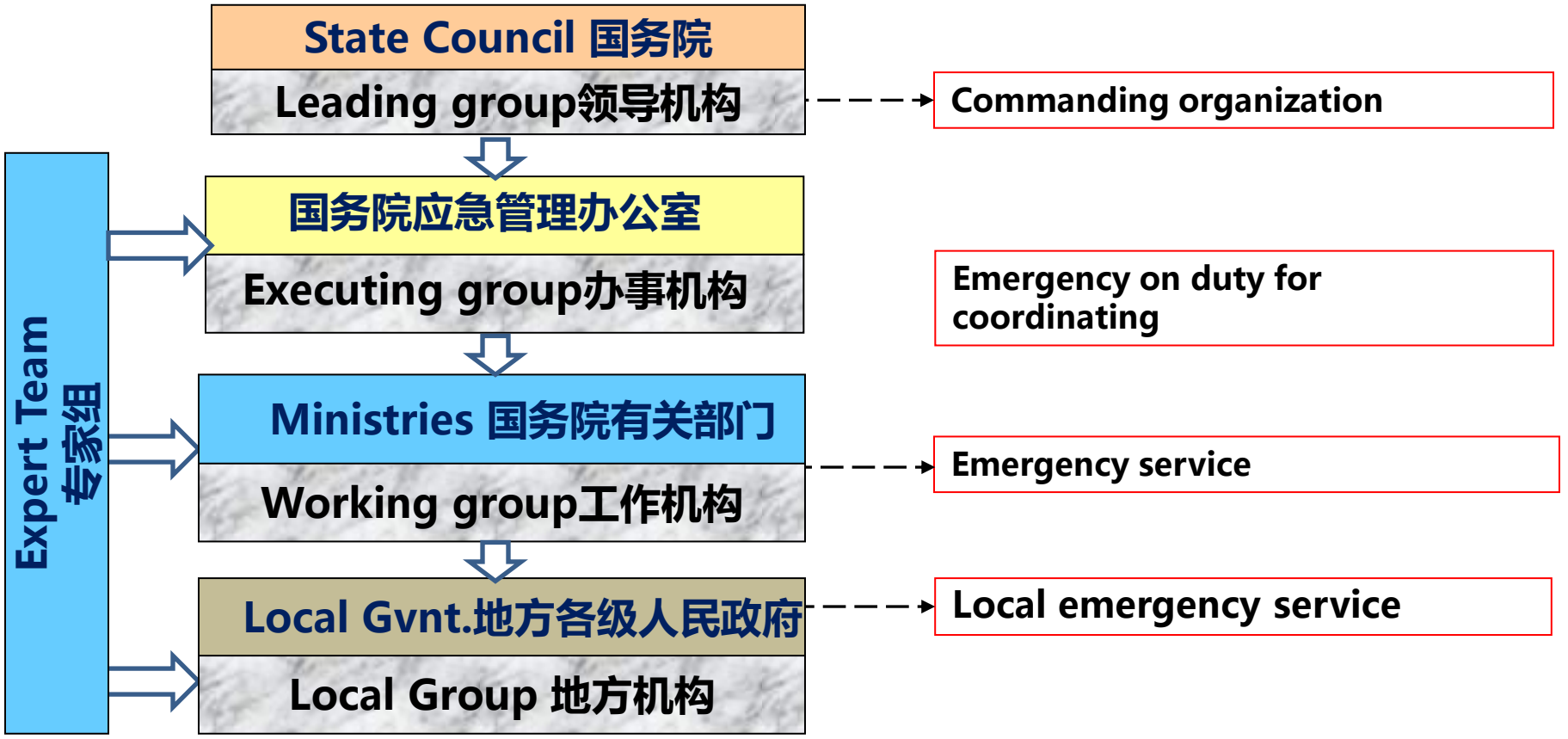


Ratio of economic losse to GDP



Huge population and economic losses caused by the severe disasters affect social harmony.

National Emergency Commanding System
国家应急指挥组织体系

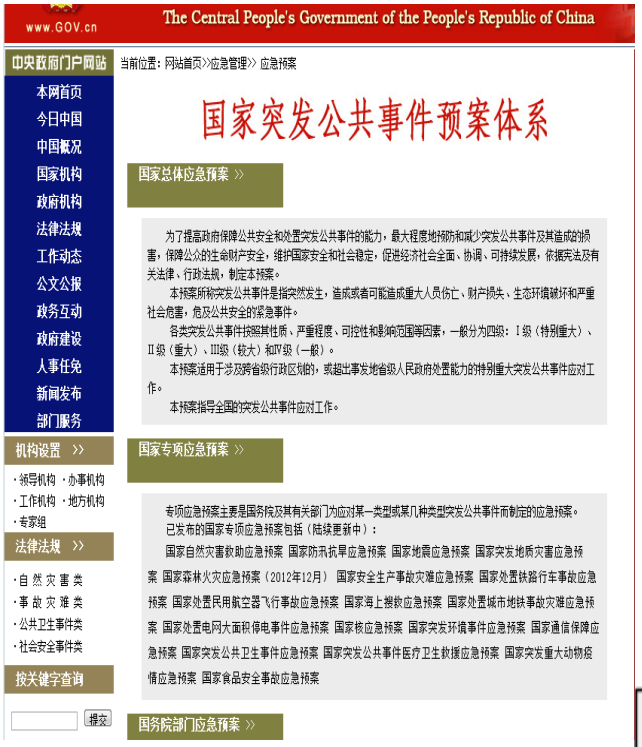


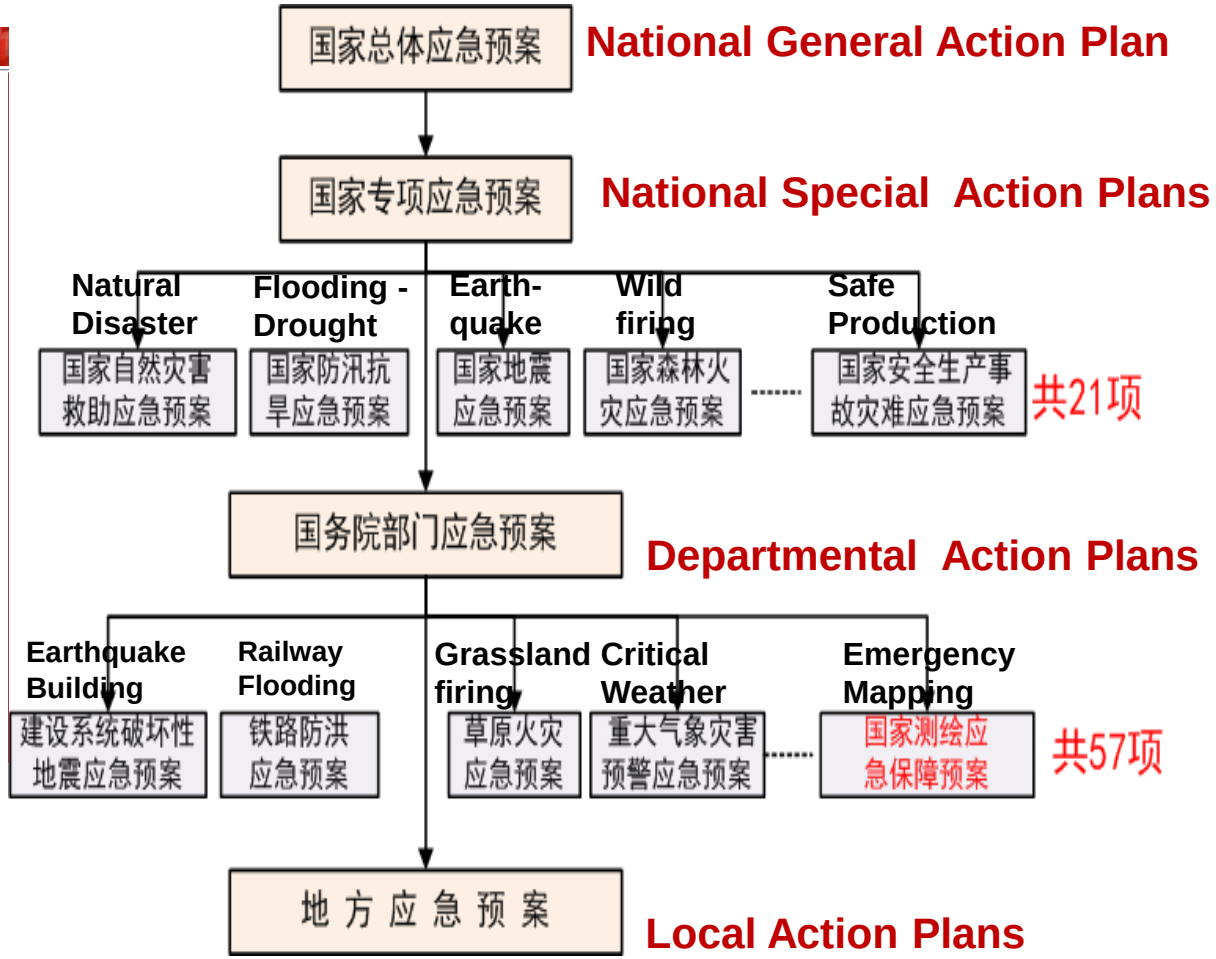
China has established national emergency platform including 8 rescuing bases and 19 aerial emergency transportation service bases.

National System of Emergency Action Plan
国家突发公共事件预案体系

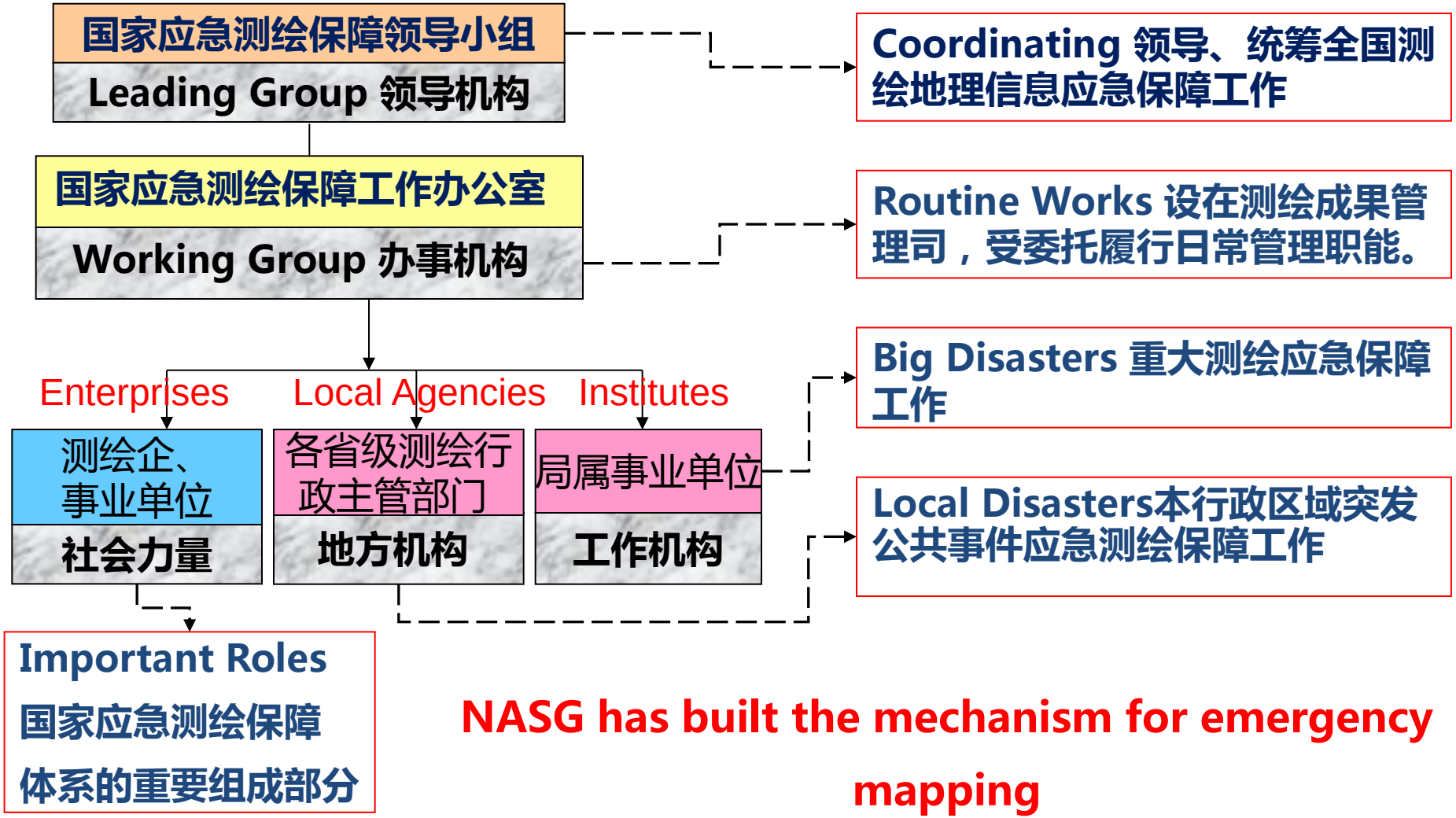
The State Council issued the National System of Emergency Action Plan in 2006.

国务院颁布了《国家突发公共事件总体应急预案》(2006)





Organization of Emergency Mapping
应急测绘的组织机构



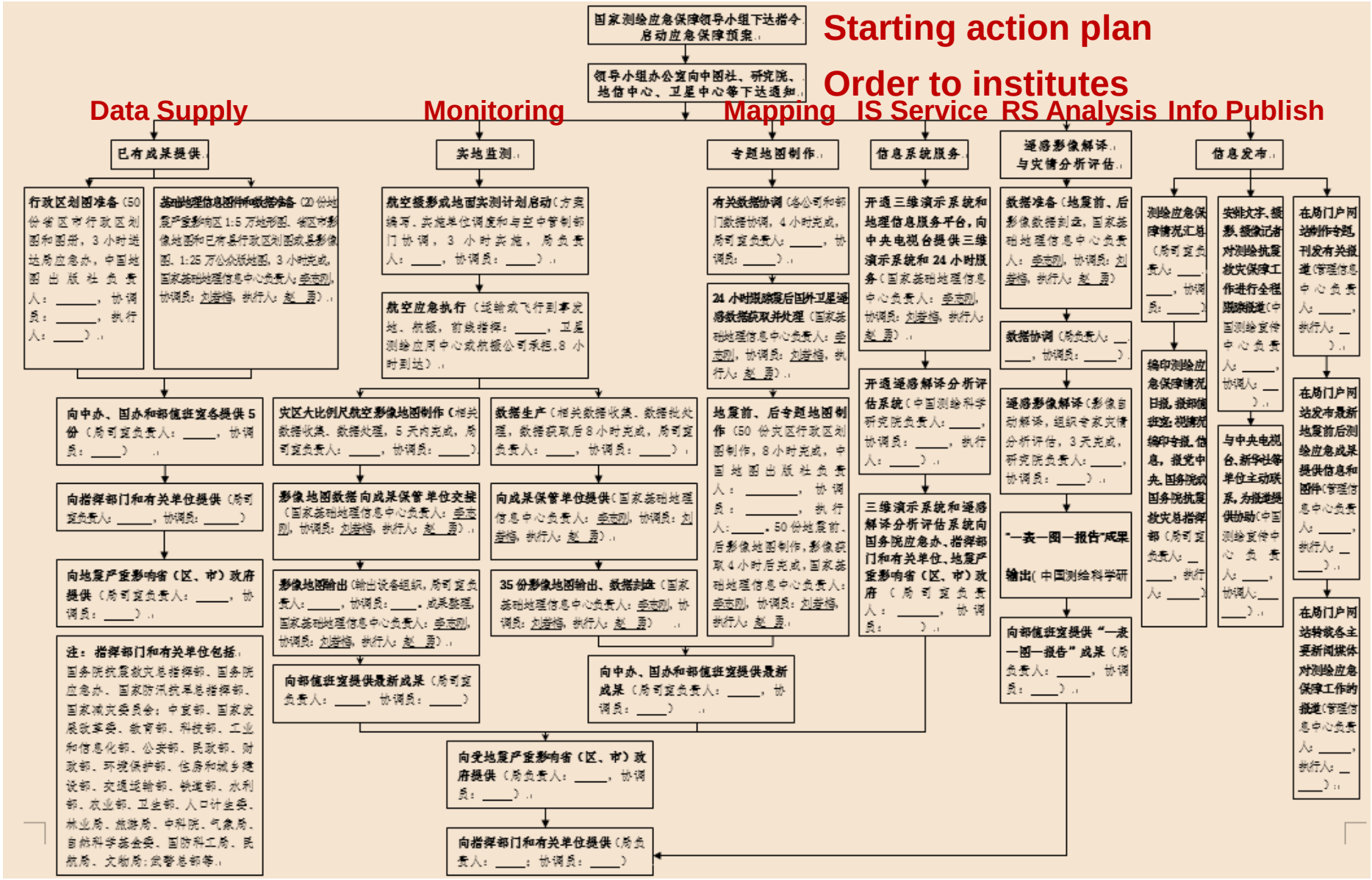
NASG has built the mechanism for emergency mapping

National Emergency Mapping Action Plan
国家应急测绘保障预案

National Emergency Mapping Action Plan issued on Mar.18,2009

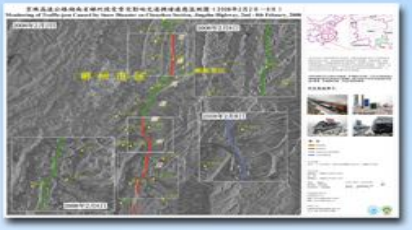
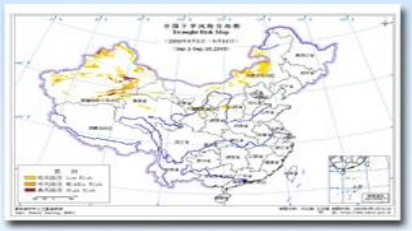
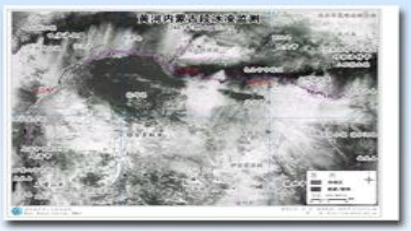
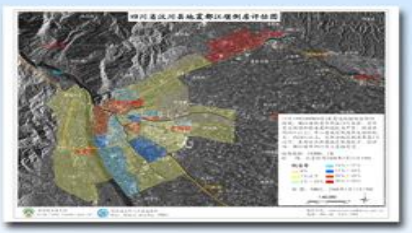
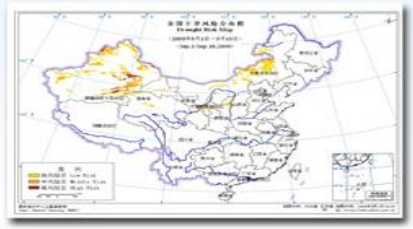
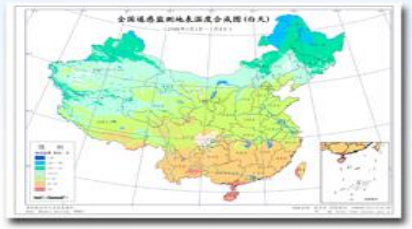
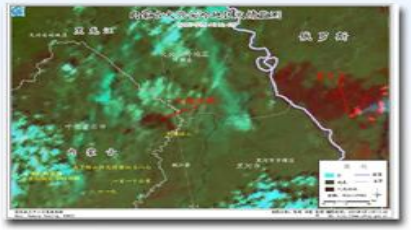
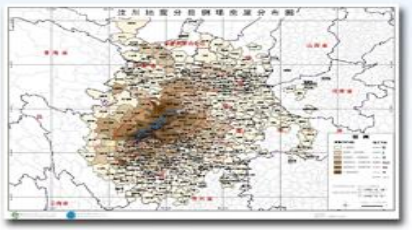
Mechanism + Capability + Plan -→ Quick Service

Procedure for Disaster Response
灾害响应工作流程



Products of Remote Sensing applied in disaster prevention and mitigation
遥感减灾应用产品体系

Product system
(减灾应用产品体系)

Risk analysis 灾害风险	Disaster monitoring 灾害监测	Damage evaluation 灾情评估	Decision support 决策支持
			
			
			

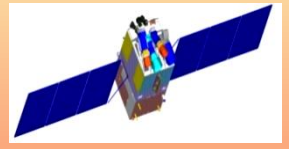
Outline

1. National Emergency Mapping System
2. Status of its Development and Application
3. Challenges of its Development and Application
4. National Emergency Geospatial Information Project
5. Conclusion and Suggestions

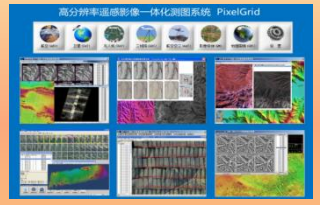
Emergency Response Process
灾害响应业务流程

Data acquisition → Processing & Interpretation → Evaluation & Warning → Publishing service → Planning & Recovery

数据获取

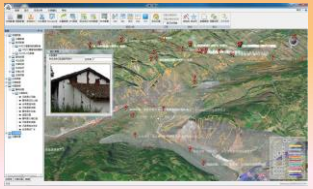


处理解译



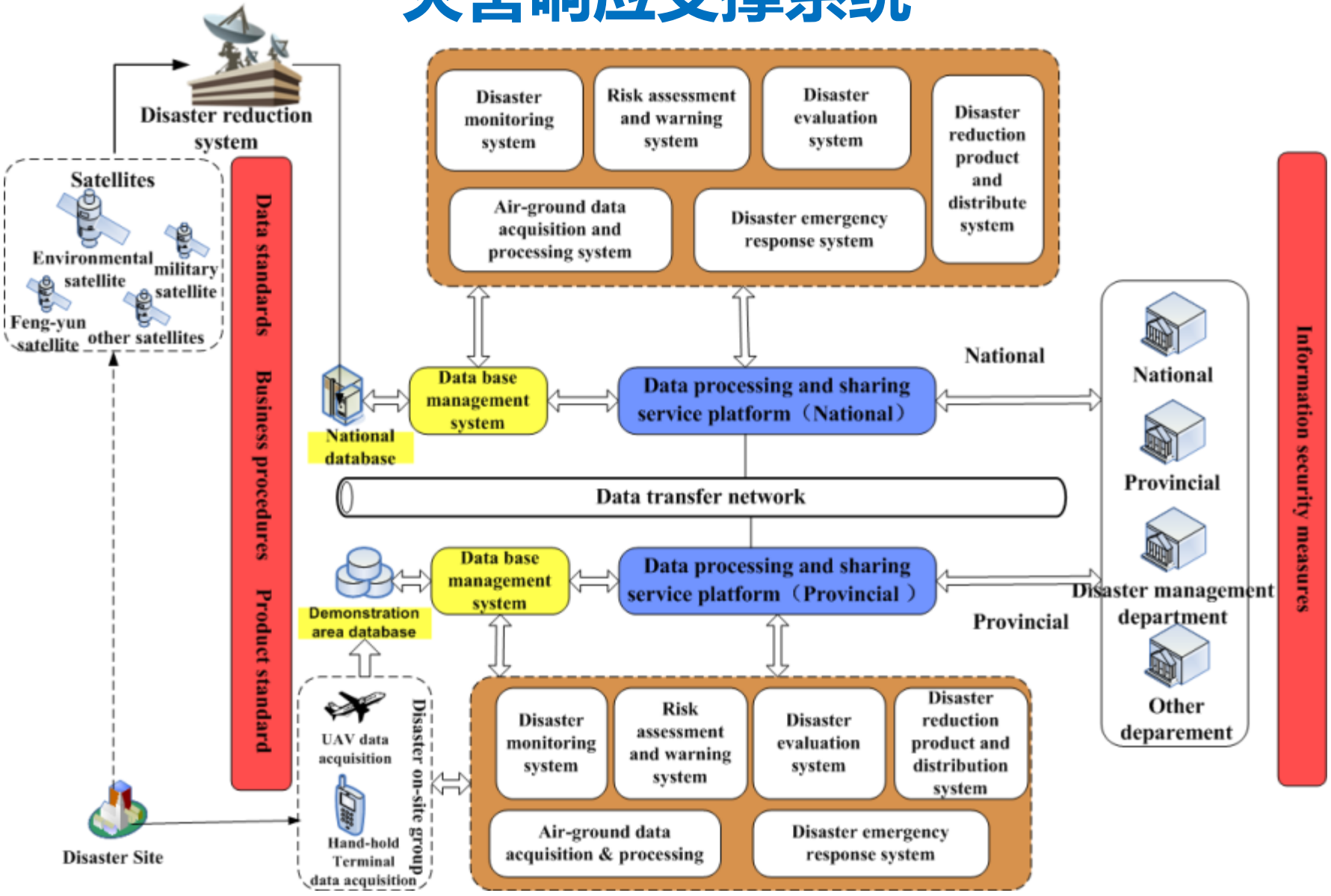
评估预警

发布服务



规划重建

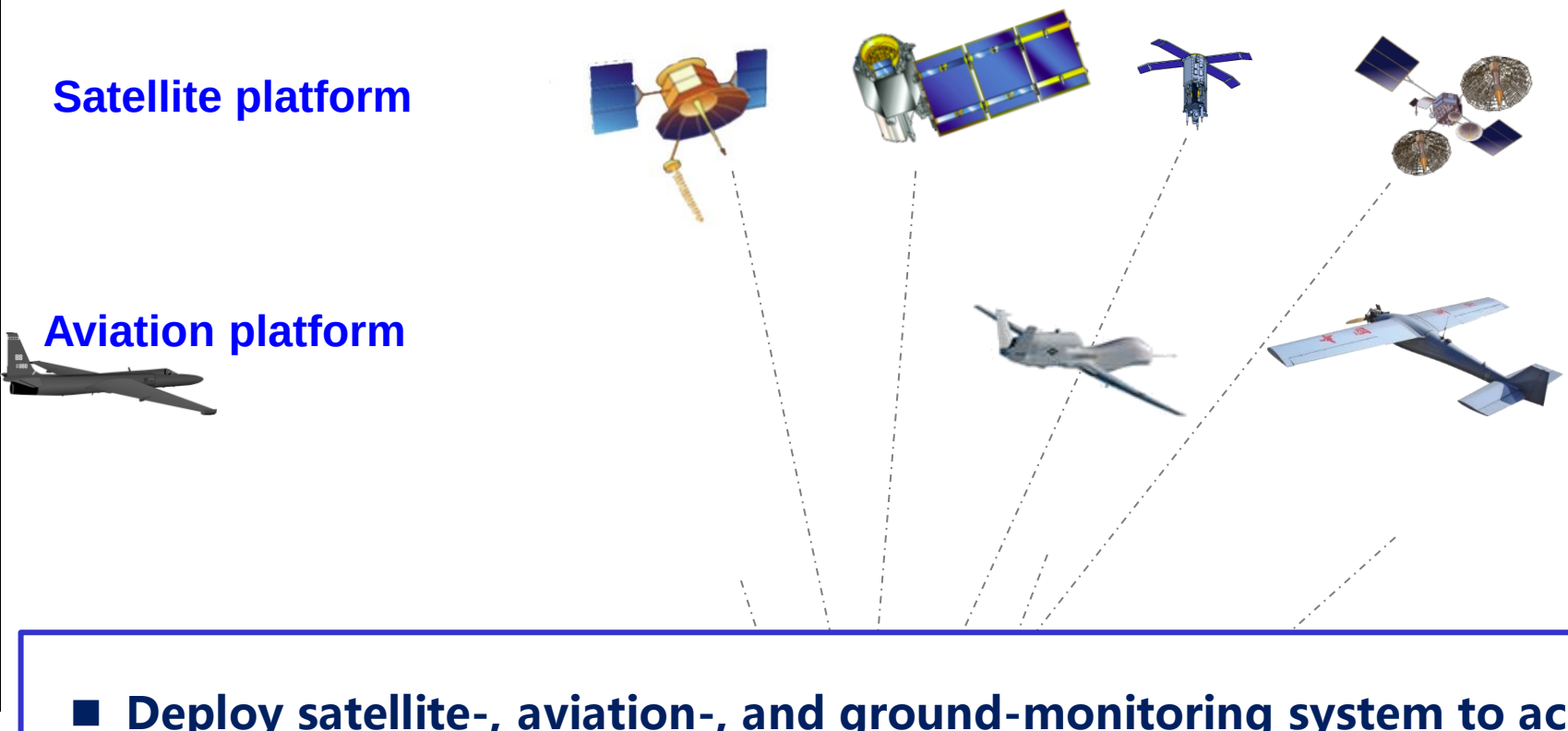
Emergency response support System
灾害响应支撑系统



1、Establishing an integrated (Satellite-, Aviation-, Ground-) monitoring system

Satellite platform

Aviation platform



- Deploy satellite-, aviation-, and ground-monitoring system to acquire high-resolution images in the disaster areas for emergency surveying and mapping.
- Response time:< 12 hour.

