ISO19152-LADM−Osaka- Naniwa capital (645AD) 3D cadastral mapping

Hiroyuki HASEGAWA , CEO, GeoNet,Inc.
Naofumi KISHIMOTO, Professor Dr. of Osaka Metropolitan University
Erdoo Paula, AWAI, Osaka Metropolitan University, Japan
Marin ODAHARA, Osaka Metropolitan University, Japan

Key words: ISO19152-LADM, Osaka-Naniwa capital, 3D cadastral mapping, JohRi Land Administration, Agrarian reform arable land arrangement

SUMMARY

Consistency of the Japanese cadastral system, from Osaka-Naniwa capital - JohRi land administration(645 AD.) to the current land registration, has been supported by modern maps (since 1880s) and aerial photos (since 1928) in Osaka, Japan, as national standard.
The most pressing issue is the Japanese cadastral system and 3D cadastral map creation for Nankai Trough mega-earthquake and storm surge countermeasures in Osaka Bay area.
Based on the accuracy of 1cm on the ground by GNSS geodetic networking, we could establish 3D cadastral mapping, proceeding to helicopter/ drone photogrammetry by bundle triangulation for 3D image modeling and diorama designing of urban area 3D modeling, using non glasses 3D display, to build consensus among landowners in land registration process.
4D-IMADAS (Image Map Archive Designed Aerial Studies) covers the total process of 3D mapping, based on Geocentric GNSS Geodetic networking, combined single-stroke TS/TLS surveying and authentic photogrammetry with bundle triangulation and satellite photogrammetry, as the basis for 3D cadastral mapping. Aerial photography is reconstructed as 3D image models on digital stereo plotter for Cadastral mapping, to ensure the title of land registration with historical reality of land property.
Proposal of ISO19152-LADM for 3D cadastral maps could be well prepared, showing the achievements from Osaka 3D cadastral mapping works.

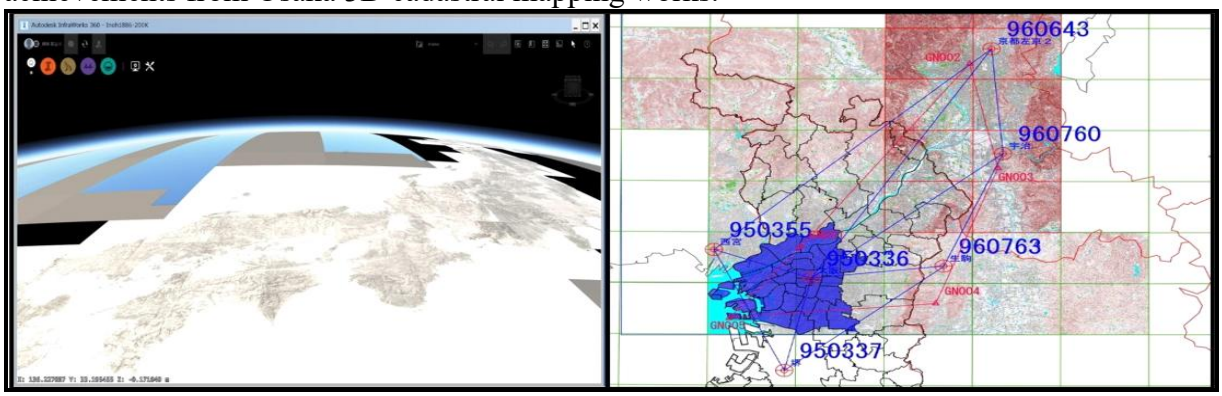


Figure 1: 1880s maps on CAD Globe : Osaka GNSS geodetic networking

ISO19152-LADM−Osaka- Naniwa capital (645AD) 3D cadastral mapping

Hiroyuki HASEGAWA , CEO, GeoNet,Inc.
Naofumi KISHIMOTO, Professor Dr. of Osaka Metropolitan University
Erdoo Paula, AWAI, Osaka Metropolitan University, Japan
Marin ODAHARA, Osaka Metropolitan University, Japan

1. 3D CADASTRAL MAPPING FOR EARTHQUAKE MONITORING

UN-GGRF(Global Geodetic Reference Frame) oriented GNSS reference station：GNOK, GeoNet, Inc., Osaka, Japan has been established for monitoring Osaka Uemachi and Ikoma active faults (AIST database) in Japan. The National Institute of Advanced Industrial Science and Technology (AIST), Geological Survey of Japan has “Active fault database of Japan” with the entrance of “Search for behavioral segments” https://gbank.gsj.jp/activefault/index. Osaka city and prefectural area are surrounded by 5-10 Geospatial Information Authority of Japan’s - Electronic Control Points (National Basic Triangulation Points), which are included in GNSS CORS and unified with other GNSS reference stations, like German SAPOS service, cooperating with German researchers since1998.

Geocentric coordinate satellite surveying – GNSS Geodetic networking has realized single-stroke geodetic surveying (in the National Land Survey Act) for 3D cadastral mapping, using 30 sec interval data as GNSS observables from GSI’s ECPs. Osaka-Uemachi active faults pass through OsakaJyo castle, Osaka High Court and JR Shin Osaka station area, despite the incomplete real estate registration map.

Based on the achievement of Geocentric coordinate satellite surveying – GNSS Geodetic networking starting from Osaka area project in 1999, we have achieved satellite surveying with a ground accuracy of 1cm for 3D cadastral mapping on the accuracy standards of the National Land Survey Act, applying at least 5 ECPs for Osaka City area (Approximately 2.75 million people live in an area of approximately 225 square kilometers).

GNSS - One Step Networking: σ= 1cm of 20 ECPs in Osaka-Kyoto area and 20 ECPs in Japan-Osaka-Kyoto area has been adjusted since 2016 Kumamoto earthquakes, using geocentric coordinates of ECPs.

Figure 1-01: Osaka Uemachi and Ikoma active faults (AIST database)

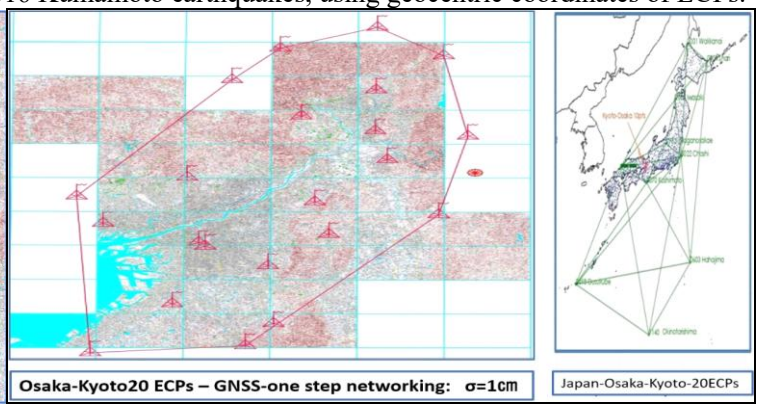


Figure 1-02: GNSS - Networking: σ= 1cm of Osaka-Kyoto 20ECPs: Japan-Osaka-Kyoto-20 ECPs

1.1 . Method for Geocentric GNSS networking of German standard satellite geodesy

For GNSS – One Step Networking: σ= 1cm, the author translated the textbook " Satellite Geodesy" and installed German standard GNSS Geodetic Networking software "GEONAP".

Satellite Geodesy as a Parameter Estimation Problem has a basic Concept of observable - 3D vector of GNSS electronic wave from GNSS satellite to receiver antenna, and this is because GNSS satellites orbit in elliptical orbits centered around the Earth's center of gravity. Geo Centric GNSS Networking deals with 3D coordinate transformations and map projection, starting from Geo Centric coordinate system via WGS84/GRS80 ellipsoid coordinates to Transverse Map Projection Coordinates (UTM national coordinates), using simultaneous least square adjustment of observation equations. In the least square adjustment, using batch file below, the standard deviations of unknowns (GX,GY,GZ) and discrepancies from official coordinates are regarded as precision and accuracy, are derived for the first basic solution. Then ellipsoidal and map projected coordinates are simultaneously computed.

