United Nations International Meeting on the Applications of Global Navigation Satellite Systems

05-09 December 2022 | Vienna, Austria

Keeping Pace with Global Standards – Modernizing the Philippine Geodetic Reference Frame

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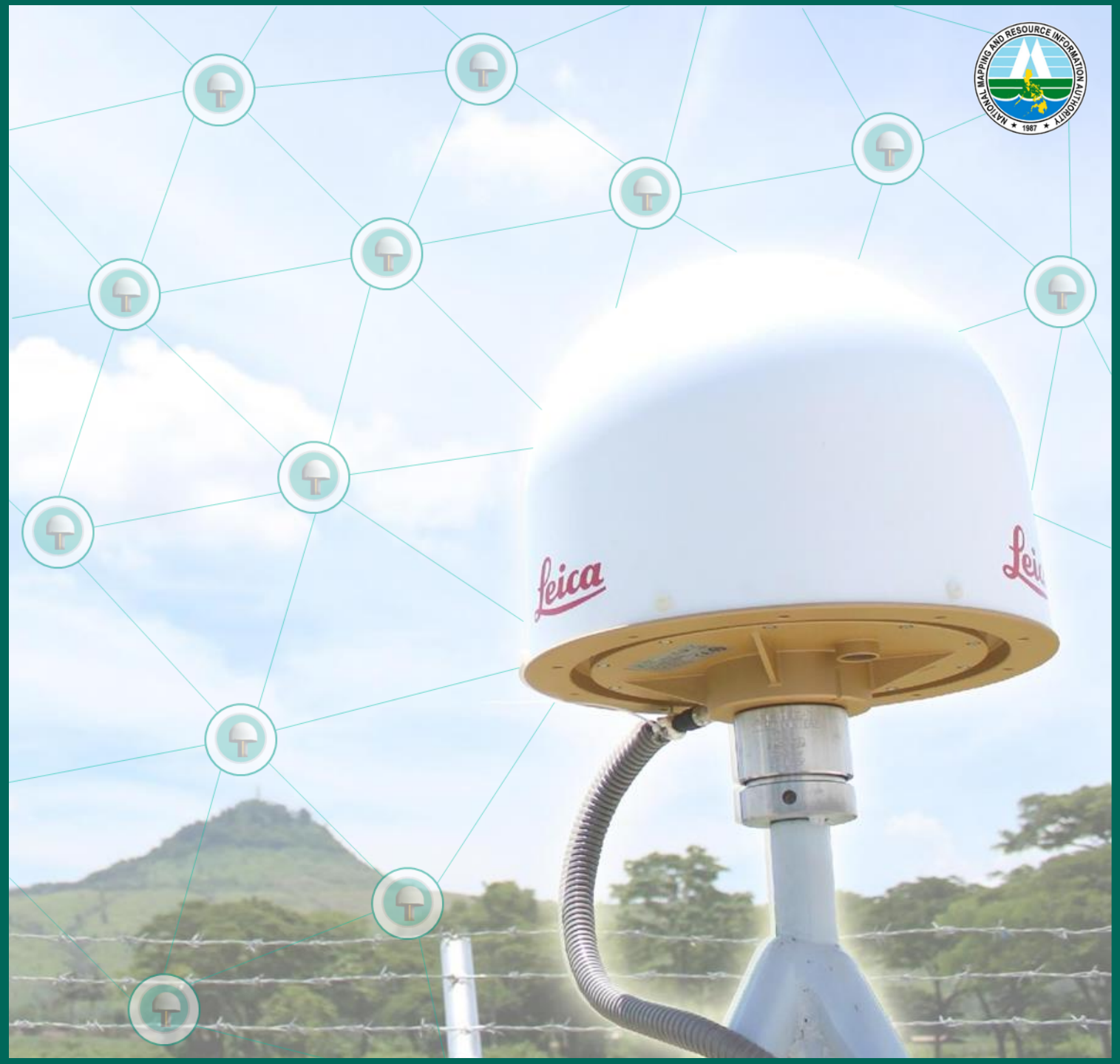
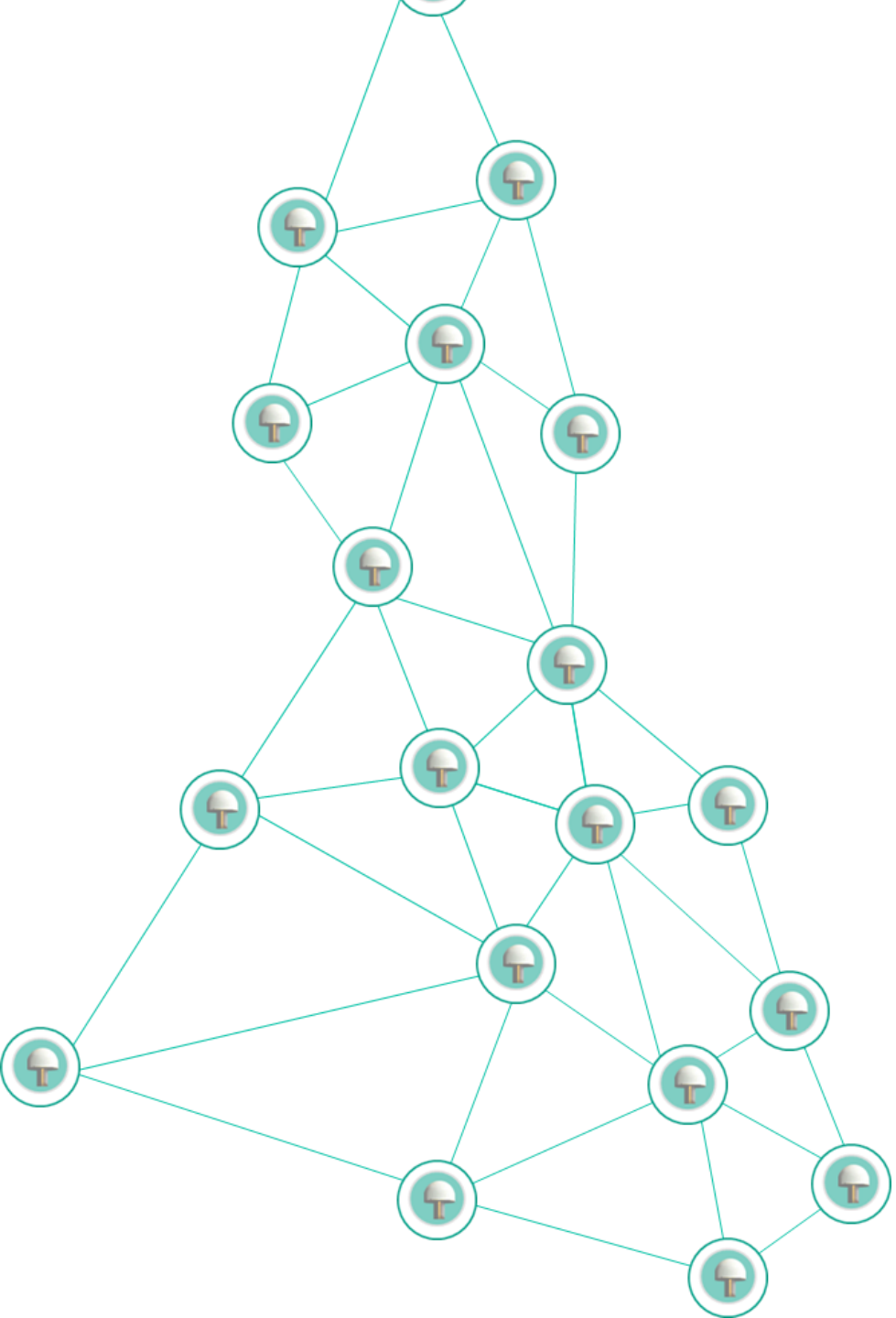
PHILIPPINES

