

4D- IMADAS with 3D Mapping of Kyoto-Angkor (Khmer) Capitals

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GeoNet, Inc.; Japan, APSARA national authority; Cambodia

Key words: Satellite photogrammetry, 4D- Image Map Archives of Heian capital and Angkor capital, World 3D cadastral system, Aerial photos bundle adjustment for 3D - diorama

SUMMARY

Kyoto Heian Capital plans, established in 794 A.D. were well documented by historians and excavated by archaeologists for many decades, with historical maps of several eras. Reconstructed capital plans are now being transformed into World geodetic datum system, using 3D-CAD approaches. Modern trigonometric and plane table surveying for mapping were applied in 1890s, 1910s and 1930s for urban planning. The first stage of Japanese cadastral mapping with cadastral books were organized in Tokyo, Osaka and Kyoto cities in 1912 by prefectural and city administrations. We have created 3D-diorama of Kyoto city in 1946, using aerial photogrammetry - bundle adjustment and stereo matching in ortho photo - mosaicked image production. Angkor dynasty, established in 802 A.D. is now being reconstructed on CAD-Globe with old maps and aerial photos, using Infrastructure Modeling, and we are to apply 3D city modeling of Kyoto city and Angkor Empire in 4D-Image Map Archive Designed Area Studies (4D-IMADAS) for restoration of Angkor Wat area and 3D cadastral survey of Kyoto- Heian capital as Historical/Archaeological Reality.



Kyoto-Heian capital, Angkor capital and Cambodia map grids

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1. OLD MAP PROJECTIONS AND 4D IMAGE MAP ARCHIVE IN 19-20-21ST CENTURIES

After opening the nation, in late 19th century, Japanese modern regime and military organizations started mappings, trigonometric control point surveying for national land information and taxation. Shogun regime conducted feudal territory land mappings four times nationwide from 17th to 19th centuries with domestic primitive surveying devices and Japanese own arithmetic and mathematics. Learning from European scientific references in physics and astronomy, in early 19th century shogun government organized mapping projects along coast lines and major roads for some decades. We have those technological legacy as “Inoh’s map series” in different scales on durable excellent Japanese papers. Map projections were derived from Germany on Bessel 1841 ellipsoid and polyhedron projection.

1.1 Tadataka Inoh’s 200K maps in 1820-1888 to Japan Geodetic Datum 2000 maps

Tadataka Inoh’s medium scale maps were used as basic maps for many decades combined with trigonometric geodetic network projects nationwide from 1880s to 1920s as basic maps for 1/50,000 mapping. Those maps were rearranged in 200K maps of longitude 1 deg. x latitude 40 min., in the years from 1887 to 1893, before Sino-Japanese war in 1894 - 1895 and Russian-Japanese war in 1904- 1905. About 130 map sheets are now summarized on 3D-CAD as georeferenced image maps. The comparison with year 2000 coastal lines shows production accuracy and usability, with many geographical names and boundaries as historical reality before aerial photogrammetric mapping.

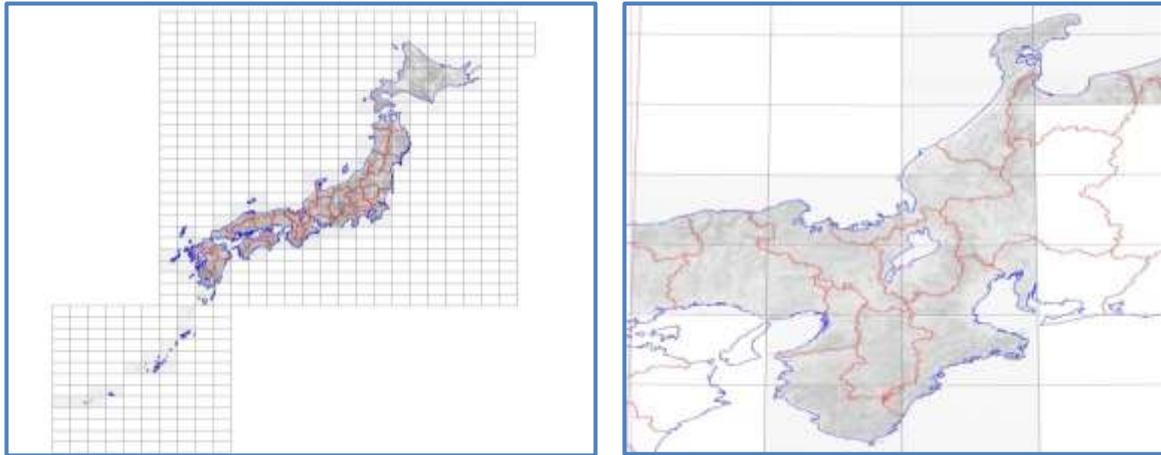


Fig.1. 1880s-200K maps (130 maps) – year 2000 map coast lines (blue) in JGD06 zone

