NASA's Space Geodesy Project

S. M. Merkowitz, S. Desai, J. Esper, R. S. Gross, L. Hilliard, F. G. Lemoine, J. L. Long, C. Ma, J. F. McGarry, D. Murphy, C. E. Noll, E. C. Pavlis, M. R. Pearlman, D. A. Stowers, and F. H. Webb

NASA Goddard Space Flight Center
Jet Propulsion Laboratory, California Institute of Technology
University of Maryland, Baltimore County
Harvard-Smithsonian Center for Astrophysics

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The Geodetic Measurement System

VLBI
- Orientation of ITRF with respect to ICRF
- ITRF Scale

SLR
- Origin of ITRF (Earth's CM)
- ITRF Scale
- Position spacecraft in ITRF ("Orbits")

GNSS
- Precise monitoring of Polar Motion and Rotation Rate
- Position spacecraft in ITRF ("Orbits")
- Position instruments on Land and Sea (Tide Gauges and Buoys, Geodetic Instruments)

DORIS
- Position spacecraft in ITRF ("Orbits")
- Enhances global distribution of ITRF Station positions and velocities

Technique Connectivity (Station Co-Location)

Fully Define ITRF

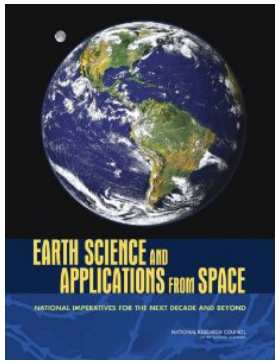
VTS: ITRF Performance Improvement

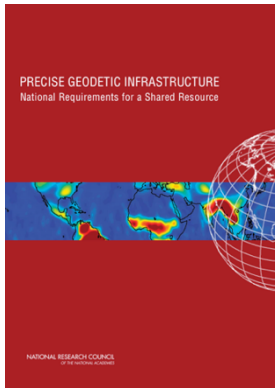
Origin, Scale, Orientation

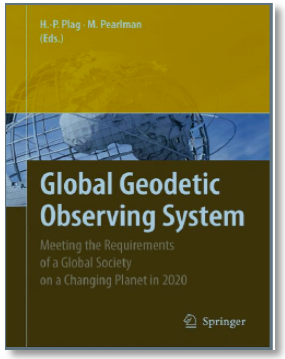
Low-Density Global Distribution

High-Density Global Distribution

Supporting Future Requirements







- **Science Driver:**
  - Most stringent requirement on the ITRF comes from sea level studies:
    - "accuracy of 1 mm, and stability at 0.1 mm/year"
    - This is a factor 10-20 beyond current capability.
  - About 30 modern integrated stations are required to meet these requirements.
- **National Research Council Recommendations:**
  - Upgrade U.S. stations with modern SLR and VLBI,
  - Work with international partners to deploy additional stations,
  - Establish and maintain a high precision real-time GNSS/GPS national network,
  - Make a long-term commitment to maintaining the ITRF,
  - Continue to support the activities of the GGOS.
- **NASA Response:**
  - Contribute to building a new global network of integrated geodetic stations through GGOS and the international services.
  - Network should be there for the coming Decadal Survey missions.
  - NASA proposes to provide 6-10 of these stations if the next generation technology can be demonstrated to function as required.
  - Complete the next generation SLR and VLBI developments.

