Aug 2024

PALLADYNE AI™

An AI platform to deliver human-like reasoning & autonomy for commercial and defense applications

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Palladyne AI At-a-Glance

NASDAQ
PDYN

Robotics DNA
30+ years in robotics and robotics software. Legacy leadership in dexterous mobile robot technology across aviation, construction, energy, and defense sectors

Experience
30+ years of robotics engineering excellence. Technology team led by CTO with 25+ years of AI/ML expertise

Salt Lake City, UT
Innovation and operations

~65
team members, world-class robotics & AI/ML software engineers

Palladyne AI: 30+ Years of Innovation and Evolution

Government/DoD R&D

Dexterous Robotic Systems

Purpose-Built Solutions

AI Software

1983 — Sarcos spins out of University of Utah (1983)

2015 — Purchase from Raytheon (2015)

2015 — Raytheon buys Sarcos (2007)

2021 — Start AI Software Development (2019)

2021 — Sarcos Robotics begins trading publicly (2021)

2023 — New AI Software Focus (2023)

2024 — Sarcos becomes Palladyne AI

2024 — Anticipated customer trials launch

Automation of Complex Tasks Has Been Limited For Several Reasons:

- Most industrial robots are highly programmed for a single specific task and cannot process variations in objects, tasks, or the environment
- Programming and implementation of industrial robots have been time-consuming and costly, often yielding an insufficient customer ROI
- Today's state-of-the-art AI approaches (e.g., LLM[1] for generative AI) require massive data sets to train models, limiting tasks solely to what is contained in the data sets

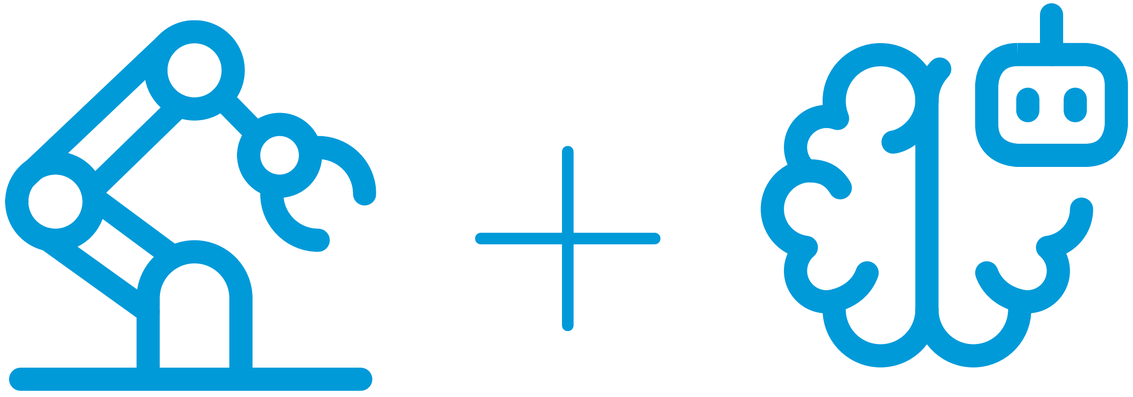
1. Large language models.

Our Vision: To Automate Tasks Too Complex For Traditional Automation By Enabling Machines to Observe, Learn, Reason & Act Like Humans

- Substantially accelerate speed of programming and training
- Increase agility, task sets and use cases
- Reduce need for human intervention and oversight
- Reduce cost of standing up and maintaining automation
- For mobile machines, evolve from human-in-the-loop to human-on-the-loop
- Eliminate need for continuous cloud connectivity

Automate Tasks Too Complex for Traditional Automation

Real-time, Closed-Loop Autonomy Enables Robots to Observe, Learn, Reason & Act Like Humans



Commercial Robots

Hardware-agnostic, real-time closed-loop autonomy software solution

Addresses key challenges in traditional robotic deployments:

- Many processes remain under-automated due to complexity of task or environment
- High cost and complexity of programming and deployment
- Point solutions unable to learn and adapt in real-time, require re-training to perform new or modified tasks

Industrial Mfg.