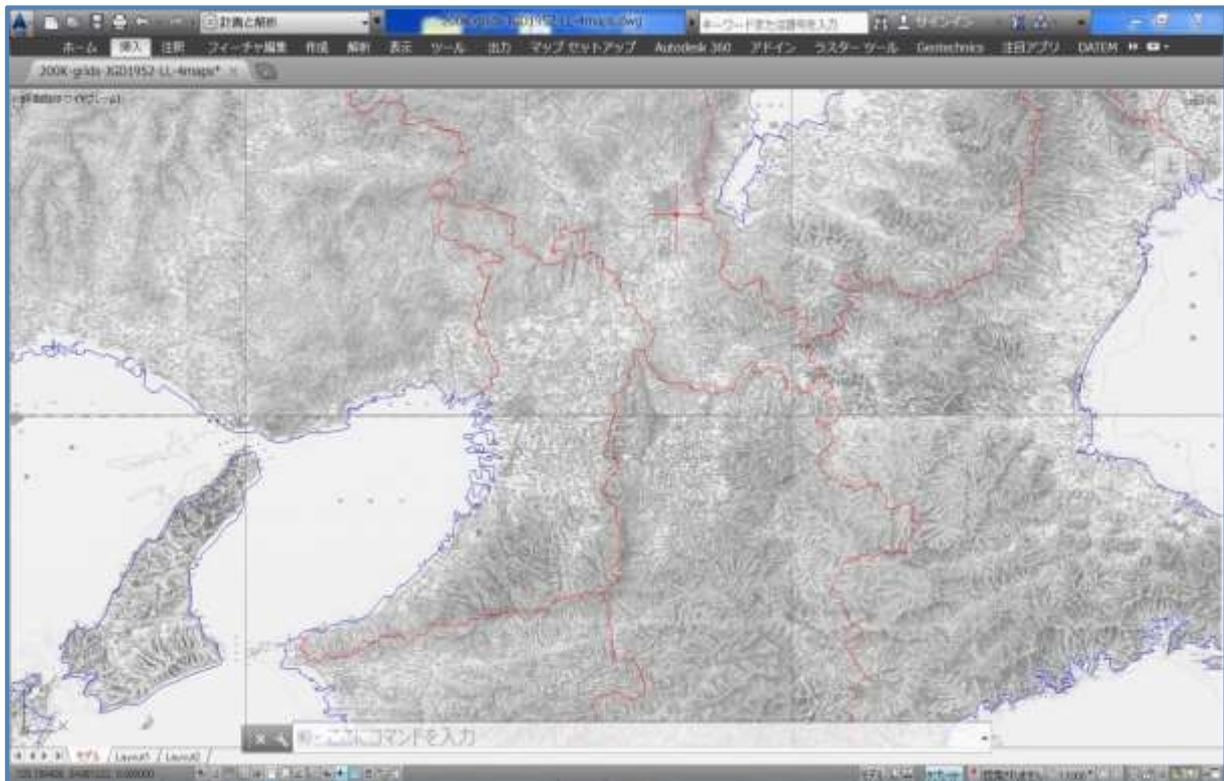


Fig.2. 1880s-200K maps-Osaka Awaji coast lines

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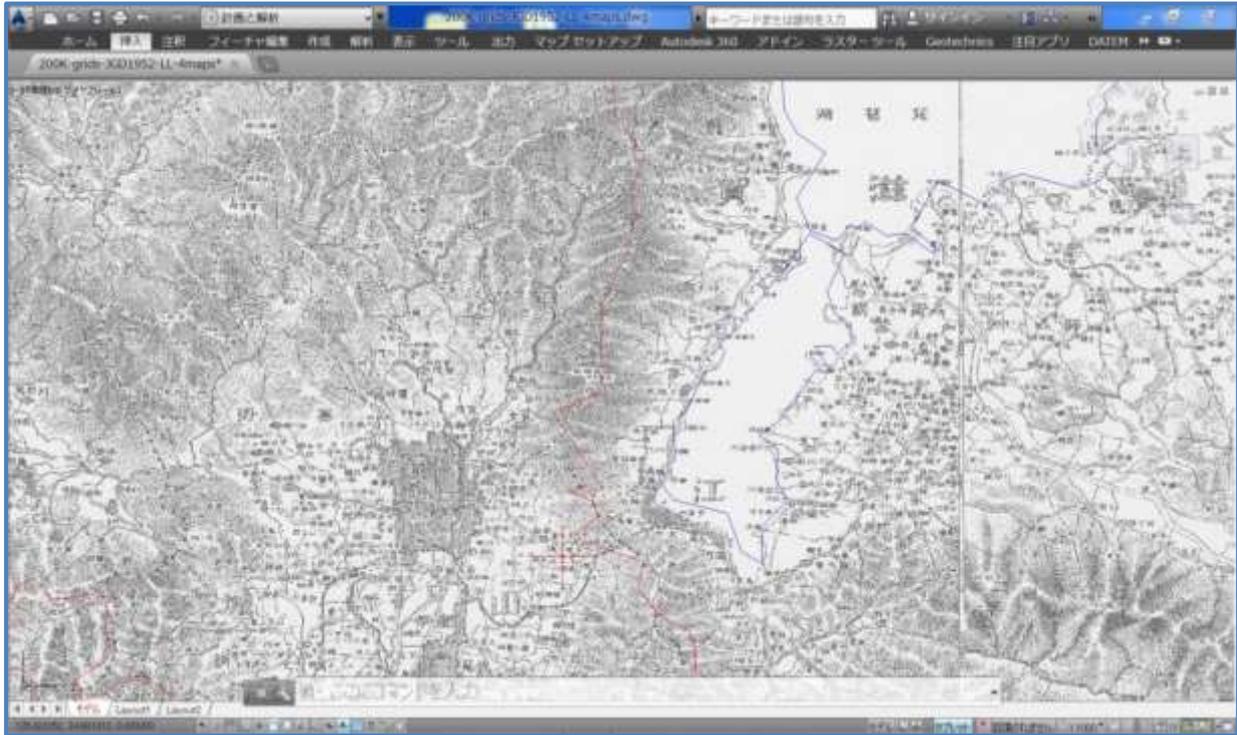


