

# **Cadastrre2014 Japan – Initiative for Restoring Original Boundaries by Using Past Aerial Photos**

**Hiroyuki HASEGAWA and Tsutomu IMASE, Japan**

**Key words:** Japanese cadastral system, precise photogrammetry, 3D- Image Map Archive, PEGASUS satellite surveying, Construction Information Modeling

## **SUMMARY**

Japanese cadastral survey is summarized of current status and agendas by Mr. N. Samejima's book in 2011. Cadastral survey, conducted with relevant acts for National Land Survey Act, faces to lessons from Hanshin Earthquake (1995) and East Japan Earthquake (2011) in surveying applications. Future solutions are proposed on satellite surveying and photogrammetry in Japan. Studying worldwide status and agendas, like Cadastre2014, Land Administration Domain Model Standard and Social Tenure Domain Model, we now look into German AAA and SAPOS satellite data service, as Land Information System. New Japanese Basic Act on Land Resilience would affect the Survey Act, Basic Act on the Advancement of Utilizing Geospatial Information, Real Property Registration Act and National Land Survey Act. Japanese Basic Act on Land Resilience and Construction Information Infrastructure Modeling of MLITT are to be promoting initiatives for cadastral survey as well. Based on our projects for restoring original boundaries by using past aerial photos, we propose a cadastral survey Japan- initiative, using 3D Image Map Archive, 1 second geodetic network adjustment on electronic control points, real time parcel point determination and 3D mapping for Real Property Registration Act based Maps.

# **Cadastral2014 Japan – Initiative for Restoring Original Boundaries by Using Past Aerial Photos**

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## **1. INTRODUCTION**

Japanese cadastral survey is well described by Mr. Nobuyuki Samejima in his masterpiece book “Japanese Cadastral System” (2011, in Japanese) to overview the Japanese Cadastral Systems historically and systematically about current status and agendas.

Japanese Cadastral system started with “ Real Property Registration Law “, which was the first civil code in Japan, based on the unification after the feudal era and modernization of Japan. It was also arranged with taxation system based on land ownership with tentative cadastral maps called “Kozu: official parcel map“, which is now dealt as “provisional cadastral map“ in a legal affairs bureau as a register office. This national project called “ Chiso Kaisei Jigyo: Land tax reform projects“ were organized and started in 1873 and completed in 1881, with registration books, land certificates and tentative cadastral maps.

Land liberation Policy during the American occupation period from 1945 to 1952 issued Land Survey Act for cadastral survey, land utilization investigation and water resource investigation, to set up the administrative procedures, technical standards with accuracy measures. The major achievements are cadastral maps as fundamental materials for taxation system and land registration system.

In this paper, the current status of the achievements for cadastral maps in Real Property Registration Act is to be stated and compared with those of other countries.

Mr. Samejima was the organizer of the most recent cadastral surveying projects so called City Block Ground Control Surveying projects, and in the urbanized area he planned and promoted the installation of official signals, so called city-block ground control points.

Since Japanese cadastral system has been influenced by its global geophysical and geodynamical location, which could be easily affected by earthquakes and Tsunamis, then the major and fundamental subjects are to confirm the accuracy and stability of the coordinates of ground control points and cadastral maps, including the change and transition of the reference coordinate systems. After the earthquake in 2011.3.11 for half a year till the end of September 2011 , cadastral surveyors in Japan were to register the sets of arbitrary coordinates on the parcel points, instead of regular coordinates in the world coordinate system of the official parcel map, according to the current land registration system,. Likely and expected mega

earthquakes and tsunami disasters has forced us the innovative change in methodology for cadastral survey. In 2011, we adjusted the ECP coordinates of relevant areas by parameter estimation approach of satellite surveying by ourselves as shown in Fig. 1.