Logistics

Defense

Aerospace/ Aviation

Construction

Infrastructure Maintenance & Repair

Energy

AI for the Real (Physical) World

Most AI Today Lives in the Digital World

Digital World AI/ML Approach

- Objective is to predict outcomes and make recommendations to empower humans – increase efficiency, improve decision making, optimize processes, develop new products, etc.
- Harnesses enormous amounts of data utilizing significant cloud-based computing to gather, ingest, integrate, analyze, and learn from data

Palladyne AI's Real-World AI Approach

- Objective is to enable machines to effectively operate autonomously in real-world environments (structured, dynamic, and unstructured)
- Algorithms designed to enable machines to react to changing circumstances and complete tasks without re-training or reprogramming
- Requires less data – uses on-robot[1] compute to ingest, integrate (fuse), analyze, learn, and react to changing circumstances without connecting to the cloud

"The key for us is enabling autonomy in an unstructured environment that can dynamically change. We focus on generalized autonomy, providing closed-loop functionality to adapt to tasks continuously."

- Dr. Denis Garagić, co-founder and Chief Technology Officer, Palladyne AI

1. Occurs on the robot without a connection to the cloud.

Palladyne™ IQ: AI Software Platform for Robotics

Real-Time Closed-Loop Autonomy Framework Designed to Enable Machines to Observe, Learn, Reason, and Act Like Humans

Act

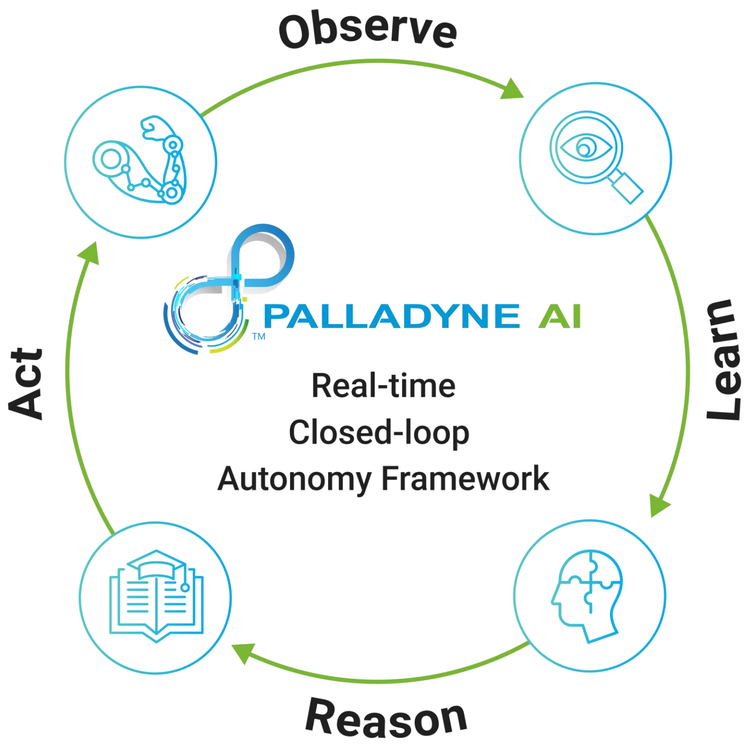
Precise Robotic Control & Completion of Tasks

- Completes the task by accurately controlling the manipulator arm, robot, and/or end effector
- Achieves complex combination of tasks over extended periods of time in a stable, safe, and precise manner

Reason

Human-like, AI-based Reasoning to Determine Best Course of Action Without Human Intervention

- Enables robots to adapt to unexpected events in real-time
- Generates real-time motion plans based on situational awareness at the edge



Real-time perceiving, learning & decision-making occurs at the edge without retraining or cloud connectivity

Observe

Advanced Perception & Observation to Improve Situational Awareness

- Perceives environment using a mix of sensor inputs, e.g., vision, LiDAR, radar, acoustic, etc.
- Utilizes Multi-Modal Sensor Fusion to make perception more robust to sensor occlusion and noise

