

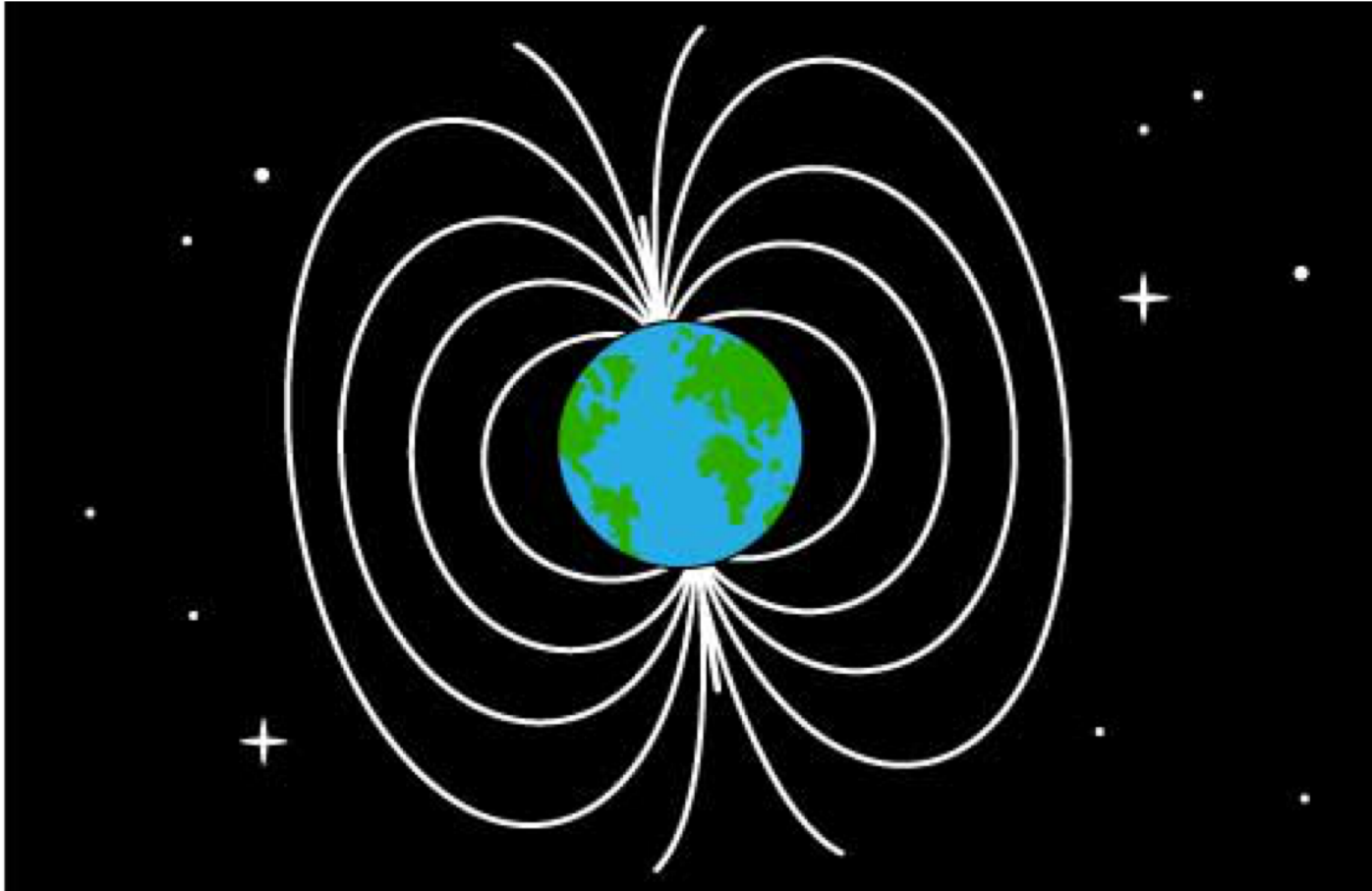
Ground-based measurements: MAGNETOMETERS

With thanks for contributions by Mark Moldwin
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Peter Chi (UCLA), and Chris Balch (NOAA-SWPC)

CPI is a member of ACSWA (American Commercial Space Weather Association - ACSWA.us)

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The magnetic field is the footprint of the Earth's space environment on the ground.



