Emerging Geospatial Innovations Enabling Global Capability for Climate and Crisis Response

Second United Nations World Geospatial Information Congress

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As a U.S. Department of Energy (DOE) national lab, ORNL is part of a network for discovery and innovation.
ORNL facts and figures

- 3,200 research guests annually
- Nation's most diverse energy portfolio
- World's most intense neutron source
- 2,511 journal articles published in FY21
- Managing major DOE projects: US ITER, exascale computing
- ~5,800 employees
- 3,200 research guests annually
- Nation's largest materials research portfolio
- World-class research reactor
- 241 invention disclosures in FY21
- 52 patents issued in FY21
- $2.4B annual expenditures
- $750M modernization investment
- Forefront scientific computing facilities
- World's most intense neutron source
- 52 patents issued in FY21
High resolution settlement and population data with GeoAI and HPC
LandScan Global Population Distribution Data Sets

LandScan Global (1km)

LandScan HD (90m)

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Mapping human settlements from high resolution images

Addis Ababa, Ethiopia

Yaoundé, Cameroon
Reducing the scope of the population mapping problem

Separating buildings from non-building area:

<table>
<thead>
<tr>
<th>Country</th>
<th>Total area (km²)</th>
<th>Built-up area (km²)</th>
<th>% built-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mali</td>
<td>~1,240,000</td>
<td>247.7</td>
<td>0.02%</td>
</tr>
<tr>
<td>Venezuela</td>
<td>~915,000</td>
<td>1,163.5</td>
<td>0.13%</td>
</tr>
</tbody>
</table>

Approximately 99.98% of Mali and 99.87% of Venezuela are non-building

Mapping buildings means population models have a more manageable task - they need only explain the variation in population density within the small fraction of land area that is inhabited.
United States: high resolution buildings map

- 60,000 images (~1.2 PB)
- 0.3-1 m multispectral 2011-2021
- 74 trillion pixels
# Automated Building Mapping at Scale

## Technology Description
- Automated high-resolution building extraction based on advanced deep learning applications

## HPC Utilization
- Scaled to 12 Summit nodes (96 total GPUs)
- Model training with 110,000 World View labelled images (covering 9,314 km² globally) in less than 45 minutes

## Impact
- Average processing time for a half-meter 4-band image averaging 35,000 x 35,000 pixels is 3 minutes using a single V100 GPU.
- For the country of Iraq:
  - 4 minutes to extract all buildings using 3,206 GPUs on Summit
  - 8 hours to extract all buildings using 24 DGX1 GPUs plus 16 DGX2 GPUs
• Overlay pre-event building footprints (in blue), we compare our results to the FEMA damage assessment database

• 88% of destroyed/major damaged building (3722 out of 4225) are identified through this rapid assessment
Baga, Nigeria (February 2015)

Automated Count: 9601

Automated Count: 151
Mariupol damage assessment

Pre-event

June 26, 2016

March 22, 2022

Post-event

Mariupol Derived Products:
- Building structure footprints
- Change map and analysis
- Land use/Land cover map
- Building structure use map
- Change driven damage map

Change map
Mosaic of July 2015 and September 2019

**Damages:** Significant apartments and residential structures show damages in March 2022 imagery.
High resolution elevation models at global scale
High resolution digital surface model

Active sensing
• Radar (e.g., Shuttle Radar Topography Mission)
• Lidar (light detection and ranging)

Stereo imagery
• Higher resolution (900x vs. state-of-practice)
• No additional hardware needed
• Fortuitous – no tasking needed
• Passive – not detectable
• Low SWAP – large standoff distance
• Scalable to the world
## 3D Digital Surface Model Generation

### Technology Description
- Automated generation of high-resolution digital surface models (DSM) from optical stereo imagery
- Operational GOTS (govt off the shelf) capability

### HPC Utilization
- Implemented best-in-class algorithm in stereo known as semi-global matching (SGM)
- Accelerated SGM for GPU HPC platforms

### Impact
- Ability to process roughly 200,000 km² of WorldView-3-quality per week
- High resolution DSMs serve as foundational elements for many humanitarian and disaster response applications
GeoAI/ML Deployment at the Edge
GeoAI at the Edge: Hurricane Damage Assessment

- Utilizing UAS to process imagery onboard, find utility poles and assess their condition (up or down), and reports back over constrained communications environments.
Small Satellite Ground Station (GS) Infrastructure for Climate and Crisis Response

• Create an interconnected, robust platform for data collection, transmission, analysis, and edge processing for a wide range of science applications

• Develop a high-performance computing and AI/ML test bed for use on/with space-based platforms

• Lower the bar to advance technology for industry, academia, and government

• Phase I partnerships with
  - SAR
  - Hyperspectral
Federated Cyberinfrastructure: HPC to Edge Computing

- Create access to best in class, geographically distributed resources
  - Data
  - Scalable computation
  - Analysis and visualization
- Platform for data integration and knowledge dissemination
- Enables on time and on demand information and knowledge delivery, particularly for time critical mission support
Discussion