



**ADVANTEST**<sup>®</sup>

**Keith Schaub**

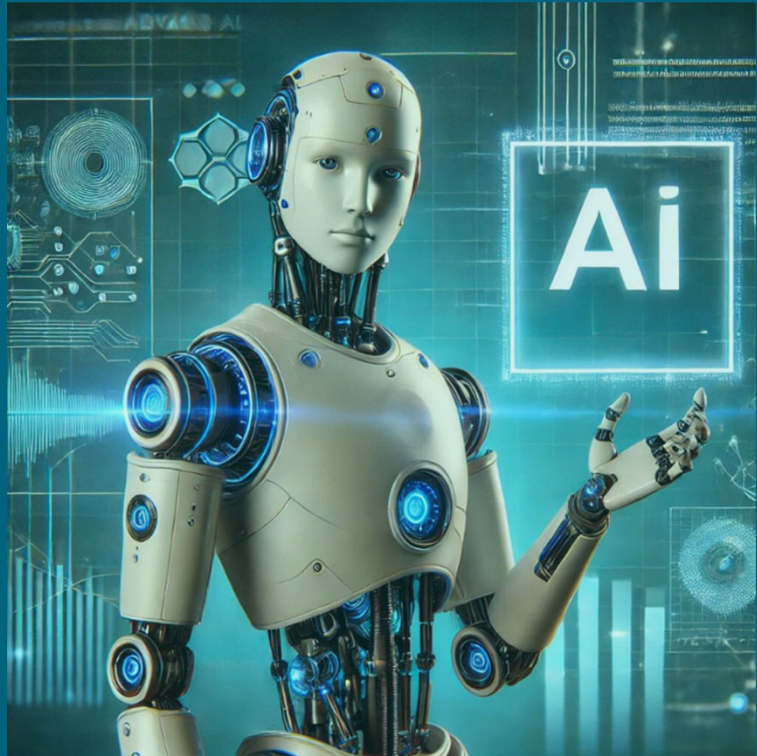
Vice President of Technology and Strategy  
Advantest America Inc.  
Oct. 29, 2024

TestConX Korea

## The Rise of AI-Enhanced Test Engineering: Transforming Challenges into Opportunities

All images created with ChatGPT 4o

## Disclaimer



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## Agenda



01

Introduction and Overview of Large Language Models (LLM)

02

New Developments and Capabilities

03

Detailed Engineering Use Cases

04

Conclusions and Future Outlook

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## LLMs (Large Language Models)

01



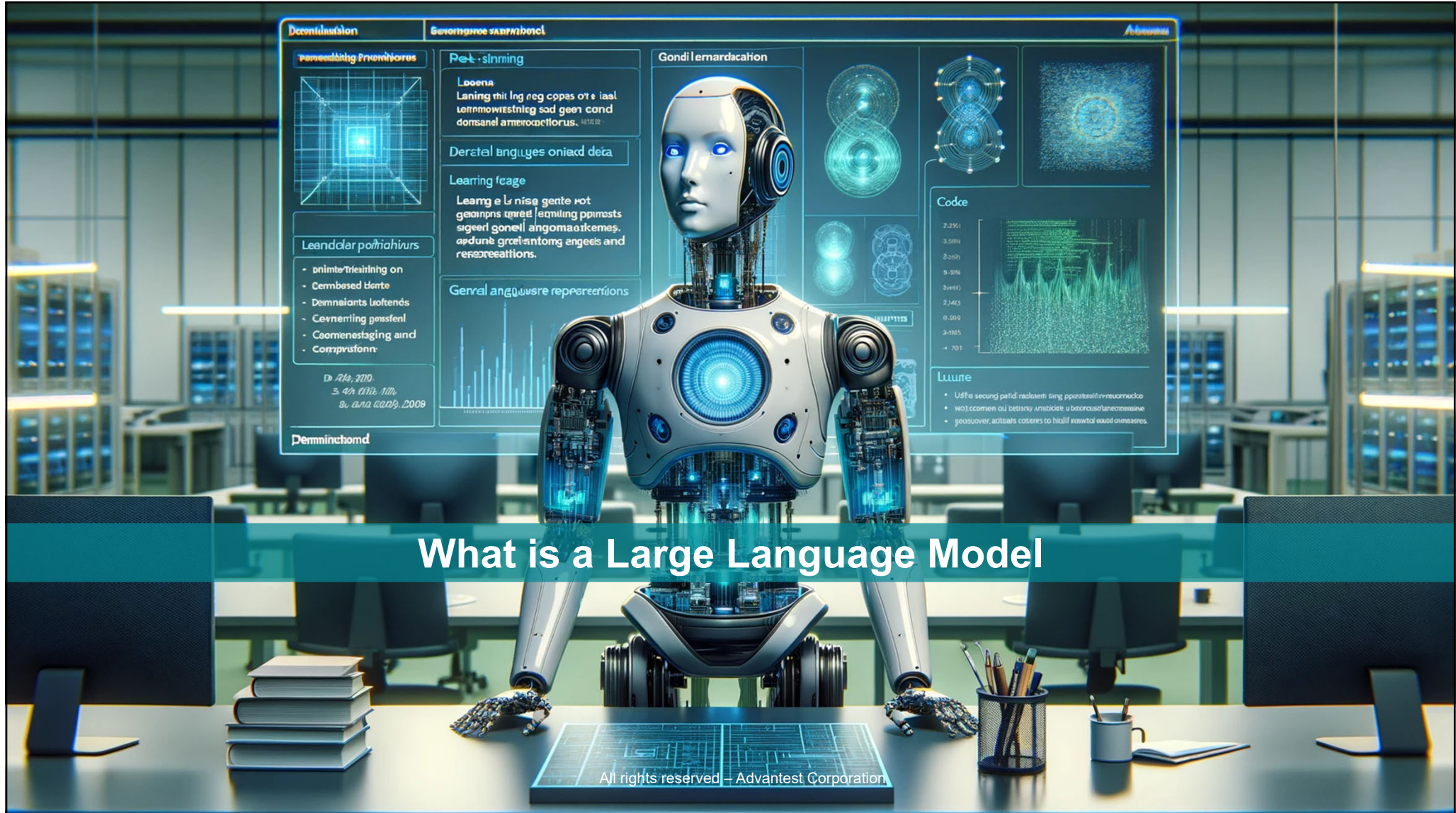
## Introduction

- › What are LLMs
- › Exponential improvements
- › Importance to semiconductor test
- › Capabilities today and projected

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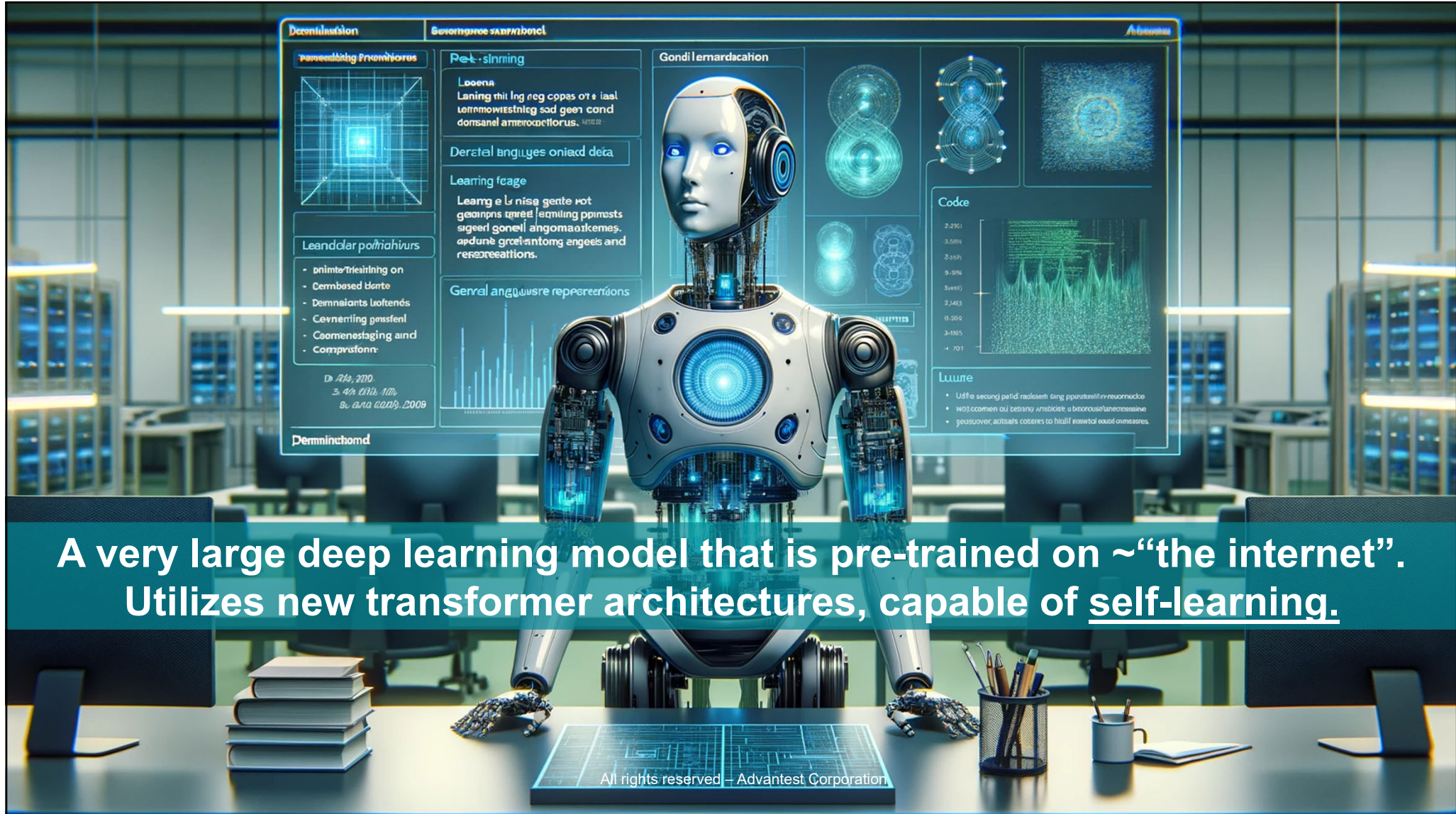




## What is a Large Language Model

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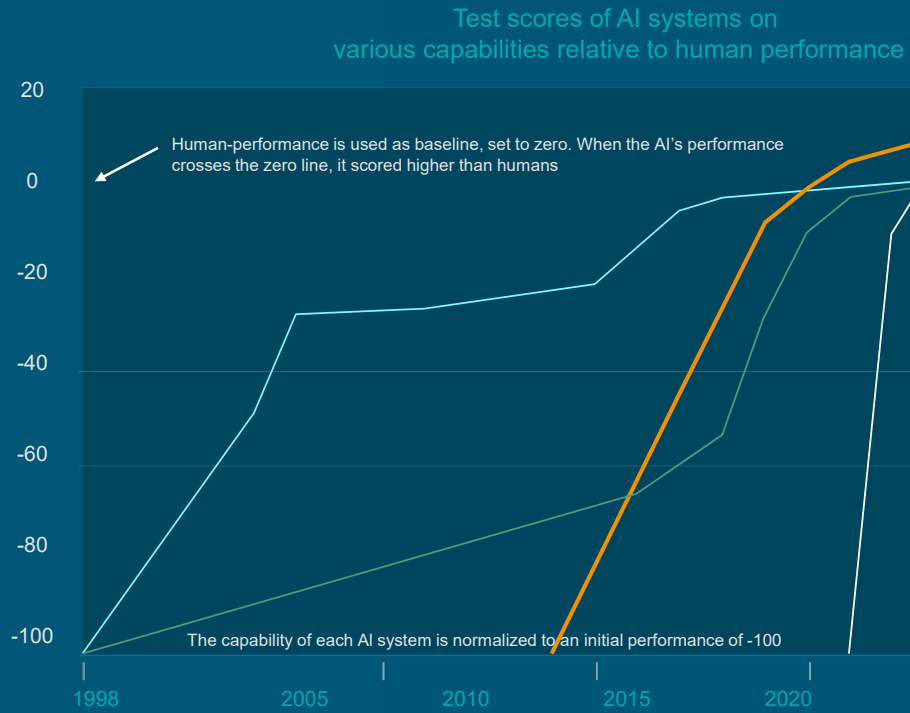




A very large deep learning model that is pre-trained on ~“the internet”. Utilizes new transformer architectures, capable of self-learning.

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## What a Difference a Year Makes



**2017**

Transformer "Attention is all you Need"

Fast (parallel architecture / GPUs)

Ability to focus attention

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## Why LLMs are Important for Semiconductor Test



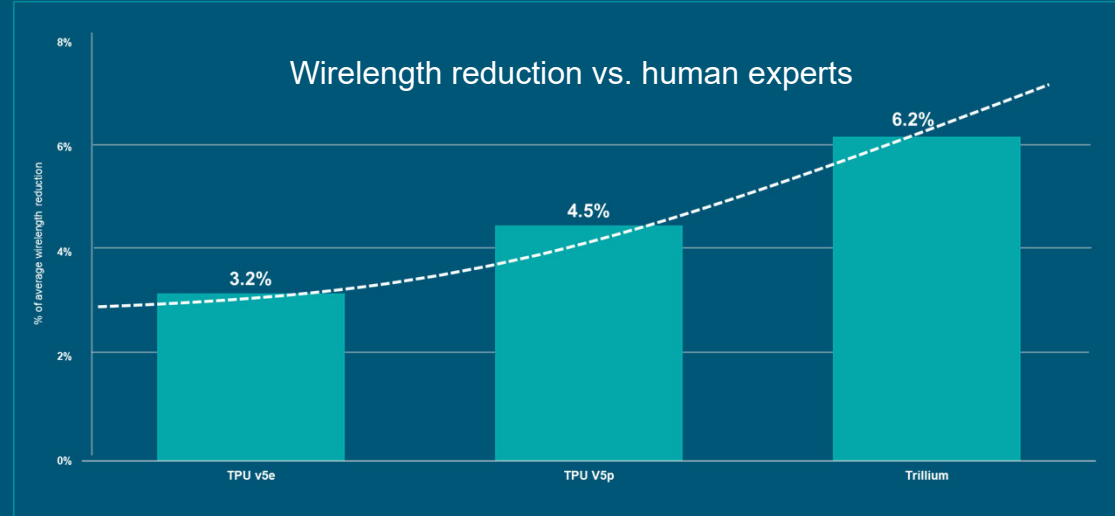
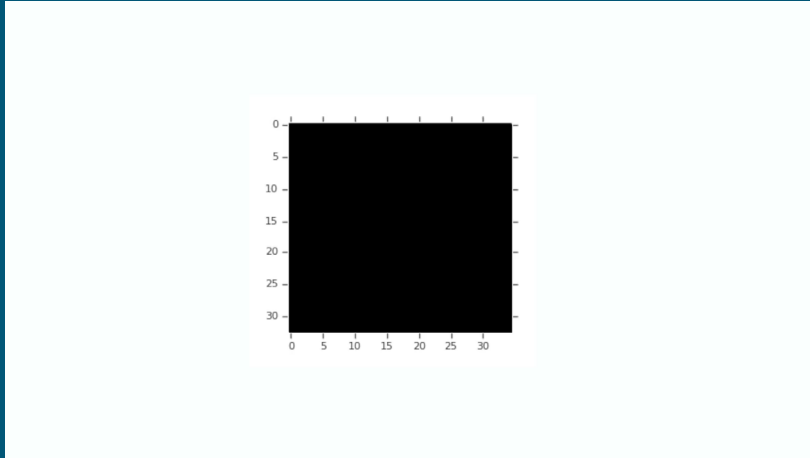
### Software - Code Generation

- › Tester Software Expertise
- › Enhanced Accuracy and Consistency
- › Accessibility and Skill Augmentation
  - › Democratizes complex coding tasks
  - › Fosters collaboration

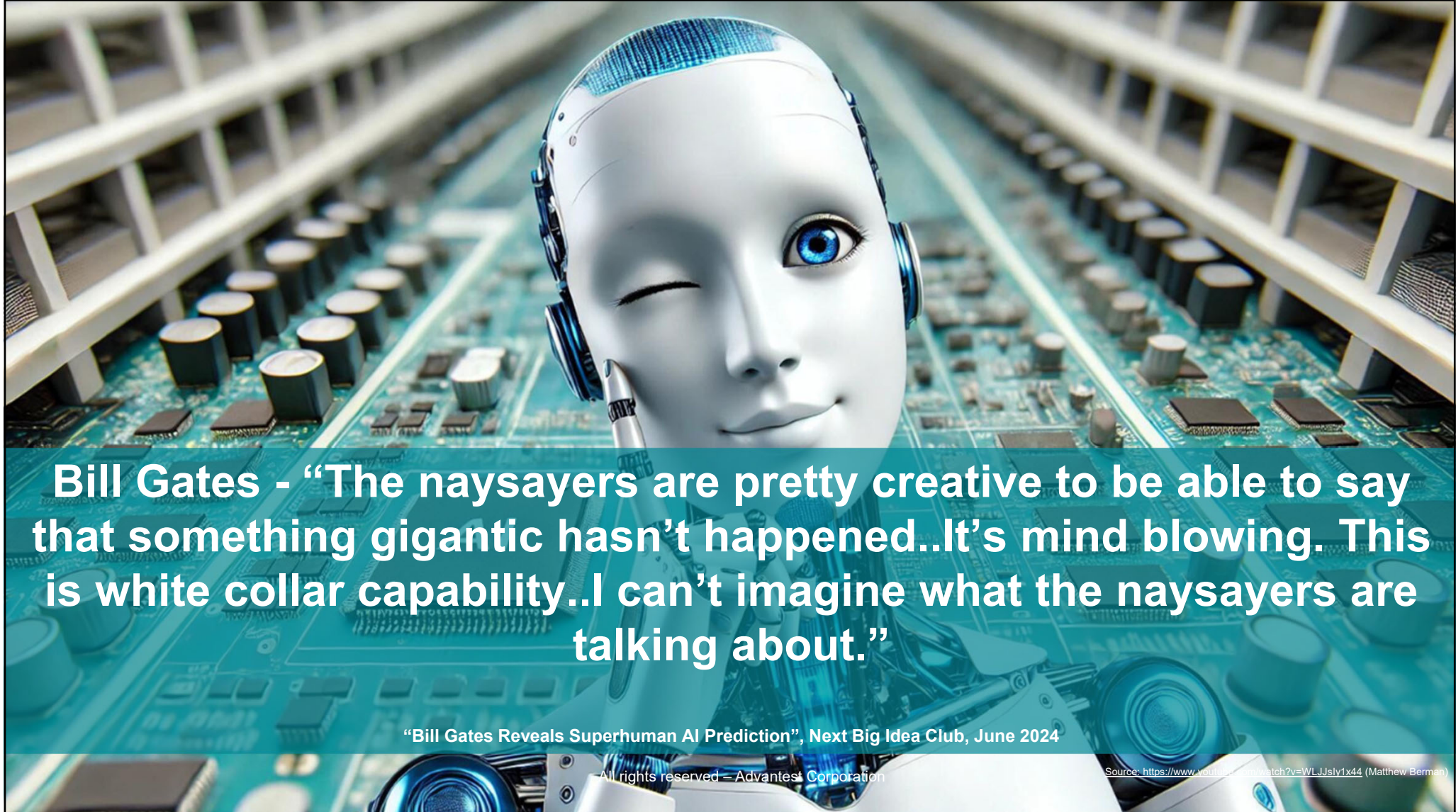
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## LLMs Optimizing New AI Chip Design Layouts



