Autonomous Topographic Actuating Radar (ATAR) Sensing Device for the Lunar South Pole

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Problem Statement

NASA's **Artemis** mission aims to establish a base at the Moon's South Pole for manned expeditions. Analyzing telemetry from lunar landings helps find POIs and aids future in-situ science experiments. Lessons from Apollo show the importance of autonomous science, especially the challenge of lunar colonization for habitat and vehicle development.

Mission Objective

The deployment of an inert LiDAR collection device would provide primary telemetry. ATAR is a device is positioned in areas of interest to the mission and will continuously capture LiDAR data fused with additional telemetry, such as temperature, average solar power generated, and atmospheric conditions at the site of placement.

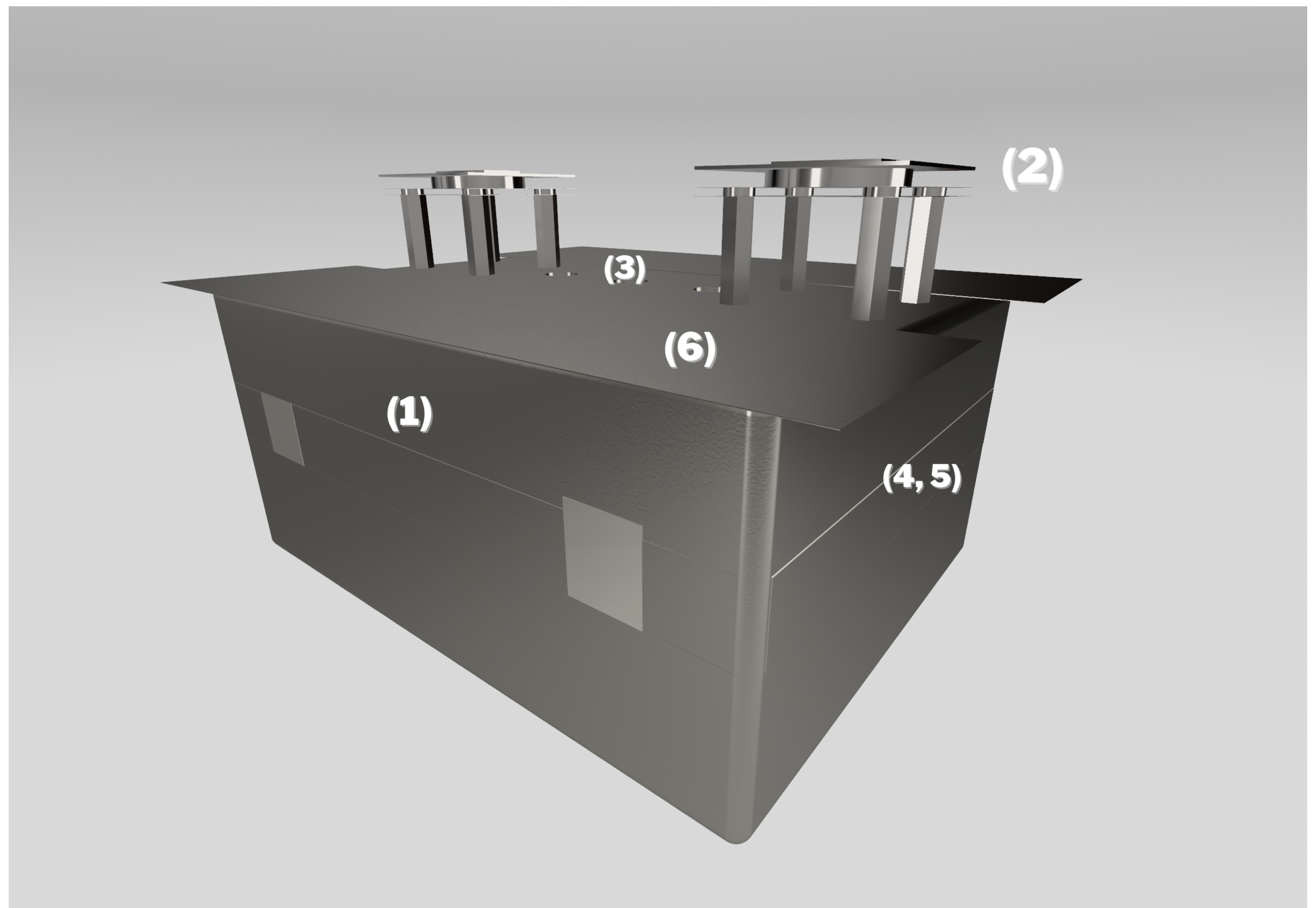


Figure 1. CAD model renderings of ATAR

Deploying multiple instances of ATAR across POIs would establish a telemetry-harvesting network of information to assist with manned expeditions to the Moon.