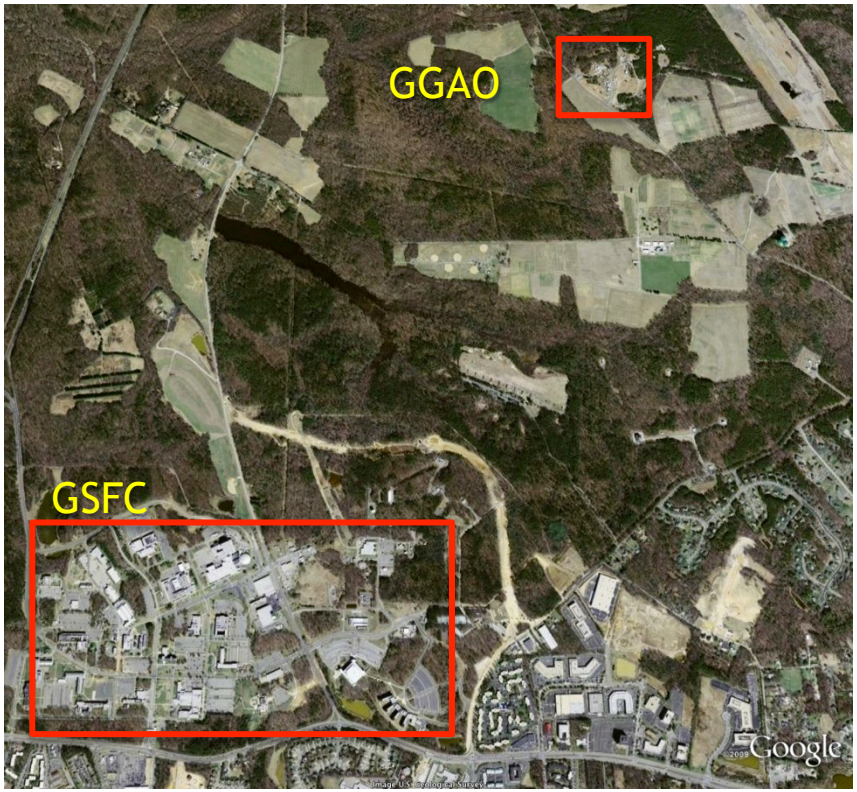
NASA's Space Geodesy Project

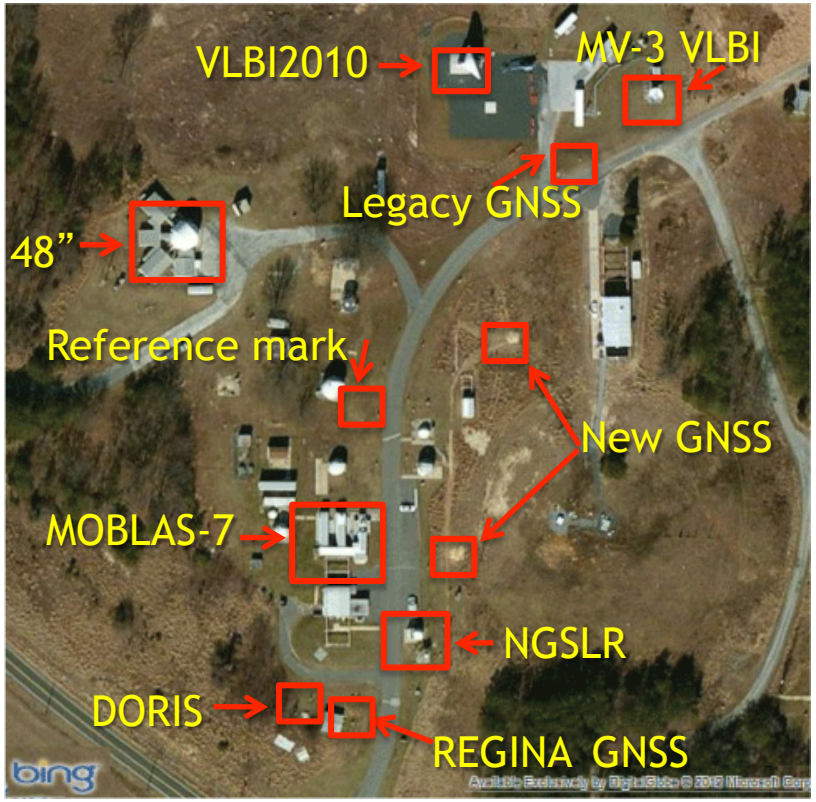
- New NASA initiative started at the end of 2011 in response to the Earth Science Decadal and the National Research Council study "Precise Geodetic Infrastructure." Part of the President's Climate Initiative.
- Goddard led in partnership with JPL and participation from the Smithsonian Astrophysical Observatory and the University of Maryland.
- Goals:
  - Establish and operate a prototype next generation space geodetic station with integrated next generation SLR, VLBI, GNSS, and DORIS systems, along with a system that provides for accurate vector ties between them.
  - Plan and implement the construction, deployment and operation of a NASA network of similar next generation stations that will become the core of a larger global network of modern space geodetic stations.

VLBI	NGSLR	GNSS	Vector Tie
			

Prototype Next Generation Geodetic Site at GGAO

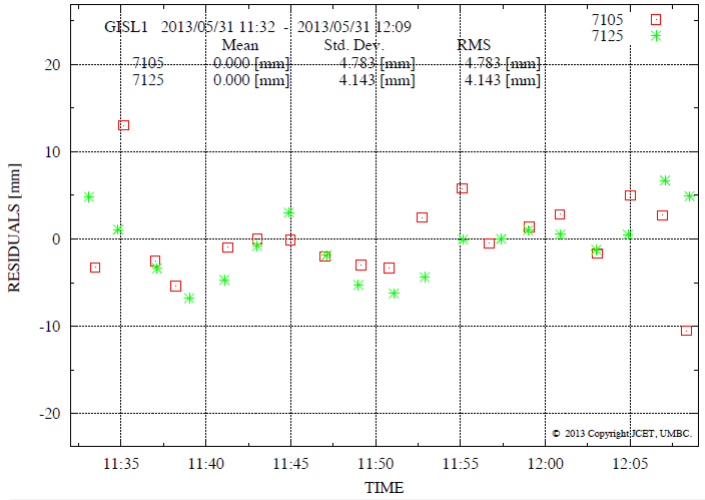
- Goddard Geophysical and Astronomical Observatory (GGAO) is located 5 km from Goddard Space Flight Center in the middle of the Beltsville Agricultural Research Center. GGAO is one of the few sites in the world to have all four geodetic techniques co-located at a single location.





Next Generation Satellite Laser Ranging (NGSLR)

Demonstrated excellent agreement between **NGSLR** & **MOBLAS-7** tracking the LAGEOS satellites with mm-level precision



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

NGSLR successfully completed a 2-year development effort by demonstrating key performance requirements, including:

- LAGEOS normal point precision ~ 1 mm.
- Robust day and night satellite ranging from LEO to GNSS altitudes (up to 22,000 km).
- System stability < 1 mm (RMS) over an hour.
- Semi-automated operations.