AI design layout already better than human experts



**Bill Gates - “The naysayers are pretty creative to be able to say that something gigantic hasn’t happened..It’s mind blowing. This is white collar capability..I can’t imagine what the naysayers are talking about.”**

“Bill Gates Reveals Superhuman AI Prediction”, Next Big Idea Club, June 2024

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Source: <https://www.youtube.com/watch?v=WLJJslv1x44> (Matthew Berman)



## LLMs (Large Language Models)

02



## New Developments and Capabilities

- › Key LLM Improvements
- › Future Projected Capabilities

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## What's new in LLMs and why we Care

## Key LLM Improvements Using GPT 3.5 to GPT 4-Turbo as example




**High Translation Accuracy**

- Trained on multiple range of languages
- Translate code languages



**Longer Memory**

- Capable of tracking lengthy conversation context and maintaining continuity
- Conversation memory can be the length of a book



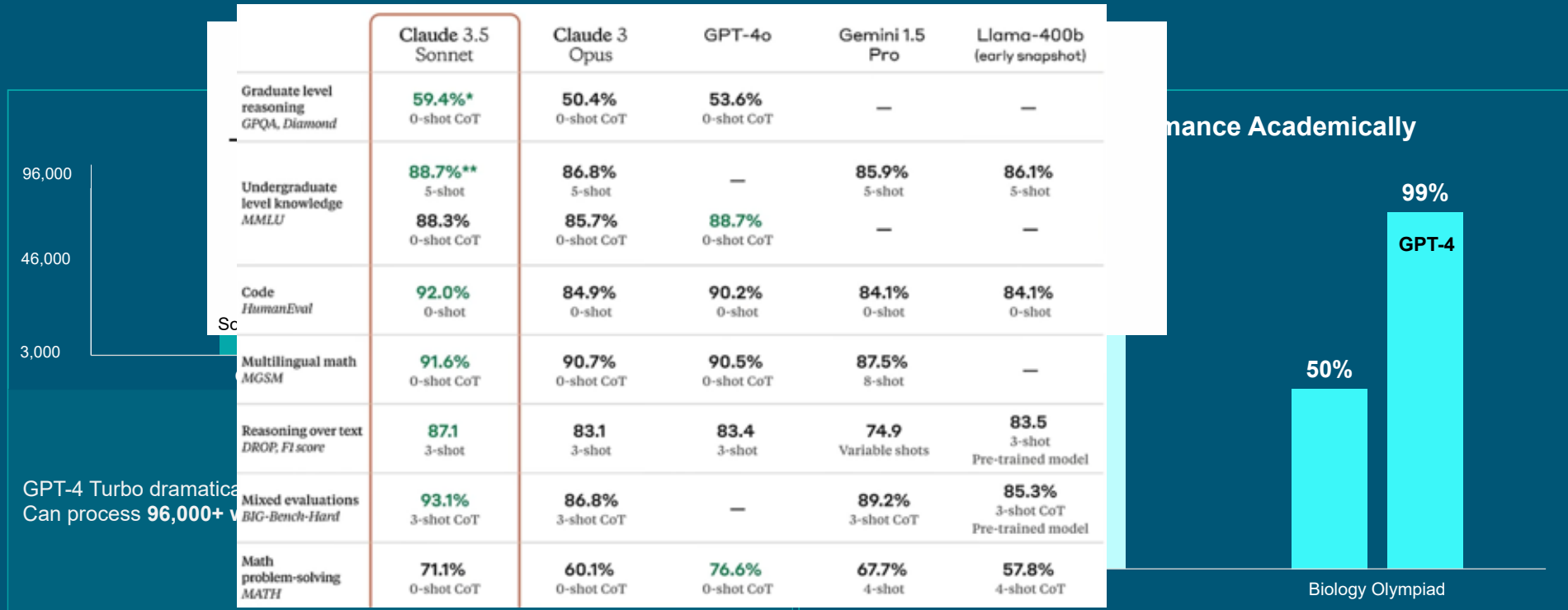
**Steerability**

- Better able to assist with supplement instructions or context depending on engineer's prompts
- Useful in generating domain specific answers

**Key Insight: Dramatically Improves Engineers Ability to Work Abstractly**



## Dramatically Smarter with Larger Memory

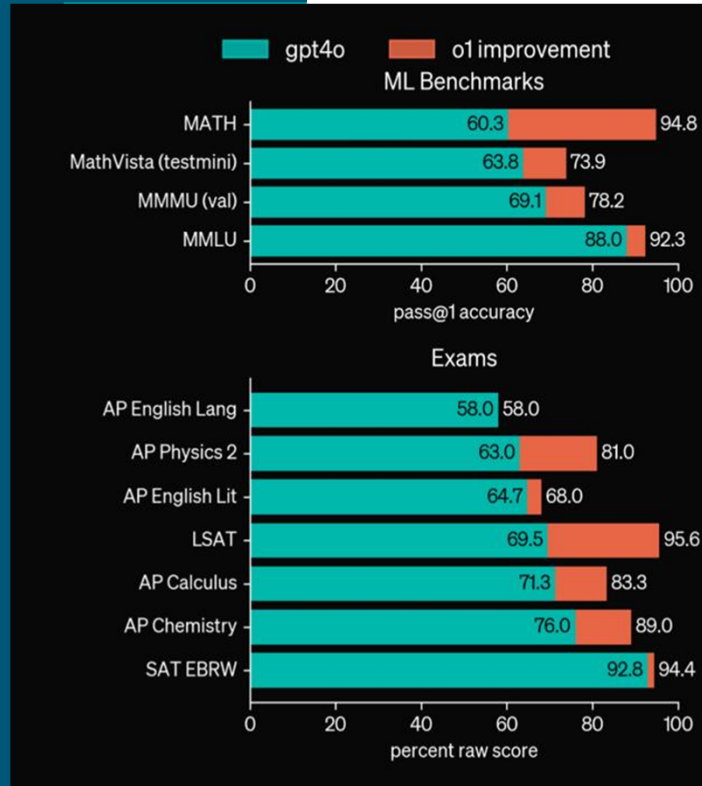


GPT-4 Turbo dramatically  
Can process 96,000+ v

## Bigger is Better, Models Continue to Grow in Size

**NEW**

People cannot distort



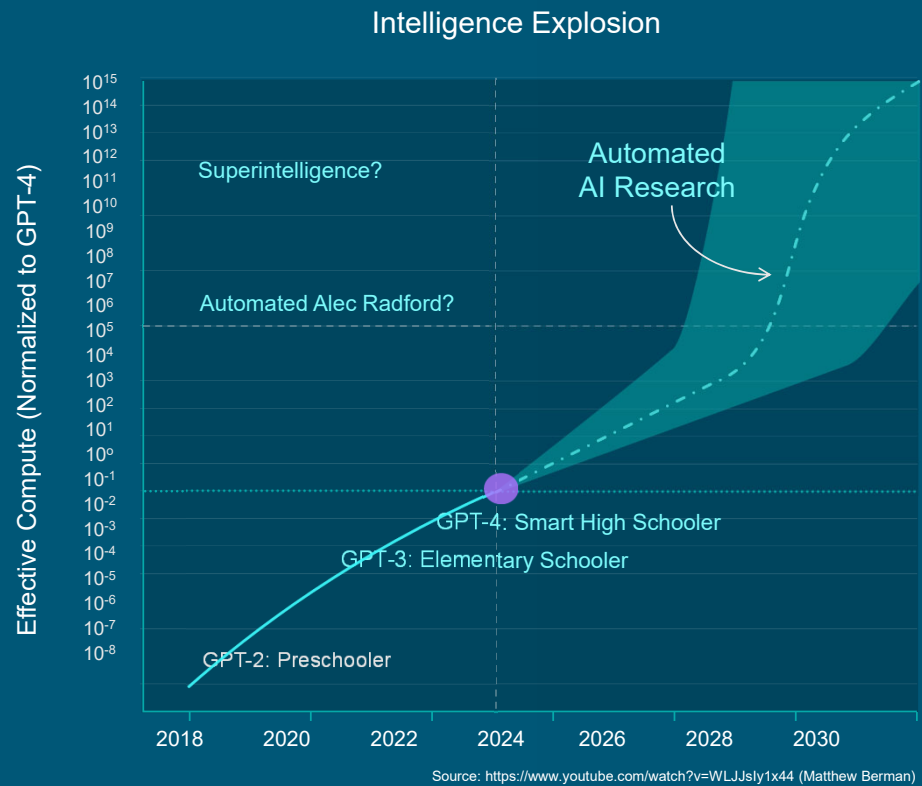
	Claude 3.5 Sonnet	Claude 3 Opus	GPT-4o	Gemini 1.5 Pro	Llama-400b (early snapshot)	GPT-4o1
Graduate level reasoning <i>GPQA, Diamond</i>	59.4%* 0-shot CoT	50.4% 0-shot CoT	53.6% 0-shot CoT	—	—	
Undergraduate level knowledge <i>MMLU</i>	88.7%** 5-shot	86.8% 5-shot	—	85.9% 5-shot	86.1% 5-shot	92.3
Code <i>HumanEval</i>	92.0% 0-shot	84.9% 0-shot	90.2% 0-shot	84.1% 0-shot	84.1% 0-shot	
Multilingual math <i>MGSM</i>	91.6% 0-shot CoT	90.7% 0-shot CoT	90.5% 0-shot CoT	87.5% 8-shot	—	
Reasoning over text <i>DROP, FI score</i>	87.1 3-shot	83.1 3-shot	83.4 3-shot	74.9 Variable shots	83.5 3-shot Pre-trained model	
Mixed evaluations <i>BIG-Bench-Hard</i>	93.1% 3-shot CoT	86.8% 3-shot CoT	—	89.2% 3-shot CoT	85.3% 3-shot CoT Pre-trained model	
Math problem-solving <i>MATH</i>	71.1% 0-shot CoT	60.1% 0-shot CoT	76.6% 0-shot CoT	67.7% 4-shot	57.8% 4-shot CoT	94.8

**Chat GPT-4: ~1.8 Trillion Parameters!**

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## Projected Capabilities



**NEW**

### GPT-4o1 (2024) ~ Smart PHD

Employs “System 2” thinking, focusing on analytical and reasoned thought processes. Allows for more accurate and context-aware answers, particularly in complex problem-solving scenarios.

### GPT-4 (2023) ~ Smart High Schooler

“Wow, it can write pretty sophisticatedly”.

From code to math to Fermi estimates, it can think and reason.

GPT-4 is now useful in my daily tasks.

### GPT-3 (2020)<sup>4</sup> ~ Elementary Schooler

“Wow, with just some few-shot examples it can do some simple useful tasks.”

It started being cohesive.

For the first time, it was also commercially useful in a few narrow ways: for example, GPT-3 could generate simple copy for SEO and marketing.



	GPT-4 (2023)	GPT-3.5 (2022)
Uniform Bar Exam	90th	10th
LSAT	88th	40th
SAT	97th	87th
GRE (Verbal)	99th	63rd
GRE (Quantitative)	80th	25th
US Biology Olympiad	99th	32nd
AP Calculus BC	51st	3rd
AP Chemistry	80th	34th
AP Macroeconomics	92nd	40th
AP Statistics	92nd	51st

Source: <https://www.youtube.com/watch?v=WLJJsly1x44> (Matthew Berman)

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## Whose High Schoolers Are They Talking About?

## New Visual Capability and Understanding

### Illustration

User: Can you describe this Image?



GPT-4: A little girl making friends with a robot in a Japanese market

### Visual Inputs

- › GPT-4 capable of accepting image prompts
- › Allows users to extract outputs such as code, natural language, summary, etc. from input image

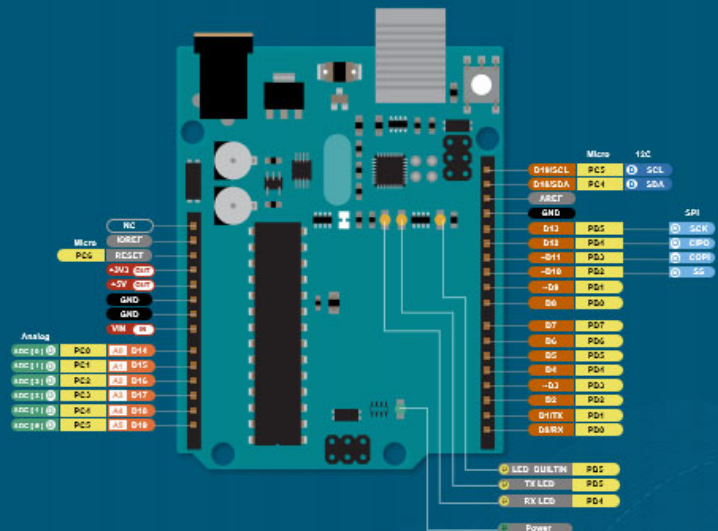
### Larger Word Processing

	GPT-3.5	GPT-4	GPT-4 Turbo	<b>NEW</b> GPT-4 o1
Input Tokens	4,000	32,000	124,000	64,000
Output Tokens			4,000	64,000

## Visual Understanding of Semiconductors

### Illustration

KS: Can you describe this Image?



### Visual Inputs

- › GPT-4 capable of accepting image prompts
- › Allows users to extract outputs such as code, natural language, summary, etc. from input image

**GPT-4:** The image you provided shows a typical Arduino Uno board layout. The Arduino Uno is a popular microcontroller board based on the ATmega328P microcontroller. It is widely used in electronics, education, and prototyping due to its simplicity and ease of use.



## LLMs (Large Language Models)

03



### • Detailed Use Cases

- › Complex Data Analysis with Zero Shot
- › Beyond Zero Shot
- › Assisting with Complex Semiconductor Test Engineering