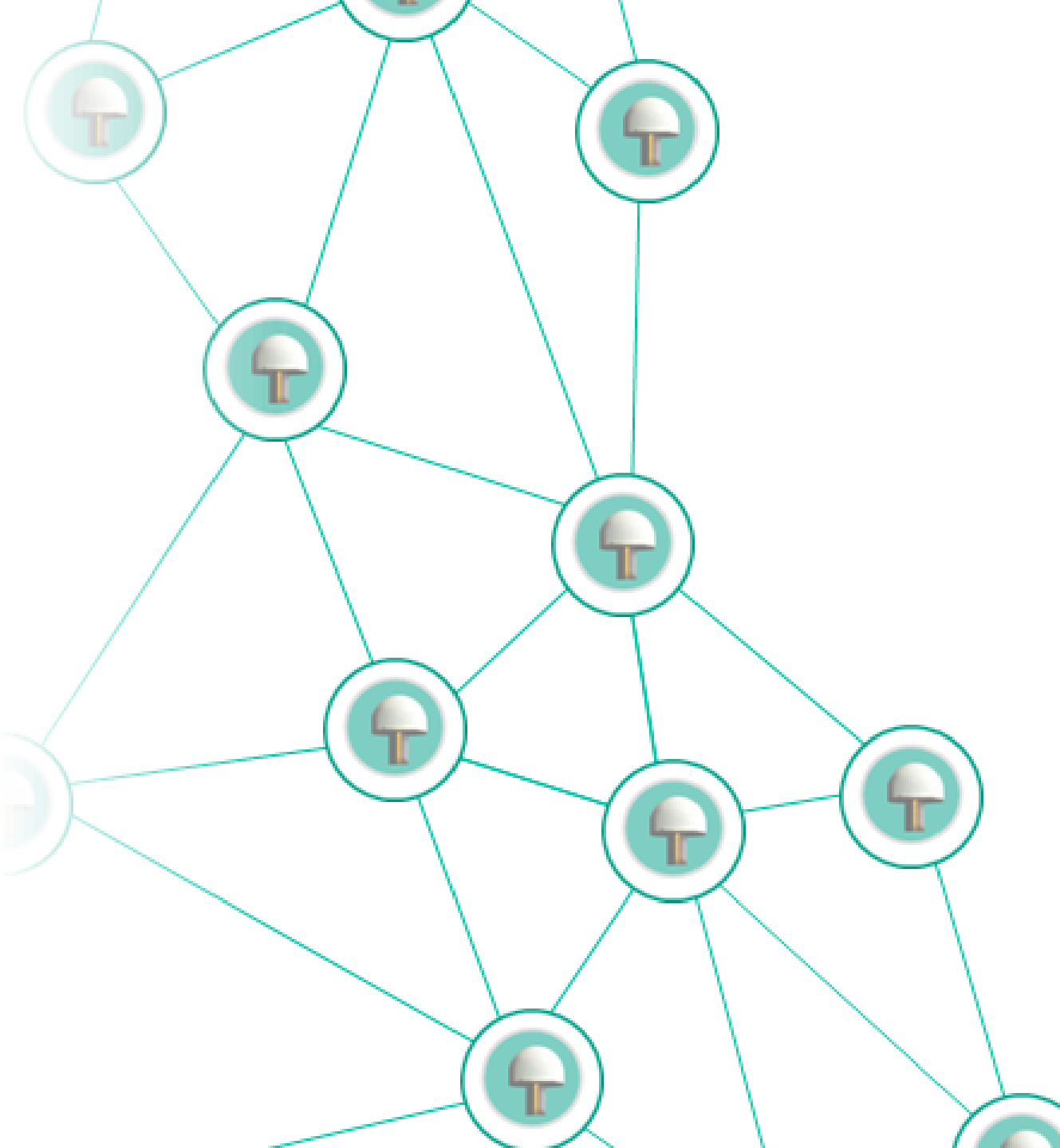


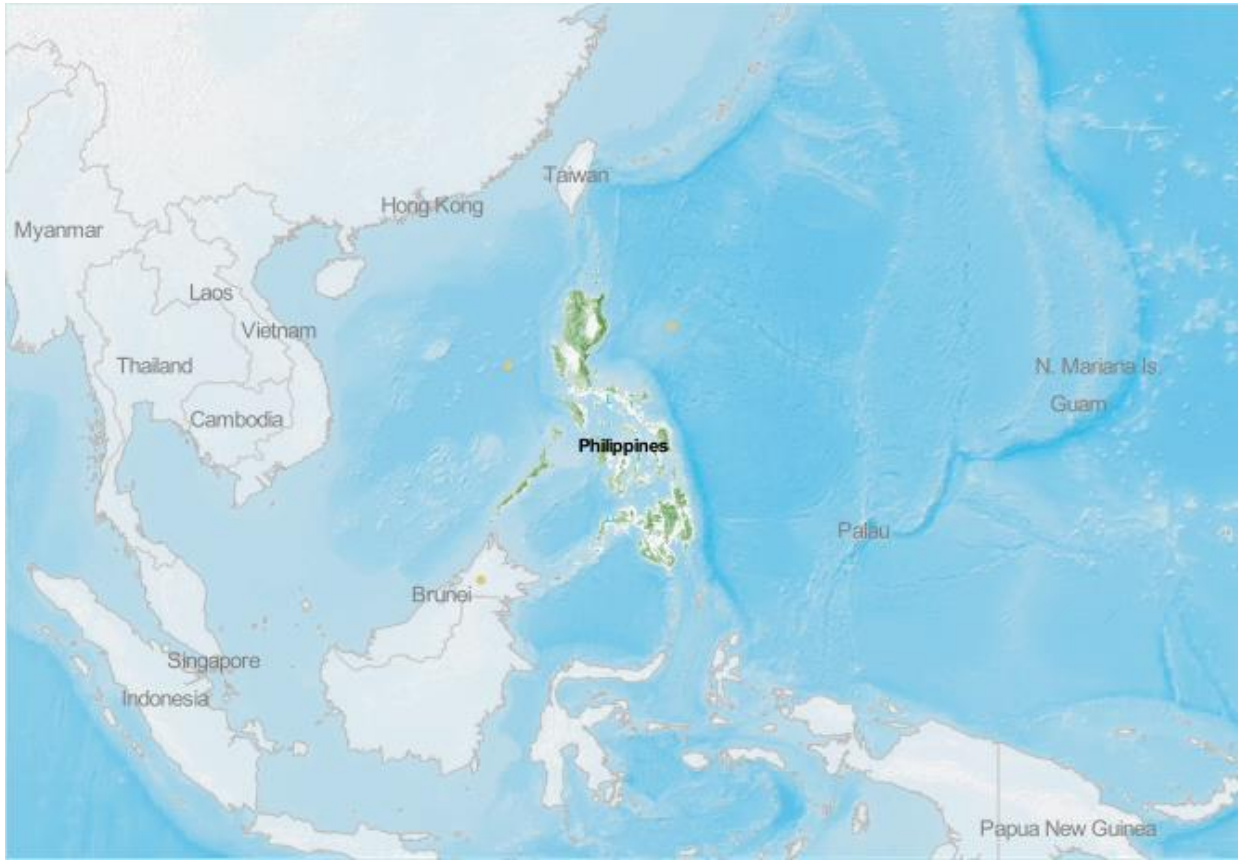


OUTLINE

- Geodetic & Geologic Landscapes of the Philippines
- Motivations/Drivers for Modernization
- Modernization Plan and Status of Implementation
- Challenges and Strategies
- Way Forward

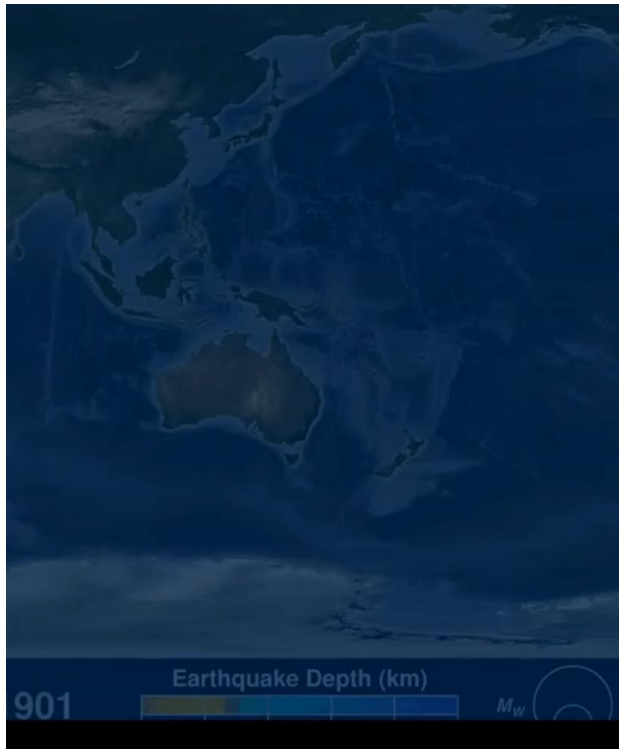
GEOLOGIC & GEODETIC LANDSCAPES OF THE PHILIPPINES

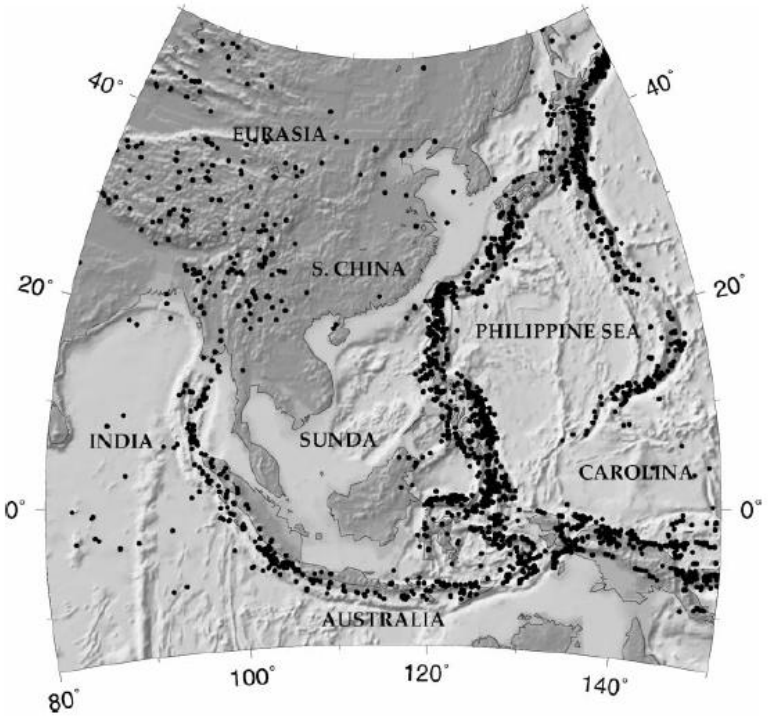




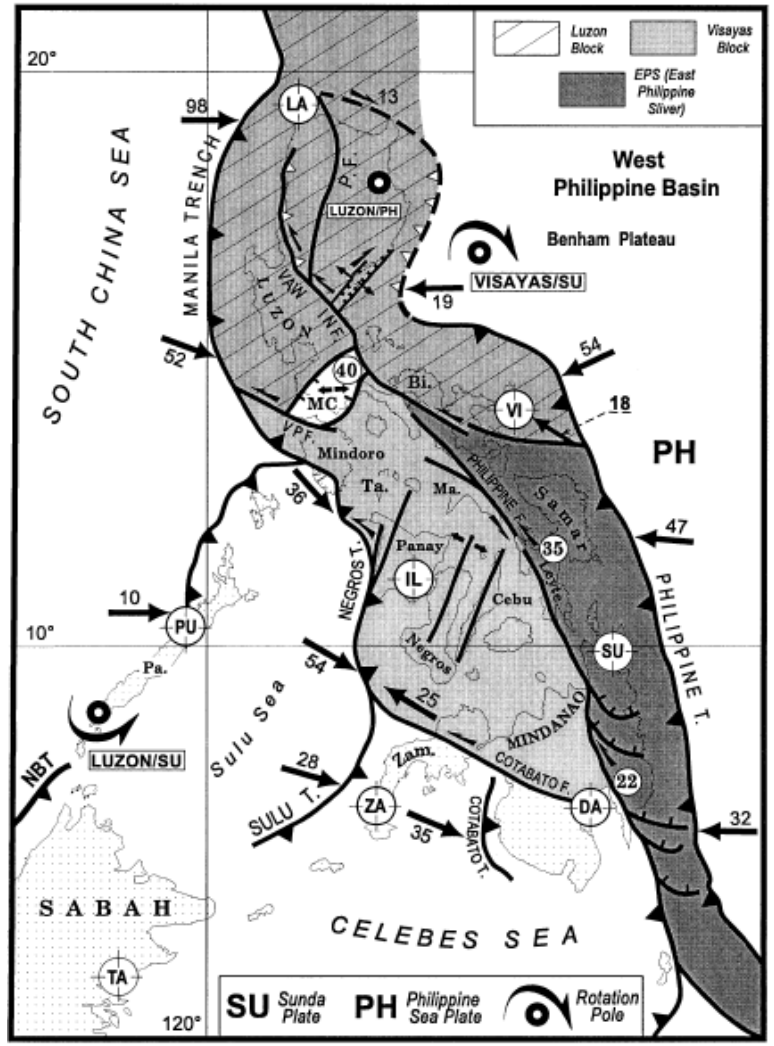
The Philippines

Geologic Landscape





Locations of shallow earthquakes outlining the main plate boundaries (Rangin et. al., 1999)



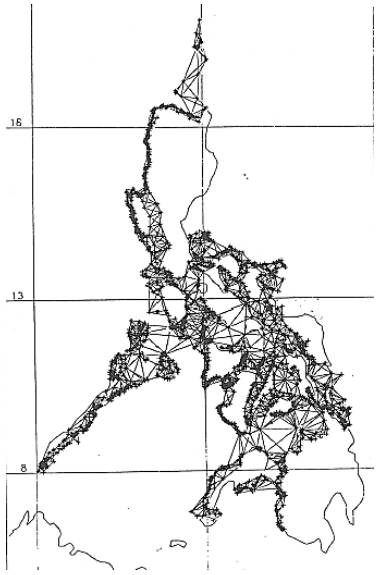
Distribution of the major tectonic boundaries and active mobile microblocks in the Philippines (Rangin et. al., 1999)

Geodetic Landscape

Evolution of Geodetic Infrastructure

Primary Triangulation Network of the Philippines

1901 – 1927



- Established by the US Coast and Geodetic Surveys using optical instruments and astronomical observations
- Datum established is local and static, with origin located at Balanacan in Mogpog, Marinduque
- Triangulation network used as reference in cadastre, topographic surveys, etc.

Geodetic Landscape

Evolution of Geodetic Infrastructure

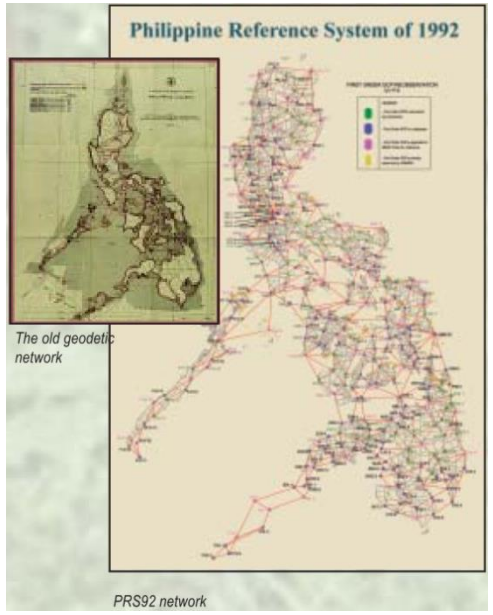
Primary Triangulation Network of the Philippines

1901 – 1927

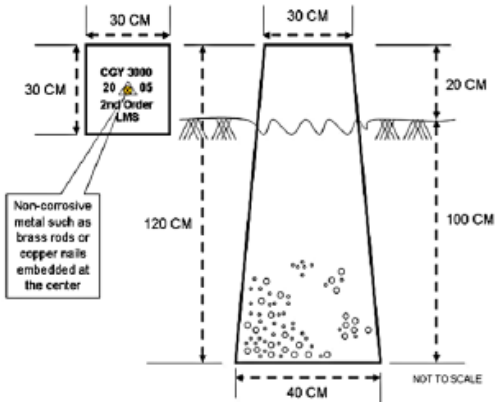
Philippine Reference System of 1992

PRS92

1989 – 1992



- Established using Global Positioning System (GPS) technology
- Datum is still local and static, retaining its origin at Balanacan
- Philippine Reference System of 1992 (PRS92) became the standard reference for surveying and mapping as per E.O. No. 45, as amended
- At the time of establishment, PRS92 was the best fit reference system for the Philippines