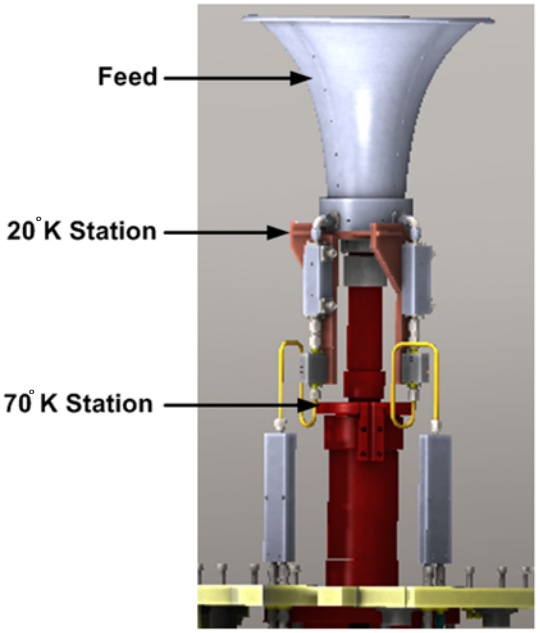
NGSLR is now the basis for the new NASA Space Geodesy Network that will consist of up to 10 new stations around the world.

VLBI Geodetic Observing System (VGOS) Concept

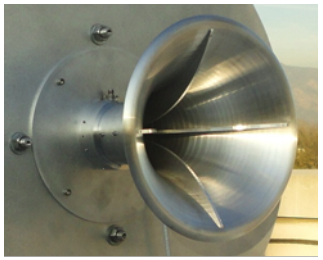
Function	Benefit	Requirement
Fast antenna	More observations for troposphere	Azimuth slew rate 5 deg/sec
Smaller antenna	Reduced cost	12-meter meets agility and gain requirements, >50% aperture efficienvy
Broadband feed	RFI avoidance, increased sensitivity	2-14 GHz meets “RFI tolerant” bandwidth and legacy compatibility requirement
Multiple bands	Increased sensitivity, data precision	4 x 512 MHz
Much higher data recording rate	Increased sensitivity	8 Gbps
Digital signal processing	Stable instrumentation	

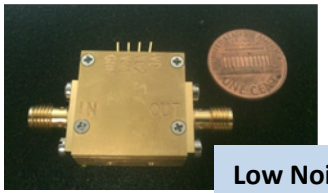
VGOS prototype as-built at GGAO

12 meter antenna



GGAO Cryogenic Front End Components

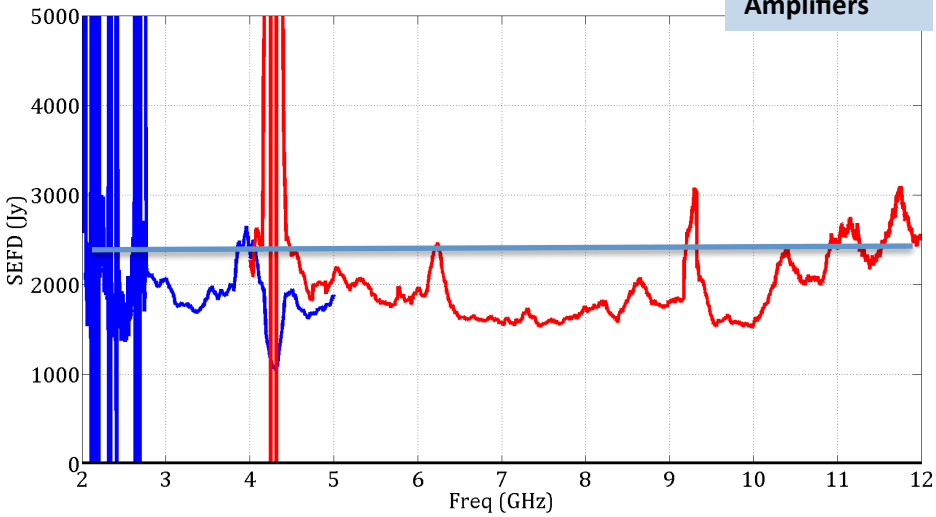




Low Noise Amplifiers

Fully Assembled Rack of Digital Back End Components

Broadband Sensitivity Performance



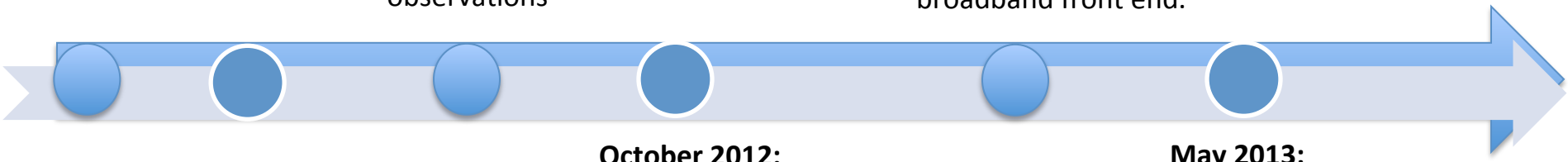
GGAO VLBI2010 Geodetic Sessions

- Geodetic sessions (end-to-end VLBI2010 observations with more than one antenna) were performed with ever increasing realism.