Satellites (卫星)

Nowadays, more than 140 satellites are running in China.

Satellite Series 卫星系列	Satellite 卫星类型	Key Parameters 参数
Resource Satellite 资源卫星	ZY-1 02C	• Spatial resolution分辨率：2.36m • Revisit time重返周期： 3 – 5 days
	CBERS-04	• Spatial resolution分辨率：5m • Revisit time重返周期: 3 days
	ZY-3	• Spatial resolution分辨率：2.5m • Revisit time重返周期: 5 days
HJ Satellites 环境与减灾卫星	HJ-1A	• Spatial resolution分辨率：30m • Revisit time重返周期: 2 days
	HJ-1B	
	HJ-1C (SAR)	● Band波段：S ● Polarisation极化：VV ● Spatial resolution分辨率：5m ● Revisit time重返周期: 31 days

Satellite series 卫星系列	Satellite 卫星类型
Marine Satellite 海洋卫星	HY-1A,1B
Meteorological satellite 气象卫星	FY-2C、FY-2E、FY-2F、FY-2G、FY-3A、FY-3B、FY-3C

Gaofen Satellites
高分专项(高分1、2号)

Beidou Navigation Satellite
北斗导航系统

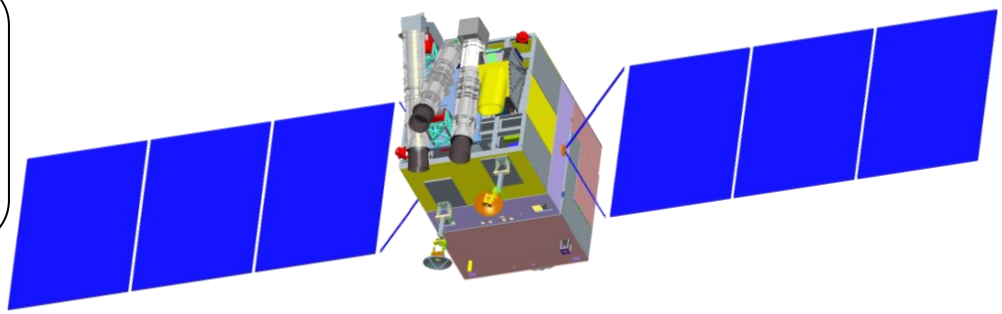
Satellites (卫星)

The first civilian data-transferring high resolution optical stereo mapping satellite – “ZY-3”
首颗民用高分辨率光学传输型立体测绘卫星 "资源三号 “

Tri-linear Pan cameras
Forward/Backward: 3.5m
Nadir: 2.1M

Multi-spectrum
4 bands 5.8M

配置三线阵测绘相机和多光谱相机



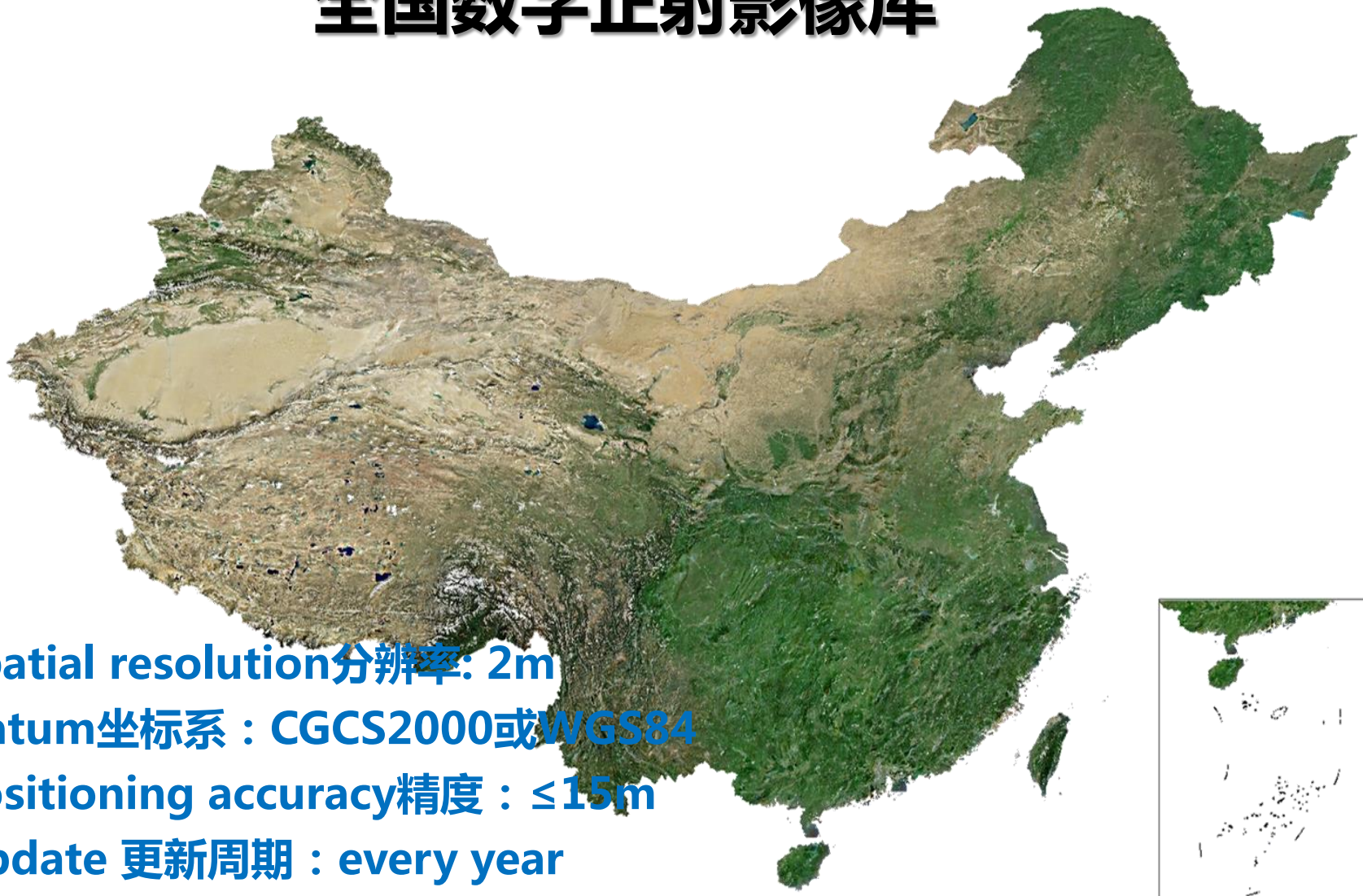
B/H: 0.89
卫星基高比
0.89

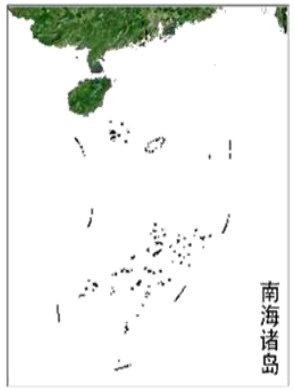
Cycle time: 59 days
Revisit: 5 days
Lifetime: 5 years
Total mass: 2630 kg
回归周期59天，
重访周期5天，
工作寿命5年，
重量约2630kg

Sun-Synchronous orbit altitude: 506km
506公里的太阳同步圆轨道

Global coverage Latitude: 84 degree
地球南北纬84度以内地区
无缝影像覆盖

China’s DOM Database
全国数字正射影像库





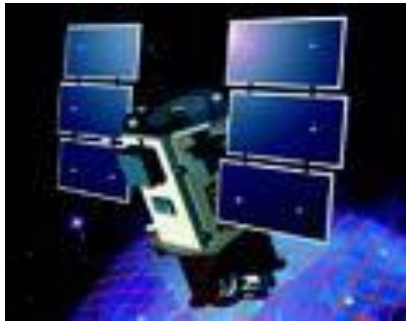
- Spatial resolution分辨率: 2m
- Datum坐标系：CGCS2000或WGS84
- Positioning accuracy精度：≤15m
- Update 更新周期：every year
- Start 起始时间：2014

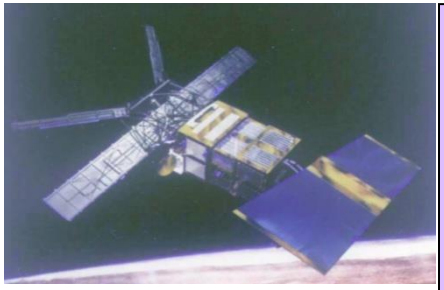
Planned Mapping Satellites测绘卫星规划

2-5m Pan、6-10m multi-spectrum

1-2m Pan、3-6m multi-spectrum

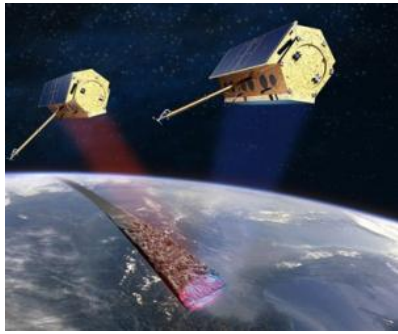
0.5-1m Pan、1-3m multi-spectrum

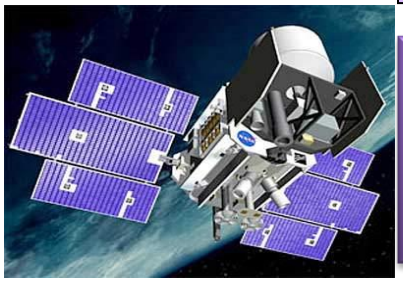




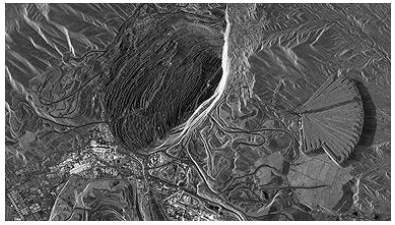
3-5m 、C band/S band SAR

0.5-1m、multi-band SAR





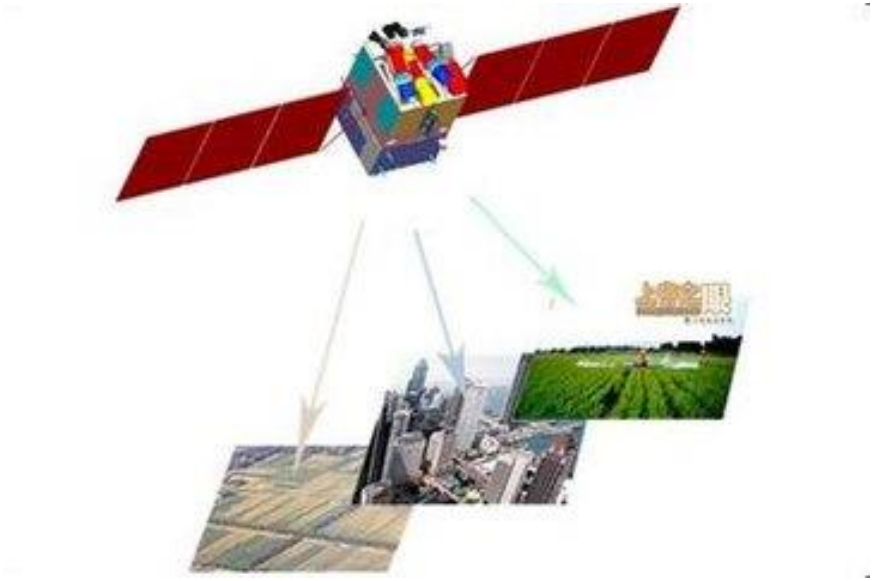
2 Bands Laser Ranging, 1 m Pan

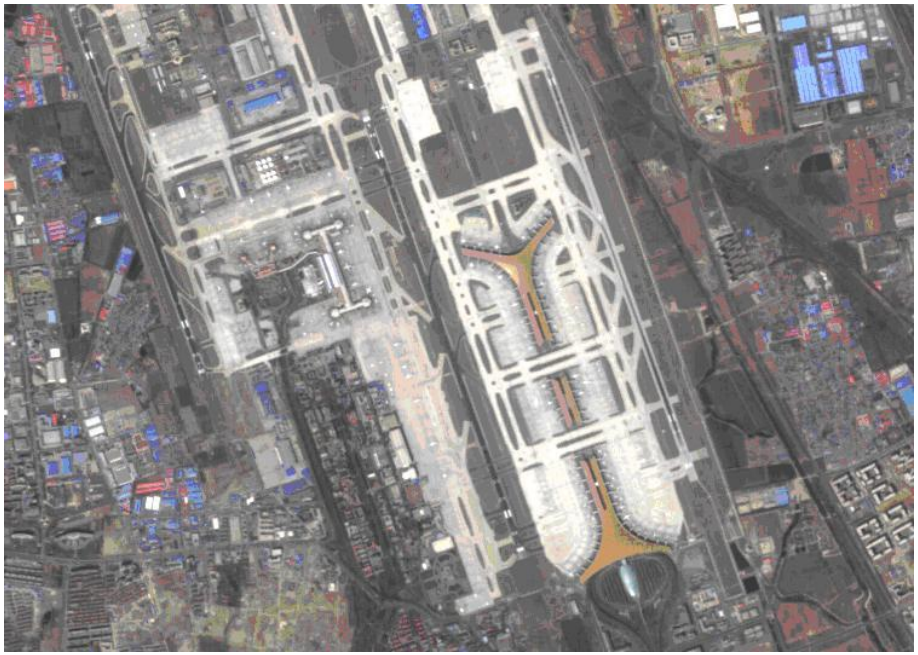


Satellites (卫星)

“Mapping Satellite-1 (天绘一号) ” 01星+02星+03星

- **Long-term on-orbit operations**
- **Acquire 3D geo-information**
- **Overcome the defects of short lifetime.**





Integration of three cameras:

- ✓ **linear CCD camera,**
- ✓ **high resolution of 2m panchromatic camera**
- ✓ **multi-spectral camera**

Satellites (卫星)

“Gaofen-1(高分1号)” + “Gaofen-2(高分2号)”

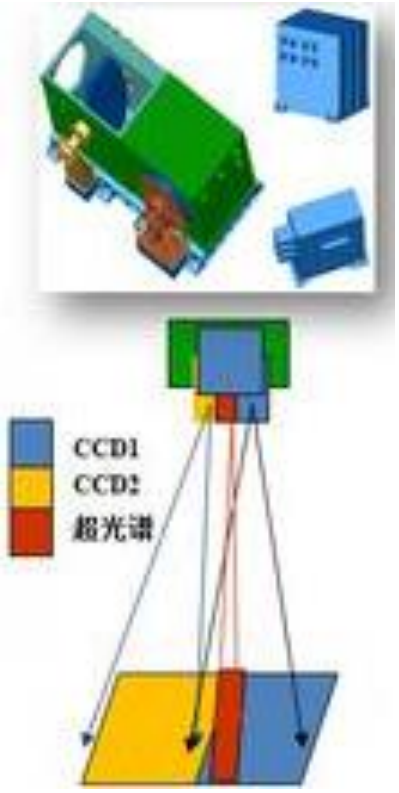
- Sub-meter resolution
- Multi-spectral optics images

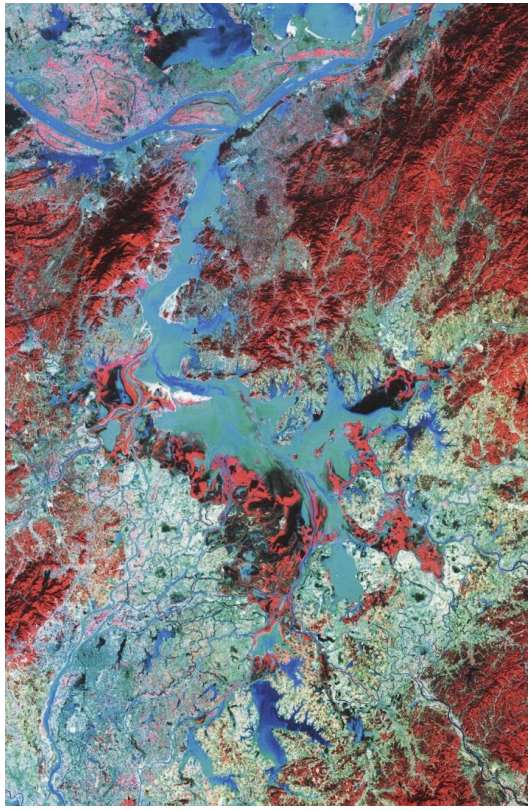
The Gaofen series will be formed by 7 satellites in 2020 for high (spatial, temporal, and spectral) resolution images.

Satellites (卫星)

HJ-1 (A/B/C)

- Joint observation of optics and SAR
- Revisit time shortened
- Large scale and all-weather monitoring





Aviation (航空)

CASMSAR-the First Airborne SAR Mapping System in China
机载多波段多极化干涉SAR测图系统 —CASMSAR

Bands	X	P
Polarimetry	Quad (全极化)	Quad (全极化)
Interferometry	single pass (双天线单轨)	repeat pass (重轨)
Spatial resolution	0.3 – 5m	
Flight height	3,000 – 10,000m	
Mapping scale	1: 5,000 – 1: 50,000	

Aviation (航空数据获取)

Digital Aerial Camera System(SWDC、TOPDC)
国产数字航摄系统(SWDC、TOPDC)

High precision, high resolution, application in national basic aerial photogrammetry, land resource investigation, etc.

SWDC-4

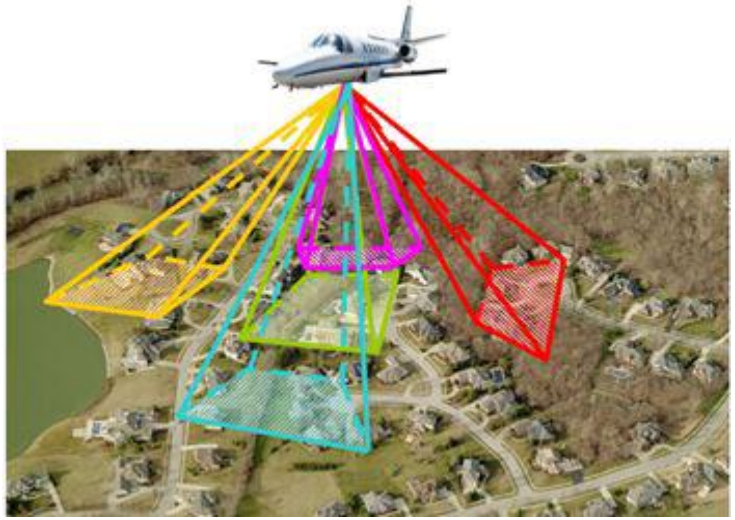
TOPDC-5倾斜数字航摄仪

存储控制设备

Aviation (航空)

Oblique camera system (倾斜摄影系统)

Front view



Right view

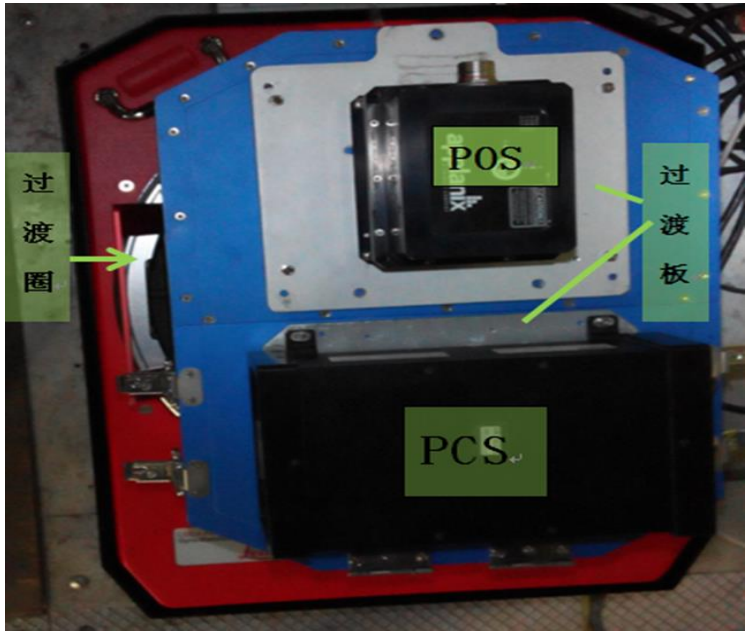
Back view

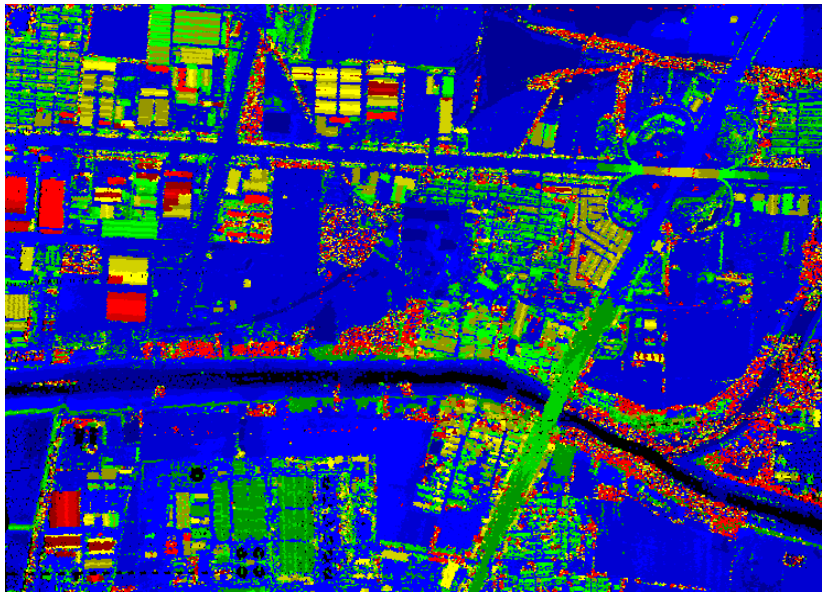
Left view

Aviation (航空)

Lidar LC-3500（机载激光雷达LC-3500系统）

High density of point cloud, high resolution elevation extraction.



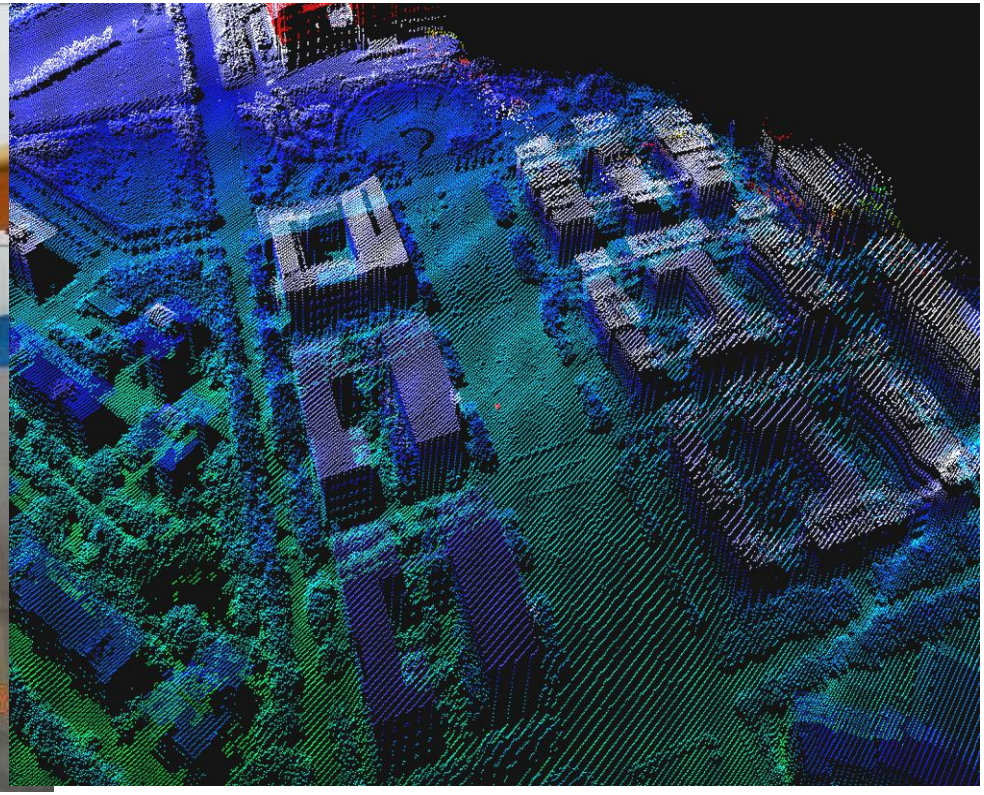


Aviation (航空)

Ultra-light aerial remote sensing system
高精度轻小型航空遥感系统

High accuracy, efficiency, flexible, low-cost.