Learn

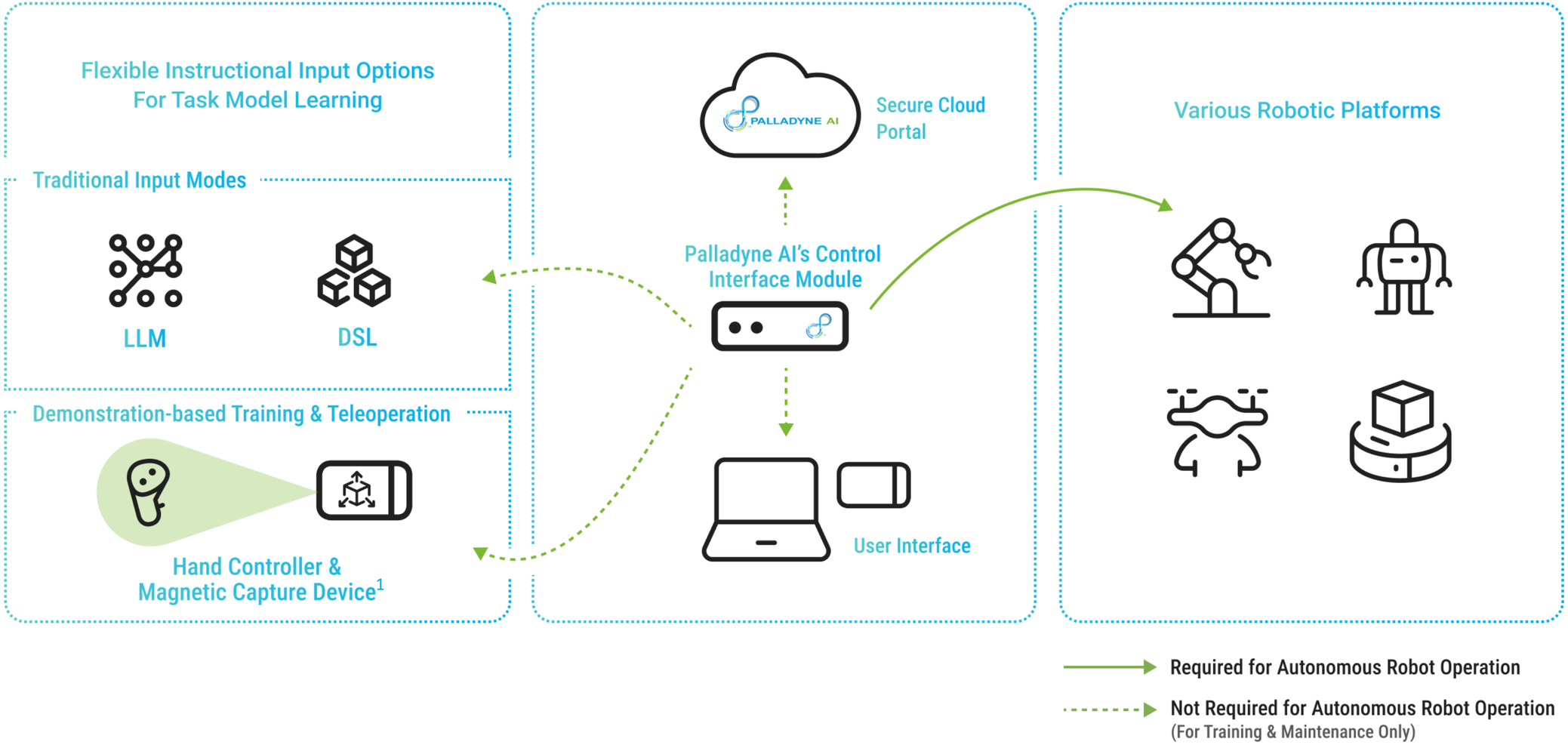
Intelligent Machine Learning to Accelerate Onboarding for New & Complex Tasks

- Robots learn novel or complex combination of tasks via dynamic reasoning and learning
- Learning occurs with minimal demonstrations (1-5)[1]
- Learning model adapts to environments

1. Based on internal testing, actual figures will vary depending on complexity of the task.

Palladyne™ IQ Architecture

Designed to Maximize System Flexibility, Adaptability, Mobility & Learning. Cloud Connectivity Not Required for Autonomous Robot Operations.