January 2012:
1st 12m broadband observations

April 2012:
1st legacy to broadband observations

January 2013:
1st joint broadband-legacy 24 hour session.
1st use of S-Band in broadband front end.



May 2012:
1st automated multi-source session (6 hours)

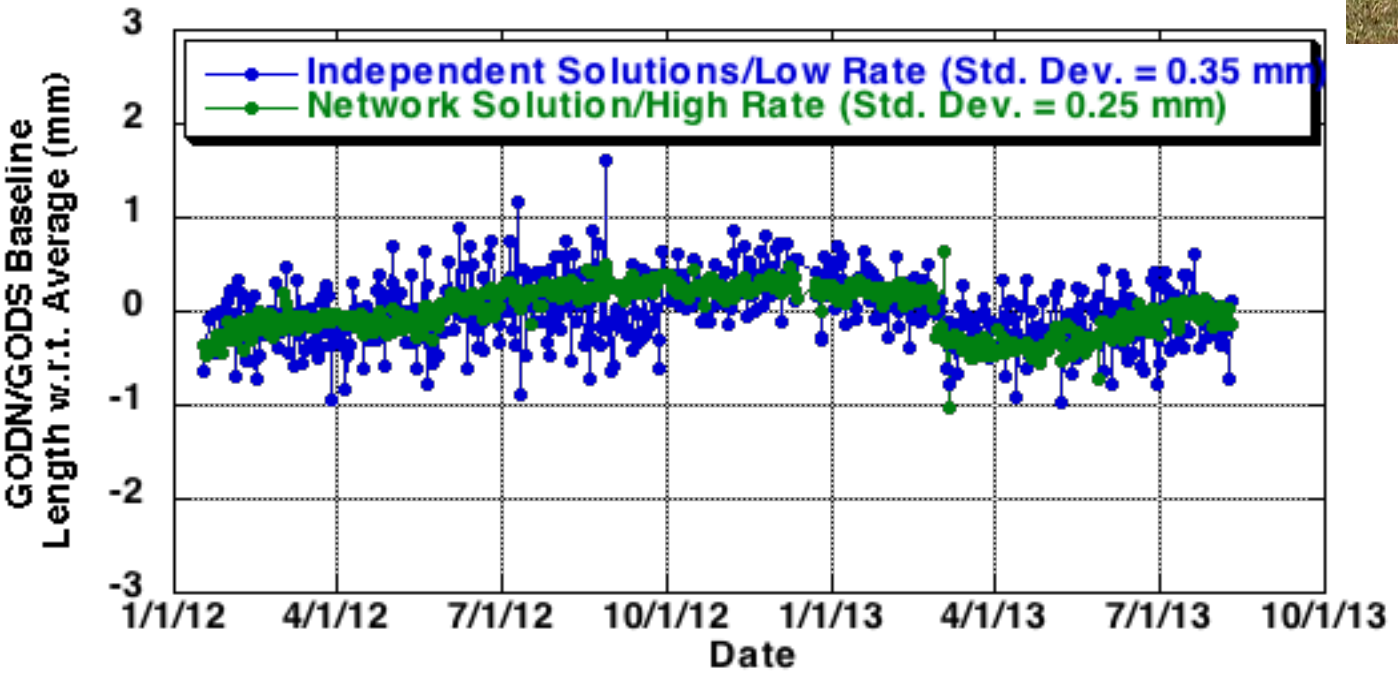
October 2012:
Two 6-hr broadband geodetic sessions.
Use SLR radar avoidance mask.

May 2013:
1st 24-hour broadband geodetic session.
1139 30-second scans.

Realism

Modern GNSS Stations at GGAO

- Two new GNSS stations installed at GGAO (GODN and GODS):
  - Collecting data since 2012-01-17.
    - Multi-constellation (GPS, GLONASS, Galileo)
- Standard deviation of GPS-based baseline lengths < 0.5 mm.
  - Independent GPS-based positioning of each station and simultaneous network positioning (both with dual frequency data).
- < 1 mm agreement between baseline length from GPS and independent local tie survey.