Geodetic Landscape

Evolution of Geodetic Infrastructure

Primary Triangulation Network of the Philippines

1901 – 1927

Philippine Reference System of 1992

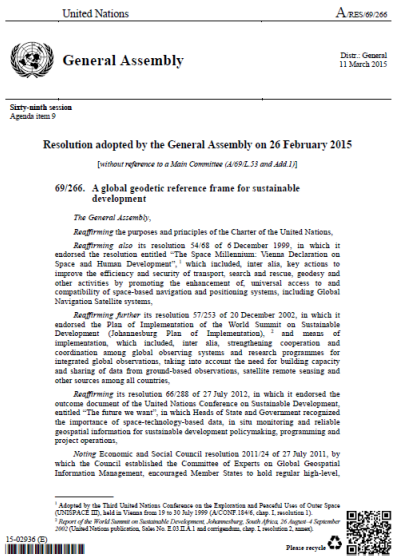
PRS 92

1989 – 1992

U.N. G.A. Resolution No. 69/366

United Nations

2015



United Nations A/RES/69/266

General Assembly Distr.: General 11 March 2015

Sixty-ninth session
Agenda item 9

Resolution adopted by the General Assembly on 26 February 2015

[without reference to a Main Committee (A/69/L.53 and Add.1)]

69/266. A global geodetic reference frame for sustainable development

The General Assembly,

Reaffirming the purposes and principles of the Charter of the United Nations,

Reaffirming also its resolution 54/68 of 6 December 1999, in which it endorsed the resolution entitled "The Space Millennium: Vienna Declaration on Space and Human Development",[1] which included, inter alia, key actions to improve the efficiency and security of transport, search and rescue, geodesy and other activities by promoting the enhancement of, universal access to and compatibility of space-based navigation and positioning systems, including Global Navigation Satellite systems,

Reaffirming further its resolution 57/253 of 20 December 2002, in which it endorsed the Plan of Implementation of the World Summit on Sustainable Development (Johannesburg Plan of Implementation),[2] and means of implementation, which included, inter alia, strengthening cooperation and coordination among global observing systems and research programmes for integrated global observations, taking into account the need for building capacity and sharing of data from ground-based observations, satellite remote sensing and other sources among all countries,

Reaffirming its resolution 66/288 of 27 July 2012, in which it endorsed the outcome document of the United Nations Conference on Sustainable Development, entitled "The future we want", in which Heads of State and Government recognized the importance of space-technology-based data, in situ monitoring and reliable geospatial information for sustainable development policymaking, programming and project operations,

Noting Economic and Social Council resolution 2011/24 of 27 July 2011, by which the Council established the Committee of Experts on Global Geospatial Information Management, encouraged Member States to hold regular high-level,

[1] Adopted by the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in Vienna from 19 to 30 July 1999 (A/CONF.184/6, chap. I, resolution 1).

[2] *Report of the World Summit on Sustainable Development, Johannesburg, South Africa, 26 August–4 September 2002* (United Nations publication, Sales No. E.03.II.A.1 and corrigendum, chap. I, resolution 2, annex).

15-02936 (E)

Please recycle

- UN General Assembly Resolution No. 69/366
  'A global geodetic reference frame for sustainable development'
- Recognizes the importance of global navigation satellite systems (GNSS) technology in the society
- Encourages member states to adopt and contribute to the realization of a global geodetic reference frame

Geodetic Landscape

Evolution of Geodetic Infrastructure

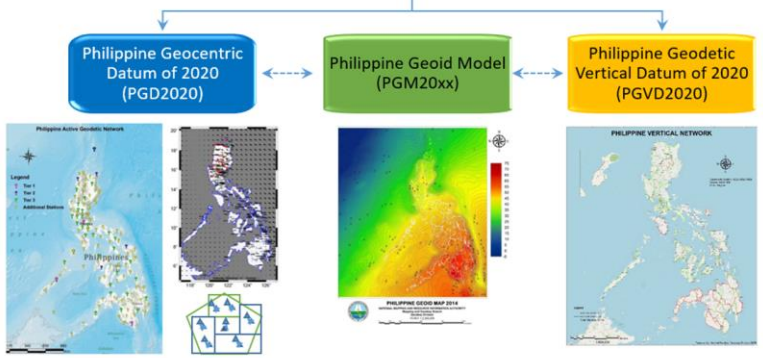
Primary Triangulation Network of the Philippines
1901 – 1927

Philippine Reference System of 1992
PRS92
1989 – 1992

U.N. G.A. Resolution No. 69/366
United Nations
2015

Modernization of the Philippine Geodetic Reference System
2016 – 20xx

Modern PGRS



Geometric RF:
Name: *PGD2020*
Type: *Semi-dynamic and Geocentric*
in *ITRF2014 (reference epoch 16 January 2020)*

Vertical RF:
Name: *PGVD 2020*
Type: *MSL-fitted geoid* **Realized**
Will be connected *to the IVRF (WHS)*

Comes with a *National Geoid, Deformation Model and Distortion Grid*

- The future of positioning in the Philippines
- Aims to align the country's reference to a global geodetic reference frame (i.e. WGS84/ITRF)
- New reference system will be able to account for effects of geodynamics (i.e. earthquakes, plate tectonics)
- Takes full advantage of modern positioning techniques

Geodetic Landscape

Current Frames in Use

Horizontal

- Luzon Datum 1911
- Philippine Reference System of 1992 (PRS92)
- World Geodetic System of 1984 (WGS84) or ITRF

- *Propagated by GNSS observation*
- *Physical realization: geodetic control points (passive & active)*

Vertical

- Mean Sea Level

- *Propagated by geodetic leveling*
- *Physical realization: benchmarks*

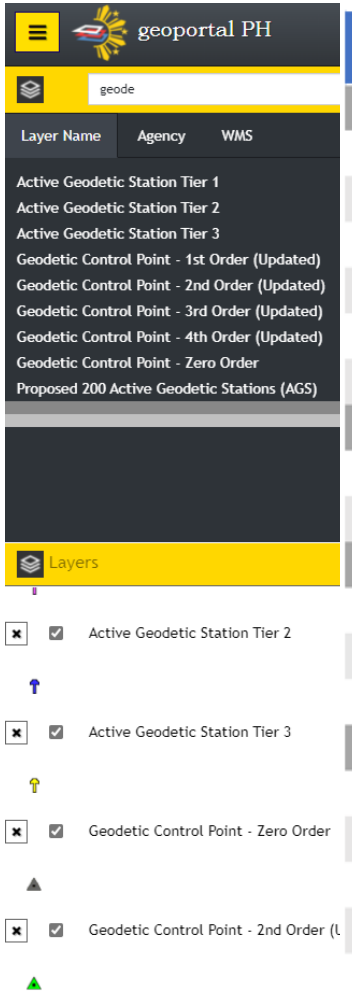
Gravity

- NAMRIA Absolute Gravity Station

- *Densified using gravity observations*
- *Physical realization: gravity stations*

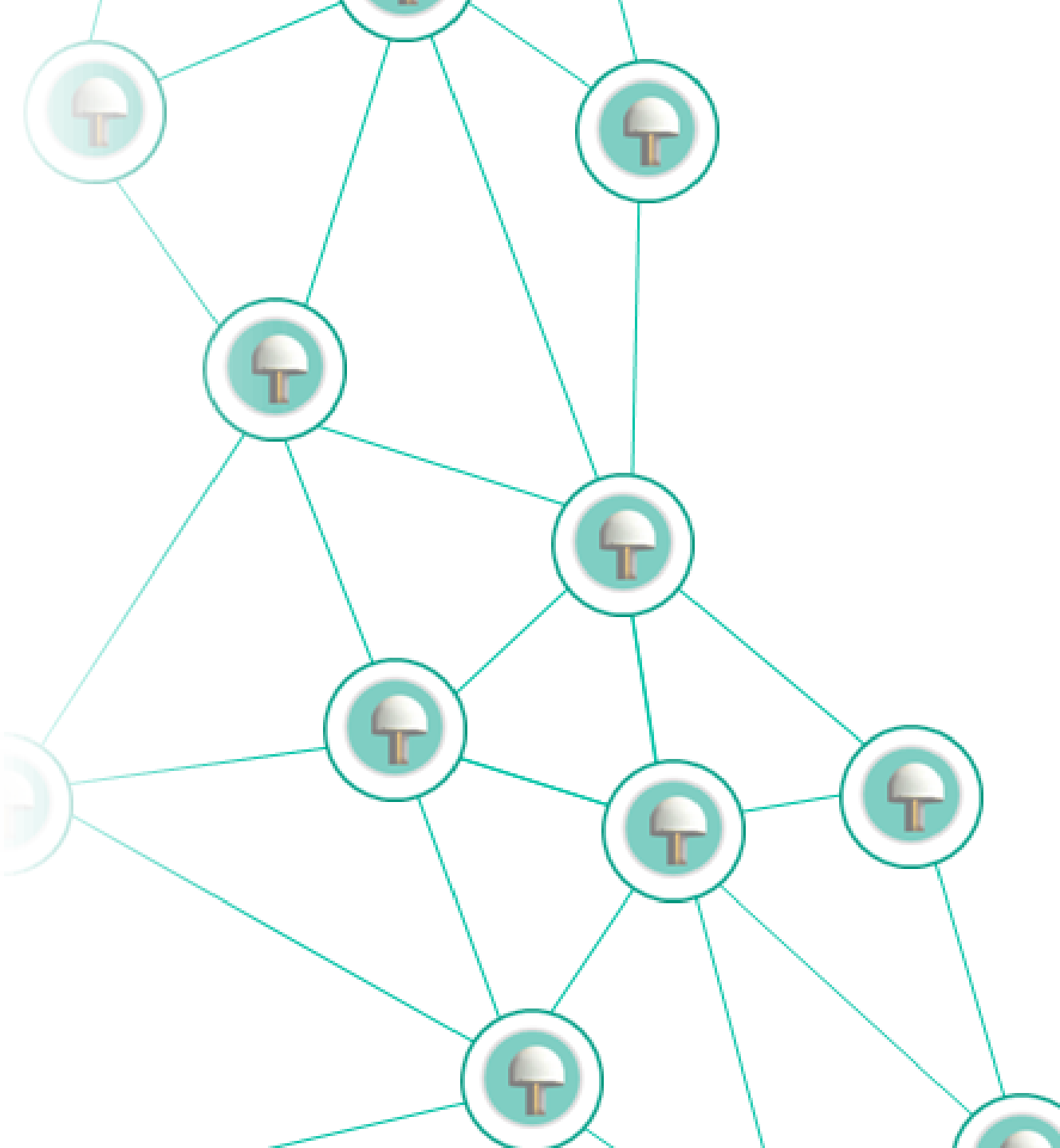
Geodetic Landscape

Existing Geodetic Infrastructure



	Accuracy Standard	Spacing	Number
Horizontal			
AGS	1 ppm	100km	57 + 1 (shared)
Zero order	1 ppm	70km	60
1st order	10 ppm	50km	314
2nd order	20 ppm	20 km	2,449
3rd order	50 ppm	10km	28,027
4th order	100 ppm	5km	32,021
Vertical			
1st order	$4\sqrt{K}$ (mm)	1 km (national roads)	16,326
2nd order	$8.4\sqrt{K}$ (mm)	0.5 km (city streets)	2,332
Gravity			
1st order		Provincial	83
2nd order I		Municipal	1,583
2nd order II		2-3 kms	6,517
International Collaborations			
IGS sites	4 (PIMO, PTAG, PPPC, PGEN)		
DORIS site	1 (Manille)		
APREF / APRGP	PTAG / All PAGeNet AGS		
MGM-Net	2 (PLUZ, PMIN)		
REGINA	1 (PTGG)		

