The Role of CORE and Co-location Sites and the Activities Underway to Improve the Global Space Geodesy Network

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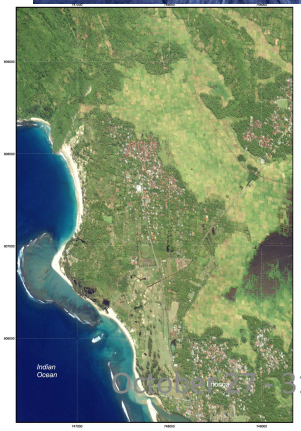
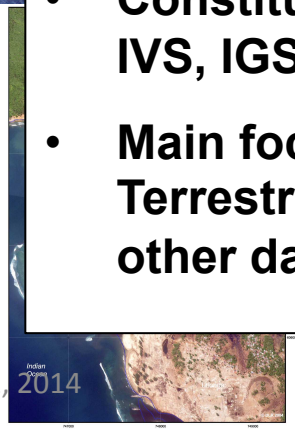
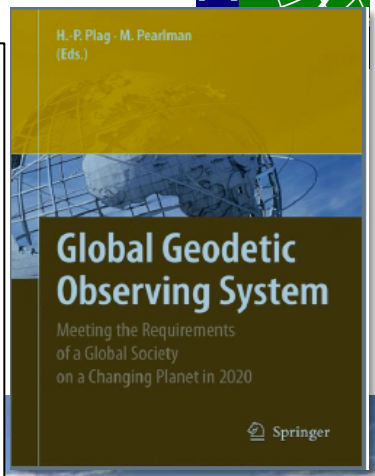
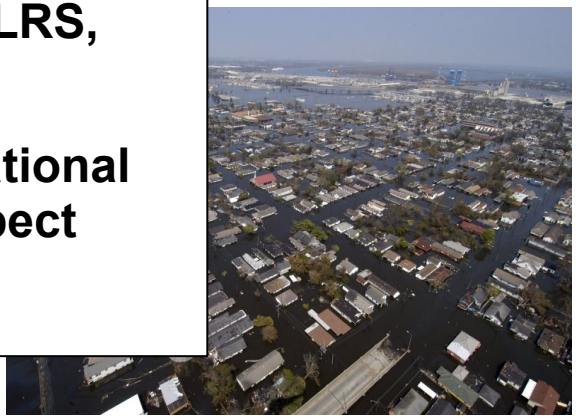
Global Geodetic Observing System (GGOS)





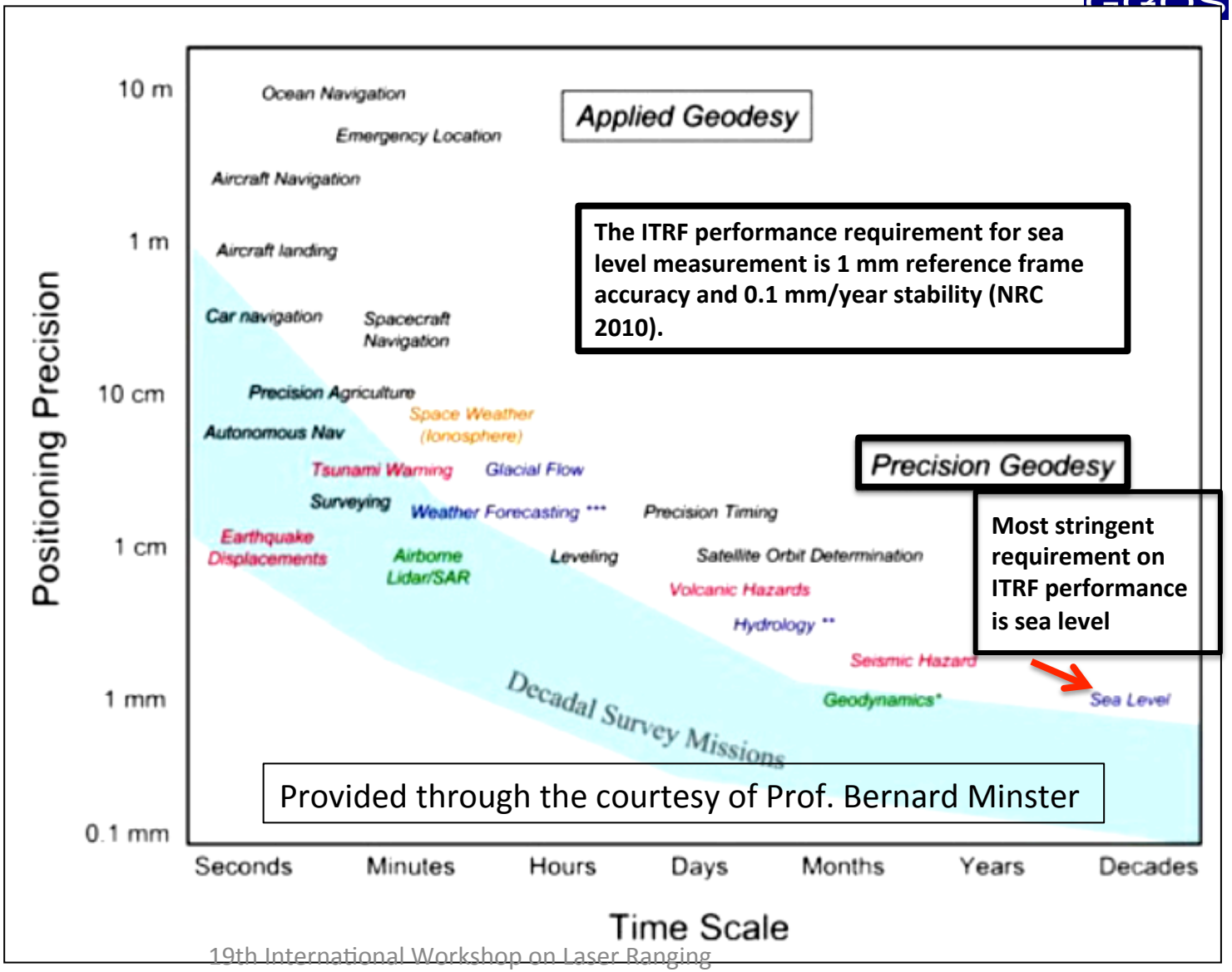
- Established by the IAG to integrate the three fundamental areas of geodesy (Earth's shape, gravity field, and rotation), to monitor geodetic parameters and their temporal variations in a global reference frame with a target relative accuracy of 10E-9 or better (See GGOS 2020)
- **Provide products & services with the geodetic accuracy necessary to address important geophysical questions and societal needs,** and to provide the robustness and continuity of service which will be required of this system in order to meet future needs and make intelligent decisions
- **Constituted mainly from the Services (ILRS, IVS, IGS, IDS, IGFS, IERS, etc.)**
- **Main focus at the moment is the International Terrestrial Reference Frame, but we expect other data products to emerge**





