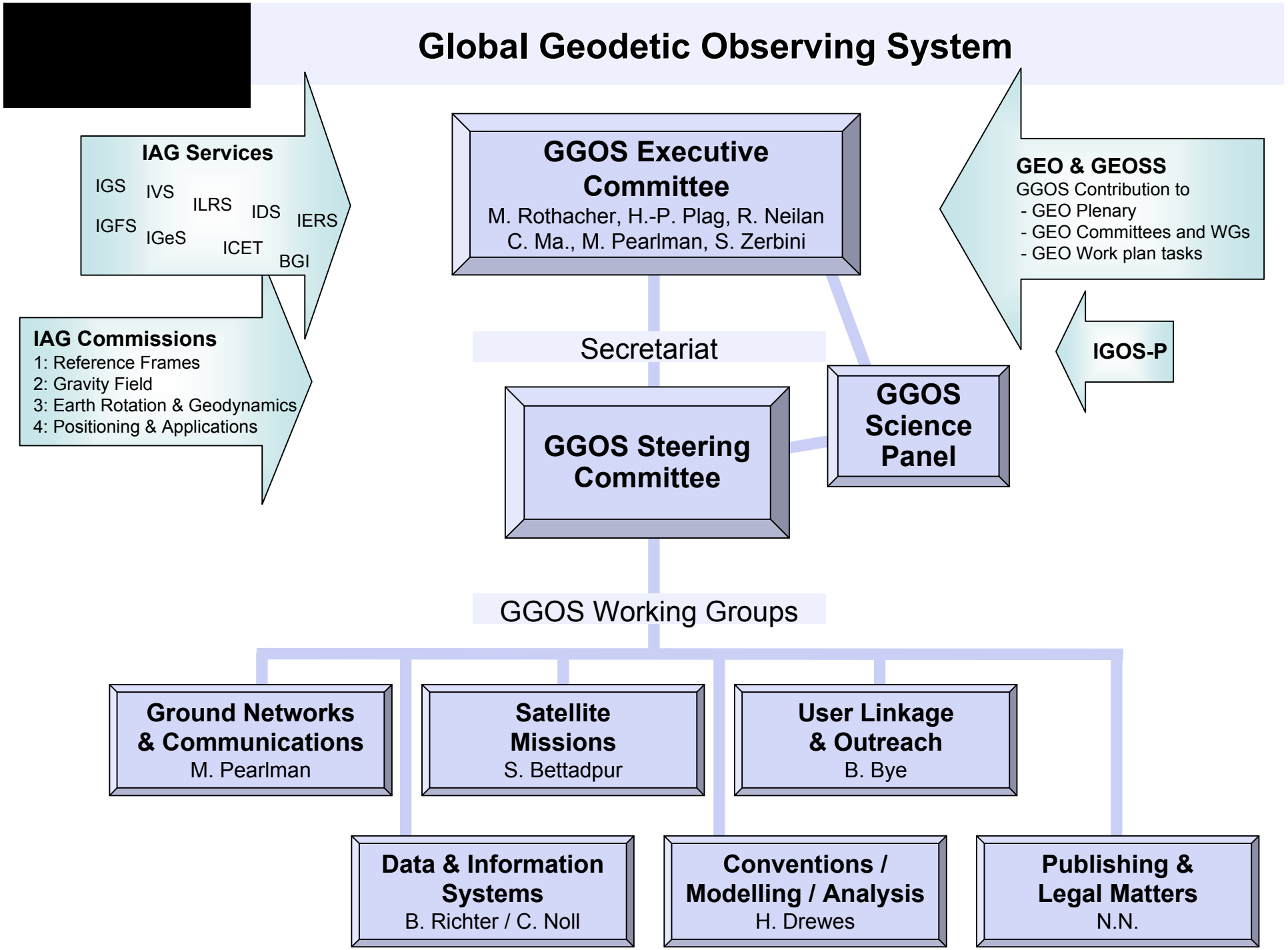
GGOS Working Group on Ground Networks and Communication

Mike Pearlman
Harvard-Smithsonian Center for Astrophysics

IGS Workshop
Darmstadt, Germany
May 8, 2006

Global Geodetic Observing System



GGOS Working Group on Ground Networks and Communications

Charter

- Work toward the implementation of properly designed and structured ground-based geodetic networks to materialize the reference systems to support sub-mm global change measurements over space, time and evolving technologies.

- Work with the IAG measurement services (the IGS, ILRS, IVS, IDS and IGFS) to develop a strategy for building, integrating, and maintaining the fundamental network of instruments and supporting infrastructure in a sustainable way to satisfy the long-term (10-20 year) requirements identified by the GGOS Science Council.