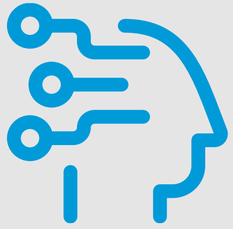
1. Only one hand controller is required (and included) in the basic Robot Training & Teleoperation Package; two controllers would be required for applications requiring two manipulators working in concert.

Expected Advantages of Our AI Software Platform

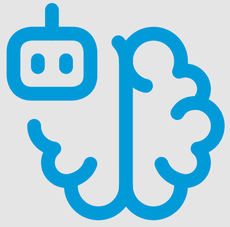
How Our Approach Differs

- Hardware agnostic[1]
- Addresses robotic-specific challenges beyond integration
- Solves for system stability and pose estimation/end effector orientation
- Robots able to plan and execute complex combination of tasks over extended periods of time, even in dynamic and unstructured environments

- Fuses multi-sensor data inputs together to improve system flexibility & adaptability
- Flexible instructional input options for task model learning (i.e., LLMs, DSLs[2], motion-capture-based teleoperation, video input, etc.)
- Can provide language-to-motion instructions ideal for edge computing/robotics applications; doesn't require cost/latency associated with use of LLMs requiring connectivity to the Cloud



- Full stack, closed-loop autonomy enables adaptability to dynamic changes in environment or defined task without human intervention or reprogramming
- Uses probabilistic machine learning techniques to learn the task, accounting for uncertainty and variability
- Dynamic model inference methods require much less training data; robots can learn to generalize with only a few demonstrations (1~ 5)[4]
- Computational efficiencies gained through use of Palladyne AI's domain-specific language models



- Complex task-learning capabilities are similar to humans; in some cases, we believe robots can be trained in significantly less time than it takes relying on currently available state-of-the-art approaches[3]
- Enables edge computing; lower total cost of ownership with no need to incur recurring cloud services costs
- Improves system implementation and startup times

1. Designed to work with most industrial robots being sold today. According to the Proficient Market Insights' "Global Robot Operating System" report, ROS 1 robots comprised of 74% of the total ROS market in 2021, "Global Robot Operating System (ROS) Market 2022 Size Of $ (globenewswire.com).
2. Domain specific languages.
3. Robotics Transformer 1 & 2 deep learning-based approach, 2022 – 2023.
4. Based on internal testing, actual figures will vary depending on complexity of the task.

Hardware Agnostic[1]

Expected to Enable Stationary and Mobile Robotic Platforms to be Agile and Autonomous, Reduce Human Intervention and Increase ROI

Industrial Robots and Cobots

Unmanned Aerial Vehicles

Unmanned Ground Vehicles and Humanoids

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Benefits of Computing on the Edge

Traditional AI / ML Product Solution (Cloud Compute[1,2])

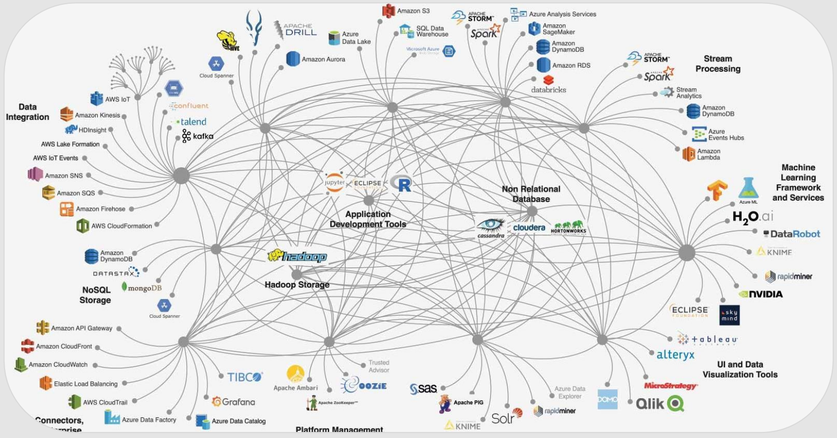
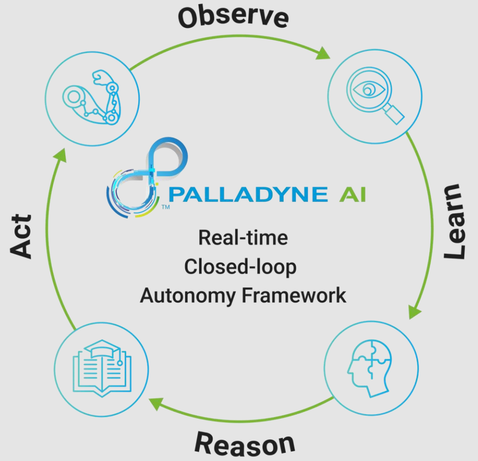


