# HALO: High-efficiency Automated Low-SWaP Operations

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**Client:** Dr. Ryan T. White (rwhite2009@my.fit.edu), NEural TransmissionS (NETs) Lab

**Date(s) to Meet with Client:**
- August 20th, 2025

**Goal and Motivation:**

Currently, orbital object detection, done through the Vision Transformer (ViT) neural network architecture, is carried out on large computers; however, this is not sustainable as larger computers take up too much space and resources within satellite systems. It is ideal for orbital object detection functionalities to be carried out on smaller computers, such as a Raspberry Pi, as they take up much less space and resources. The current method to make neural networks compatible with running on smaller computers is to take out layers of the model; however, this reduces accuracy. The technique I aim to use is to condense the neural network's weights to a smaller representation. Currently, weights are stored as floats in C++, which occupy 32 bits. I aim to reduce the weights to a 1-bit representation.

There has been some research and development in 1-bit representations for the ViT architecture; however, the smallest representation is currently only 1.58 bits, and its use is not directed for large-scale object detection and segmentation, as would be used in on-orbit satellite characterization. Therefore, I aim to expand upon these successes and develop a 1-bit quantization for a ViT deployable on on-orbit satellites to be used in autonomous systems.

**Approach:**

**Accurate Object Detection**

The user will be able to detect and identify orbital objects, more specifically, satellite objects, within a given image space.

**Low-SWaP Hardware Compatibility and Deployability**

The user will be able to send to space smaller object detection-capable computers that take up less space and resources.

**Autonomous Operations Abilities**

The user will gain the ability to run these computer vision models on satellite hardware and execute autonomous operations, such as docking and repairs. Automating these operations will reduce the need to send up manned missions and increase the longevity of active missions.

**Novel features/functionalities:**

One-bit representations of weights have been restricted mainly to LLM transformers and have not been explored extensively for vision transformers and vision tasks, such as classification and segmentation.

**Algorithms and Tools:**

- Python
- Jupyter Lab
- Multiple datasets for training and testing: hardware in the loop (HIL), web satellite data, and digital twin on-demand data.
- Neural Networks and Vision Transformers (ViTs)
- Hailo-8 NPU/ HailoRT (for model inference)
- Raspberry Pi AI Hat+ (Neural Network Accelerator)
- Jetson AGX Oring Developer Kit (64GB)/Jetson Xavier NX Series (8GB) (as back-up)

**Technical Challenges:**

- I plan to utilize a neural network, but I do not have much experience using and training neural networks.
- I will have to do more research on ViTs to understand their functionalities better.
- I will have to determine the best hardware tool to utilize - either the Raspberry Pi or the Jetson; the Raspberry Pi may not allow for necessary low-level quantization.

**Milestone 1 (Sep 29):**

- Literature Review researching the deployment of Neural Networks onto Raspberry Pi's and ViTs.
- Load a Vision Transformer (ViT) onto the Raspberry Pi AI Hat+ and establish a baseline for model performance using metrics such as framerate and accuracy.
- Create Requirement Document
- Create Design Document
- Create Test Plan

**Milestone 2 (Oct 27):**

- Reduce ViT down to a 4-bit representation using model quantization.
- Tune the 4-bit model to recoup losses in accuracy.

**Milestone 3 (Nov 24):**

- Reduce model size down to 1-bit, prioritizing size reduction over accuracy retention.

**Task Vector for Milestone 1**

| Task | Sloan |
|---|---|
| Literature Review | Research |
| Obtain Dataset | Search/acquisition |
| Load ViT onto Raspberry Pi | Interface with hardware |
| Requirement Document | Write 100% |
| Design Document | Write 100% |
| Test Plan | Write 100% |

**Approval from Faculty Advisor**

- "I have discussed with the team and approve this project plan. I will evaluate the progress and assign a grade for each of the three milestones."
- Signature: _____ Date: _____