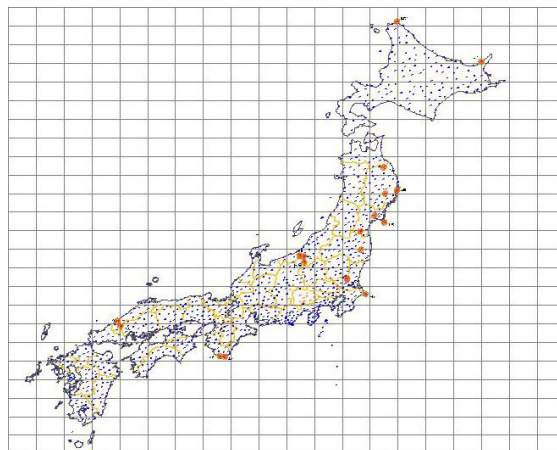


Fig.1. Parameter Estimation adjustment on ECPs' coordinates

### 1.1 Japanese land administration system and cadastral survey

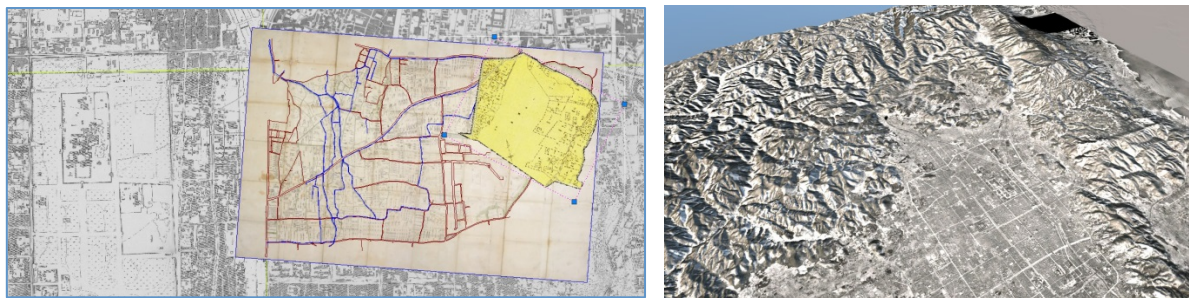
Cadastral maps related with Japanese land administration are Real Property Registration Maps, tentative parcel maps, cadastral maps of Land survey act and so on. As for national objectives to set up procedures for Real Property Registration and land administration, mapping with coordinates is the most essential aspect. In reality the maps are influenced by the earthquakes, being referenced to and compared with existing tentative maps, even tentative parcel maps are the basic sources in registration at register offices. Geocentric coordinate system which has the origin at gravity center (World Geodetic Datum system) is mostly referenced for regular and ordinary mapping, also for the cadastral survey. In cadastral survey, especially in land registration process, so called antique aerial photos in 1940s taken nationwide by US Air Force are now used as shown in Fig. 2, which still now show the ancient parcel allotments in 8<sup>th</sup> century, as the first commemoration of land administration.



Fig. 2. Past Aerial Photos in stereo model (1948; Mizuho-city, Gifu prefecture )

These aerial photos are enlarged as the same scale print for identification and measuring to have an evidence of the boundaries, using distances on the print and map. In this field, we have applied the state of the art technology in photogrammetry. These US photos had 2 types of photo scales, 1/40,000 and 1/10,000. Aerial photos in 1/40,000 were used for topographic mapping of 1/25,000 (Map/1 mm= Ground/25m) in 1950s. The intrinsic accuracy obtained are now increased 5-10 times on 3D digital image modeling/measuring PC, so in some areas with 1/10,000 photo scale the improved accuracy is realized to be comparable with 1/600 parcel map (Map/1 mm= Ground/0.6m)

Furthermore 3D image model could be realized on PC and measured, relating to other large scale maps in 3D-CAD system (AutoCAD), and 3D image map data are produced for 3D infrastructure modeling. For research of the forestry boundary and investigation on land ownership boundary related to cadastral survey, produced examples are shown in Fig. 3.



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Fig.3. 3D image map (Kyoto Univ.; 1936 / 1800) and 3D image diorama (Kyoto city; 1946)  
This kind of investigations is conducted in the official process of parcel confirmation procedures to be requested for Cadastral survey and parcel lot identification, using not only 3D map feature mapping but also 3D diorama monitoring/ modeling for time series boundary identification.

## **1.2 Lessons from Kobe Earthquake (1995) and East Japan Earthquake (2011)**

The author reported publically the research works of Kobe Earthquake (1995), by configuring database system on PC with ground controls and aerial photos triangulated, fulfilling Deformation Analysis and proposing forthcoming disaster- prevention database system. This research project was also the first trial of GPS surveying system in practice. We have increased our potential in surveying technology in the fields of satellite surveying, Aerial photogrammetry and satellite 3D image modeling supported by 3D-CAD evolution.

In 2011, after the East Japan Earthquake, half of the Electronic Control Points of GSI (Geographical Survey Institute; Japan) out of 1200 points stopped to supply their reference coordinates, and only provided observation data with 30 second interval. Then 2 weeks after the 2011 Earthquake we started the adjustment of the coordinates of the damaged areas in eastern Japan with our own PEGASUS (Parameter Estimation GnsS Assisted SURveying System) approach dealing with nationwide scope as above shown in Fig. 1.