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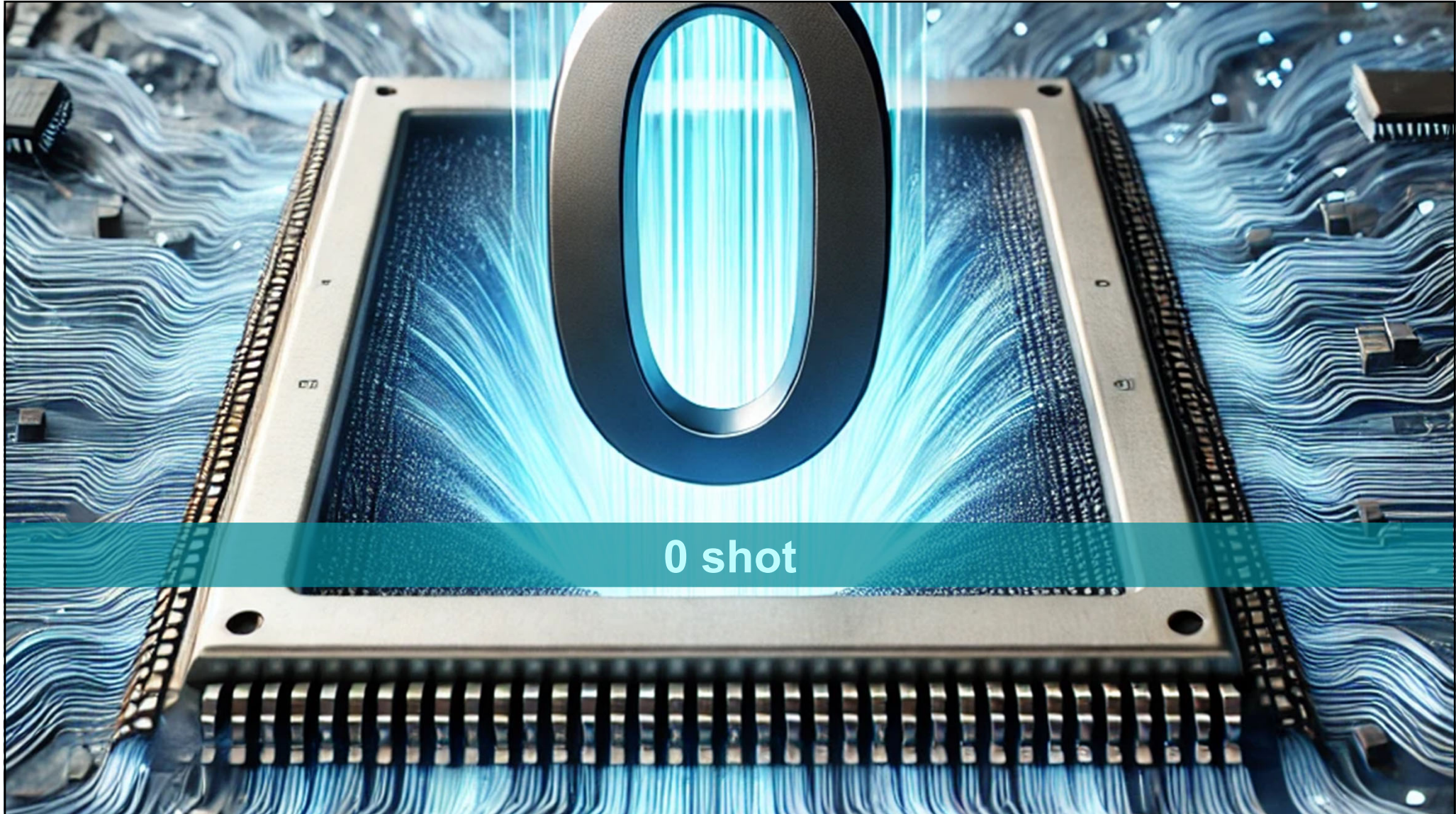
## The Data Puzzle: Complex Data Analysis

```
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35, 0 Heading (AFTER) 0.00, rad
40, 0 Heading 90.00, deg
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50, 0 RAW: 1, s: 0, aX: 0.20, aY: 0.60, gZ: -0.01, timeS: 31314.00, heading_rad: 0.00, heading_deg: 0.00
55, 0 RAW: 2, s: 0, aX: 1.14, aY: 3.39, gZ: -0.01, timeS: 31326.00, heading_rad: 0.00, heading_deg: 0.00
60, 42 RAW: 3, s: 0, aX: 0.12, aY: 5.61, gZ: 0.02, timeS: 31338.00, heading_rad: 0.00, heading_deg: 0.03
65, 41 RAW: 4, s: 0, aX: 0.78, aY: 4.29, gZ: 0.04, timeS: 31350.00, heading_rad: 0.00, heading_deg: 0.07
70, 40 RAW: 5, s: 0, aX: 0.60, aY: 3.39, gZ: 0.02, timeS: 31362.00, heading_rad: 0.00, heading_deg: 0.10
75, 40 RAW: 6, s: 0, aX: -1.24, aY: 2.37, gZ: 0.05, timeS: 31374.00, heading_rad: 0.00, heading_deg: 0.15
80, 39 RAW: 7, s: 0, aX: 0.23, aY: 2.56, gZ: -0.07, timeS: 31386.00, heading_rad: 0.00, heading_deg: 0.12
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90, 39 RAW: 9, s: 0, aX: -1.01, aY: 0.21, gZ: 0.06, timeS: 31410.00, heading_rad: 0.00, heading_deg: 0.20
95, 39 RAW: 10, s: 0, aX: -1.03, aY: 2.72, gZ: 0.07, timeS: 31422.00, heading_rad: 0.00, heading_deg: 0.27
100, 39 RAW: 11, s: 0, aX: 1.01, aY: 0.77, gZ: -0.02, timeS: 31434.00, heading_rad: 0.00, heading_deg: 0.27
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115, 40 RAW: 14, s: 0, aX: 0.65, aY: 1.04, gZ: -0.01, timeS: 31470.00, heading_rad: 0.01, heading_deg: 0.30
120, 40 RAW: 15, s: 0, aX: -2.35, aY: -2.47, gZ: -0.09, timeS: 31482.00, heading_rad: 0.00, heading_deg: 0.26
125, 0 RAW: 16, s: 0, aX: 2.66, aY: 1.17, gZ: -0.12, timeS: 31494.00, heading_rad: 0.00, heading_deg: 0.19
130, 0 RAW: 17, s: 0, aX: 1.20, aY: 0.00, gZ: -0.04, timeS: 31506.00, heading_rad: 0.00, heading_deg: 0.19
135, 0 RAW: 18, s: 0, aX: -1.39, aY: 0.79, gZ: 0.00, timeS: 31518.00, heading_rad: 0.00, heading_deg: 0.19
140, 0 RAW: 19, s: 0, aX: 0.65, aY: 1.31, gZ: -0.02, timeS: 31530.00, heading_rad: 0.00, heading_deg: 0.19
145, 0 RAW: 20, s: 0, aX: 1.05, aY: 0.01, gZ: -0.15, timeS: 31542.00, heading_rad: 0.00, heading_deg: 0.10
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RAW: 22, s: 0, aX: -0.37, aY: -1.41, gZ: -0.09, timeS: 31566.00, heading_rad: -0.00, heading_deg: -0.08
RAW: 23, s: 0, aX: 1.41, aY: -0.31, gZ: -0.13, timeS: 31578.00, heading_rad: -0.00, heading_deg: -0.08
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RAW: 26, s: 0, aX: 2.84, aY: -0.12, gZ: -0.15, timeS: 31614.00, heading_rad: -0.01, heading_deg: -0.35
RAW: 27, s: 0, aX: -3.05, aY: -0.25, gZ: -0.20, timeS: 31626.00, heading_rad: -0.01, heading_deg: -0.47
RAW: 28, s: 0, aX: 6.03, aY: -1.78, gZ: -0.19, timeS: 31638.00, heading_rad: -0.01, heading_deg: -0.58
.
.
RAW: 89, s: 0, aX: 3.33, aY: -6.36, gZ: 0.03, timeS: 32361.00, heading_rad: -0.03, heading_deg: -1.43
RPM1 49.50, RPM2 51.00, Counter1 33, Counter2 34, distanceTraveled 34.34, posX -0.00, posY 34.34
```

```
30, 0 Heading (BEFORE) 0.00, rad
35, 0 Heading (AFTER) 0.00, rad
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45, 0 RAW: 1, s: 55, aX: 0.14, aY: 0.13, gZ: -0.02, timeS: 46866.00, heading_rad: 0.00, heading_deg: 0.00
50, 0 RAW: 2, s: 60, aX: 0.12, aY: -0.03, gZ: -0.02, timeS: 46878.00, heading_rad: 0.00, heading_deg: 0.00
55, 0 RAW: 3, s: 65, aX: 0.25, aY: -0.11, gZ: -0.02, timeS: 46890.00, heading_rad: 0.00, heading_deg: 0.00
60, 0 RAW: 4, s: 70, aX: 0.44, aY: -0.17, gZ: -0.02, timeS: 46902.00, heading_rad: 0.00, heading_deg: 0.00
65, 0 RAW: 5, s: 75, aX: 0.52, aY: 0.36, gZ: -0.10, timeS: 46914.00, heading_rad: -0.00, heading_deg: -0.05
70, 23 RAW: 6, s: 80, aX: 0.18, aY: 1.17, gZ: -0.12, timeS: 46926.00, heading_rad: -0.00, heading_deg: -0.12
75, 22 RAW: 7, s: 85, aX: 0.42, aY: 0.02, gZ: -0.04, timeS: 46938.00, heading_rad: -0.00, heading_deg: -0.12
80, 21 RAW: 8, s: 90, aX: -0.04, aY: 0.38, gZ: -0.06, timeS: 46950.00, heading_rad: -0.00, heading_deg: -0.14
85, 21 RAW: 9, s: 95, aX: -0.55, aY: -0.66, gZ: -0.20, timeS: 46962.00, heading_rad: -0.00, heading_deg: -0.26
90, 21 RAW: 10, s: 100, aX: 0.92, aY: -0.72, gZ: -0.31, timeS: 46974.00, heading_rad: -0.01, heading_deg: -0.46
95, 21 RAW: 11, s: 100, aX: -0.61, aY: -1.14, gZ: -0.56, timeS: 46986.00, heading_rad: -0.01, heading_deg: -0.84
100, 21 RAW: 12, s: 100, aX: 0.62, aY: -1.62, gZ: -0.80, timeS: 46998.00, heading_rad: -0.02, heading_deg: -1.37
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110, 21 RAW: 14, s: 100, aX: 0.45, aY: -0.38, gZ: -0.97, timeS: 47022.00, heading_rad: -0.05, heading_deg: -2.65
115, 21 RAW: 15, s: 100, aX: 1.47, aY: 0.48, gZ: -1.04, timeS: 47034.00, heading_rad: -0.06, heading_deg: -3.35
120, 22 RAW: 16, s: 100, aX: -0.33, aY: 0.08, gZ: -1.08, timeS: 47046.00, heading_rad: -0.07, heading_deg: -4.07
125, 0 RAW: 17, s: 100, aX: -0.56, aY: 0.30, gZ: -1.09, timeS: 47058.00, heading_rad: -0.08, heading_deg: -4.81
130, 0 RAW: 18, s: 100, aX: -0.58, aY: -0.03, gZ: -1.15, timeS: 47070.00, heading_rad: -0.10, heading_deg: -5.59
135, 0 RAW: 19, s: 100, aX: -0.87, aY: -1.06, gZ: -1.14, timeS: 47082.00, heading_rad: -0.11, heading_deg: -6.35
140, 0 RAW: 20, s: 100, aX: 1.73, aY: -0.16, gZ: -1.17, timeS: 47094.00, heading_rad: -0.12, heading_deg: -7.14
145, 0 RAW: 21, s: 100, aX: 0.72, aY: 0.57, gZ: -1.15, timeS: 47106.00, heading_rad: -0.14, heading_deg: -7.92
150, 0 RAW: 22, s: 100, aX: 0.25, aY: 0.42, gZ: -1.15, timeS: 47118.00, heading_rad: -0.15, heading_deg: -8.69
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RAW: 25, s: 100, aX: -1.14, aY: -0.38, gZ: -1.19, timeS: 47154.00, heading_rad: -0.19, heading_deg: -11.07
RAW: 26, s: 100, aX: 0.43, aY: -0.50, gZ: -1.20, timeS: 47166.00, heading_rad: -0.21, heading_deg: -11.88
RAW: 27, s: 100, aX: 1.69, aY: -0.20, gZ: -1.24, timeS: 47178.00, heading_rad: -0.22, heading_deg: -12.72
RAW: 28, s: 100, aX: 0.70, aY: 0.67, gZ: -1.21, timeS: 47190.00, heading_rad: -0.24, heading_deg: -13.54
.
.
RAW: 117, s: 100, aX: 0.29, aY: 1.39, gZ: -0.62, timeS: 48249.00, heading_rad: -1.60, heading_deg: -91.43
```

Data







## 0 Shot: LLM Help! What the Heck is this Data?

KS

Review the attached text data file and summarize the interesting findings you determine.

### The Data Puzzle: Complex Data Analysis

```
30,0 Heading (BEFORE) 0.00, rad
35,0 Heading (AFTER) 0.00, rad
40,0 Heading 90.00, deg
45,0 RAW: 0, s: 0, ax: 0.32, ay: 0.07, gz: -0.02, timeS: 31302.00, heading_rad: 0.00, heading_deg: 0.00
RAW: 1, s: 50, ax: 0.12, ay: -0.03, gz: -0.02, timeS: 46874.00, heading_rad: 0.00, heading_deg: 0.00
50,0 RAW: 2, s: 0, ax: 1.14, ay: 3.39, gz: -0.01, timeS: 31326.00, heading_rad: 0.00, heading_deg: 0.00
RAW: 3, s: 65, ax: 0.25, ay: -0.11, gz: -0.02, timeS: 46890.00, heading_rad: 0.00, heading_deg: 0.00
55,0 RAW: 4, s: 70, ax: 0.44, ay: -0.17, gz: -0.02, timeS: 46902.00, heading_rad: 0.00, heading_deg: 0.00
60,0 RAW: 5, s: 75, ax: 0.52, ay: -0.39, gz: -0.10, timeS: 46914.00, heading_rad: 0.00, heading_deg: 0.00
65,0 RAW: 6, s: 80, ax: 0.18, ay: 1.17, gz: -0.12, timeS: 46926.00, heading_rad: 0.00, heading_deg: 0.10
70,0 RAW: 7, s: 85, ax: 0.42, ay: 0.02, gz: -0.04, timeS: 46938.00, heading_rad: 0.00, heading_deg: -0.12
75,0 RAW: 8, s: 90, ax: -0.04, ay: 0.38, gz: -0.06, timeS: 46950.00, heading_rad: 0.00, heading_deg: -0.14
RAW: 9, s: 95, ax: -0.55, ay: -0.56, gz: -0.20, timeS: 46962.00, heading_rad: 0.00, heading_deg: -0.26
80,0 RAW: 10, s: 100, ax: 0.92, ay: -0.72, gz: -0.31, timeS: 46974.00, heading_rad: -0.01, heading_deg: -0.46
85,0 RAW: 11, s: 100, ax: -0.61, ay: -1.14, gz: -0.55, timeS: 46986.00, heading_rad: -0.01, heading_deg: -0.84
90,0 RAW: 12, s: 100, ax: 0.52, ay: 1.52, gz: -0.80, timeS: 46998.00, heading_rad: -0.02, heading_deg: -1.37
95,0 RAW: 13, s: 100, ax: 1.17, ay: -0.61, gz: -0.93, timeS: 47010.00, heading_rad: -0.03, heading_deg: -2.00
100,0 RAW: 14, s: 100, ax: 0.45, ay: -0.38, gz: -0.97, timeS: 47022.00, heading_rad: -0.05, heading_deg: -2.65
105,0 RAW: 15, s: 100, ax: 1.47, ay: 0.48, gz: -1.04, timeS: 47034.00, heading_rad: -0.06, heading_deg: -3.35
110,0 RAW: 16, s: 100, ax: -0.33, ay: 0.58, gz: -1.05, timeS: 47046.00, heading_rad: -0.07, heading_deg: -4.07
115,0 RAW: 17, s: 100, ax: -0.55, ay: 0.30, gz: -1.09, timeS: 47058.00, heading_rad: -0.08, heading_deg: -4.81
120,0 RAW: 18, s: 100, ax: -0.58, ay: -0.03, gz: -1.15, timeS: 47070.00, heading_rad: -0.10, heading_deg: -5.59
125,0 RAW: 19, s: 100, ax: -0.87, ay: -1.06, gz: -1.14, timeS: 47082.00, heading_rad: -0.11, heading_deg: -6.35
RAW: 20, s: 100, ax: 1.73, ay: -0.16, gz: -1.17, timeS: 47094.00, heading_rad: -0.12, heading_deg: -7.14
130,0 RAW: 21, s: 100, ax: 0.72, ay: 0.57, gz: -1.15, timeS: 47106.00, heading_rad: -0.14, heading_deg: -7.92
135,0 RAW: 22, s: 100, ax: 0.25, ay: 0.42, gz: -1.15, timeS: 47118.00, heading_rad: -0.15, heading_deg: -8.59
140,0 RAW: 23, s: 100, ax: 0.70, ay: 0.73, gz: -1.17, timeS: 47130.00, heading_rad: -0.17, heading_deg: -9.48
145,0 RAW: 24, s: 100, ax: 0.09, ay: -0.87, gz: -1.18, timeS: 47142.00, heading_rad: -0.18, heading_deg: -10.27
150,0 RAW: 25, s: 100, ax: -1.14, ay: -0.38, gz: -1.19, timeS: 47154.00, heading_rad: -0.19, heading_deg: -11.07
RAW: 26, s: 100, ax: 0.43, ay: -0.50, gz: -1.20, timeS: 47166.00, heading_rad: -0.21, heading_deg: -11.88
RAW: 27, s: 100, ax: 1.59, ay: -0.20, gz: -1.24, timeS: 47178.00, heading_rad: -0.22, heading_deg: -12.72
RAW: 28, s: 100, ax: 0.70, ay: 0.67, gz: -1.21, timeS: 47190.00, heading_rad: -0.24, heading_deg: -13.54
RAW: 29, s: 0, ax: 6.03, ay: -1.78, gz: -0.19, timeS: 31638.00, heading_rad: -0.01, heading_deg: -0.53
RAW: 89, s: 0, ax: 3.33, ay: -6.36, gz: 0.03, timeS: 32361.00, heading_rad: -0.03, heading_deg: -1.43
RPM1 49.50, RPM2 51.00, Counter1 33, Counter2 34, distanceTraveled 34.34, posX: 0.00, posY: 34.34
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```



The provided data file appears to contain a series of numerical and text entries that suggest a record of some physical or mechanical tests, possibly involving motion, rotation, or vibration, given the mention of RPM (revolutions per minute), positions (posX, posY), distances, and acceleration (ax, ay, gz). These entries are interspersed with "RAW" data lines that include sensor readings such as acceleration in the X and Y directions (ax, ay), gyroscopic measurements (gz), and timestamps (timeS).

Key observations from the data include:

## LLM's Analysis and Key Observations in ~ 5 seconds



- 1. Periodic Data with Zeroes:** There are several sequences where values increment from 0 up to a maximum and then back to 0, suggesting some cyclic or repeating process. This pattern could indicate a device or system being tested in a controlled manner, where specific parameters are gradually increased and then decreased.
- 2. Presence of Sensor Readings:** The "RAW" data lines provide insight into the behavior of a system under test, including acceleration and rotational motion. The presence of acceleration (aX, aY) and gyroscopic data (gZ) implies the testing or monitoring of a device's movement or orientation.
- 3. Variations in Speed:** The mention of RPM1 and RPM2, along with associated counter values, suggests that the test involves two components or systems whose rotational speeds are monitored. These speeds vary across different sections of the data, which might indicate different test conditions or adjustments to the system's operation.
- 4. Spatial Data:** The "posX" and "posY" entries suggest that the position of the device or an object within a plane is being tracked. This could be part of a navigation, positioning, or motion control test.

## LLM's Analysis and Key Observations (continued)



**5. Changes in Heading:** There are references to heading changes (in radians and degrees), indicating that the orientation or direction of the system or device is a critical parameter being monitored or controlled during the tests.

**6. Timestamps and Sequence:** The data includes timestamps (timeS), suggesting that the sequence of events or measurements is important. This temporal information could be used to analyze the dynamics of the system over time.

This summary suggests that the data file could be related to tests or experiments involving a device or system with moving parts, possibly a vehicle or robotic system, where acceleration, orientation, and position are crucial. The detailed sensor readings, along with rotational and positional data, hint at comprehensive testing scenarios aimed at understanding or improving the system's performance in varying conditions.



## LLM Thoughtfully Interpreting the Data

KS

If you had to guess what physical device this data is coming from, what would be your guess and why?

Based on the analysis of the data provided, it appears likely that this data could be coming from a **robotic or autonomous vehicle system**.

Here are several reasons supporting this guess:

1. Presence of RPM Data: The RPM (Revolutions Per Minute) readings suggest a device that includes rotating parts, such as wheels or motors. This is typical of vehicles or robots.
2. Sensor Data Variety: The data includes multiple types of sensor readings such as acceleration (aX, aY), gyroscope (gZ), and heading (both in radians and degrees). This combination of sensors is commonly used in autonomous vehicles and robotics to monitor movement and orientation, essential for navigation and maintaining balance.
3. Dynamic Movement Indications: The fluctuations in acceleration and gyroscopic data indicate dynamic movement and complex maneuvering capability, which aligns well with the operational characteristics of autonomous systems that require precise control over movement and positioning.

4. Structured and Time-stamped Data: The detailed time stamps and structured format of the data imply a system that collects continuous telemetry, typical of testing scenarios for vehicles and robots where monitoring real-time performance is crucial.

5. Headings and Position Data: The detailed orientation data and positional changes (as indicated by heading degrees changing over time) suggest navigation capabilities, which are essential for autonomous vehicles and mobile robots.

These characteristics are all indicative of a device that is mobile, contains sophisticated navigational aids, and requires continuous monitoring and control, which are hallmarks of robotic systems and autonomous vehicles.

## LLM Explaining its Thought Process and Analysis

KS

Why do you not think it is a drone?



It's certainly possible that the data could be from a drone; however, a few aspects of the data might suggest otherwise, or at least make other options like ground-based vehicles or robots seem more likely.

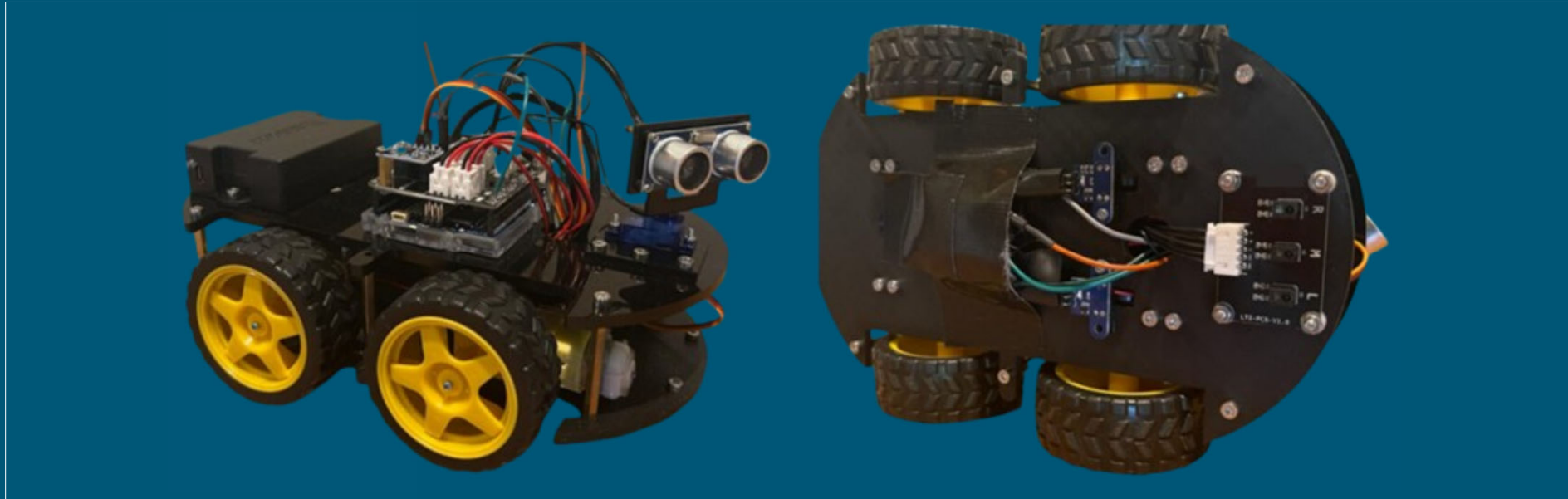
Here are some considerations:

1. Stability in Heading Data: Drones, especially when flying, typically exhibit more variability in their heading due to the need to constantly adjust to wind and other aerial conditions. The data shows stable headings with occasional changes...
2. Acceleration and Gyroscope Values: The acceleration and gyroscope data points show significant changes, but these are generally less chaotic than one might expect from a flying drone...
3. RPM Data: The specific mention of "RPM1" and "RPM2" with close values might suggest a dual motor setup commonly found in ground vehicles. In drones...the variations between them could be more distinct based on flight dynamics and control inputs.
4. Lack of Three-Dimensional Movement Data: Drones typically operate in a three-dimensional space and would generally have more pronounced variations in the Z-axis accelerometer readings to reflect vertical movements. The data provided primarily shows changes in the X and Y axes, which could be more indicative of a terrestrial vehicle.

## New Image Analysis Enhance Capabilities

KS

Take a look at the picture and tell me if your analysis was correct, and provide any additional updates or corrections from your previous analysis.



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## Yes, I Was Correct, Why Do You Doubt Me?



Based on the image you've provided, it appears the data is indeed from a ground-based robotic vehicle. This conclusion aligns with the observations and analysis provided earlier....:

**Sensor Array:** The robot is equipped with multiple sensors, including what appear to be ultrasonic sensors (for distance measurement) and possibly other types of sensors. This matches the data complexity seen in the file, where multiple types of sensor data were logged.

**Wheel and Motor Configuration:** The vehicle has a four-wheel setup with visible motor connections, which could explain the RPM readings for two different motors (RPM1 and RPM2) as identified in the data...

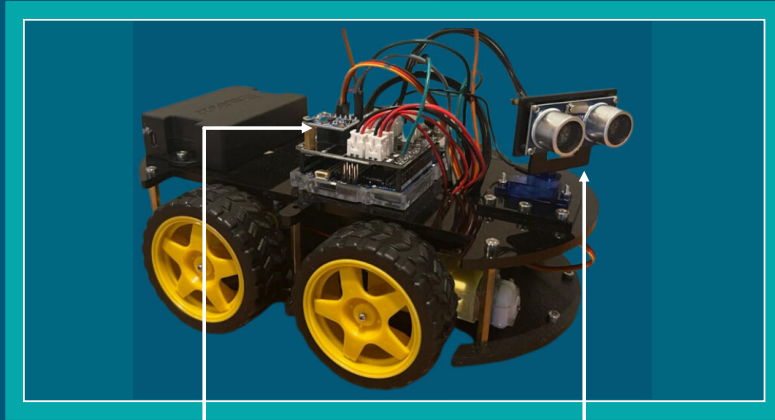
**Robotic Platform and Control Unit:** The platform shows a mounted control unit, likely containing the microcontroller or computer managing inputs from the sensors and controlling the motors indicative of a robotic system...

**Construction and Design:** The robust construction and the presence of a mounted battery pack support the idea that this vehicle is designed for substantial autonomous operation...

**Wiring and Circuitry:** The detailed wiring and circuitry visible suggest a customized or developmental robotic platform...

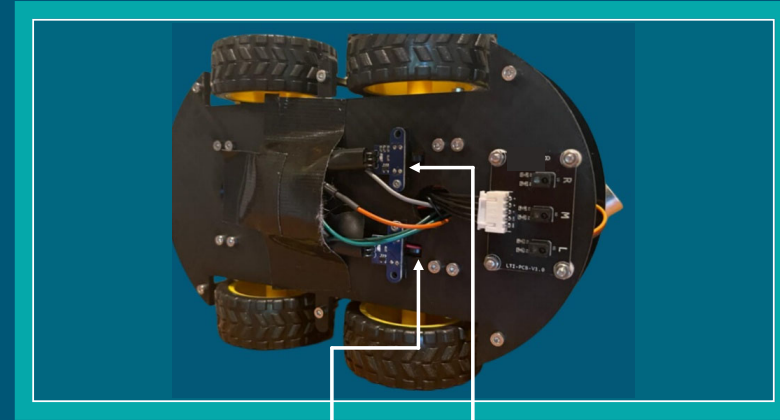
Your image confirms that the data likely comes from a robotic vehicle designed for complex operations and environments, incorporating multiple sensors for navigation and control....

## The Big Reveal



Accelerometer, Gyro

Ultrasound (radar)



Optical Encoders

## LLM Understood and Communicated all of this

edge angles of ultrasound sweep masked to 0