Practical applications of Space Geodesy
US National Research Council Study

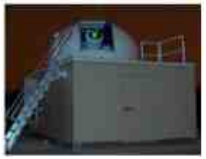
- **Geodesy** is the science of the Earth's shape, gravity and rotation, including their evolution in time.
- **Techniques** used to observe the geodetic properties of the Earth **provide the basis for the International Terrestrial Reference Frame (ITRF)**
- The **ITRF** is the foundation for virtually all **airborne, space-based, and ground-based Earth observations**, and is fundamentally important for **interplanetary spacecraft tracking and navigation**.



GGOS Reference Frame Requirement

- **Basis upon which we measure change over space, time, and evolving technology**
- **Most stringent requirement from sea level rise:**
  - **"accuracy of 1 mm, and stability at 0.1 mm/yr"**
  - **This is a factor 10-20 beyond current capability**
- **Accessibility: 24 hours/day; worldwide**

  Users anywhere on the Earth can position their measurements in the reference frame
- **Space Segment:**
  - **LAGEOS, LARES, GNSS, DORIS, Quasars to define the reference frame**
- **Ground Segment (Core Sites):**
  - **Global distributed network of "modern technology", co-located SLR, VLBI, GNSS, DORIS stations locally tied together with accurate site ties**
  - **Dense network of GNSS ground stations to distribute the reference frame globally to the users**

VLBI	NGSLR	GNSS	DORIS	Vector Tie
				

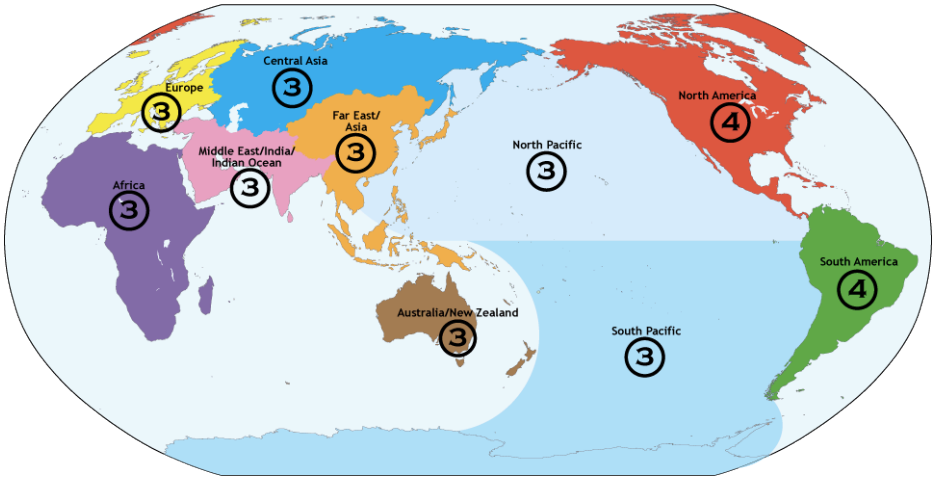
Simulation Studies to Scope the Network

(impact on the Reference Frame)

(Erricos Pavlis)

Simulation studies show:

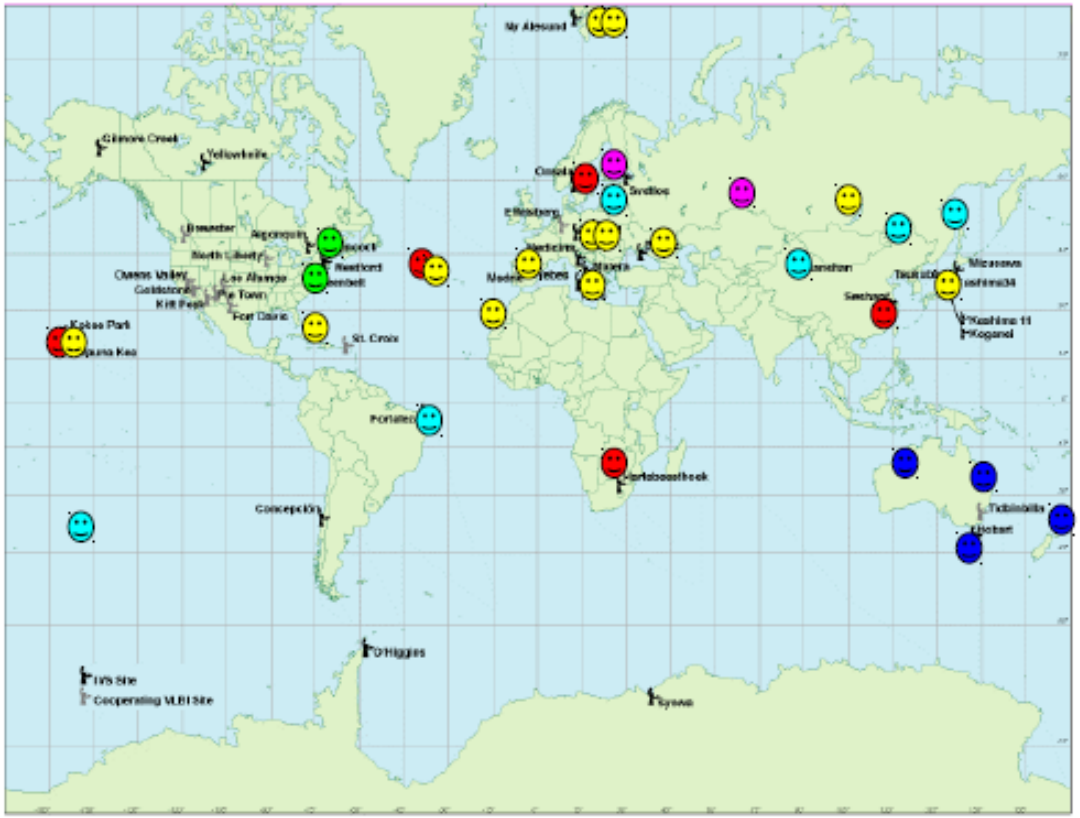
- ~32 globally distributed, well positioned, new technology, co-location sites will be required to define and maintain the reference frame;
- ~16 of these co-location stations must track GNSS satellites with SLR to calibrate the GNSS orbits which are used to distribute the reference frame.



- Major Challenge
- Major issues are the systematic errors – they will alias into the data results
- Will require time, significant resources, and strong international participation