Photo Source: c3.ai

- Complex, extremely large data-set integration
- Enormous amounts of cloud compute required
- Predict outcomes, make recommendations driven by large data sets and models
- Humans utilize in decision making, process improvement and optimizations

Closed-Loop Autonomy for Robotics (Edge Compute)



- Environmental, situational awareness data from local workspace, more constrained (domain specific approach)
- Real-time human-like reasoning applied to base models based on unexpected events
- “Closed-loop” – adapting to those events real-time and update base models without retraining
- Structured and unstructured environments without retraining

1. C3.ai: A Full-Stack IoT Platform for Everyone.
2. The Gordian Knot of Structured Programming (c3.ai).

Hidden Costs of Power-Hungry AI Approaches

How It's Done Today

Photo Source: Freepik

"You'll be astonished how much power it takes to generate a single AI image[1]"

- Stable Diffusion's open-source XL model used almost as much power per image as that required to charge a smartphone fully
- Creating 1,000 images using the same model generated CO_2 emission equivalent of 4.1 miles driven by a gas-powered car
- Power usage by AI servers on a global scale is equivalent to what Argentina uses in 1 year
- Google reported[1] it used 5.6 billion gallons of water to cool their AI servers in 2022 (20% increase over 2021)

Photo Source: Google Research

"RT-1: Robotics Transformer for real-world control at scale[2]"

- Example: Model trained on real-world robotics dataset:
  - 130k episodes
  - 700+ tasks
  - Collected from 13 robots over 17 months

"RT-2: Vision-Language-Action Models[3]"

- "….the model size: 5B vs 55B for the RT-2 PaLI-X variant.."

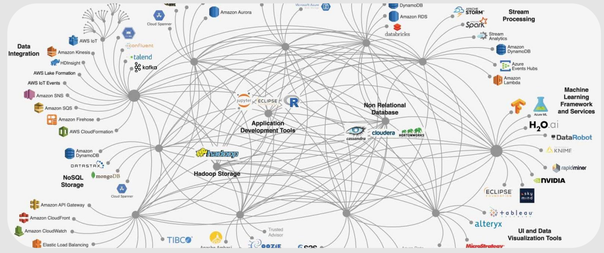


Photo Source: c3.ai

"The Gordian Knot of Structured Programming[4]"

- The 'build it yourself' approach requires numerous integrations of underlying components not designed to work together, resulting in a degree of complexity that overwhelms even the best development teams

1. Futurism.com
2. Google Research Blog
3. Robotics-transformer2.git.io
4. C3.ai

Palladyne™ IQ

Potential Use Cases

Examples based on discussions with potential customers

Manufacturing

Sub Parts Assembly[1]

Structured Manufacturing Line, Task Variability

Tasks & Challenges

- Changes in production line (products, fixes, updates) come at high cost – robot retraining and manufacturing downtime

Opportunity & Expected Benefits

- Low cost/quickly able to repurpose manipulators/ robots to perform new task. Minimal production downtime for new task training
- Employee can train in and deploy models across robots quickly
- Quickly adapt to varying tasks on a multi-product assembly line set up
  - Run assembly lines with mixed products to meet demand
  - Robots automatically adapt tasks to be performed based on object detected
  - Provides flexibility & future-proof task planning; extends usability & life of robot