Fig.3. 1880s-200K maps - Kyoto Biwako-lake coast lines

1.2 Modern 20K maps of Kyoto City area in 1890 and 1912

For Kyoto City area, large scale mappings had been completed in 1890 and 1912, without and with trigonometric geodetic coordinates. Those maps are now connected to the unified World Geodetic Datum, using ellipsoidal transformation from Bessel 1841 to GRS80 ellipsoids of ITRF94 geodetic datum, as Historical Reality of the period early 20th century.



Fig.4. 1889: maps / prefectural boundaries and 1889: Imperial palace; Kyoto University



Fig.5. 1910: maps and enlarged maps of Imperial palace; Kyoto University

1.3 Urban planning base maps of 3K in 1936

As the first large scale urban planning base maps, Kyoto city office produced 1/3,000 maps in latitude-longitude coordinate system, using plane table surveying applied for polyhedron map projection. This mapping was supported by authentic trigonometric network and levelling network adjustments. Large scale maps are now succeeded to new transverse Mercator projection via datum transformation, to world geodetic datum system 2000.



Fig.6. 1910: Map grids – 1936:Map grids – 1936: Map images of Imperial palace

2. AERIAL PHOTOGRAMMETRY IN KYOTO CITY AREA

3D image models are the major components in 4D Image Map Archive. Aerial photogrammetry has evolved from 2D- topographic mapping to 3D image modeling on 3D-CAD system for Landscape modeling and designing. We use many types of aerial photos in different decades along with photogrammetric developments towards digital camera and advanced orientations and DEM – Ortho - Mosaic with 3D-diorama for landscape-designing.

2.1 10K-40K aerial photos taken by US aerial cameras

Even though there may be valuable military aerial photos before the World War II, current available aerial photos of Japan were taken by US Air Force nationwide in 1946-1948 before Korean War from 1950-1953. Duplicated paper prints lack, in quality, fiducial marks calibrated focal length and lens distortion corrections for interior orientation. Based on

model orientation theory based on spatial similarity transformation, we could acquire 3D models with exterior orientations from bundle adjustment, to clear subsistent obstacles.

2.2 Bundle triangulation of 1946 aerial photos and 3D image modeling and 3D-diorama

In 1946 aerial photos were taken by commonly used 5” lens camera in 1: 10,000 and 1: 40,000 photo scales. After having scanned paper prints, tie point measurement for bundle adjustment was processed on 3D- photogrammetric station: Summit Evolution (DATEM), and MATCH-AT (INPHO) to construct 3D image models on 3D PC-display-3D-CAD for mensuration. These 3D image models are used for 3D diorama.

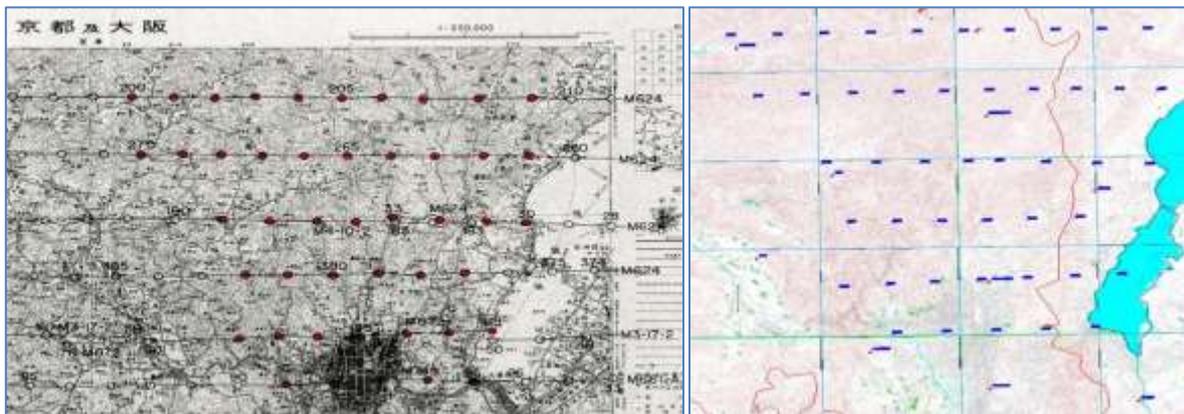


Fig.7. USAF exposure points in 1946 (Index map and adjusted coordinates)