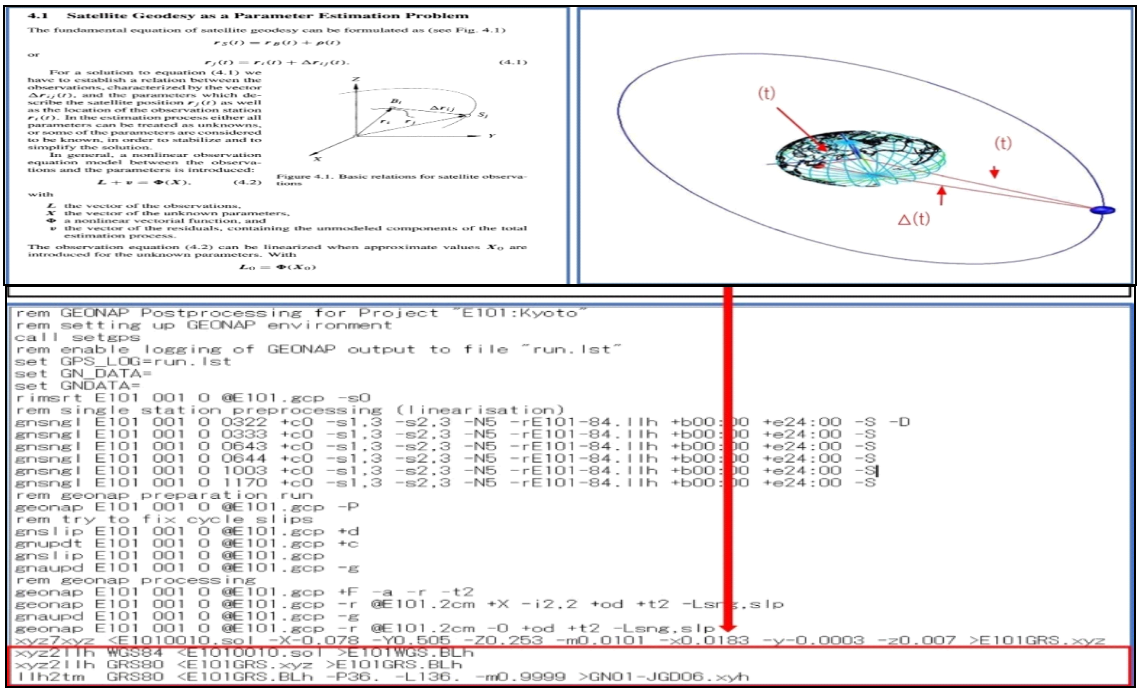


Figure 1-1-01: Basic Concept of observable - 3D vector of GNSS pseudorange

Figure 1-1-02: Batch file of GNSS geodetic networking to map projection

Geo Centric GNSS networking for 3D cadastral mapping, based on single-parcel cadastral surveying - radiation method could be started on GNSS stations (GNOK-GNSE-GNOS stations) near JR Shin Osaka station in Osaka Uemachi active faults, as Geo Centric GNSS networking- Single point GNSS networking.

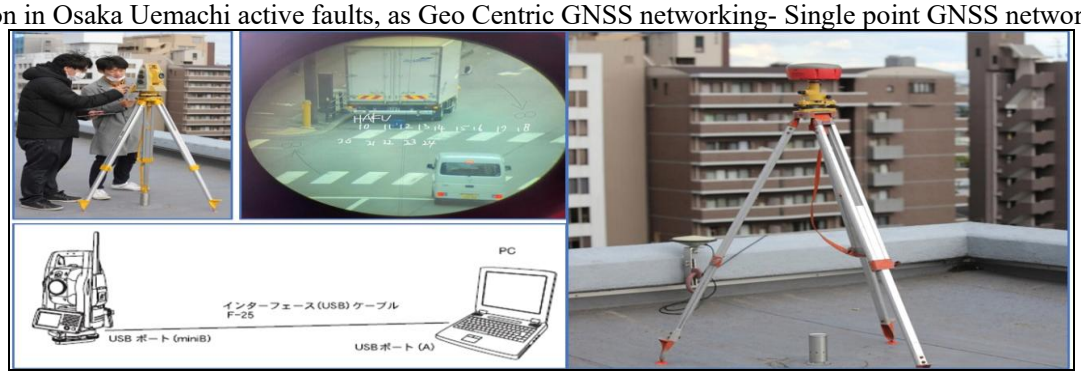


Figure 1-1-03: Single point GNSS networking : Osaka Uemachi active faults area

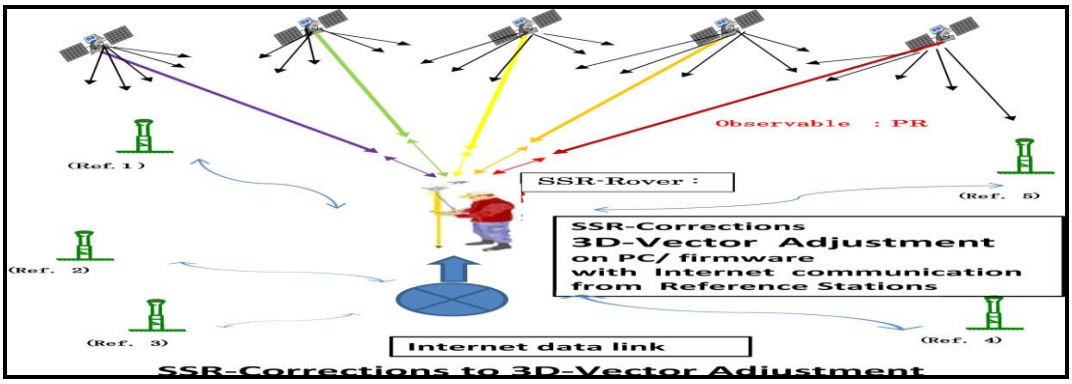


Figure 1-1-04: Geo Centric GNSS networking : Single point GNSS networking

After an earthquake, Osaka ECPs should be surveyed by Geo Centric GNSS networking- Single point GNSS ground surveying, using Osaka City GCP,like 2007A.

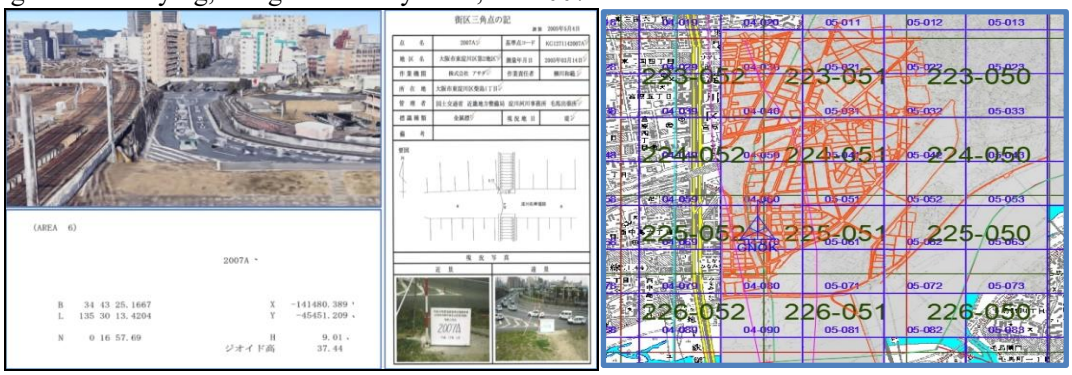


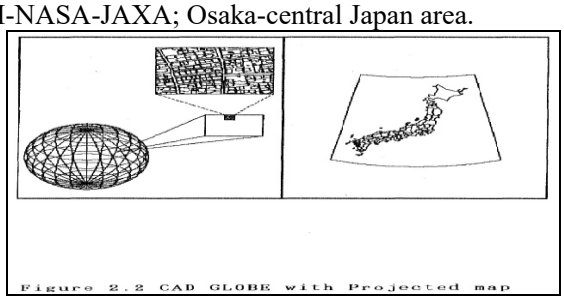
Figure 1-1-05: Geo Centric GNSS networking, Osaka ECPs after an earthquake and JR Shin Osaka station -3D Cadastral mapping grids

To improve Japan's official survey accuracy regulations, the whole process is carried out according to the procedures of German Survey Accuracy Standard : Richtlinie Raumbezug. And I have visited to State Office for Geoinformation and Land Surveying of Lower Saxony (LGLN) on April 28th,2017, for confirmation of applications.

Figure 1-1-06: German Survey Accuracy Standard and Gauss bronze statue
Figure 1-1-07: German Survey – GeoInformationsSysteme

2. 3D CADASTRAL MAPPING – CAD GLOBE –AutoCAD MAP IMAGE

“CAD Globe” was presented in ISPRS 1992 Washinton DC, as an extension of Digital Mapping CAD with the most advanced CAD based digital stereo plotter of that era. 3D Cadastral Mapping：3D diorama version is constructed on a CAD Globe with 30m DEM, using 1910-50K- basic maps and 30m DEM-NASA-JAXA; Osaka-central Japan area.