1. Potential use cases based on discussions with potential customers.

Kitting and Parts Sequencing

Pick/Place/Sort Parts into Assembly Kits/Containers[1]

Tasks

- Kitting and parts sequencing for complex assemblies

Challenges

- Can be difficult to automate without sophisticated planning, human intervention & high programming costs
- Variability in parts can lead to inefficiencies and errors, causing delays, rework, and increased costs
- Adapting to real-time demand changes is difficult for industries with fluctuating demand, like consumer electronics or automotive

Opportunity & Expected Benefits

- Advanced object detection, ML and AI enables robot to:
  - Achieve continuous workflow without disruptions or human intervention by dynamically adapting to unexpected events or real-time changes in kitting/sequencing orders
  - Recognize and pick/place complex parts geometries efficiently, even in variable conditions and dynamic environments
  - Quickly and accurately classify parts and determine their optimal sorting location, helping streamline production and enabling parts traceability
- Reduces overhead costs and increases throughput, providing a faster ROI

1. Potential use cases based on discussions with potential customers.

Surface Preparation

Grit Blasting, Hydro Blasting, Sanding, and Grinding

Tasks

- Removal of paint, rust, and debris from surfaces using various media blasting and grinding tools to clean and prepare surface for maintenance or finishing processes:
  - **Heavy MFG**: Prepare components, chassis, and heavy machinery for finishing processes
  - **Structural Maintenance & Repair**: Cleaning and preparing structural surfaces for paining & coating (e.g., ship hulls, tanks, bridges, and offshore structures)

Challenges

- Difficult to achieve consistent automation when surface material and conditions are highly variable
- High precision results require delicate handling or adaptability to different surface geometries - typically requires manual work or human intervention
- Manual surface preparation tasks expose human workers to high risk of injury due to hazardous materials and environments

Opportunity & Expected Benefits

- Advanced object detection, ML and AI enables robot to:
  - Manipulate blast hose and tools accurately by adapting to varying surface conditions in real-time
  - Achieve a precise and consistent result, reducing the need for re-work and human intervention
  - Learn from human-based demonstrations and data, enhancing ability to adjust to real-time situations, reducing downtime and the need for costly re-programming
  - Detect and respond quickly to potential hazards, ensuring safer operation and compliance with safety regulations
- Reduces overhead costs and increases throughput, providing a faster ROI