Members of the Working Group

- IGS: Angelyn Moore, Norman Beck
- ILRS: Mike Pearlman, Werner Gurtner
- IVS: Chopo Ma, Zinovy Malkin
- IDS: Pascal Willis
- IGFS: Rene Forsberg, Steve Kenyon
- ITRF and Local Survey: Zuheir Altamimi, Jinling Li, Gary Johnston
- IERS Technique Combination Research Centers: Marcus Rothacher
- IAS (future International Altimetry Service): Wolfgang Bosch
- Data Centers: Carey Noll
- Data Analysis: Erricos Pavlis, Frank Lemoine, Frank Webb, John Ries, Dirk Behrend

Early Steps in the Process

- **Take stock of what exists - Stations, Products, Surveys, etc.**
- **Determine requirements**
- **Define critical contributions each technique contributes to the TRF, POD, EOP;**
- **First - consider the TRF since its accuracy influences all other GGOS products;**
- **Characterize the improvements anticipated over the next 10 years for each technique;**
- **Using simulation techniques, quantify the improvement in the TRF as stations are added and station capabilities (co-location, data quantity and quality) are improved;**
- **Scope the network that would satisfy the user requirements;**

Develop a Plan for Full Network Integration

- Full range of applications including the geometric and gravimetric reference frames, EOP, POD, geophysics, oceanography, local deformation monitoring, and other geodetic and gravimetric applications required for the long-term observation of global change;
- Network of fundamental stations of colocated techniques;
- Adequate system of ground survey control;
- Match data and product communication with requirements.

Taking Stock of what we have

Lists on the INDIGO web site:

- IGS, ILRS, IVS and IDS ground stations including colocations;
- Data Products of the IGS, ILRS, IVS, IDS, IERS
- Gravity and tide gauge information yet to be included;

Some thoughts on what we need

(Input will come from the GGOS Science Panel)

- **Measure Earth CoM variability to 0.1 mm with monthly resolution and resolve seasonal (annual and semi-annual) signals to 0.05 mm in amplitude and 5 degrees in phase;**
- **Measure the scale of the TRF with a long-term accuracy of 0.01 ppb/yr;**
- **Maintain a global vertical datum (Core Observatories' heights) with an accuracy of 0.1 mm/yr (excluding seasonal signals);**
- **Measure UT1- UTC at 2-3 microsec every day and nutation at 25-50 microarcsec each day, (VS WG2 report);**
- **Measure Earth Orientation parameters with an accuracy of 0.050 mas (polar motion) and 0.025 mts (LOD) for daily averages);**
- **Measure long-wavelength gravity changes (zonal terms to degree 10? and tesserals/sectorials to degree 4, 6 with weekly resolution and an accuracy better than 10% of the signal;**
- **Improve by an order of magnitude the ties between the Solar System Barycentric frame with the TRF, using SLR tracking of planetary probes and interplanetary missions with multiple tracking systems (RF Doppler, VLBI, etc.), to improve the TRF and Conventional Inertial Reference Frame ties.**