具有高精度、高效率、灵活机动、低成本等特征。



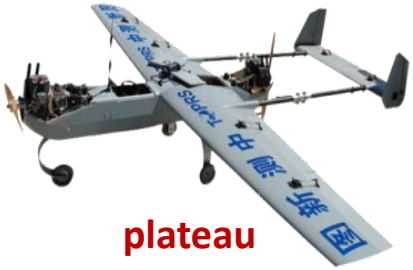
Aviation (航空)

UAV remote sensing system
无人机遥感系统

Played an important role in emergency response, 3D digital city, etc.

Long endurance
长航时型

Mini-model
手抛型



plateau
高原型

monitoring
监测型

general
通用型

Unmanned airship
无人飞艇

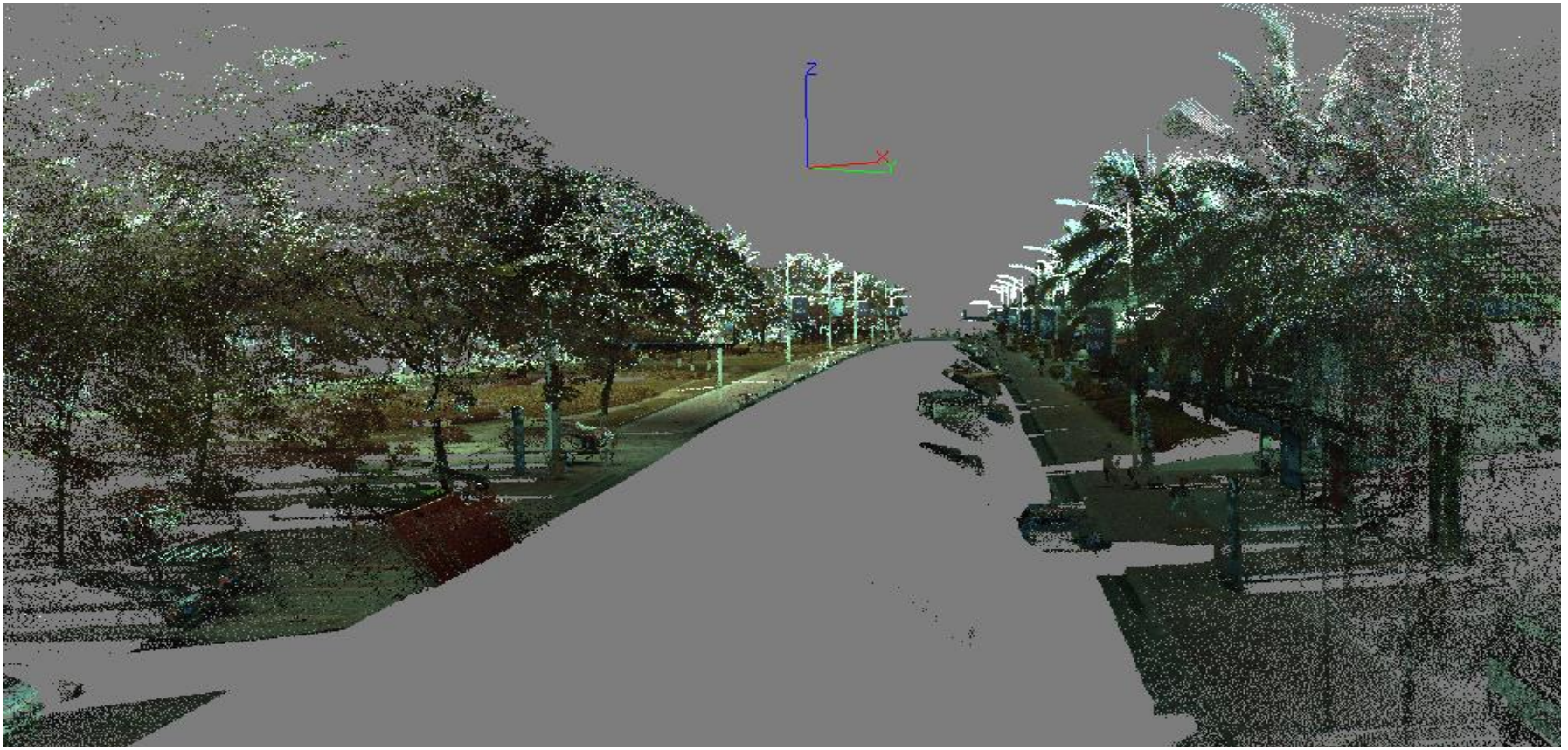
Ground (地面)

National Geo-information Emergency Monitoring vehicle
国家地理信息应急监测系统

UAV images acquisition, image rapid processing, data tele-transmission, remote consultation, and emergency transportation.

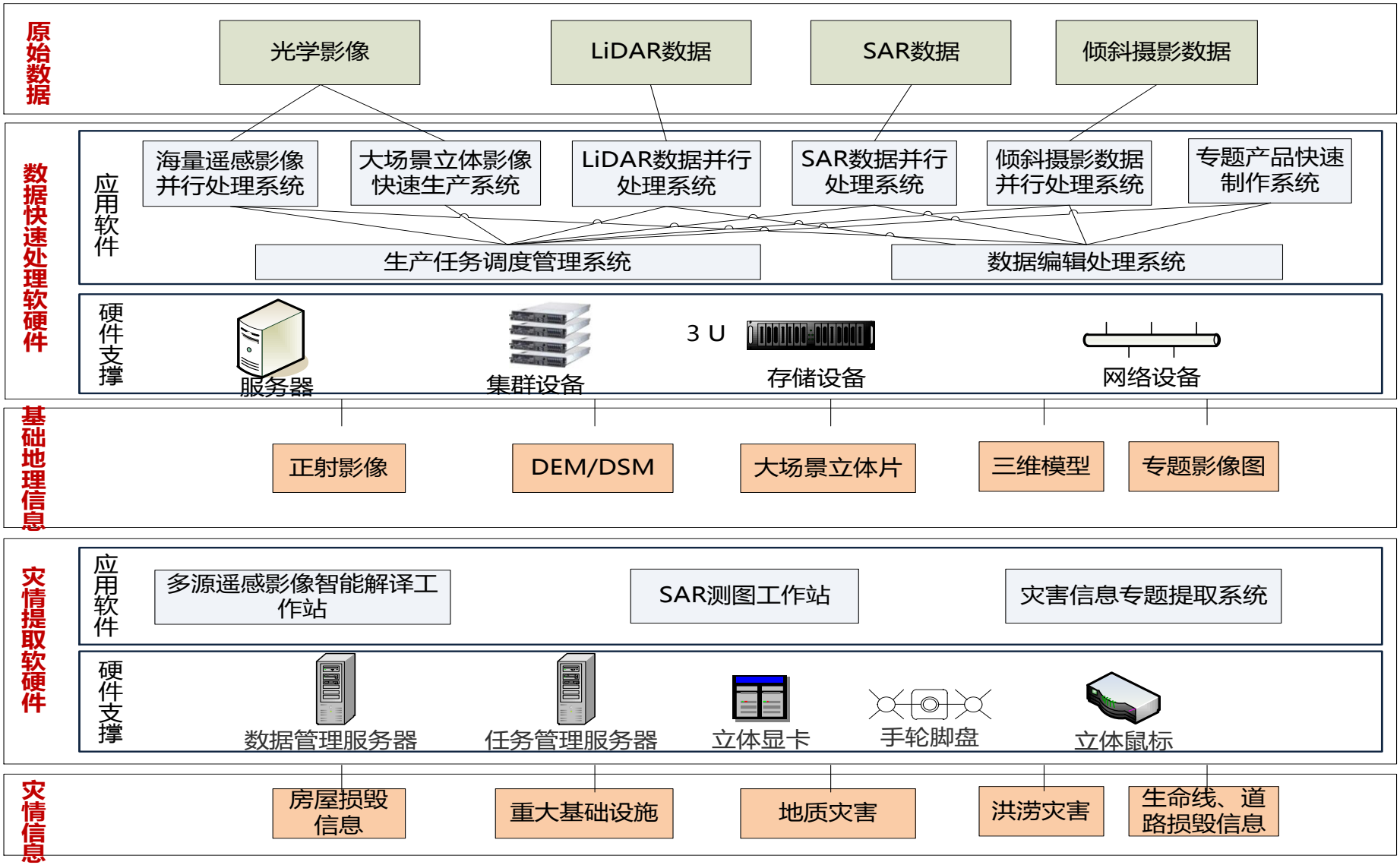
■ Ground (地面)

SSW Mobile Mapping System
SSW车载激光建模测量系统



Applied in road reconstruction, 3D modeling, etc.

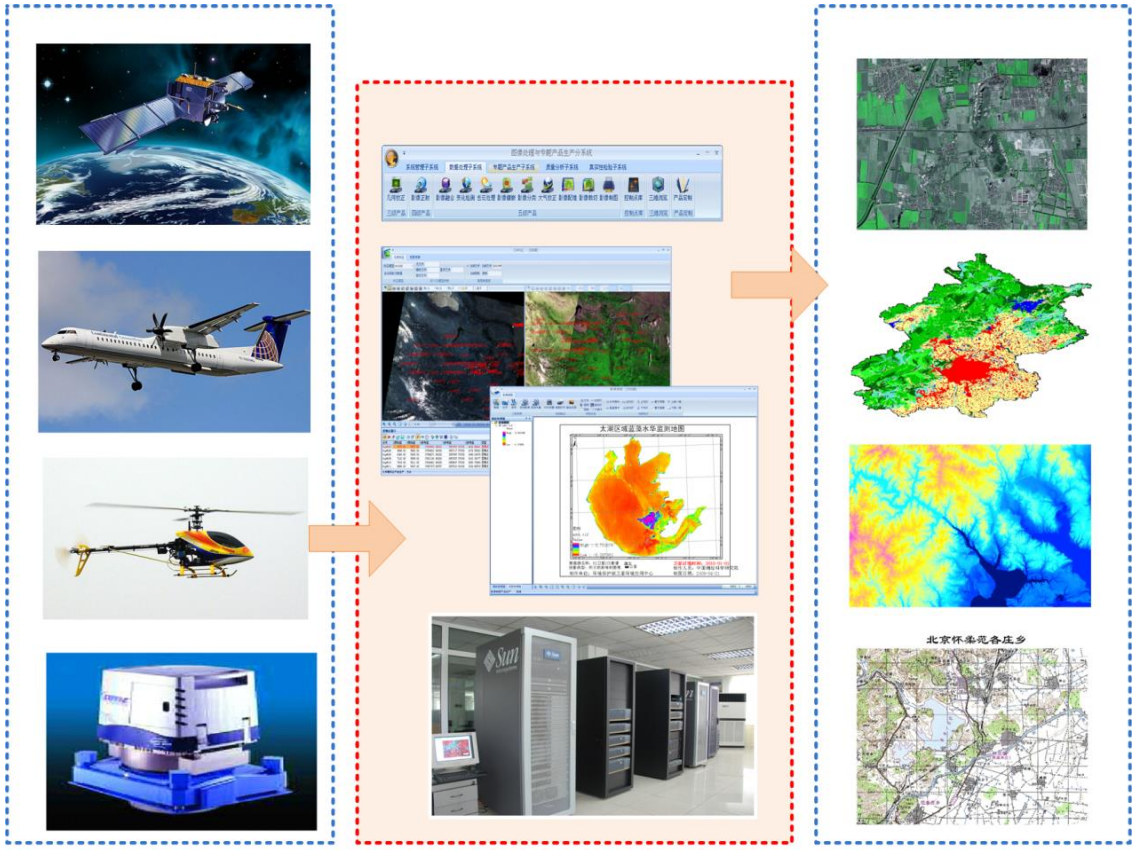
2、Establishing a technical platform for rapid data processing and disaster information extraction



Data processing（数据处理）

ImageInfo—Distributed cluster processing platform
集群分布式大型遥感数据处理平台

High performance, integrated, automatic and rapid generation of geographic information products.

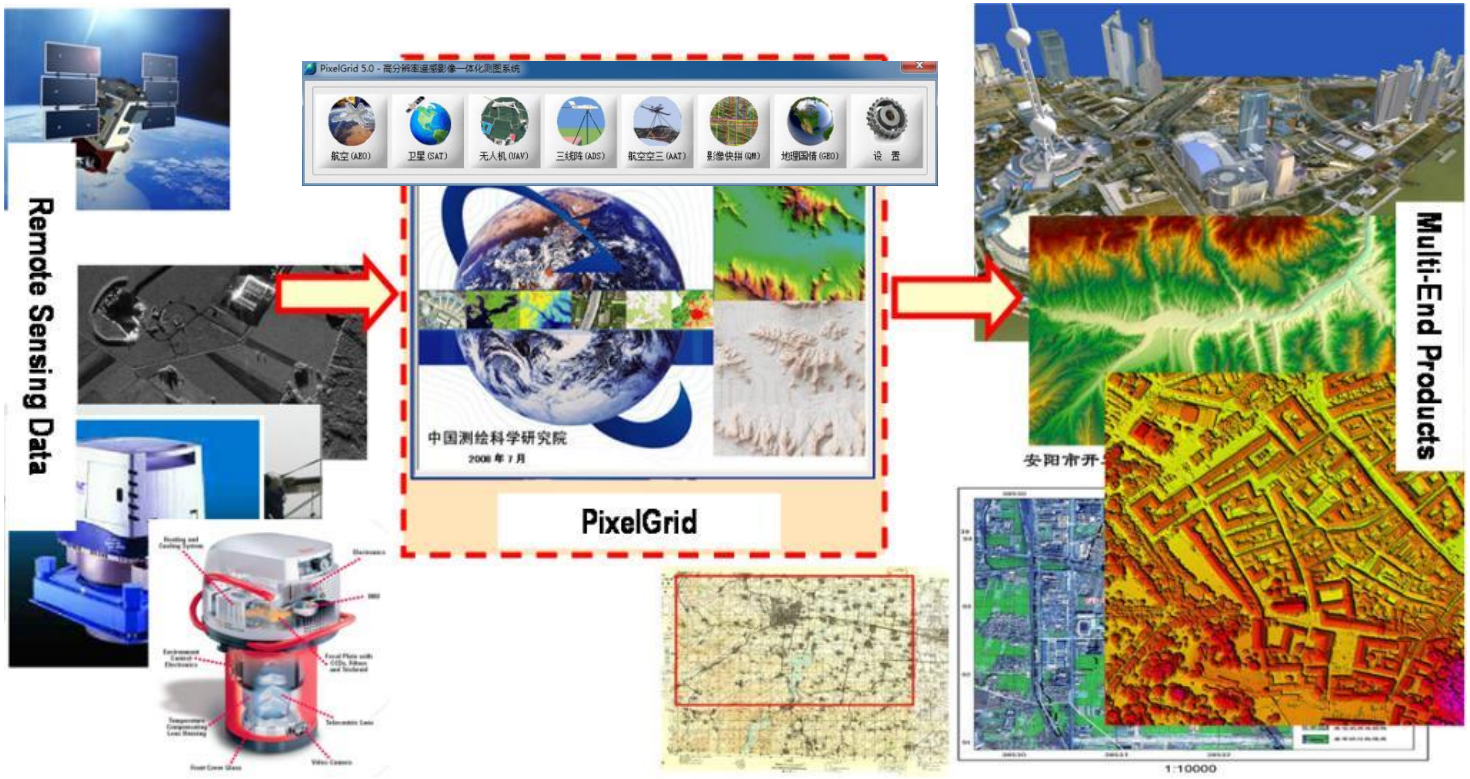


Data processing（数据处理）

PixelGrid—High-resolution remote sensing image mapping system

高分辨率遥感影像一体化测图系统—PixelGrid

Rapid automatically processing Satellite images, Aerial images, UAV and Oblique images with distributed system.



Data processing（数据处理）

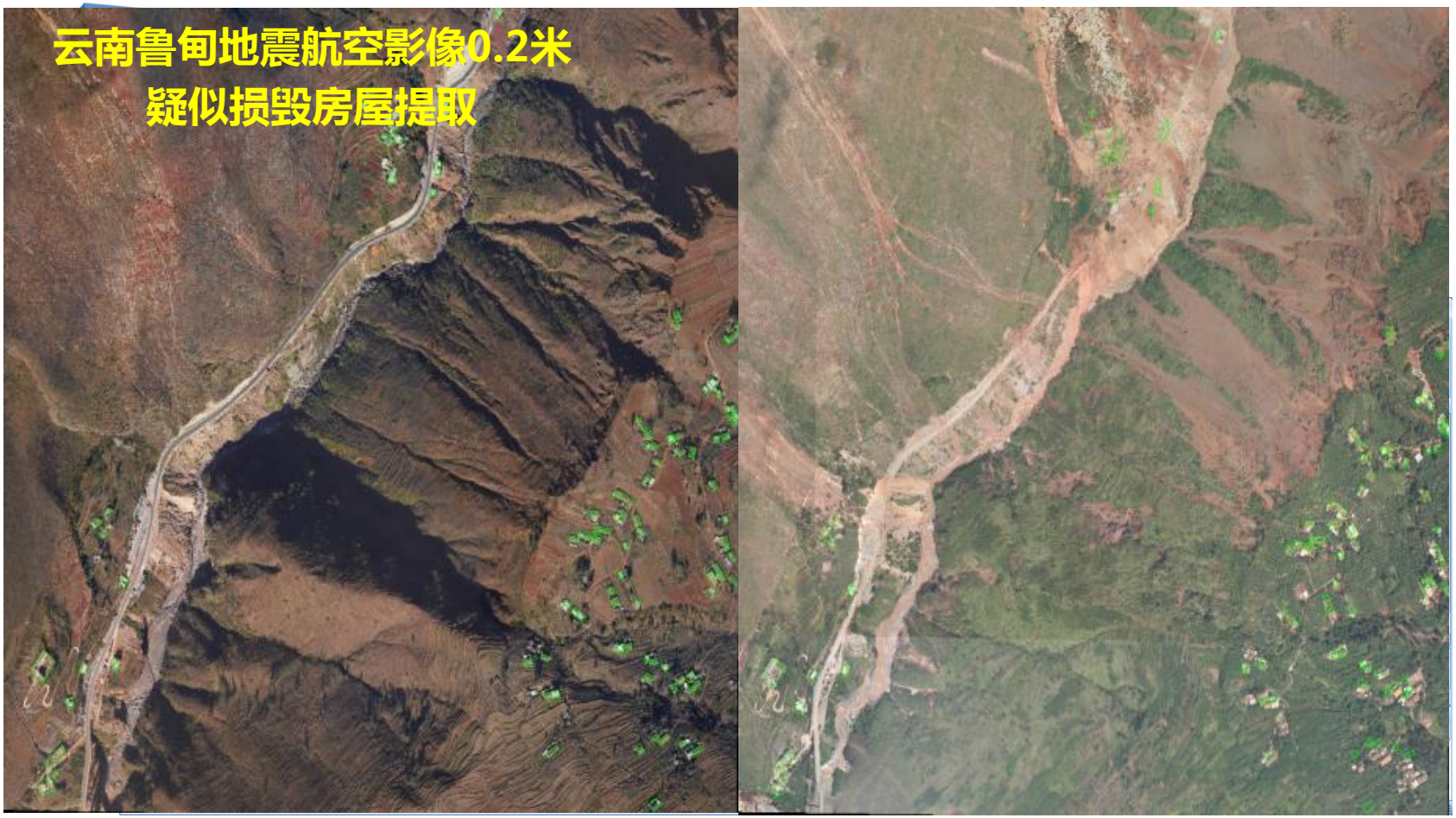
DPGrid

A new generation of digital photogrammetric system (DPGrid) with a ability of fast and parallel processing of aerial images over a large area.

Data processing（数据处理）

Remote sensing image interpretation workstation—FeatureStation

遥感影像智能解译工作站—FeatureStation

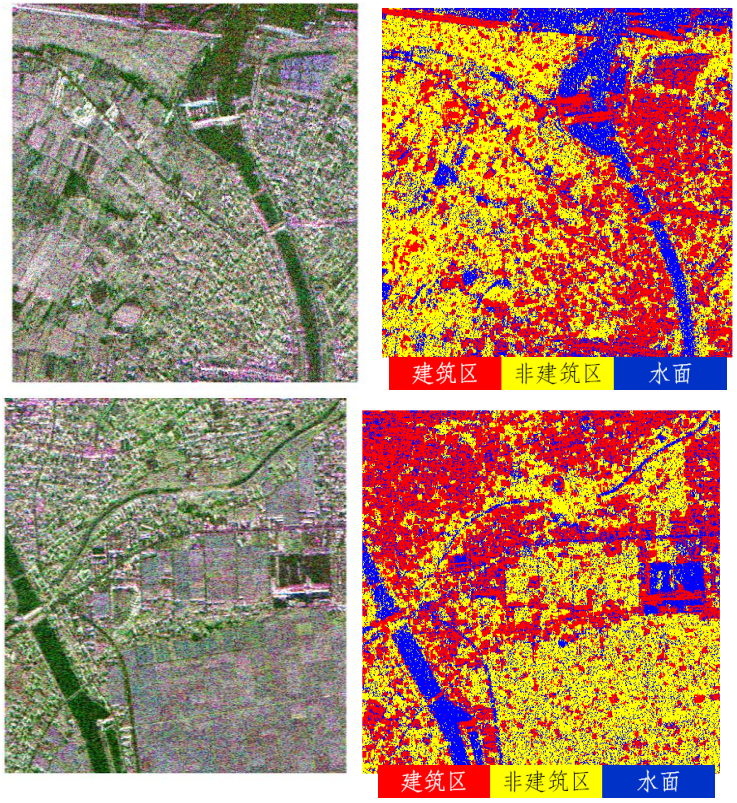


Extraction of disaster information in “collect - edit - quality inspection” mode.

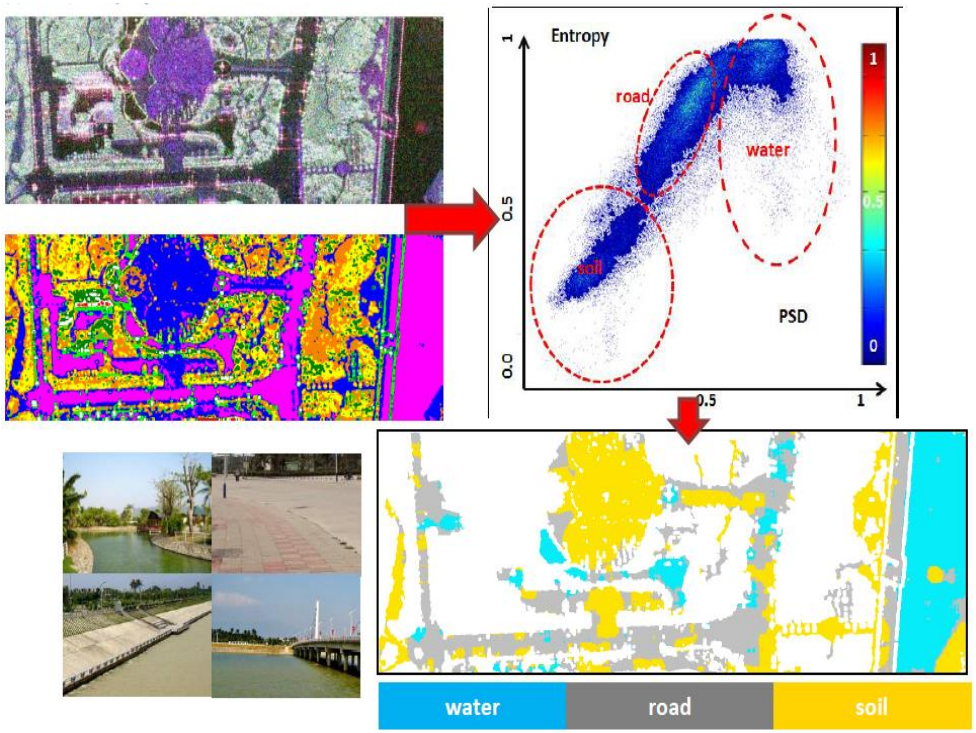
Data processing（数据处理）

SAR mapping workstation SAR测图工作站

Works for the generation of 1:5,000 - 1:50,000 scale of 4D products (DOM/DEM/DSM/DLG) with comprehensive utilization of InSAR, Stereo-SAR, PolSAR data.