1. Potential use cases based on discussions with potential customers.

Palladyne™ Pilot

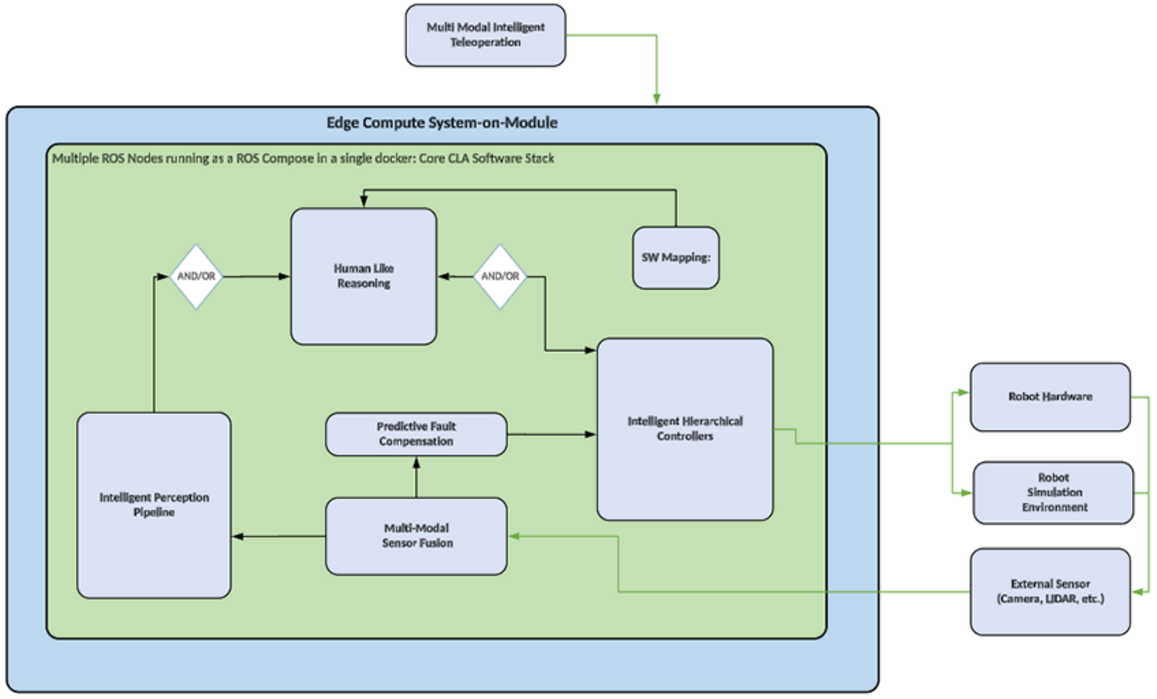
Potential Use Cases

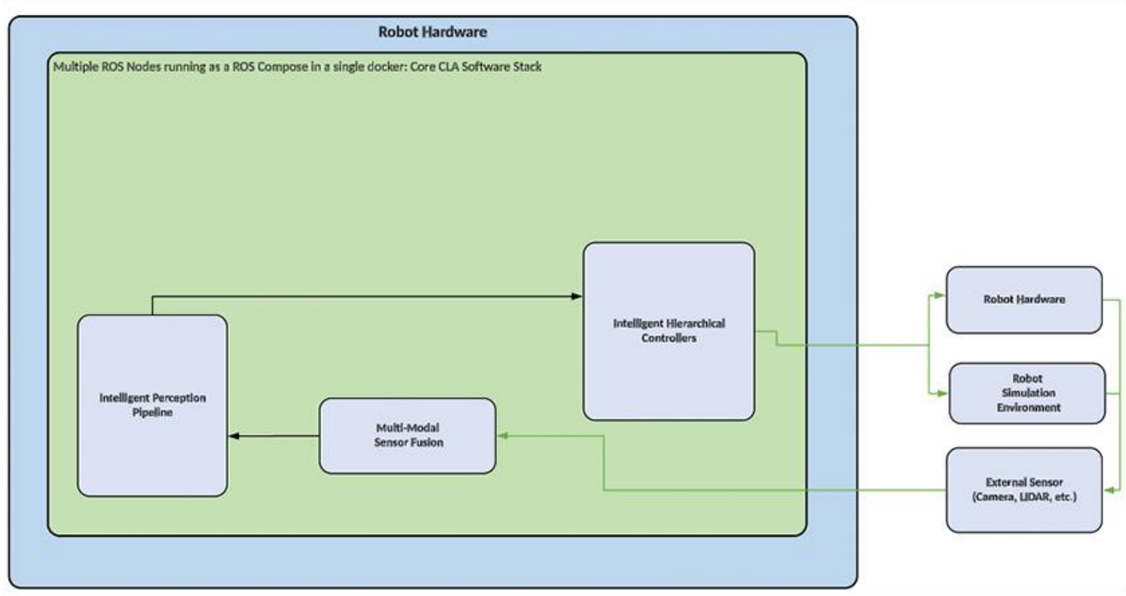
Examples based on discussions with potential customers

PALLADYNE AI PROPRIETARY

Enabling Robust Situational Awareness, Autonomous Detection/Tracking and Control of UAVs & UAGs

Leverages Foundational Capabilities of the AI/ML Software Framework





AI/ML Software Framework

(Full Stack Closed-Loop Autonomy)

Situational Awareness, Autonomous Detection/Tracking & Control[1] Framework

(Leverages a subset of the AI Software Framework)

1. Control of sensors only; does not control UAV/UGV's flight or navigational functionalities.

Defense/Commercial

Unmanned Aerial Vehicles[1]

Unstructured, In-flight

Tasks

- Persistent detection, tracking, and classification

Challenges

- Highly unstructured environment – in flight
- High levels of uncertainty

Opportunity & Expected Benefits

- Persistent sensor-based detection, tracking, and classification resolves representation uncertainty and enhances situational awareness
- Shared situation and/or navigation across UAVs enhances the collective knowledge and understanding of the entire fleet