In this process, we confirmed that we could get adjusted coordinates and standard deviations by least square adjustment after every 1 second observation and network adjustment. This adjustment could be applied in two ways, in real time mode and in post processing mode, which are to monitor and to find every second premonitory signs before a big earthquake and to alert the earthquake along seismic fault lines and breakwater front against Tsunami attacks. By the way, in Japan, forestry areas and tall building urban areas are currently regarded as unmeasurable areas according to surveying specification of GSI. For such frontier areas, PEGASUS (Parameter Estimation GnsS Assisted SURveying System) could deal with multi GNSS GPS, GLONASS, QZSS, Galileo) observables simultaneously in a geodetic network adjustment. This ensures satellite surveying at cm accuracy level nationwide, even in the forestry and urban areas.

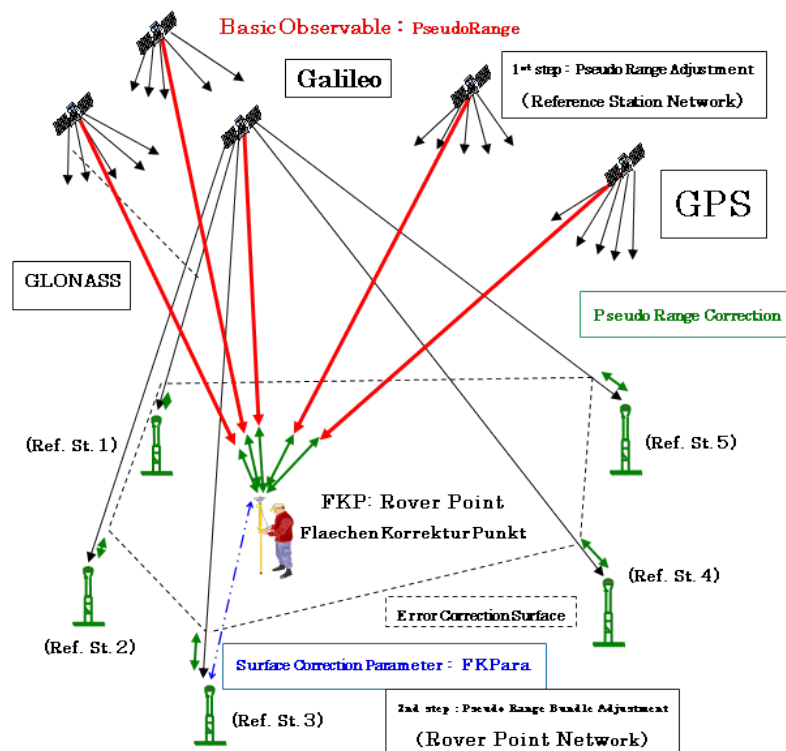


Fig. 4. PEGASUS – FKP satellite surveying approach

These activities could be organized and processed by cadastral surveyors in accordance with land registration, and channeled to the decisive progress of Land Information Investigation (Cadastral Survey) and the enterprise projects of 3D land basic data Infrastructure. These process and activities could be combined with MLITT's Construction Information Infrastructure Modeling Initiative, using 3D-CAD system for Land Information Data schema.

### 1.3 National Land Survey Act

; Cadastral Survey and technological evolution in Surveying

Current cadastral survey is classified into terrestrial method and aerial photogrammetric method for cadastral surveying. The accuracy levels are classified into 6 stages; higher order 1-3 to lower order 1-3. This specification was derived from Cadastral survey in Land survey act, which is caused and activated by the farmland liberation policy after the Worldwar II. On the other hand, Japanese surveying technology supported urban planning, express way and new main railway constructions and road facilities mappings, then surveying instrument industry, especially ground surveying instrument ( Total Station ) manufacturers were well grown up to lead the world market. Now Japanese surveying technology and its technical

potential has grown up to the levels of multi GNSS network of Electronic Control Points, large scale mapping by photogrammetry and 3D-CAD combined ground surveying systems and GIS applications. Currently we have now realized, at the summit of technology, 1cm ground accuracy surveying in the gravity-center origin coordinate system, combining satellite surveying – photogrammetry – Total Station surveying on the ground.