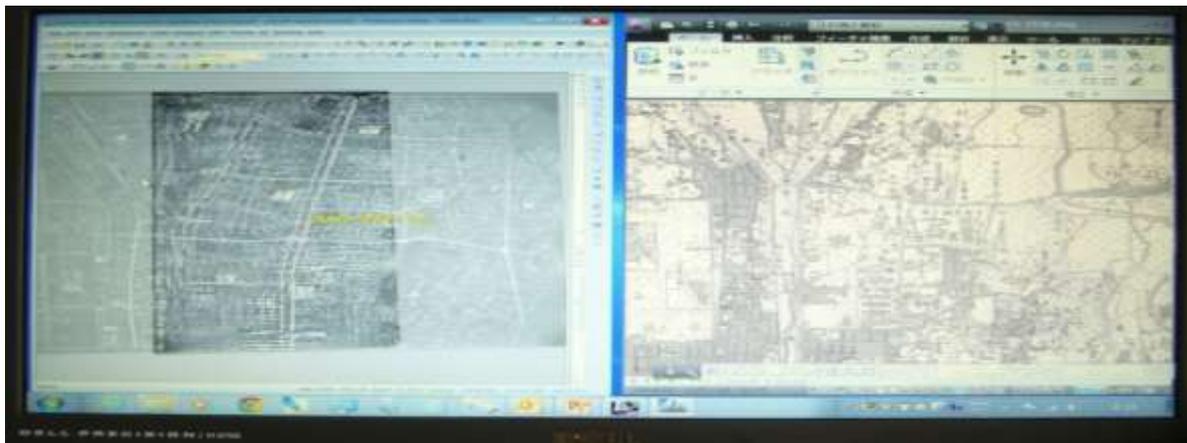


Fig.8. Kyoto University 1946 stereo model -1911 Image Map on AutoCAD Map



Fig.9. 1946 aerial photos + 5m DEM for Kyoto University 3D diorama

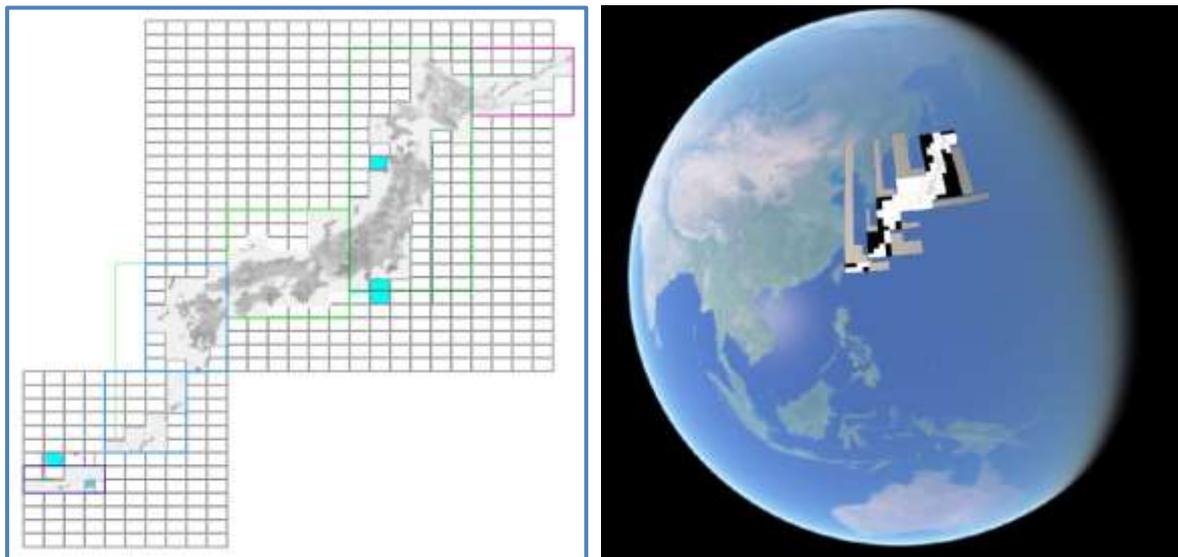


Fig.10. Image Map (1886) and CAD-Globe (Autodesk Infravorks): Japan archipelagos

3. KYOTO HEIAN CAPITAL PLAN : DESIGN AND EXCAVATED REALITY

In 8th century of ancient eras of Japanese history, Kyoto Heian Capital plan was well organized after previous capital plans and referred to Tang dynasty of China, with rectangular symmetrical location of unit blocks, configuring imperial palace, governmental facilities and aristocrat-citizen residential sites, characterized by the central major street of 84m. The designed plan, so called Jyo (streetwise block)- Bou (avenue-wise block), had been kept as standard for many later centuries during construction and reconstruction projects. The historical reality has been revealed by archaeological excavations in these decades.