There are two (related) use cases for magnetic field data – science and operations.

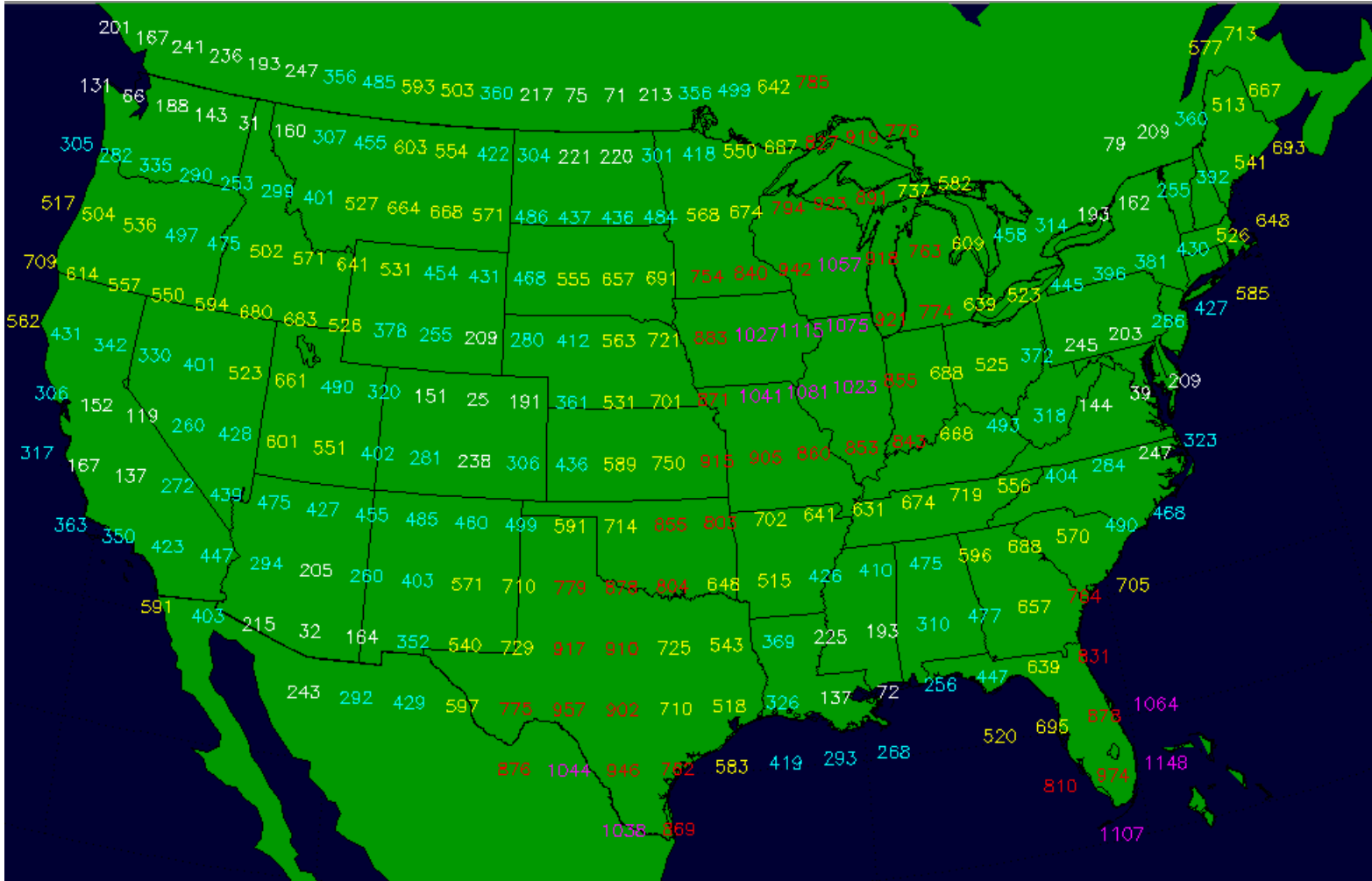
Science

- Space weather
- Sun-earth interactions
- Crustal geophysics
- Geomagnetically-induced currents
- Magnetoseismic research
- Geophysical hazard research
- Ionospheric/Auroral process

Operations

- Power utilities
- GPS accuracy
- Communications
- Polar flights
- Satellite drag
- Geomagnetic indices: Kp, Dst, AE
- Supporting data for satellite-based measurements
- **NOAA Operational Products**

The observatory network is sparse



Distances (km) of grid points to nearest observatory with 5 NRCAN and 8 USGS stations.