#### 1.4 Satellite Surveying and Photogrammetry in Japan

World well known electronic control points network in Japan is now equipped with the receivers which acquire the data from not only GPS but also GLONASS, Galileo and QZSS (Quasi Zenith Satellite System). This situation ensures PEGASUS for real time 1 sec. network adjustment.

As for photogrammetry, we have oriented 3D satellite image models on PC, with 3D-CAD system, expecting the next projects for forestry area (70% of national land area) to be modeled, measured and mapped in 3D drawings. Parallel with domestic projects, we are now supporting Myanmar students in Kyoto University for forestry mapping with high resolution satellite images, like ALOS, IKONOS and GeoEye stereo images.

On the other hand, antique and old aerial photo films are stored with the number of 10,000,000 frames in Japan. These existing photos are the source of 3D image models, by applying bundle adjustment technique of aerial triangulation, and we have already established the procedures for those photos in 1940s in Japan and Myanmar and other south eastern Asian countries, using antique aerial photo prints of British RAF (Royal Air Force) cameras.

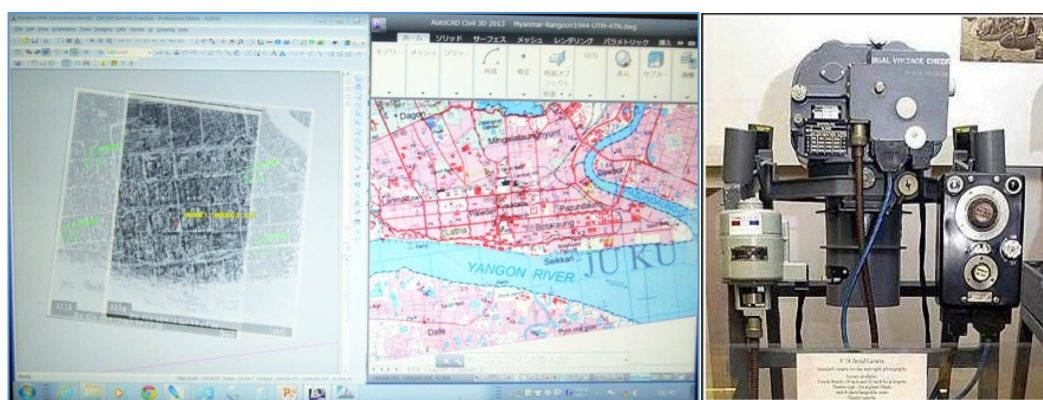


Fig. 4. Photogrammetric stereo model (1944) ,Image map (2005) and RAF-F24 camera(1944)  
In the current developments, UAV (Unmanned Aviation Vehicle)- multi copter type or small helicopter with camera hole on the floor are used to realize 1cm accuracy photogrammetry along the ordinary roads to form continuous 3D image models to be measured in 3D-CAD

environment. Along the extension of this application, precise 3D city modeling is possible with life line data groups, like water supply, sewage, gas, electricity and communication lines, which are poorly mapped in 2D by the municipalities, sometimes as paper maps. Surveying technology supporting cadastral survey has now realized worldwide the goals from 100 years ago, which Dr. Jordan, who named this surveying technology as Photogrammetry in 1875, in Germany dreamed in his surveying textbook in 1910 ( Handbuch der Vermessungskunde).



Fig. 5. UAV ( Multi- copter type) and oblique image ( Mizuho city – Sunami branch office )

## 2. WORLDWIDE STATUS AND AGENDAS IN CADASTRAL SURVEY

From standpoint of Japanese cadastral surveyors, in the field of cadastral survey, the vision “ Cadastre 2014 “ of FIG-Commission7 took the roll of the Charter of the United Nations, to be the guideline for Normalization and Standardization worldwide for 20 years.

The achievement of the pioneer; ITC, the Netherlands is LADM(Land Administration Domain Model Standard), and from Germany as the most advanced country of the land registration system AAA-data schema is the Model of “Vermessung- GeoInformations Systeme”. The author translated “ AAA- specification” into Japanese in 2007, during the course of revision of Japanese public surveying specification, and now have the essence of “AAA-specification” for the forthcoming Japanese specification based on the Survey act.

### 2.1 From Cadastre2014 to Land Administration Domain Model Standard

6 statements of Cadastre2014 are still now shining. LADM (Land Administration Domain Model Standard) was born in this vision, and is a well prepared domain model for land legal system and land administration in land infrastructure information system. And corresponding ISO standards give land administration organizations guidelines in practice.