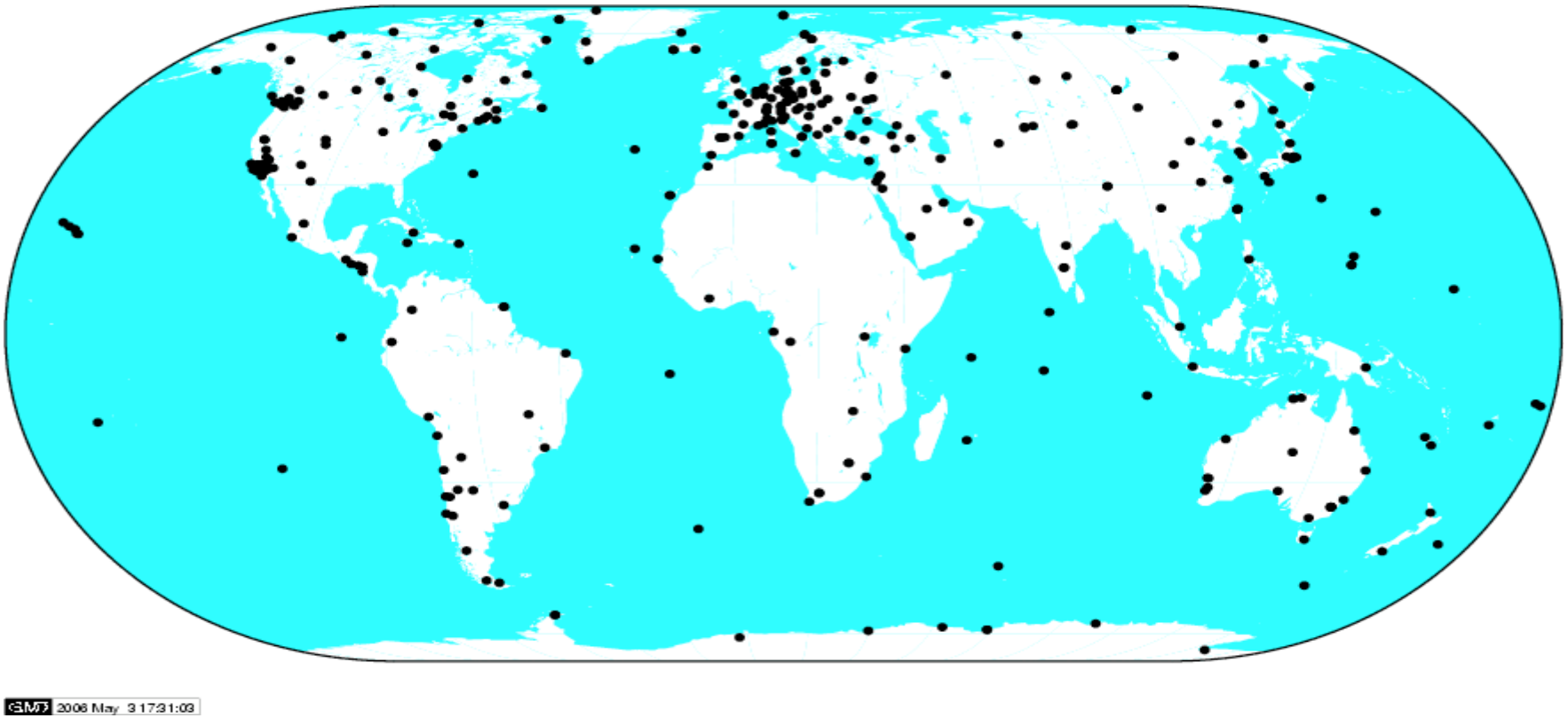
ANTICIPATED CHANGES IN GNSS OVER THE NEXT 10 YEARS

(provided by Angie Moore and Frank Webb)

- **GPS:**
  - **L2C (2nd civil signal) – Full operational capability (FOC) 2013**
  - **Block IIF/L5 (3rd civil signal) – launch 2007, operational control 2009, FOC 2014**
  - **GPS III Satellite RFP due out soon. BOC1,1 @ L1; nominal first launch 2013**
- **GLONASS:**
  - **Currently 13 operational; plan to return to 24 sats by 2011**
  - **Recent M satellites have 2nd civil signal @ L2, but few receivers yet**
  - **K satellites (3rd civil signal @ L2) launch 2008**
- **Galileo:**
  - **4 operational satellites in 2008**
  - **FOC 2010**
- **LEO's with GPS: More of them**

IGS Network Map

(from http://igscb.jpl.nasa.gov)