Lots of Activity Underway on VGOS

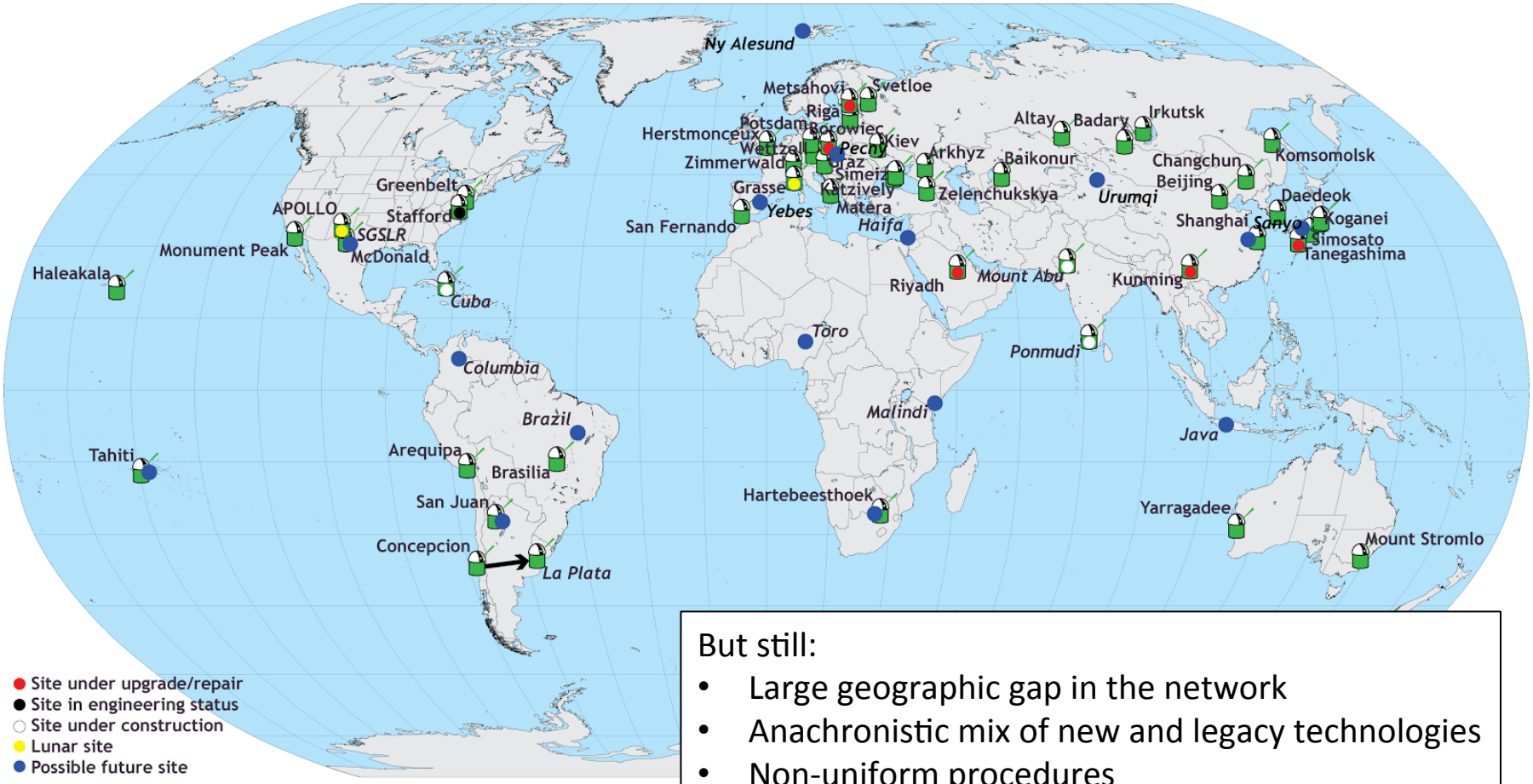
New VGOS radio telescopes for IVS



- operational
- under construction
- funded
- proposal submitted
- planning phase
- planning phase upgrade

based on available information
February 2014

Projected SLR Network



But still:

- Large geographic gap in the network
- Anachronistic mix of new and legacy technologies
- Non-uniform procedures

Two Recent Initiatives

- Expansion of the Russian Network to Support:
  - GLONASS accuracy and time transfer
  - GGOS
- NASA Space Geodesy Project to support the NASA role in International Space Geodesy and GGOS

The development of the foreign segment of the Russian SLR network

In addition to existing stations Baikonur (Kazakhstan) and Brasilia (Brazil) the same SLR station will be installed in 2015 near Havana, Cuba (the station is ready). Four new-generation stations of submillimeter accuracy will be installed in future in 4 from 6 possible sites: San Juan (Argentina), HartRAO (South Africa), Haifa (Israel), the branch of the Shanghai Observatory (China), Java (Indonesia), Tahiti (French Polynesia).

- staions is ready

- next generation stations

NASA's Space Geodesy Project

- Demonstration of prototype next-generation core site:
  - NGSLR demonstrated required performance and is tracking current ILRS satellites including daylight ranging to GNSS.
  - Prototype VLBI2010 system demonstrated required performance and successfully performed several end-to-end geodetic sessions.
- Implementation (with USNO) of new VGOS station in Hawaii underway; Upgraded SLR site planed for Mt Haleakala;
- McDonald selected for Western US site for VLBI and SLR .
- Upgrade underway to the NASA GNSS network to support new constellations (Galileo, GLONASS, Beidou) in addition to GPS.
- Ongoing discussions and planning with our international partners for the deployment of the new NASA network overseas.

NGSLR & MOBLAS-7 simultaneously ranging at the Goddard Geophysical and Astronomical Observatory (GGAO)