(Figure courtesy of Chris Balch, NOAA-SWPC)

Most magnetometer arrays are NSF-supported

- Each array has its own scientific goal and infrastructure
- SuperMag consortium provides data access to multiple arrays

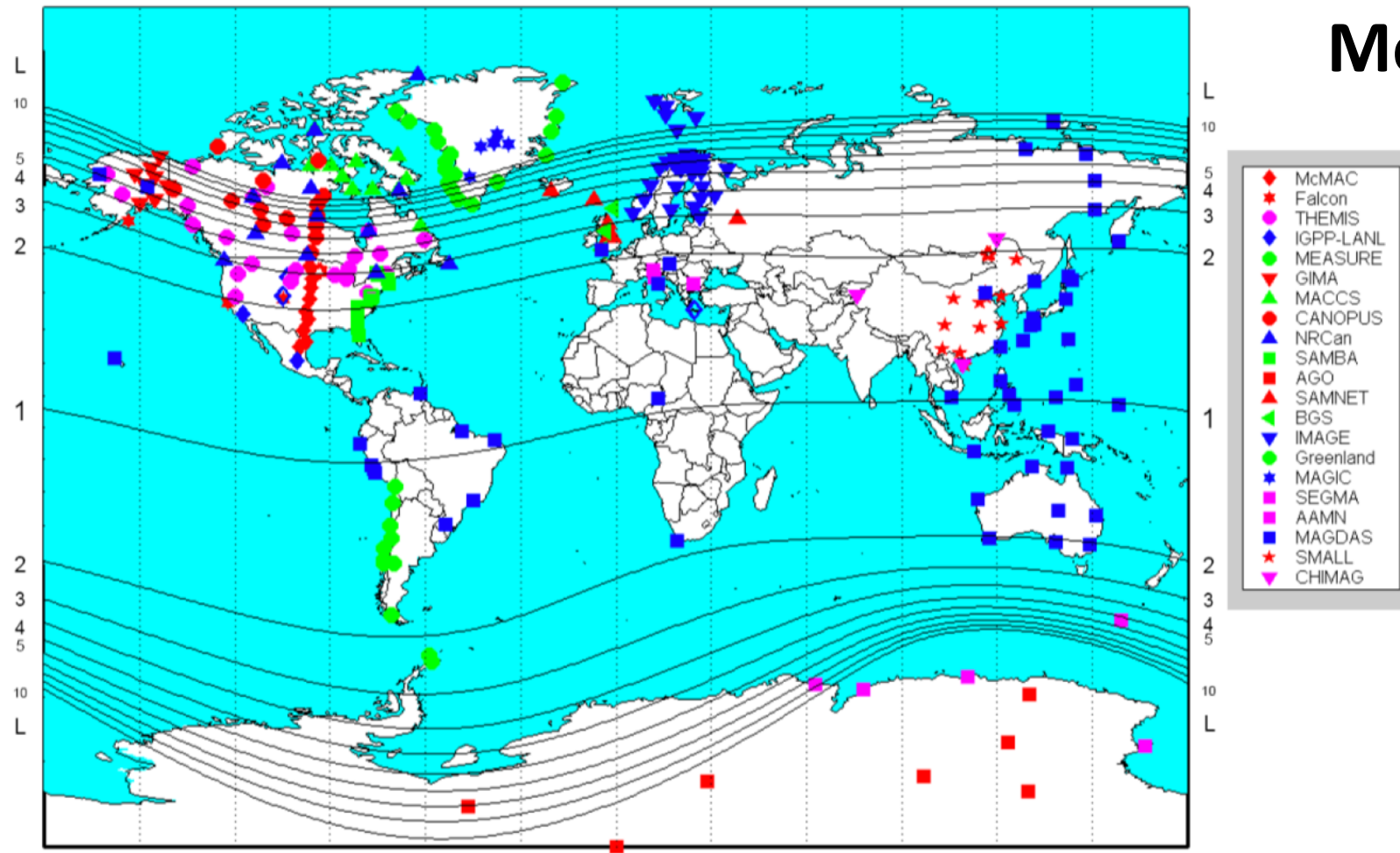


Figure 2. A world map of high-cadence (5-second a sample or better) geomagnetic observations for