NASA’s Next Generation Space Geodesy Network
Typical Core Site Requirements and Layout

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Introduction

• The Space Geodesy Project (SGP) at NASA has been defining the requirements and layout for a “typical Core” geodetic site:
  – Includes SLR, VLBI, GNSS, and DORIS (CNES) stations, tied together with a Vector Tie System (VTS).

• Within programmatic constraints, Core Site (CS) identification follows a systems engineering process
  – Site characteristics are pitched against identified requirements.

• Here is an abridged version of the process leading to identification, and the layout of an idealized CS with unencumbered terrain.
SGP Objectives and Science Requirements

- **SGP0.1:** SGP shall continue to operate, maintain, and where applicable, upgrade the current NASA Space Geodesy Network.

- **SGP0.2:** SGP shall contribute to building, operating, and maintaining a new global network of integrated geodetic stations.

- **SGP1.1:** SGP shall contribute to a stable Terrestrial Reference Frame (TRF) that meets the needs of NASA’s Earth orbiting missions, Earth Surface and Interior Program, and deep space navigation.

- **SGP1.2:** SGP shall contribute to measurements of Earth orientation parameters (EOP) that meet the needs of NASA’s Earth orbiting missions, Earth Surface and Interior Program, and deep space navigation.

- **SGP1.3:** SGP shall contribute to determining accurate precision orbits to meet the needs of NASA's geodetic, Earth observation, navigation and space science missions.
PRIB3.1 (Baseline Requirement TRF): Co-located global geodetic network shall permit the realization of the ITRF with the following attributes: 

\[ \text{Accuracy: } \leq 1 \text{ mm (1-Sigma) in X,Y,Z (decadal scale); Stability: } \leq 0.1 \text{mm/yr (annual scale).} \]

Circles highlight suggested NASA and NASA partnership core sites.

Choosing Stations within a ~1000 km area around the “simulation sites” does not affect the resulting ITRF accuracy attributes.
**SIT3.1: ITRF Site Stability / Continuity**

- **SIT3.1.1**: SGP Site shall be located away from major plate boundaries and known active faults (> 100 km) and on bedrock.

- **SIT3.1.2**: SGP Sites shall have only secular (linear) motion, with stable rates, varying by ≤0.1 mm/y over a minimum of three (3) years.

- **SIT3.1.3**: The area surrounding the site shall be largely unaffected from loading transients, i.e. historically no frequent major droughts or floods recorded, and local extraction or injection of underground liquids (water, oil, etc.) shall not result in significant (>10%) loading amplitude variations over time.

- **SIT3.1.4**: At least one GNSS Station shall remain at any legacy SGP Site after decommission.

- **SIT3.1.5**: If a Site is to be decommissioned and there is an operational SLR Station, the SLR Station shall not be decommissioned until the new SGSLR Station at the Site is verified to operate as expected.

- **SIT3.1.6**: If a Site is to be decommissioned and there is an operational VLBI Station, the VLBI Station shall not be decommissioned until the new VGOS Station at the Site is verified to operate as expected.
**SIT3.2**: NSGN Site Data Acquisition Requirements

**SIT3.2.1**: The *average SGSLR Data* generated by each NSGN Site shall be 16 Gbits/week

**SIT3.2.3**: The *average VGOS Data* generated by each NSGN Site shall be 55 TByte/day for non-real-time data collection (3080 Tbits/week).
SIT3.3: Site Infrastructure Requirements

SIT3.3.1: NSGN Sites shall have *broad-band internet communications* for near real-time data transfer and instrument control and monitoring.

SIT3.3.2: *Electrical power* shall be available to NSGN Sites.

SIT3.3.3: A *typical* NSGN Site shall have an *area* (1000 x 1000) sqf (305 x 305) sqm
**SIT3.4: Non-ITRF NASA Science Requirements**

**SIT3.4.1 (Altimetry):** A well distributed NSGN network of SLR Stations shall support a total of 24-30 passes per day with a NP accuracy of 1 cm.