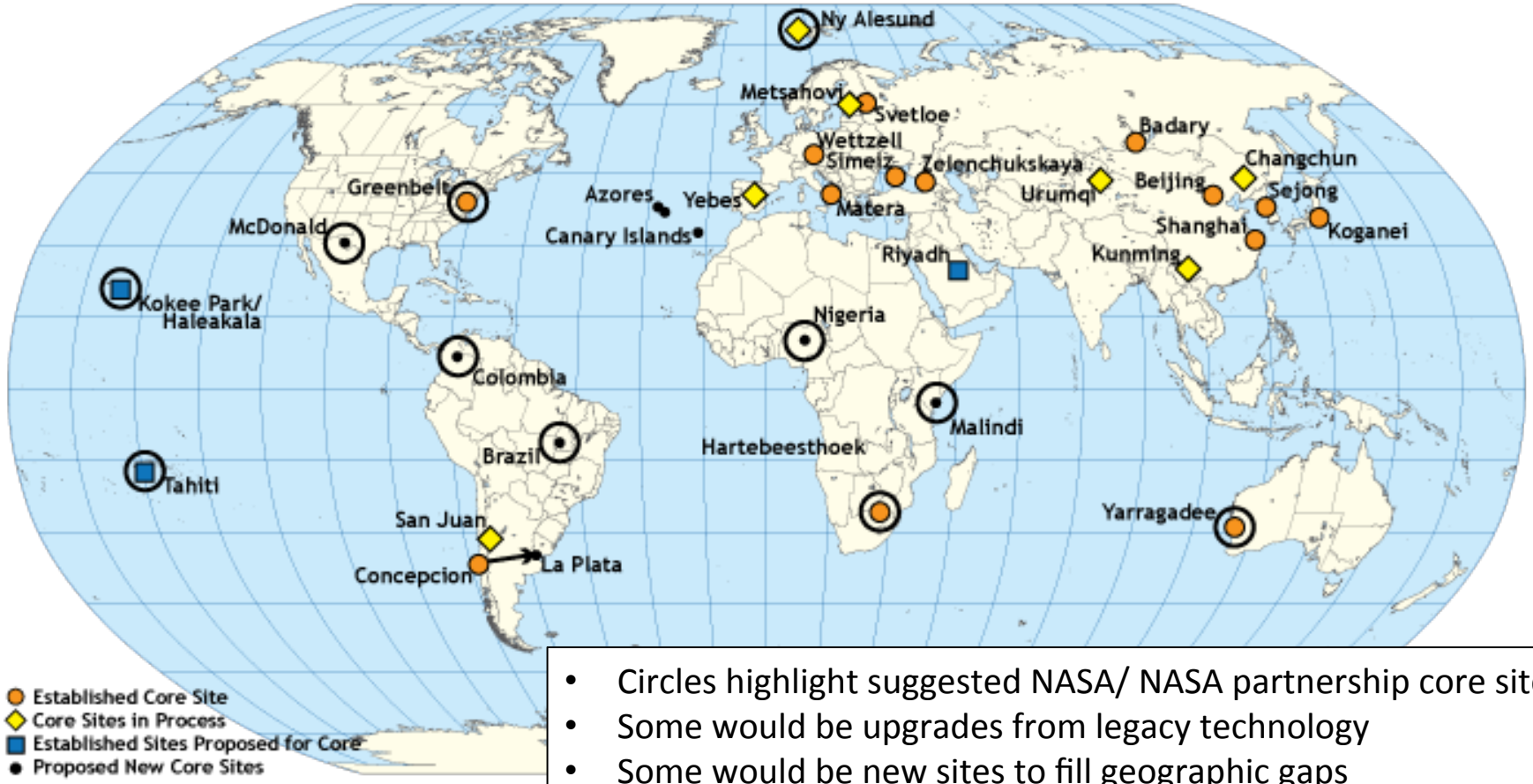
Next Generation Satellite Laser Ranging (NGSLR)

Very Long Baseline Interferometry (VLBI)

Global Navigation Satellite System (GNSS)

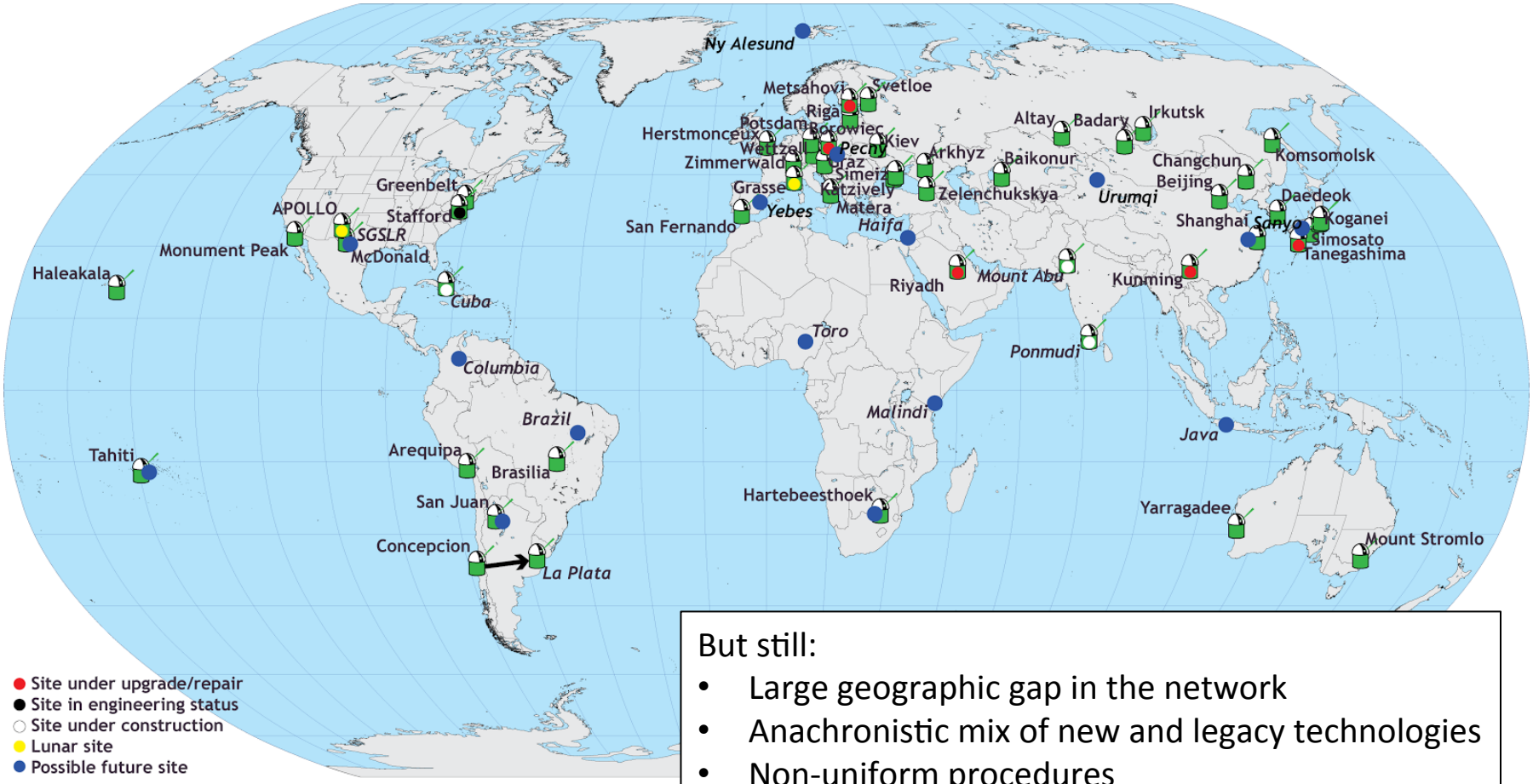
Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)