Heliophysics research in the last decade [16]. Some recently built stations are not included in this map.

(image courtesy Peter Chi – UCLA)

NSF-funded array focused on operational infrastructure

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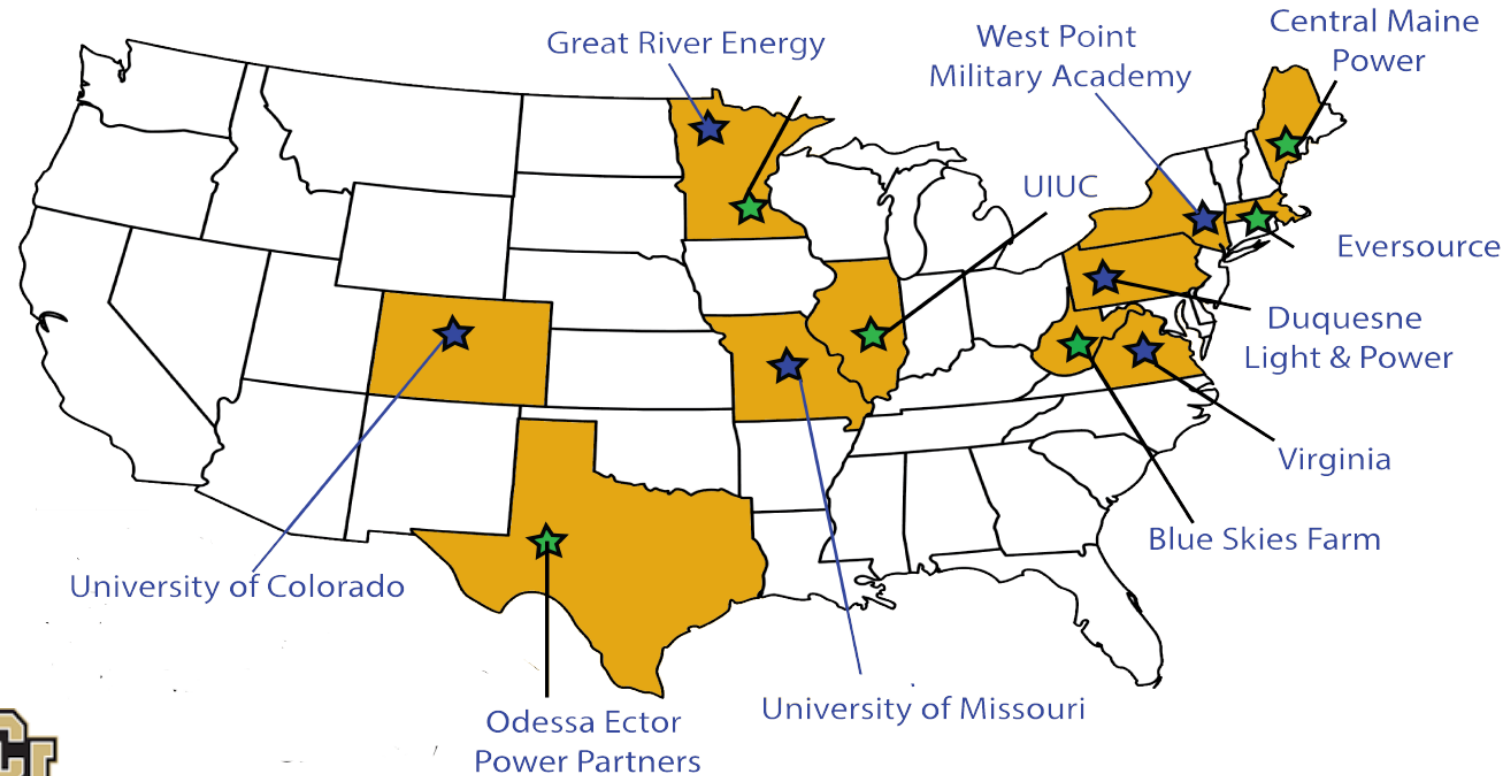
cpi Computational Physics, Inc
an employee-owned company