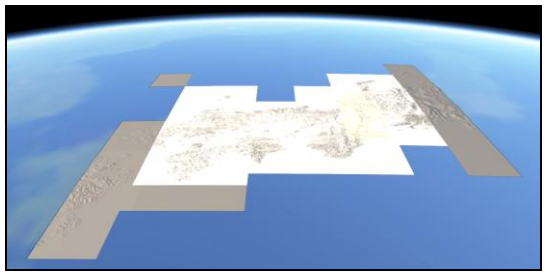


Figure 2-0-01: CAD GLOBE (AutoCAD: 1992 ISPRS Washington Congress)
Figure 2-0-02: CAD Globe with 30m DEM; Osaka-central Japan area

2.1 Japan's first cartographic aerial photography

Osaka city took aerial photos for mapping in 1928 and 1942, for the first time, before and during the World War II, based on the airport near Osaka−Jyo castle. Some paper print images have been scanned to realize 3D image models on digital stereo plotter with AutoCAD and 3D display for 4D Image Map Archives Designed Aerial Studies (IMADAS).

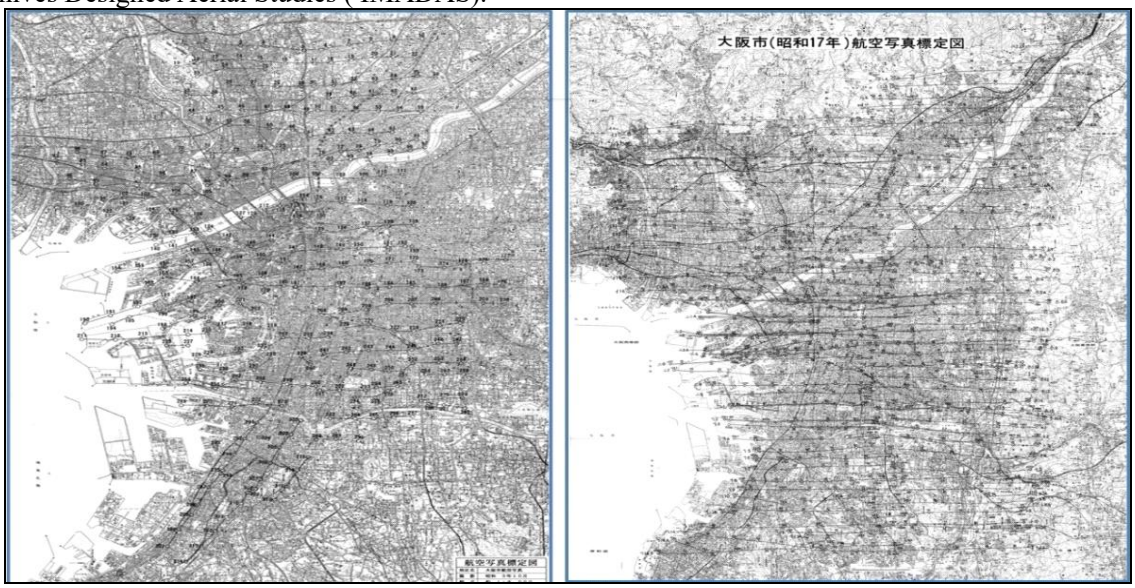


Figure 2-1-01: 1928 Index Map（300 photos） : 1942 Index Map（2700 photos）

2.2 Osaka-Naniwa-capital and JohRi land administration, Osaka prefectural boundaries

“Osaka prefectural history” (M. Hattori: OMU) introduced Osaka-Naniwa-capital and JohRi land administration as summarized research works of historians and geographers. The basic lines coincide with

the main street (Naniwa Daido) from Osaka-Naniwa capital-palace center, which was excavated since 1950s guided by the Osaka Metropolitan University professors.

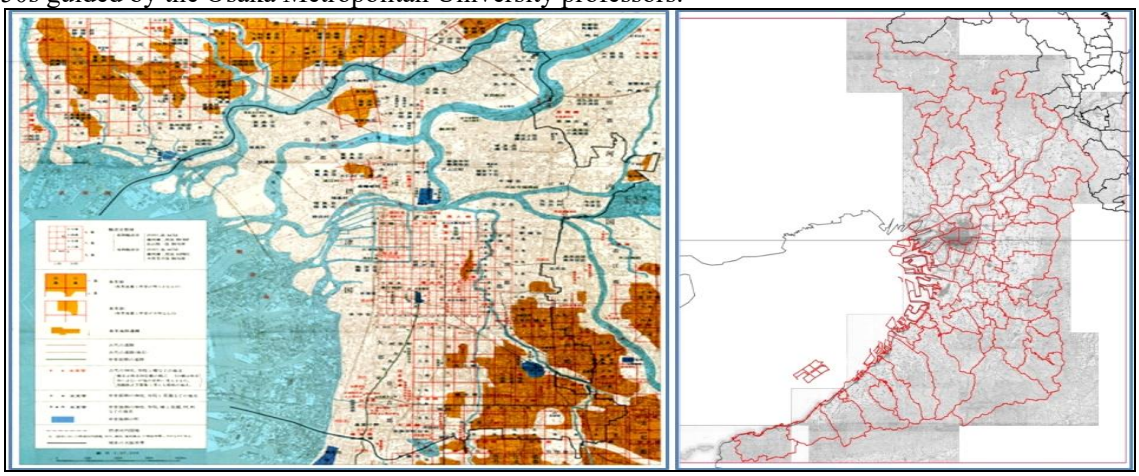


Figure 2-2-01: Osaka-Naniwa-capital and JohRi land administration (Osaka prefectural history (M. Hattori: OMU))

2.2.1 Naniwa Capital - Naniwa Daido(main street) on Yamato river (650s AD)

Naniwa Capital - Naniwa Daido(main street) are historically identified with old river flows and terrain structure, since major change of Osaka plain area was caused by the replacement of the Yamato River in 1704 and the interpretation of the old channel. For 3D image models, 1928, 1942 and 1948 aerial photographs are to be oriented and adjusted by bundle triangulation, with stereo matching image DEM(Digital Elevation Model) for continuous 3D image model Viewing/ Measuring/ Archiving on digital stereo plotter with AutoCAD.

Figure 2-2-1-01: Replacement of the Yamato River in 1704 and the old channels

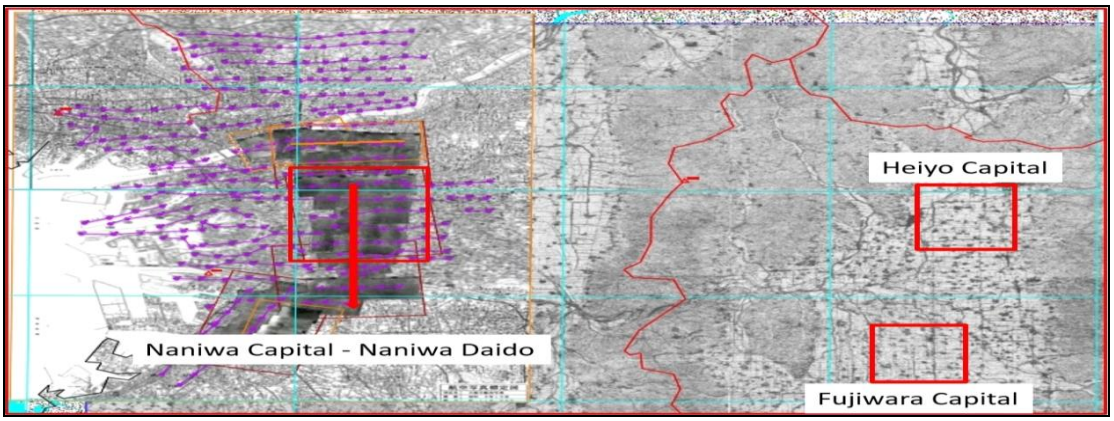


Figure 2-2-2-01: Naniwa Capital - Naniwa Daido, Fujiwara・Heijyo capitals

Continued after the Naniwa Capital - Naniwa Daido(main street), Fujiwara capital (694 - 710) and Heijyo capital (710 – 784) were constructed by subsequent emperors. On the above 1908 – 20K maps and 1928-aerial photos(Osaka city), Naniwa Capital - Naniwa Daido(main street) and Fujiwara ・Heijyo capitals area are located.