3.1 Capital plan documentation in 8th century

Engishiki- laws and ordinances; rules and regulations of Heian dynasty issued in 8th century- designed and defined the capital plan called Kyotei explicitly in old scale system. As fundamental sizes of several kinds of roads and blocks were expressed in Shaku - Jyou - Chou scales, we could define Jyo-Bou plan as a whole for the entire area of Heian Capital in old scale system. To put the capital plan on the existing maps in different eras and dynasties, we have to refer to not only documental evidences but also excavated reality in metric system.

3.2 Excavated Capital zones and facilities

Kyoto city archaeological research institute was established for archaeological researches and is responsible to reveal the historical status of Heian Capital with Capital plan. Since most of buried ruins of Heian Capital are covered by existing buildings and roads, excavation processes took for many years, even in partial areas. So major parameters to designate the designed capital plan onto the current coordinate system are as follows;

- (1) Scale factor of the scale systems between old and current metric scale
- (2) Origin of the rectangular capital plan, the intersection of most southern road and the major central road, which could be measurable at excavation site.
- (3) Azimuthal angles of major central road (north-south) and street lines(west-east)

Current results of the above mentioned parameters are shown as follows;

- (1) Old 1 Shaku = 29.844518cm; 1 Jyou=10Shaku; 1 Chou= 40 Jyou= 119.378m
- (2) Origin x = -110,862.58m; Origin y = -23,233.30m (in Japan Geodetic Datum1952; Pl. Re. Co.No.6)
- (3) Azimuth= -14'23" (from true north), which corresponds about 21m for 5km(N-S line)

3.3 3D reconstruction of Heian Capital plan on 3D-CAD system

With explicit definition of Heian Capital plan, graphical expression of Heian Capital plan on 3D-CAD system, based on description of Engishiki; historical official document , is shown.



Fig.11. Heian-Capital Plan (by Yamada), Plan basic map (in DWG) and 3D-diorama

3.4 Kyoto Heian Capital 4D- Image Map Archive for future 3D cadastral mapping

By overlaying on DEM (Digital Elevation Model) , 3D-diorama could be designed. This is the key aspect of BIM (Building Infrastructure Modeling) to realize landscape modeling.

4D-Image Map Archive could be the database for 3D cadastral mapping in Japan. Nationwide geodetic networking of 1300 Japan Electronic Control Points ensures the ground accuracy of 1sec/ 1cm for GCPs as basic references of “ One Step Parcel Cadastral Mapping” authorized by official specification. We have now AutoCAD -3D digitizer series with Total Station, 3D-TLS, DGPS and GNSS receivers shortly as driving engines.

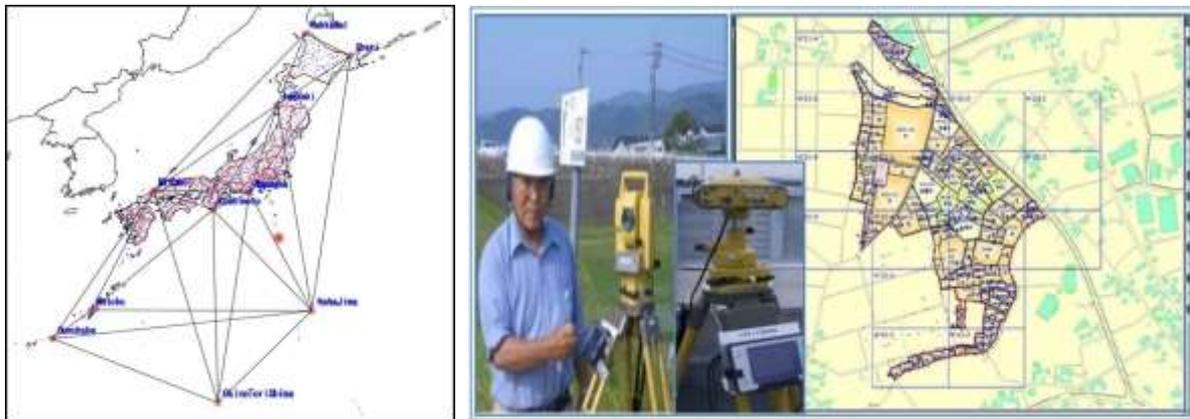


Fig.12. Japan Geodetic Networking and “One Step Parcel Cadastral Mapping”

4. Cambodia-Angkor 4D-IMADAS

In Khmer (Angkor) empire, the extensive irrigation projects provided rice surpluses that could support a large population. Related land ownership-cadastral system is one of the most interested archaeological research works for Angkor Wat restoration projects nowadays.