ATAR Instrument Specifications

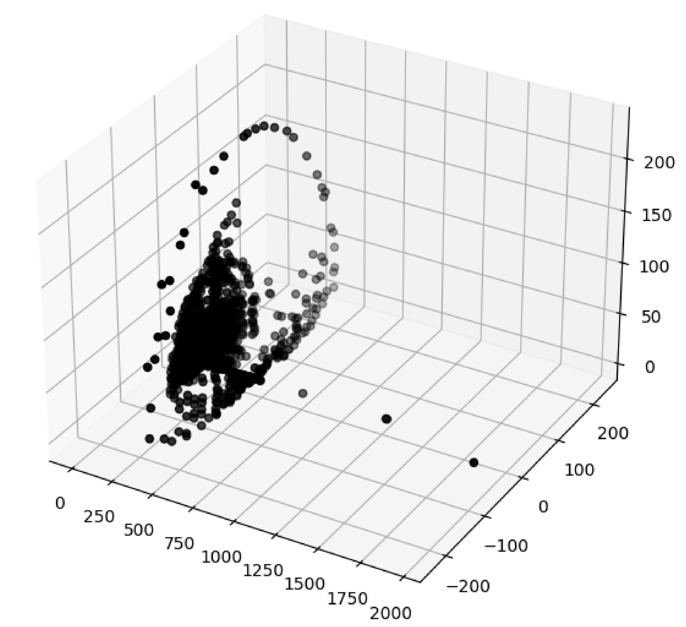
ATAR is an **autonomous sensing device** deployed either manually by a human operator or by a robotic system.

The ATAR system encompasses the Thermal Control System (TCS) (1), Instrument Suite (2), Communication (3) Command and Data Handling (C&DH) (4), Power Distribution (5), and Power (6) subsystems.

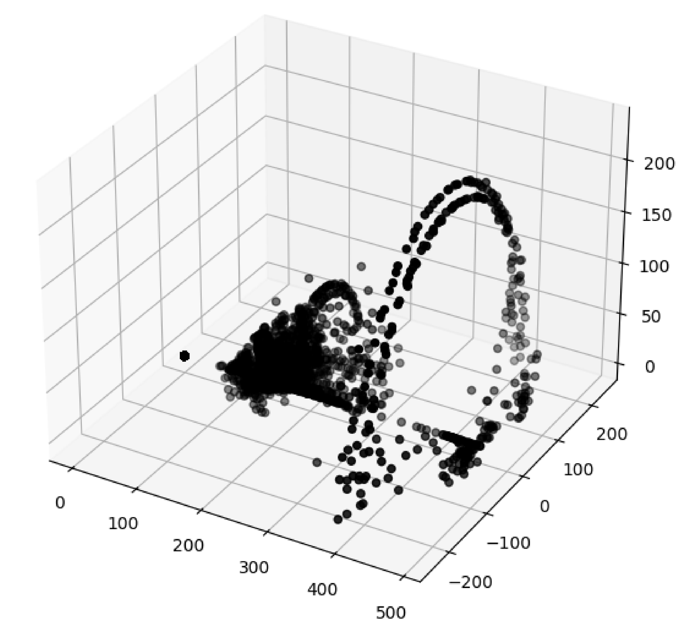
- The total **system mass** amounts to just 2.989 kg.
- ATAR consumes power at a rate of 12.17 Wh.
- ATAR encompasses a **Design of Life** lasting 15.7 hours.

Data

The mechanical system of the device, which houses the servomotors was found to actuate at very low speeds. Due to the weight of the LiDAR sensors and a weak mechanical structure (Cokoino, 2024), the system struggled to maintain adequate performance under heavy loads. The slow rotation of the servomotors, paired with misaligned angular measurements, results in inaccurate graphical visualizations.



(a) Point cloud generated by LiDAR 1



(b) Point cloud generated by LiDAR 2

Figure 2. Point cloud generation from ATAR field testing measurements

Mathematical Modeling

ATAR's modeling algorithm generates a point cloud visualization of its spherical boundary constraints. The algorithm models the 2 DOF mechanical constraints.

Algorithm 1: Mathematical simulation of ATAR spherical perimeter bounds

$A_i \leftarrow$ angular increments
N_ω(yaw) $\leftarrow$ total number of yaw slices
N_θ(pitch) $\leftarrow$ total number of pitch slices
Function *Simulate*(A_i, N_ω, N_θ):
  coordinates $\leftarrow$DataFrame columns $[x, y, z, \omega, \theta]$
  increment_value $\leftarrow$($A_i \times \pi$)/(180)
  $\omega \leftarrow 0$
  for $i \leftarrow N_\omega$ **do**
    ω += increment _value
    $\theta \leftarrow -\pi \times 180$
    x_distances $\leftarrow$GetMockDistances(N_x)
    for $j \leftarrow N_\theta$ **do**
      append RegisterCoordinates(x_distances[j], ω, θ) to coordinates
      θ += increment_value**end**
  end
  return coordinates