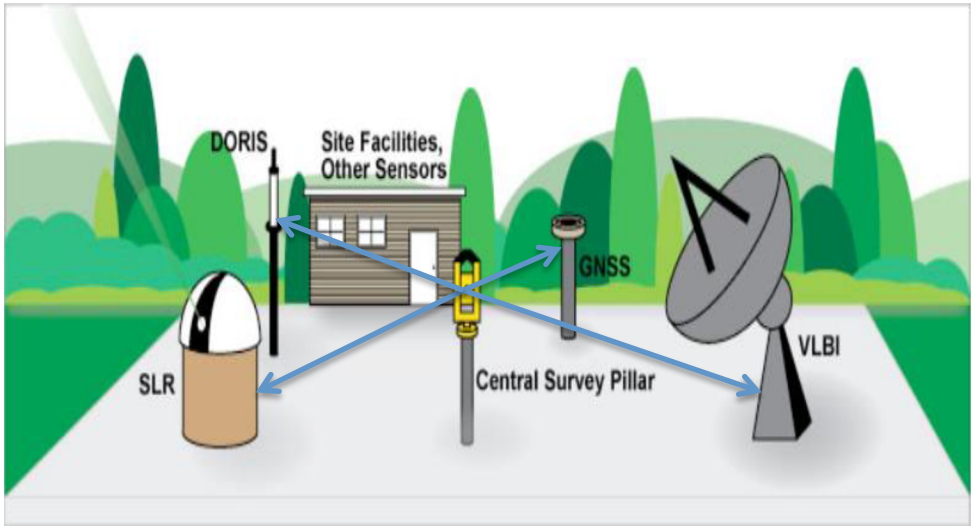
DORIS at GGAO

DORIS Global Network

- GGAO DORIS beacon part of a global network of ~57 stations
- DORIS located at GGAO since June 2000
- Beacons emit at 2 Ghz and 400 Mhz; the observable is dual-frequency 1-way Doppler
- DORIS receivers are located on altimeter satellites (TOPEX/ Poseidon, Jason1-2, ENVISAT, Cryosat-2, SARAL) and remote sensing satellites (SPOT-2, SPOT-3, SPOT-4, SPOT-5); future satellites include: Jason-3, SENTINEL-3, Jason-CS & SWOT.

Vector Tie System at GGAO

- The Vector Tie System (VTS) is a combination of a precise local-tie survey and a periodic monitoring system for measuring site stability.
- Demonstrated sub-mm accuracy at GGAO.
- Demonstrated semi-autonomous operation of monitoring system:
  - Find and identify target prism; verify prism correction,
  - Process distances measurements to correct for atmospheric correction.

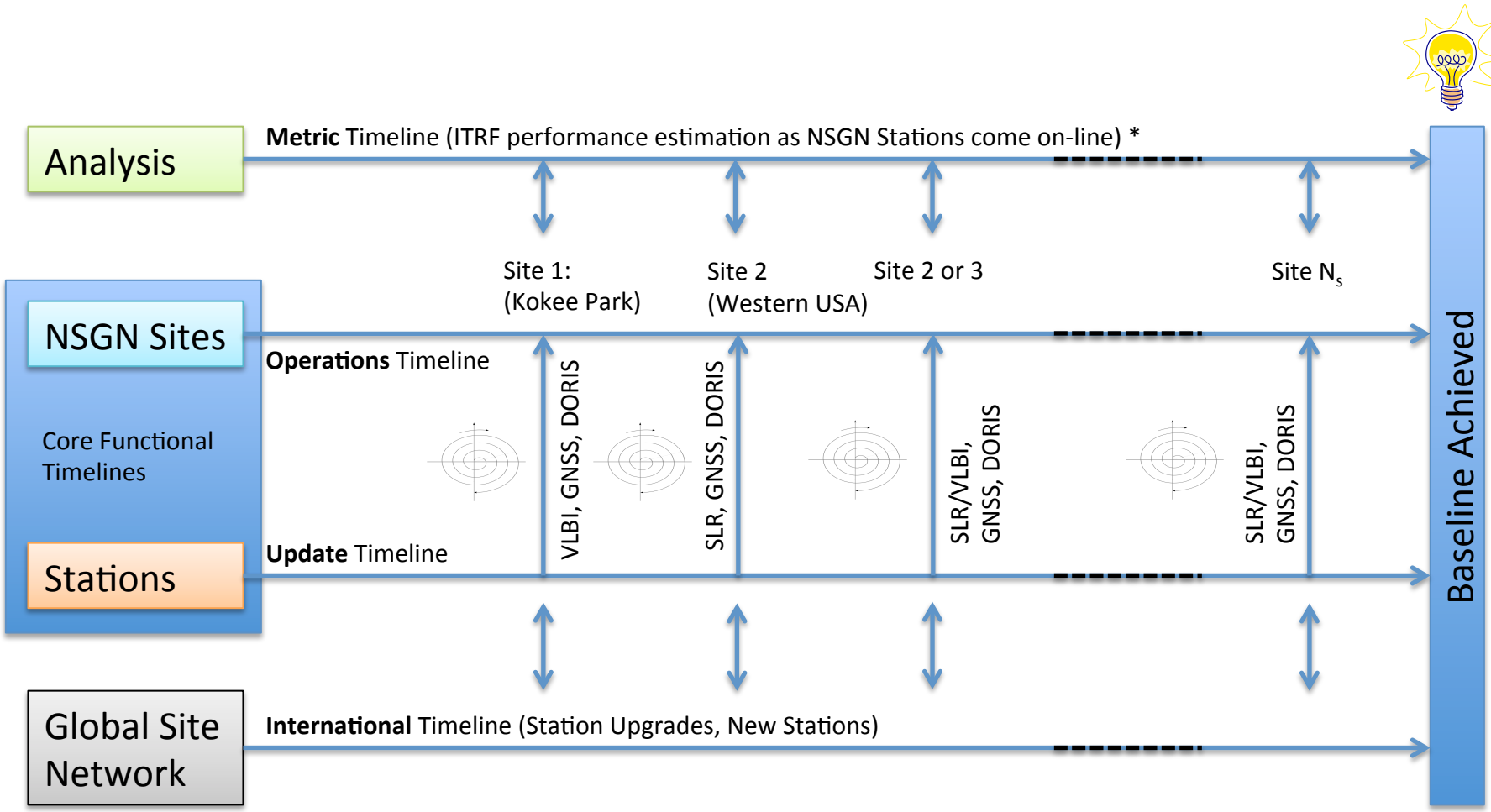


Local Reference Frame tie to all geodetic Stations

GGAO Robotic Total (Range) Station

NASA Network Deployment Timelines: Meeting the Baseline ITRF Performance

- The NASA Space Geodesy Network (NSGN) is deployed within the context of a global network, and in timelines that reflect different functional aspects.