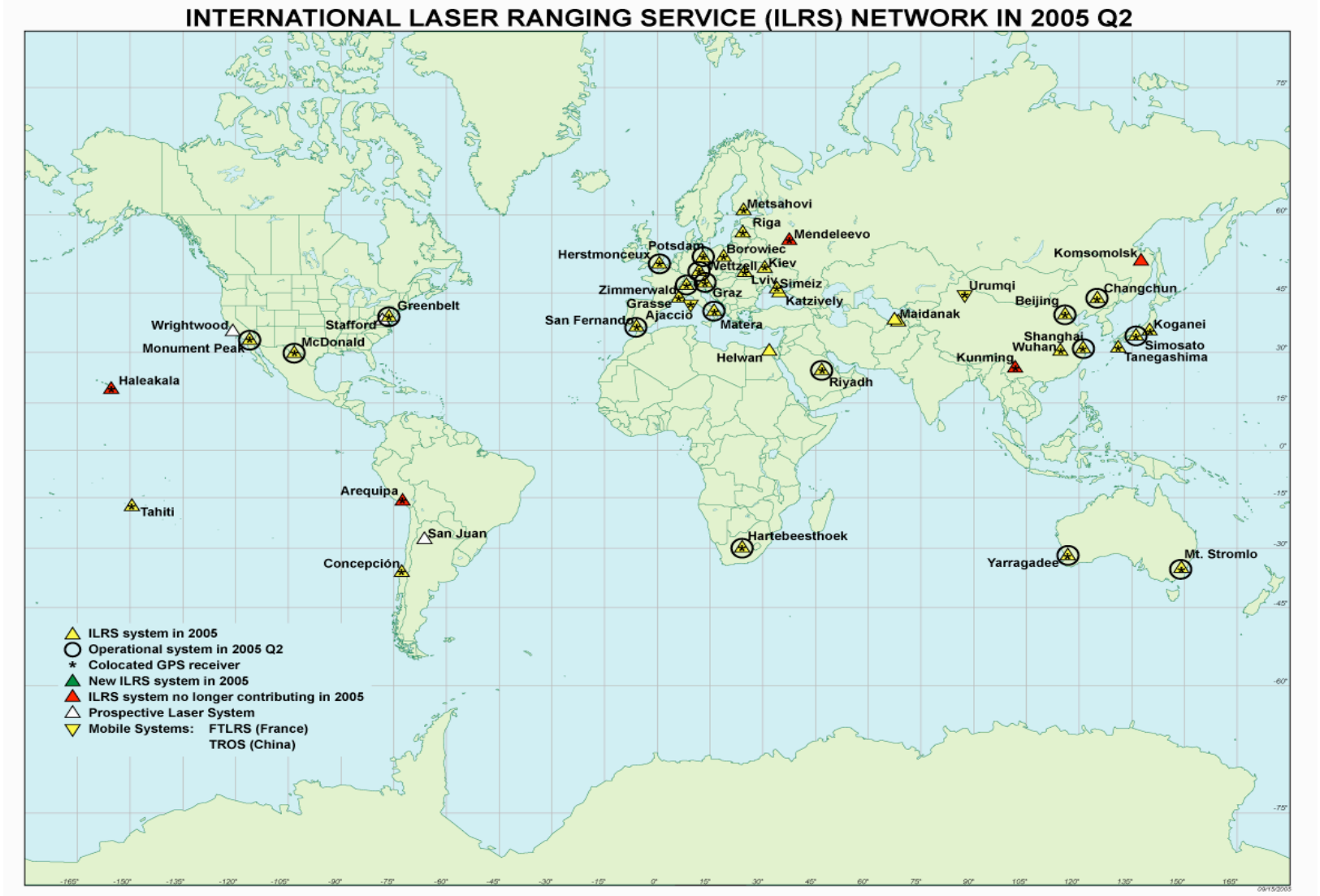
May 8, 2006

IGS Workshop 2006
Darmstadt Germany

ANTICIPATED CHANGES IN SLR OVER THE NEXT 10 YEARS

(provided by Werner Gurtner and Mike Pearlman)

- **Ground Segment Technology**
  - **Kilohertz ranging, faster satellites acquisition/turnover**
  - **Semi-autonomous and autonomous operations**
  - **Higher resolution event-timers deliver picosecond timing.**
  - **Real-time communication: Data flow, scheduling**
  - **Transponders – interplanetary ranging**
  - **Two-wavelength operation for atmospheric refraction delay recovery**
- **Operations**
  - **More rapid pass interleaving**
  - **Specialization (e.g., low – high targets)**
  - **Commercialization of non-scientific tracking support**
- **Accuracy**
  - **Improved system accuracy (mm tracking)**
  - **Modeling improvements (e.g. atmosphere)**
  - **Target definition (retrorefector design)**
  - **Network design: Better distribution**
- **Space Segment**
  - **Improved array designs – hollow cubes, Luneberg reflector**
  - **New satellites – LARES, etc.**