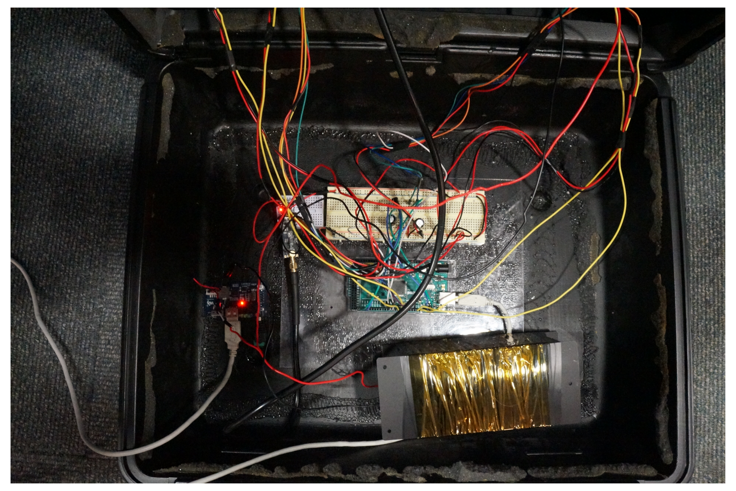
References

Cokoino and Mosiwi, CKK0006, (2024), Cokoino, `https://github.com/Cokoino/CKK0006`

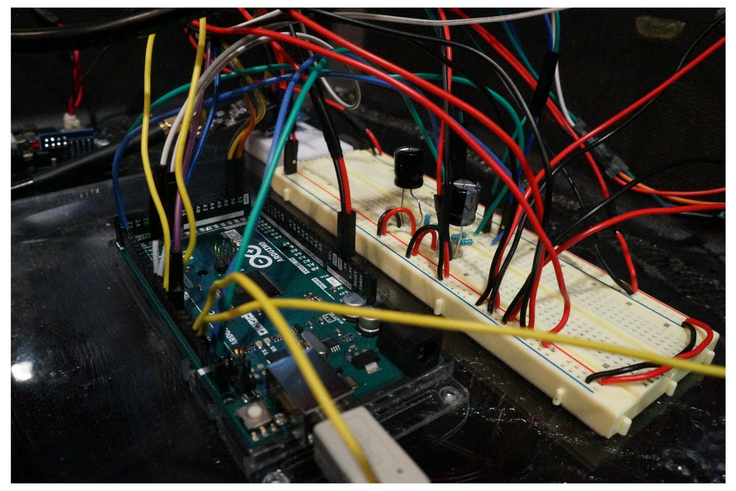
Garmin Support Center.*Lidar-Lite V3HP Operation Manual and Technical Specifications*. 2018. `https://cdn.sparkfun.com/assets/9/a/6/a/d/LIDAR_Lite_v3HP_Operation_Manual_and_Technical_Specifications.pdf`

Engineering Design

ATAR posseses a shielded body enclosure that houses the Power, Power Distribution, and C&DH. Placing LiDAR sensors at opposite ends of the device enables a complete 360-degree scan of the environment, with each sensor covering a 180-degree field of view. The Arduino controls the pitch and yaw of the servomotors, incrementally scanning the surroundings and collecting data at each angle.



(a) Interior Isometric View



(b) C&DH, Power Distribution and Comm

Figure 3. ATAR detailed close-ups of subsystem subassemblies

The engineering team of the STAR research group took a reverse engineering approach, starting with the validation of scientific instruments, followed by the design of circuitry, implementation of software and communication protocols, and concluding with the development of power subsystems.

Trade Studies

The research group conducted trade studies comparing three different LiDAR sensing devices. Despite Intel's sensor outperforming the others, the grop ultimately selected Garmin due to mission constraints.

Criteria	Explanation	Grade	Weight	LIDAR-Lite v3HP	Intel RealSense™ LiDAR Camera L515	iPhone 11 LiDAR
Cost	Science instruments cannot exceed the cost of the allocated budget and must reside in a reasonable range	3 = least expensive, 2 = mid expensive, 1 = most expensive	40%	$149.99	$589.00	Owned
Mass	Instrument cannot exceed mechanical structure derived constraints	3 = least heavy, 2 = mid-heavy, 1 = most heavy	30%	37g	997g	194g
Depth	Instrument should contribute to be able to accurately measure distances to render a 3D point cloud	3 = highest depth, 2 = mid depth, 1 = least depth	30%	1-dimensional	3-dimensional	3-dimensional
Average	-	-	-	66.7%	80.00%	63.33%

Figure 4. Trade studies conducted for the selection of the ATAR science instrument demonstrate the preference of the Intel LiDAR sensor

Conclusion

Searching for water ice on the Moon presents challenging obstacles. The Apollo missions demonstrated the challenges associated with in-situ experiments conducted by astronauts on the Moon and emphasized a need for autonomous science. Deploying multiple instances of ATAR across POIs would establish a telemetry-harvesting network of information to assist with Artemis missions and enhance our current understanidng of the southern lunar pole.