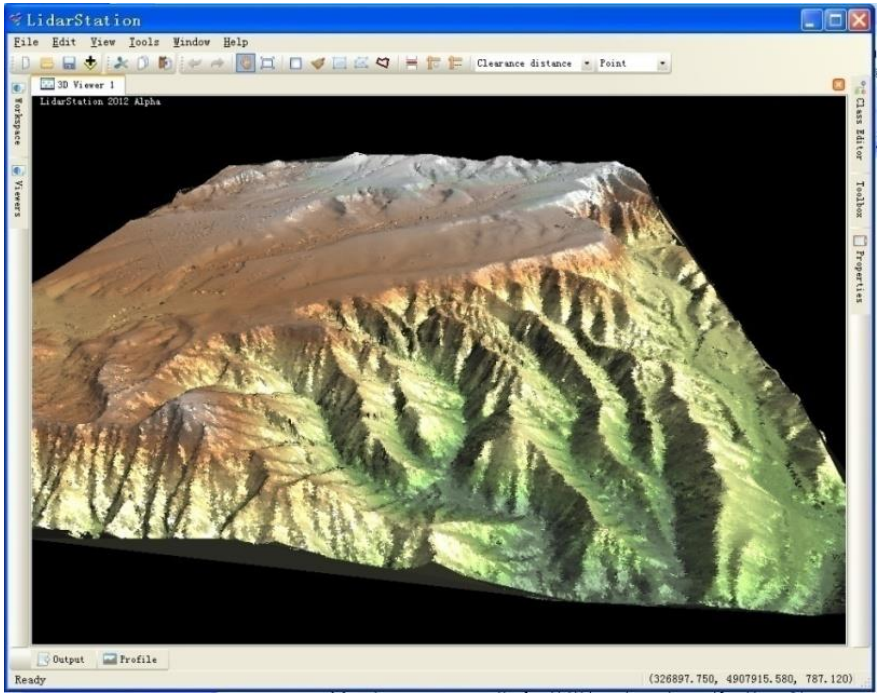
建筑区提取

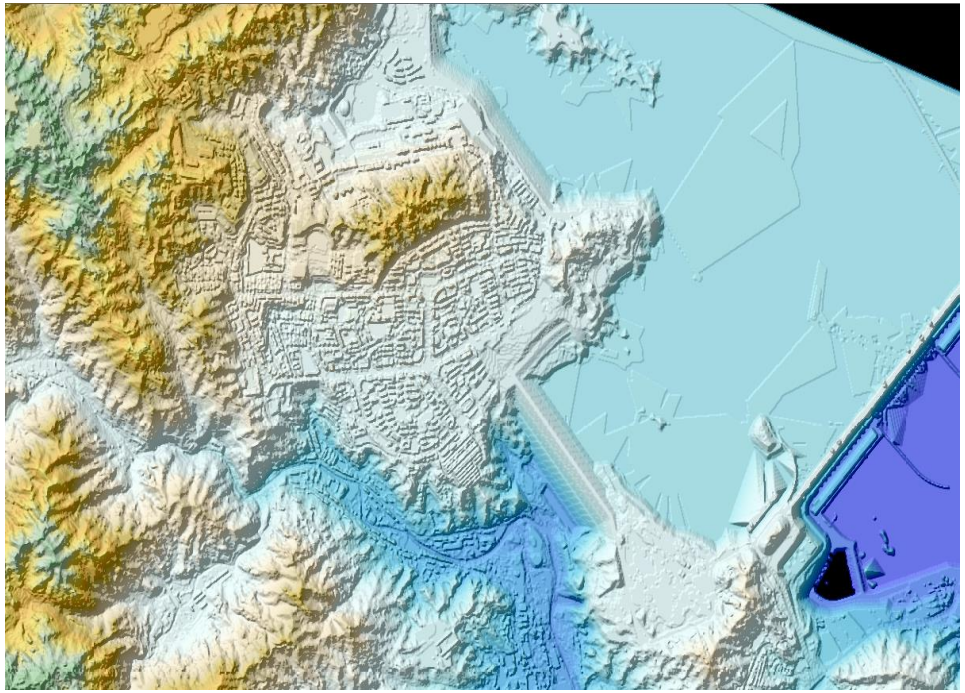


水体提取

Data processing（数据处理）

机载激光雷达数据处理系统 LIDAR data processing system





Visualization, operability, high precision and efficiency.

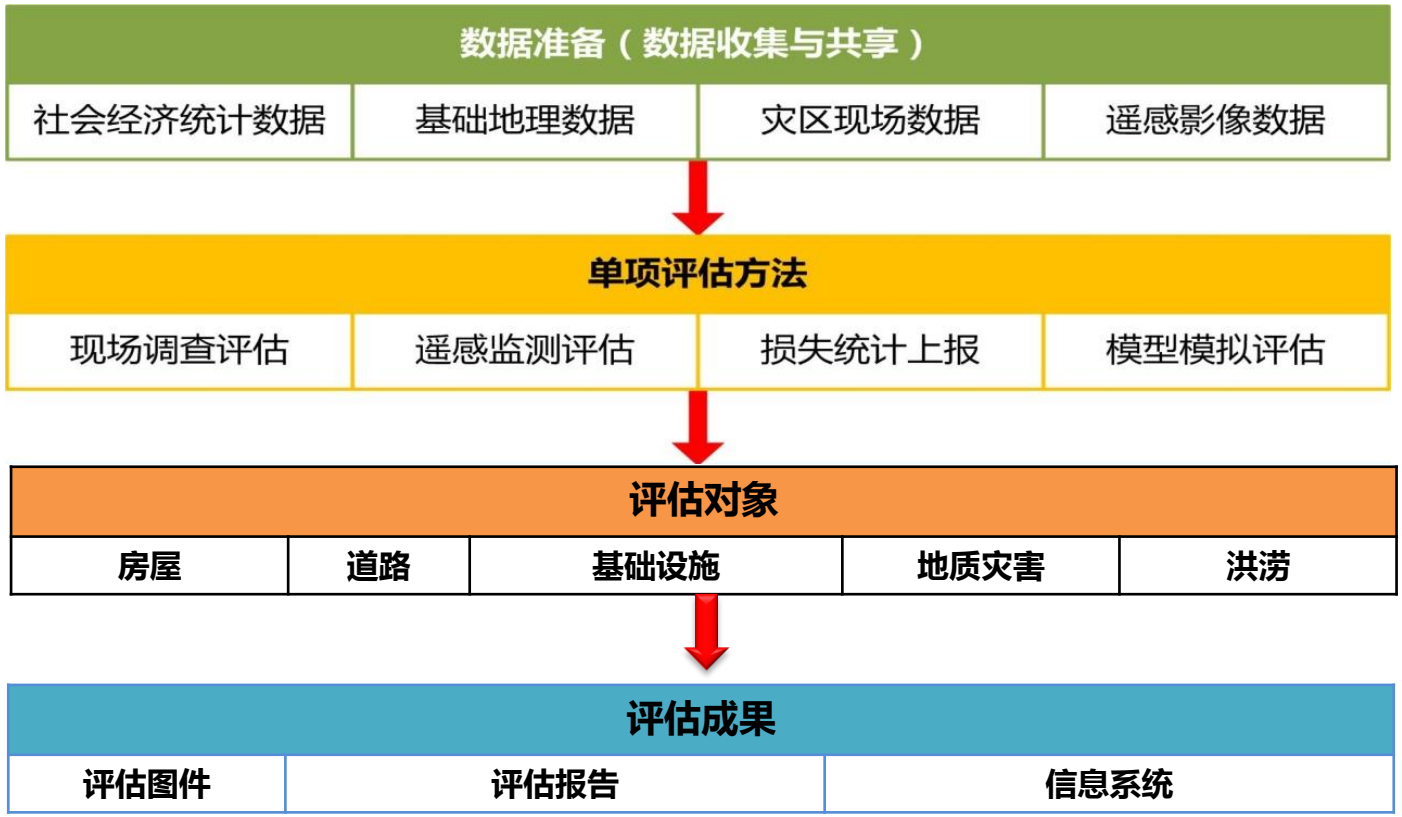
3、 Disaster evaluation and early-warning
初步形成灾情评估预警技术

Data Preparation

Evaluation Methods

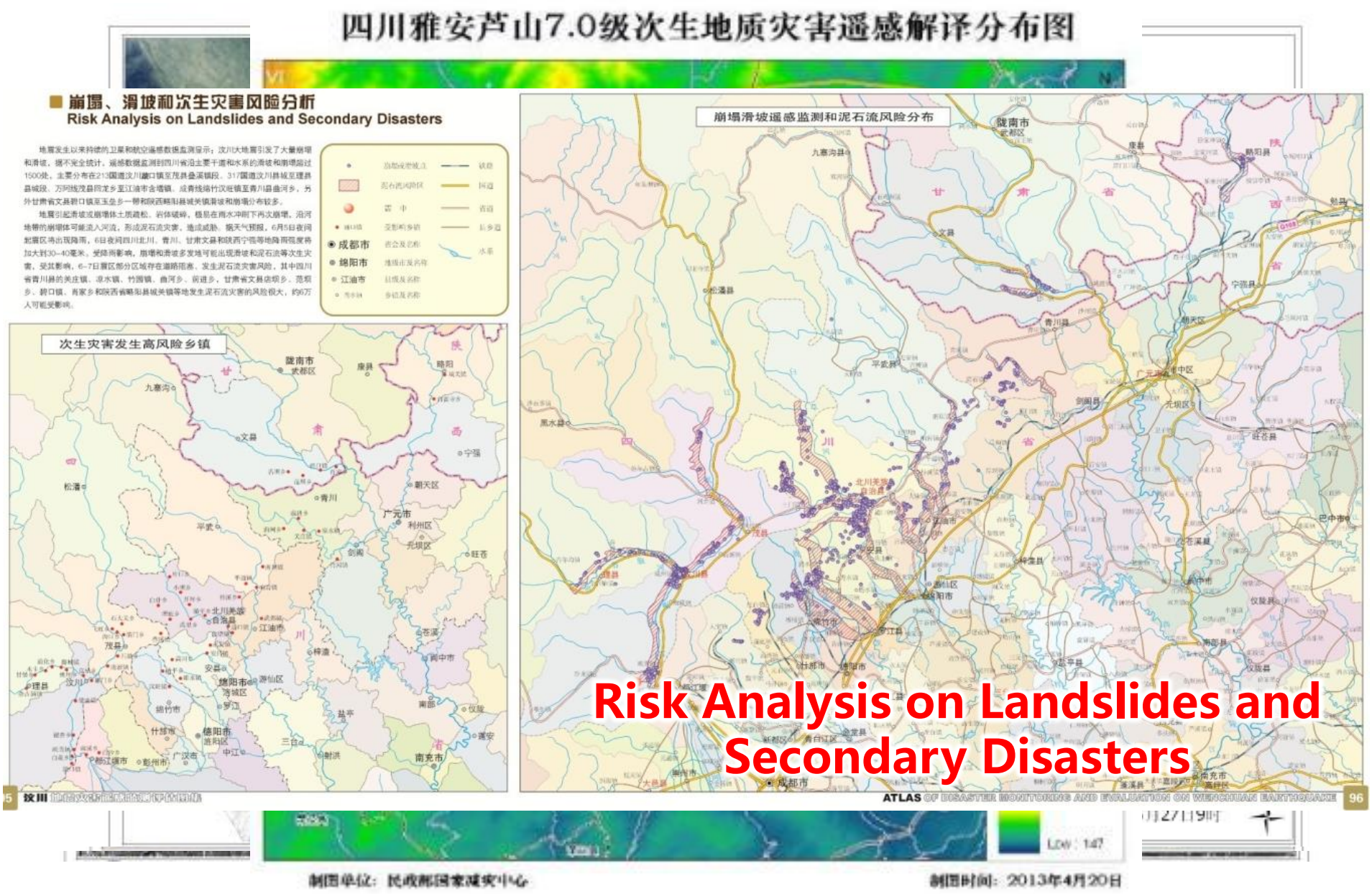
Evaluation Objects

Evaluation Results



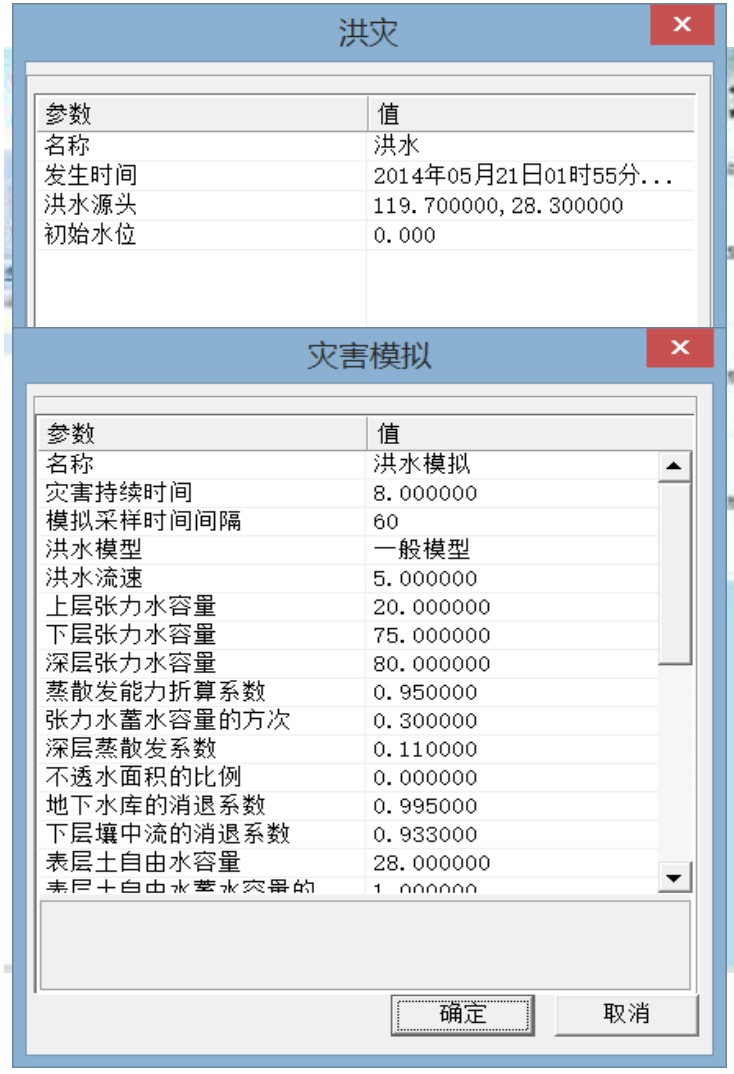
Combining the extracted disaster information with assistant data, use remote sensing evaluation and simulation assessment model to produce the maps, reports and information of collapsed houses, damaged roads , landslide and other infrastructure, etc.

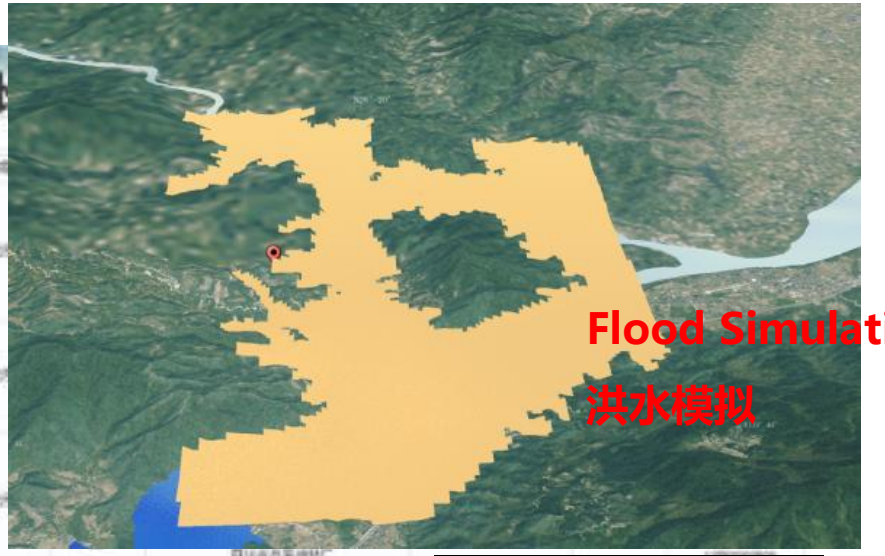
灾情评估图件 Disaster Evaluation Maps

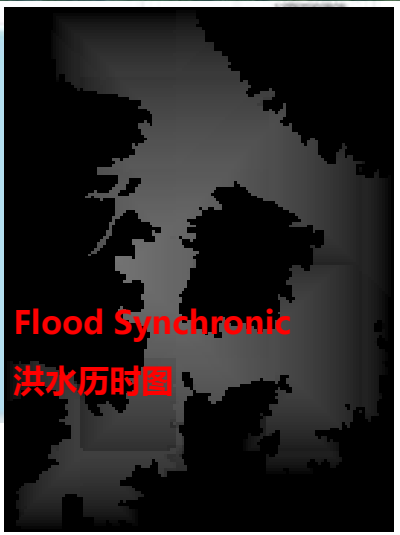


Information system for disaster evaluation and early-warning (灾情评估预警信息系统)

Disaster Evaluation and early-warning system 灾情评估预警系统







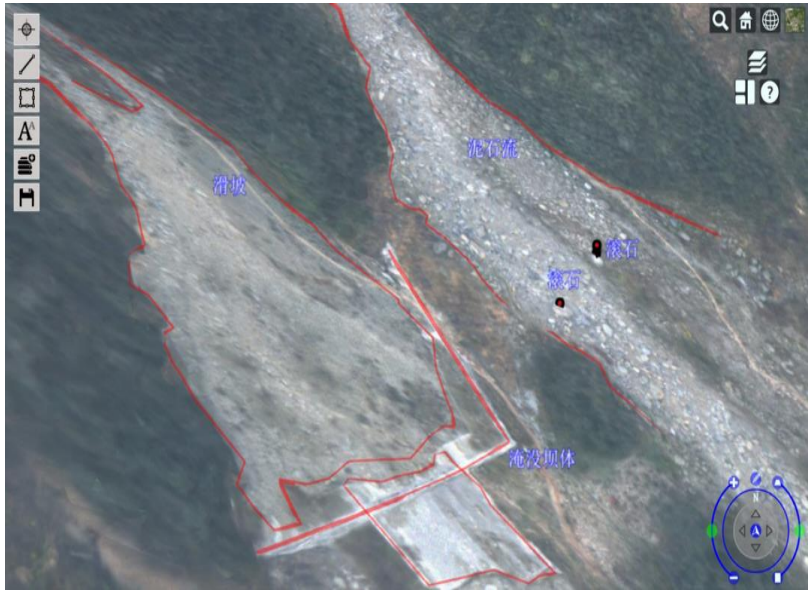
Information system for disaster evaluation and early-warning (灾情评估预警信息系统)

Emergency consultation system 应急会商研判系统

Works with internet B/S model-based to realize long-distance emergency consultation and joint-interpretation.

基于互联网的B/S方式，实现异地联合、会商研判、应急解译。

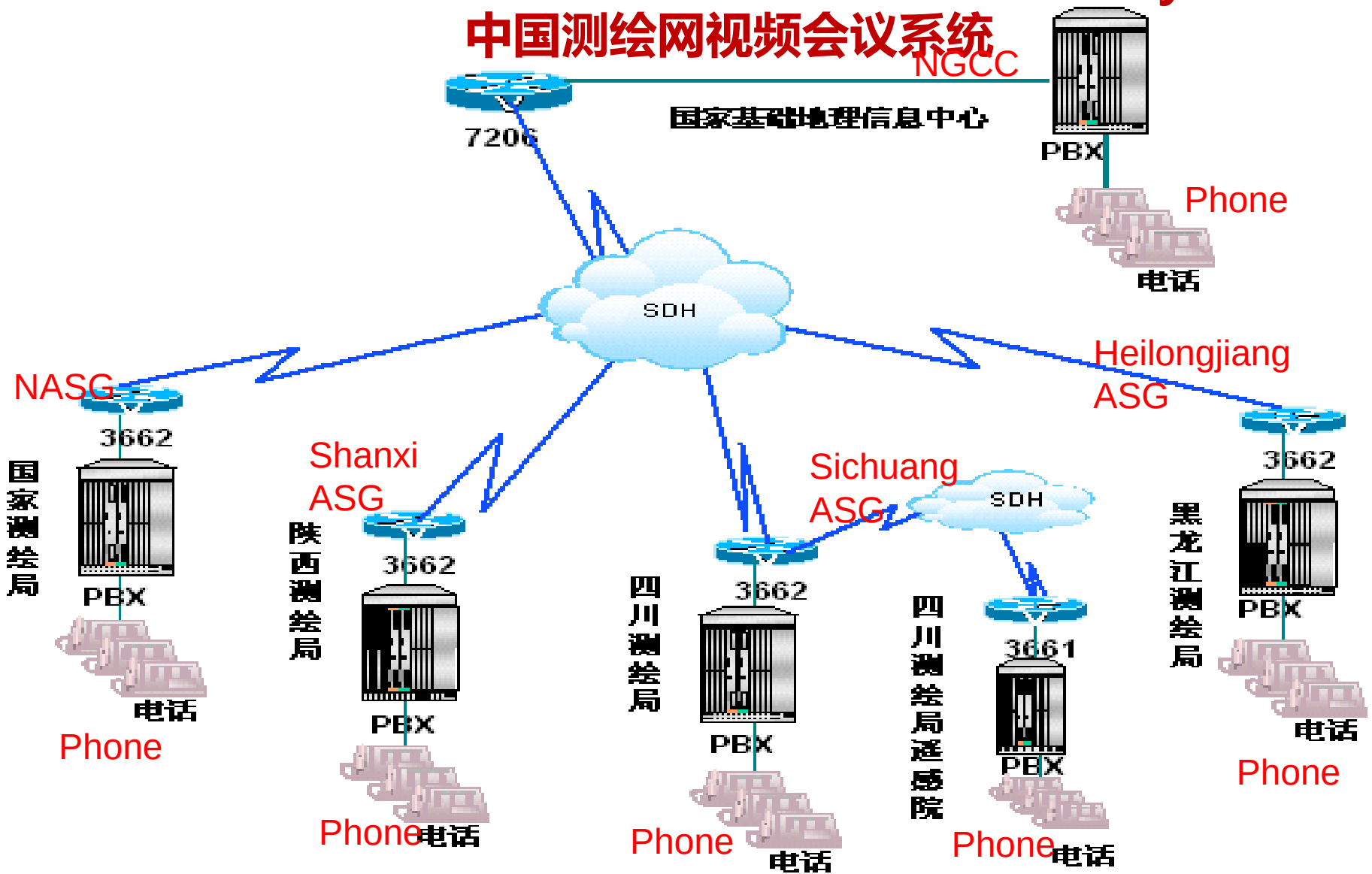
Video conference 语音视频会商



3D plotting 三维标绘

Information system for disaster evaluation and early-warning (灾情评估预警信息系统)

