HALO:
High-efficiency Autonomous Low-SWaP Operations

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GOALS AND MOTIVATION

- **Problem**
  - Current orbital object detection systems run ViT systems on large computers
    - Unsustainable for satellite systems due to space and resource limits
- **Solution**
  - Utilize smaller computers (Jetson AGX Orin) for detection systems
  - Reduce model size for efficiency

- **Problem within a Problem**
  - Reducing model size also reduces accuracy
- **Proposed Solution**
  - Compress weights instead of removing layers
    - 32-bit → 1-bit

- **Objective**
  - *Develop a true 1-bit quantization method for ViTs* deployable on satellites to enable autonomous orbital object detection

APPROACH

- **Accurate Object Detection**
  - The user will be able to detect and identify orbital objects within a given image space.
- **Low-SWaP Hardware Compatibility and Deployability**
  - The user will be able to send smaller, object-detection-capable computers into space that take up less space and resources.
- **Autonomous Operations Abilities**
  - The user will be able to run the computer vision model on satellite hardware and execute autonomous operations.

NOVEL FEATURES

- 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.

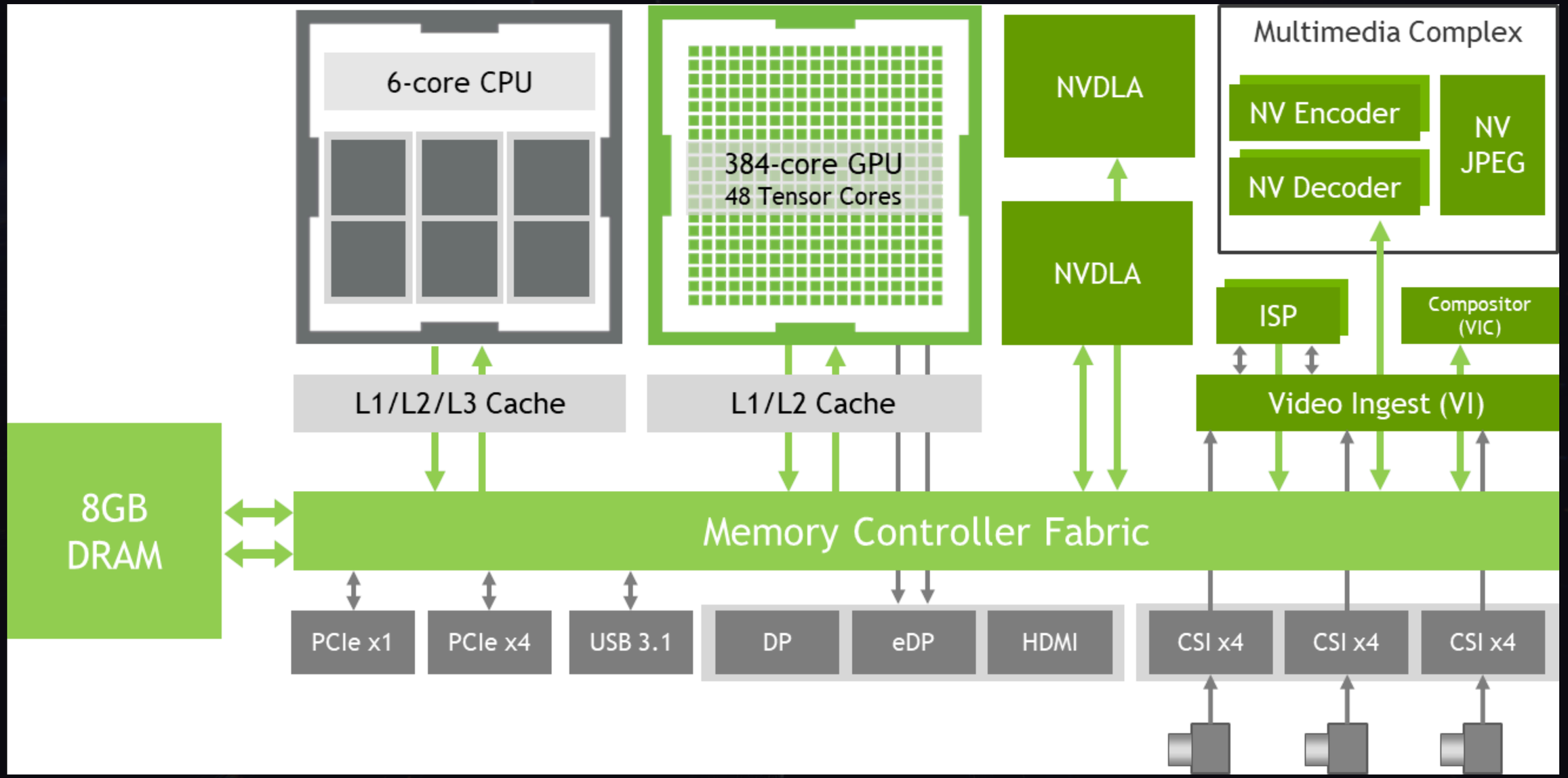
ALGORITHMS AND TOOLS

- Python
- Jupyter Lab
- Multiple data sets:
  - Hardware In the Loop (HIL)
  - Web Satellite Data (WSD)
  - Digital Twin On-Demand Data
- Neural Networks and Vision Transformers (ViTs)
- Jetson AGX Orin Developer Kit