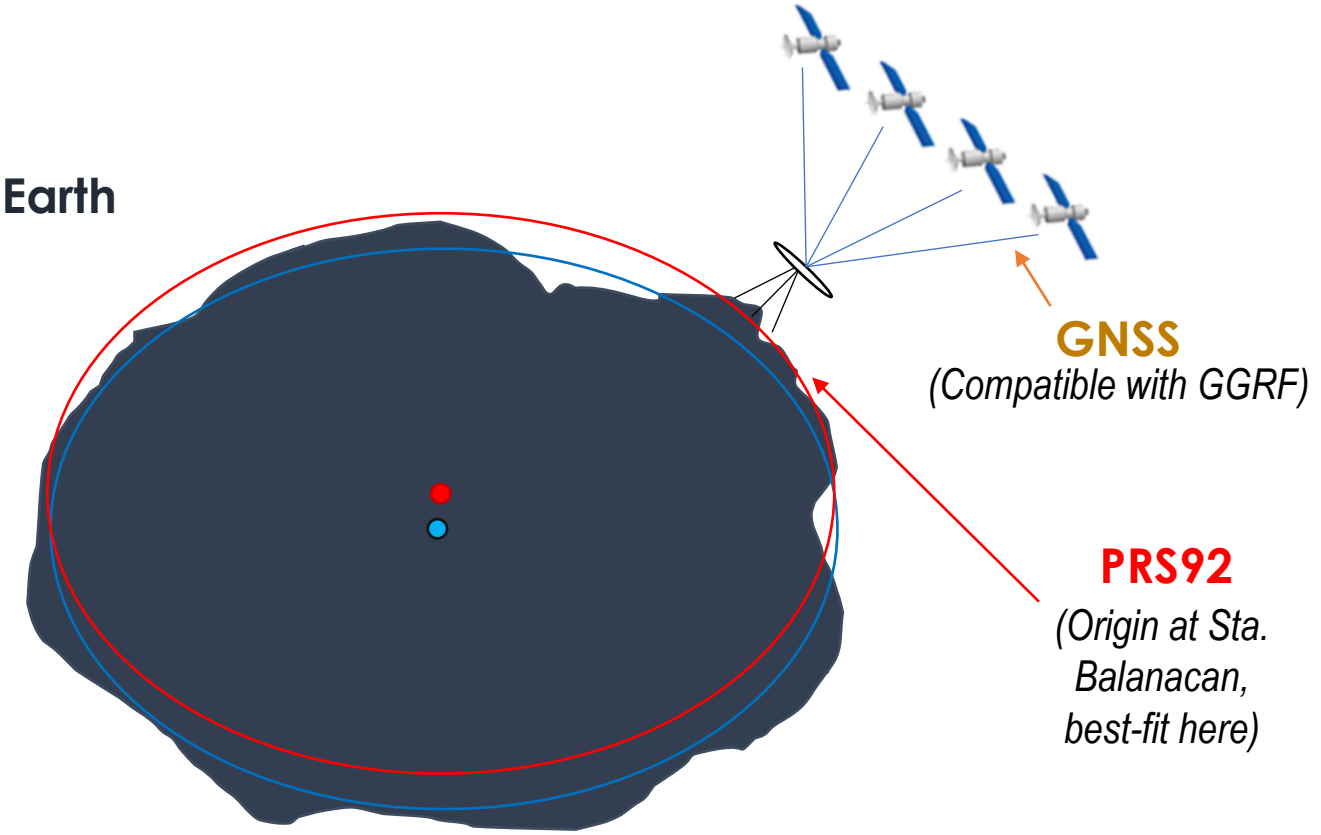
MOTIVATION/ DRIVERS

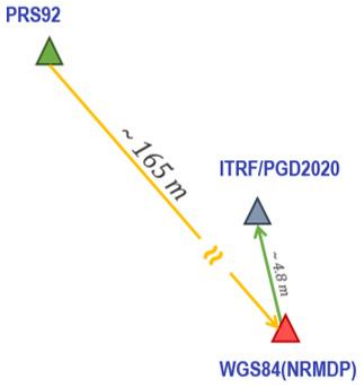


Limitations of Current Reference Frame

Our current geodetic reference is local

GGRF
(Origin at center of the earth, best-fit globally)





Limitations of Current Reference Frame

… and does not account for geodynamics

2005

2022

- Earthquakes
- Plate motion (~30 mm/yr = 0.51m shift in 17yrs)
- Improvements in measurement/modelling of the earth

ILN-1, 1990-2010 (PASUQUIN)

YEAR	WGS84 COORDINATES	
	LATITUDE (φ)	LONGITUDE (λ)
1990	18°23'41.13460"	120°35'49.02518"
2010	18°23'41.19088"	120°35'49.04865"
Δ	$\Delta\varphi$ =	
	≈ 1	

Source:
E.D. Lopez
Migration to Geocentric Datum
20 May 2019

Station PLW-7 (1990-2010)

Station	WGS 84 Coordinates	
	Latitude, φ	Longitude, λ
PLW-7 (1990.496)	9° 44' 25.33347"	118° 44' 25.60607"
PLW-7 (2010.918)	9° 44' 25.28000"	118° 44' 25.58260"
Δt =21.422 years	$\Delta\varphi$ = -0.0	
Note: 1" ~30m	v_φ =0.002	
	~7.5 cm/y	

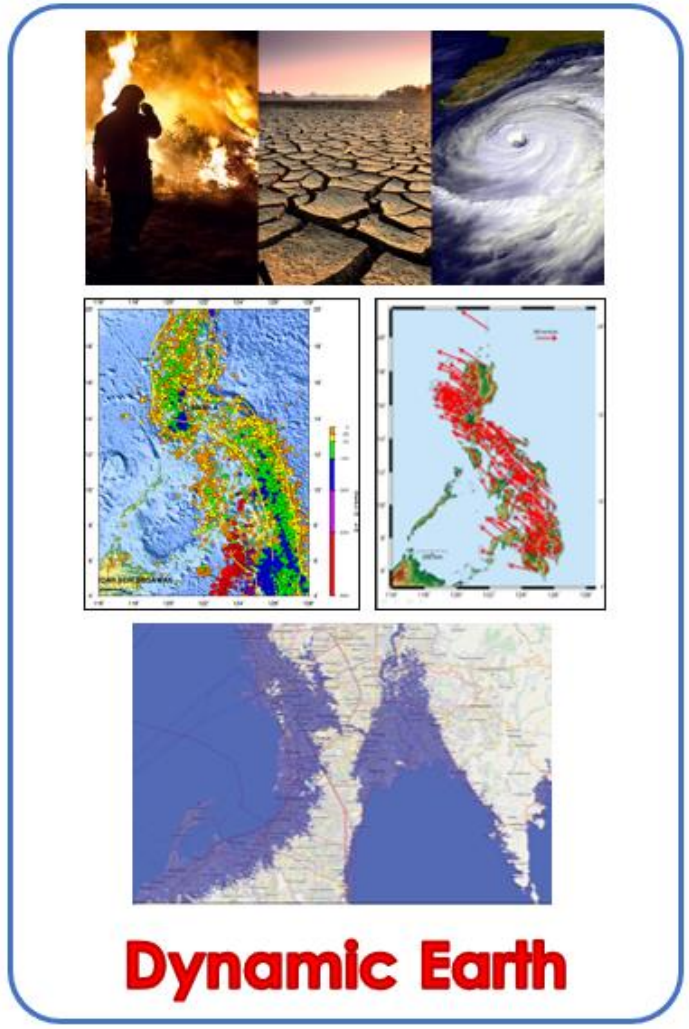
ZGN-6, 1990-2010 (SIOCON)

YEAR	WGS84 COORDINATES	
	LATITUDE (φ)	LONGITUDE (λ)
1990	7°42'28.92679"	122°08'11.80289"
2010	7°42'28.84885"	122°08'11.82369"
Δ	$\Delta\varphi$ = -0.07794"	$\Delta\lambda$ = +0.02080"
	≈ 2.338m (S)	≈ 0.624m (E)

Located in a plate boundary zone characterized by active and complex tectonics and high seismicity

Drivers for Modernization

1. Need to monitor deformations and global events
2. Call for "FAIR" (Findable, Accessible, Interoperable, Reusable) geodetic products and services
3. Maximize benefits from modern geodetic technologies
4. International commitments & standards



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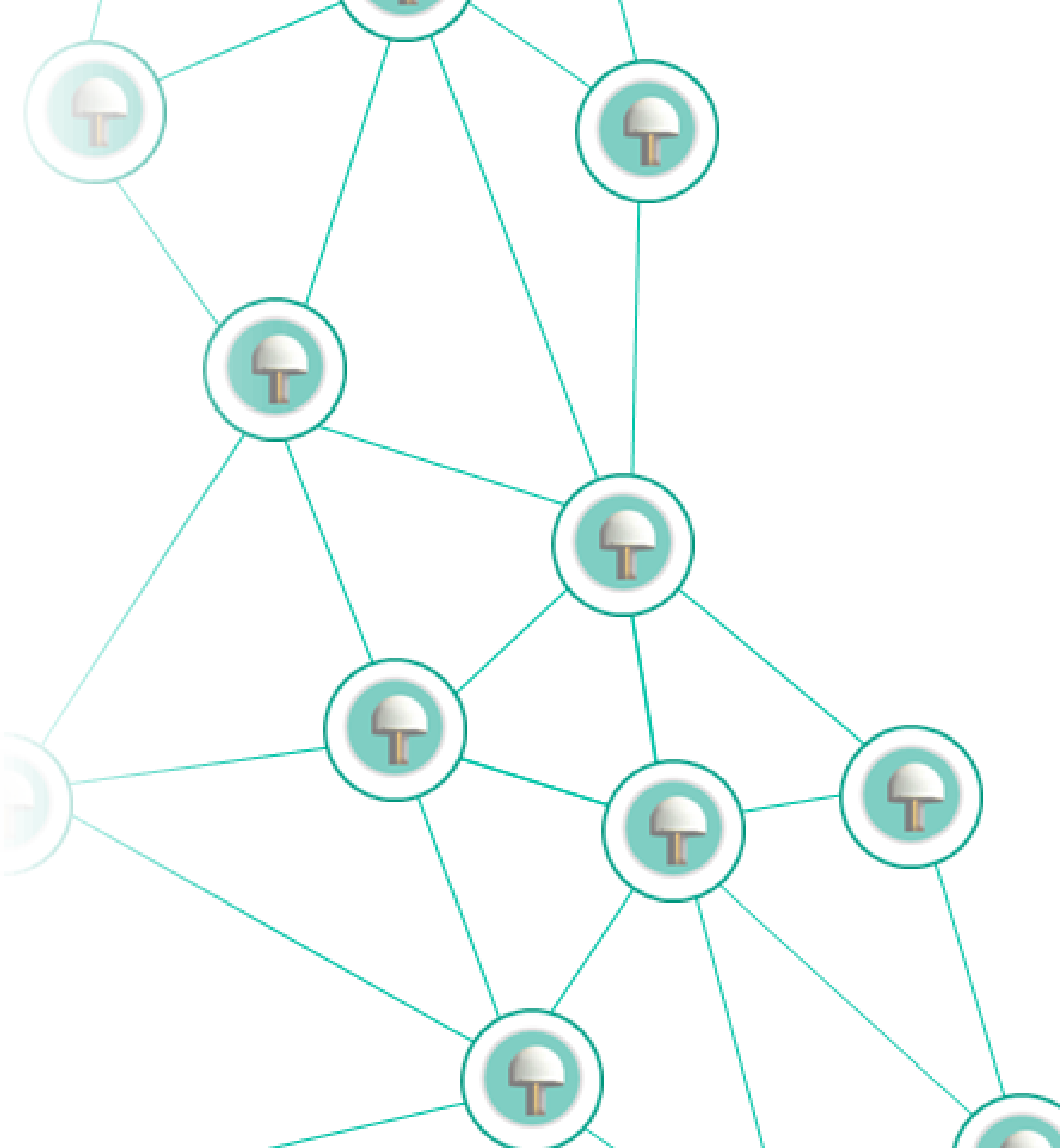
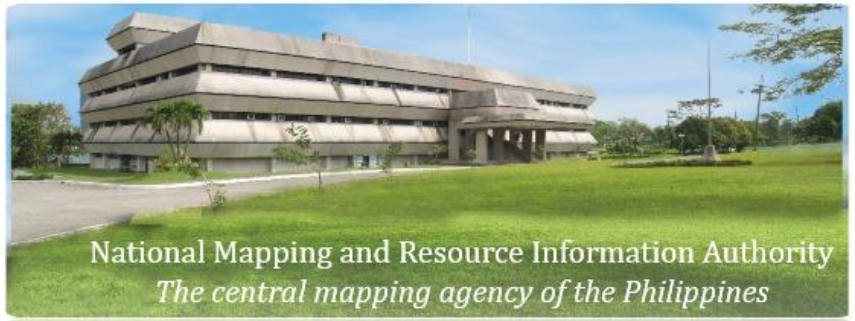
MODERNIZATION PLAN

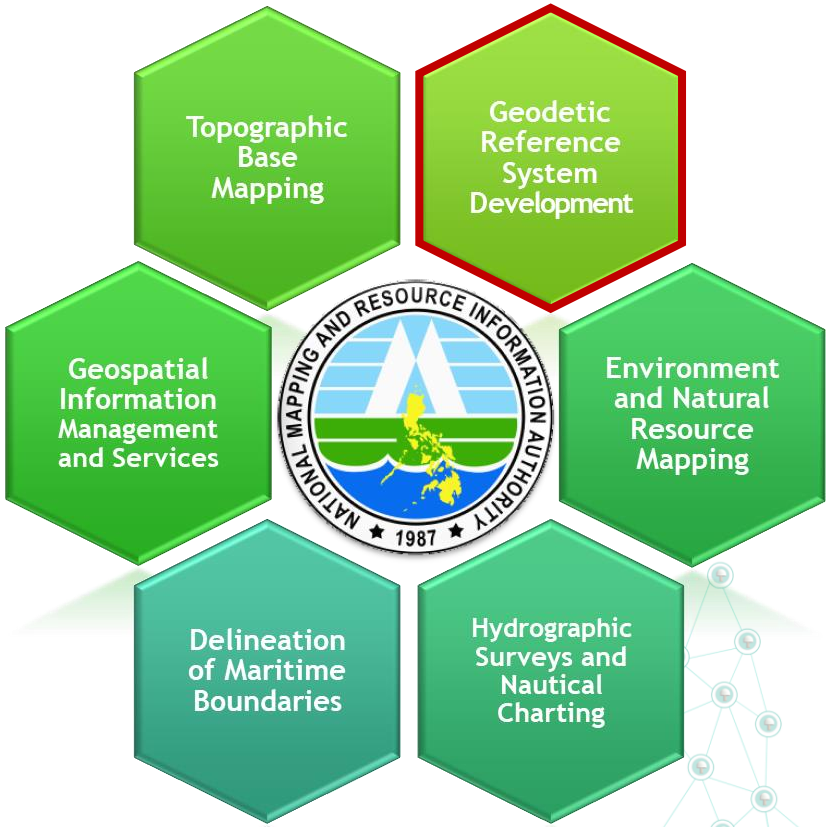


PGRS Modernization

- NAMRIA as central mapping agency of the government is spearheading the implementation of the PGRS Modernization



Created by virtue of Executive Order No. 192 s. 1987 to act as the central mapping agency and provide the public with mapmaking services...