GIC Magnetics



University of Colorado
Boulder

MagStar



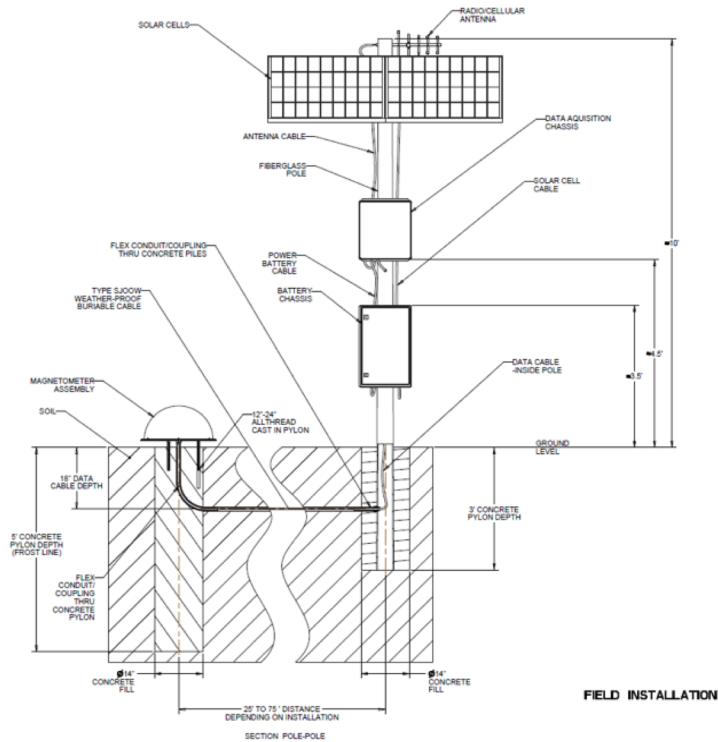
<http://magstar.cpi.com>

MagStar Array Partners



MagStar Installation

- Secure communication over long-range wireless
- Low-latency data transfer (fraction of a second for 1Hz data)
- Temperature corrected
- Custom low-noise, low power DAQ
- Containerized, cloud-based operational system