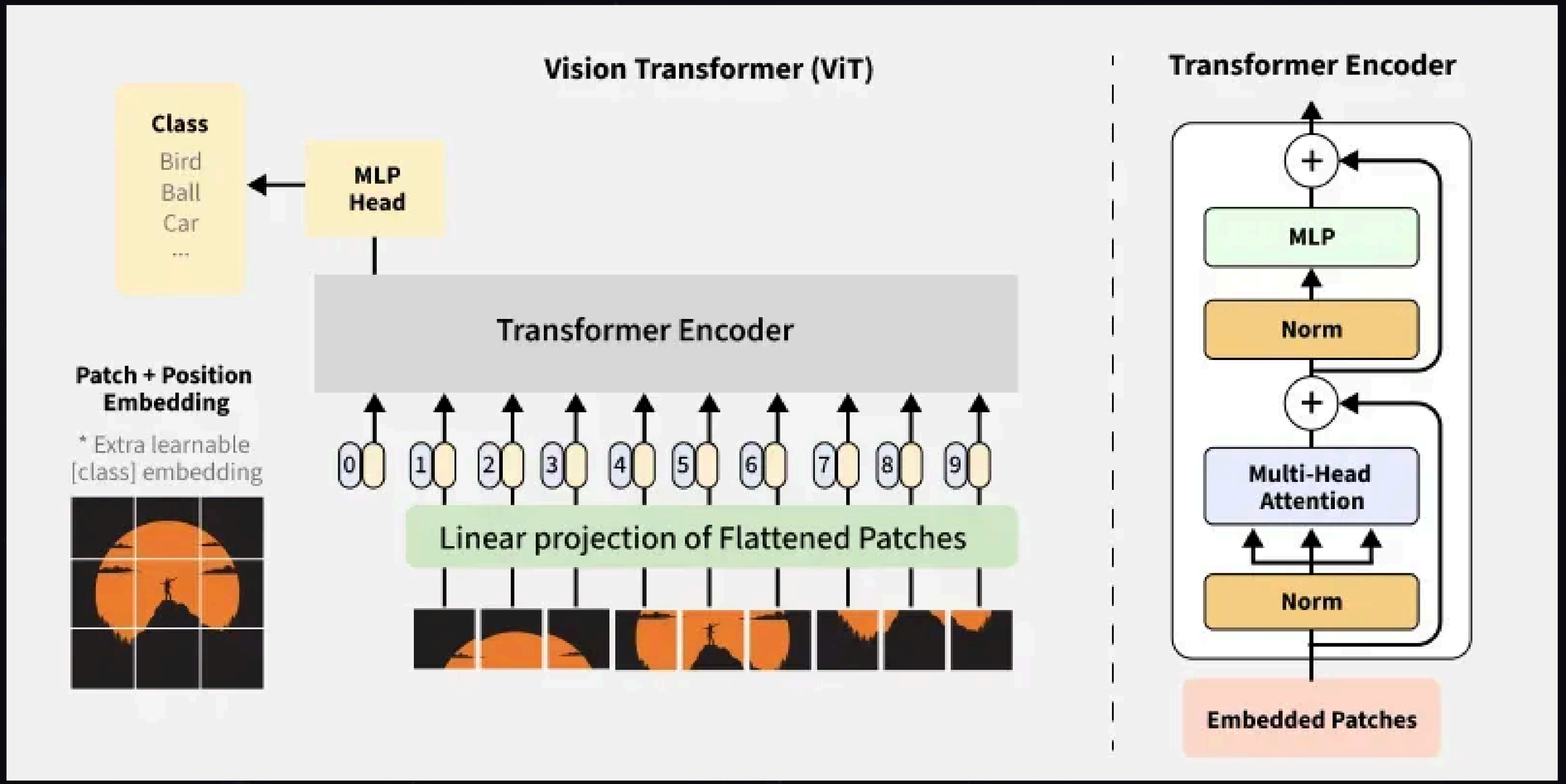
TECHNICAL CHALLENGES

- Maintaining accuracy as lower bit models are implemented
- Balancing power draw while still adhering to Low-SWaP parameters
- Ensuring the Jetson AGX Orin has the proper infrastruction to effectively run lower bit models

SYSTEM ARCHITECTURE DESIGN - JETSON AGX ORIN



NEURAL NETWORK ARCHITECTURE - VISUAL TRANSFORMER



EVALUATION - 16-BIT MODEL

- No traditional accuracy score when dealing with detection models
  - Fails to account for nuance in detections
- Confidence scores are used instead

- Across 898 detections on 100 images:
  - **Overall Confidence**: mean = 0.91
    - Indicates strong certainty in bounding boxes
  - **Per-Image Stability**: mean = 0.94, IQR = 0.91-0.97
    - IQR shows low variance in confidence scores → indicates stable predictions

PROGRESS SUMMARY

Task	Completion	Sloan	To Do
Literature Review	100%	Research	None
Load ViT onto Raspberry Pi	100%	Interface with hardware	None
Hardware Swap	100%	Switch out Pi for Jetson	None
16-bit Representation	100%	Load 16-bit onto Jetson	None

MILESTONE 4

- Implement 8-bit model
- Record metrics for 8-bit model
- Demo 8-bit model
- Implement 4-bit model
- Record metrics for 4-bit model
- Demo 4-bit model

MILESTONE 5

- Implement 2-bit model
- Record metrics for 2-bit model
- Work towards implementing 1-bit model
- Record metrics throughout implementation and testing

MILESTONE 6

- Complete 1-bit model
- Record final metrics for 1-bit model
- Create demo video
- Create showcase poster

TASK VECTOR - MILESTONE 4

Task	Sloan
Implement 8-bit model	100%
Record metrics for 8-bit model	100%
Demo 8-bit model	100%
Implement 4-bit model	100%
Record metrics for 4-bit model	100%
Demo 4-bit model	100%

THANK YOU!
QUESTIONS?