Continuous Monitoring of Greenland Outlet Glaciers Using an Autonomous Terrestrial LiDAR System: Design, Development, and Testing at Helheim Glacier, Greenland

C31B-0292

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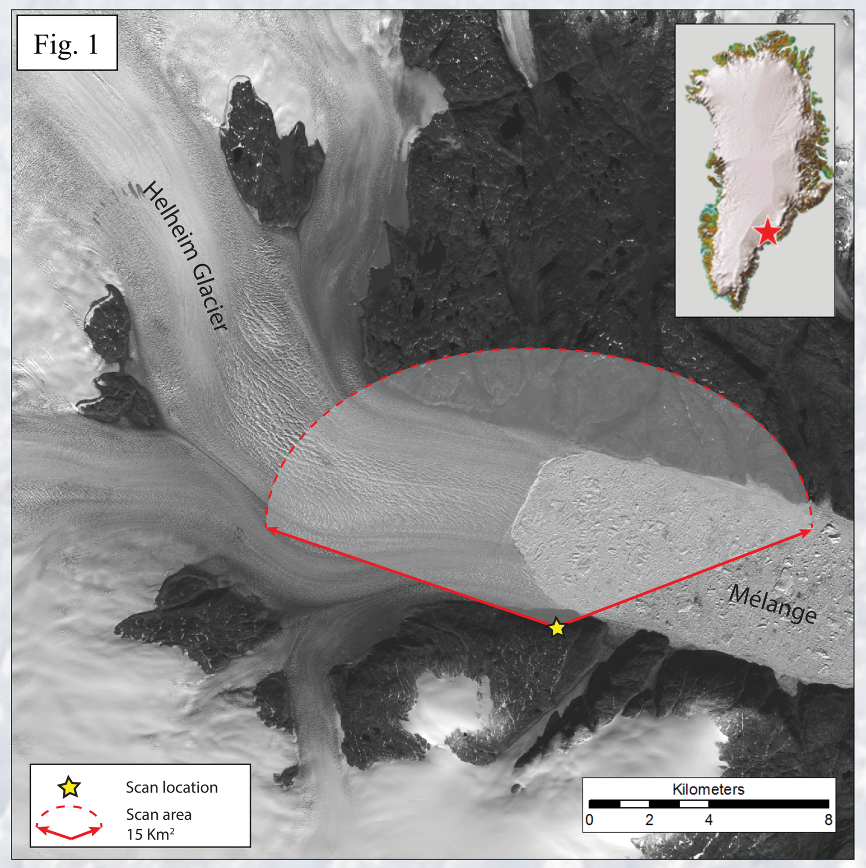
Introduction

Greenland's fast-flowing tidewater outlet glaciers play a critical role in modulating the ice sheet's contribution to sea level rise. Increasing evidence points to the importance of ocean forcing at the marine margins as a control on outlet glacier behavior, but a process-based understanding of glacier–ocean interactions remains elusive, in part because our current capabilities for observing and quantifying system behavior at the appropriate spatial and temporal scales are limited. The establishment of a comprehensive monitoring network covering Greenland's largest outlet glacier–fjord systems is necessary to collect long-term data of critical in situ glaciological, oceanographic and atmospheric parameters needed to understand evolving relationships between different climate forcing and glacier flow (*Understanding the Response of Greenland's Marine-Terminating Glaciers to Oceanic and Atmospheric Forcing*, sponsored by US CLIVAR, Beverly, MA, June 2013).