Fig.13. Khmer Empire (A.D. 900) and SRTM- Angkor Wat area (AutoCAD Infracore)

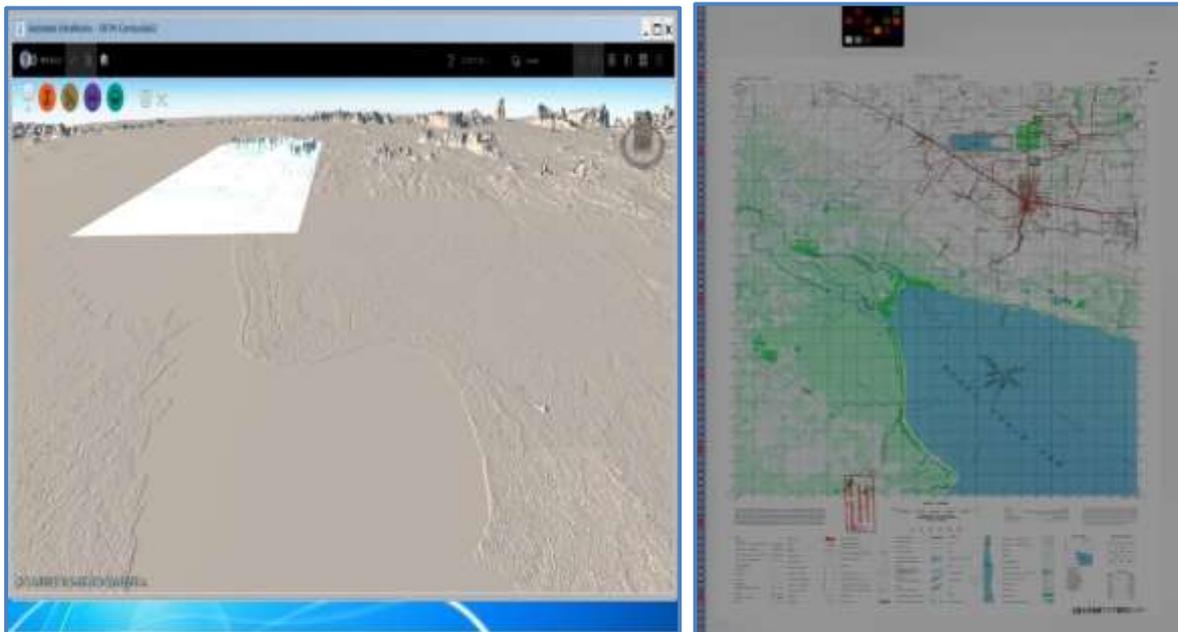


Fig.14. Infracore- Angkor Wat area with JICA 100K map (1998: Kyoto University)
 Based on the existing maps, 4D- Image Map Archive could be configured on AutoCAD-
 Civil3D, unified on World Geodetic Datum map sheet design as follows;

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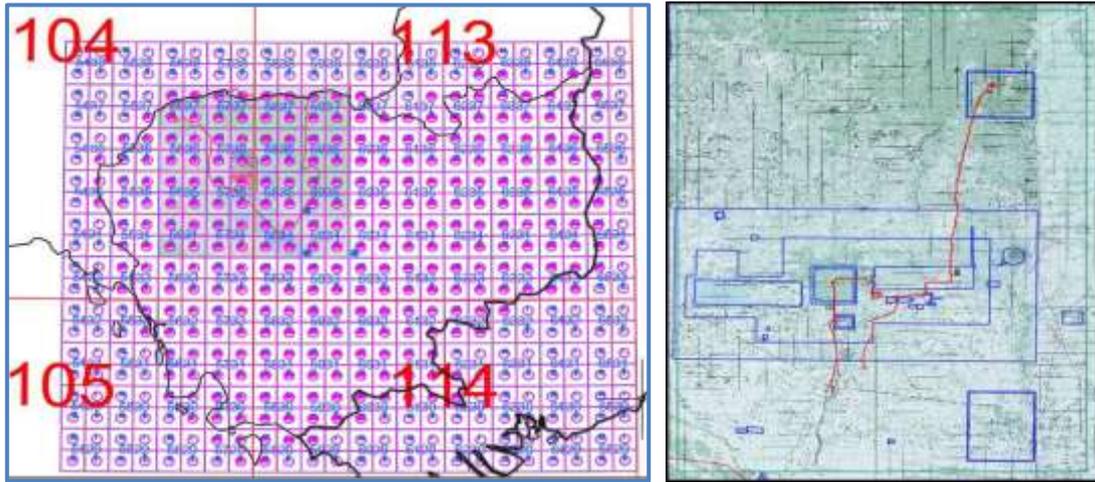