Online Video Conference via China Survey Net
中国测绘网视频会议系统



4、 Establishing a platform for publishing disaster information

Cross-platform application system

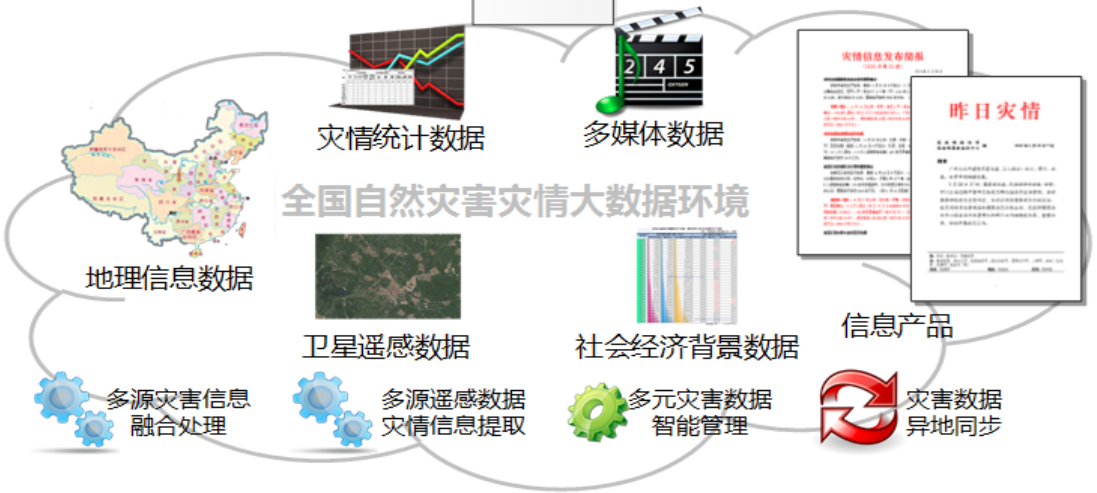
跨平台
应用
体系

Synergic service system

业务
协同
服务
体系

National disaster big data intelligent computing system

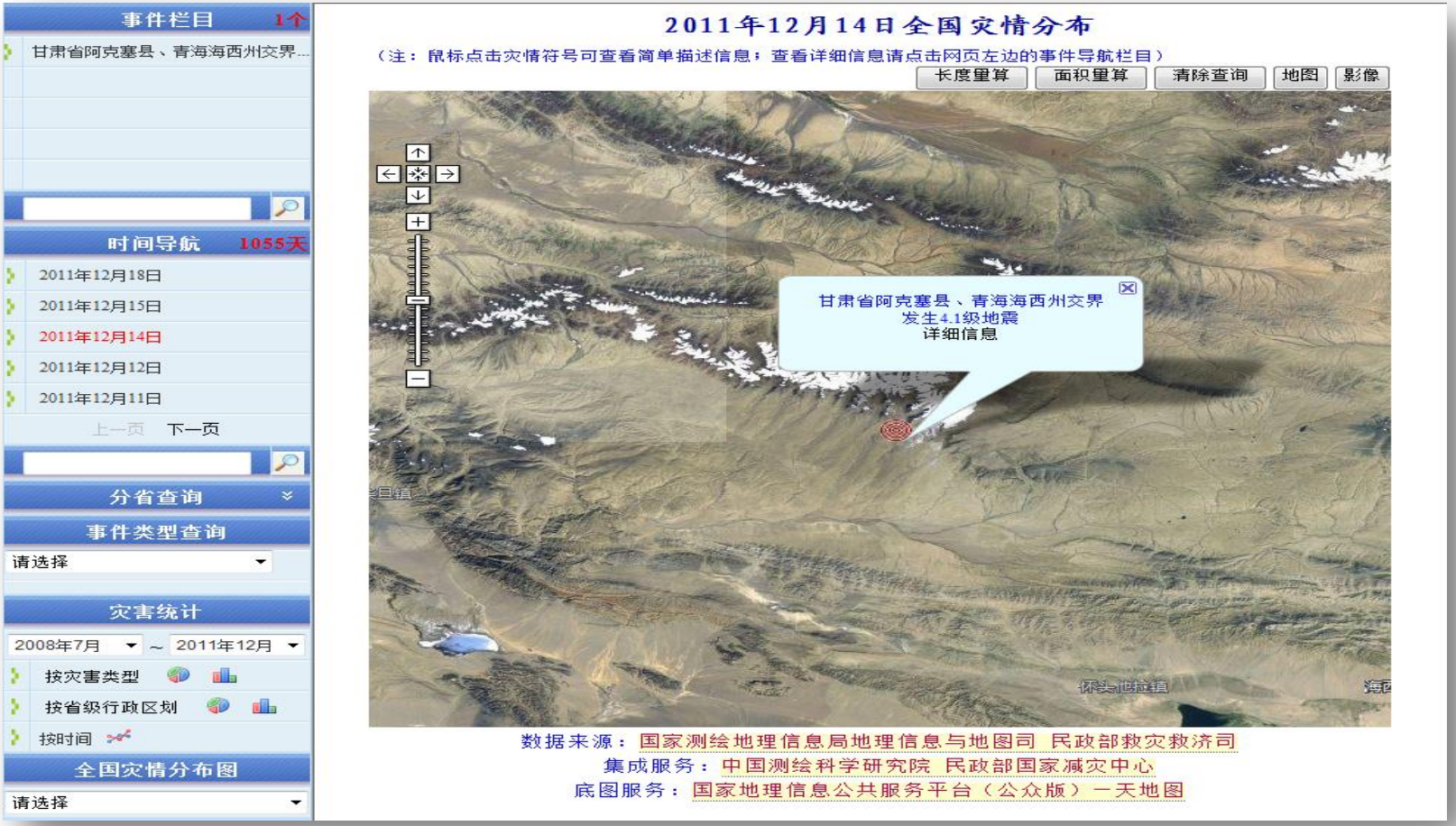
全国
灾情
大数据
智能
计算
体系



information service（信息服务）

Public service platform for disaster information : MapWorld 灾害信息服务公共平台（天地图网站）

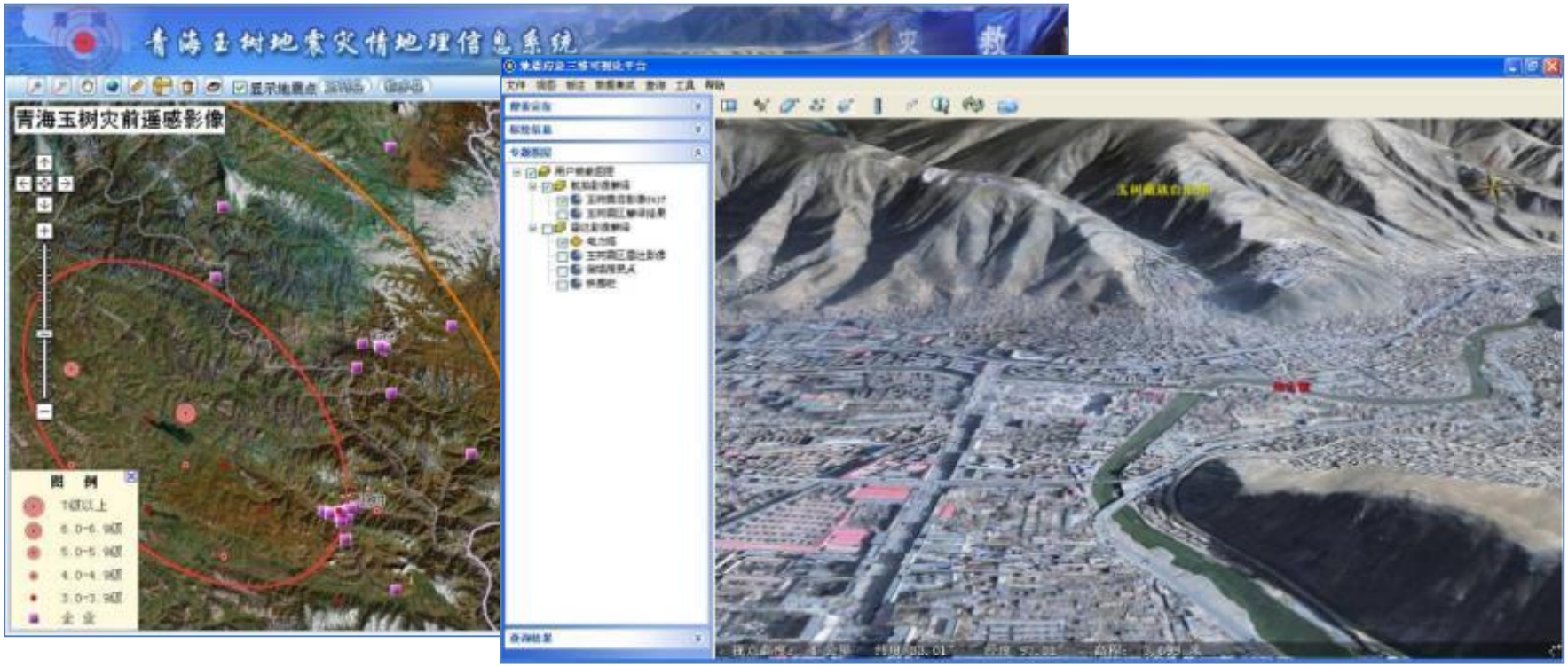
Provides 24-hours disaster information service for the public, enterprises, professional institutions.



信息服务（information service)

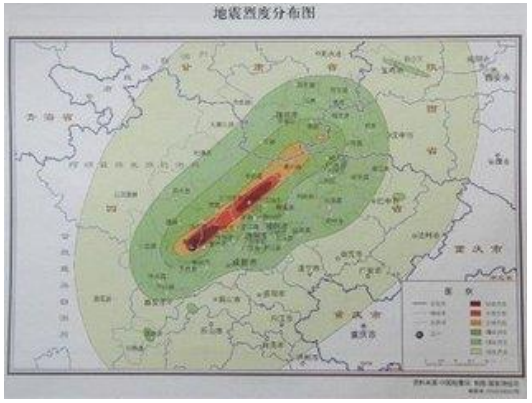
Government service platform for disaster information
灾害信息服务政务平台

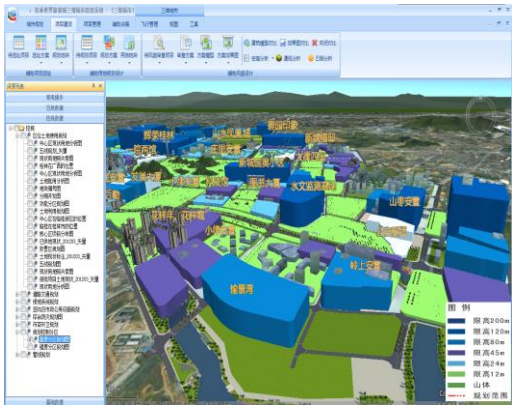
Provide disaster information for the governments and military.



5、 Post-disaster reconstruction planning
初步形成灾后规划重建技术

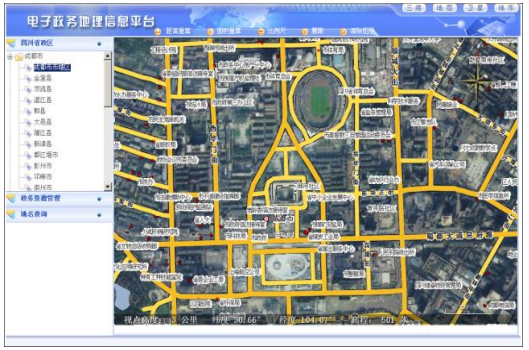
Post-disaster planning
灾后规划设计

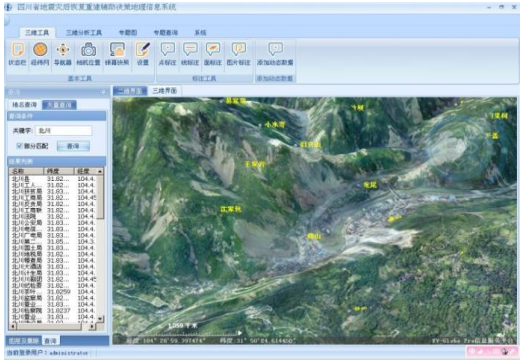




Reconstruction monitoring
重建情况监测

Information system
信息系统

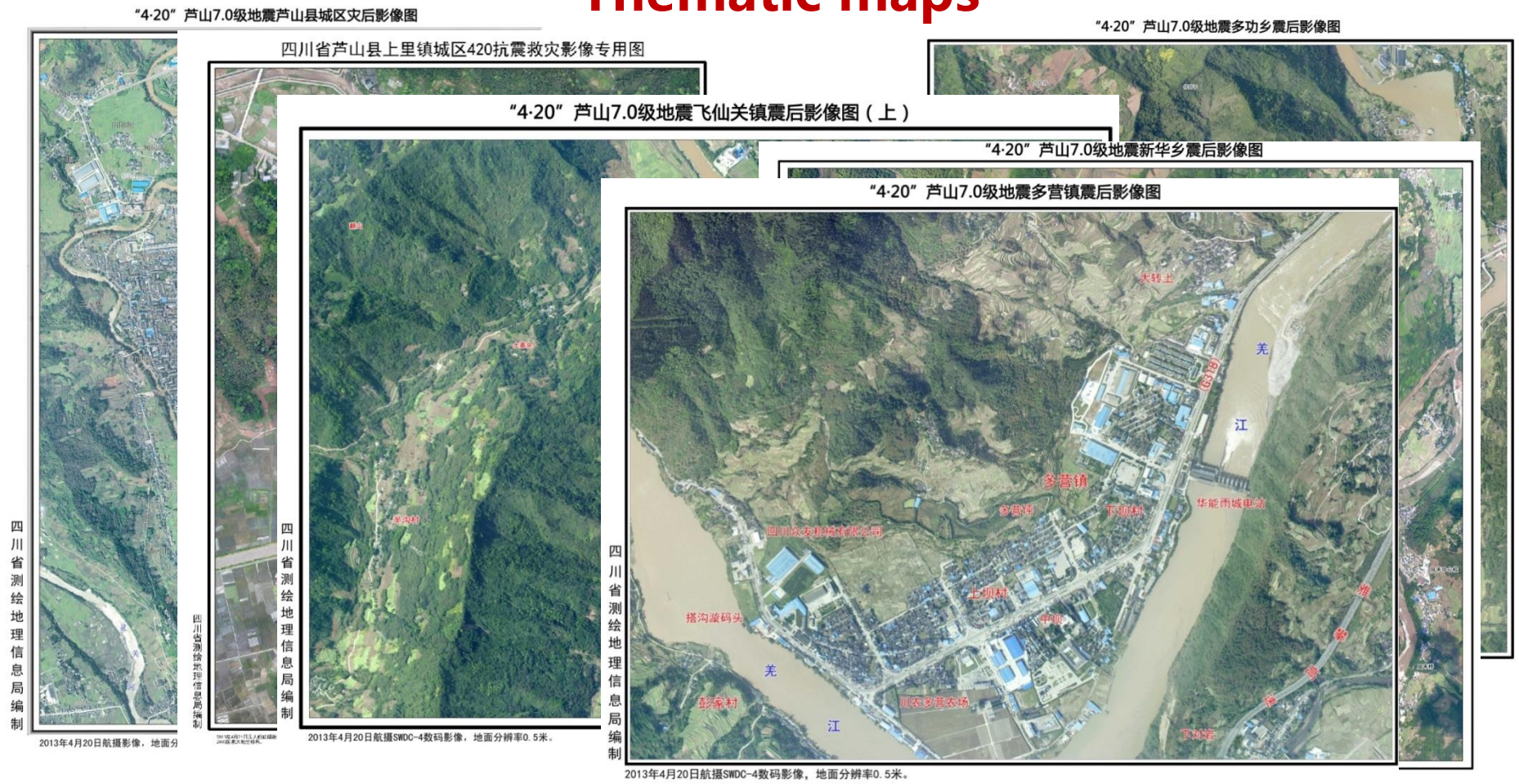




Post-disaster reconstruction planning (灾后规划重建)

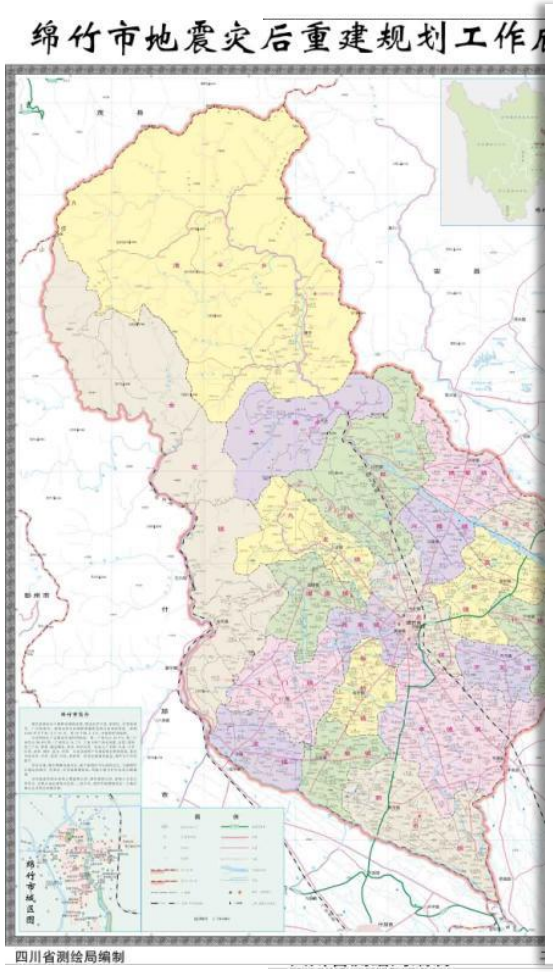
影像专题图

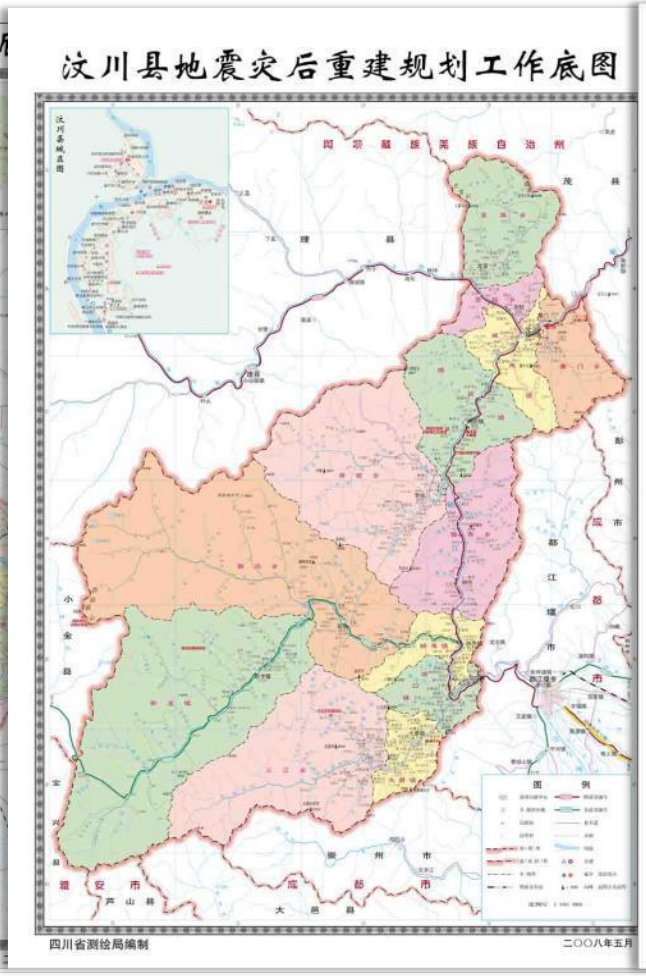
Thematic maps

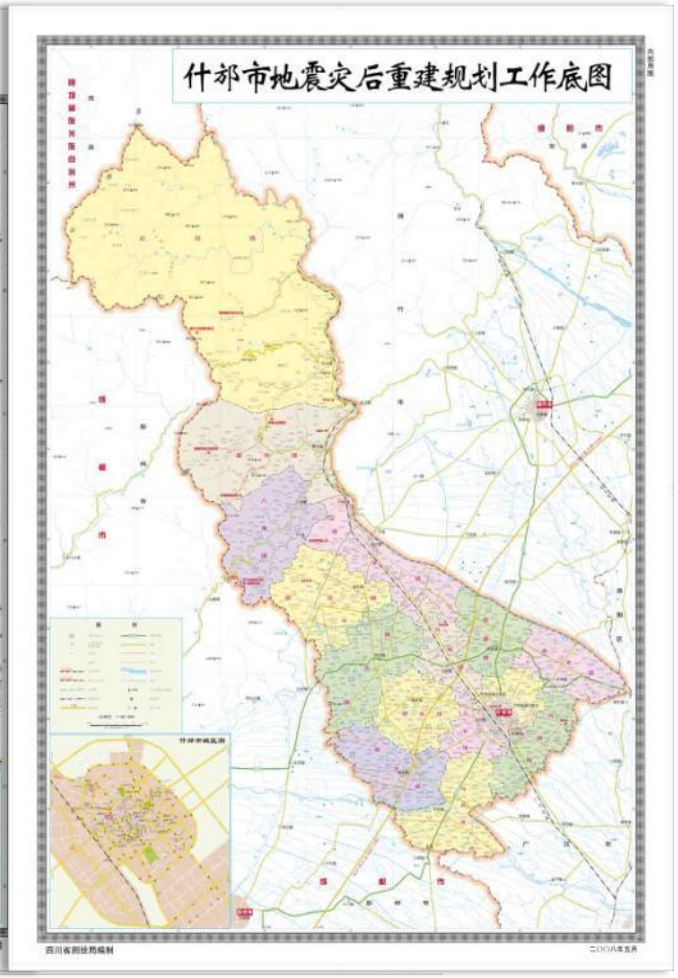


Post-disaster reconstruction planning (灾后规划重建)

工作底图
Base maps



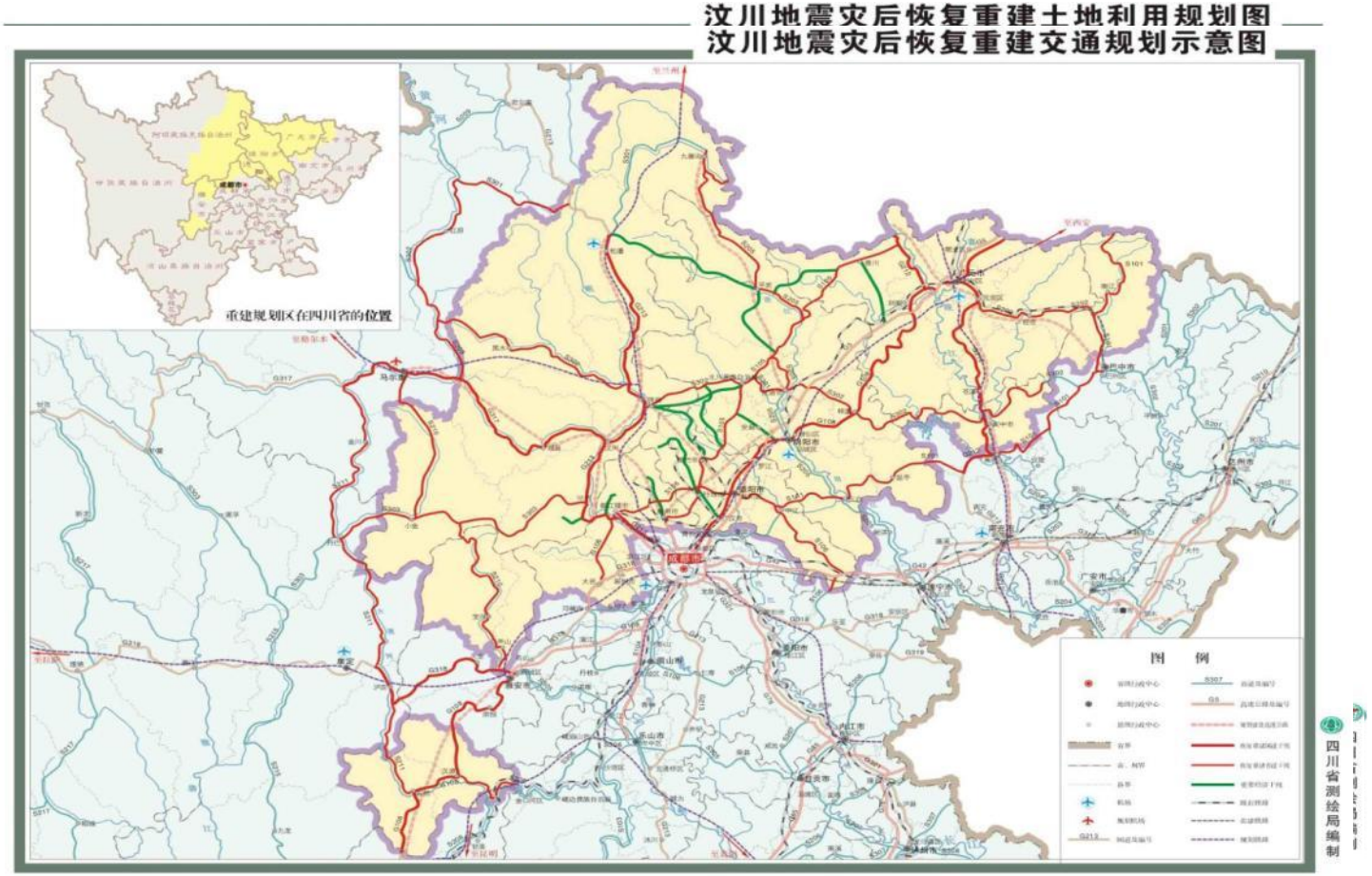




Post-disaster reconstruction planning (灾后规划重建)

规划重建规划专题图

Thematic maps of post-disaster reconstruction planning



Post-disaster reconstruction planning (灾后规划重建)

规划重建辅助决策地理信息系统

Assistant system for decision-making during reconstruction planning

Post-disaster reconstruction planning (灾后规划重建)

北川灾后三维景观模型

3D landscape model of post-disaster in Beichuan

北川新城三维景观模型

3D landscape model of new city in Beichuan

Case 1

Wenchuan Earthquake（汶川地震），12.05.2008

The most destructive (magnitude 8), the most widely spread catastrophic earthquake with the most difficult relief since the founding of P.R.China.

①龙门山前山断裂 Front fault of Longmen mountain
②龙门山中部断裂 Middle fault of Longmen mountain
③龙门山后山断裂 Back fault of Longmen mountain
④,⑤岷江断裂带 Fault zone of Min river
⑥,⑦,⑧金汤弧形构造带 Jintang arc structure zone

- 汶川地震共由 8 个 7.1—7.6 级地震组成(陈运泰等,2008),是几十秒钟内沿龙门山中部断裂发生的多点连续破裂行为。
- Wenchuan earthquake consists of eight earthquakes with 7.1-7.6 grade (Yuntai Chen, et al., 2008), which were multi-point continuous fracture motion along middle fault of Longmen mountain in several ten seconds.
- 第一次破裂的震中位于NE向龙门山断裂带的中部断裂与NNE向岷江断裂、近EW向的金汤弧形构造交汇处。
- The first earthquake center was located at the intersection of middle fault of Longmen mountain with NE direction, fault of Min river with NNE direction and Jintang arc structure with nearly EW direction.

Wenchuan Earthquake
汶川地震（1）

- Green Channel to supply map service around the clock .

开通测绘成果应急提供绿色通道，实施24小时测绘应急服务保障。

- Urgent rescue : supplied 1183 map sheets and 26 3D GIS to 18 provinces and 49 departments.

紧急救援：向中办、国务院应急办、国家减灾委等部委、18个对口救援省份计49个部门或组织提供1183幅专题地图，26套震区三维地理信息系统。

- Disaster Assessment: supplied 262 thematic maps and 27 information systems to 27 departments.

灾情评估: 提供给国务院汶川地震专家委员会、民政部抗震救灾专家组等27家单位提供262幅专题地图，27套灾情评估系统。

- Recovery & Planning: supplied 78 recovery planning maps, near one thousand atlas and two recovery planning GIS.