May 8, 2006

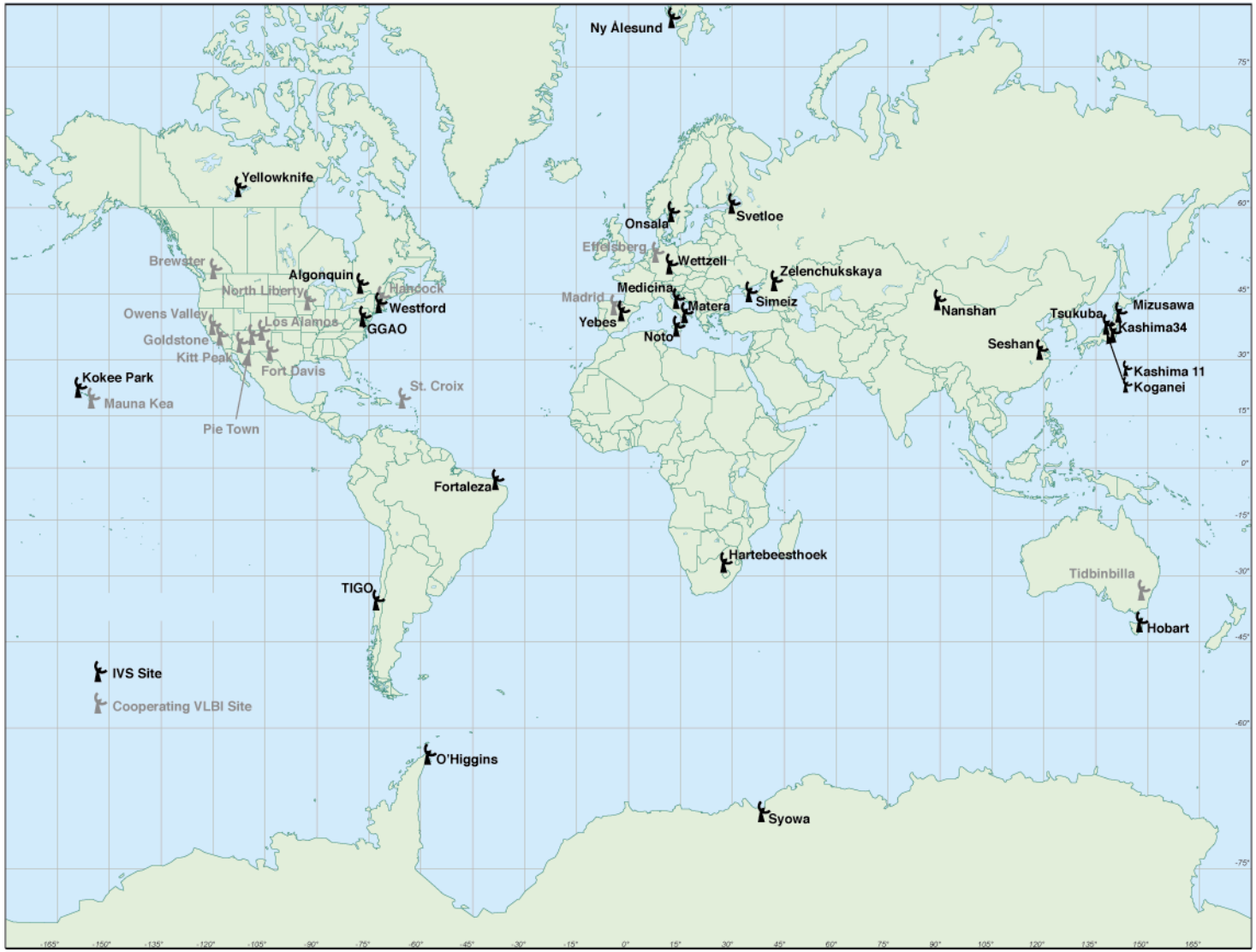
IGS Workshop 2006
Darmstadt Germany

ANTICIPATED CHANGES IN VLBI OVER THE NEXT 10 YEARS

(provided by Chopo Ma)

- **Faster slewing, robust, stiffer, more efficient antenna and mount;**
- **Very wide bandwidth, calibrated, cryogenic feed and receiver;**
- **All digital, wide bandwidth, programmable backend;**
- **Higher bandwidth recording;**
- **Higher throughput correlator (more stations and higher data rates);**
- **Higher stability frequency standards;**
- **e-vlbi.**

IVS Network Stations



May 8, 2006

IGS Workshop 2006
Darmstadt Germany

ANTICIPATED CHANGES IN DORIS TECHNOLOGY IN THE NEXT 10 YEARS

Several new satellite launches expected 2008-2009
(but long-term DORIS constellation difficult to predict)

New multi-channel receivers on-board
(more data on ground + potentially larger ground network)

Improved geodetic results
(better phase measurements + emulation between DORIS Analysis Centers: from 2 to 4+)