**SSR2 (Plate Tectonics/POD):** The NSGN network shall be well distributed around the globe, and shall have a long history of operation.
Site Preparation - Technical

- Site Preparation Activities
  - Site visit and prepare detailed engineering requirements report
  - Soil borings and geotechnical report
  - Perform detailed topographic survey
  - Civil design / prepare construction documents
  - Competitive bids / award construction contract
  - Construction activities
  - Site occupancy review and acceptance
Site Preparation - Programmatic

• US Sites
  – National Environmental Protection Agency (NEPA) requirements
    • Environmental Assessment
    • Sediment & Erosion Control / Storm water Management
  – Site ownership and required agreements
  – Status

• International Sites with NASA participation require:
  – Approved agency-to-agency agreement(s)
  – Initial site assessment
Site Block Diagram
## Site Infrastructure

<table>
<thead>
<tr>
<th>Item</th>
<th>Description / Infrastructure</th>
<th>Qty</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GENERAL SITE WORK</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Security Fence</td>
<td>4000</td>
<td>LF</td>
</tr>
<tr>
<td>2</td>
<td>Access road, asphalt, 1000' x 20'</td>
<td>2222</td>
<td>SY</td>
</tr>
<tr>
<td>3</td>
<td>Site Road, asphalt, 1000' x 18'</td>
<td>2000</td>
<td>SY</td>
</tr>
<tr>
<td>4</td>
<td>HV Overhead Power &amp; Xfmr</td>
<td>1</td>
<td>LS</td>
</tr>
<tr>
<td>5</td>
<td>Underground Power on Site</td>
<td>1000</td>
<td>LF</td>
</tr>
<tr>
<td>6</td>
<td>Underground Communications Duct</td>
<td>1500</td>
<td>LF</td>
</tr>
<tr>
<td>7</td>
<td>Water Distribution on site</td>
<td>300</td>
<td>LF</td>
</tr>
<tr>
<td>8</td>
<td>Septic Tank and Drain Field</td>
<td>1</td>
<td>LS</td>
</tr>
<tr>
<td>9</td>
<td>Operations Building, 25' x 40'</td>
<td>1000</td>
<td>SF</td>
</tr>
<tr>
<td><strong>VGOS VLBI Site</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Earthwork</td>
<td>1</td>
<td>LS</td>
</tr>
<tr>
<td>2</td>
<td>Antenna Foundation, 26' x 26' x 5'</td>
<td>126</td>
<td>CY</td>
</tr>
<tr>
<td>3</td>
<td>Reflector assembly area, access area</td>
<td>5000</td>
<td>SY</td>
</tr>
<tr>
<td>4</td>
<td>Power &amp; 480V - 208/120 V Xfmr</td>
<td>1</td>
<td>LS</td>
</tr>
<tr>
<td>5</td>
<td>Grounding &amp; Lightning Protecion</td>
<td>1</td>
<td>LS</td>
</tr>
<tr>
<td>6</td>
<td>Electronics Shelter, 12' x 20'</td>
<td>240</td>
<td>SF</td>
</tr>
<tr>
<td>7</td>
<td>Underground conduit</td>
<td>100</td>
<td>LF</td>
</tr>
<tr>
<td><strong>SGSLR Site</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Foundation &amp; Pillar for Telescope</td>
<td>4</td>
<td>CY</td>
</tr>
<tr>
<td>2</td>
<td>Concrete Pad for Shelter 12' x 16' x 1'</td>
<td>7</td>
<td>CY</td>
</tr>
<tr>
<td>3</td>
<td>Power 208/120V, 3-ph, 60 Hz, 100 Amp</td>
<td>1</td>
<td>LS</td>
</tr>
<tr>
<td>4</td>
<td>Grounding &amp; Lightning protection</td>
<td>1</td>
<td>LS</td>
</tr>
<tr>
<td>5</td>
<td>Underground conduit</td>
<td>50</td>
<td>LF</td>
</tr>
</tbody>
</table>

* LF = Lineal Feet; SY = Square Yard; LS = Lump Sum (meaning “a good guess”); SF = Square Foot; CY = Cubic Yard
Site Facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office space (500 sq. ft. or ½ Ops Bldg.)</td>
<td>Operations Bldg.</td>
</tr>
<tr>
<td>Lab/engineering space (500 sq. ft. or ½ Ops Bldg.)</td>
<td>Operations Bldg.</td>
</tr>
<tr>
<td>Storage space</td>
<td>Operations Bldg.</td>
</tr>
<tr>
<td>Communications (telephone, Internet/LAN)</td>
<td>Site level</td>
</tr>
<tr>
<td>Bathroom/kitchen/rest areas</td>
<td>Operations Bldg.</td>
</tr>
<tr>
<td>Environmental control (localized)</td>
<td>Site/station level</td>
</tr>
<tr>
<td>Backup power/communications system</td>
<td>Site level</td>
</tr>
<tr>
<td>Site/station security system</td>
<td>Site/station level</td>
</tr>
<tr>
<td>Personal protection system</td>
<td>Site level</td>
</tr>
</tbody>
</table>
Electrical Power Supply Requirements

• Assume Site nominal Voltage 240V, frequency 50-60Hz.

• Power conversion carried out at the individual Stations, unless noted otherwise. Approximate total power needs follow.