2.2.2 The Naniwa capital axis line - Naniwa Daido - JohRi base line : Restoration using the North Star azimuth method

The Origin of cadastral land administration was JohRi land administration from 645AD, and JohRi land administration base line coincides with capital axis line (Naniwa Daido) as the first reference line of cadastral system since then. Shinobu Takesako's "Identification of ancient pole star direction (2022)" found the North Star Azimuth angle at DaigokuDen (Main Building) of Naniwa Capital, according to his astronomical research of the oldest Chinese Capital planning. I applied the center line of North Star Azimuth angle on to the transformed oldest 20K map with excavation report of Naniwa Daido ruin site and old provincial territories. The coincidence of the lines could indicted me the original metrology of North Star direction in 650 AD. Restoration of the Naniwa capital axis line - Naniwa Daido - JohRi land administration base line has been substantiated with excavation report, 1880s map and 1961 AutoCAD map. Naniwa Daido was excavated in 1980 with Johri base line as the following report images,

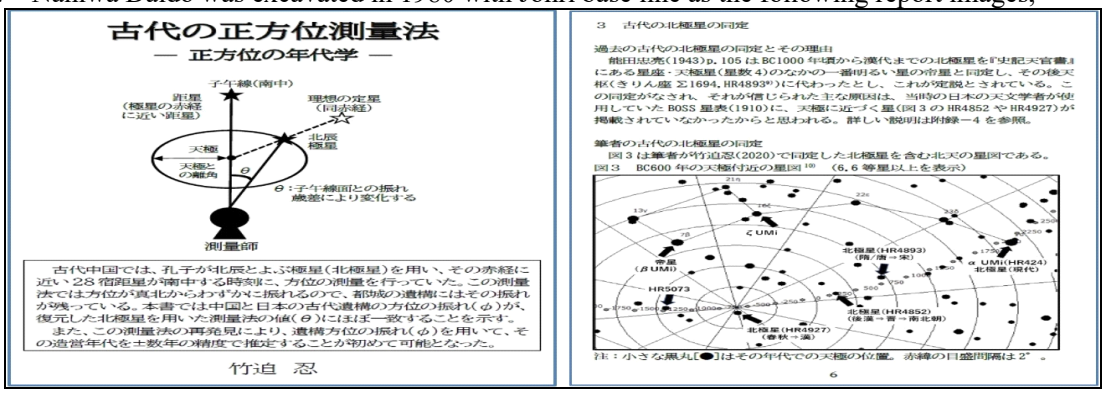
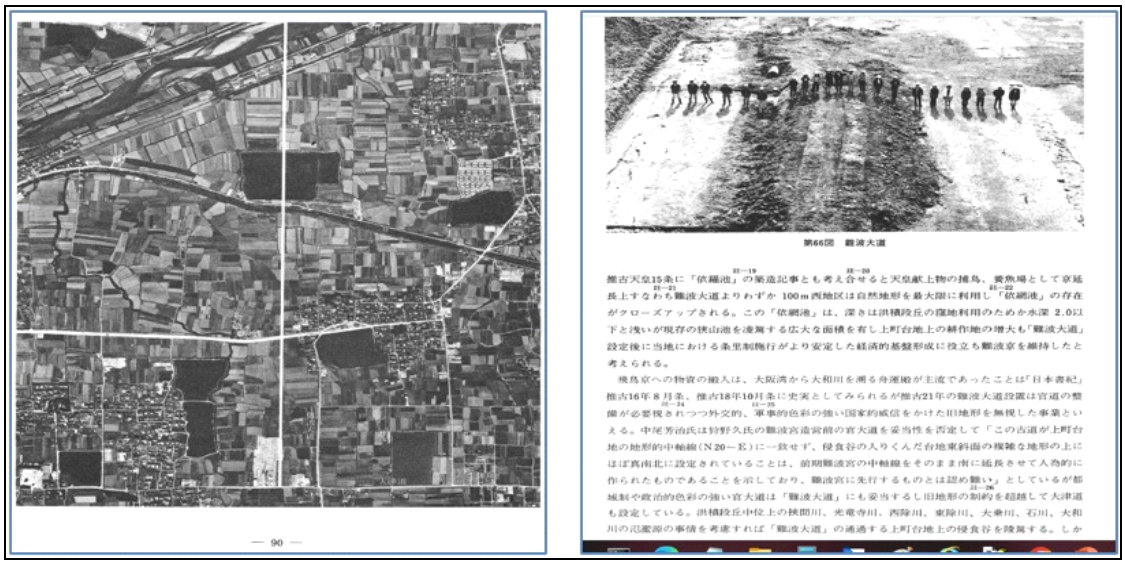


Figure 2-2-3-01 Shinobu Takesako：Identification of ancient pole star direction



第66図　難波大道

推古天皇15条に「依網池」の築造記事とも考え合せると天皇献上物の捕鳥、薬狩場として京延長上すなわち難波大道よりわずか 100ｍ西地区は自然地形を最大限に利用し「依網池」の存在がクローズアップされる。この「依網池」は、深さは洪積段丘の農地利用のためか水深 2.0以下と浅いが現存の狭山池を凌駕する広大な面積を有し上町台地上の耕作地の増大も「難波大道」設定後に当地における条里制施行がより安定した経済的基盤形成に役立ち難波京を維持したと考えられる。

飛鳥京への物資の搬入は、大阪湾から大和川を溯る舟運路が主流であったことは「日本書紀」推古16年８月条、推古18年10月条に史実としてみられるが推古21年の難波大道設置は官道の整備が必要視されつつ外交的、軍事的色彩の強い国家的威信をかけた旧地形を無視した事業といえる。中尾芳治氏は狩野久氏の難波宮造営前の官大道を妥当性を否定して「この古道が上町台地の地形的中軸線（N20－E）に一致せず、侵食谷の入りくんだ台地東斜面の複雑な地形の上にほぼ真南北に設定されていることは、前期難波宮の中軸線をそのまま南に延長させて人為的に作られたものであることを示しており、難波宮に先行するものとは認め難い」としているが都城制や政治的色彩の強い官大道は「難波大道」にも妥当するし旧地形の制約を超越して大津道も設定している。洪積段丘中位上の狭間川、光竜寺川、西除川、東除川、大乗川、石川、大和川の氾濫源の事情を考慮すれば「難波大道」の通過する上町台地上の侵食谷を陸橋する。しか

Figure 2-2-3-02: Naniwa Daido and excavated image in 1980 with Johri base line

The Naniwa capital axis line - Naniwa Daido - JohRi land administration base line was identified on Ortho Mosaic image map, referring to the North Star azimuth method.

North star direction + true north angle on map grid = North Star azimuth (650AD): Naniwa capital axis line is located on “Ortho image map (1961: Sakai city central library) “, which coincided with excavated ” Naniwa Daido‐central line” towards Main palace building”

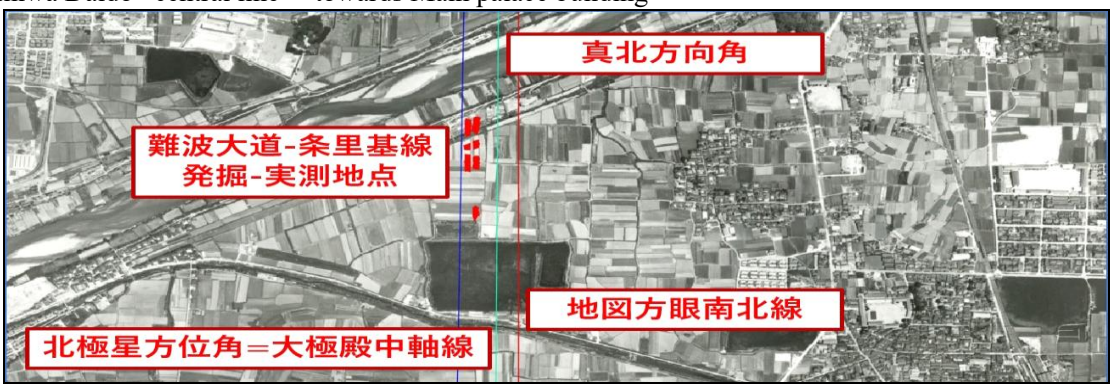


Figure 2-2-3-03: Coincidence among North Star Azimuth, excavated Johri base line on the 1961 ortho image

2.3 Basic maps of 3D cadastral mapping ：old city guide maps (1846～)

Japan’s first cadastral maps is the cadastral books of Osaka (1911：Osaka cadastral maps; vol. 1). Before the first cadastral maps, there were many city guide maps of Osaka, produced by the nation famous map publishers in Osaka. Based on the old surveyed urban maps and vintage aerial photos, 3D cadastral map will be generated by geocentric GNSS networking and One-stroke-parcel mapping designated on Land Survey Act.