```
30, 0 Heading (BEFORE) 0.00, rad
35, 0 Heading (AFTER) 0.00, rad
40, 0 Heading 90.00, deg
45, 0 RAW: 0, s: 0, aX: 0.32, aY: 0.07, gZ: -0.02, timeS: 31302.00, heading_rad: 0.00, heading_deg: 0.00
50, 0 RAW: 1, s: 0, aX: 0.20, aY: 0.60, gZ: -0.01, timeS: 31314.00, heading_rad: 0.00, heading_deg: 0.00
55, 0 RAW: 2, s: 0, aX: 1.14, aY: 3.39, gZ: -0.01, timeS: 31326.00, heading_rad: 0.00, heading_deg: 0.00
60, 42 RAW: 3, s: 0, aX: 0.12, aY: 5.61, gZ: 0.02, timeS: 31338.00, heading_rad: 0.00, heading_deg: 0.03
65, 41 RAW: 4, s: 0, aX: 0.78, aY: 4.29, gZ: 0.04, timeS: 31350.00, heading_rad: 0.00, heading_deg: 0.07
70, 40 RAW: 5, s: 0, aX: 0.60, aY: 3.39, gZ: 0.02, timeS: 31362.00, heading_rad: 0.00, heading_deg: 0.10
75, 40 RAW: 6, s: 0, aX: -1.24, aY: 2.37, gZ: 0.05, timeS: 31374.00, heading_rad: 0.00, heading_deg: 0.15
80, 39 RAW: 7, s: 0, aX: 0.23, aY: 2.56, gZ: -0.07, timeS: 31386.00, heading_rad: 0.00, heading_deg: 0.12
85, 40 RAW: 8, s: 0, aX: -1.43, aY: 1.40, gZ: 0.02, timeS: 31398.00, heading_rad: 0.00, heading_deg: 0.15
90, 39 RAW: 9, s: 0, aX: -1.01, aY: 0.21, gZ: 0.06, timeS: 31410.00, heading_rad: 0.00, heading_deg: 0.20
95, 39 RAW: 10, s: 0, aX: -1.03, aY: 2.72, gZ: 0.07, timeS: 31422.00, heading_rad: 0.00, heading_deg: 0.27
100, 39 RAW: 11, s: 0, aX: 1.01, aY: 0.77, gZ: -0.02, timeS: 31434.00, heading_rad: 0.00, heading_deg: 0.27
105, 40 RAW: 12, s: 0, aX: 1.45, aY: 0.54, gZ: 0.03, timeS: 31446.00, heading_rad: 0.01, heading_deg: 0.30
110, 40 RAW: 13, s: 0, aX: -0.28, aY: 0.86, gZ: -0.03, timeS: 31458.00, heading_rad: 0.01, heading_deg: 0.30
115, 40 RAW: 14, s: 0, aX: 0.65, aY: 1.04, gZ: -0.01, timeS: 31470.00, heading_rad: 0.01, heading_deg: 0.30
120, 40 RAW: 15, s: 0, aX: -2.35, aY: -2.47, gZ: -0.09, timeS: 31482.00, heading_rad: 0.00, heading_deg: 0.26
125, 0 RAW: 16, s: 0, aX: 2.66, aY: 1.17, gZ: -0.12, timeS: 31494.00, heading_rad: 0.00, heading_deg: 0.19
130, 0 RAW: 17, s: 0, aX: 1.20, aY: 0.00, gZ: -0.04, timeS: 31506.00, heading_rad: 0.00, heading_deg: 0.19
135, 0 RAW: 18, s: 0, aX: -1.39, aY: 0.79, gZ: 0.00, timeS: 31518.00, heading_rad: 0.00, heading_deg: 0.19
140, 0 RAW: 19, s: 0, aX: 0.65, aY: 1.31, gZ: -0.02, timeS: 31530.00, heading_rad: 0.00, heading_deg: 0.19
145, 0 RAW: 20, s: 0, aX: 1.05, aY: 0.01, gZ: -0.15, timeS: 31542.00, heading_rad: 0.00, heading_deg: 0.10
150, 0 RAW: 21, s: 0, aX: 0.63, aY: 0.82, gZ: -0.10, timeS: 31554.00, heading_rad: 0.00, heading_deg: 0.05
RAW: 22, s: 0, aX: -0.37, aY: -1.41, gZ: -0.09, timeS: 31566.00, heading_rad: -0.00, heading_deg: -0.00
RAW: 23, s: 0, aX: 1.41, aY: -0.31, gZ: -0.13, timeS: 31578.00, heading_rad: -0.00, heading_deg: -0.08
RAW: 24, s: 0, aX: 1.96, aY: -0.65, gZ: -0.16, timeS: 31590.00, heading_rad: -0.00, heading_deg: -0.17
RAW: 25, s: 0, aX: -0.48, aY: 2.73, gZ: -0.15, timeS: 31602.00, heading_rad: -0.00, heading_deg: -0.26
RAW: 26, s: 0, aX: 2.84, aY: -0.12, gZ: -0.15, timeS: 31614.00, heading_rad: -0.01, heading_deg: -0.35
RAW: 27, s: 0, aX: -3.05, aY: -0.25, gZ: -0.20, timeS: 31626.00, heading_rad: -0.01, heading_deg: -0.47
RAW: 28, s: 0, aX: 6.03, aY: -1.78, gZ: -0.19, timeS: 31638.00, heading_rad: -0.01, heading_deg: -0.58
.
.
.
RAW: 80, s: 0, aX: 0.68, aY: 0.68, gZ: 0.03, timeS: 32361.00, heading_rad: -0.03, heading_deg: -1.43
RPM1 49.50, RPM2 51.00, Counter1 33, Counter2 34, DistanceTraveled 34.34, posX -0.00, posY 34.34
```

driving straight

RPM counters ~equal