恢复重建（规划）: 向发改委等提供78幅恢复重建规划图，向三个受灾省及有关方面提供上千份汶川灾害地图集；2套规划重建系统。

Wenchuan Earthquake: Data service

汶川地震（2）：数据成果提供服务

Paper maps: 53000 sheets

Navigation Maps: 1630 (1.2 TB)

Site locating: 1200

为国办、国务院应急办、国家防总、民航总局、地震局等紧急提供纸质地形图53000张。为国务院应急办、国家防总、环保部、住房和城乡建设部、解放军疾病预防控制中心、交通运输部等紧急提供基础地理信息数据35989幅，导航电子地图1630幅，数据量逾1.2TB。

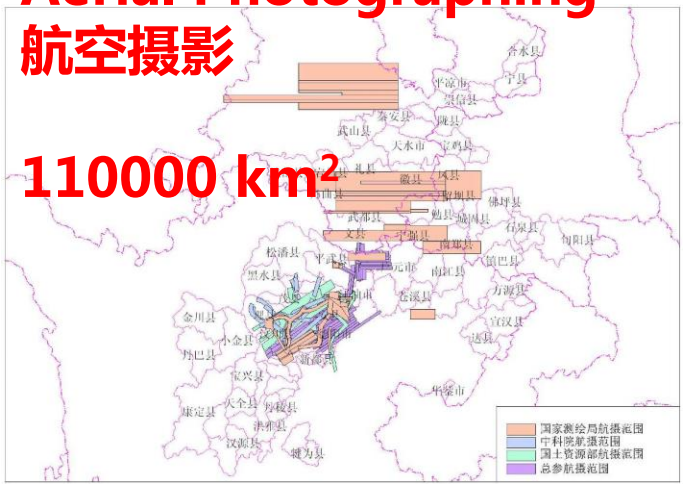
为空降空投等提供控制点近1200点，读取坐标数据3000多个

Wenchuan Earthquake: Image acquisition

汶川地震（3）：影像获取

Aerial Photographing
航空摄影

110000 km²

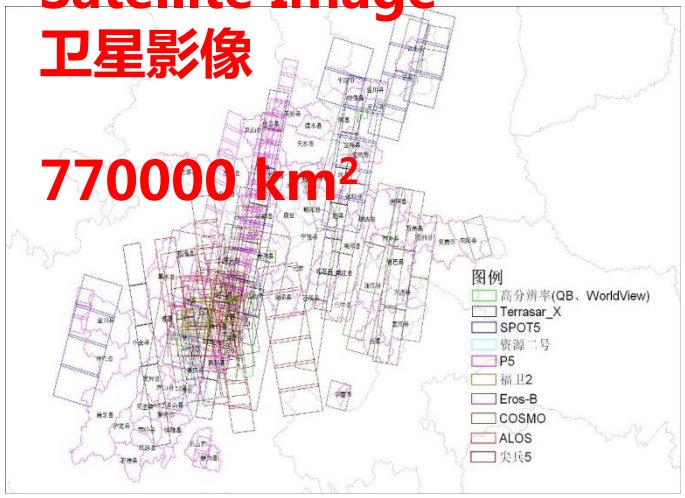


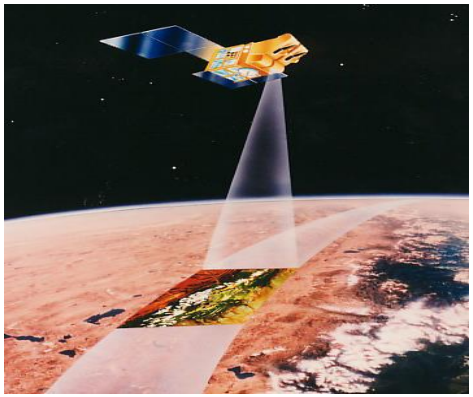
紧急调集包括无人机、直升机在内的9架飞机，装备具有自主知识产权的数码航摄仪，对灾区实施航空摄影

航摄面积：
国家测绘地理信息局
62000km²
国土资源部 10788km²
中国科学院 9480km²
其他29000km²
总面积达11万平方公里

Satellite Image
卫星影像

770000 km²



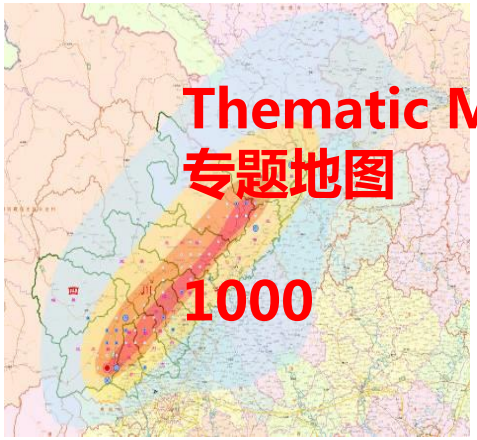


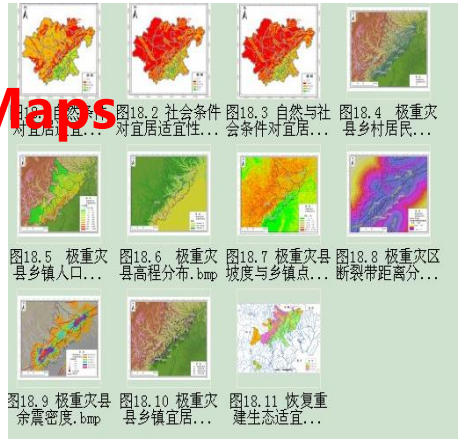
协调国内外多颗遥感卫星不断获取灾区影像

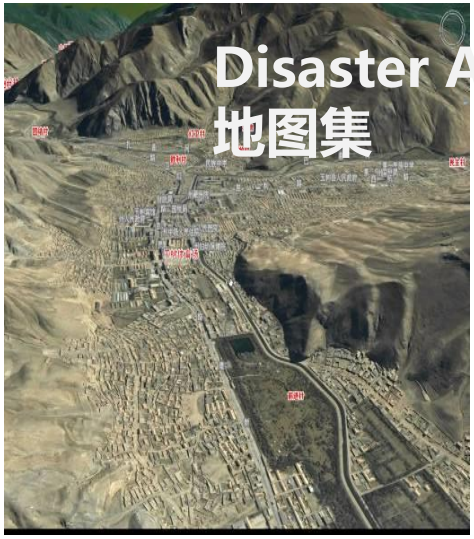
高分辨率影像：8475km²
TerraSAR：75160km²
SPOT5：98253km²
资源二号：6711km²
P5：59185km²
福卫2：57574km²
EROS-B:447km²
COSMO:138526km²
ALOS:132249km²
尖兵5：191400km²
总面积约77万平方公里

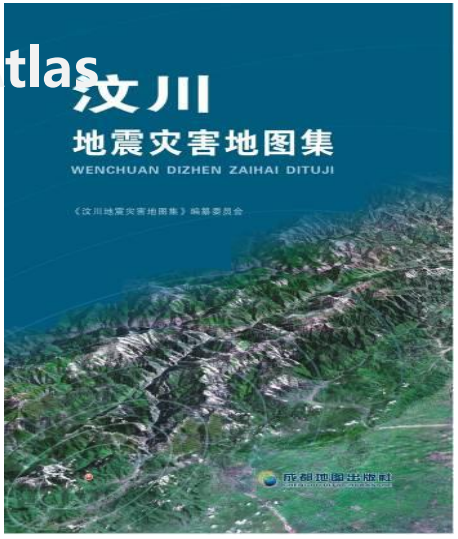
Wenchuan Earthquake: Thematic mapping

汶川地震（4）：专题地图服务







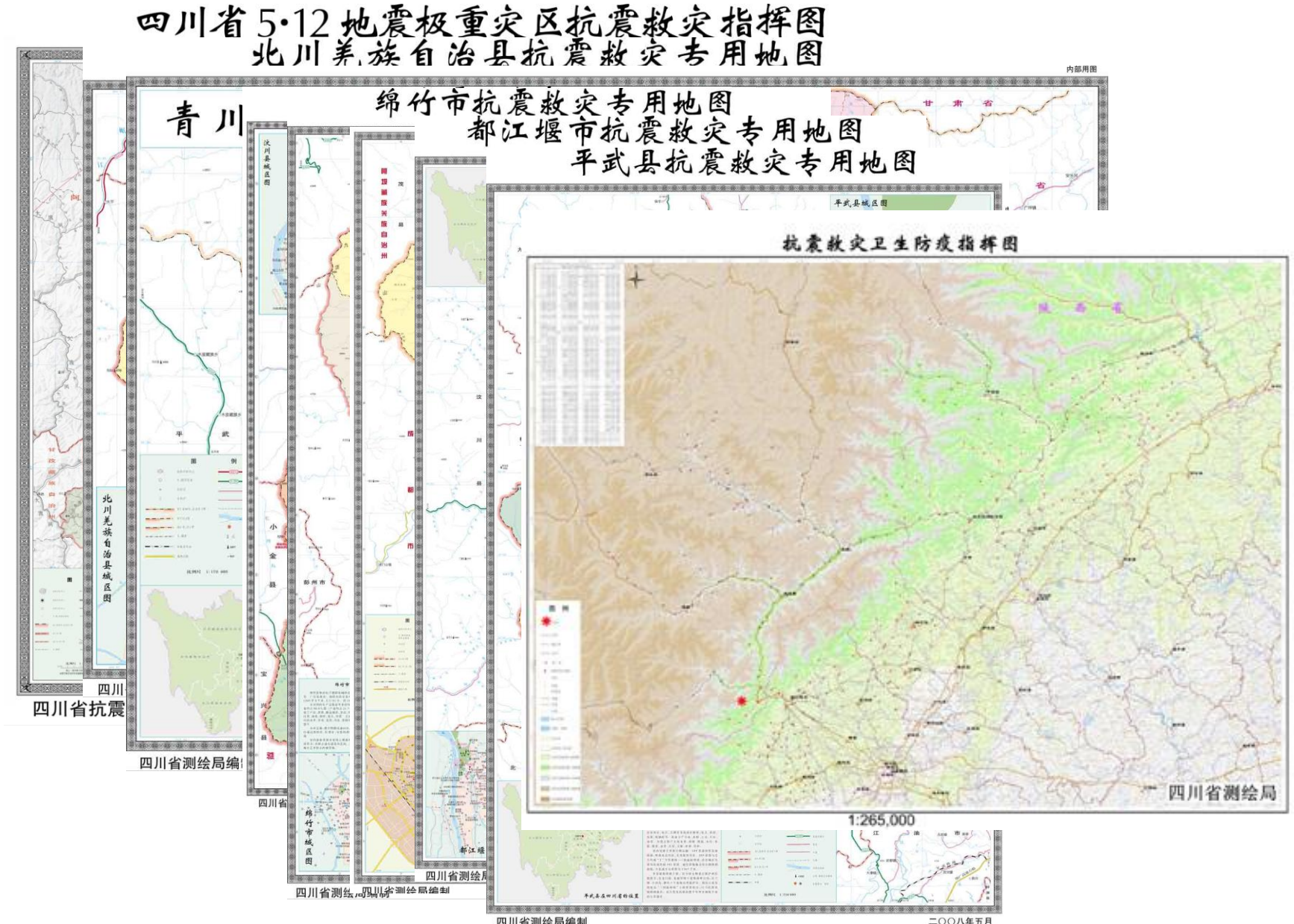


More than 1000 thematic maps, including:

- **relief, traffic, administrative maps ;**
- **intensity maps, hazard extent and damage evaluation maps ;**
- **image maps reflecting the on-site situation for more than 30 severely affected towns. ;**
- **Recovery and reconstruction base maps;**

Wenchuan Earthquake: Thematic mapping

汶川地震（4）：专题地图服务



Wenchuan Earthquake: Thematic mapping

汶川地震（4）：专题地图服务

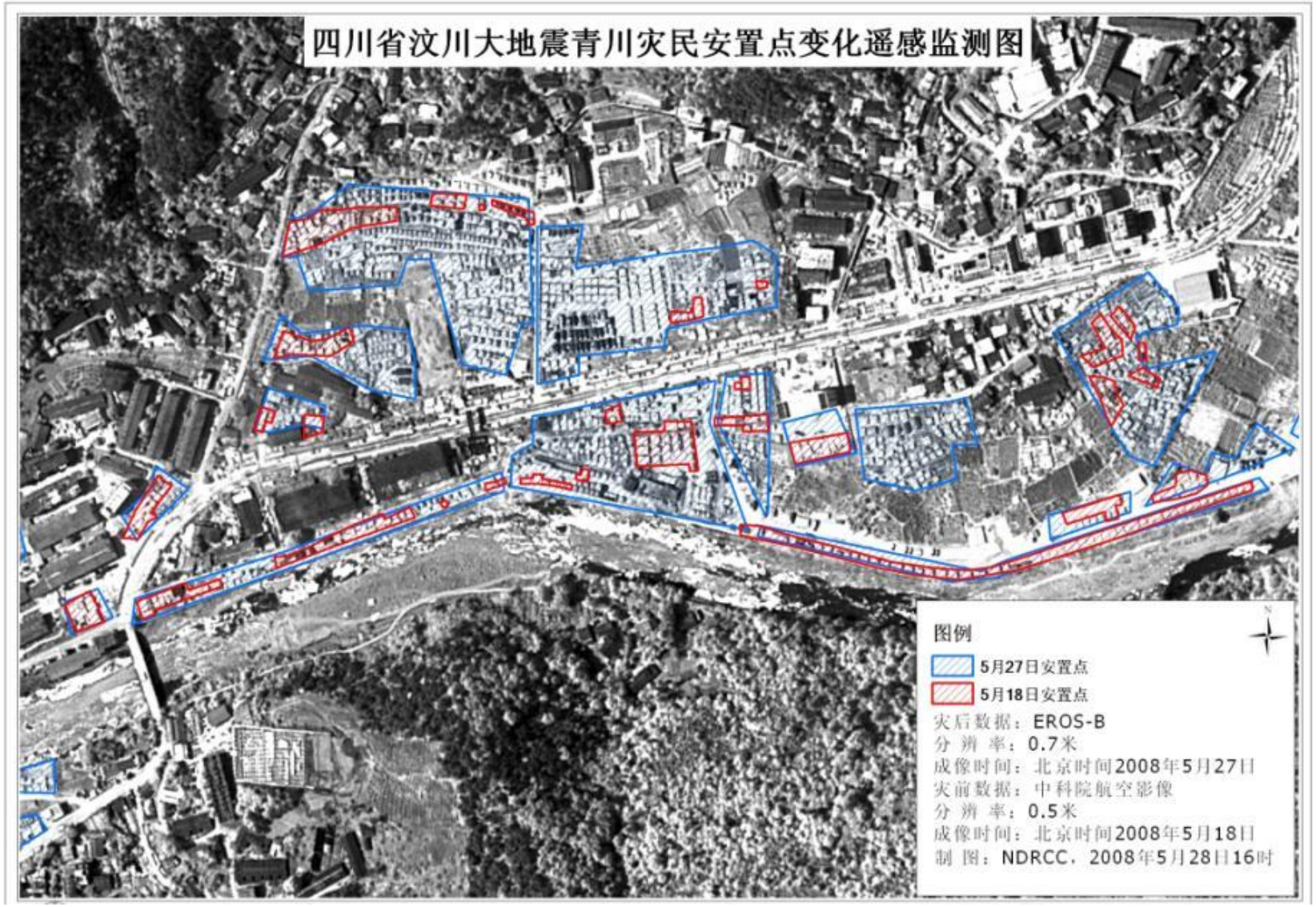
8.13 泥石流虹口影像图

四川省测绘局

采用2010年8月19日0.2米无人机航拍数码影像制作

Wenchuan Earthquake: Thematic mapping

汶川地震（4）：专题地图服务



Wenchuan Earthquake: GIS applications

汶川地震（5）：GIS 系统开发

抢险救灾、灾情评估分析、灾后重建规划

Rescuing	Assessment	Recovery
震区三维地理信息系统	灾害综合评估地理信息系统	灾后重建规划信息集成系统

基础地理数据、影像数据、灾区专题数据、图像视频

Emergency Decision GIS Platform

汶川地震抗震救灾应急会商系统平台

为41个部委或组织，共提供55套系统

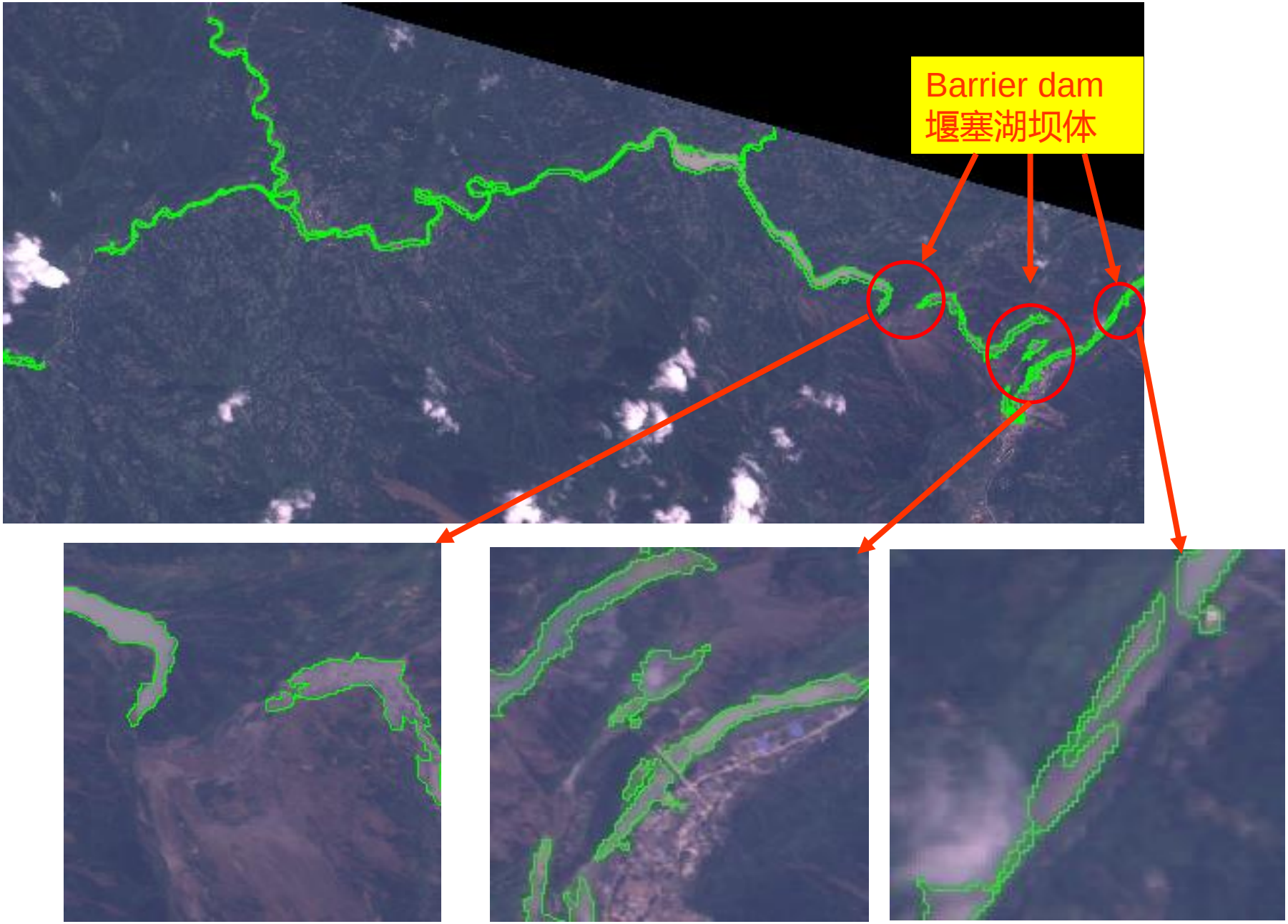
Tangjiashan Barrier lake 唐家山堰塞湖

River border before the Earthquake
灾前唐家山堰塞湖库区河道的边界

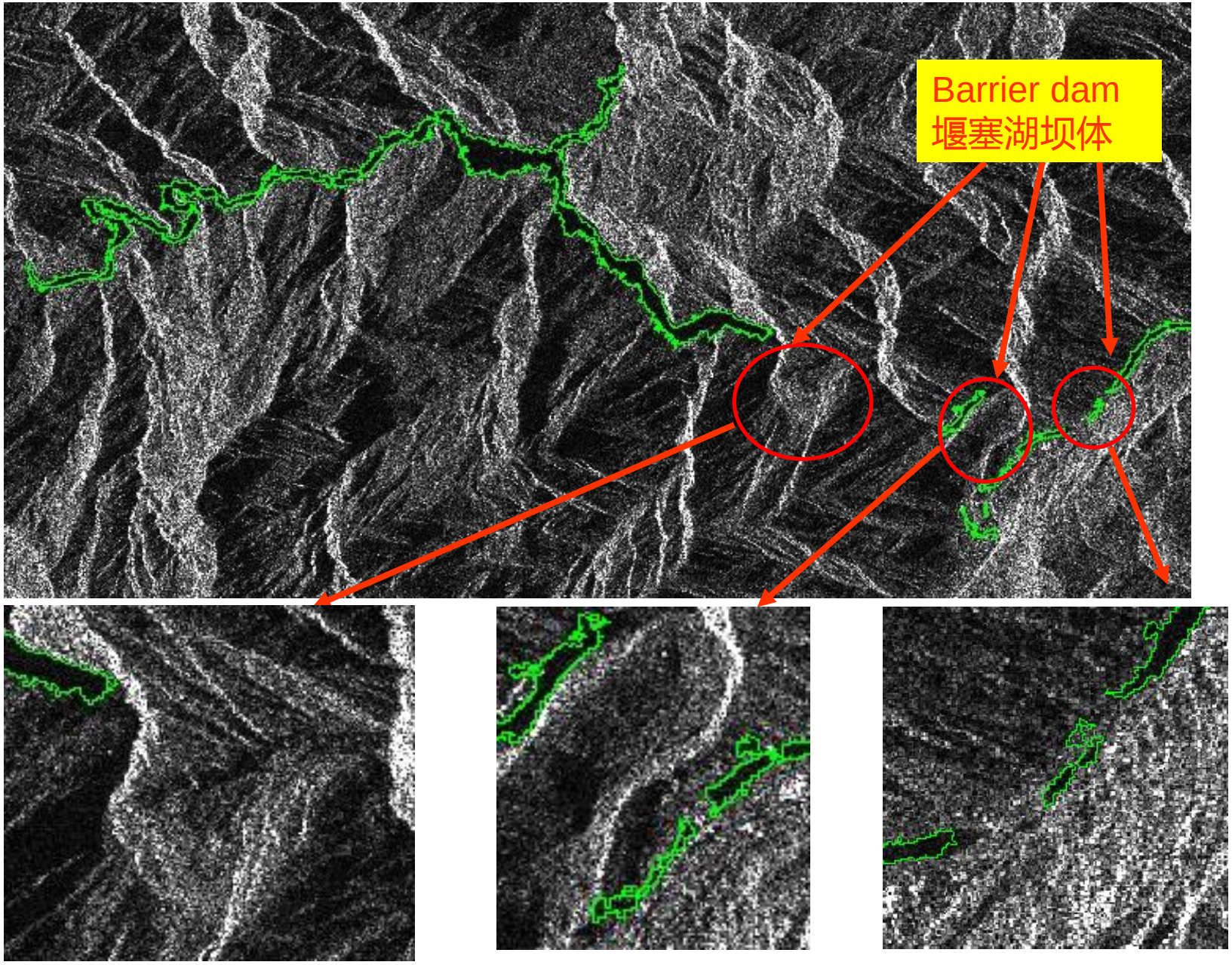
Data: SPOT 5 (2006-11-10)

2006年11月10日SPOT5融合后的影像对唐家山堰塞湖库区河道边界提取结果

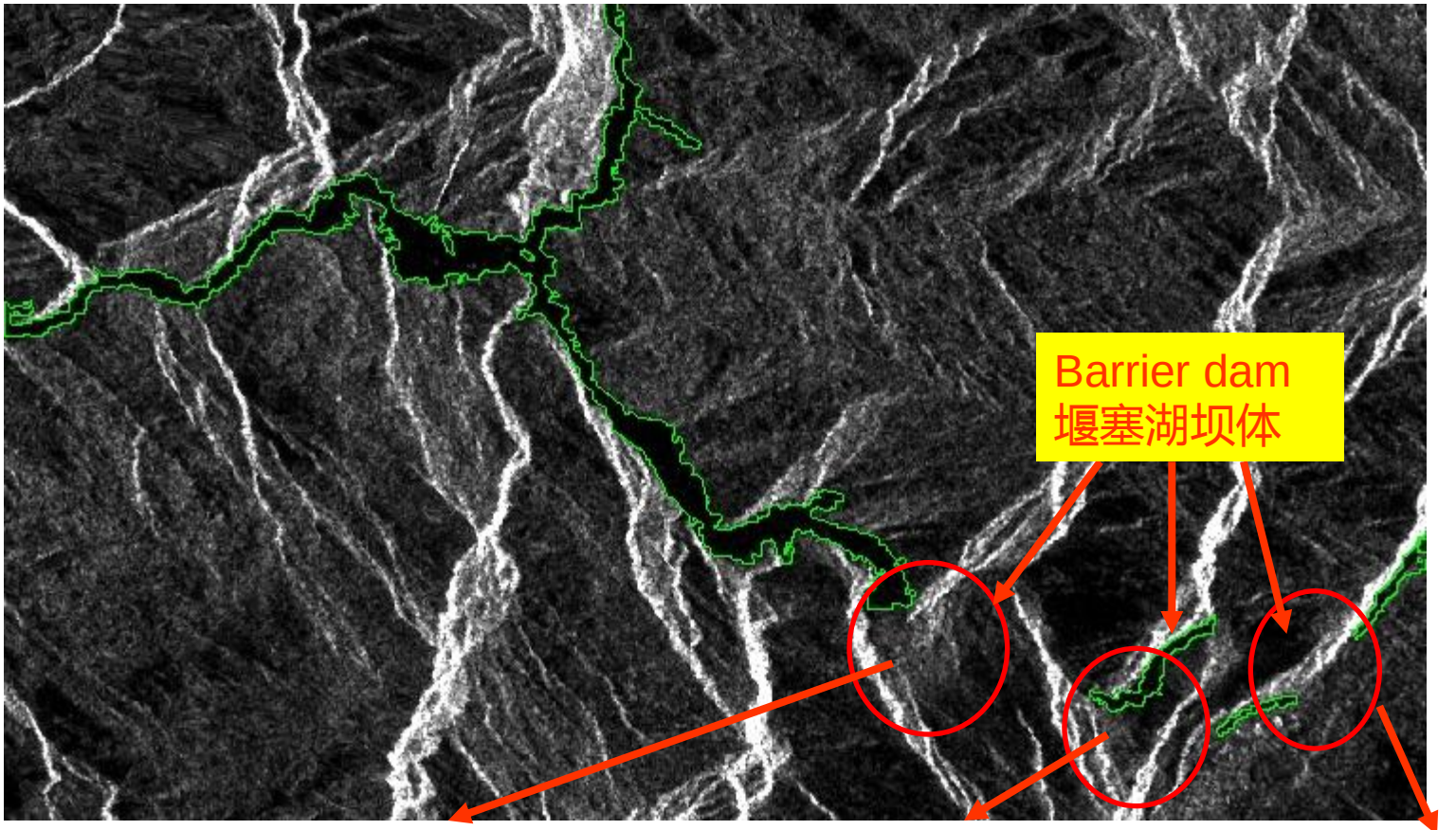
River border extracted based on Formosat-2 (8 m), 2008-05-14

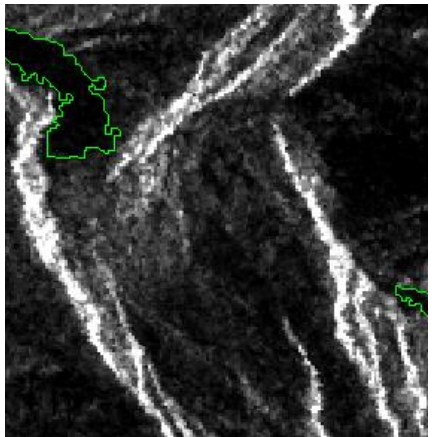


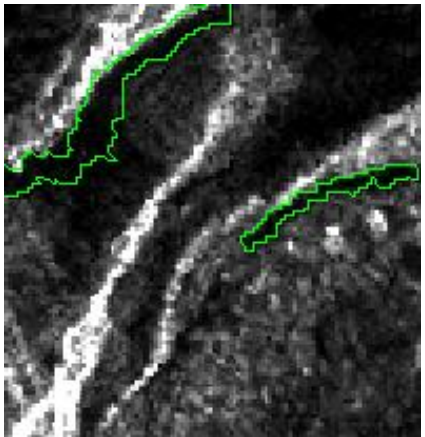
River border extracted based on Radarsat (7 m), 2008-05-17