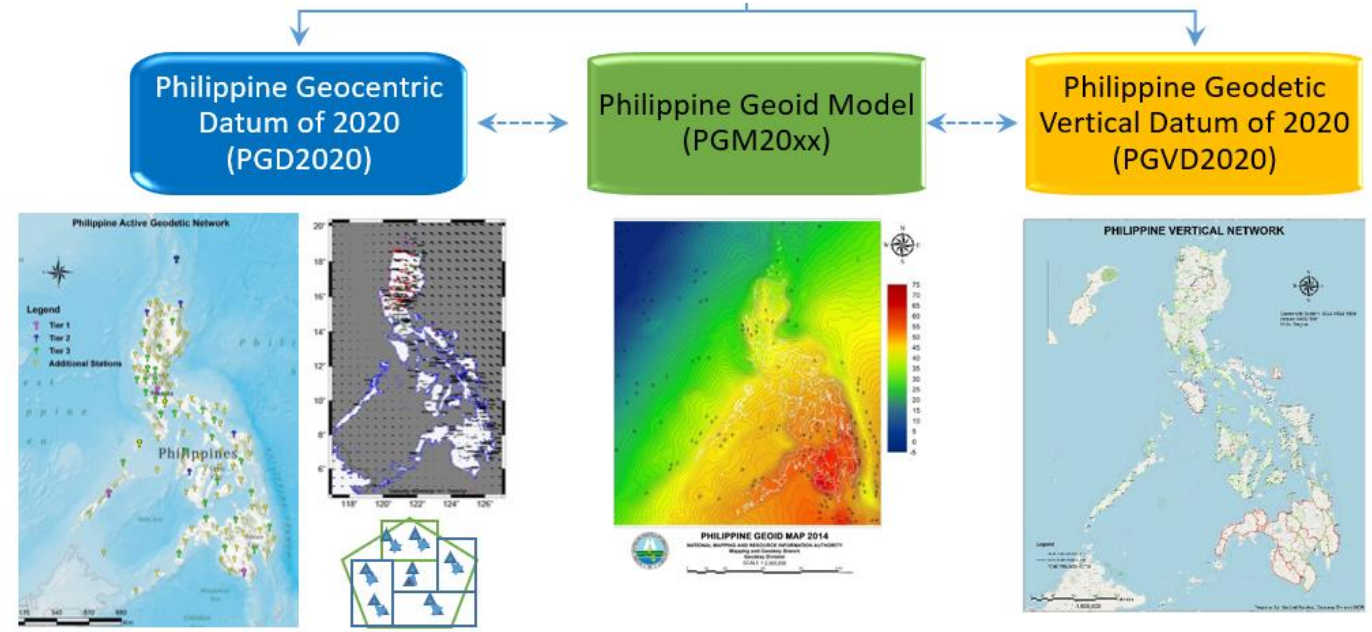


Modern PGRS

Government

Academe

Private Sector



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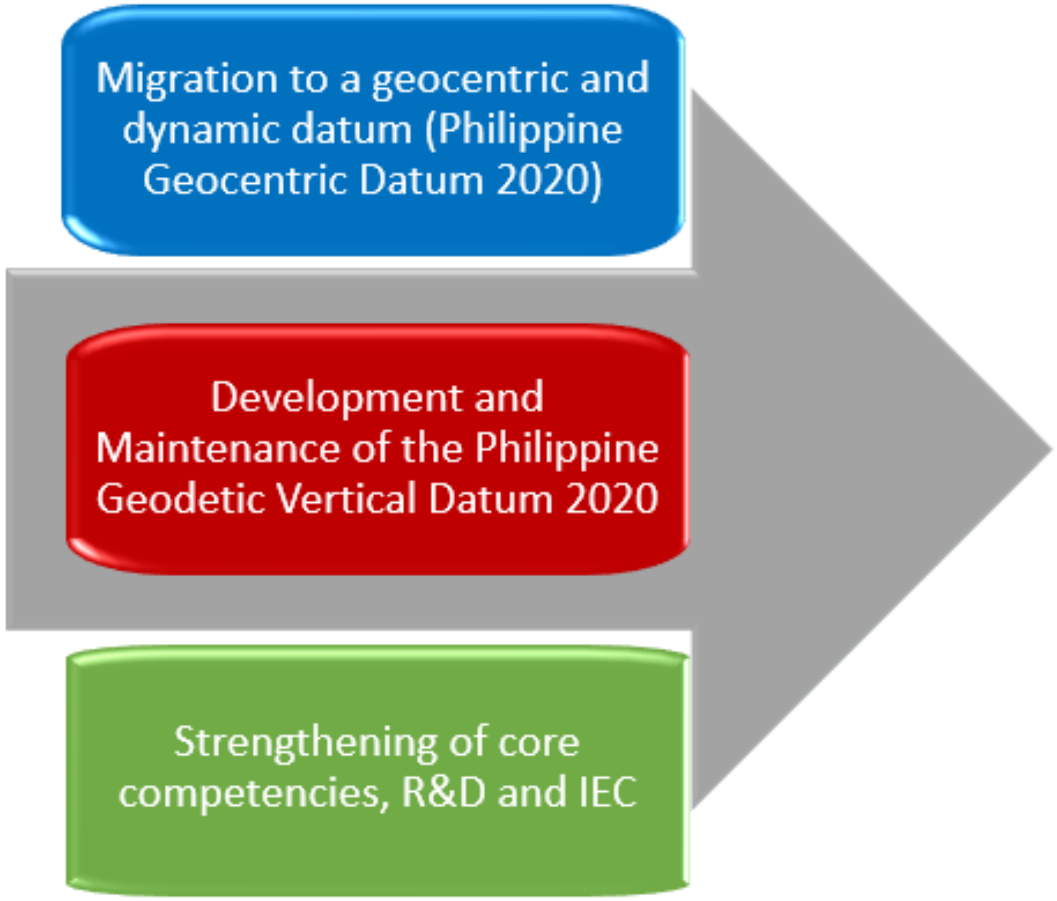
Modern PGRS

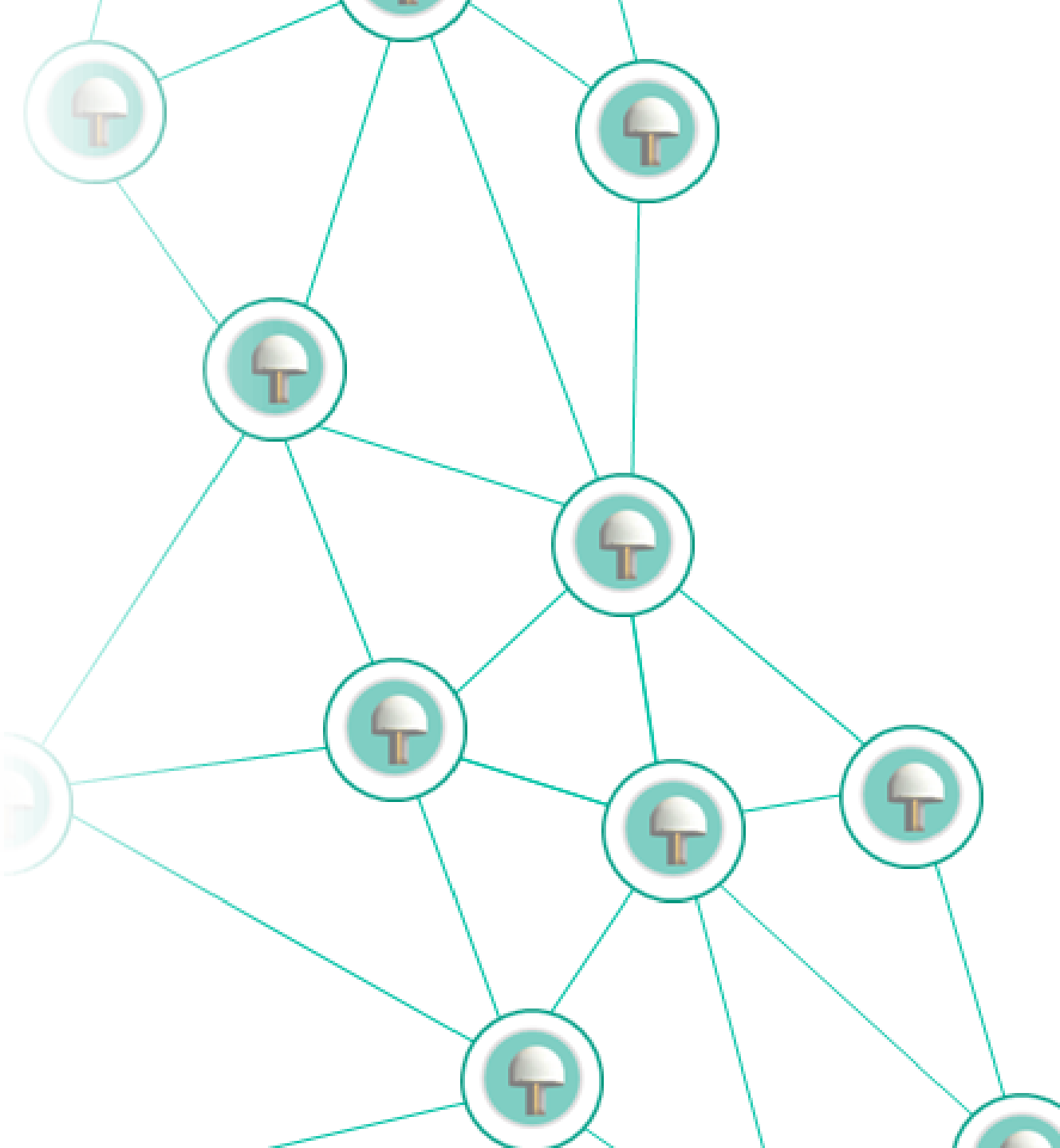


- Establish 200 AGS
- Develop deformation model and distortion grid
- Compute ITRF coordinates of PAGeNet
- Re-observe 3000 GCPs (Zero, 1st and 2nd) for 3 cycles

- Densify gravity stations
- Re-compute PGM20xx

- Train NAMRIA staff
- Massive IEC campaigns
- Amendment of existing policies, standards and workflows
- R&D on PGRS Modernization

STATUS OF IMPLEMENTATION

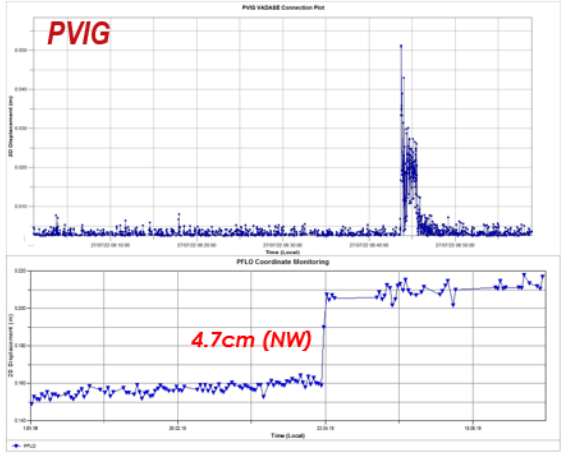


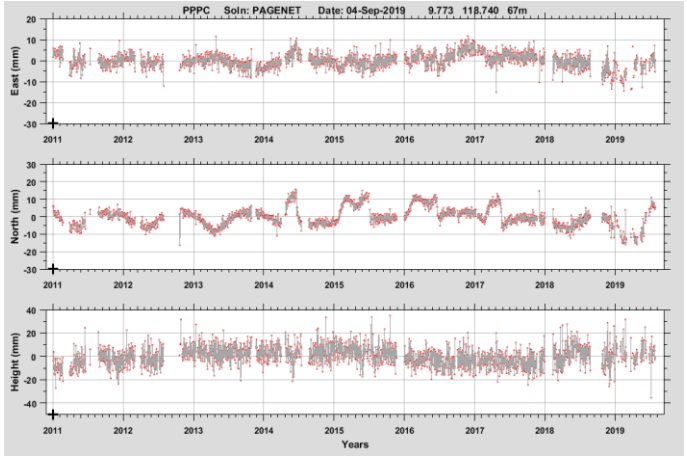
What has been done to date?