NASA and Partnership
Current and Projected Core Sites



- Circles highlight suggested NASA/ NASA partnership core sites
- Some would be upgrades from legacy technology
- Some would be new sites to fill geographic gaps

Projected SLR Network



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Sejong Site (South Korea)

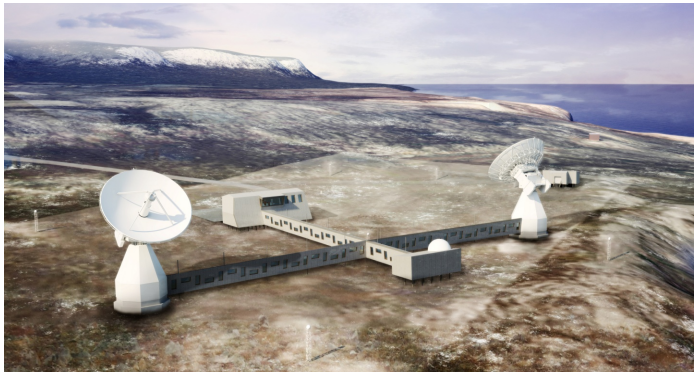
- VLBI, GNSS and Gravimeter : NGII (National Geographic Information Institute)
  - In testing
- SLR : KASI (Korea Astronomy & Space Science Institute)
  - Operational at KASI HQ in Daejeon,
  - To be relocated to Sejong site in late 2014

- 40cm Rx and 10cm Tx telescope
- 2kHz repetition rate
- 2.5mJ/pulse and 50ps pulse width
- Aircraft detection using a radar

- 22m Cassegrain antenna
- Rx frequency : 2, 8, 22 and 43GHz
- Aperture efficiency : ~60%
- GNSS receiver and Gravimeter