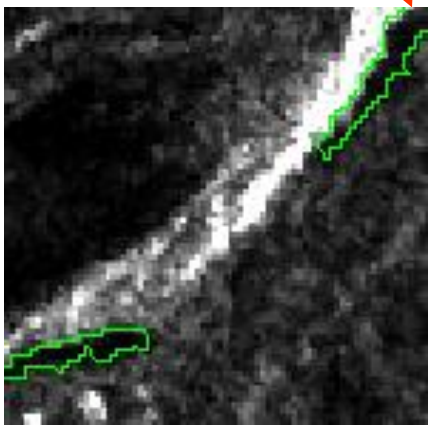


River border extracted based on ASAR (20 m), 2008-05-22

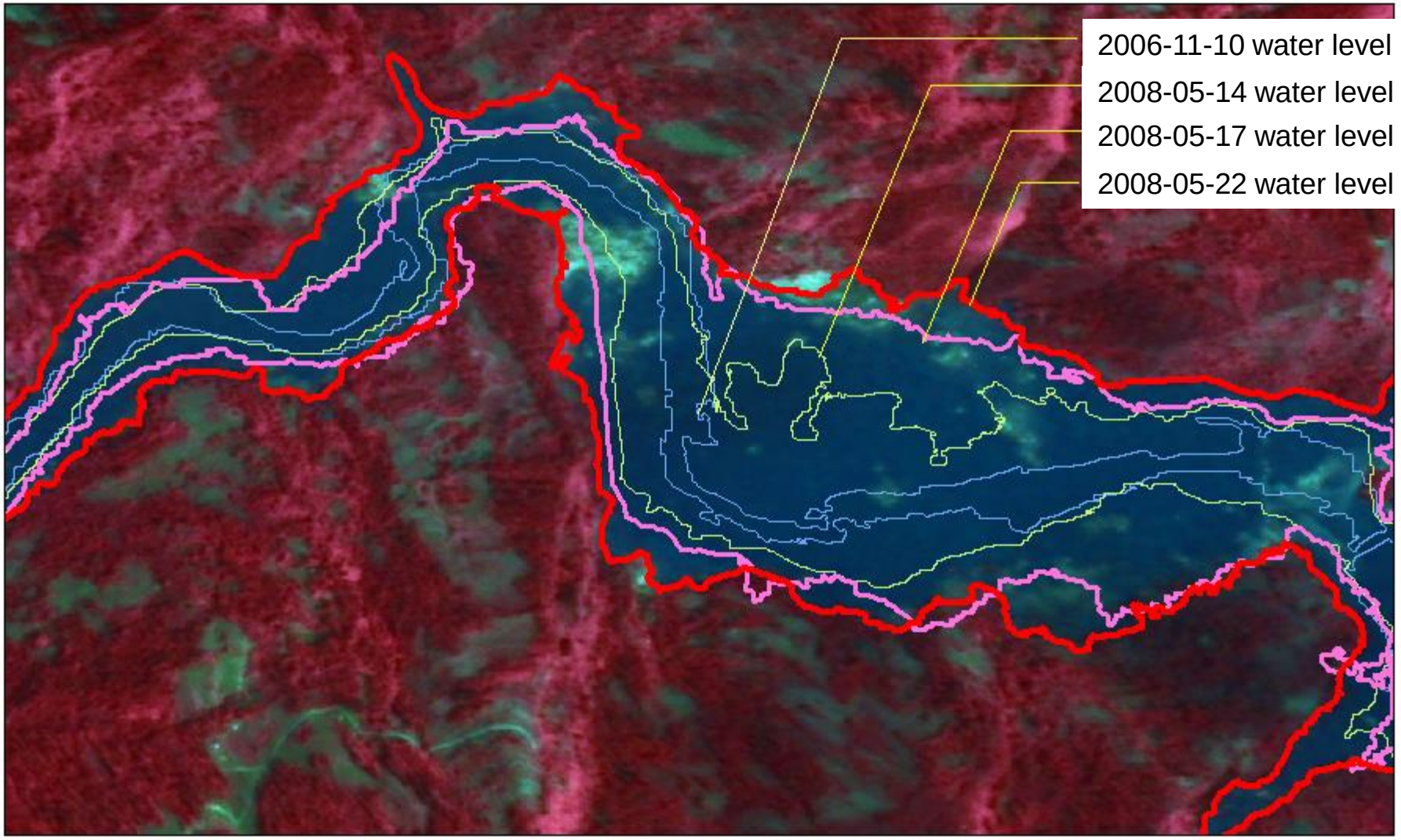




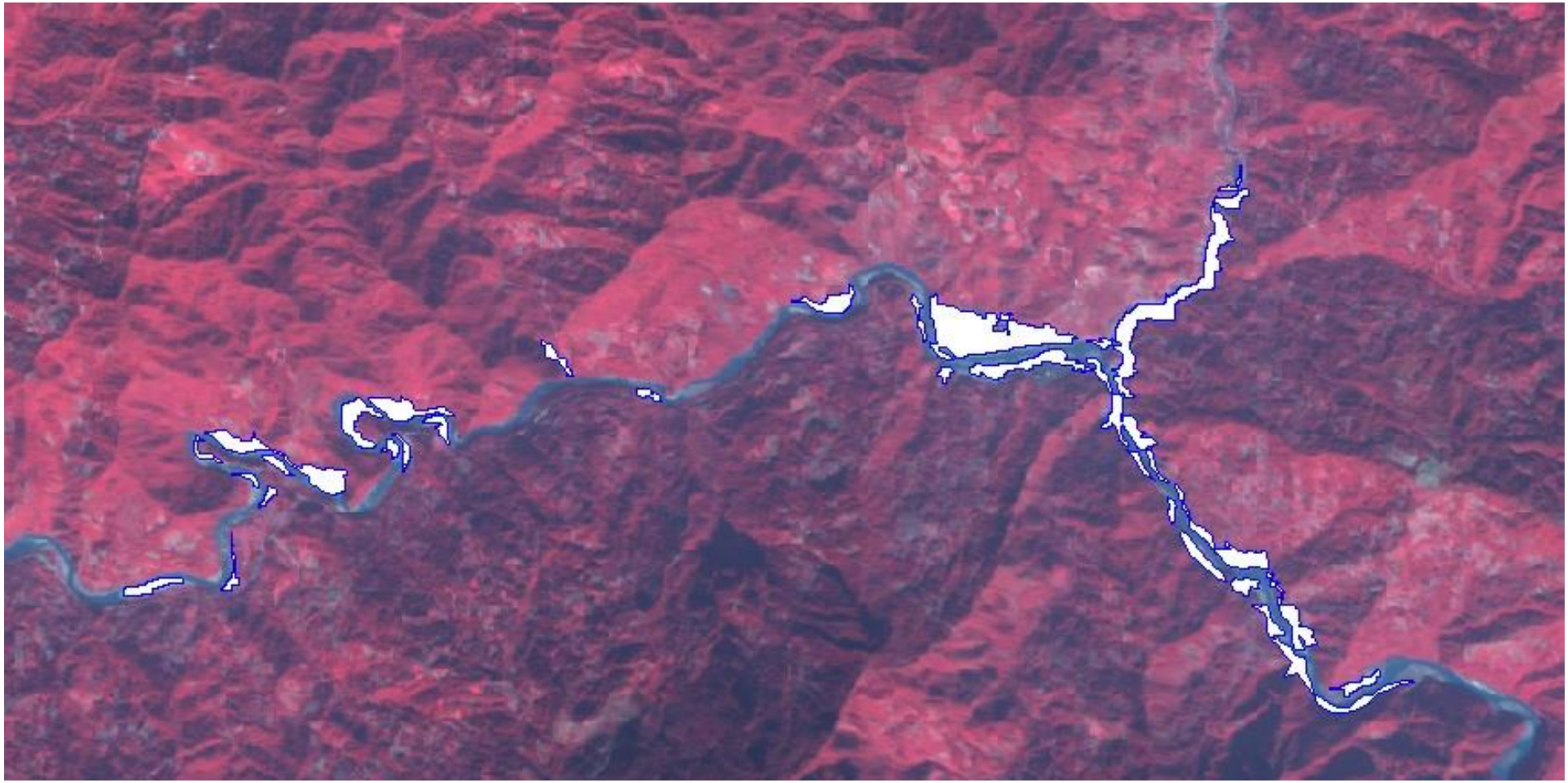




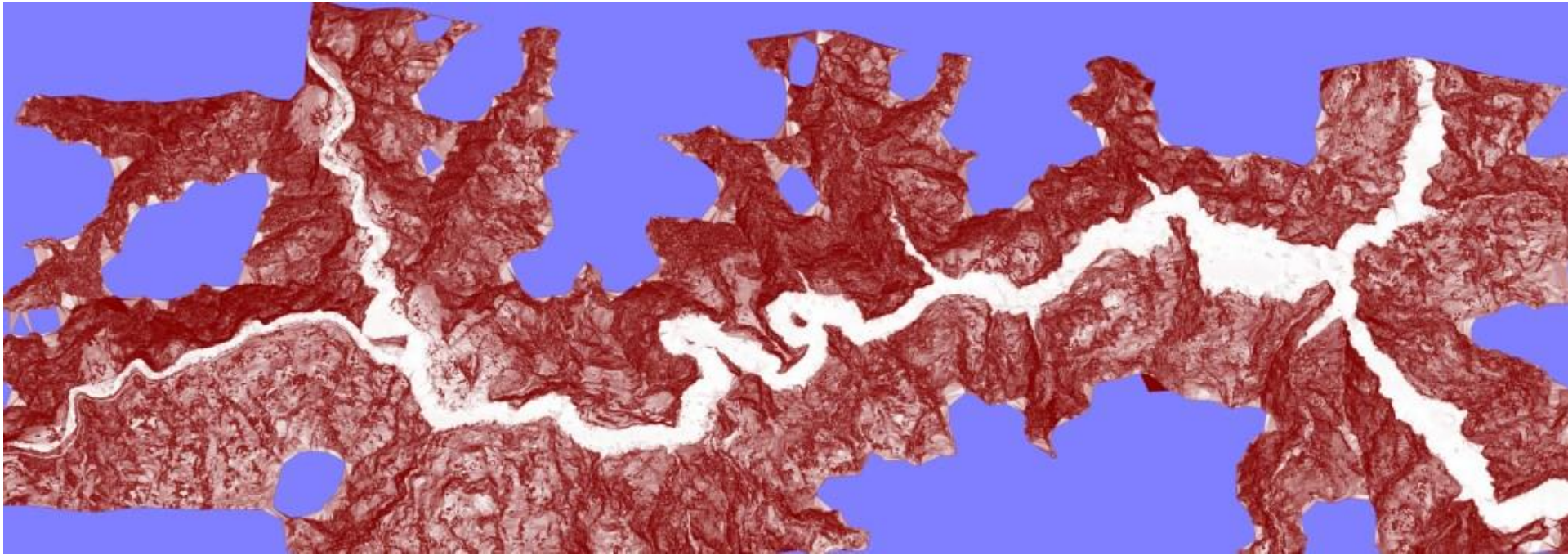
Water-level changing map in Tangjia shan barrier lake



The changed area (in white color) of the river from 2006-11-10 to 2008-05-17

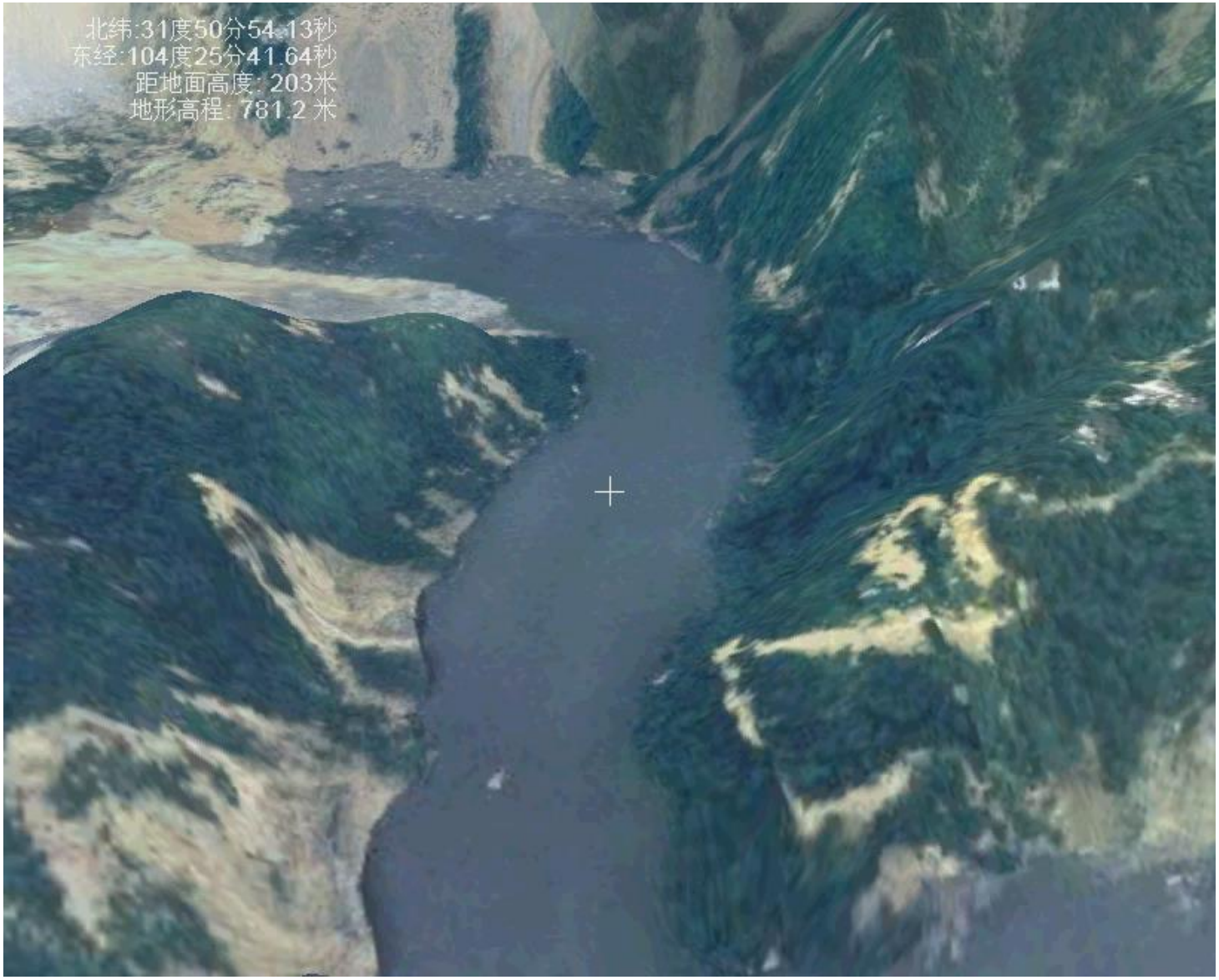


Topographic map (TIN) derived from Lidar in Tangjiashan



Sensor：ALS50 II
Resolution：0.3 m, 2 x 2 m
Date：2008-05-31

Visualization for Supporting Decision Making



Wenchuan Earthquake: Recovery Mapping

汶川地震（6）：灾后重建测绘保障服务

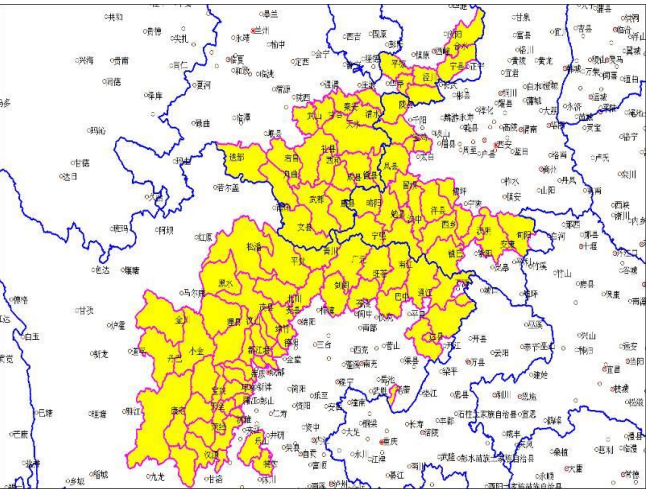


Image maps: 280000 km²

One county one map: 95 counties

Urban maps: 1:5000

综合利用已有和正在获取的遥感影像资料，在2个月内快速生产汶川地震受灾地区面积约28万平方公里的系列影像地图。

用已有SPOT5、P5、CBERS02B以及地震以后新获取的数据，制作95个县的分县影像地图，实现“一县一图”供宏观分析决策使用。

利用震后高分辨率影像，编制川、陕、甘三省95个县内城镇及重点区域1:5000比例尺影像地图，满足灾区城镇规划设计的需要。

分辨率0.5-1米,叠加1:5万全部地名，收集城镇大比例地名资料，包括街道等。

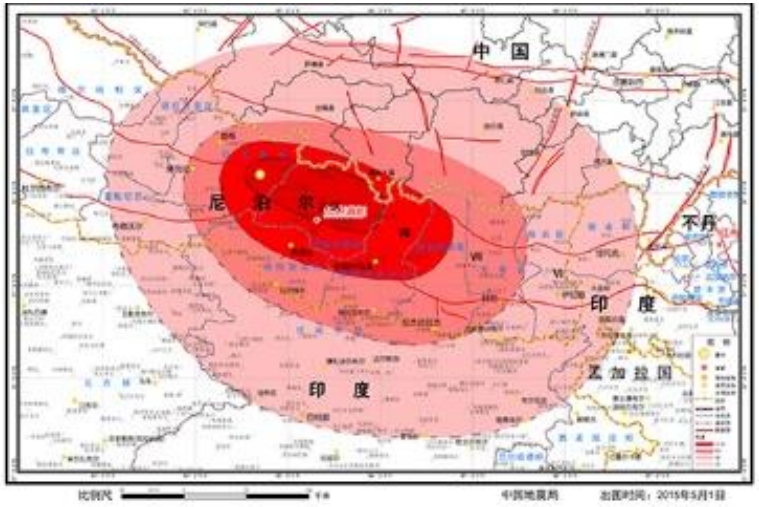
Wenchuan Earthquake: Recovery Mapping

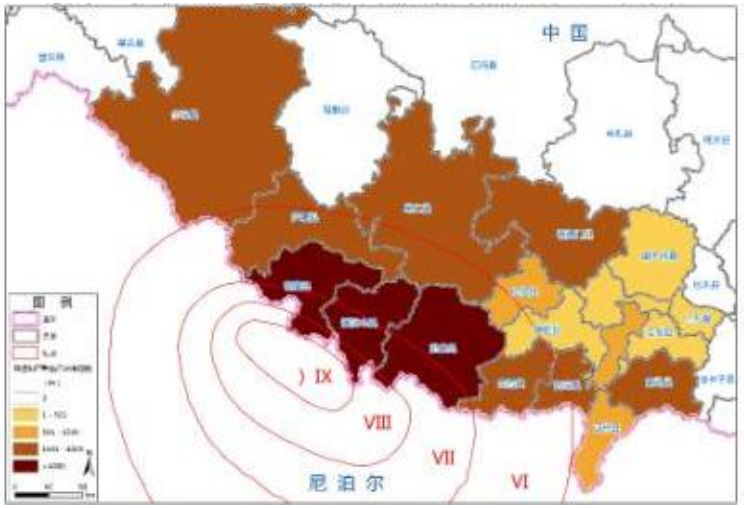
汶川地震（6）：灾后重建测绘保障服务

Case 2

Nepal Earthquake（尼泊尔地震），25.04.2015

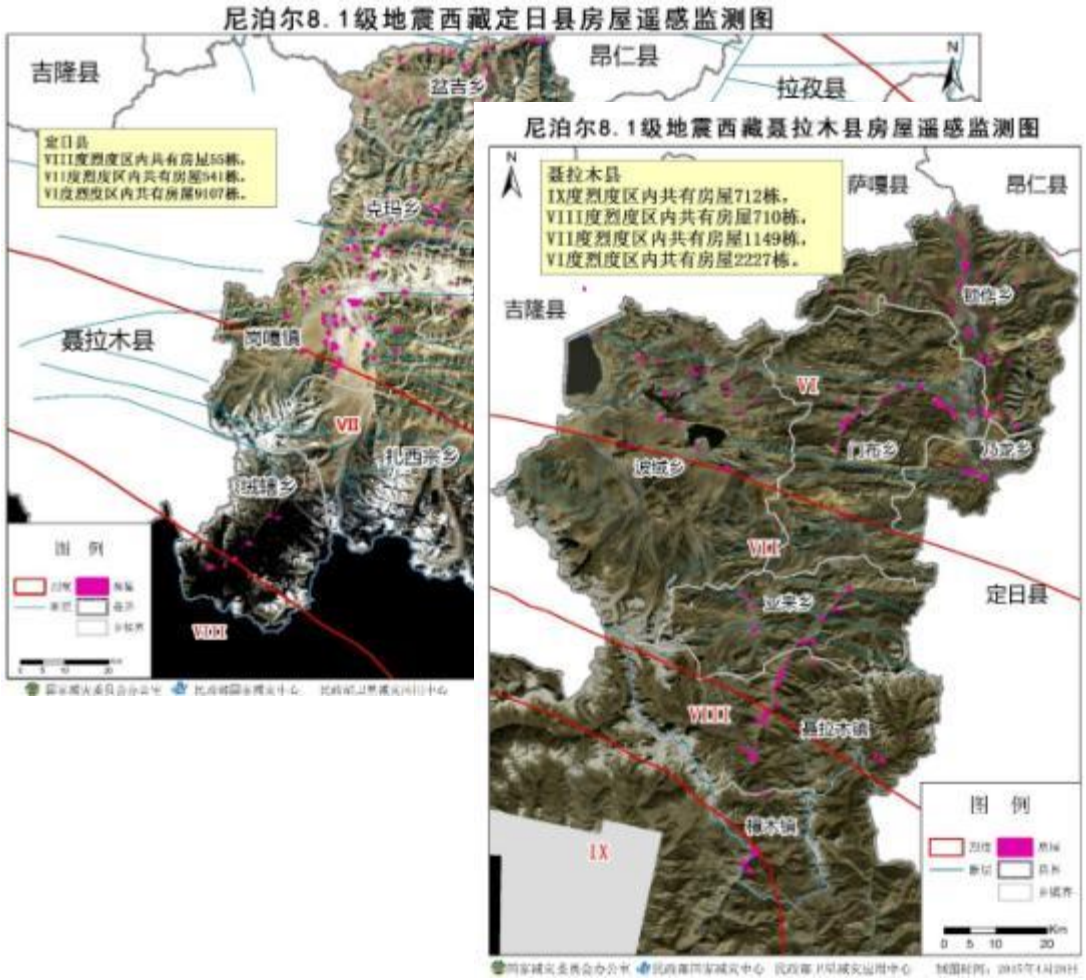
Epicenter was located in Pokhara (magnitude 8.1), Nepal's second largest city. Nepal, China, India, Bangladesh, Pakistan were affected. The southwest region of Tibet adjoining Nepal was strongly affected .