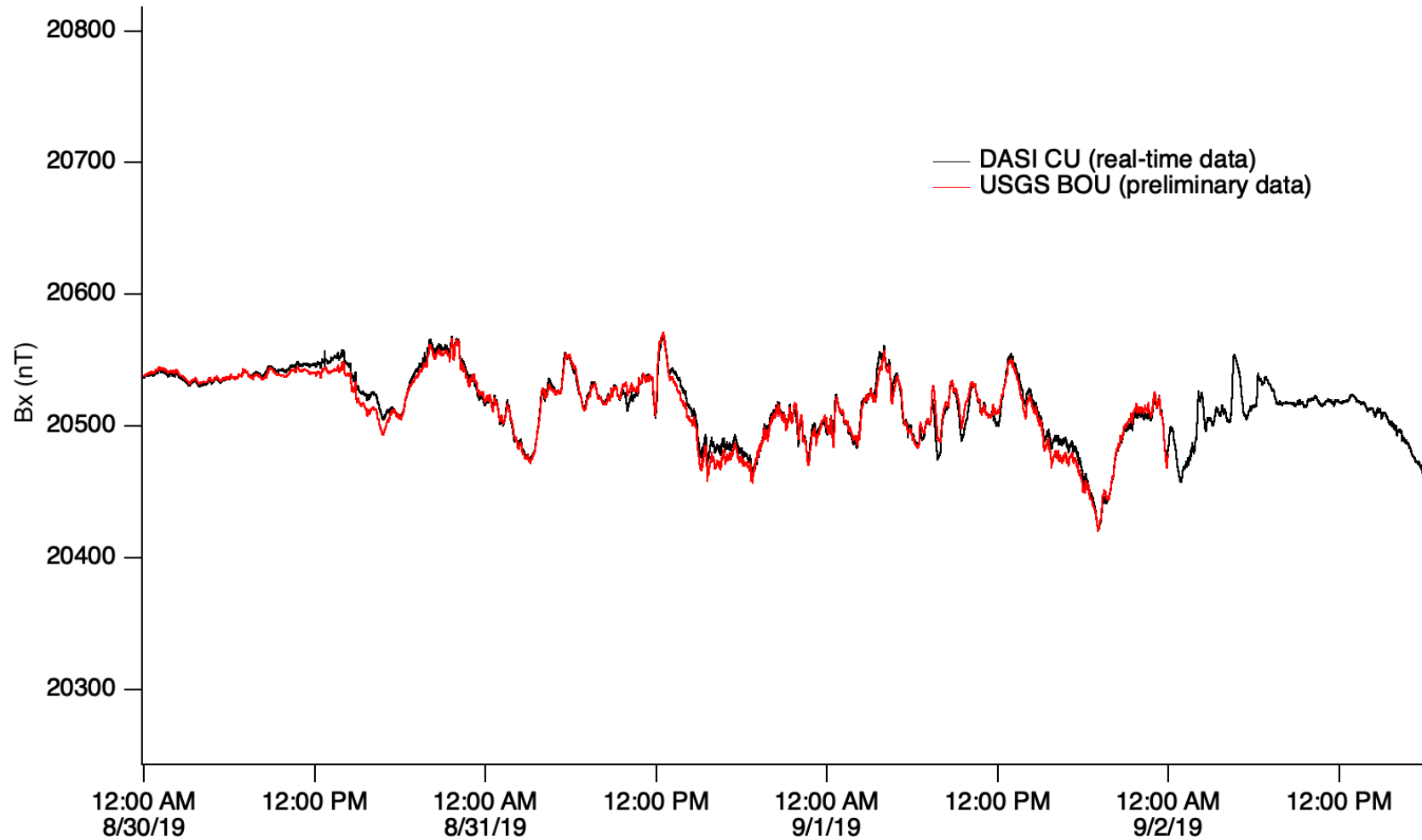


Barlow ops system

- Lightweight postgres/SQL/python backend
- Cloud-based, containerized deployment of backend computing infrastructure
- Secure data transfer with SSH key-locked communication
- Automatic failover and manual transfer of data streams
- REST and Python API for real-time access
- Remote system log-in capability



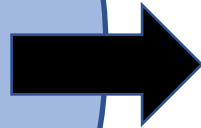
MagStar calibration



Scientific and operational needs

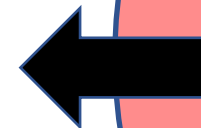
Scientific needs

- High-quality data
- Reliable uptime
- Better coverage over US
- Maintenance support