```
30, 0 Heading (BEFORE) 0.00, rad
35, 0 Heading (AFTER) 0.00, rad
40, 0 RAW: 0, s: 50, aX: 0.29, aY: 0.04, gZ: -0.02, timeS: 46854.00, heading_rad: 0.00, heading_deg: 0.00
45, 0 RAW: 1, s: 55, aX: 0.14, aY: 0.13, gZ: -0.02, timeS: 46866.00, heading_rad: 0.00, heading_deg: 0.00
50, 0 RAW: 2, s: 60, aX: 0.12, aY: -0.03, gZ: -0.02, timeS: 46878.00, heading_rad: 0.00, heading_deg: 0.00
55, 0 RAW: 3, s: 65, aX: 0.25, aY: -0.11, gZ: -0.02, timeS: 46890.00, heading_rad: 0.00, heading_deg: 0.00
60, 0 RAW: 4, s: 70, aX: 0.44, aY: -0.17, gZ: -0.02, timeS: 46902.00, heading_rad: 0.00, heading_deg: 0.00
65, 0 RAW: 5, s: 75, aX: 0.52, aY: 0.36, gZ: -0.10, timeS: 46914.00, heading_rad: -0.00, heading_deg: -0.05
70, 23 RAW: 6, s: 80, aX: 0.18, aY: 1.17, gZ: -0.12, timeS: 46926.00, heading_rad: -0.00, heading_deg: -0.12
75, 22 RAW: 7, s: 85, aX: 0.42, aY: 0.02, gZ: -0.04, timeS: 46938.00, heading_rad: -0.00, heading_deg: -0.12
80, 21 RAW: 8, s: 90, aX: -0.04, aY: 0.38, gZ: -0.06, timeS: 46950.00, heading_rad: -0.00, heading_deg: -0.14
85, 21 RAW: 9, s: 95, aX: -0.55, aY: -0.66, gZ: -0.20, timeS: 46962.00, heading_rad: -0.00, heading_deg: -0.26
90, 21 RAW: 10, s: 100, aX: 0.92, aY: -0.72, gZ: -0.31, timeS: 46974.00, heading_rad: -0.01, heading_deg: -0.46
95, 21 RAW: 11, s: 100, aX: -0.61, aY: -1.14, gZ: -0.56, timeS: 46986.00, heading_rad: -0.01, heading_deg: -0.84
100, 21 RAW: 12, s: 100, aX: 0.62, aY: -1.62, gZ: -0.80, timeS: 46998.00, heading_rad: -0.02, heading_deg: -1.37
105, 21 RAW: 13, s: 100, aX: 1.17, aY: -0.61, gZ: -0.93, timeS: 47010.00, heading_rad: -0.03, heading_deg: -2.00
110, 21 RAW: 14, s: 100, aX: 0.45, aY: -0.38, gZ: -0.97, timeS: 47022.00, heading_rad: -0.05, heading_deg: -2.65
115, 21 RAW: 15, s: 100, aX: 1.47, aY: 0.48, gZ: -1.04, timeS: 47034.00, heading_rad: -0.06, heading_deg: -3.35
120, 22 RAW: 16, s: 100, aX: -0.33, aY: 0.08, gZ: -1.08, timeS: 47046.00, heading_rad: -0.07, heading_deg: -4.07
125, 0 RAW: 17, s: 100, aX: -0.56, aY: 0.30, gZ: -1.09, timeS: 47058.00, heading_rad: -0.08, heading_deg: -4.81
130, 0 RAW: 18, s: 100, aX: -0.58, aY: -0.03, gZ: -1.15, timeS: 47070.00, heading_rad: -0.10, heading_deg: -5.59
135, 0 RAW: 19, s: 100, aX: -0.87, aY: -1.06, gZ: -1.14, timeS: 47082.00, heading_rad: -0.11, heading_deg: -6.35
140, 0 RAW: 20, s: 100, aX: 1.73, aY: -0.16, gZ: -1.17, timeS: 47094.00, heading_rad: -0.12, heading_deg: -7.14
145, 0 RAW: 21, s: 100, aX: 0.72, aY: 0.57, gZ: -1.15, timeS: 47106.00, heading_rad: -0.14, heading_deg: -7.92
150, 0 RAW: 22, s: 100, aX: 0.25, aY: 0.42, gZ: -1.15, timeS: 47118.00, heading_rad: -0.15, heading_deg: -8.69
RAW: 23, s: 100, aX: 0.70, aY: 0.73, gZ: -1.17, timeS: 47130.00, heading_rad: -0.17, heading_deg: -9.48
RAW: 24, s: 100, aX: 0.09, aY: -0.87, gZ: -1.18, timeS: 47142.00, heading_rad: -0.18, heading_deg: -10.27
RAW: 25, s: 100, aX: -1.14, aY: -0.38, gZ: -1.19, timeS: 47154.00, heading_rad: -0.19, heading_deg: -11.07
RAW: 26, s: 100, aX: 0.43, aY: -0.50, gZ: -1.20, timeS: 47166.00, heading_rad: -0.21, heading_deg: -11.88
RAW: 27, s: 100, aX: 1.69, aY: -0.20, gZ: -1.24, timeS: 47178.00, heading_rad: -0.22, heading_deg: -12.72
RAW: 28, s: 100, aX: 0.70, aY: 0.67, gZ: -1.21, timeS: 47190.00, heading_rad: -0.24, heading_deg: -13.54
.
.
.
RAW: 117, s: 100, aX: 0.29, aY: 1.39, gZ: -0.62, timeS: 48249.00, heading_rad: -1.60, heading_deg: -91.43
```

left turn (-90 deg)



## LLM Wrote / Integrated Multiple Complex Programs

### Autonomous Vehicle/Mapping Application

- Flash-SocketIO Server
- Data File
- Live Streaming to Web UI
- Live Plotting
- Def
  - Receive Data
  - On\_Key\_Events
  - Polar to Cartesian
  - Update Position
  - Update Heading
- With Socket
- Multi-threading

### Arduino Program

- WiFi Server
- All Libraries and Headers
- Update Heading
- Update Position
- Forward/Backward/Left/Right/Brake
- Calculate RPM
- Interrupts
- Calibrate Gyro Sensor
- Handle Commands
- Prepare Data Packet
- Sweep and Measure

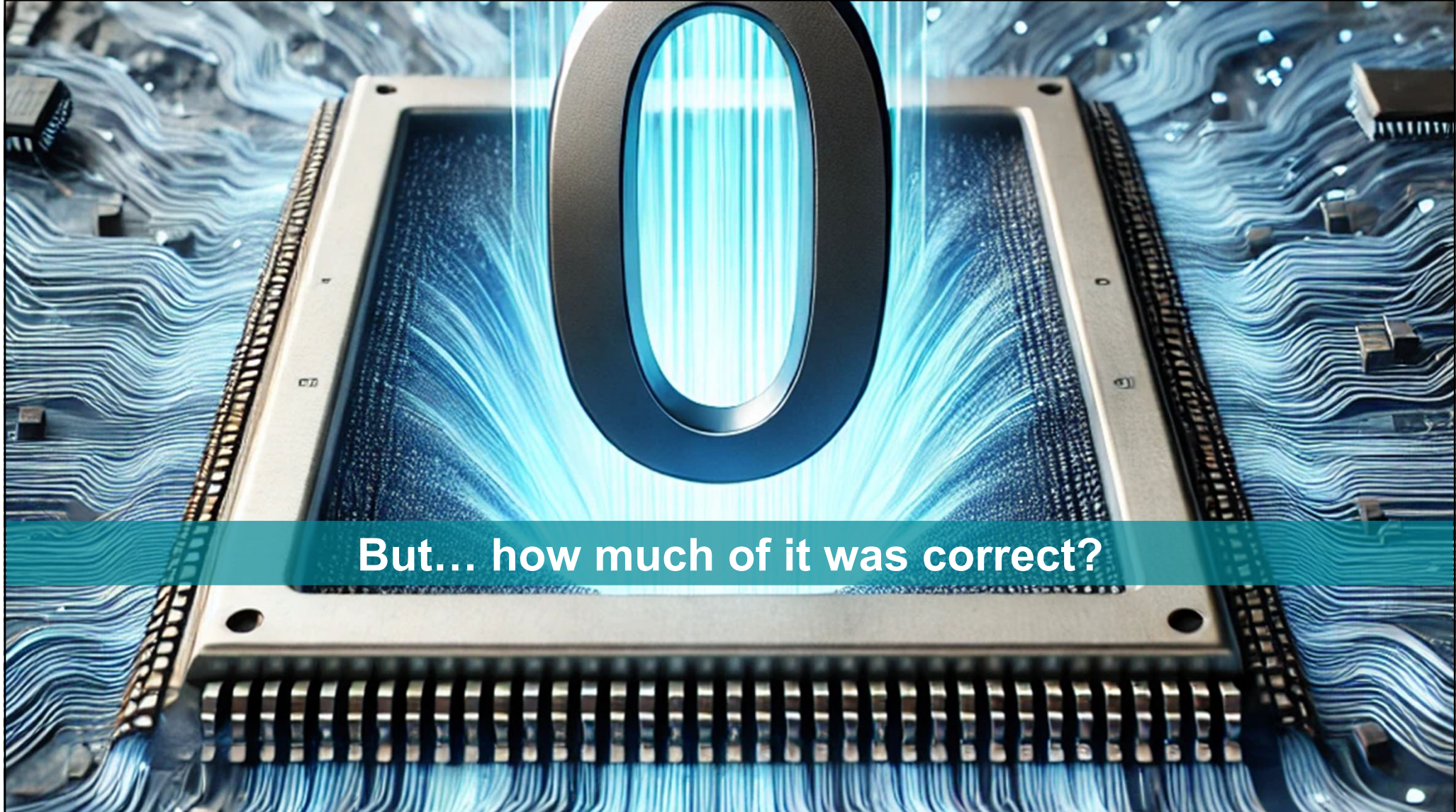


This Photo by Unknown Author is licensed under CC BY-NC



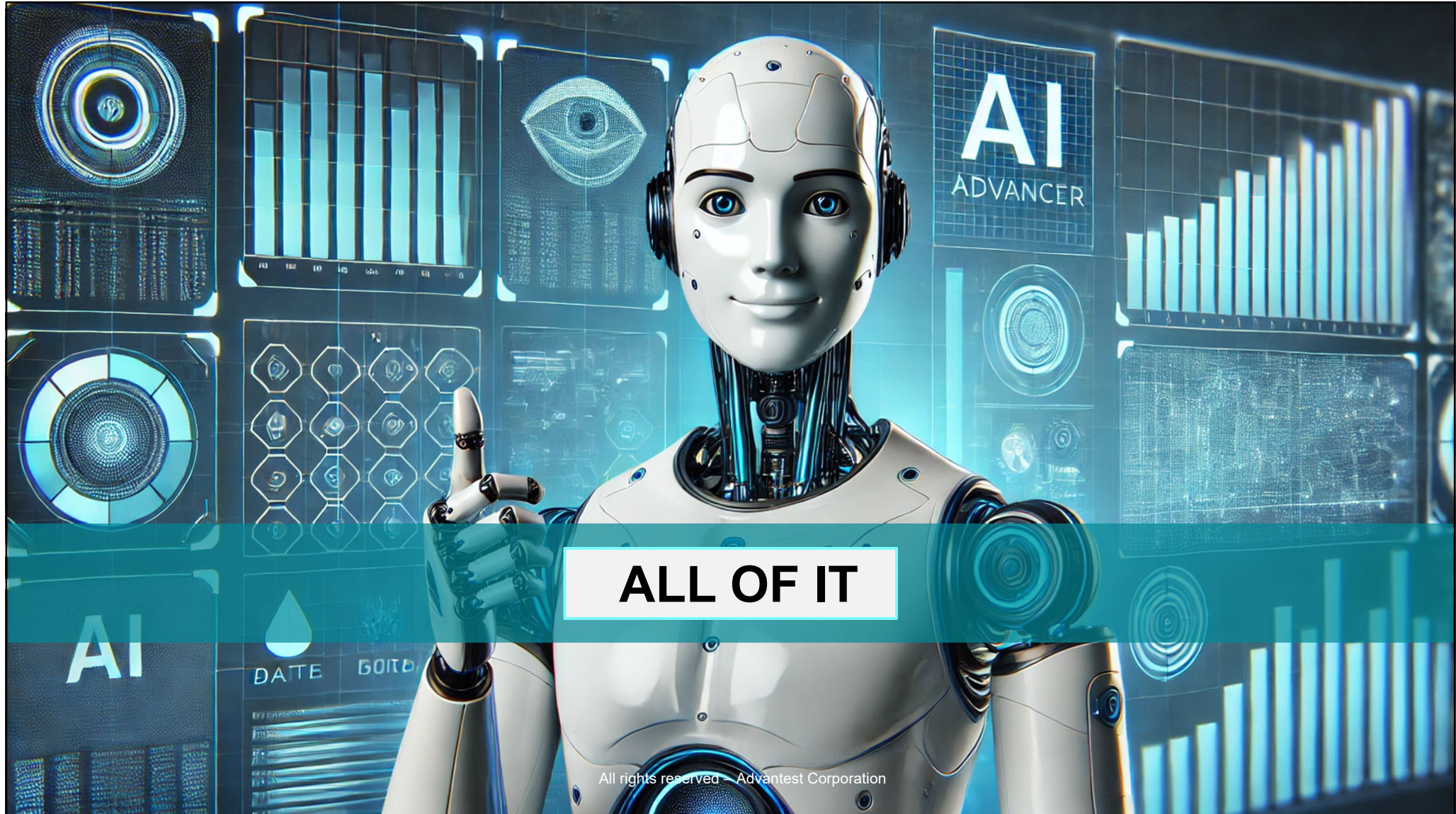
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But... how much of it was correct?





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## LLM Accurately Interpreted Entire Application from a Text File!

Car drives around and generates an environmental map ✓

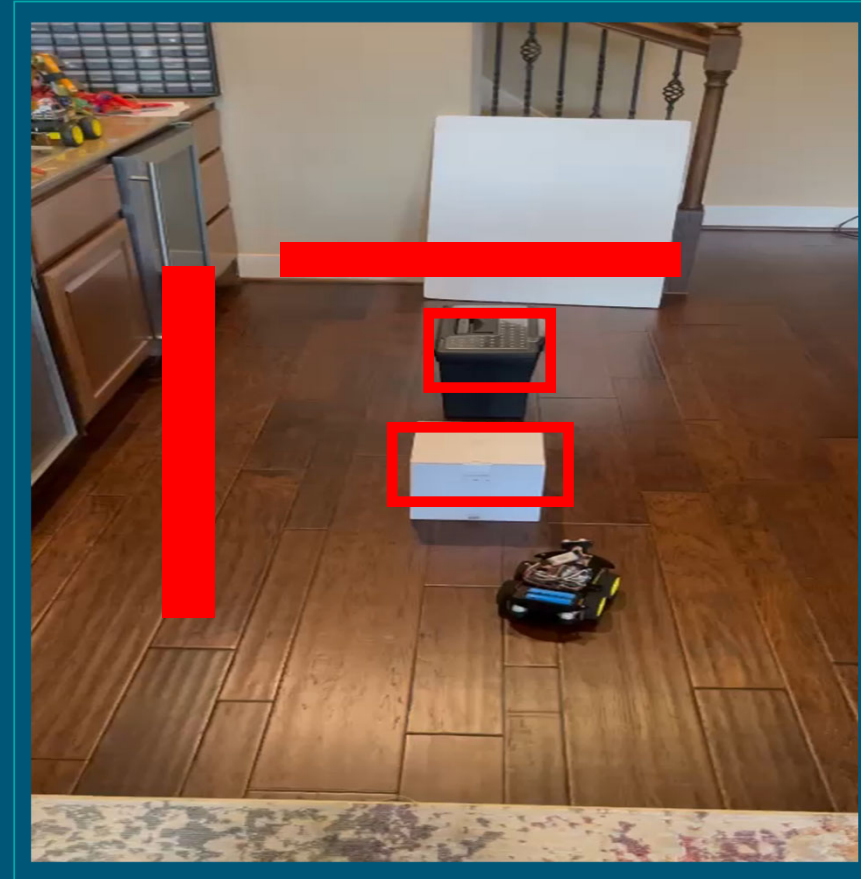
Live stream sensor data ✓

Ultrasound – Obstacle tracking/mapping ✓

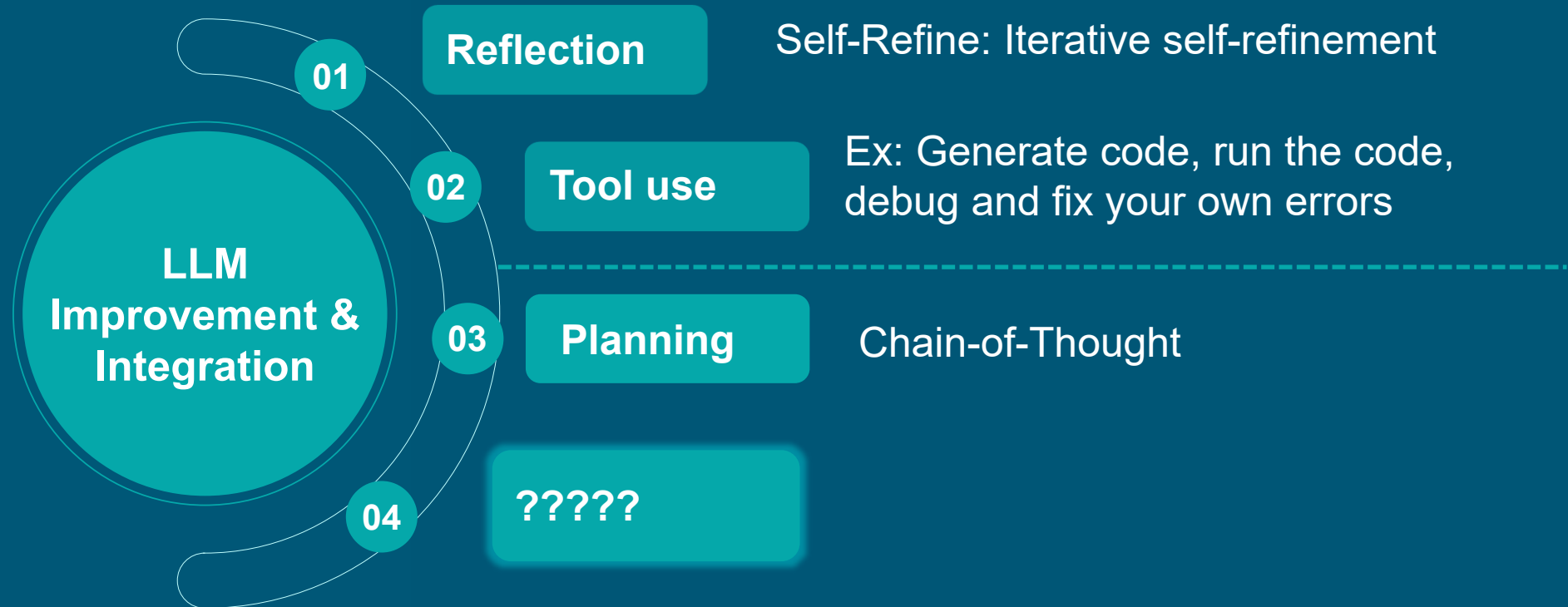
Gyro – Direction/Heading tracking ✓

Accelerometer – Distance tracking ✓

Optical Encoders – Distance tracking ✓

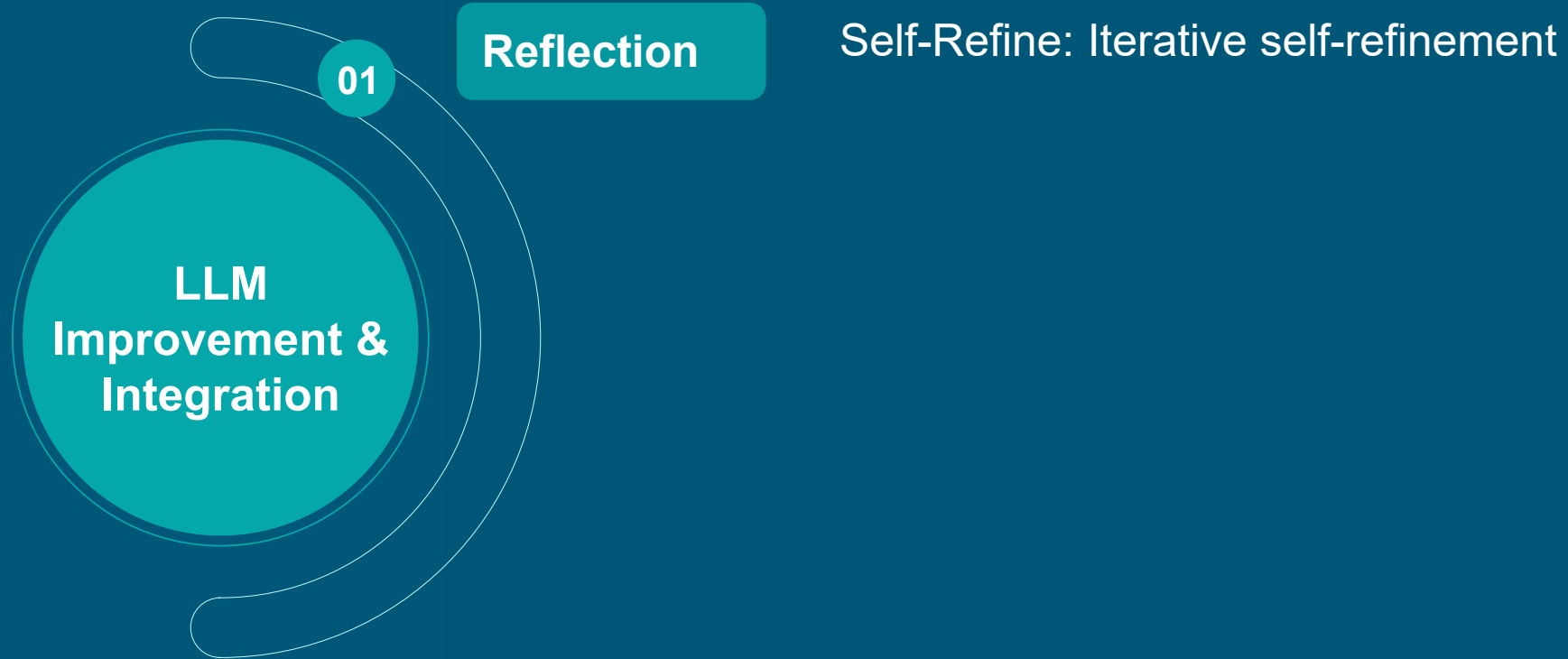


## Beyond 0 Shot



Source: Agentic Reasoning, Andrew Ng, March 2024  
[https://www.youtube.com/watch?v=sa178ACTGT&ab\\_channel=SequoiaCapital](https://www.youtube.com/watch?v=sa178ACTGT&ab_channel=SequoiaCapital)

## Reflection





## LLM with Reflection Improves Accuracy

KS

The attached data is from an arduino based autonomous car project. The electric car has 4 wheels. The left and right wheels can operate independently such that when the car turns, it rotates about its center point. The car has several sensors on it including: an ultrasound that is forward facing and sweeps from 30-120 degrees, an accelerometer, a gyro, and optical encoders on the left and right wheels that measure the amount of wheel rotation. Analyze the attached dataset, summarize and report your findings, reflect on your analysis, update and edit your findings before you provide the summary and provide a step-by-step description of your analysis and how you reached your conclusions.



Analyzing the provided dataset from an Arduino-based autonomous car project involves dissecting the data to understand the behavior and performance of the car during its operation. This analysis will focus on several key aspects based on the provided dataset: ultrasound sensor readings, wheel rotation measurements, and accelerometer, gyro sensor data. Here's a step-by-step description of the analysis process and the findings:

## LLM with Reflection Step-by-Step Explanation with Greater Accuracy/Details

### Step 1: Understanding the Dataset Structure -

The dataset contains multiple types of data, including:

**Ultrasound sensor** readings, showing distances detected as the sensor sweeps from 30 to 150 degrees.

**Accelerometer (aX, aY)** and **gyro (gZ)** sensor readings, indicating the car's acceleration and rotational velocity, respectively.

**Optical encoder** readings for the left and right wheels (RPM1, RPM2), providing insights into the wheel rotation speed.

Car's positional data (posX, posY) and the total distance traveled.

### Step 2: Analyzing Ultrasound Sensor Readings

The ultrasound sensor sweeps from 30 to 150 degrees, providing distance measurements. The readings show distances detected within certain angles, notably between 60 to 120 degrees, with no detections (0 distance) outside this range. This indicates the sensor's field of view and detection range. The consistent detection of distances around 40 units within this angle range suggests the presence of an object or wall parallel to the car's path.

## LLM with Reflection

### Step 3: Examining Wheel Encoder Data

The wheel rotation data, presented as RPM (Revolutions Per Minute) for both left and right wheels, shows the operation of the car's propulsion system. For instance, RPM readings of 49.50 for RPM1 and 51.00 for RPM2 indicate a slight difference in wheel speeds, possibly as the car maneuvers or corrects its path. The Counter values indicate the number of rotations detected, correlating with the car's movement and distance traveled.

### Step 4: Assessing Accelerometer and Gyro Sensor Data

The accelerometer and gyro sensor data provide insights into the car's acceleration and rotational movements. The readings show variations in acceleration ( $aX$ ,  $aY$ ) and gyroscopic rotation ( $gZ$ ) over time. For example, changes in  $aX$  and  $aY$  values suggest linear movements and turns, while  $gZ$  indicates rotational velocity, useful in understanding the car's turning dynamics.

### Step 5: Calculating Position and Distance Traveled

The positional data ( $posX$ ,  $posY$ ) alongside the `distanceTraveled` value give a quantitative measure of the car's movement over time. For instance, a `distanceTraveled` value of 34.34 units, with  $posX$  and  $posY$  changes, indicates the car's forward movement and its directional change.



## LLM with Reflection (Conclusion)

### Reflections and Conclusions

The dataset provides a comprehensive overview of the autonomous car's sensory and movement dynamics during operation.

By analyzing the ultrasound sensor readings, it's clear that the car can detect obstacles within a specific range and angle, allowing for navigational adjustments. The wheel encoder data reflects the car's movement and speed adjustments, while the accelerometer and gyro data offer insights into the car's acceleration and turning behavior.

Overall, the analysis highlights the autonomous car's ability to navigate and respond to its environment based on sensor inputs and movement data.

This understanding is crucial for optimizing the car's performance and autonomy in real-world conditions.

## Tool Use

LLM  
Improvement &  
Integration

02

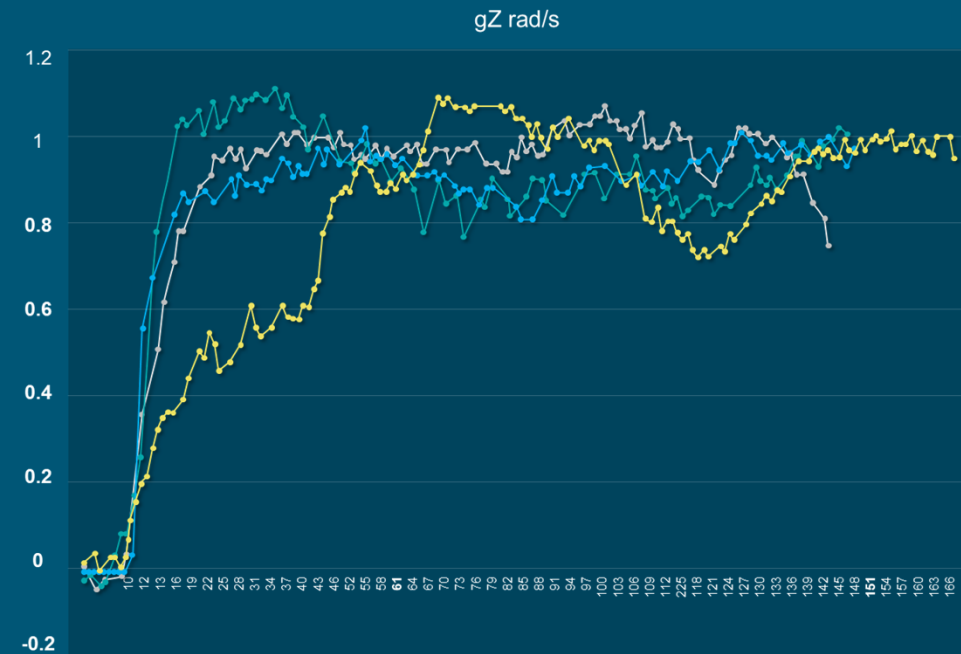
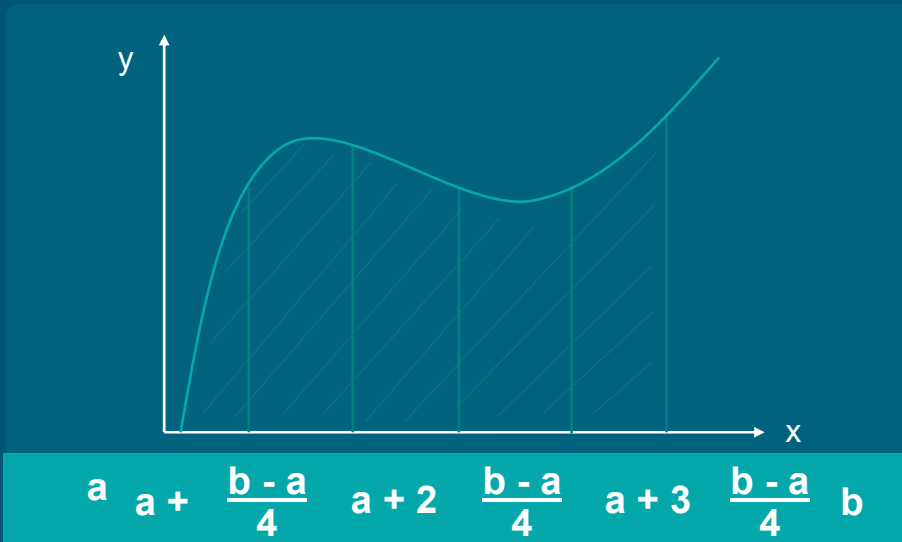
Tool use

Ex: Generate algorithm code, run the code, debug and fix your own errors

## LLM with Tool Use

KS

Using the gyro data, and rows (502-509), generate an algorithm using the trapezoidal-rule in python that integrates the gyro data to estimate the heading. Show and explain how the algorithm works and perform a couple of calculations that can be used to verify the integration is being performed correctly. Execute the python algorithm on some of the data and print the input data and the results in a table. Please explain your results step by step.





## LLM Generates Algorithm, Explains it, Codes It, Runs it



The algorithm implemented uses the trapezoidal rule to integrate the gyroscopic data (gZ values) and estimate the heading changes in degrees. Here's a detailed step-by-step explanation of how it works, applied to the first two data points from rows 502-509:

1. We start with an initial heading of `0` degrees at timestamp `46986` ms.
2. The next reading is at timestamp `46998` ms with a `gZ` value of `-0.80` radians per second.
3. We calculate the change in heading using the trapezoidal rule:  
$$\Delta\theta = \frac{(gZ_{\text{initial}} + gZ_{\text{final}})}{2} \times \Delta t$$

Where:

  - `gZinitial` is the initial gyro reading (`-0.56` radians/sec),
  - `gZfinal` is the final gyro reading (`-0.80` radians/sec),
  - `Δt` is the time difference in seconds (`0.012` seconds, calculated from the difference between `46998` ms and `46986` ms).
4. We then convert the resulting change in heading to degrees, since the output heading must be in degrees.
5. This process is repeated for each pair of subsequent gyro readings and timestamps.

Below is a table printed using pandas for better readability, showing the timestamps, gyro data, and the calculated headings:

## LLM Tabulates Results and Flexes



This table lists each timestamp with the corresponding gyro reading and the estimated cumulative heading in degrees calculated using the trapezoidal rule. The negative sign indicates the direction of rotation (typically counterclockwise if using the conventional right-hand rule for coordinate systems).

47010.0	-0.93	-1.062264	-2.00
47022.0	-0.97	-1.715436	-2.65
47034.0	-1.04	-2.406423	-3.35
47046.0	-1.08	-3.135225	-4.07
47058.0	-1.09	-3.881216	-4.81
47070.0	-1.15	-4.651271	-5.59



# Let's Try Something Even Harder

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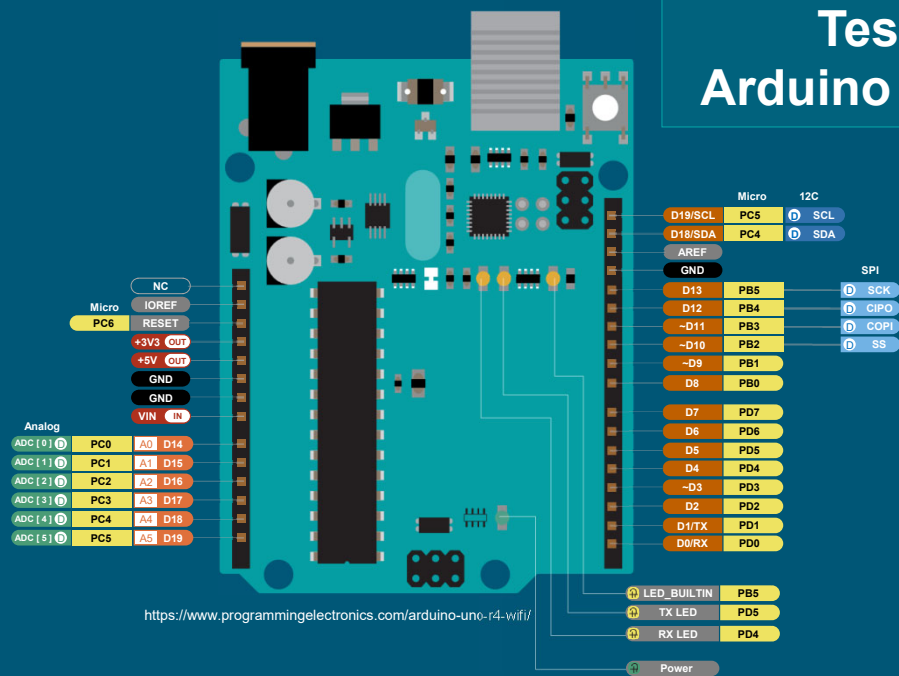
## Assisting with Complex Semiconductor Test Engineering

**ADVANTEST**

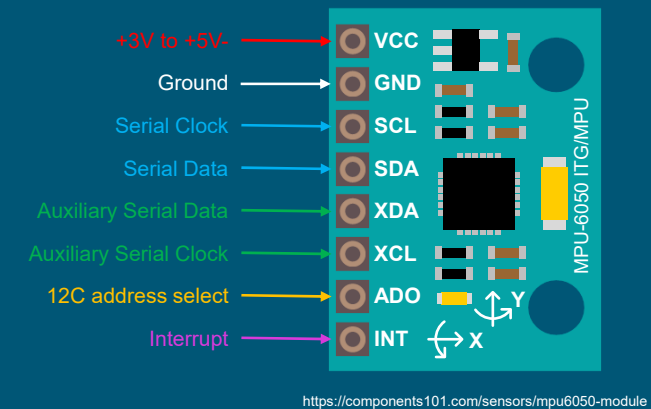
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## LLM Semiconductor Test Engineer Assistant

Tester  
Arduino Uno R4

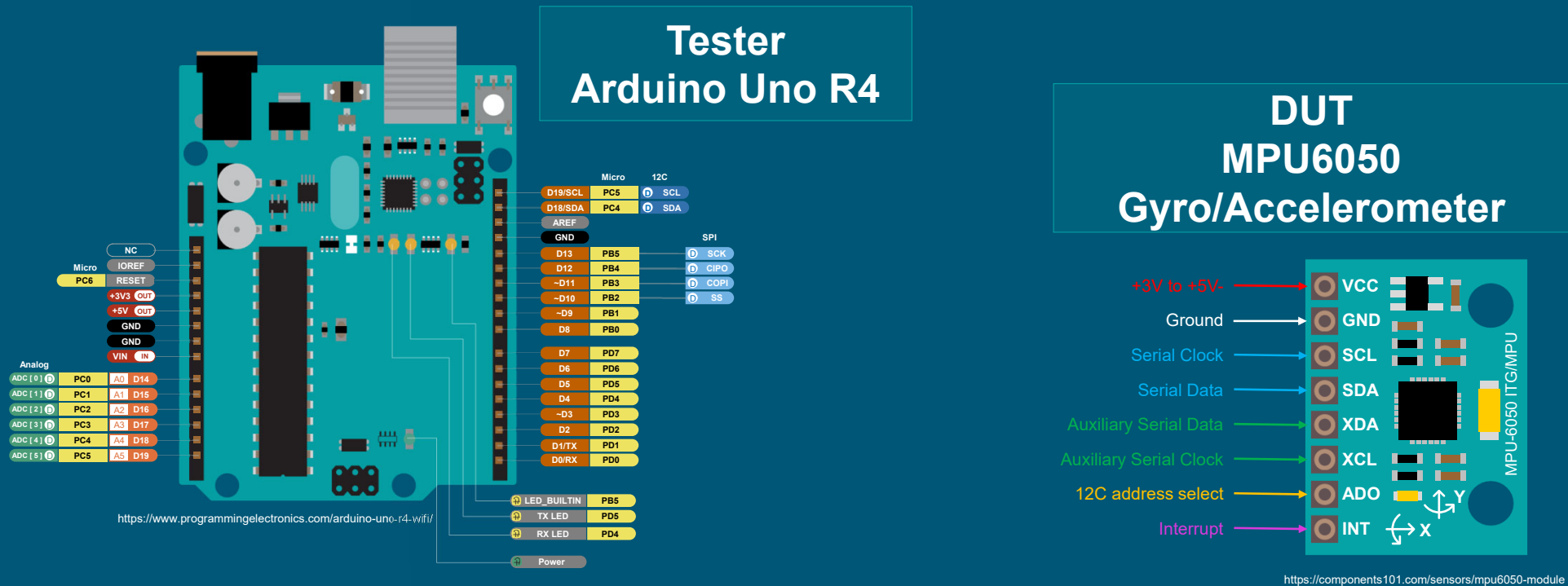


DUT  
MPU6050  
Gyro/Accelerometer



### Can the LLM Design the Loadboard using ONLY Images?

## LLM Semiconductor Test Engineer Assistant



KS

Given the two images, the first is the pin diagram for the R4, the 2nd is the pin diagram for the MPU6050, can you provide the connection diagram, i.e. draw the connections please.

← This can't possibly work?!

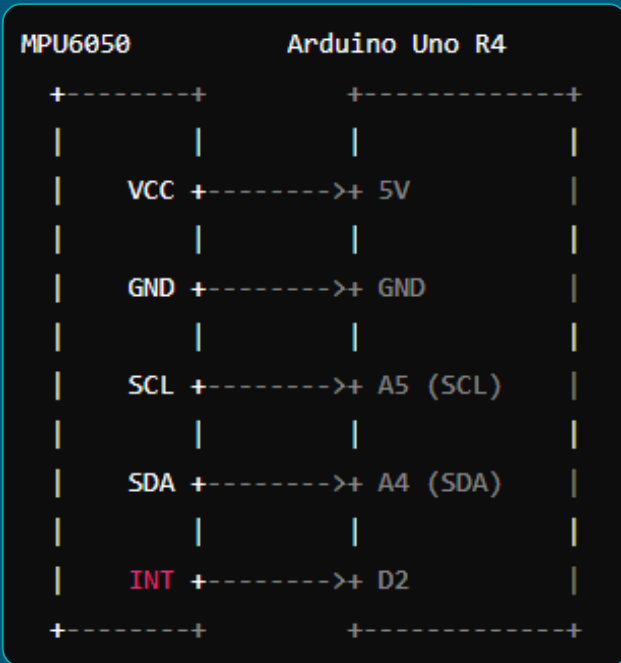
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## Generates the Loadboard Connections and Flexes!



Here's a simple ASCII diagram showing how to connect the MPU6050 to the Arduino Uno R4:



### Explanation:

VCC to 5V: Connect the VCC pin of the MPU6050 to the 5V pin on the Arduino Uno R4 to power the sensor.

GND to GND: Connect the GND (ground) pin of the MPU6050 to one of the GND pins on the Arduino to establish a common ground.

SCL to A5 (SCL): Connect the SCL (Serial Clock Line) pin of the MPU6050 to the A5 pin on the Arduino, which is the dedicated SCL pin for I2C communication.

SDA to A4 (SDA): Connect the SDA (Serial Data Line) pin of the MPU6050 to the A4 pin on the Arduino, which is the dedicated SDA pin for I2C communication.

INT to Digital Pin: Optionally, connect the INT (Interrupt) pin of the MPU6050 to a digital pin on the Arduino (e.g., pin 2) if you want to use the interrupt feature.



## Explains the Pin Selection



KS

why did you select and use D2 and not D1?

Selecting Digital Pin 2 (D2) on the Arduino Uno R4 for the MPU6050's interrupt connection over Digital Pin 1 (D1) is primarily due to the specific roles these pins play on the Arduino board. Here's why D2 is a better choice than D1 in this context:

Functionality of Pins D0 and D1:

On the Arduino Uno R4, Digital Pins 0 (D0) and 1 (D1) are designated for RX (receive) and TX (transmit), respectively. These pins are used for serial communication between the Arduino and the computer or other serial devices. Using these pins for general I/O (especially when they are actively being used for serial communication, such as during debugging or when interfacing with a PC) can lead to conflicts or disruptions in communication.

General I/O Pins:

Digital Pin 2 (D2), .... This makes D2 a more versatile and interference-free choice for handling interrupts.

Interrupt Capability:

Additionally, both D2 and D3 on the Arduino Uno R4 are capable of handling external interrupts (marked as interrupt 0 and interrupt 1 respectively). Using D2 allows you to utilize the `attachInterrupt()` function....

By using D2, you avoid potential issues with serial communication disruptions and gain the ability to use hardware interrupts...

## LLM Generates the Test Program

KS



please generate a simple arduino r4 test program that we can use to test that the MPU6050 is functioning properly at a basic level

To create a simple test program for the Arduino Uno R4 to check the basic functionality of the MPU6050, you'll need to incorporate an Arduino library that supports the MPU6050, such as the Wire library for I2C communication and potentially a library specifically for interfacing with the MPU6050.

### Assumptions:

**Libraries:** I'm assuming you have the Wire library and a library like MPU6050 installed in your Arduino IDE. If not, you can install it via the Library Manager in the Arduino IDE.

**Connection:** The MPU6050 is connected as previously described, with SDA to A4, SCL to A5, VCC to 5V, GND to GND, and INT to D2 (optional for this basic test).

**Output:** The test will output accelerometer and gyroscope data to the Serial Monitor to verify that the sensor is providing readings.

### Arduino Sketch:

```
cpp Copy code
#include <Wire.h>
#include <MPU6050.h>

MPU6050 mpu;

void setup() {
  Serial.begin(9600);
  Wire.begin();
  mpu.initialize();
  if (!mpu.testConnection()) {
    Serial.println("MPU6050 connection failed");
  } else {
    Serial.println("MPU6050 connection successful");
  }
}

void loop() {
  // Declare storage variables for MPU6050 data
  int16_t ax, ay, az;
  int16_t gx, gy, gz;

  // Read the raw accel/gyro data from the MPU6050
  mpu.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);

  // Print the output values
  Serial.print("Accel X: "); Serial.print(ax); Serial.print(" ");
  Serial.print("Accel Y: "); Serial.print(ay); Serial.print(" ");
  Serial.print("Accel Z: "); Serial.print(az); Serial.print(" ");
  Serial.print("Gyro X: "); Serial.print(gx); Serial.print(" ");
  Serial.print("Gyro Y: "); Serial.print(gy); Serial.print(" ");
  Serial.print("Gyro Z: "); Serial.println(gz);

  delay(1000); // Delay a second before next loop iteration
}
```

## LLM Generates the Test Program

KS

please generate a simple arduino r4 test program that we can use to test that the MPU6050 is functioning properly at a basic level



To create a simple test program for the Arduino Uno R4 to check the basic functionality of the MPU6050, you'll need to incorporate an Arduino library that supports the MPU6050, such as the Wire library for I2C communication and potentially a library specifically for interfacing with the MPU6050.

Assumptions:

**Libraries:** I'm assuming you have the Wire library and a library like MPU6050 installed in your Arduino IDE. If not, you can install it via the Library Manager in the Arduino IDE.

**Connection:** The MPU6050 is connected as previously described, with SDA to A4, SCL to A5, VCC to 5V, GND to GND, and INT to D2 (optional for this basic test).

**Output:** The test will output accelerometer and gyroscope data to the Serial Monitor to verify that the sensor is providing readings.

KS

I don't have this lib. I'm using the Adafruit\_MPU6050.h library, can you rewrite the code using that library instead please.

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Arduino Sketch:

```
cpp Copy code
#include <Wire.h>
#include <MPU6050.h>

MPU6050 mpu;

void setup() {
  Serial.begin(9600);
  Wire.begin();
  mpu.initialize();
  if (!mpu.testConnection()) {
    Serial.println("MPU6050 connection failed");
  } else {
    Serial.println("MPU6050 connection successful");
  }
}

void loop() {
  // Declare storage variables for MPU6050 data
  int16_t ax, ay, az;
  int16_t gx, gy, gz;

  // Read the raw accel/gyro data from the MPU6050
  mpu.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);

  // Print the output values
  Serial.print("Accel X: "); Serial.print(ax); Serial.print(" ");
  Serial.print("Accel Y: "); Serial.print(ay); Serial.print(" ");
  Serial.print("Accel Z: "); Serial.print(az); Serial.print(" ");
  Serial.print("Gyro X: "); Serial.print(gx); Serial.print(" ");
  Serial.print("Gyro Y: "); Serial.print(gy); Serial.print(" ");
  Serial.print("Gyro Z: "); Serial.println(gz);

  delay(1000); // Delay a second before next loop iteration
}
```



## LLM Re-generates the Test Program



If you're using the Adafruit\_MPU6050 library from Adafruit, it simplifies the process of working with the MPU6050....

Below is the revised Arduino sketch using the Adafruit\_MPU6050 library.

Assumptions:

Library Installation: You have installed the Adafruit\_MPU6050 library via the Arduino Library Manager.

Library Dependencies: The Adafruit\_MPU6050 library also requires the Adafruit\_Sensor library and the Adafruit\_Unified\_Sensor library. These should be installed as well.