* Technique-specific analysis also carried out concurrently to measure individual performance changes.

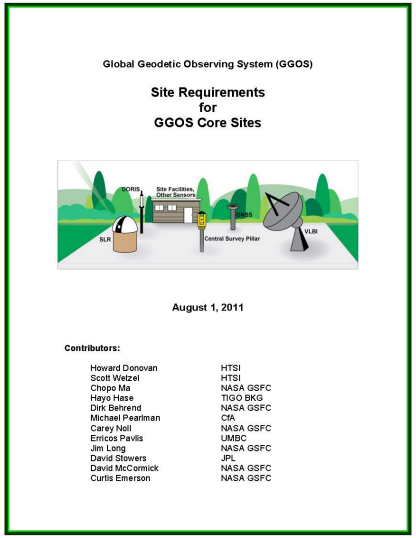
SGP Site Selection Strategy

- Conceptual global site distribution based on simulation results for a 32 site network as a starting point by regions;
- Recognize existing and projected international sites that other groups plan to bring to new technology status;
- Examine present NASA and NASA partnership sites as potential sites;
- Seek candidate sites in the under-populated regions with a reasonable chance of success.
- For each identified site:
  - Examine value added of the geodetic position,
  - Examine Site Conditions (cloud cover, ground stability, etc.),
  - Examine human imposed conditions (RF/optical interference, air traffic, etc.),
  - Examine Political / Programmatic Conditions (agreement situation, land ownership and control, partnership arrangements),
  - Examine site accessibility, logistics, infrastructure, security, power, communications).
- Qualify the Site (good or bad candidate)

August 8, 2011

Call for Participation
The Global Geodetic Core Network: Foundation for Monitoring the Earth System

A Project of the Global Geodetic Observing System (GGOS) as a contribution to the Global Earth Observation System of Systems (GEOSS)


Global Geodetic Observing System (GGOS)