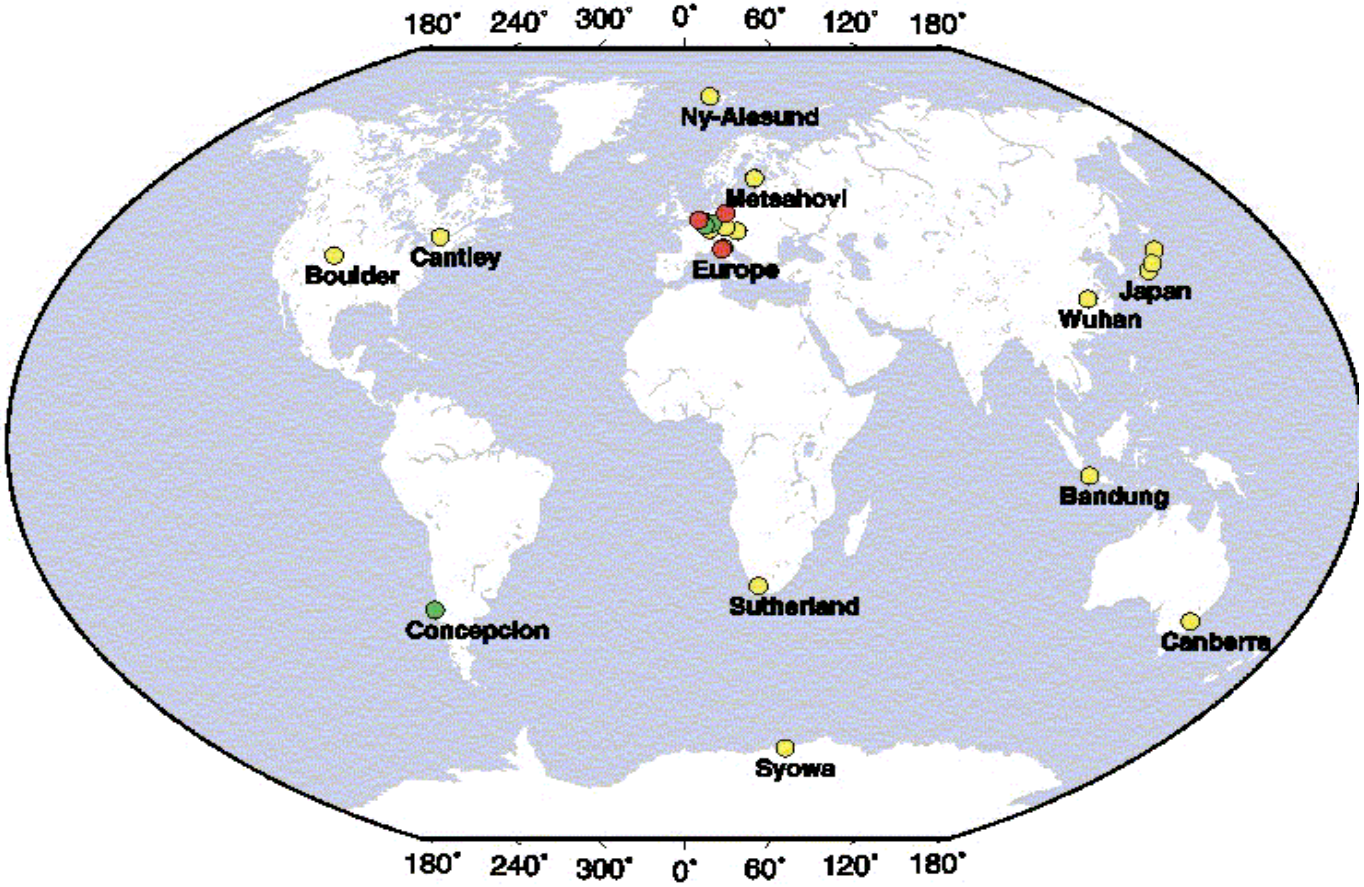
P. Willis, F. Lemoine

GGOS, GN&C, Apr 2006

Current network of coordinated