## 2.2 Land Administration Domain Model and Social Tenure Domain Model

While FIG Commission 7 groups have been communicating with members of United Nations, FAO or World Bank for land administration systems, they might have created the concept of STDM ( Social Tenure Domain Model), cooperating with UN-Habitat activities or REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries: REDD+).

In Japan traditional and customary land use /utilization systems are related with land boundary issues of commonly owned forests and areas. Land boundary issues are now also related with new social aspects of inheritance and legacy issues and transition of settlements to uplands after the tsunami hazards as the problems of cadastral survey system.

## 2.3 German AAA and SAPOS satellite data service

The author translated AAA-system related technical and business documents, and looked at the technological developments and business formations of SAPOS (German satellite data service) for many years, attending in their annual meetings. In this process we introduced Parameter Estimation Satellite Surveying system, so called FKP real time surveying into Japan. One of the fruitful results of Parameter Estimation Satellite Surveying was the completion of multi-GNSS-FKP experiment in Nagano Prefecture in 2012. This success would contribute us to solve the remaining obstacles of satellite surveying in forestry and urban areas. The other substantial and promoting aspect is InterNet communication technology for establishing reference stations and rover receivers with multi- GNSS satellites. And the combination of QZSS positioning satellites and ALOS satellite 3D image models would contribute cadastral survey in other Asian and African countries.



Fig. 6. AAA-document(in English/Japanese) and AFIS-ALKIS-ATKIS (in German)

## **2.4 German Surveying- and Land Information System and Cadastral Survey**

Comparing Japanese GIS (Geographic Information System) with German GIS (Geo Informations Systeme), we find fundamental differences in geo reference system and Cadastral Information System between two countries. Through the contents of yearbooks: “German Surveying- and Land Information System”, we could comment, from Japanese viewpoint, the status, trends and prospects of German GIS, derived from those books; Das deutsche Vermessungs und GeoInformationswesen 2010-2011-2012-2013-2014 ( Wichmann Verlag ).

## **3. JAPANESE BASIC ACT ON LAND RESILIENCE**

Having learned from East Japan earthquake, tsunami hazard and more from explosion accidents at Atomic Power Plant, Japanese government issued “Japanese Basic Act of Land Resilience” in Dec. 2013 to reconstruct damaged regions in 2011 earthquake, to prepare against Nankai ( Southern Sea area ) - Trough Tsunami, Tokyo- area epicenter earthquake by replacing old deteriorated express ways and bridges and embankments with resilient infrastructure. We need to consider the relationship between above mentioned Act with countermeasures and land administration policies with cadastral systems.

### **3.1 Survey Act and Basic Act on the Advancement of Utilizing Geospatial Information.**

The Survey Act is the fundamental law among other laws for land surveying, and, by the article 33, requires the public surveying specifications by official planning organizations. According to the article 34, Minister of LITT has settled the normalized specification of the public surveying specification. In the current contents, there are 3 major application fields, Ground Control Surveying, Photogrammetric Mapping and Applied Surveying, which includes Road designing, Waterway surveying and Land surveying. Then Cadastral surveyors are asking for new specifications corresponding with the new surveying technologies. Basic Act on the Advancement of Utilizing Geospatial Information by Geospatial Information Authority of Japan (GSI) in 2007 does not deal with land administration and cadastral survey explicitly, and requirement for positioning accuracy is at lower level. Now it is quite urgent to stabilize the positioning accuracy of ground control points and parcel points with respect to the national reference system in gravity center origin coordinate system. So the author sent an official letter to the minister of LITT last year to state that newly submitted public surveying specifications based on the survey act should be quickly checked and approved, considering

about their importance and for the sake of emergency.

### 3.2 Real Property Registration Act and National Land Survey Act

Current Real Property Registration Act and National Land Survey Act are to be improved for reconstructions, against natural disasters and for reduction of the disaster damages. The substantial countermeasures are new public surveying specifications and their quick check and adequate approval, if possible at first for reconstruction and against disasters.

### 3.3 East Japan Earthquake in 2011 and Japanese Basic Act on Land Resilience

Japanese Basic Act of Land Resilience realizes land resilience plans starting for reconstruction projects of damaged areas in 2011 earthquake with supplying fiscal budgets. How far the contribution for land administration and cadastral system would be is closely related to effects of policies for anti-disaster, reduction of damages and reconstruction process based on land and cadastral information as requested by Cadastre2014 vision.