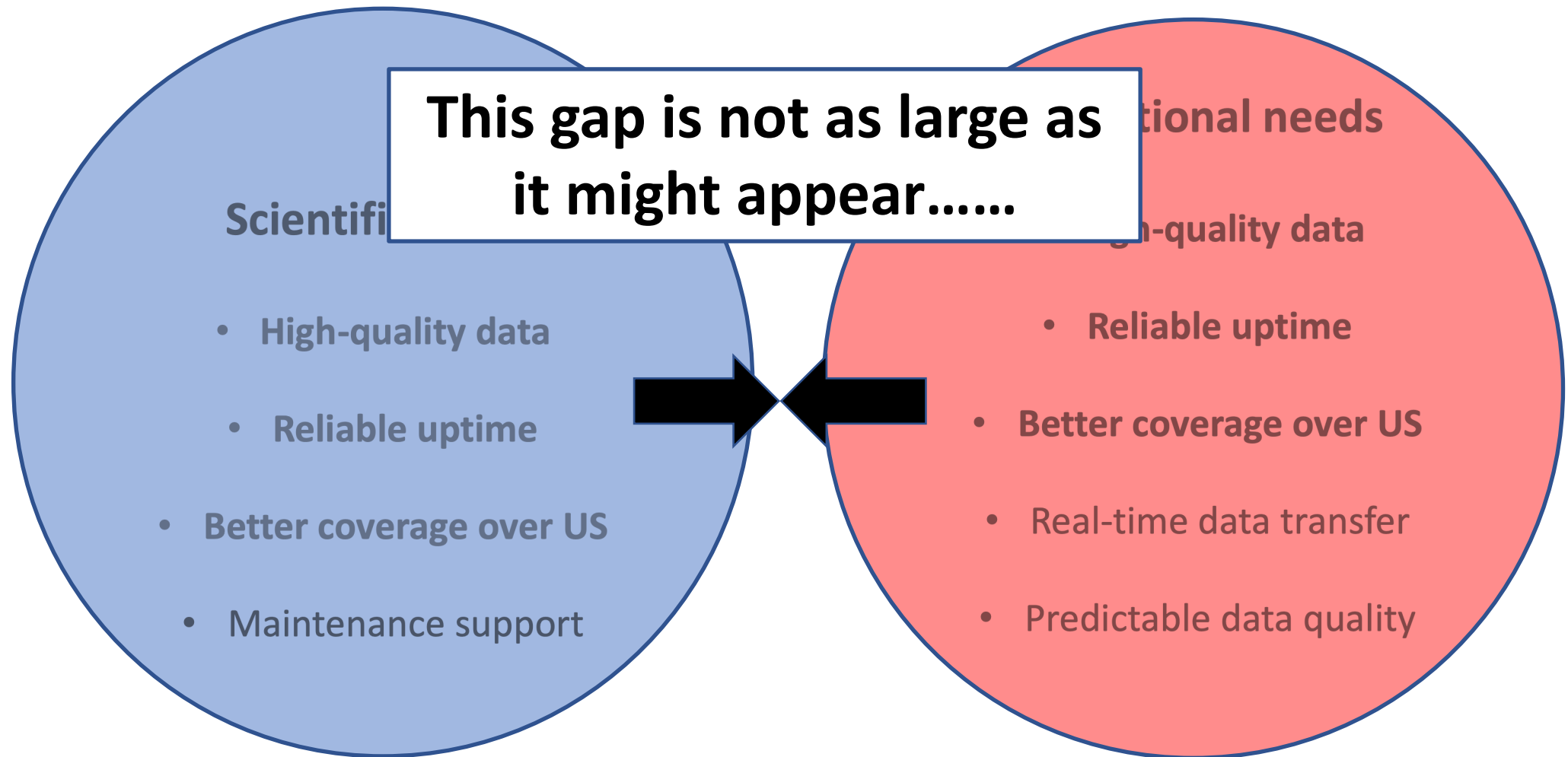


Operational needs

- High-quality data
- Reliable uptime
- Better coverage over US
- Real-time data transfer
- Predictable data quality