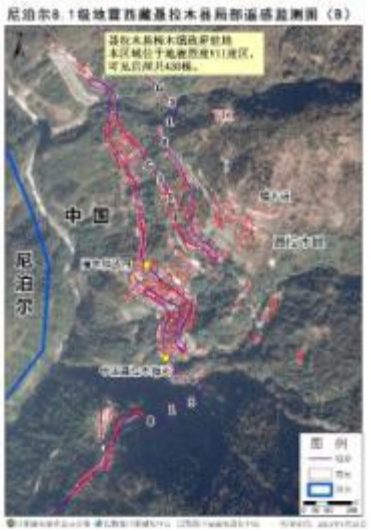


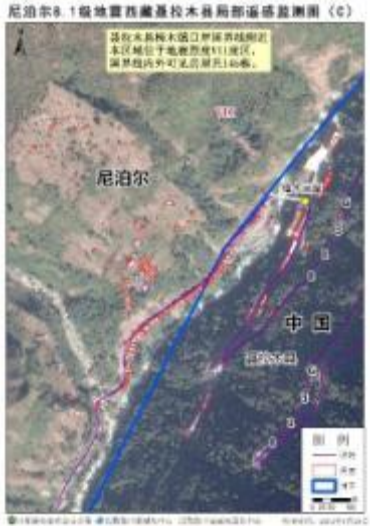


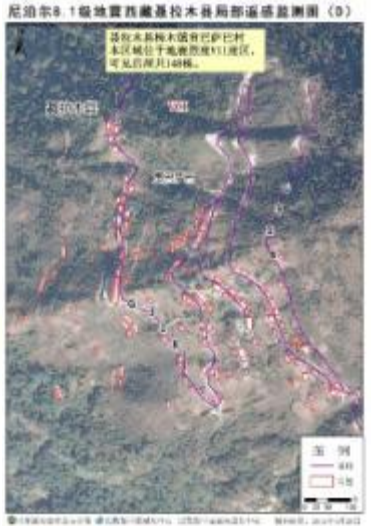
Damaged houses delineation 房屋存量提取

- **Distribution and structure of the houses in the affected regions under different intensity of the earthquake.**



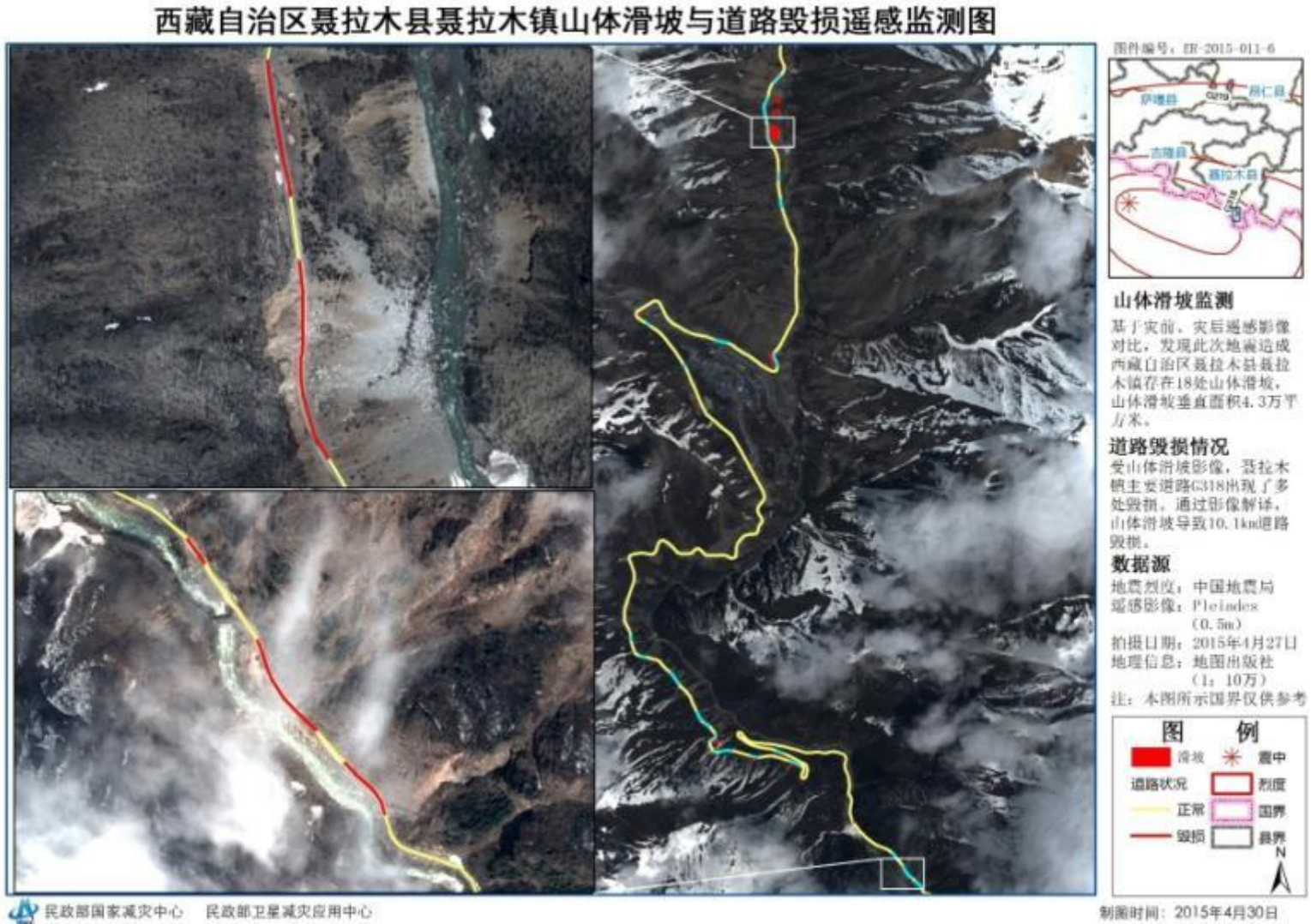






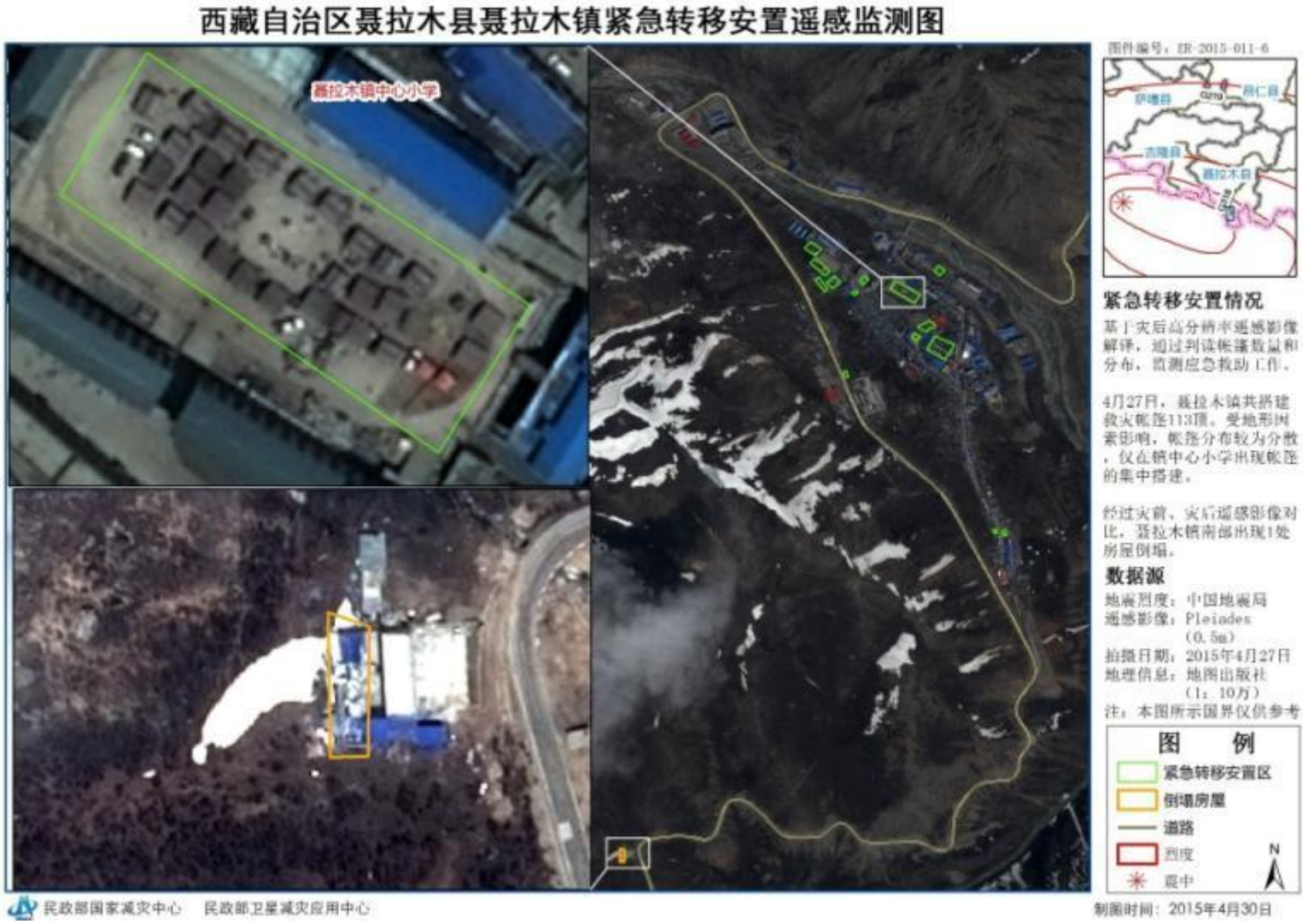
Secondary disaster monitoring and road damage assessment
次生灾害监测与道路毁损评估

- **The earthquake caused 18 landslides in the town of Nyalam, which resulted in 10.1 km road damaged.**



Emergency relocation monitoring 紧急转移安置监测

- **Based on the high-resolution images, interpret the number of tents and their distribution for emergency relocation.**



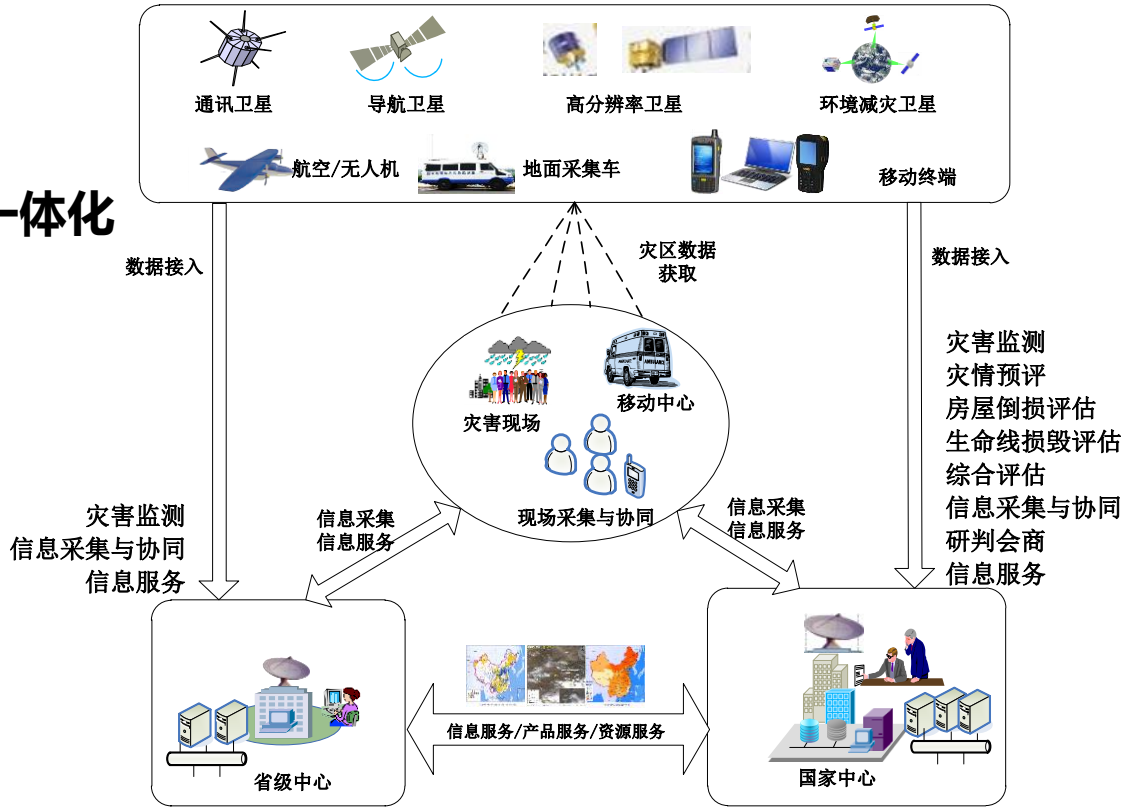
Outline

1. National Emergency Mapping System
2. Status of its Development and Application
3. Challenges of its Development and Application
4. National Emergency Geospatial Information Project
5. Conclusion and Suggestions

Challenge 1：Improve data sharing and access mechanisms

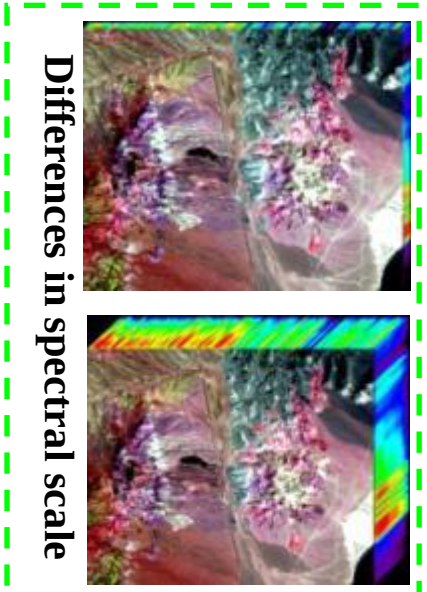
Linkage-联动, collaborative-协同, fast-快速,efficient-高效

- ■Nation wide 覆盖全国
- ■Space-Air-Ground 天空地一体化
- ■High suitability 高适应性
- ■High flexibility 高机动性
- ■High reliability 高可靠性
- ■Quick service 快速服务

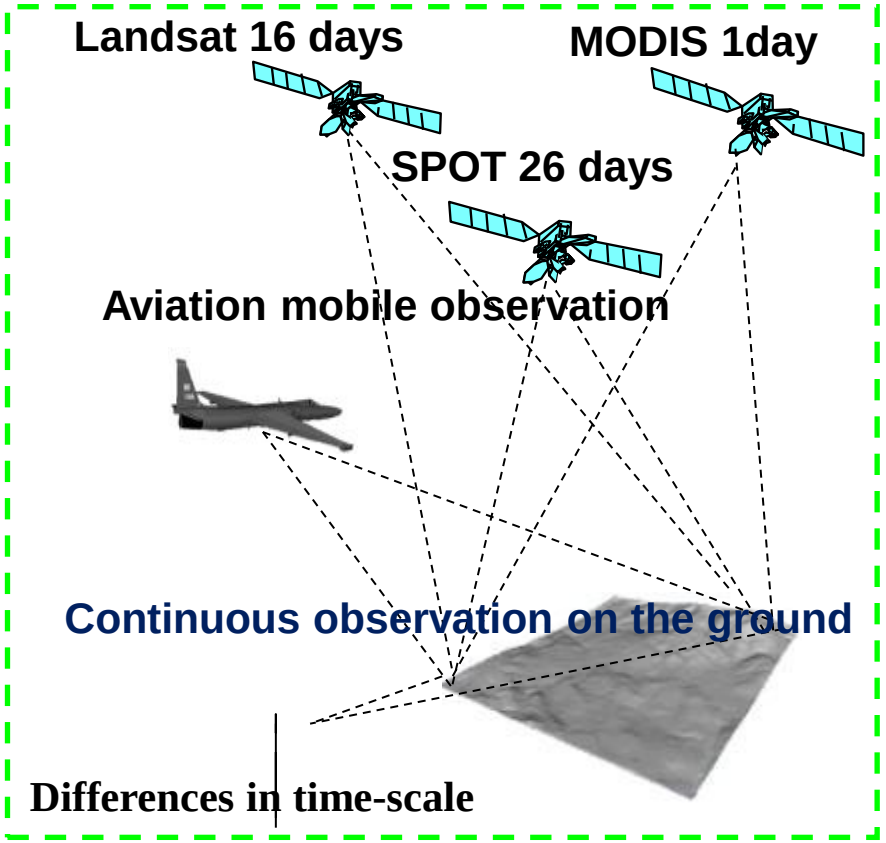


Challenge 2: Multi-sensor data assimilation and information co-processing

Problem description:



$$\hat{X} = \arg\max_{x} f[p_{spa}(X), p_{spe}(Y), p_{time}(Z), p_{All}(X,Y,Z)]$$

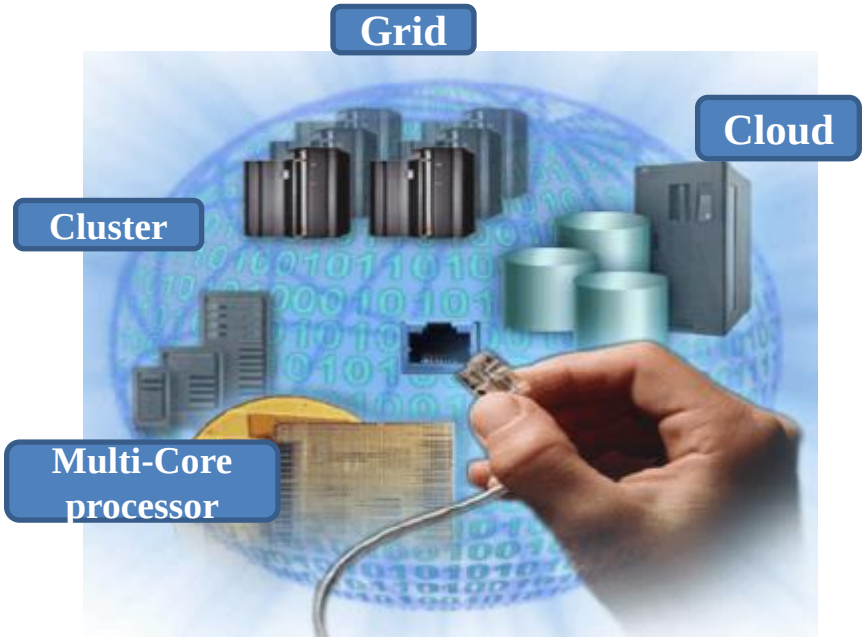


Difficulty: How to achieve assimilation and information fusion with multi-temporal/spectral data?

Challenge 3 :Objective and accurate monitoring and evaluation

Objective-客观, accurate-准确,quantitative-定量, orientation-定位

- Optimization of data processing;
- Improvement of rapid information extraction and analysis;
- Enhancement of ground verification and comprehensive application of the damage assessment result.



High-performance computing for Integrated hard/soft and big data

Plan Implement Assessment

Challenge 4: “New technology + disaster management”, promote disaster management scientific and modernized

- **Disaster Management Model：** Government + Public

  灾情管理模式：政府+公众

- **Disaster Management Method：** Cloud + Net +End (new information infrastructure)

  灾情管理手段：云+网+端（新信息基础设施）

- **Disaster Management Method：** Photogrammetry and Remote sensing, Geographic Information + Cloud Computing +Big Data

  灾情管理方法：摄影测量与遥感+地理信息+云计算+大数据

Outline

1. National Emergency Mapping System
2. Status of its Development and Application
3. Challenges of its Development and Application
4. National Emergency Geospatial Information Project
5. Conclusion and Suggestions

Construction goal
建设目标

Improve the ability of acquisition, processing, analysis and efficiency.

Disaster response time improve 3-4 times.

- **National aviation emergency ability construction —— Emergency response time <8h, data acquisition time <6h**
- **National emergency center capability construction —— Provide the first batch of emergency products < 1 day**
- **Emergency field surveying and mapping capacity construction ——Complete security equipment < 2h, motor to the scene < 8h**
- **National emergency resource sharing capacity construction —— Publish all kinds of products quickly, provide 7 * 24 hours non-stop operation.**

General layout of National Emergency Surveying and Mapping support services
国家应急测绘保障服务总体布局

- 1个国家应急测绘中心
National emergency surveying and Mapping Center

- 3支国家应急测绘保障分队
National emergency surveying and mapping support unit

- 12个国家航空应急测绘保障区
National aviation emergency surveying and mapping support divisions

国家应急测绘专业力量 —1支国家队

National emergency surveying and mapping professional power

地方应急测绘力量
Local power
31个省（直辖市、自治区）应急测绘分中心
Emergency sub center

军队应急测绘力量
Army power

部门应急测绘力量
Department power

共同承担国家应急测绘保障服务工作

Undertake the work of national emergency surveying and mapping support services

Composition of construction content
建设内容组成

National emergency surveying and mapping capacity construction

国家应急测绘能力建设

共4部分13个系统

国家航空应急测绘能力建设
National aviation emergency ability construction

- 固定翼无人机航空应急测绘系统 Fixed-wing UAV
- 无人直升机航空应急测绘系统 Unmanned helicopter
- 有人机航空应急测绘系统 Manned vehicle

国家应急测绘保障分队能力建设
National emergency support capability construction

- 应急前线现场勘测系统 Site survey
- 分队应急数据资源存储管理系统 Data storage management

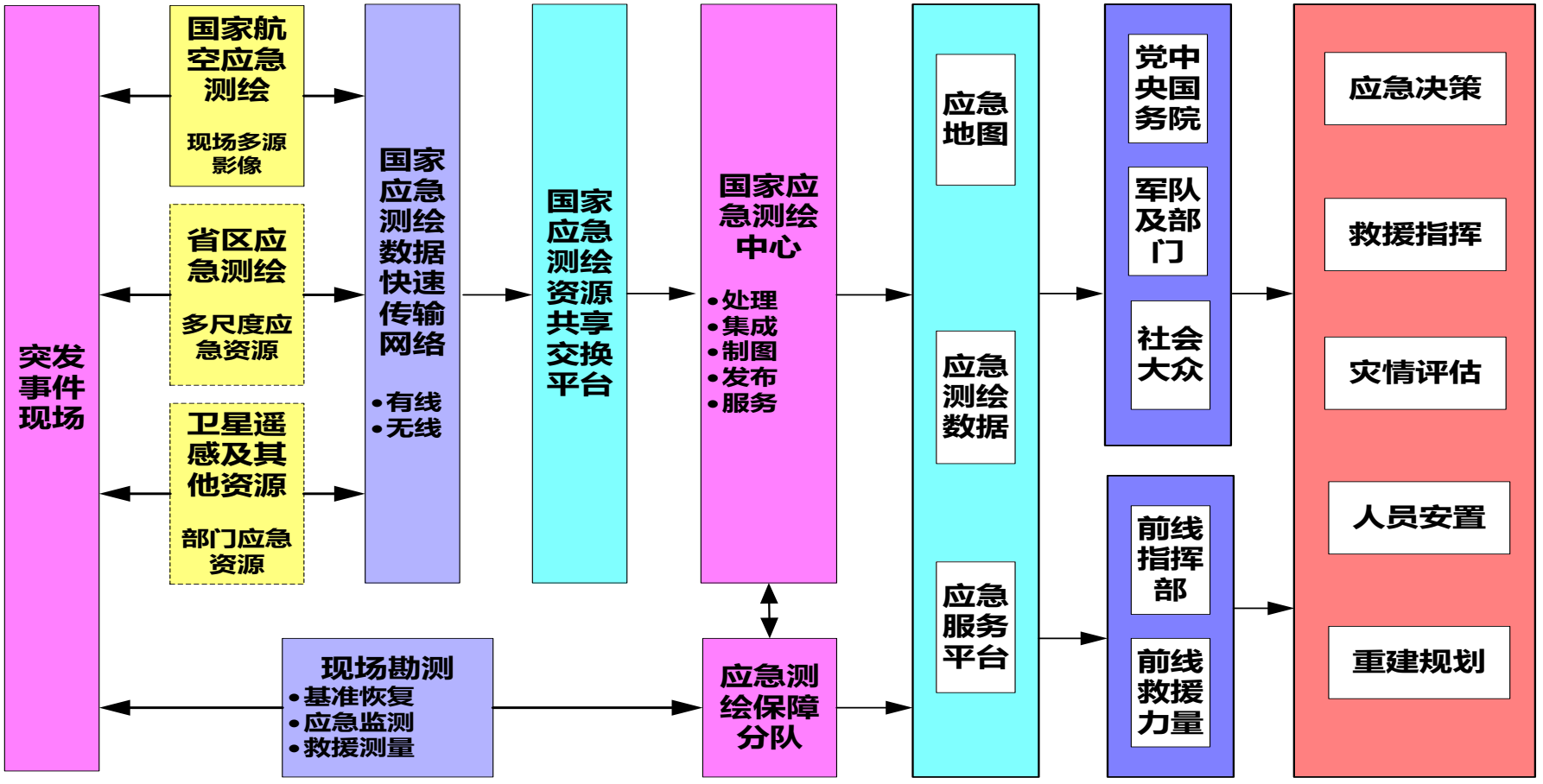
国家应急测绘中心能力建设
Emergency field surveying and mapping capacity construction

- 应急测绘快速处理 Processing
- 应急地图快速制图 Mapping
- 应急测绘快速服务 Service
- 应急测绘存储 Storage
- 应急测绘调度系统 Scheduling

国家应急测绘资源共享能力建设
National emergency resource sharing capacity construction

- 应急基础底图数据库系统 Basic map database system
- 应急测绘资源共享平台 Resource sharing platform
- 应急测绘数据快速传输网络 Data fast transmission network

Process of emergency surveying and mapping 应急测绘保障业务流程



Outline

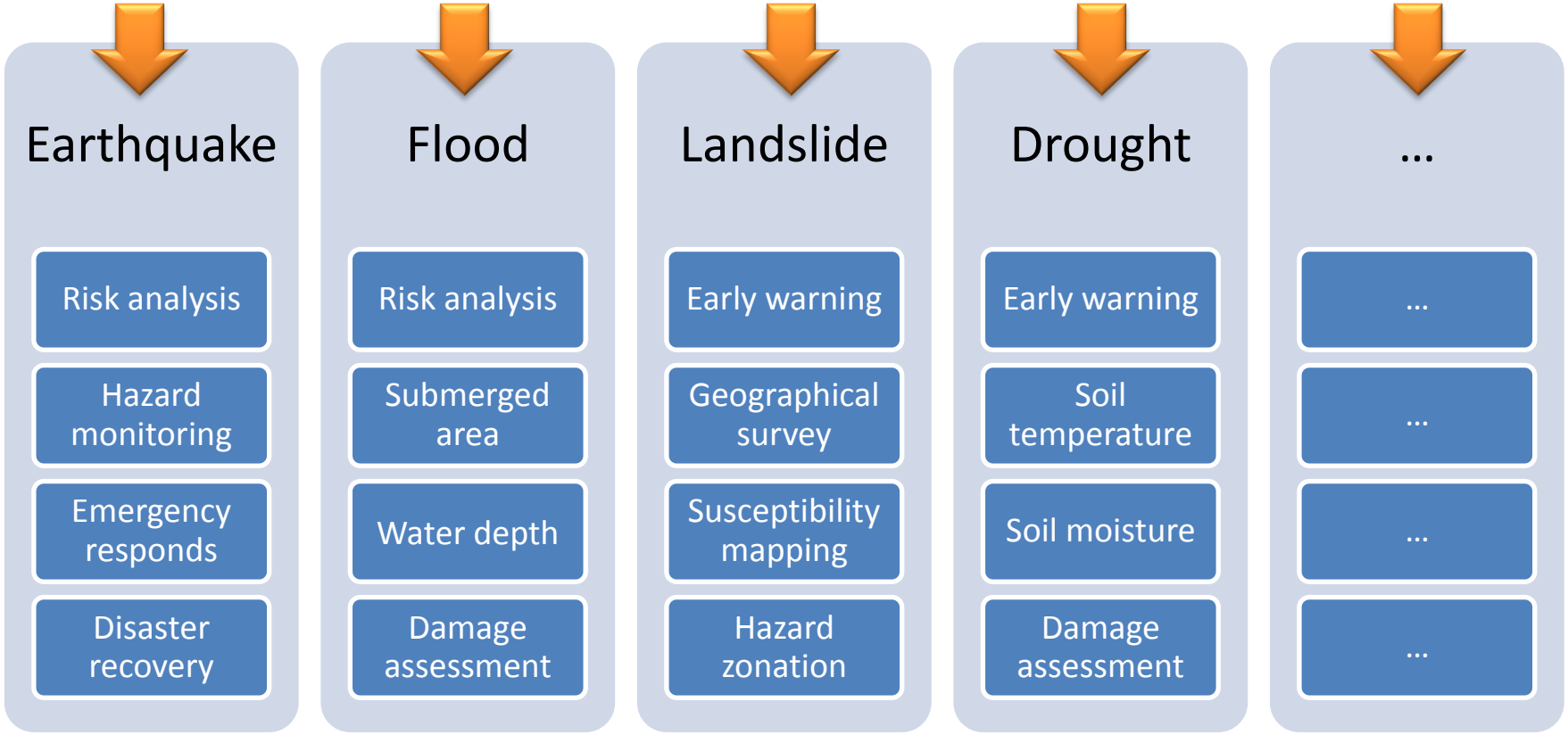
1. National Emergency Mapping System
2. Status of its Development and Application
3. Challenges of its Development and Application
4. National Emergency Geospatial Information Project
5. Conclusion and Suggestions

Conclusion

- Emergency Mapping System
- Quick response mechanism
- Commanding information platforms
- Emergency mapping brigades
- Increased Capability
- Performed well in mega incidents

Photogrammetry and remote sensing application in disaster monitoring
摄影测量与遥感在灾害监测中的应用

Photogrammetry and Remote Sensing applied in natural disaster prevention and mitigation



Suggestions

Be quick要快、Be effective要有效、Be accurate要准确

- **Enhance earth observation with high resolution satellites systems and global navigation satellite systems**
- **Strengthen the spatial information infrastructure construction.**
- **Construct the rapid response system and mechanism on the national level (CNDRSS)**
- **Strengthen the international cooperation in spatial information science and technology**

Thank You !