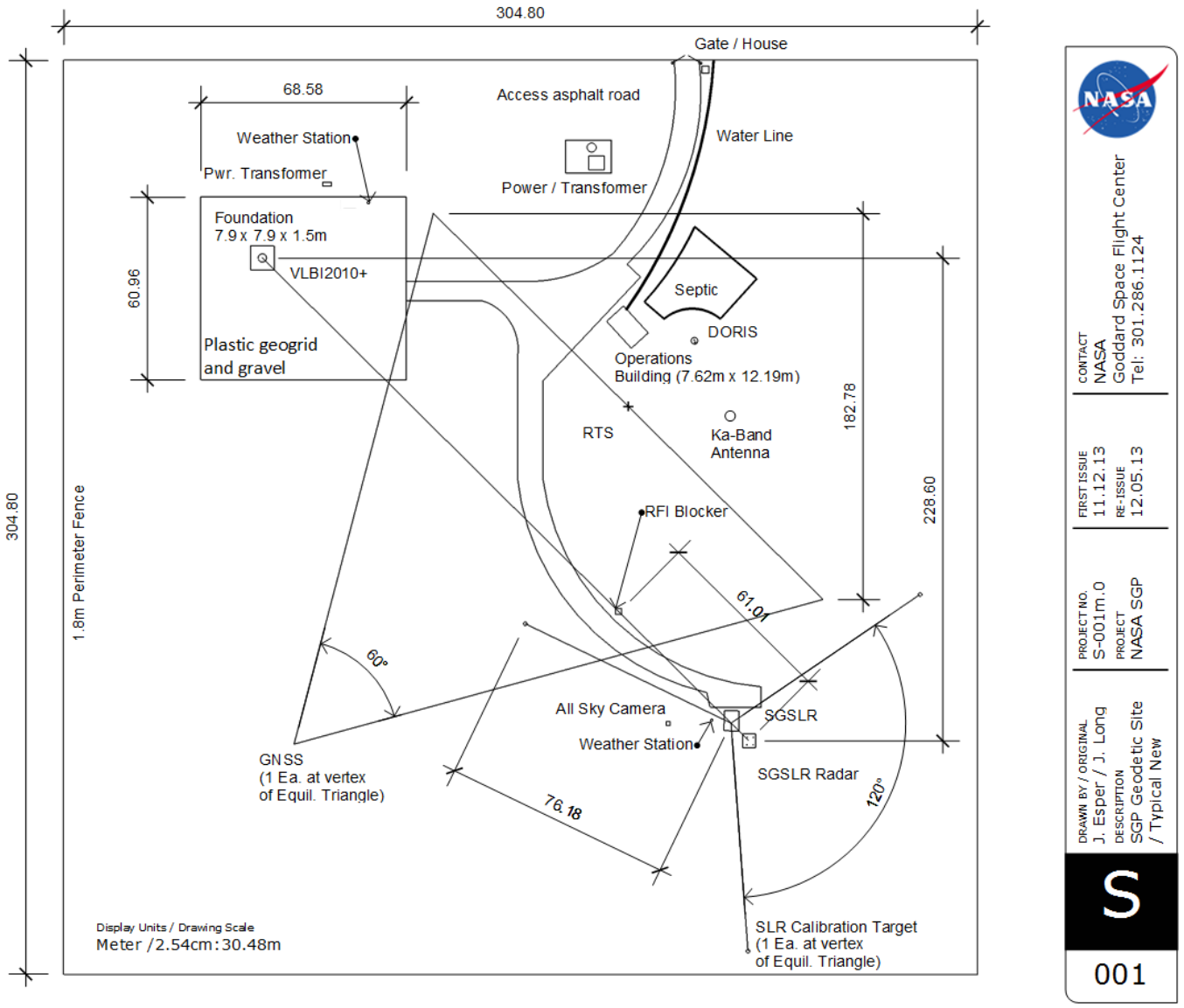
Site Requirements
for
GGOS Core Sites

August 1, 2011

Contributors:

Howard Donovan	HTSI
Scott Wetzel	HTSI
Chopo Ma	NASA GSFC
Hayo Hase	TIGO BKG
Dirk Behrend	NASA GSFC
Michael Pearlman	CfA
Carey Noll	NASA GSFC
Erricos Pavlis	UMBC
Jim Long	NASA GSFC
David Stowers	JPL
David McCormick	NASA GSFC
Curtis Emerson	NASA GSFC

Typical Site Layout



CONTACT
NASA
Goddard Space Flight Center
Tel: 301.286.1124

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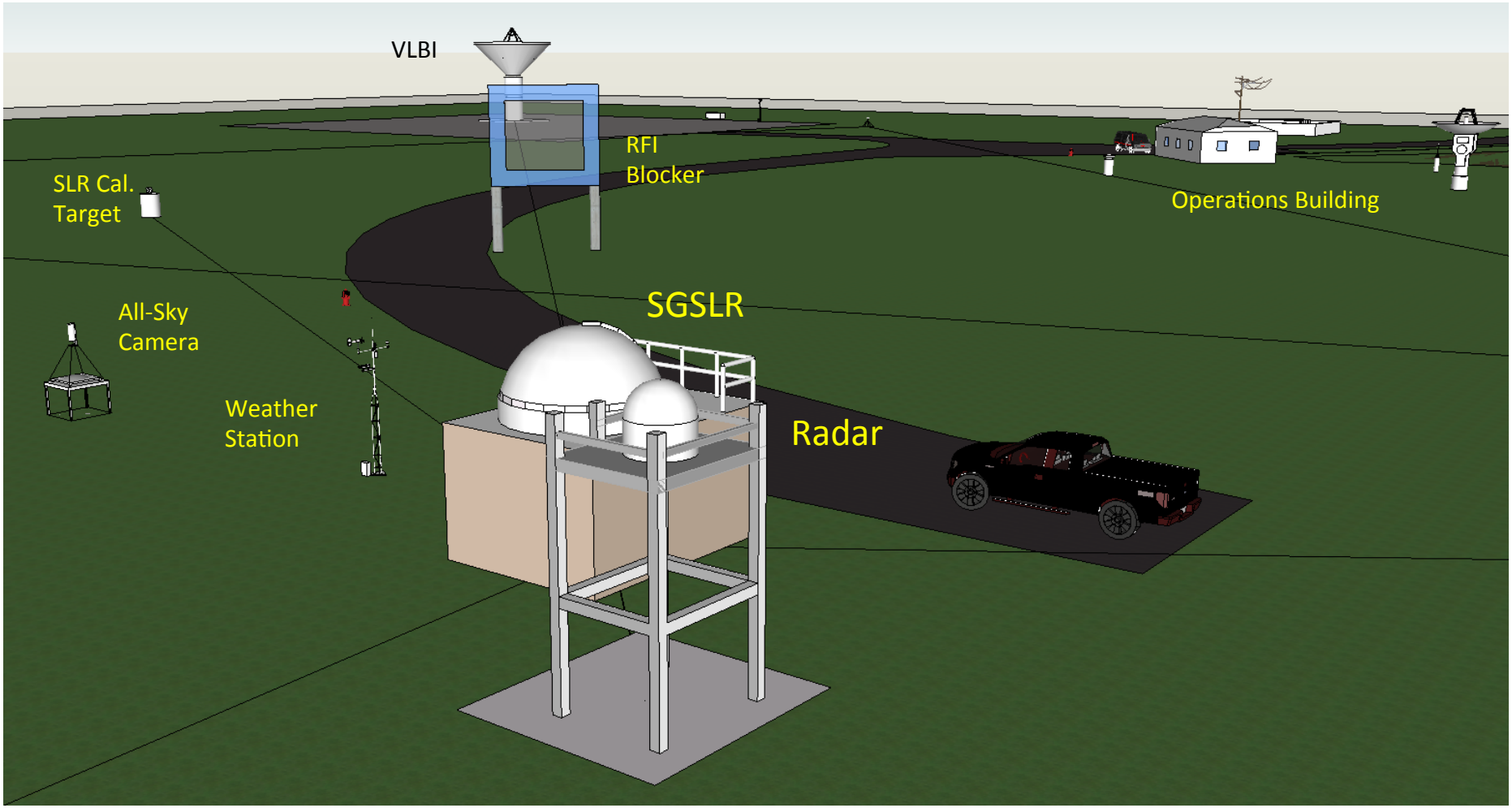
S-001m.0
PROJECT
NASA SGP