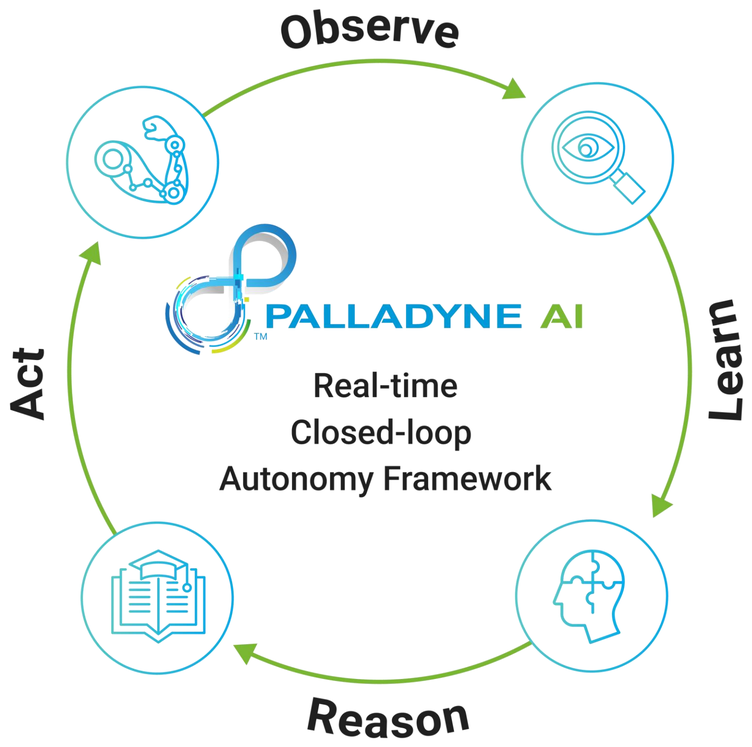
1. Potential use cases based on discussions with potential customers.

Palladyne™ IQ

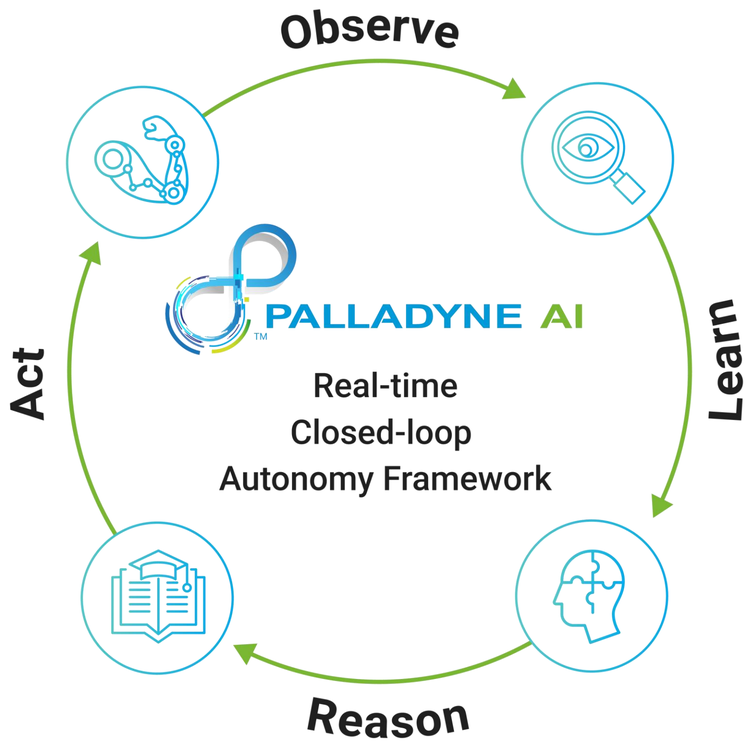
Demonstration

Fast Demo-Based Training

Multi-SKU Pick & Place Into Put Wall



Fully Autonomous Robot Operation After Training



Thank You

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