```
#include <Wire.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_MPU6050.h>

Adafruit_MPU6050 mpu;

void setup() {
  Serial.begin(115200);
  while (!Serial); // Wait for the serial port to be available (useful for boards with
  Serial.println("Adafruit MPU6050 test!");

  // Try to initialize the MPU6050 sensor.
  if (!mpu.begin()) {
    Serial.println("Failed to find MPU6050 chip");
    while (1) {
      delay(10); // halt the program here
    }
  }

  Serial.println("MPU6050 Found!");
  mpu.setAccelerometerRange(MPU6050_RANGE_8_G);
  mpu.setGyroRange(MPU6050_RANGE_500_DEG);
  mpu.setFilterBandwidth(MPU6050_BAND_21_HZ);

}

void loop() {
  /* Get new sensor events with the readings */
  sensors_event_t a, g, temp;
  mpu.getEvent(&a, &g, &temp);

  // Print the values out.
  Serial.print("Accel X: "); Serial.print(a.acceleration.x); Serial.print(" m/s^2, ");
  Serial.print("Y: "); Serial.print(a.acceleration.y); Serial.print(" m/s^2, ");
  Serial.print("Z: "); Serial.print(a.acceleration.z); Serial.println(" m/s^2");

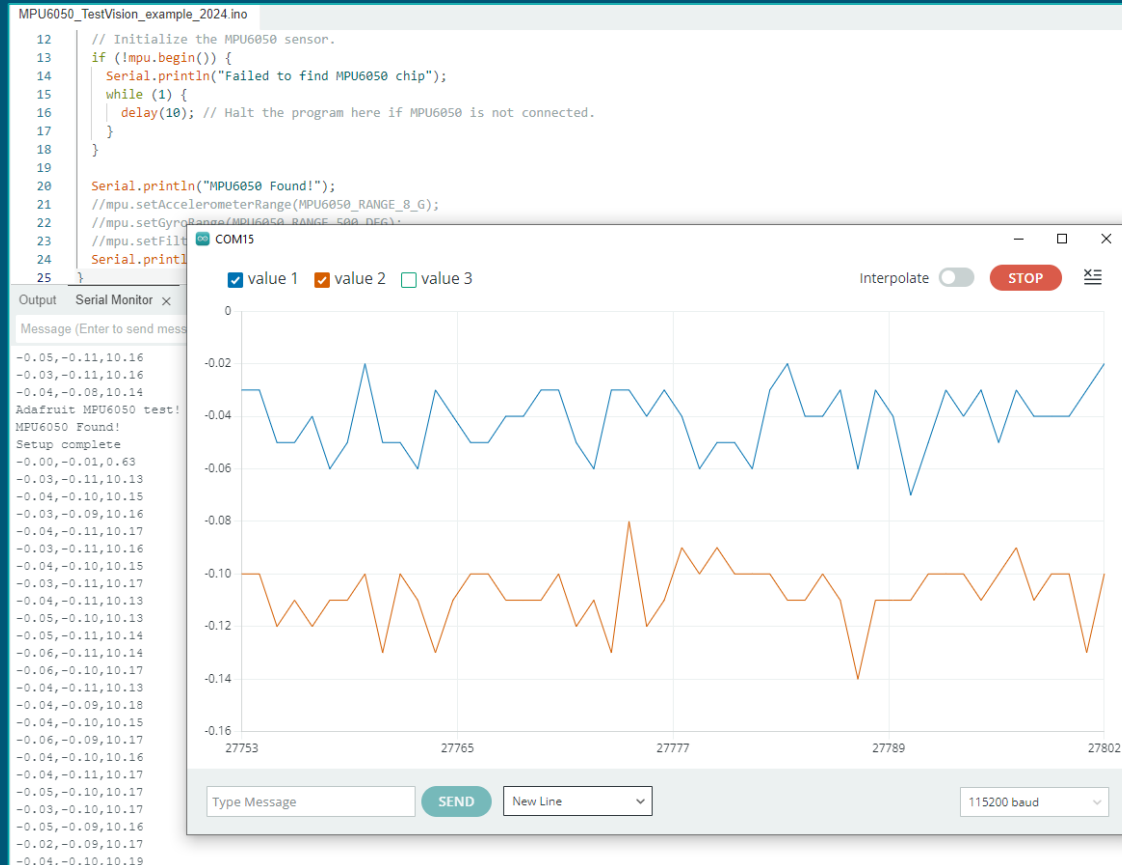
  Serial.print("Gyro X: "); Serial.print(g.gyro.x); Serial.print(" dps, ");
  Serial.print("Y: "); Serial.print(g.gyro.y); Serial.print(" dps, ");
  Serial.print("Z: "); Serial.print(g.gyro.z); Serial.println(" dps");

  Serial.print("Temp: "); Serial.print(temp.temperature); Serial.println(" degrees C");

  delay(1000);
}
```



## MPU Test Program Works!



But...

We notice the X,Y accel. values are not centered around 0.

...Let's Make It Harder...

...Can the LLM understand and fix it?

## LLM Showing Signs of Intelligence?

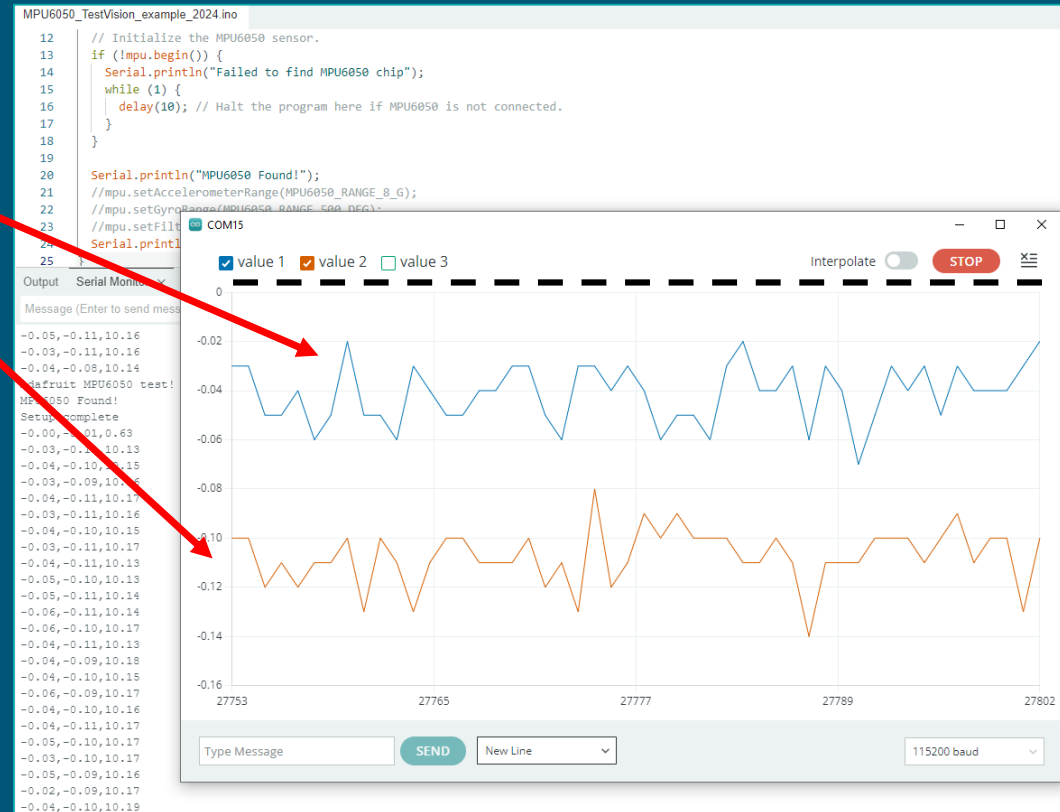
Audience Observation:

- X,Y acceleration data
  - Not centered around 0
  - Noisy, bouncing Up/Down

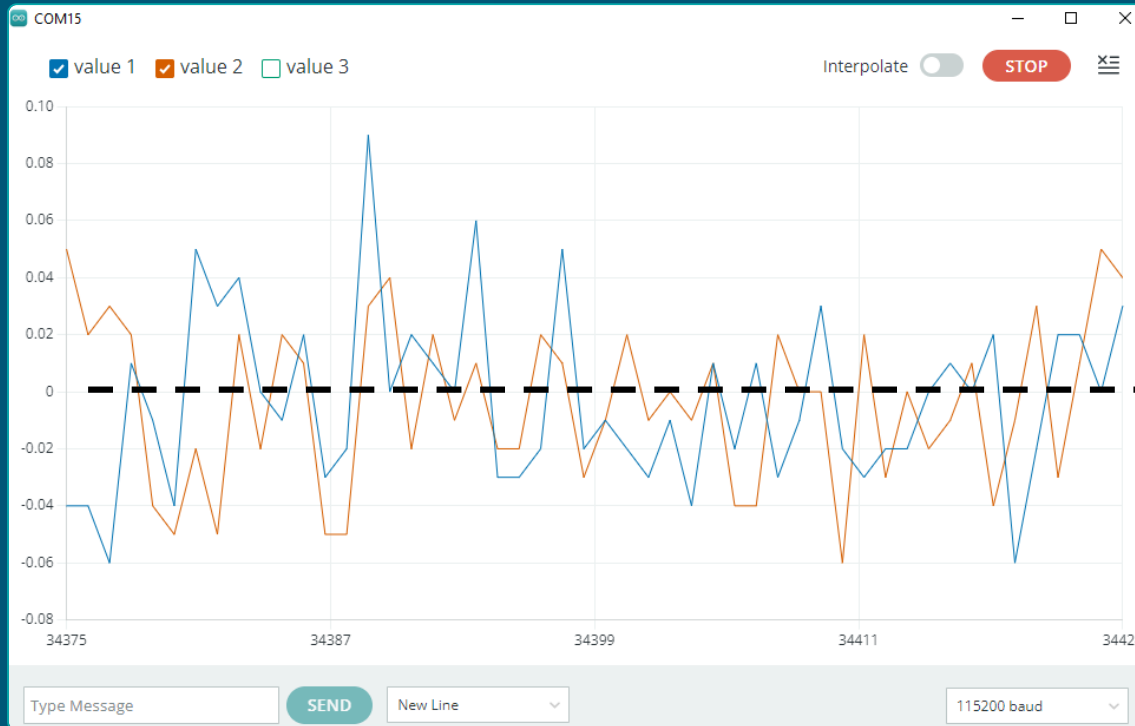
To fix the non-zero X, Y, data,

- LLM must
  - “interpret” the picture
  - Realize that it needs to be calibrated (because it’s analog)
  - Create the calibration algorithm
  - Rewrite the code

**Surely it can’t do this!?**



## LLM Showing Signs of Intelligence



Yes, it can already do this and will only continue to get better

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### Enhanced Arduino Sketch with Calibration and Filtering:

```
cpp Copy code

#include <Wire.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_MPU6050.h>

Adafruit_MPU6050 mpu;

float offsetX = 0, offsetY = 0, offsetZ = 0;
int numSamples = 100;

void calibrate() {
  sensors_event_t a, g, temp;
  for (int i = 0; i < numSamples; i++) {
    mpu.getEvent(&a, &g, &temp);
    offsetX += a.acceleration.x;
    offsetY += a.acceleration.y;
    offsetZ += a.acceleration.z - 9.81; // Adjust for gravity on the z-axis
    delay(10);
  }
  offsetX /= numSamples;
  offsetY /= numSamples;
  offsetZ /= numSamples;
}

void setup() {
  Serial.begin(115200);
  while (!Serial);
  Serial.println("Adafruit MPU6050 test!");

  if (!mpu.begin()) {
    Serial.println("Failed to find MPU6050 chip");
    while (1) {
      delay(10);
    }
  }

  Serial.println("MPU6050 Found!");
  mpu.setAccelerometerRange(MPU6050_RANGE_8_G);
  calibrate();
}
```



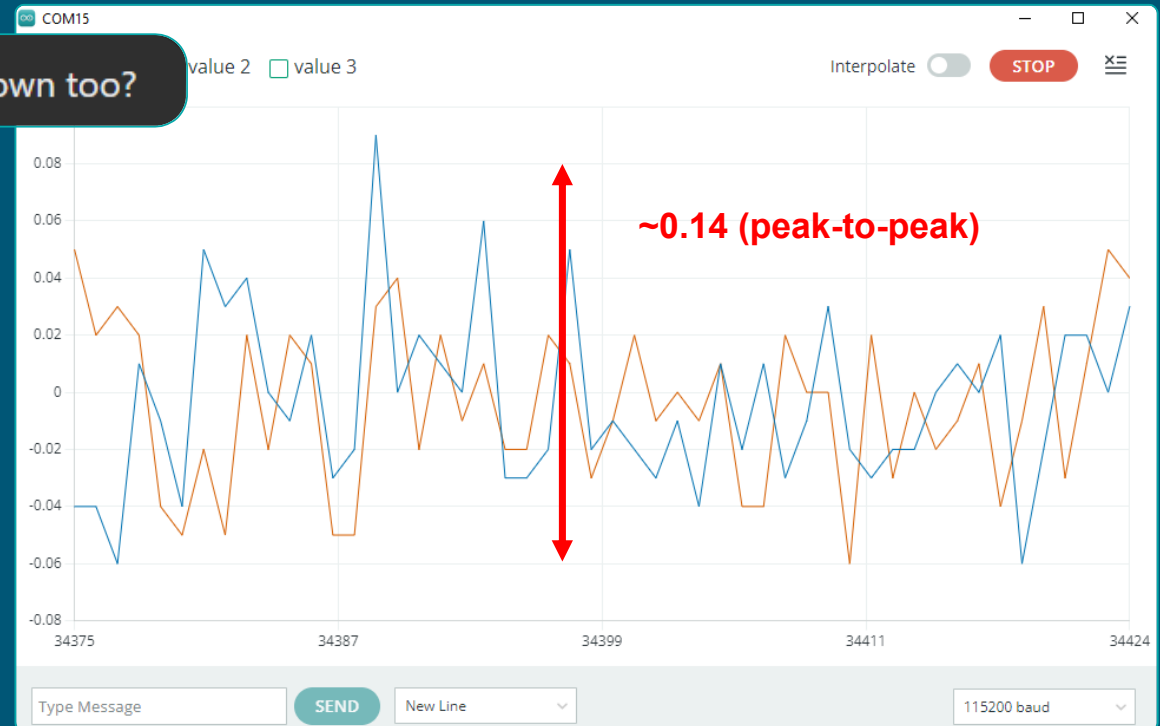
## LLM, Just How Smart Are You?

KS

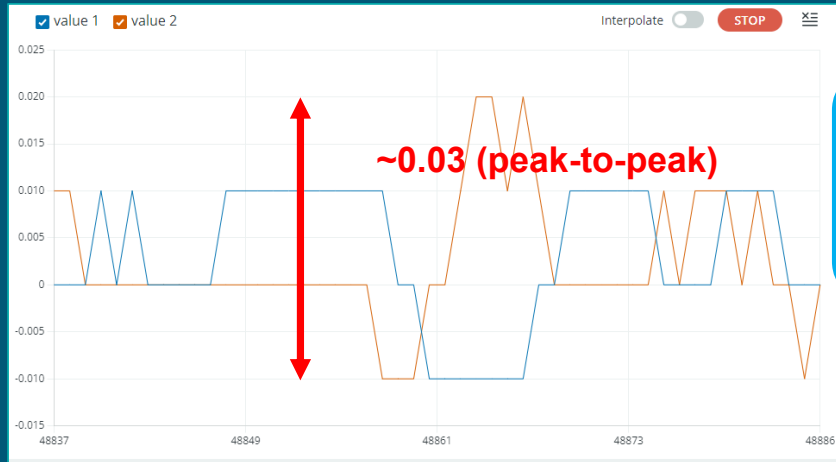
Can you fix the noisy bouncing up and down too?

To fix the noise...

- LLM must
  - “interpret” the picture
  - Generally, understand the nature of analog noise and provide a method to reduce it
  - Generate the algorithm / code
  - Re-integrate everything together



## LLM Calibrated and Filtered



Successfully integrated filter  
Reduced noise ~4.6X

**Key Takeaway:**  
“Today”, already able to be very helpful at an engineering level!

```
float movingAverage(float *window, float newSample) {
    window[index++] = newSample;
    if (index >= WINDOW_SIZE) {
        index = 0;
        windowFull = true;
    }

    float sum = 0;
    int count = windowFull ? WINDOW_SIZE : index;
    for (int i = 0; i < count; i++) {
        sum += window[i];
    }
    return sum / count;
}
```

```
void loop() {
    sensors_event_t a, g, temp;
    mpu.getEvent(&a, &g, &temp);

    float calibratedX = a.acceleration.x - offsetX;
    float calibratedY = a.acceleration.y - offsetY;
    float calibratedZ = a.acceleration.z - offsetZ;

    float filteredX = movingAverage(window, calibratedX);
    float filteredY = movingAverage(window, calibratedY);

    Serial.print(filteredX);
    Serial.print(" ");
    Serial.println(filteredY);

    delay(100);
}
```

```
float filteredX = movingAverage(window, calibratedX);
float filteredY = movingAverage(window, calibratedY);
```

```
#include <Wire.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_MPU6050.h>
```

```
Adafruit_MPU6050 mpu;
```

```
#define WINDOW_SIZE 10
float windowX[WINDOW_SIZE];
float windowY[WINDOW_SIZE];
int index = 0;
bool windowFull = false;

float offsetX = 0, offsetY = 0, offsetZ = 0;
int numSamples = 100;
```

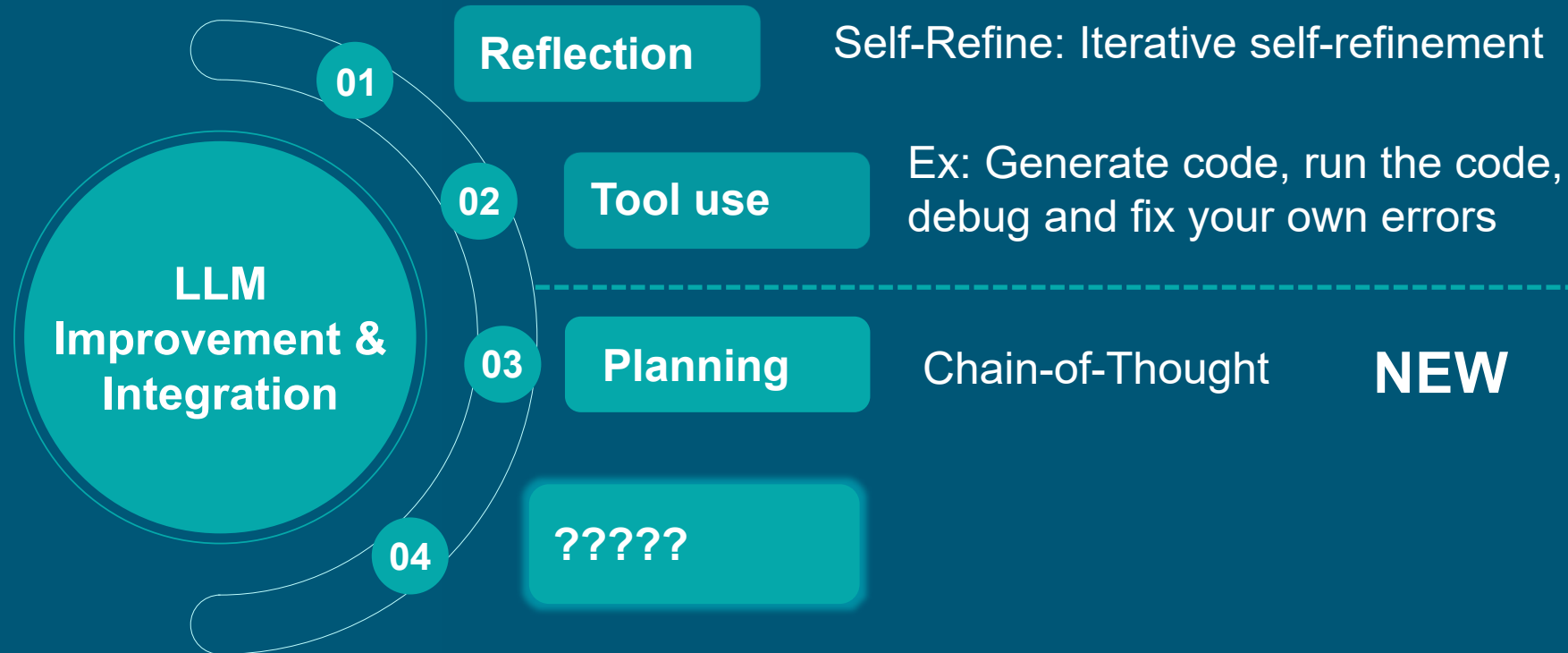
```
void calibrate() {
    sensors_event_t a, g, temp;
    for (int i = 0; i < numSamples; i++) {
        mpu.getEvent(&a, &g, &temp);
        offsetX += a.acceleration.x;
        offsetY += a.acceleration.y;
        offsetZ += a.acceleration.z - 9.81; // Adjust for gravity on the z-axis
        delay(10);
    }
    offsetX /= numSamples;
    offsetY /= numSamples;
    offsetZ /= numSamples;
}
```