Fig. 1



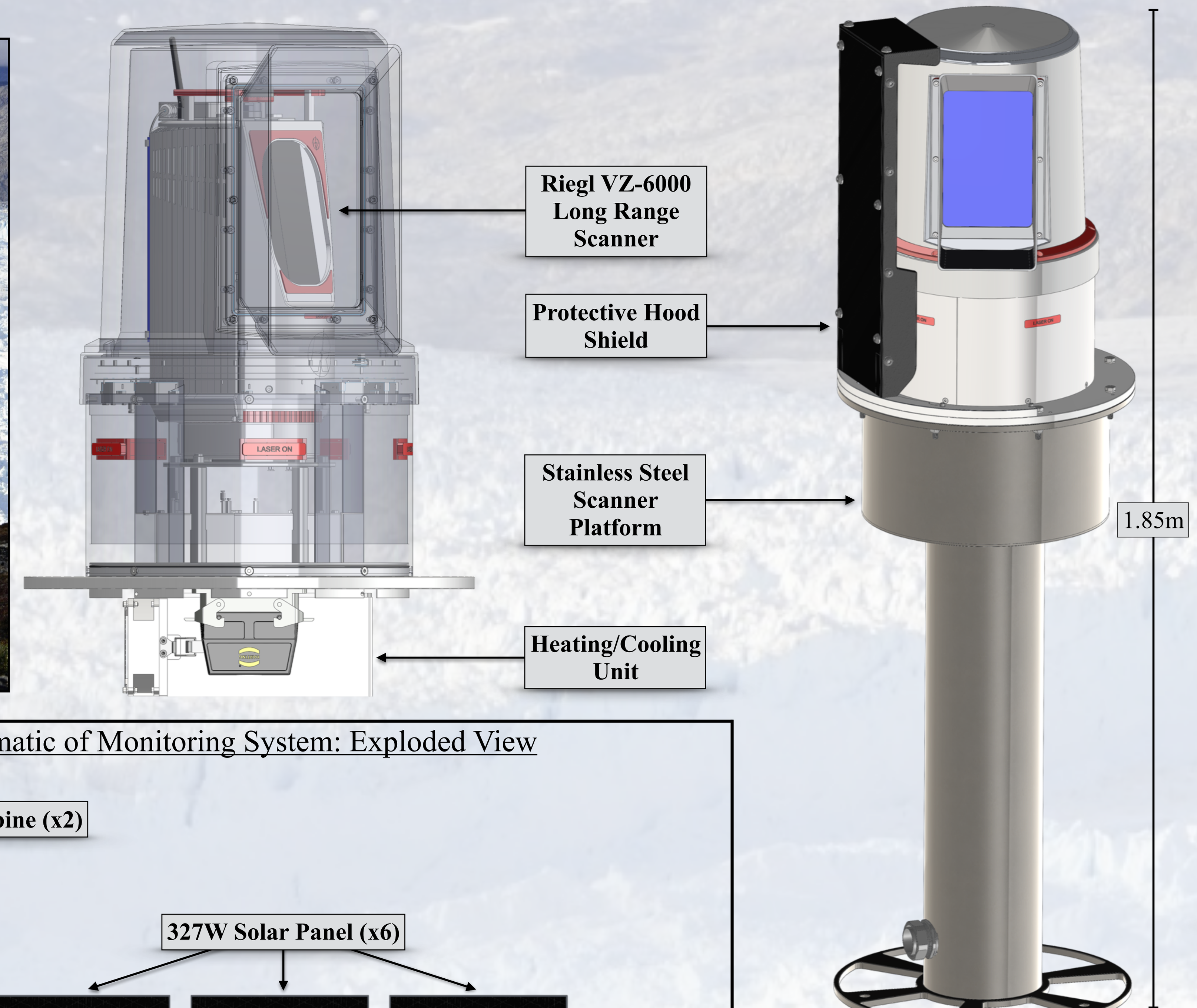
Based on past campaign-style surveys conducted at Helheim Glacier, Greenland (**Figure 1**) using a long-range (6-10km) Terrestrial LiDAR Scanner (TLS), we have developed an Autonomous TLS (A-TLS, or Atlas) to acquire repeat, multi-dimensional point-cloud measurements of the mélange, terminus, and lower-reaches of the glacier. We draw on past experience to design the power, communications, and installation components of the new system, and use previously acquired data from the Riegl VZ-6000 sensor collected August 2013 and July 2014 at Helheim to optimize our data collection strategy and design the data processing and telemetry subsystems to ensure year-round data collection. We will install the system at Helheim Glacier in the Spring/Summer of 2015. Scans will be collected at a minimum every 6-hours year-round. Please visit poster **C31B-0287** to see results from the 2014 survey and processing steps. The system is comprised of a **LiDAR Scanner**, a **Power System**, and a **Communication and Control System**.