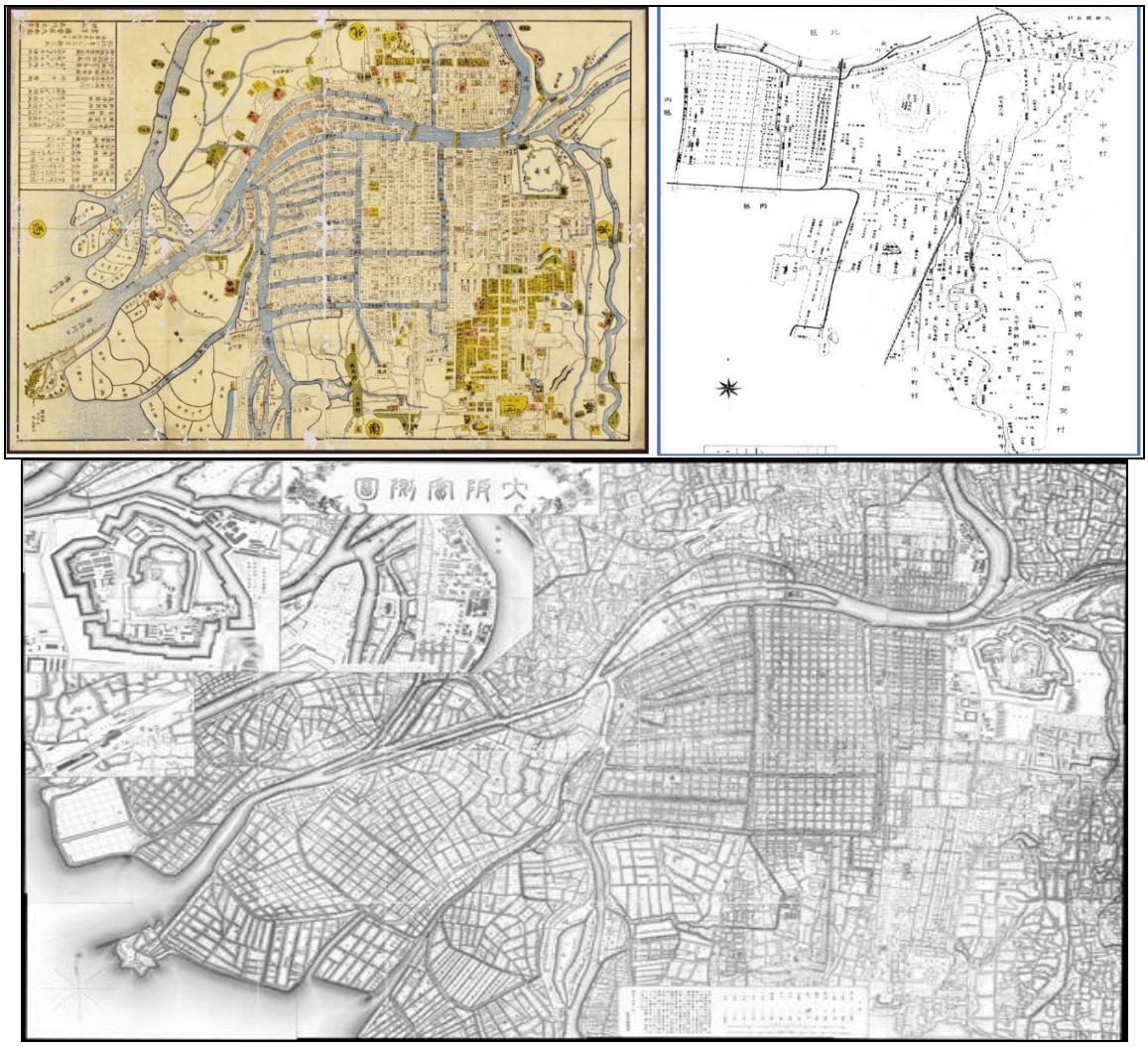


Figure 2-3-01: Osaka city guide map (1846) and the first cadastral index (1911)
Figure 2-3-02: Osaka actual survey map “大阪実測図-1887”

Before the cadastral mapping in 1910s, there was the first surveyed map Osaka in 1887, at the change of taxation from “**Kokudaka**-system” to “Land tax reform project” (1870s).

The **kokudaka** system is a system principle of Japan's early modern feudal society that was established based on the kokudaka, which was the standard yield of brown rice of the land.

The origin of land tax can be traced back to the ``tachikara'' custom of offering harvested rice to the gods during the Yamato regime. In the **Ritsuryo state** that was established through the Taika Reforms (645 AD.), ``tachikara'' was reorganized into ``rei'' in `` So(Zu), Yō(Yong) and Chō(Diao)'' a tax system after the Tang Dynasty. The tax treats the income from fields (kubunden) as taxable property. Before the Meiji period, it was called taso (taso) or koso (tributary tax).

For 3D cadastral mapping the source of JohRi land administration was explored for the main street (Naniwa Daido) of Naniwa Capital (645 AD.), using old survey maps and aerial photos.

On the Japanese cadastral system, the origin was **Taika Reform Edict**（646AD.）at Naniwa palace, and it promoted JohRi land administration system from Osaka to nationwide.

In the modern taxation system, Osaka produced the first cadastral maps (1910) as actual survey maps, so we are to connect the parcel boundary points (title of the cadastral laws) in the World Geodetic Datum coordinates, based on the Real Estate Registration Act .

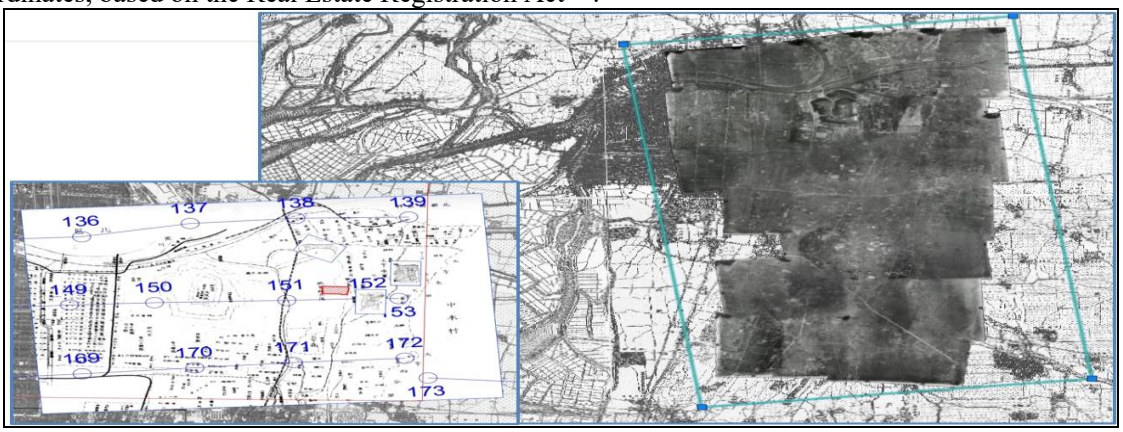


Figure 2-3-03: 1928-Mosaic-1886-20Kmaps: 1928-Osaka city aerial photos- numbers (OsakaJyo Castle area)

2.4 3D cadastral mapping of Osaka Metropolitan University – MorinoMiya campus

3D cadastral mapping of Osaka Metropolitan University‐MorinoMiya campus is under preparation, to introduce cadastral system relationship from Johri land administration to current parcel registration system as 3D-CAD cadastral map of Uemachi plateau area.