### 3.4 Japanese Basic Act on Land Resilience and Construction Information Infrastructure Modeling of Ministry of Land, Infrastructure, Transport and Tourism (MLITT)

MLITT started 3D – Infrastructure – Modeling, so called CIM (Construction Information Modeling) initiative as national grand designing in 2012. This initiative is now expected to work with Land Resilience Plan to pursue the synergy effect, also for land administration and cadastral system.

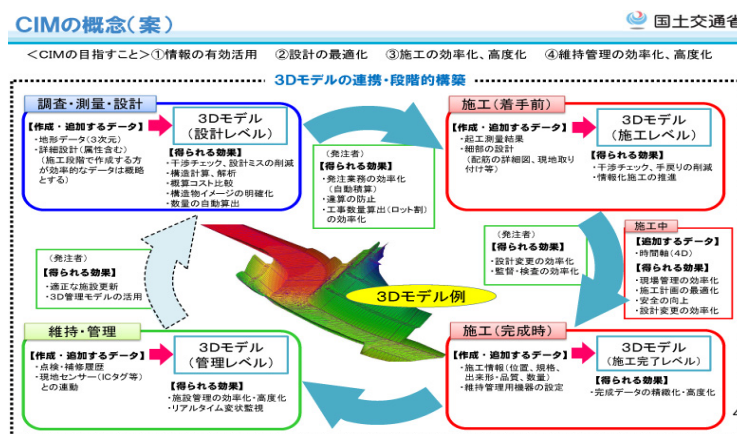


Fig. 7. MLITT's CIM (Construction Information Modeling) concept

## 4. PROPOSALS FOR CADASTRAL SURVEY JAPAN

Global crustal movements, seismic and volcanic activities caused damages in East Japan earthquake and accidents at atomic power plant, and many countries in the world are now looking into Japanese policies for anti-disaster, reduction of damages and reconstruction process. In technological history we have now reached to the level of measuring a point on the earth ,especially in Japan, at 1cm accuracy level, and when and how we could stabilize our land and cadastral system should be compared with historical events of Pompei antiquities, Lisbon earthquake in 1755 and Tschelnobyli atomic power plant accident in 1986. On the other hand, old map makers, like Tadataka Inou and cadastral surveyors in 19th century, like Tanetaro Megata completed the most advanced land and cadastral maps in Korea and Taiwan at that time. These historical backgrounds and their approaches with contemporary technology show us the potential of Japanese version of Cadastral Survey standard. We describe now the subjects for Japanese version of Cadastral Survey standard.

### 4.1 3D Image Map Archive

The author has configured “Kyoto university 3D Image Map Archive” as provisional version. The contents are antique map in 1800s, modernized maps in 1880s and 1910s, modern large scale urban planning maps in 1930 and aerial photo 3D image models in 1940s. These materials and image models are mapped on 3D-CAD screen to be used for cadastral survey projects. Aerial photos by USAF are now available for not only Japan islands but also southeastern Asian countries as photo print materials which look like treasures for cadastral survey projects.