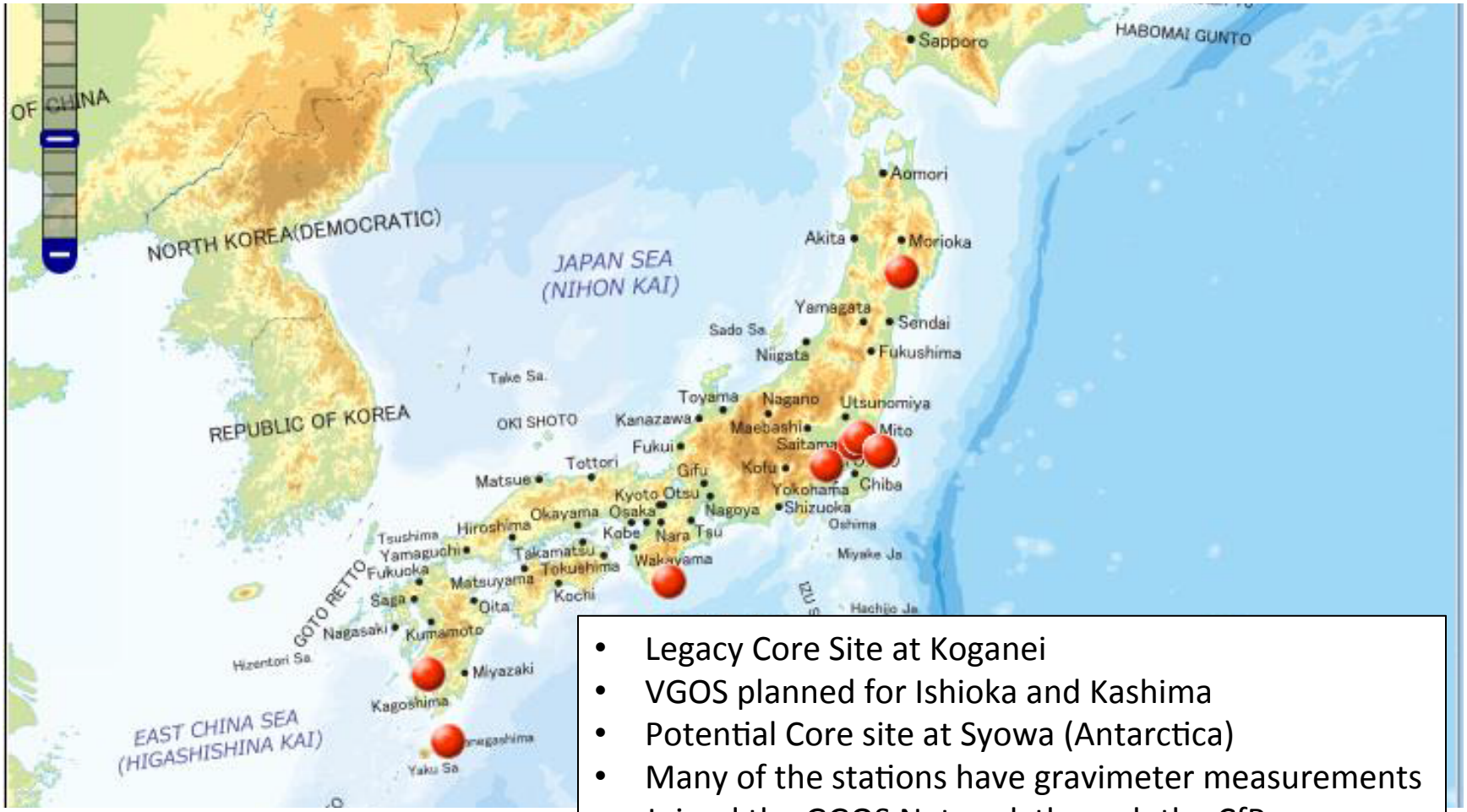
Ny Alesund Core Site
(From Ina Elsrud, PM)

- Planned to be a core station including VLBI, SLR, GNSS, DORIS, absolute gravity- and super conducting gravity meter
- Extreme interest because of the very high latitude (~80 Deg)
- Site infrastructure work is now underway
- 2018 - two VGOS telescopes, GNSS, DORIS and gravimeters
- 2020 – SLR
- 2021 – Closeout of the legacy VLBI after 3 year parallel run



Map of Sites in Japan

Response to GGOS CfP



- Legacy Core Site at Koganei
- VGOS planned for Ishioka and Kashima
- Potential Core site at Syowa (Antarctica)
- Many of the stations have gravimeter measurements
- Joined the GGOS Network through the CfP

Planned SLR Installations in India by ISRO
(Construction underway)