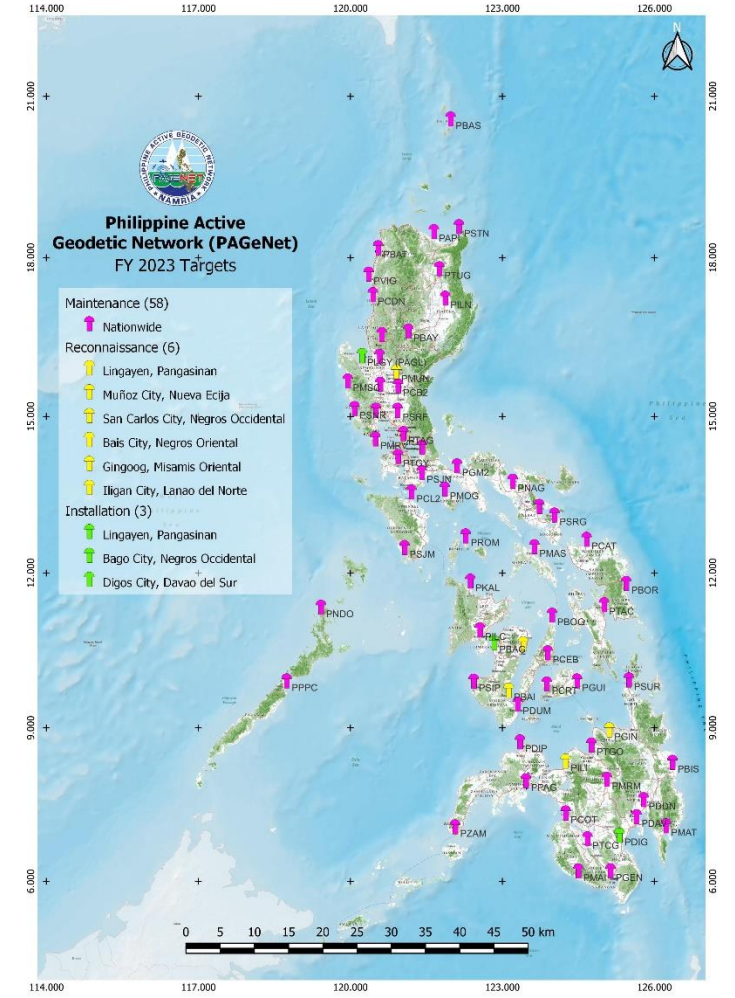
- PGD2020
  - ✓ Established 58 active geodetic stations
  - ✓ Computed PGD2020 reference coordinates of PAGeNet
  - ✓ Daily coordinate monitoring of PAGeNet using Bernese (2008-present)
  - ✓ Developed deformation model (2020 Grid)
  - ✓ Completed 1st cycle of passive GCP re-observation
  - ✓ Distortion grids (ongoing, pilot area: NCR)
- PGVD2020
  - ✓ Computed Philippine Geoid Model (latest version 2018.98)
  - ✓ Troubleshooting of level network
  - ✓ Densification of gravity stations
  - ✓ Connection to the IVRF*
- Strengthening of competencies
  - ✓ Research and development
  - ✓ Capacity building
  - ✓ IEC campaigns

What has been done to date?

- Densification of the Philippine Active Geodetic Network (PAGeNet)
  - 58 stations established to date
  - Daily coordinate monitoring with Bernese GNSS software
  - Provides vital support to applications beyond surveying and mapping

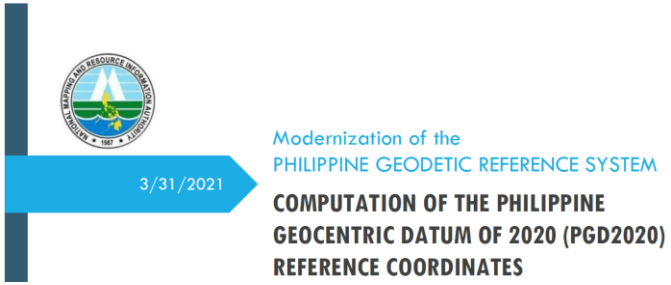




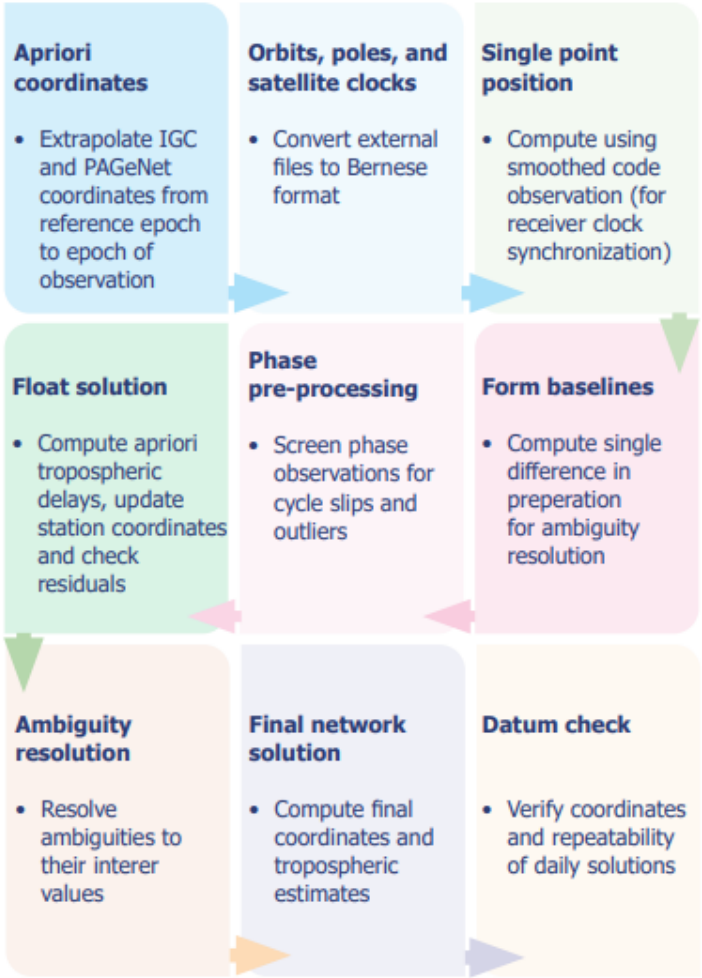


What has been done to date?

- Computation of the PGD2020 Reference Coordinates
  - Based on January 2020 PAGeNet data
  - Combination of adjusted (40 AGS) and projected (for 10 AGS with no January 2020 data) coordinates
  - Tied to 17 (13 online) International GNSS Service (IGS) stations
  - Final station coordinates have repeatability RMS of 2.51mm (N), 2.94mm (E), and 6.65mm (U)

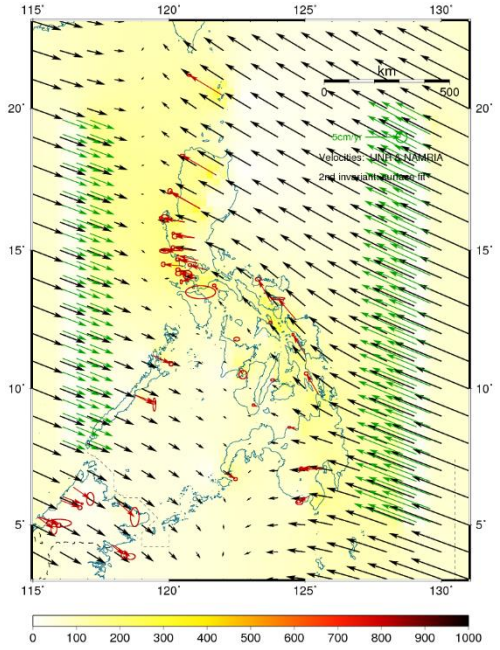


Site	Latitude (DMS)	RMSE (m)	Longitude (DMS)	RMSE (m)	Ellipsoidal Height[1] (m)	RMSE (m)
PBAS	20°26'58.20540"	0.00010	121°58'32.69172"	0.00012	79.99811	0.00038
PBAT	18°03'14.05260"	0.00010	120°32'43.78380"	0.00013	51.74248	0.00037
PBAY	16°28'53.59260"	0.00009	121°08'34.55412"	0.00011	322.87643	0.00031
PBGU	16°25'04.06560"	0.00010	120°37'04.23048"	0.00013	1545.12534	0.00040
PBOG	11°02'46.67676"	0.00008	123°58'43.70340"	0.00011	88.53255	0.00031
PCDN	17°10'16.93056"	0.00009	120°26'30.83964"	0.00013	55.33468	0.00034
PCLP	13°25'39.38412"	0.00009	121°11'40.31412"	0.00013	64.05837	0.00038
PCOT	7°11'58.57296"	0.00010	124°14'49.31736"	0.00014	86.17547	0.00042
PCRT	9°42'45.87516"	0.00010	123°52'22.55772"	0.00016	76.53025	0.00041
PDDN	7°27'33.75684"	0.00009	125°46'59.70216"	0.00012	90.59253	0.00036
PDUM	9°19'18.62544"	0.00008	123°18'00.28080"	0.00012	88.39192	0.00034
PGEN	6°03'53.68212"	0.00010	125°07'53.98104"	0.00016	121.08617	0.00042
PGUI	9°46'20.73216"	0.00009	124°28'15.83832"	0.00015	116.88435	0.00041
PGUM	13°55'12.66960"	0.00010	122°06'04.67820"	0.00016	64.02767	0.00040

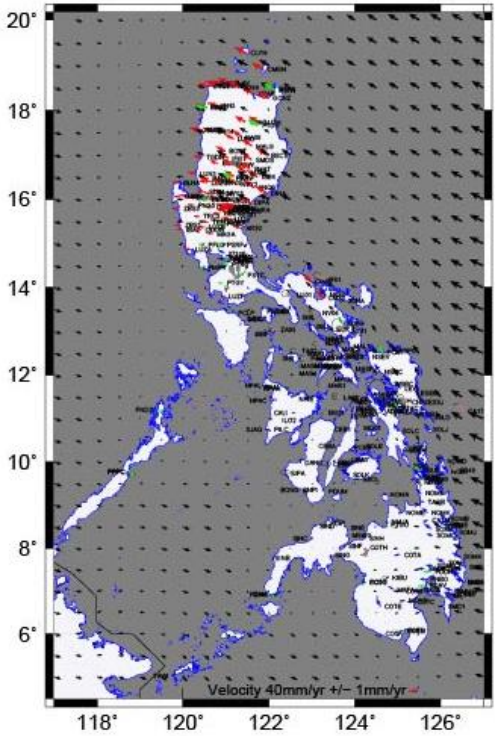


What has been done to date?