System Specifications

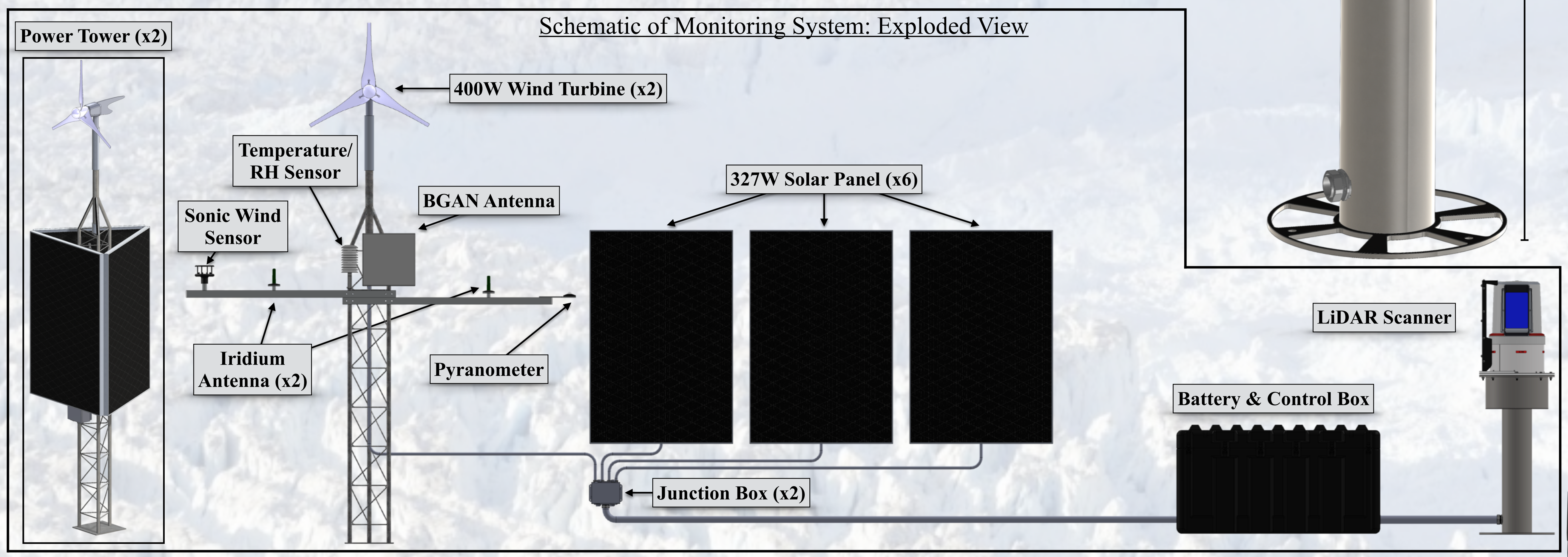
Riegl Arctic Monitoring LiDAR System	
Mode of Operation	Online Waveform Processing + Full Waveform
Wavelength	1064 nm (Class 3B Laser Product, non-eyesafe)
Minimum-Maximum Range	5–6,000 m (CRREL team has measured >10km)
Maximum Pulse Rate	300 kHz (222k measurements/second)
Accuracy/Precision	15 mm/10mm
Field-of-View	Vertical: 60º total (+/- 30º from level),Horizontal: 308.5º
Angular Increment	0.002º—0.280º (vertical), 0.002º—3º (horizontal)
Protection Class	IP64, dust- and splash-proof
Temperature Range	-10º—40ºC (Range increases with heating/cooling unit)
Average Scan for Helheim Site	30-minute duration resulting in ~29 million measurements