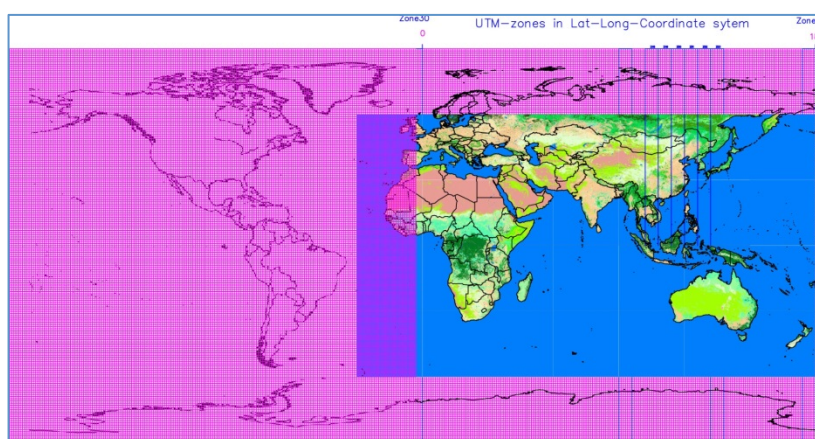


Fig. 8. ASAFAS Kyoto University : 3D Image Map Archive in 2013

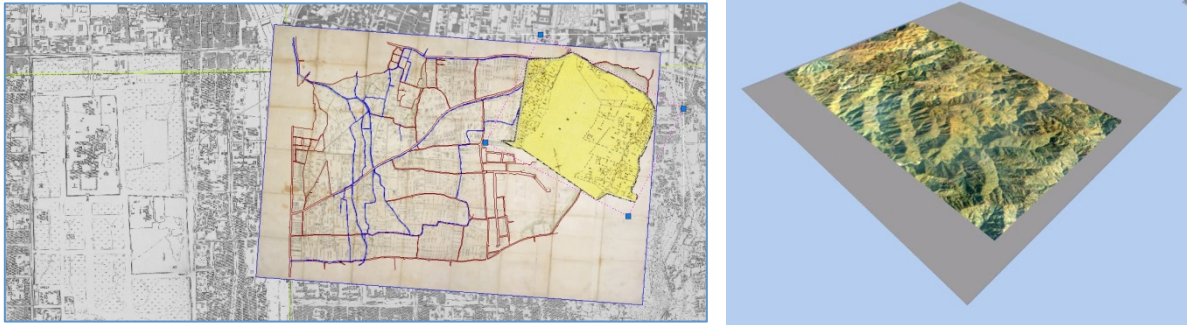


Fig. 8. Overlapped Image Maps (1936 / 1800) and 3D diorama on DEM height model

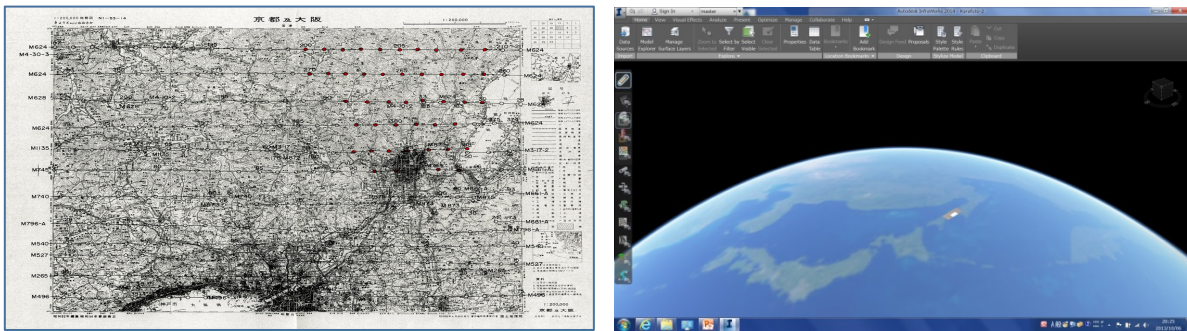


Fig. 9. USAF Flight index map (1946) and Global representation on 3D-CAD ( Japan)

In a similar way to Kyoto area, the author found photo materials of British Air Force in 1940s, covering over Myanmar, Thai and Malaysia, in Map Library of Kyoto University; Center for Southeast Asian Studies (CSEAS). Some 3D image models are now corresponded with 3D-CAD supported image maps. As for base image map, we have combined British maps (1/63360) and ex-Japanese Army maps (1/50,000) unified on the current UTM map projection archive. In addition, satellite 3D image models, like IKONOS models and ALOS models in 2000s are the measuring objects with 3D-CAD environment, then these models would be important basic materials for forthcoming cadastral systems in the world.

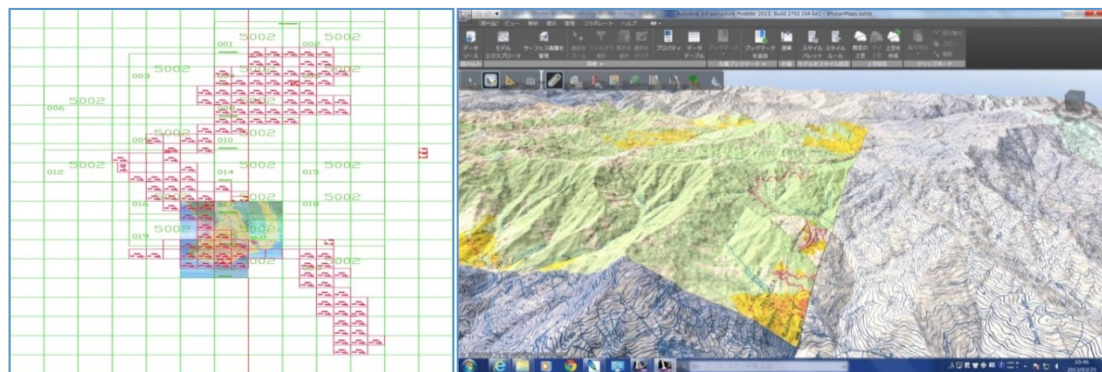


Fig. 10. UTM map projection index map ( Myanmar ) and 3D diorama ( Bhutan )