• GNSS ~ 1.2kW
• VLBI ~ 31kW
• DORIS ~ 900W
• SGSLR ~ 12.0 to 20.8kW
Core Site Optional Instrumentation

- This equipment list covers components that would **enhance** the applicability of SGP Sites in support of NASA science.
- They are **not considered essential** to the operation of the core geodetic techniques.

<table>
<thead>
<tr>
<th>External Measurement Systems</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilt meters</td>
<td>Site level</td>
</tr>
<tr>
<td>Seismometer</td>
<td>Site level</td>
</tr>
<tr>
<td>Water vapor radiometer</td>
<td>Site level</td>
</tr>
<tr>
<td>Gravimeter</td>
<td>Site level</td>
</tr>
</tbody>
</table>
Typical Site Layout: Guidelines and Assumptions

- Overall dimensions are 1000’ x 1000’
  - A controlling dimension is the separation of VLBI antenna and SGSLR radar at 750’
  - Buffer zone of ~200’ between SG instruments and the fence line.
- Layout offers strong geometry for inter-comparison surveys and TRF orientation
  - The four space geodesy techniques form a quad figure of ~500’ per side
  - The three GNSS form an equilateral triangle ~600’ per side
- RTS is near center of site and close to Ops. Bldg. (Site Hub) to minimize cable lengths
- DORIS is near Ops. Bldg. to keep cable lengths short, and located to block line-of-sight to VLBI
- SGLSR has three calibration targets 120 degrees apart at a distance of 250’
- Ops. Bldg. is centrally located: dimensions: 25’ x 40’
- GNSS receivers are located in OPS Bldg.
- VLBI site has an level assembly area constructed of plastic geogrid and gravel; 200’ x 225’
  - Pre-fabricated shelter for backend electronics to keep cable length reasonable (~120 feet)
  - Antenna foundation is 26’ x 26’ x 5’ thick
  - Data transmission from antenna to electronics and to the Ops building via fiber optic lines.
- Accommodation for septic system, water line, and external power conversion
- Accommodation for 3-meter Ka-band antenna for remote Site installations.
  - Connected to Ops building via fiber optic lines.
Site Layout Drawing
Local geography may alter the nominal location of Stations and buildings.

FOV constraints for each technique:
“non-obstructed view up to 5° elevation (GNSS/VLBI), 10° (SLR), 5° (DORIS), along 360° azimuth”.

Entry Gate View

SGSLR Ka-Band RFI Blocker Operations Building Power Station VGOS VLBI
• Most sensitive to Radio Frequency Interference (RFI).
• Sources: (1) SLR Radar; (2) DORIS Beacon; (3) Local Broadcasts (variable, sometimes unpredictable)
  – SLR Radar and DORIS are located behind SLR and Ops. Buildings, respectively.
View from Space Geodesy SLR (SGSLR)

SGSLR Building Dimensions:
5.7 x 4.2 x 3.0 m

Ground-to-SLR Dome Height:
5.0m

Ground-to-Radar Dome Height:
5.6m

Approximate building dimensions shown
View from DORIS Beacon

VLBI Behind Operations Building

Ops. Building
Dimensions: 12.2 x 7.6 x 3.0 m; Rooftop at 4.2m
Various Perspectives

Ka-Band Communications Antenna (optional)

RTS Stand

Power Station

GNSS Stations

SLR Calibration Targets
RFI Blocker – SLR Radar

- Minimum distance from SLR Radar 61m
- Dimensions 4.2m x 3.7m min; 5.9m x 5.4m nominal (includes a 20% linear size margin)
- RFI noise $\ll -80$ dBW at VLBI antenna location
- Mesh material (~79% open) to minimize wind-loading (e.g. [http://www.twpinc.com/wire-mesh/TWPCAT_11/p_100X100T0011W48T](http://www.twpinc.com/wire-mesh/TWPCAT_11/p_100X100T0011W48T))

RFI Blocker size takes into consideration full range of motion of VLBI antenna, and distance to SLR radar. Its centerline is located along the Radar-VLBI baseline.
DORIS Beacon Barrier

• DORIS barrier must be considered for two frequencies; 2GHz and 400MHz.

• Barriers modeled for 6 degrees in azimuth and elevation

- The requirements are:
  - No metallic object must be located within the envelope volume (except for the DORIS antenna nominal support).
  - Nothing must stand within the visibility cone, apart from the antenna itself.

- This implies:
  - the barrier should be placed at 5m from the antenna and
  - the barrier should raise a height that does not exceed the limit of the visibility cone
  - rem. : a derogation could be made to take a value slightly higher for the visibility cone (between 5 and 8°)