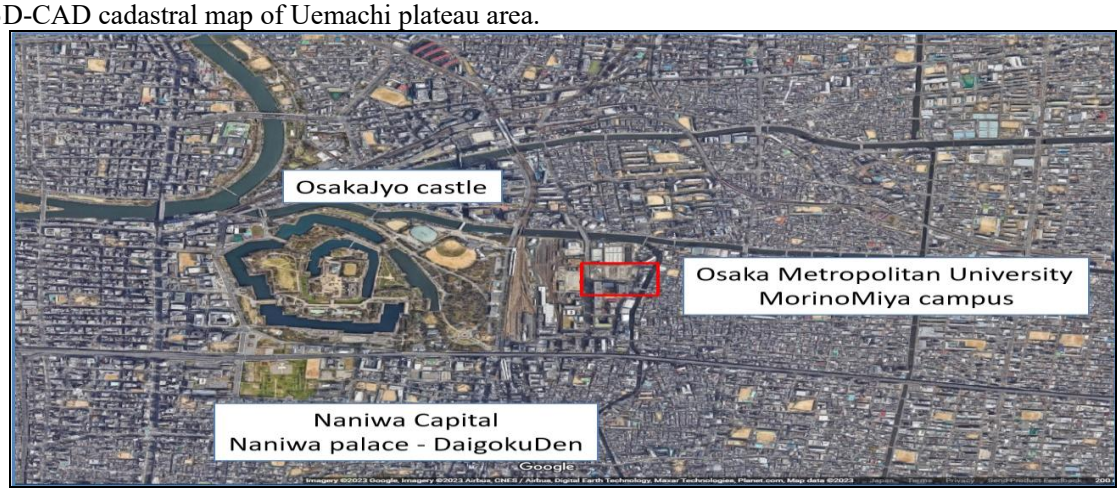


Figure 2-4-01: 3D cadastral mapping of Osaka Metropolitan University – MorinoMiya campus

2.5 Osaka Cadastral Register/Cadastral Map -Digital image creation Ledgers

The first cadastral map/book of Japan: Osaka Cadastral Register-Ledgers was made and published by Osaka Prefecture in 1911. The cadastral maps of parcel based registered ledgers are to be corresponded in 3D coordinate system, using Geo Centric GNSS networking - single-parcel cadastral surveying-radiation method.

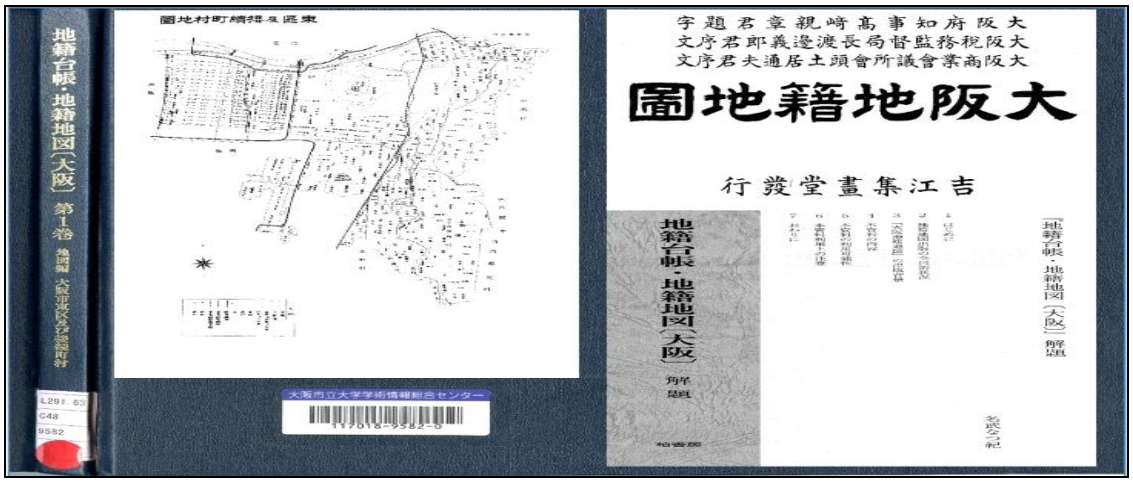


Figure 2-5-01: Osaka Cadastral Register/Cadastral Map

3. 3D CADASTRAL MAPPING STANDARD − PHOTOGRAMMTRIC APPROACH

As 3D Cadastral Mapping of Photogrammetric approach is promoted by MLITT(Cadastral Development Division), recommendable textbook on photogrammetry is “Close-Range Photogrammetry and 3D Imaging（2015）”; Thomas Luhmann, University of Oldenburg, Germany. As for Digital Stereo Plotter, which is another name of Photogrammetric 3D mapper, we are accustomed with Summit Evolution, which is a nice digital stereo plotter in the world, for aerial photo, UAV/Helicopter and Satellite photogrammetry, for 3D image modeling on AutoCAD platform.

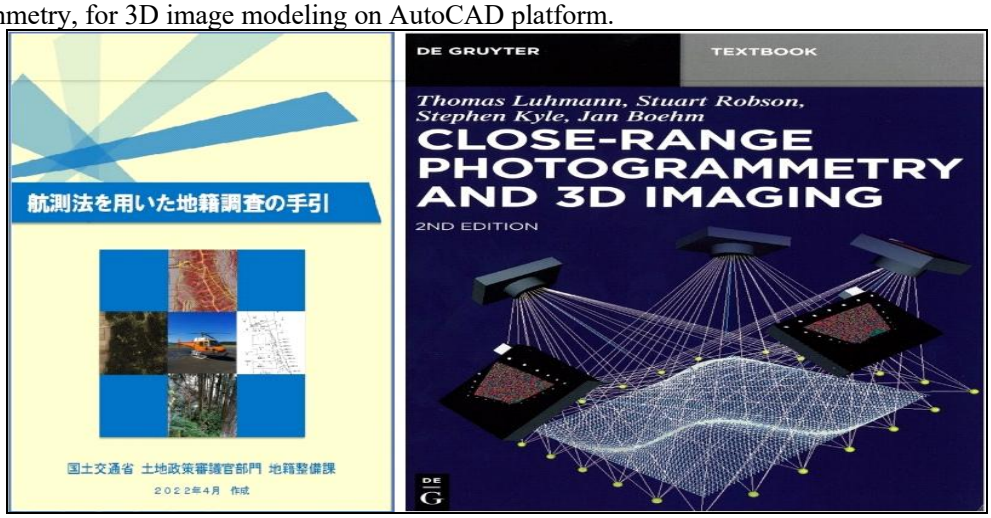


Figure 3-0-01: Cadastral Survey Work Regulations for 3D Cadastral Mapping of Photogrammetric approach: “Close-Range Photogrammetry and 3D Imaging（2015）”

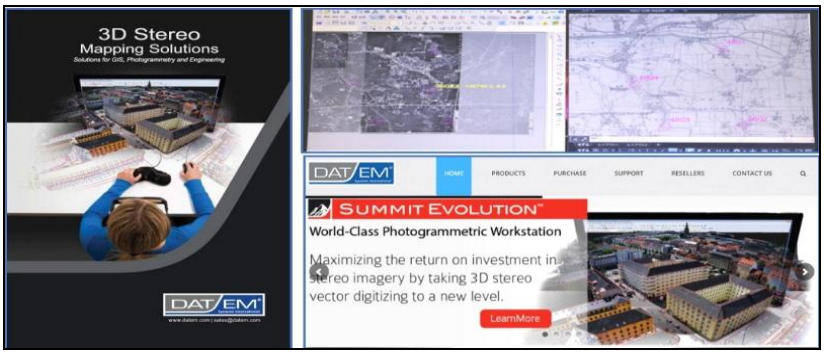


Figure 3-0-02: Summit Evolution : AutoCAD version.

Current 3D mapping is realized with Osaka city's 2025 aerial images of the index map.