DRAWN BY / ORIGINAL
J. Esper / J. Long
DESCRIPTION
SGP Geodetic Site
/ Typical New

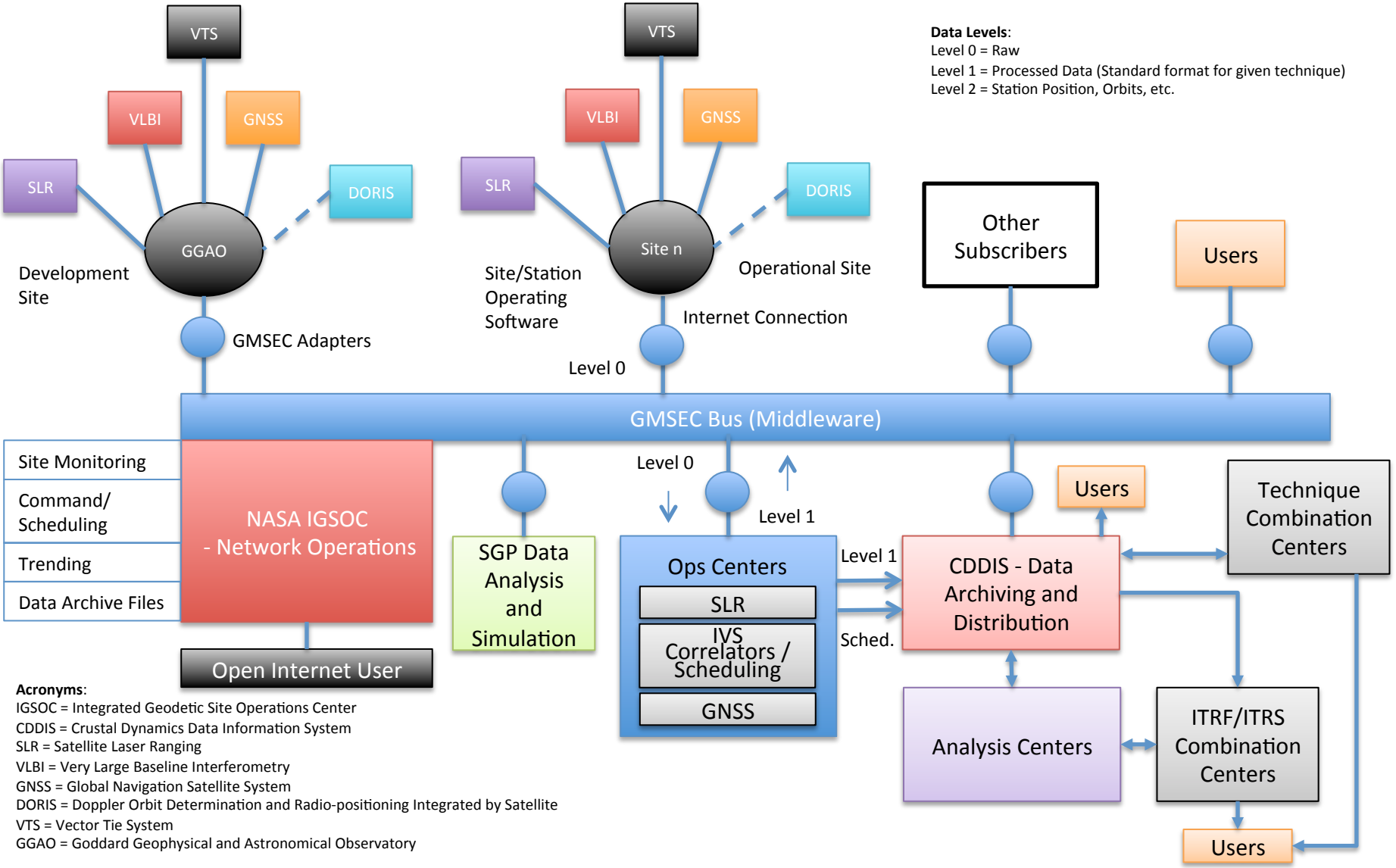
S

001

Typical Site Layout



Connecting the Network: Integrated Geodetic Site Operations Center



Data Levels:
Level 0 = Raw
Level 1 = Processed Data (Standard format for given technique)
Level 2 = Station Position, Orbits, etc.

Acronyms:
IGSOC = Integrated Geodetic Site Operations Center
CDDIS = Crustal Dynamics Data Information System
SLR = Satellite Laser Ranging
VLBI = Very Large Baseline Interferometry
GNSS = Global Navigation Satellite System
DORIS = Doppler Orbit Determination and Radio-positioning Integrated by Satellite
VTS = Vector Tie System
GGAO = Goddard Geophysical and Astronomical Observatory

Project Status Summary

- Completed 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.
  - New GNSS stations continue to operate well for ~2 years.
- Developed architecture for typical core sites and an Integrated Geodetic Site Operations Center.
- Preparations underway for site selections and deployment of the new NASA network!!!