Power, Communication, and Climate System	
Solar Panel	327 Watt (x6), 1,962 Watts Total
Wind Turbine	400 Watt (x2), 800 Watts Total
Battery	180 Ah LiFePO4 (x8), 1,440 Ah Total, 24V
Communications	Iridium SBD and Dial-up Modems, BGAN Modem
Climate Station Sensors	Temp/RH, Barometric Pressure, Solar Radiation, Wind Speed

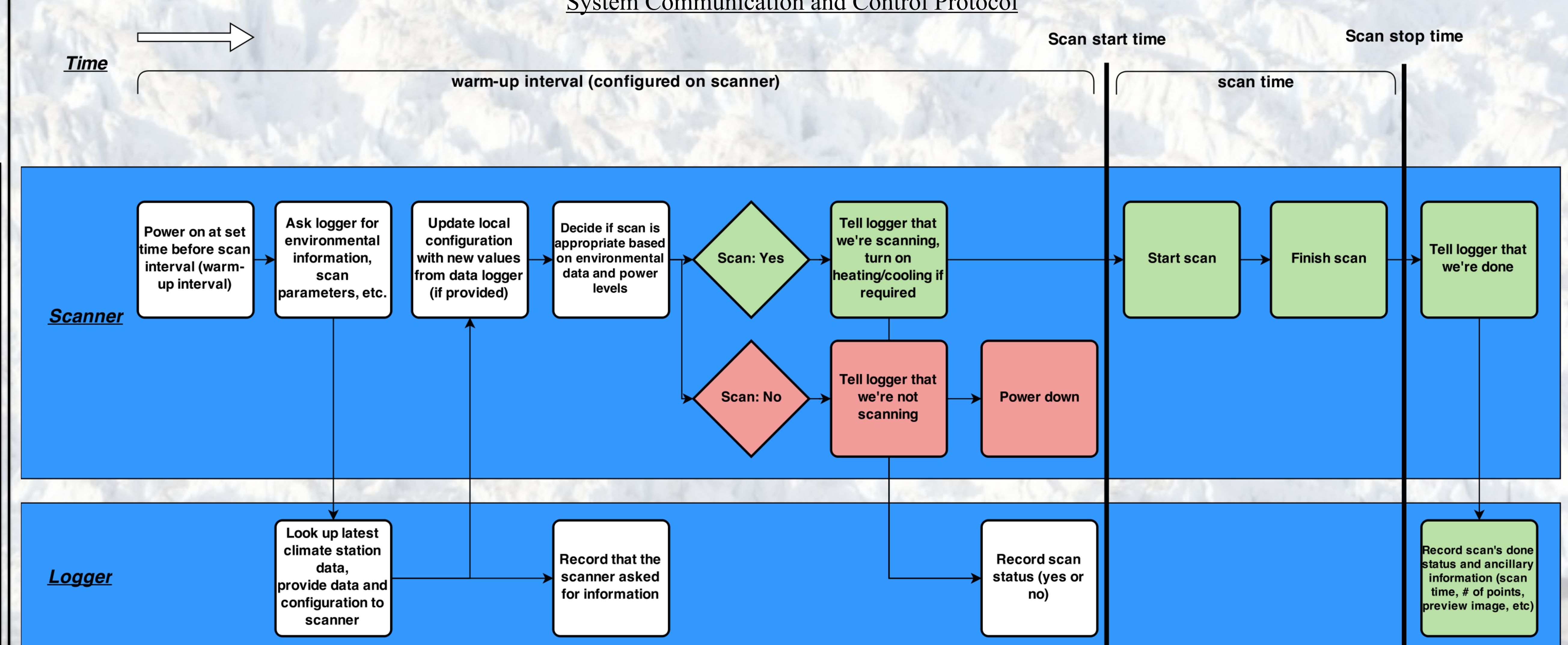
Figure 2: Artists rendering of the Atlas system installed at Helheim Glacier.