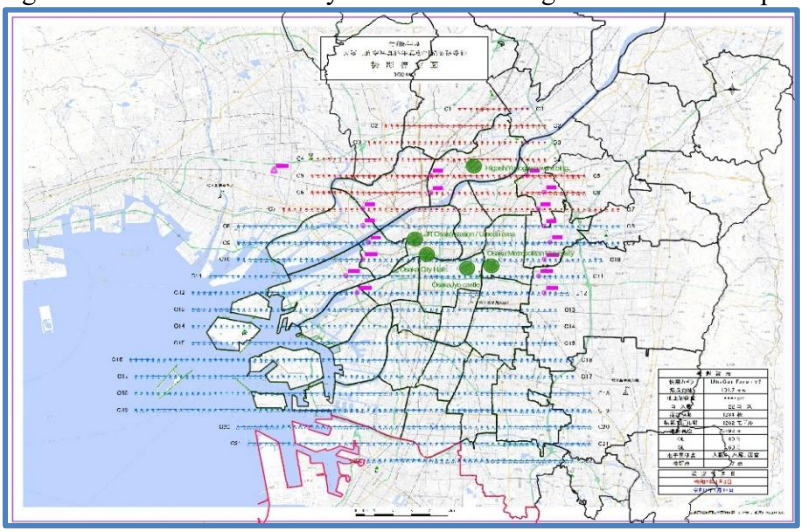


Figure 3-0-03: 3D DX map index map : 3D Image Model areas (2025.01.03)

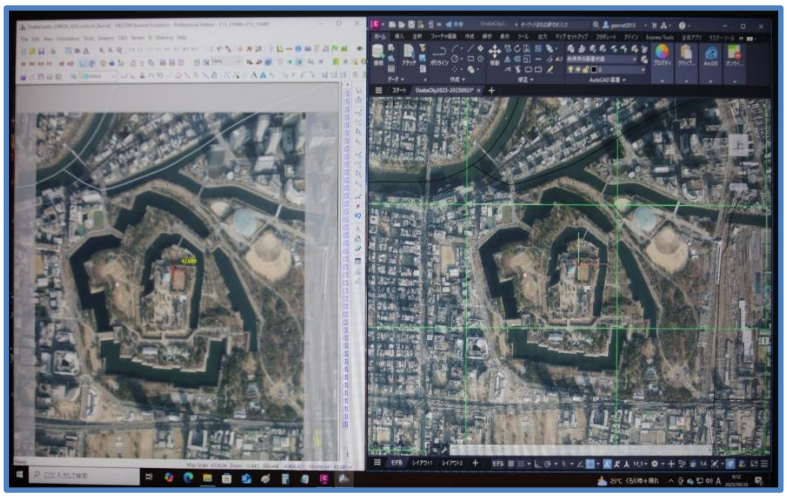


Figure 3-0-04: OsakaJyo castle and its vicinity
3D image model (Summit Evolution; with glasses)
Ortho mosaic imagemap (AutoCAD)

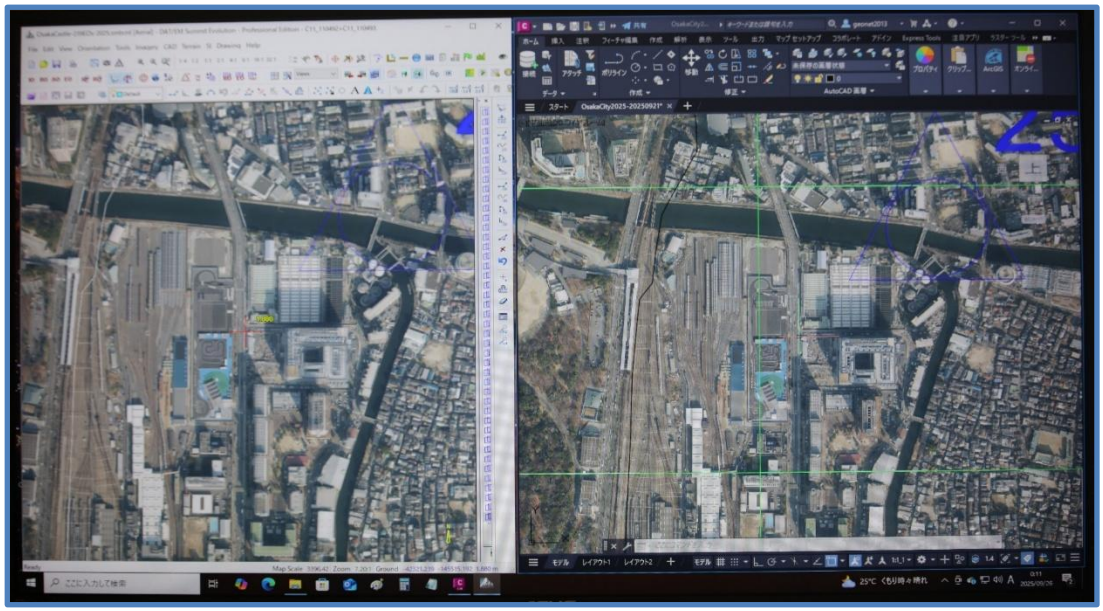


Figure 3-0-05: Osaka Metropolitan University and its vicinity
JR Osaka East line – JR OsakaJyo Kohen station

3.1 JR Shin Osaka station-3D cadastral mapping project in Higashi Yodogawa ward using 1975- aerial photos as 3D image models

With 1975-GSI aerial photo index map of CKK748-C9-C10-C11- strips (1200dpi), we started 3D cadastral mapping of JR Shin Osaka station area which is a typical earthquake active faults area in Higashi Yodogawa ward, Osaka city, where in 1970 Osaka EXPO was held in the neighboring city.

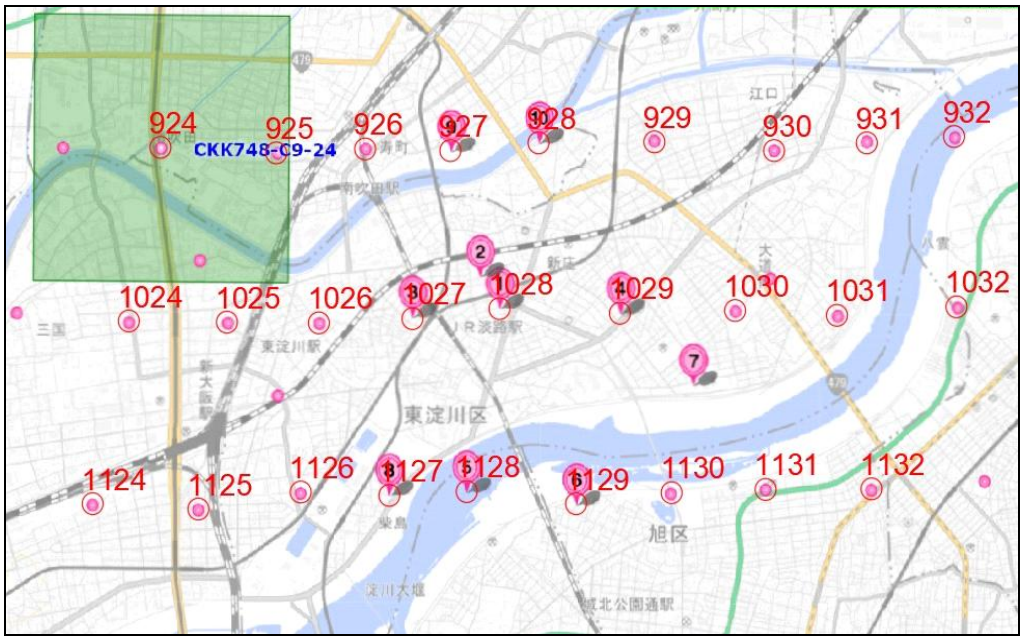


Figure 3-1-01: 1975 aerial photo index map (Higashi Yodogawa ward, Osaka city)

3.1.1 3D AutoCAD Image maps, 3D Cadastral Map and CAD Globe

Bundle Triangulation based Ortho/Mosaic 3D Image maps with manhole height DEM could provide 3D AutoCAD Image maps on CAD Globe in the World Geodetic Datum.

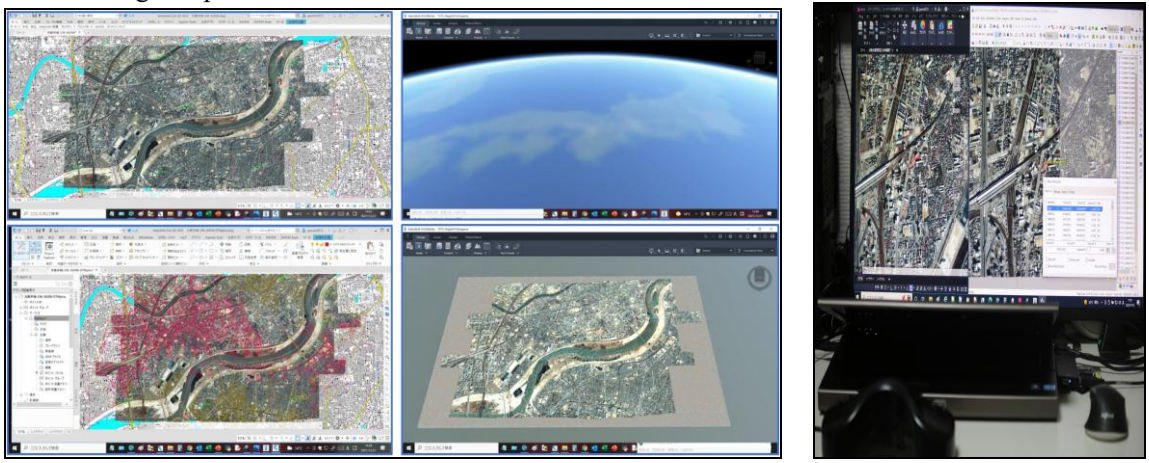


Figure 3-1-1-01: 3D AutoCAD Image maps（1975）：3D Cadastral Map: CAD Globe

3.2 OsakaJyo castle 3D-DX mapping – status quo

3D-DX -mapping 2025: Naniwa capital - OsakaJyo‐OMU MorinoMiya campus area has realized the best status quo accuracy of σ 0（Standard deviation of the observed unit weights）= 1.2um, in Automatic Bundle Trianguration of 2025-116images/Osaka city.