Scientific and operational needs



Scientific and operational needs

Scientific needs

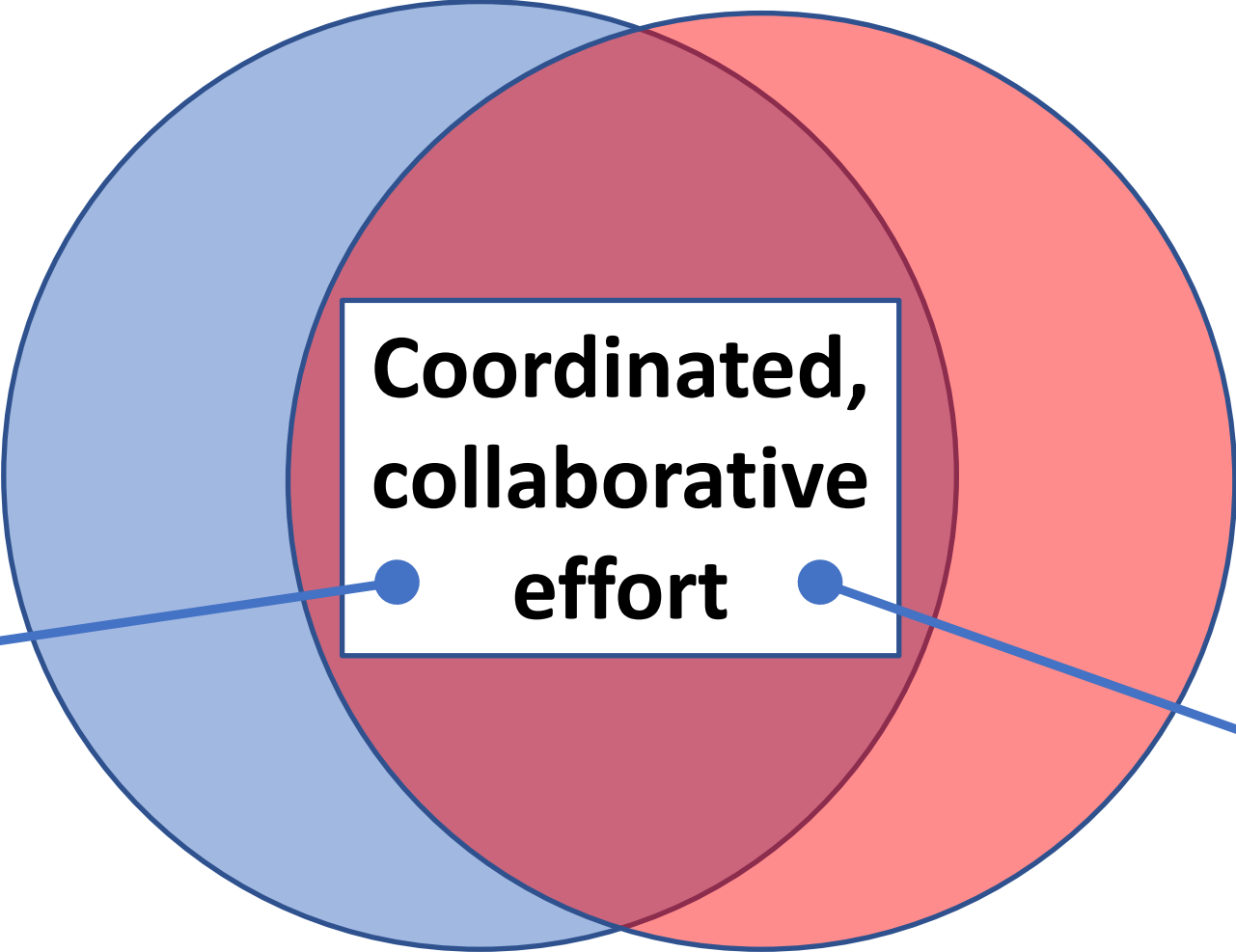
- **High-quality data**
- **Reliable uptime**
- **Better coverage over US**

- Maintenance support

Operational needs

- **High-quality data**
- **Reliable uptime**
- **Better coverage over US**

- Real-time data transfer
- Predictable data quality



The diagram consists of two overlapping circles. The left circle is light blue and represents 'Scientific needs'. The right circle is light red and represents 'Operational needs'. The intersection of the two circles is shaded a darker purple. In the center of this intersection is a white rectangular box with a blue border. Inside this box, the text 'Coordinated, collaborative effort' is written in bold black font. Two blue lines with circular endpoints point from the text box to the lists of needs on either side. One line points to the 'Maintenance support' item in the scientific needs list, and the other points to the 'Real-time data transfer' and 'Predictable data quality' items in the operational needs list.

**Coordinated,
collaborative
effort**

Biggest hurdles...

- **Long-term maintenance support** for existing high-quality magnetometer arrays
- **Reduction of maintenance** expenses through the availability of new IoT technologies and computing resources
- **Real-time data access** through infrastructure advancement

What is needed to close the gap....

- **Coordinated, collaborative effort** to close infrastructure gap between scientific needs and operational needs
- Maintain **scientific autonomy** to enable discovery
- Support for **long-term maintenance** of arrays
- **Public-private partnerships** to leverage existing industry IoT tools and advanced academic sensors and expertise

We can bridge the gap between scientific and operational magnetometer needs through a

coordinated and collaborative

public-private partnership

with support for

long-term maintenance.