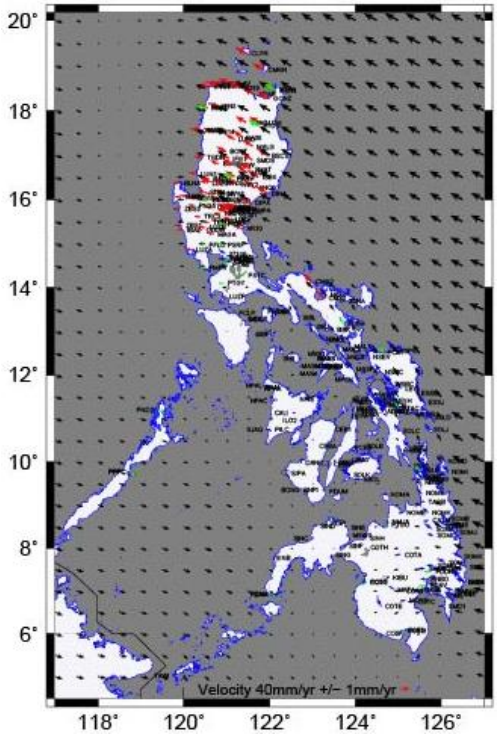
- Development of the National Deformation Model



- **2017 Prototype Deformation Model**
- *Developed with Newcastle University*
- *Input data:*
  - *PAGeNet (1 month data)*
  - *GSRM*



- **2018 Deformation Model**
- *Developed with Dr. Chris Pearson (Otago University)*
- *Input data:*
  - *PAGeNet (1 year data)*
  - *Hsu, et. al.*
  - *Kreemer, et. al. compilation*
  - *Phivolcs*



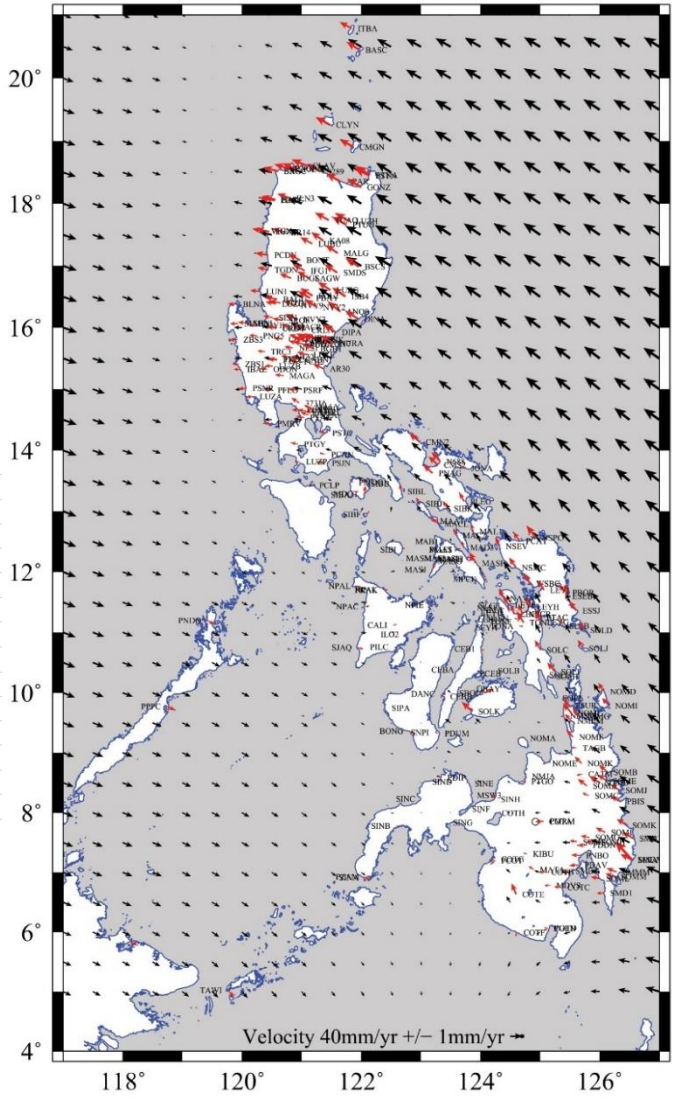
- **2019 Deformation Model**
- *Developed with Dr. Chris Pearson (Otago University)*
- *Input data:*
  - *PAGeNet (2016-2018, 33)*
  - *NAMRIA/UNAVCO (21)*
  - *Hsiu, et. al. (101)*
  - *Phivolcs (123)*

What has been done to date?

- Development of the National Deformation Model (2020 Grid)
  - Developed in-house with guidance from Dr. Chris Pearson (Otago University)
  - Input data:
    - PAGeNet (2008-2019, 43)
    - NAMRIA/UNAVCO (21)
    - Hsu, et. al. (102)
    - Phivolcs (141)
    - External constraints:
      - Kreemer, et. al. (E/W)
      - Yong, et. al. (Sabah)

Validation (RMS)

220160	E (m)	N (m)	U (m)	combined
RMS	0.0101	0.0081	0.0083	0.0154
Max	0.0261	0.0220	0.0133	0.0409
Min	-0.0122	-0.0233	-0.0212	0.0039
average	0.0056	0.0009	0.0021	0.0132
StDev	0.0085	0.0082	0.0082	0.0080
stdev mean	0.0016	0.0015	0.0015	0.0015
210040				
RMS	0.0061	0.0050	0.0104	0.0130
Max	0.0077	0.0108	0.0222	0.0230
Min	-0.0121	-0.0156	-0.0188	0.0012
average	-0.0033	-0.0016	0.0012	0.0118
StDev	0.0053	0.0049	0.0106	0.0057
stdev mean	0.0012	0.0011	0.0024	0.0013



Coordinate Computation
- To compute ITRF2014 coordinates of AGS/ passive GCPs
- Bernese GNSS Software/AusPOS

Velocity Estimation
- To compute velocity estimates of sites
- Matlab PTS script (Otago University)

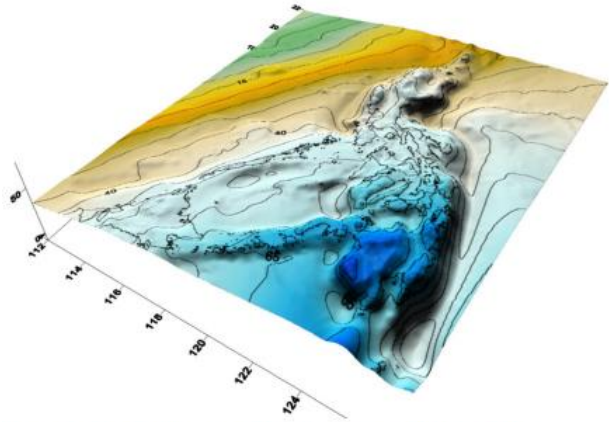
Alignment of Velocities
- To align velocity mesurements from different sources
- Rectify (executable)

Gridding
- To generate gridded velocity measurement for the entire archipelago
- Generic Mapping Tools (GMT)

Validation
- To validate gridded velocity measurement using select PAGeNet sites
- SNAP or Python script

What has been done to date?

- Development of the Philippine Geoid Model (PGM)
  - Developed through technical assistance from National Space Institute of the Denmark Technical University (DTU-Space) and funding from the U.S. National Geospatial Intelligence Agency (NGA)
  - Input data:
    - land gravity surveys
    - nationwide airborne gravity surveys
    - marine satellite altimetry (DTU-10)
    - satellite gravity data from the Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) mission release 5



igure 3. The Preliminary Philippine Geoid Model 2014 (PGM2014).The contour interval is set at 5 m

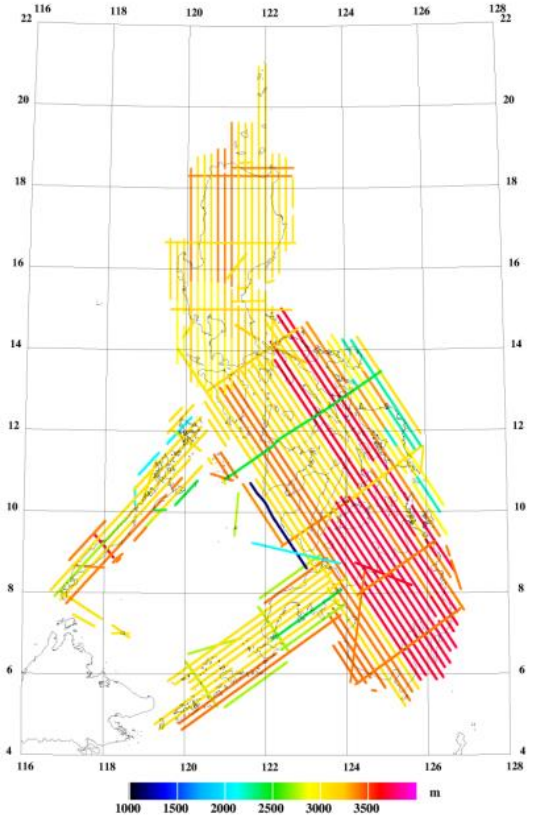
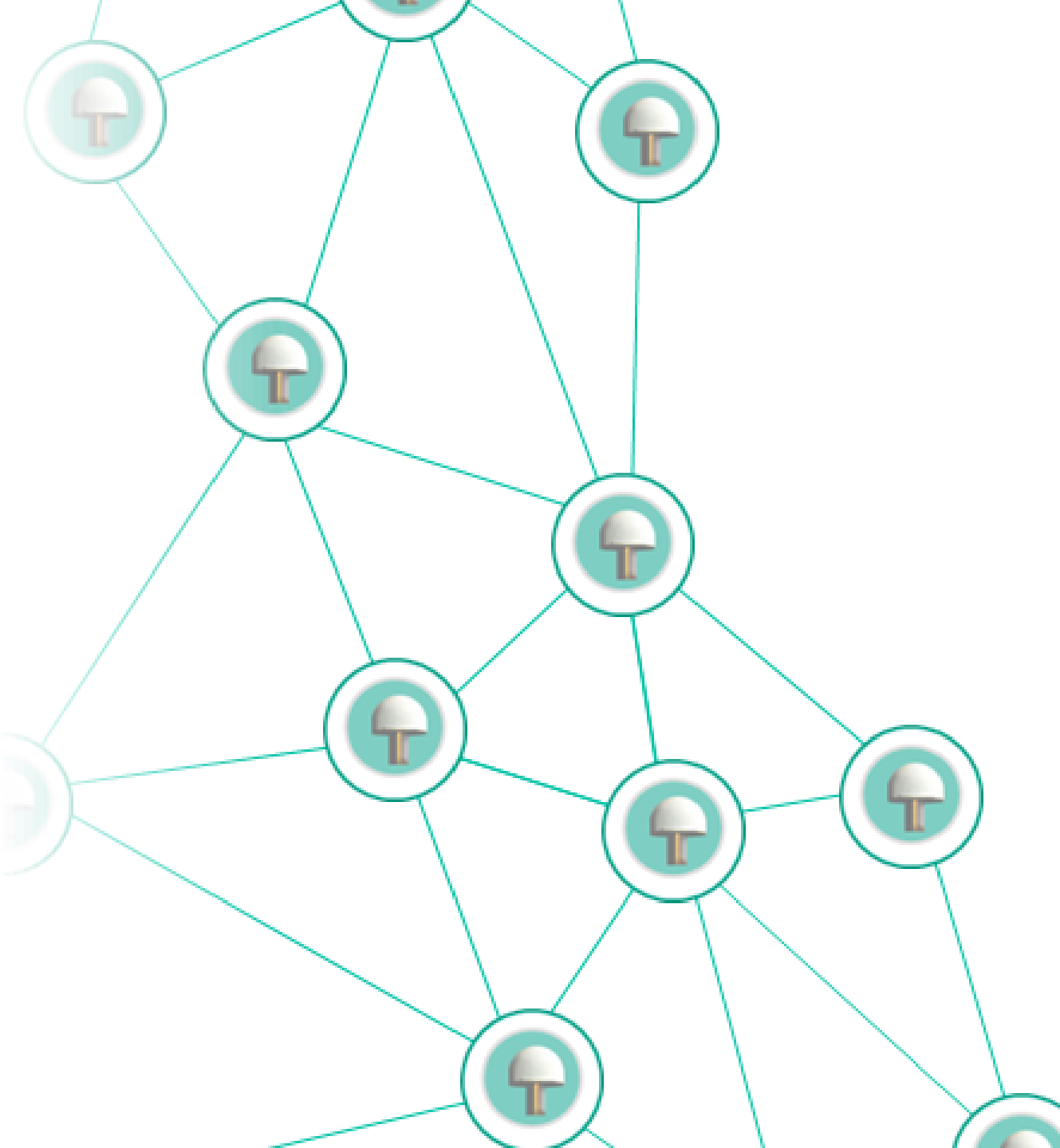


Figure 2. Flight track elevations of the airborne gravity survey

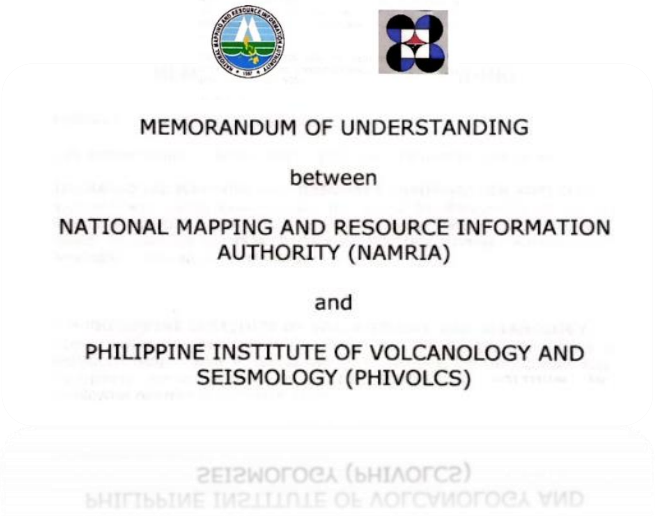
CHALLENGES & STRATEGIES



Challenges

Strengthening of geodetic infrastructure

- Issue
  - Requires substantial resources to establish and maintain (to date, only 58 of 200 target AGS installed)
  - Separate organizations carry out tasks needed for successful implementation of modern PGRS



MEMORANDUM OF UNDERSTANDING

between

NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY (NAMRIA)

and

PHILIPPINE INSTITUTE OF VOLCANOLOGY AND SEISMOLOGY (PHIVOLCS)

- Strategy
  - Partnered with other government agencies for CORS establishment/data sharing
  - Tapped local stakeholder organizations for maintaining the infrastructure (i.e. Adopt-A-Mojon program)

NAMRIA and DPWH Sign Agreement on CORS Data Sharing

News & Event(s) | | 8 April 2021 | Print

NAMRIA and the Department of Public Works and Highways (DPWH) formalized a Memorandum of Understanding (MOU) on 24 March 2021 on sharing of data from their respective Continuously Operating Reference Station (CORS) networks. The partnership intends to optimize government resources and promote the use of Global Navigation Satellite Systems (GNSS), especially for infrastructure development.