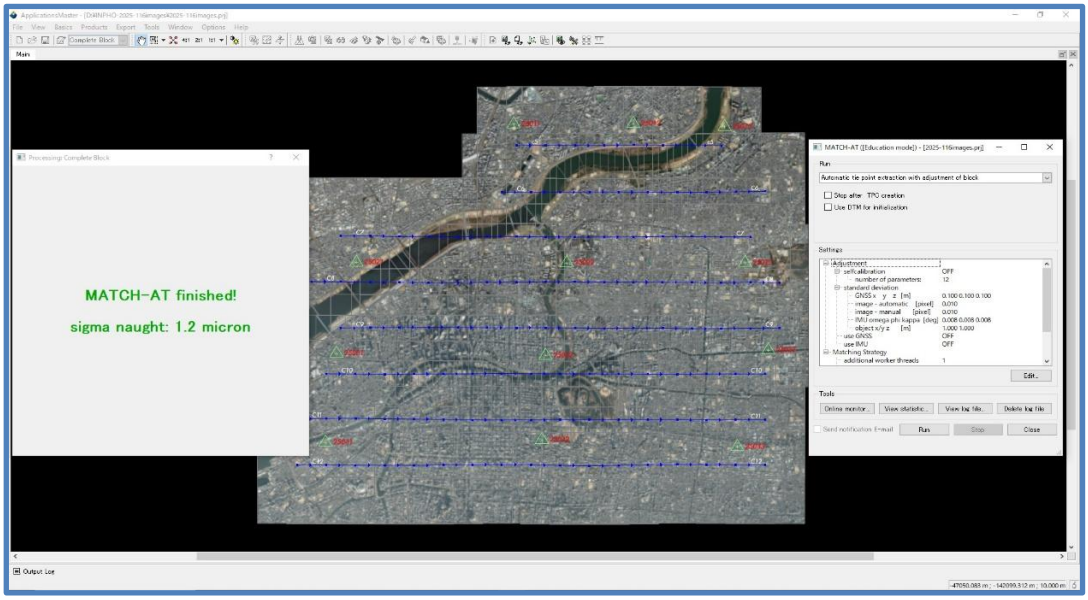


Figure 3-2-1 MATCH-AT sigma naught = 1.2 μ m: pixel resolution 6 μ m

3D image continuous models are displayed, measured and archived on a digital stereo plotter with 3D display without polarized plasses, cooperating with AutoCAD.

We could start with 1928 photos of 30% forward overlap, using ortho mosaicking for the whole area, to be used as 2D image map for cadastral mapping at parcel registration procedures. Based on the Standing Tree Method, the standing trees within Osaka Castle Park will be captured as a 3D color point cloud model using a terrestrial laser scanner and combined with the 3D-DX map.

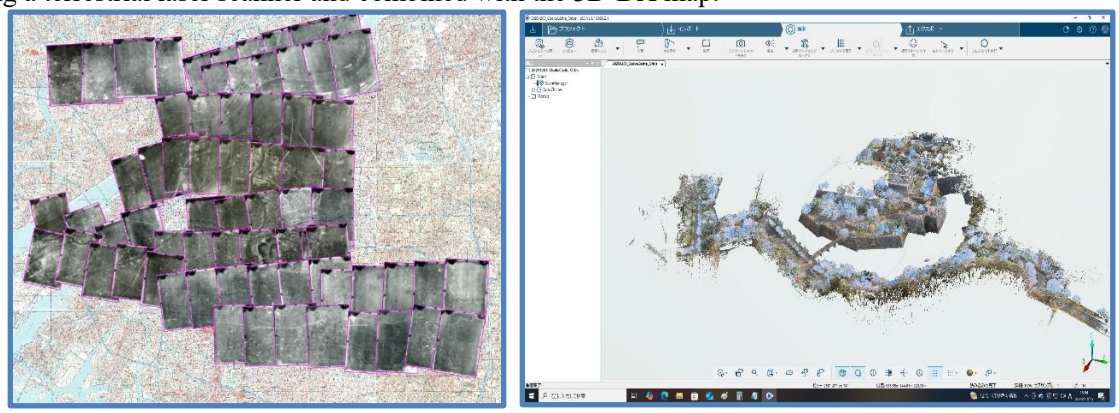


Figure 3-2-2 1928 ortho-mosaic photos : 2025 FARO 3D point cloud (OsakaJyo park)

4. CONCLUDING REMARKS

3D cadastral mapping is now carried out by 3 major survey techniques, Geocentric coordinates -GNSS satellite networking, 3D-CAD based digital stereo plotter and bundle triangulation based photogrammetry, using drone/helicopter and satellite stereo images, to be displayed, measured and archived on 3D CAD, with 3D display, for 4D Image Map Archive Designed Aerial Studies (IMADAS).

Osaka area situates in the center of Japan from ancient era of first Emperor, and a centralized state was started from Naniwa captal (645 AD.). The OsakaJyo-castle was the symbol of the national independence

with the largest number of guns against invasion of the western world, based on Military land system since the JohRi land administration system (7th century), promoting cadastral system with national mappings from 1590 to 1840, for 4 periods.
Osaka prefecture, as number one prefecture in 1890s, established Cadastral map/book ledgers, parallel with modern large scale mappings (1/3,000) in urban area, and proceeded to aerial photogrammetry in 1928 and 1942, starting from Osaka Artillery Arsenal – Airfield, where Osaka Metropolitan University Campus is constructed.
The first 3D image models of the whole area (2700 images/ 1942) are coming on Summit Evolution based 3D cadastral maps on 3D CAD-AutoCAD platform.

Acknowledgement
This research paper has been prepared and submitted for the FIG2026, along with research projects of GeoNet, Inc.. Also author would like to express deep gratitude to Professor Dr. Naofumi Kishimoto for his powerful support to this research project, from the planning phase to completion of tentative sample models.

REFERENCES

1. ” Satellite Geodesy “ 2003; Guenter Seeber; de Gruyter
2. ” Close range photogrammetry and 3D imaging” 2014
   ; Thomas Luhmann et.al.; de Gruyter
3. “ Nahbereichsphotogrammetrie”2018; Thomas Luhmann; Wichmann
4. “ Das deutsche Vermessungs- und Geoinformationswesen“2015
   ; Kummer/Koeter/Eichhorn(Hrsg.) ; Wichmann

- The above four books have been translated by the author into bilingual versions.

5. “Map Projections-A Working Manual “ 1987 ; John P. Snyder

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 Osaka, Japan.
From 2013 he was the researcher of Graduate School of Asian and African Area Studies Kyoto University, Japan. In 2013 he was the researcher of Japan Federation of Land and House Investigators’ Associations.
From 2014 to 2015 he is the representative of common research project of CSEAS (Center for Southeast Asian Studies Kyoto University): “4D IMADAS for Williams Hunt Collection”.
In 2016 satellite stereo images were constructed as 3D image model of ground resolution level accuracy for this presented paper in ACRS2017.
In FIG Working Week 2019 Hanoi, he presented the paper
:4D-IMADAS with 3D mapping of Kyoto (Heian) – Angkor (Khmer) capitals
In FIG Working Week 2025 Brisbane, he presented the paper
:Fukui City - 3D-Cadastral Map and Kyoto University - 3D-Forest Map
based on 4D-Image Map Archive Designed Aerial Survey

CONTACTS

Hiroyuki Hasegawa
CEO GeoNet, Inc.

Higashi-Nakajima 1-5-25 Higashi-Yodogawa ward, Osaka JAPAN
Tel. +81-090-2148-0501
Email: hasegawa@geonetz.com"
Web site: http:// www.geonetz.com/