Fig.15. Cambodia-APSARA maps and Angkor Wat

4.1 Approaches and basis of 3D mapping projects

For new 3D mapping projects, Satellite photogrammetry, Helicopter photogrammetry are to be applied for 1/2,500 mapping, and DGPS 3D direct mapping could be used for 1/5,000 forestry mapping. In the future, every tree- individual tree mapping could be processed with terrain laser scanner on AutoCAD- tablet by Cambodian engineers. Historical maps are well combined in 4D-Image Map Archive as follows;

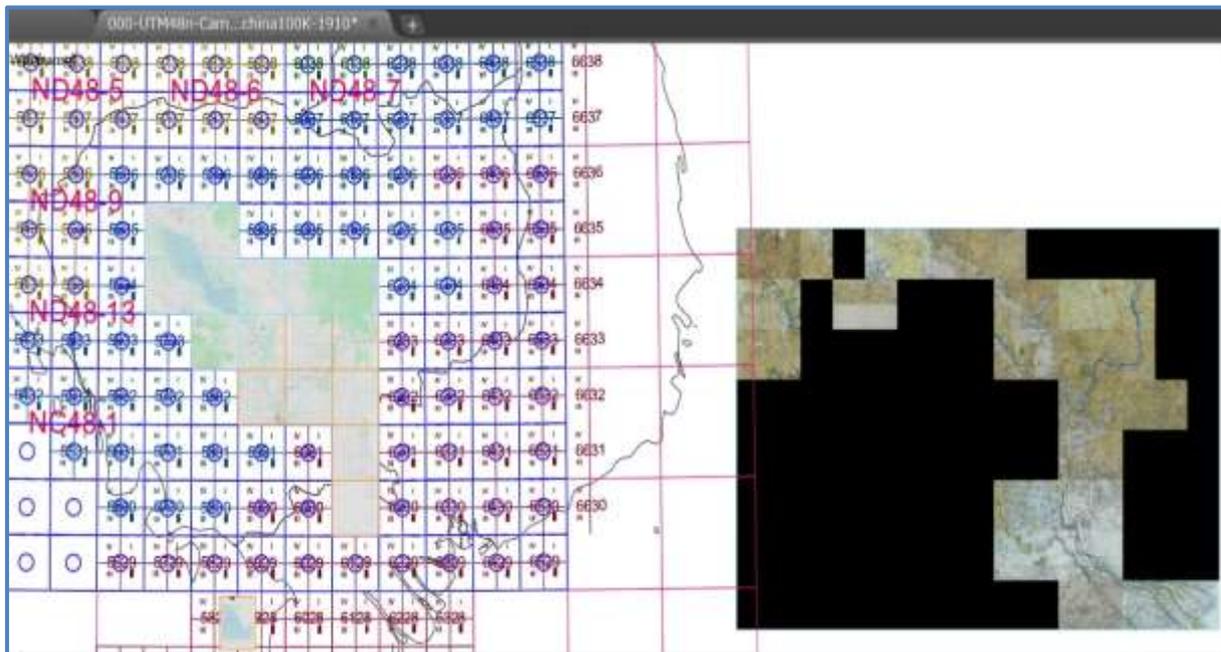


Fig.16. Cambodia-100K maps-1910- 1998

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To ensure the consistency with UN-Global GeoInformation Management (GGIM) and Global Geodetic Reference Frame (GGRF) initiatives, precise GeoReferencing based on IGS(International GNSS Service) 500 reference stations is now required as follows;



Fig. 17. 1998-1910 maps PANDA-IGS-networking

As the modern procedures for 3D mappings are as follows;

- (1) Satellite photogrammetry
- (2) Helicopter photogrammetry
- (3) DGPS 3D mapping
- (4) TLS(Terrestrial Laser Scanner) with Total Station : Dome shape traversing

4.2 Satellite photogrammetry

In 2016, successful satellite photogrammetry with stereo 3D mapping started in Kyoto University with World View 2 satellite stereo images.