Challenges

Technical issues with RF realization / Competency gap

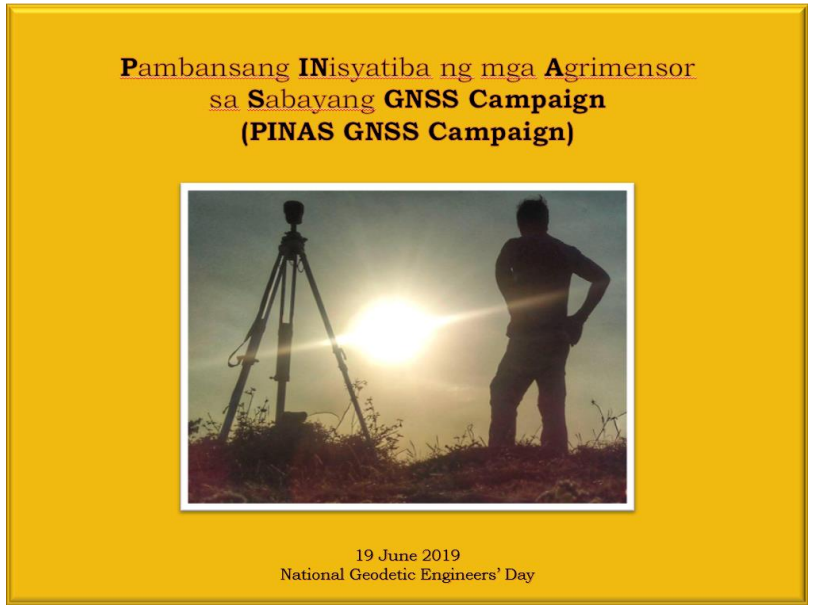
- Issue
  - Complex geodynamics make developing and updating models difficult (i.e. inclusion of earthquake patches)
  - Lack of local experts with practical experience in modern GRF development and realization

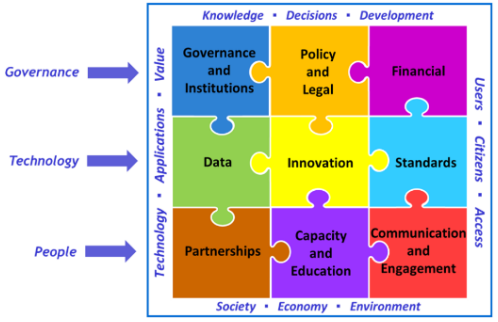
- Strategy
  - Tapped international experts to assist in the modernization
  - Partnered with academic institutions for research and development (i.e. free access to data in exchange for research related to GRF)
  - Participated in international fora on geodesy to build capacities and form networks

Challenges
Communication

- Issue
  - Lack of appreciation of geodesy among decision makers (Modernization should have been completed last 2020)

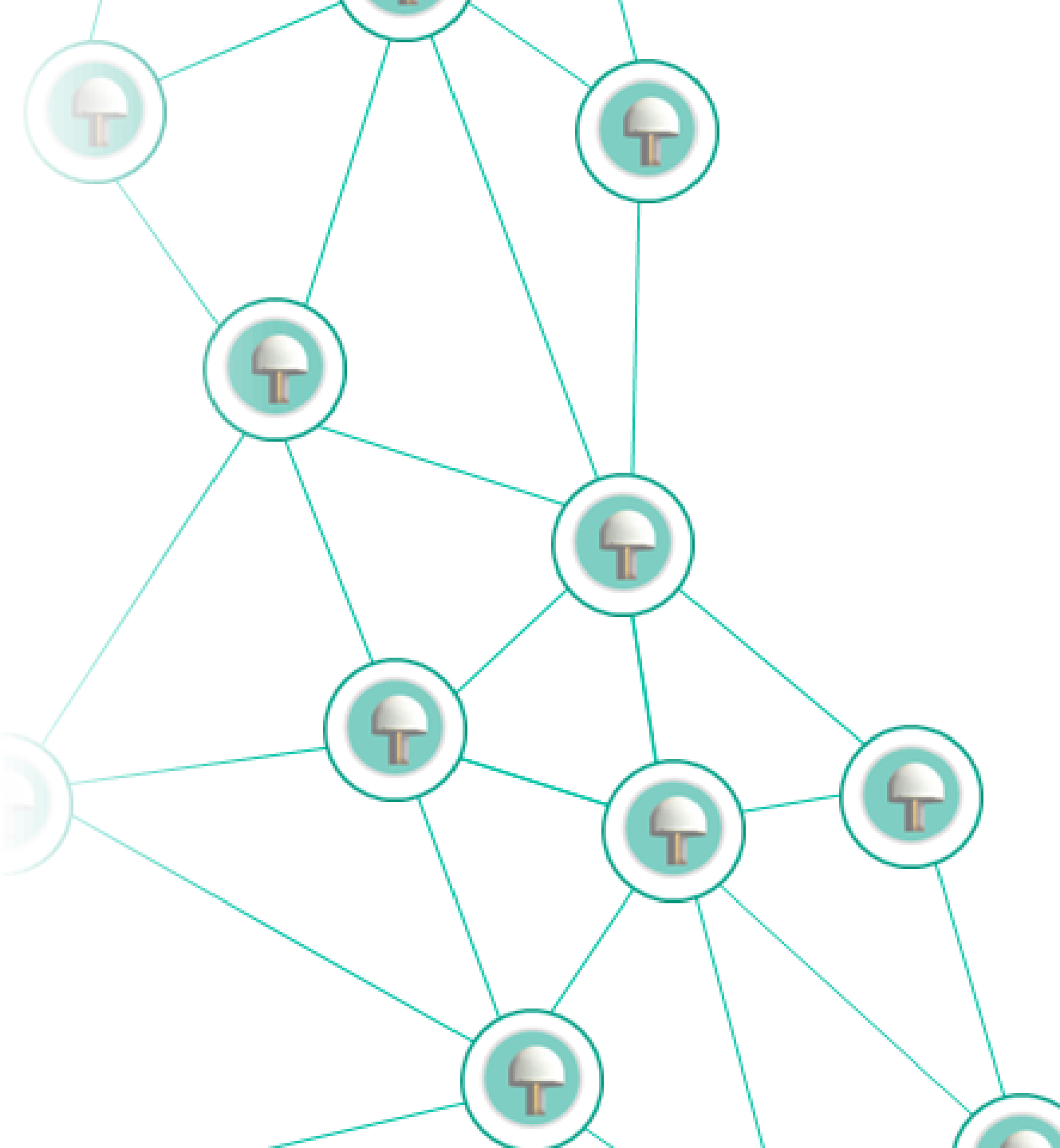
- Strategy
  - Creating champions for geodesy
  - Incorporate modernization of PGRS in the country's Integrated Geospatial Information Framework (IGIF) action plan





Geospatial Information Management: Implementation in the Philippines (Baseline Assessment)
Kelm, K., Mercado, E., Arnold, L.

WAY FORWARD

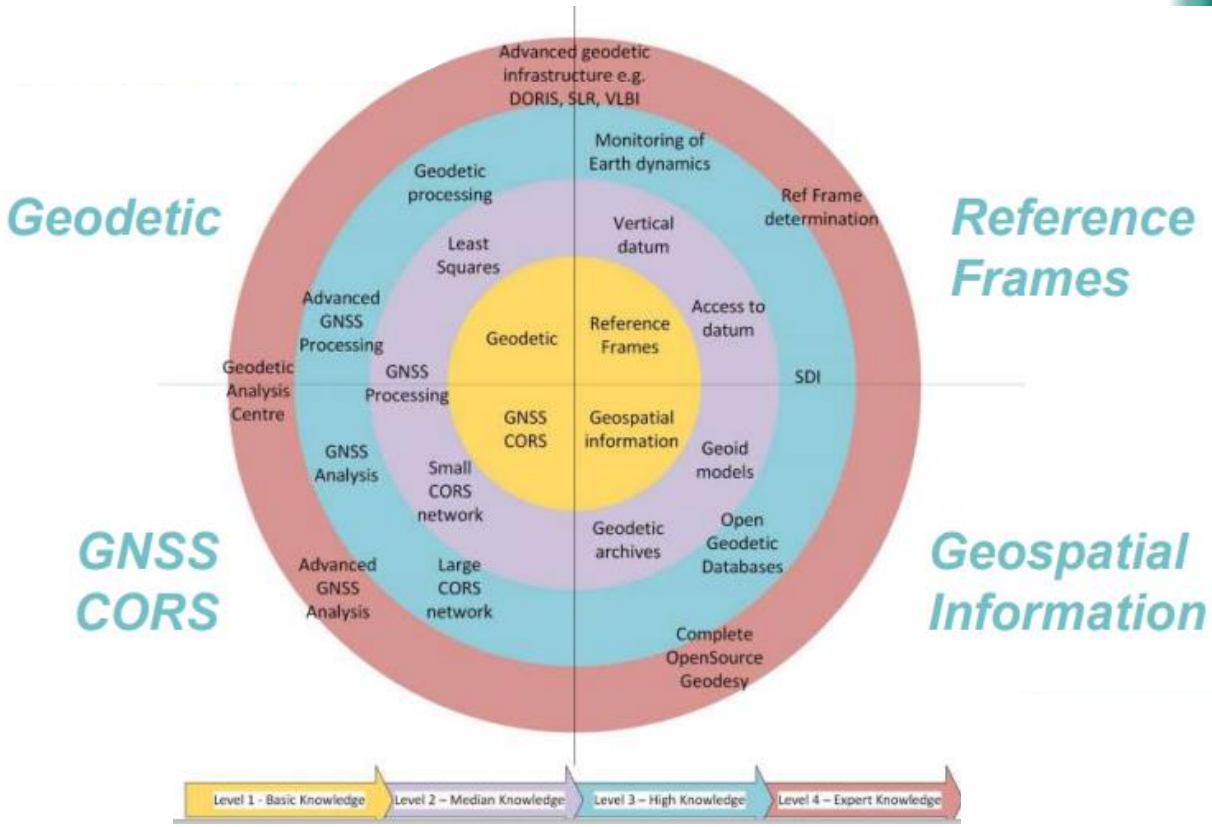


Looking ahead…

- Strengthening of geodetic infrastructure
  - Upgrading of PAGeNet (i.e. cloud hosting, densification)
  - Densification of UGCPs, gravity stations
  - Updating/refinement of geoid and deformation models (inclusion of earthquake/volcanic events, 3D deformation) and distortion grids
- Establishment and maintenance of the Modern PGRS Geodesy Portal
- Policy revisions to update existing guidelines and standards
- Communication plan to encourage buy-in among the PGRS stakeholders

Looking ahead…

- Competency and capacity building
  - Paradigm shift in how geodetic reference frame is realized and maintained requires upgrading of technical know-how not just for end-users, but also for people tasked to implement the modernization
  - ‘A reference system without a reference frame is of no practical value’
    … a reference system and frame is useless without people utilizing it



A Global Survey of Reference Frame Competency in terms of Education, Training and Capacity Building (ETCB): Results, Analysis and Update
Keenan, R., Craddock, A., Lilje, M., Sarib, R., Blick, G.

In closing…

"If a man does not keep pace with his companions, perhaps it is because he hears a different drummer. Let him step to the music which he hears, however measured or far away."

- Henry David Thoreau

Maraming salamat po!