superconducting gravimeter observatories

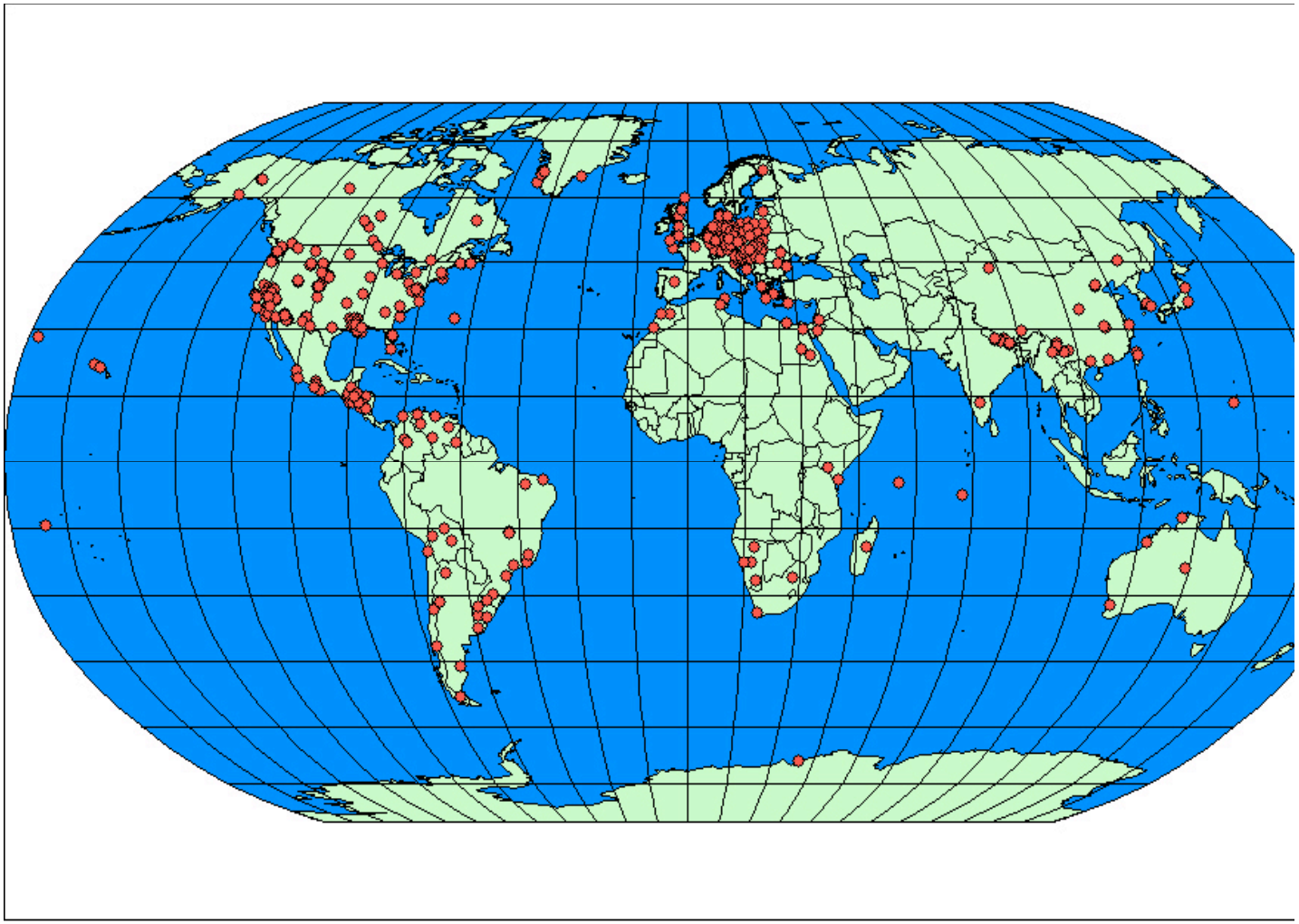
(GGP project 1997-2003)