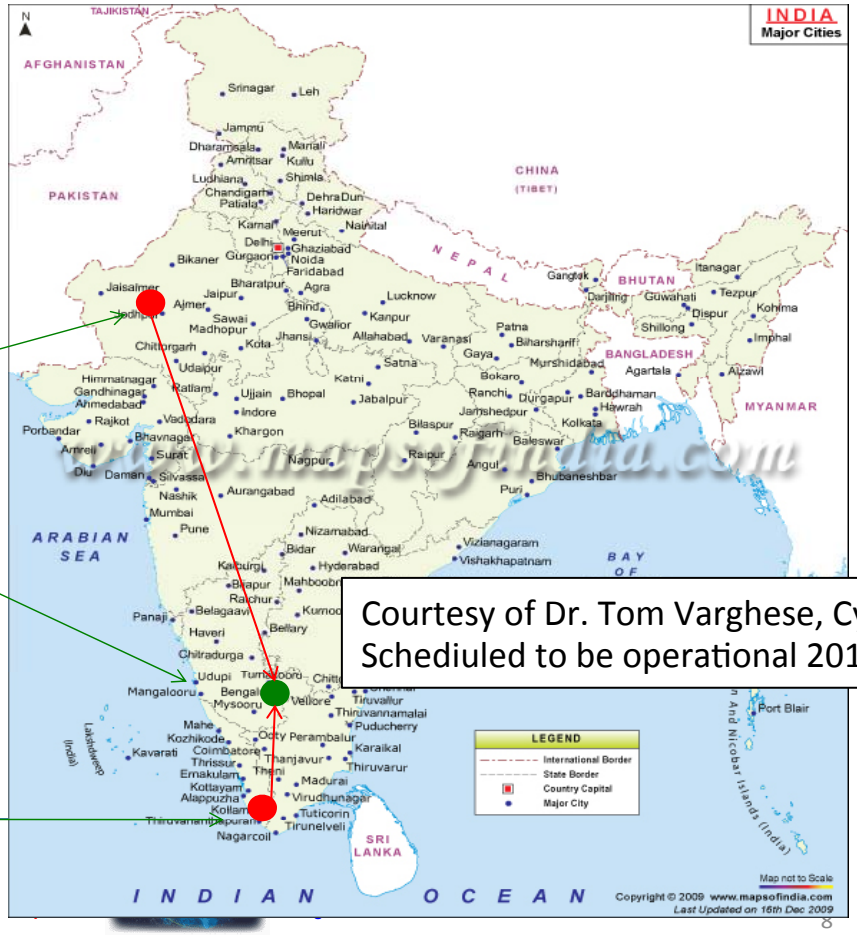
SLR in India

- 1 meter Telescope;
- Photometry, debris tracking, SLR;
- Lasercom (future);

Site #1, Mount Abu,
24° 36' Lat, 72° 42' Long
near Jodhpur, Rajasthan

Bangalore
Remote Control Center

Site #2, Ponmudi,
8° 45' Lat, 77° 6' Long
near Trivandrum, Kerala



Courtesy of Dr. Tom Varghese, CybiomsCorp
Schediuled to be operational 2015 – 2016 timeframe

cybioms corporation

The Geodetic Reference Antenna in Space (GRASP): A Mission to Enhance the Terrestrial Reference Frame

Yoaz Bar-Sever[1], R. Steven Nerem[2], and the GRASP Team

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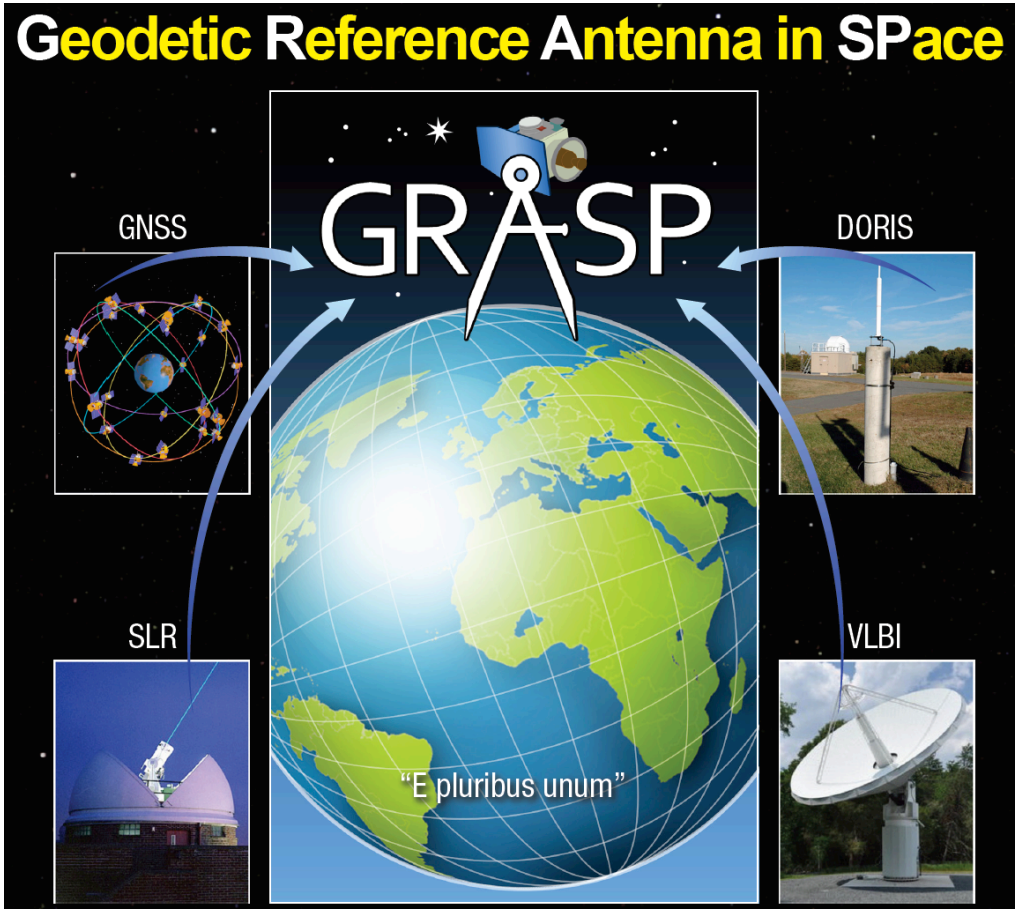

Reality

Recognizing that:

- Many sites will not be at ideal locations nor have ideal conditions;
- Some new technology stations are being deployed, but not co-located;
- Core site deployment will occur over many years;
- We will have a mix of new and legacy technologies for many years;

As a result:

- Co-location sites (non-core sites) will continue to play a vital role in our data products;
- Quality of our output will be the product of network Core Sites, Co-location sites, mix of technologies, adherence to proper operational and engineering procedures, and making best use of the data once it leaves the field;

Good News: Many groups are taking the initiative to join, build and upgrade