Fig.18. Satellite photogrammetry in Kyoto city

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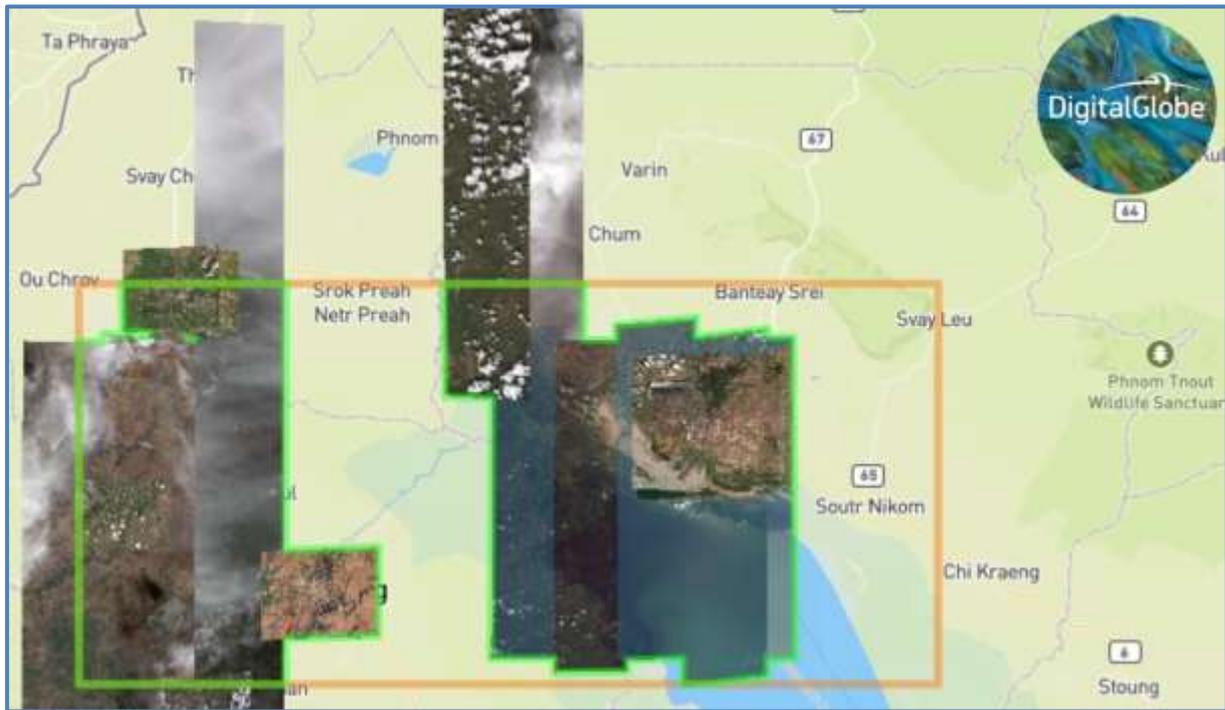


Fig.19. Digital Globe - Angkor Wat – Siem Reap area

4.3 Helicopter photogrammetry

For EXPO2025 Osaka, Helicopter photogrammetry started in Kobe and Osaka. This approach is already standardized by official specification in cadastral survey in Japan.



Fig.20. Helicopter photogrammetry on Robinson R22 with Pentax camera (2019.1.8)

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4.4 DGPS 3D mapping

As the accuracy level of 1-2m in 3D is possible, DGPS – 1sec dataset draw many types of feature lined for 3D mapping, including Digital Terrain Surface, even in dense wood.

Water streams and forestry roads could be prime applications for 3D terrain surface modeling in AutoCAD-Civil3D for 3D-diorama designing and construction.



Fig.21. Tak Tak DGPS-3D-mapping in Angkor Wat

4.5 TLS-TS Dome-shape traversing

GNSS based TLS-TS Dome-shape traversing is the future of forestry 3D surveying and mapping. Ground dataset could be well combined with airborne laser scanned dataset.



Fig.22. AutoCAD ReCap and Leika BLK360 and Terrestrial Laser Scanning in Germany

BIOGRAPHICAL NOTES

Author 1:

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. From 2013 until 2015 he was the researcher of Japan Federation of Land and House Investigators' Associations. From 2014 to 2015 he was the representative of common research project of CSEAS (Center for Southeast Asian Studies Kyoto University): "4D IMADAS for Williams Hunt Collection".

Author 2:

Heng Kim Leng got a degree of PhD in Highway, Urban Road Construction and Traffic Engineering, University of Communication and Transport, Hanoi, Vietnam, 2001. From 2004 to 2007 he worked as team leader of project study and design, University Lecturer, technical director of Soma Construction Company, and Chief Technical Department for Moha Engineering & Construction Co. Ltd. From 2008 to now holds a position of Director of Department of Technical Support and Inter-sectoral Projects, APSARA Authority; Kingdom of Cambodia.

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Kim Samnang was graduated in 2016 from SOAS University of London, London, The United Kingdoms, as Master of History of Art/Archaeology. Thesis title : "A Study of Historical Landscape, Road Networks and Communities at Banteay Chhmar Achaeological site, Cambodia". And in 2010 from Chulalongkorn University, Bangkok, Thailand, as Master of Southeast Asia Studies; Thesis title "The Comparative Study of Ancient Settlements at Kol in Cambodia and Phnom Rung in Thailand"; A new comparative approach by utilizing GIS and Remote Sensing techniques to interpret the two ancient agglomerate areas at Kol in Siem Reap province, Cambodia and Phnom Rung in Buriram province, Thailand. From 2012 to present he works at The APSARA Authority, Siem Reap, Cambodia, as APSARA GIS & IT Coordinater (for international research collaboration projects in Angkor Region).

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