(provided by Rene Forsberg and Steve Kenyon)



NGA coverage of absolute gravity

(provided by Steve Kenyon)

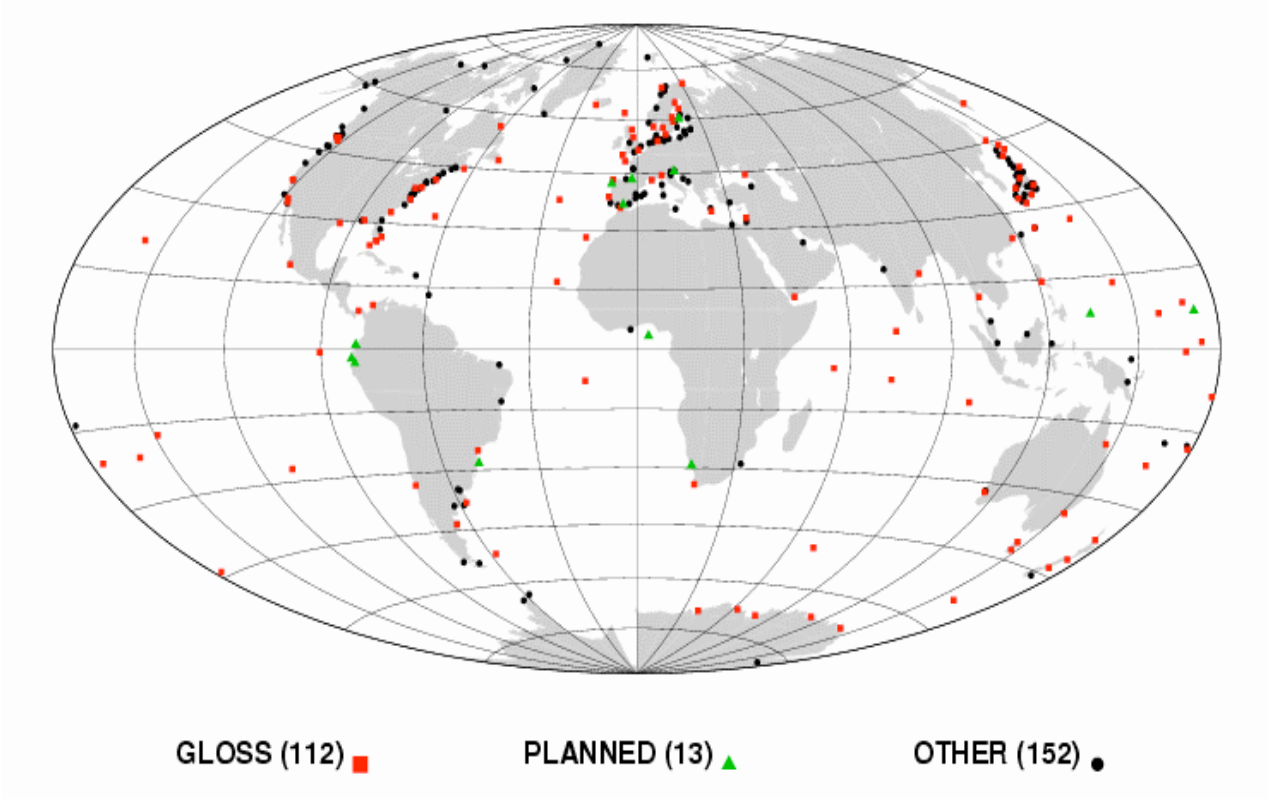


Some Questions on Gravity Field

- **"How best could we incorporate these gravity networks into our overall activity on a Global Geodetic Observing System" network design?**
  - Occupy a core set of GGOS sites with absolute gravimeters. Long-term monitoring.
- **"What are expected to be the future requirements and how did you arrive at these?**
  - A replacement for IGSN71 has been discussed. The replacement will take advantage of the large amount of new absolute and high quality reference base stations extablished in the last 20 years.
- **Should all fiducial reference geodetic observatories have a gravimeter or a program of gravimeter occupations at regular intervals?**
  - Yes, in an ideal world, if we had enough absolute meters and resources to make the measuring campaigns worthwhile.

Colocated GPS and Tide Gauges

(from http://www.sonel.org/stations/cgps/surv_update.html)



- **Issues:**
  - **Many are separated by a kilometer or more**
  - **Accessibility of the data**
- **Critical role: GPS Tide Gauge Benchmark Monitoring - Pilot Project**

Approach to Scoping the Network

- Start with the Reference Frame
- Assume that GNSS and the DORIS Networks will be at least as robust as they are presently
  - Some augmentation to fill in the network ;
  - Ground system upgrads to accommodate the new satellites capabilities;
- SLR and VLBI will each choose a “critical parameter” in the reference frame formulation that they will use as a measure to scope their networks
  - SLR - Earth Center of Mass;
  - VLBI - EOP parameters;
  - Networks must be sufficiently distributed to determine scale;
  - Sufficient global distribution so that inter-network transformations are robust
- At the moment, the Working Group is examining options for 1 mm and 0.1 mm/yr reference frame stabilities.

SLR Simulation

(by John Ries, Erricos Pavlis and Frank Lemoine)

- **Develop a mechanism for reliably evaluating the impact of changes in the SLR network**
- **Must to be able to:**
  - **Evaluate current level of TRF error (not confidently known)**
  - **Optimize use of available or future SLR resources**
  - **Determine level of tracking needs to meet future science requirement**
- **Use recovery of geocenter variability as a quick proxy for TRF origin improvement**
- **Generate a set of simulated SLR data incorporating some 'guesstimate' of dynamical and observation modeling errors**
- **Calibrate modeling errors to be consistent with observed performance with LAGEOS-1/2 (realistic spectrum of errors, include systematic biases as well as stochastic errors**
- **Insert seasonal geocenter signal (3-6 mm in this case) and compare recovery to actual performance from LAGEOS-1/2**
- **Test selected SLR network scenarios**
- **Realism of SLR data distribution and acquisition patterns is probably most critical aspect**

VLBI Simulation

(from Chopo Ma)

- Use simulation and covariance analysis to analyze network performance
- Optimize in a geometrical sense the design of a new network of VLBI antennas, improving geographical distribution
- Determine required performance characteristics of new antennas (and upgrades of current antennas) to meet overall network goals
- Analyze simulated data file to estimate Earth orientation parameters or station positions
- Perform Monte Carlo simulations by generating simulated observations and making repeated SOLVE runs with different input simulated observations
- ➔ Precision (repeatability) of estimated parameters (e.g. station positions, baseline length, Earth orientation)
- Compare simulation precision with formal parameter errors

- Procedures to analyze VLBI data with GEODYN have been implemented
- Simulation activity underway.

Summary

- **We have the groups talking to each other**
- **Meeting several times a year**
- **Weekly telecons with IGS, IVS, ILRS, IDS, IERS**
- **Some information on the networks and products on line**
- **Simulations underway - hoping we will get this scoped this year**
- **Pressing hard for reports on surveys already performed**
- **Still a lot of work to do**

A preliminary discussion on these items is included in our Poster paper from the IAG Cairns meeting which is being published in the IAG Meeting 2006 Proceedings and is available at:

M. Pearlman, et al, "GGOS Working Group on Networks, Communication, and Infrastructure" (http://cddis.gsfc.nasa.gov/docs/GGOS_IAG_0508.pdf)

An expanded version of the paper is being issued in Geomatica