#### 4.2 1 second geodetic network adjustment on Electronic Control Points

Since 1990s, 1 second observation data at Electronic Control Points (ca. 1200 pt.) in Japan are recorded and stored in GSI. Instead of current geodetic network adjustment, which reports daily coordinates of ECPs, 1 second adjustment of parameter estimation approach would be expected to show the continuous 1second sets of adjusted coordinates of ECPs from 1990s. During this process we could find many trends of displacement at ECPs, including the period of 2011 earthquake. Those dataset would be combined with the data of seismometers to figure out the behavior of earthquake activities. This kind of analysis would give us dynamic behavior of the displacements before the earthquake. In the future, immediately after 1 second of an observation we could have the adjusted coordinates for monitoring and alerting of seismic displacements and movements. If we could replace \$50,000 receivers with of \$500 sensors at sensitive points, like seismic fault sides or tidal embankments, we could have simultaneously adjusted coordinates at those monitoring points for countermeasures against an earthquake. This approach and analysis could be used for the oversea areas suffering from similar damages of cyclone, earthquake and tsunami disasters.

#### 4.3 Cadastral reference point patchwork correction and real time parcel adjustment

Since new geodetic datum in 2000, Japanese official coordinates of ECPs, triangular points and public ground control points are adjusted and fixed at Reference Fixed Point. They are corrected with Patch correction method based on Semi-dynamic approach of geodetic network adjustment stepwise according to the GCP classes. Referring to the gravity center origin coordinate system, Japanese geodesy might have its own task to trace the movement of ECPs and Triangular points according to the 1 second data records from GNSS receivers nationwide. For cadastral survey we need the process to measure the Ground Controls and Parcel Points instantaneously at site with adjusted coordinates for parcel maps.

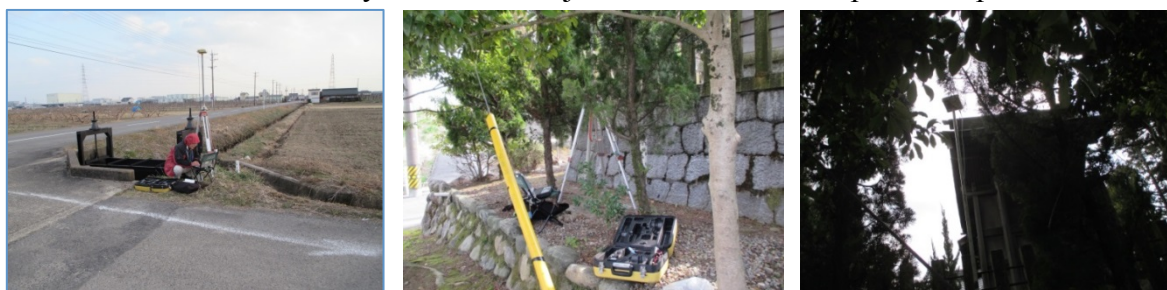


Fig. 11. PEGASUS satellite surveying on ground control points

#### **4.4 3D mapping for Real Property Registration Act based Maps**

Projects for Real Property Registration Act based Maps are related closely with national policies of 3D Land Information System. The unification of cadastral system and 3D land information system could be arranged with Land Resilience Plan by national, municipal and private sector organizations. On this way, world well known Land Information Systems, established in the Netherlands and Germany, based on ISO standards would support us for new Real Property Registration Act, cadastral system and cadastral surveying technology.

#### **Acknowledgement**

We wish to thank Professor Shigeo Kobayashi and Associate Professor Shinya Takeda for establishing 3D Image Map Archive system in ASAFAS Kyoto University facilities. We also thank the directors and the researchers of Japan Federation of Land and House Investigators' Associations for their guidance and organization of cadastral survey in honor of Cadastre2014 vision this year.

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#### **BIOGRAPHICAL NOTES**

**Hiroyuki Hasegawa** obtained a BA in Human Geography in 1971 from Kyoto University, Japan. In 1976 he was graduated from ITC, The Netherlands as Photogrammetric Technologist. From 1971 until 1999 he worked at PASCO Corporation in Tokyo, Japan. From 1999 until now he is working in GeoNet, Inc. in Nagano, Japan.

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