Schematic of Monitoring System: Exploded View

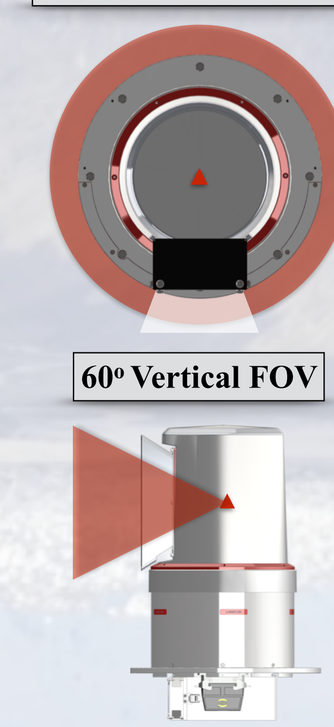


System Communication and Control Protocol



LiDAR Scanner

We utilize a Riegl VZ-6000 long-range TLS in a custom environmental housing mounted on a fixed stainless steel platform that doubles as a volume for air circulation for heating/cooling the housing. Climate station sensors (temperature, wind speed/direction, relative humidity, barometric pressure and incoming solar radiation) inform the scanner of hazardous conditions (high winds = scouring of enclosure window), drive the heating/cooling unit, and help to adjust the scan data for scaling across varying atmospheric conditions. An integrated protective shield protects the enclosure glass when at rest and during high wind events.



Power System

One of the most challenging aspects of this project is running and operating the high-powered TLS system and ancillary components without a permanent AC power source. We have developed a 1,762-Watt x 1,440Ah power system incorporating photovoltaic panels, wind turbines, smart charge controllers, and a LiFePO4 battery array. Two 12-foot aluminum towers hold the solar panels, turbines, climate station sensors, and communication antennas. A weatherproof battery and control box houses the battery array, charge controllers, and all control and communication components.

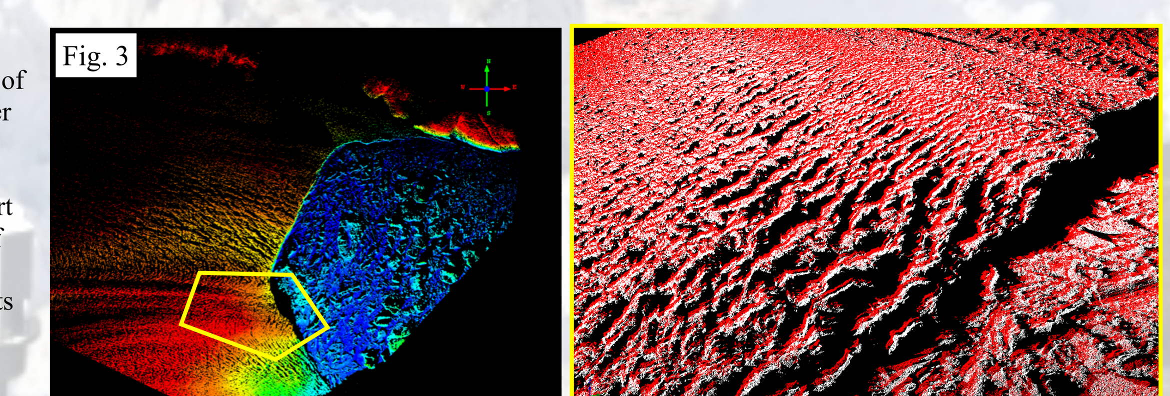
Battery & Control Box

Communication and Control System

This system allows the scanner to run autonomously on a set schedule, telemeter status and ancillary information (scan time, number of points measured, 2D preview image of the point-cloud), and make informed decisions on data acquisition based on battery health and atmospheric measurements. Due to the size of each scan (~200 Mb compressed), the raw point-cloud data will be downloaded during regular maintenance visits or captured remotely when necessary for debugging. Multiple satellite-based transmitter/receivers allow for 2-way communication, enabling remote control of the system and reconfiguration of the control programming.

Figure 3: Height colored nadir view of the Helheim Glacier point-cloud (left image). Two scans collected 6-hrs apart show the motion of the glacier and melange. Red points are the earlier scan (right image).

Fig. 3



Acknowledgements
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Scan code or visit www.glacierresearch.org to follow this and other projects.