```
void setup() {
    Serial.begin(115200);
    while (!Serial);
    Serial.println("Adafruit MPU6050 test!");

    if (!mpu.begin()) {
        Serial.println("Failed to find MPU6050 chip");
        while (1) {
            delay(10);
        }
    }

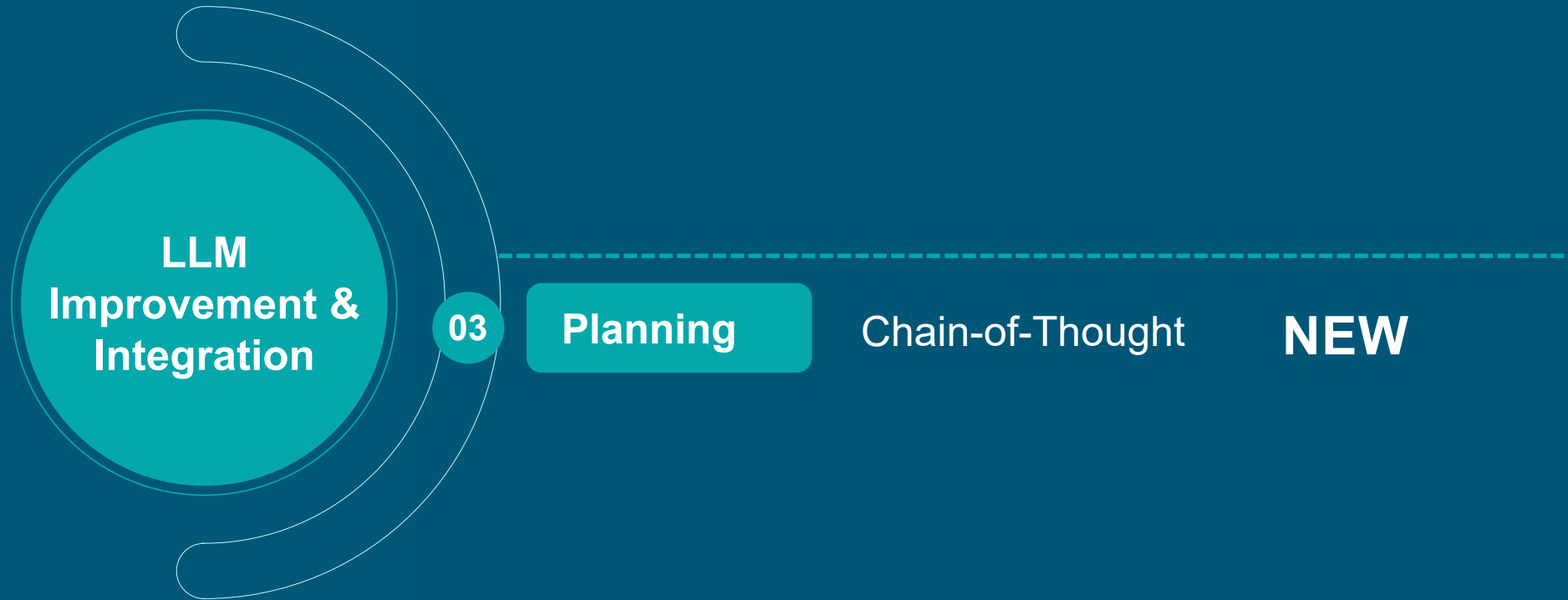
    Serial.println("MPU6050 Found!");
    mpu.setAccelerometerRange(MPU6050_RANGE_6G); // Set the range to 2G
    calibrate(); // Calibrate after setting the range
}
```

## Chain-of-Thought has Arrived



Source: Agentic Reasoning, Andrew Ng, March 2024  
[https://www.youtube.com/watch?v=sa178ACTGT&ab\\_channel=SequoiaCapital](https://www.youtube.com/watch?v=sa178ACTGT&ab_channel=SequoiaCapital)

## Chain-of-Thought

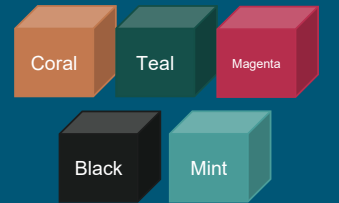


Source: Agentic Reasoning, Andrew Ng, March 2024  
[https://www.youtube.com/watch?v=sa178ACTGT&ab\\_channel=SequoiaCapital](https://www.youtube.com/watch?v=sa178ACTGT&ab_channel=SequoiaCapital)



## Chain-of-Thought Example

White	?	Cobalt	?
?	Orange	Brown	Mustard
Emerald	?	?	Purple



Where do these go?

## SOLUTION

White	Coral	Cobalt	Teal
Mint	Orange	Brown	Mustard
Emerald	Magenta	Black	Purple

Clues:

1. Coral and Magenta are in the same column
2. Black sits next to Magenta
3. Either Teal or Black sits next to Cobalt
4. Coral sits next to White

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## Hallucination

White	?	Cobalt	?
?	Orange	Brown	Mustard
Emerald	?	?	Purple



Where do these go?

Clues:

1. Coral and Magenta are in the same column
2. Black sits next to Magenta
3. Either Teal or Black sits next to Cobalt
4. Coral sits next to White

**GPT-4 Turbo STRUGGLING**  
Could NOT solve this simple puzzle

- Hallucinates incorrect answer

White	Coral	Cobalt	Mint
?	Magenta	Black	Mustard
Emerald	Orange	Brown	Purple

**WRONG!!**

## Chain-of-Thought is NOW a Reality <sup>NEW</sup>

GPT 4o-1 release September 2024

### SOLUTION

White	Coral	Cobalt	Teal
Mint	Orange	Brown	Mustard
Emerald	Magenta	Black	Purple

#### Clues:

1. Coral and Magenta are in the same column
2. Black sits next to Magenta
3. Either Teal or Black sits next to Cobalt
4. Coral sits next to White

#### Chain-of-Thought Step-by-Step Solution:

1. Identify Possible Positions for **Coral** and **Magenta** (Clue 1):
  - The only column with two blanks is **Column 2**.
  - Therefore, **Coral** and **Magenta** must be placed in **Column 2**.
  - Possible positions: (Row 1, Column 2) and (Row 3, Column 2).
2. Place **Coral** Next to **White** (Clue 4):
  - **White** is at (Row 1, Column 1).
  - "Next to" means horizontally adjacent.
  - Place **Coral** at (Row 1, Column 2) (next to White).
3. Place **Magenta** in the Same Column (Clue 1):
  - With **Coral** at (Row 1, Column 2), place **Magenta** at (Row 3, Column 2)
4. Place **Black** Next to **Magenta** (Clue 2):
  - **Magenta** is at (Row 3, Column 2).
  - Place **Black** at (Row 3, Column 3).
5. Place **Teal** Next to **Cobalt** (Clue 3):
  - Cobalt is at (Row 1, Column 3).
  - (Row 1, Column 2) is occupied by **Coral**.
  - Place **Teal** at (Row 1, Column 4).
6. Place the Remaining Color (**Mint**):
  - The only remaining blank is at (Row 2, Column 1).
  - Place **Mint** at (Row 2, Column 1).

#### Verification of Clues:

1. Coral and Magenta are in the same column: Both are in Column 2.
2. Black sits next to Magenta: Black is to the right of Magenta in Row 3.
3. Teal sits next to Cobalt: Teal is to the right of Cobalt in Row 1.
4. Coral sits next to White: Coral is to the right of White in Row 1.

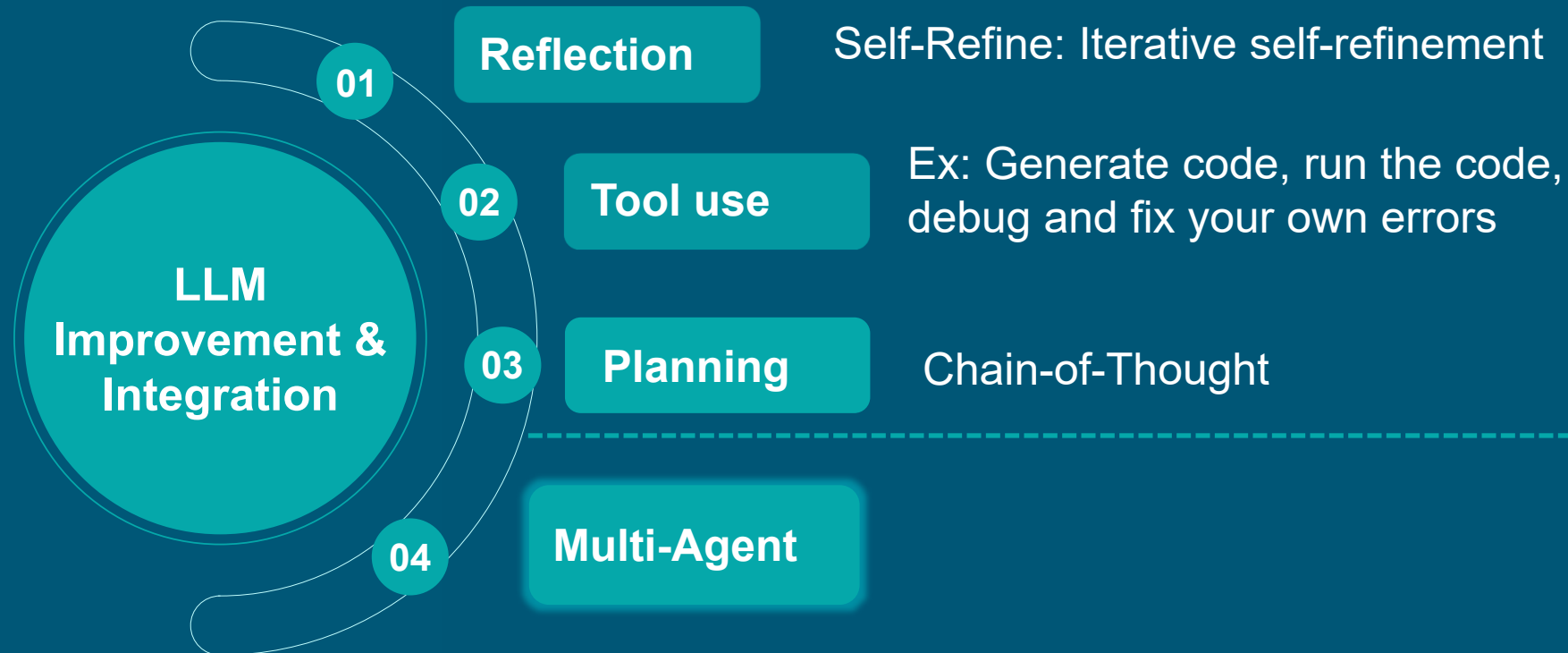
## What's Next?

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## Multi-Agent: Beyond Chain-of-Thought Agentic Reasoning for Semiconductor Testing



Source: Agentic Reasoning, Andrew Ng, March 2024  
[https://www.youtube.com/watch?v=sa78ACTGT2&ab\\_channel=SequoiaCapital](https://www.youtube.com/watch?v=sa78ACTGT2&ab_channel=SequoiaCapital)

**LLM Improvement & Integration**

**04**

**Multi-agent Collaboration**

**Specialized agents interact autonomously with one another**  
**Ex: Researcher agent**

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## LLM Agentic Reasoning

KS

I want you to be four different people. Person 1, we'll call him Alan, all he does is make a plan of attack. Nothing more. He always just makes a plan of attack. Person 2, we'll call him Bob, his job is to use Alan's plan of attack and then to provide a bunch of possible solutions. Bob only provides possible solutions. The solutions can and should range over a wide variety of possibilities. Person 3, we'll call her Cathy, her job is to provide counter solutions to all of Bob's solutions. Basically, she needs to poke holes in Bob's solutions and tell us why each solution is probably not the best, while offering alternative solutions. The last person, we'll call him Dan, his job is to critique both Bob's and Cathy's provided solutions and choose one or more of the solutions prioritizing Ease-of-Implementation and potential beneficial impact. Given that we have plateaued with our current approach, try again based on this input prompt.

**Alan** Makes plan of attack

**Bob** Uses plan of attack to come up with possible solutions

**Cathy** Provides counter-solutions to Bob

**Dan** Critiques both Bob and Cathy and chooses path forward focusing on

**Goals:**

- › Ease-of-implementation and
- › Maximize potential benefit

## Alan



### Alan's Plan of Attack:

- **Review Sensor Setup:**  
Check the installation and settings of the MPU6050 to ensure optimal conditions.
- **Advanced Software Filtering:**  
Investigate more complex filtering techniques that can be implemented on the Arduino.
- **Hardware Modifications:**  
Evaluate simple modifications that could influence data quality.
- **Practical Testing:**  
Conduct tests that mimic real operational conditions to identify underperforming aspects.



## Bob



### Bob's Possible Solutions:

- **Implement Low-pass Butterworth Filter:**  
A simple 2<sup>nd</sup> order LPF could....
- **Enhanced Power Supply Stability:**  
Add decoupling capacitor close to MPU6050's power supply pin to minimize power-related noise.
- **Temperature Compensation:**  
Integrate simple method to adjust readings based on temperature...
- **Sensor Fusion:**  
Use complementary filter to merge MPU6050 data..., to enhance stability and accuracy.

## Cathy



### Cathy's Critiques:

- **Implement Low-pass Butterworth Filter:**  
This might be too complex for real-time applications on Arduino without impacting performance
- **Enhanced Power Supply Stability:**  
Effective, but assumes power supply noise is a significant contributor without evidence.
- **Temperature Compensation:**  
Potentially overcomplicates setup with minimal impact if temp. variations aren't a major factor.
- **Sensor Fusion:**  
Increases complexity and cost, requiring careful synchronization and calibration.

## Dan



### Dan's Final Decision and Critique:

#### Chosen Paths:

- **Implement LPF:**  
While Cathy cautioned about its complexity, a 2<sup>nd</sup> order filter is a feasible compromise on Arduino. This approach directly addresses the problem by filtering out high-frequency noise without needing extensive computational resources.
- **Enhanced Power Supply Stability:**  
Chosen for its simplicity and potential benefits. Adding a decoupling capacitor is low-risk and low-cost modification that can significantly impact performance by stabilizing the power input.

#### Explanation of Choices:

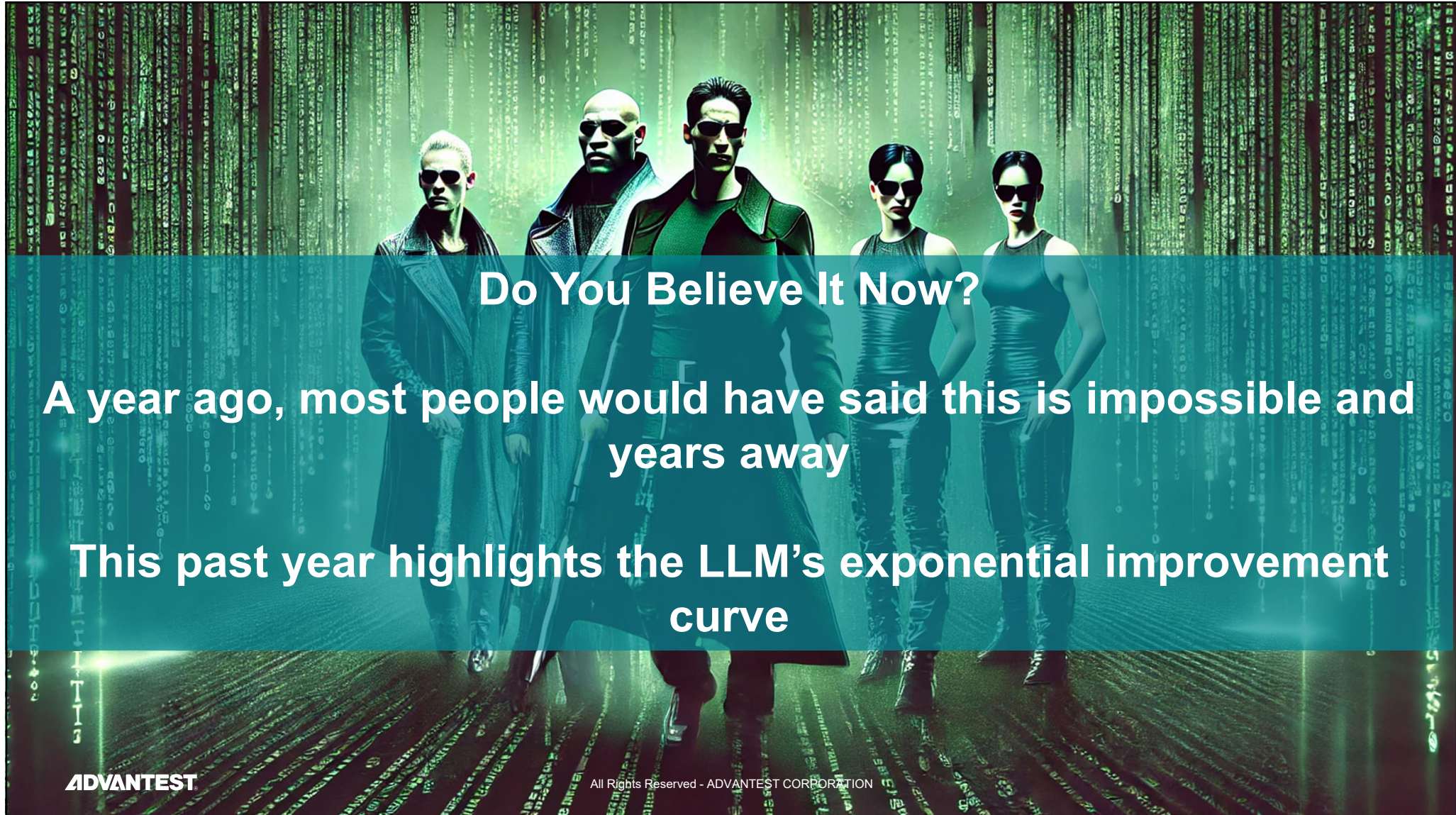
##### LPF:

Proven effectiveness, practical, maintains signal integrity

##### Enhanced Power Supply:

Ease of implementation; even if power supply isn't the primary noise source, stabilizing it can generally improve sensor output quality.





**Do You Believe It Now?**

**A year ago, most people would have said this is impossible and years away**

**This past year highlights the LLM's exponential improvement curve**

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## LLMs (Large Language Models)

04



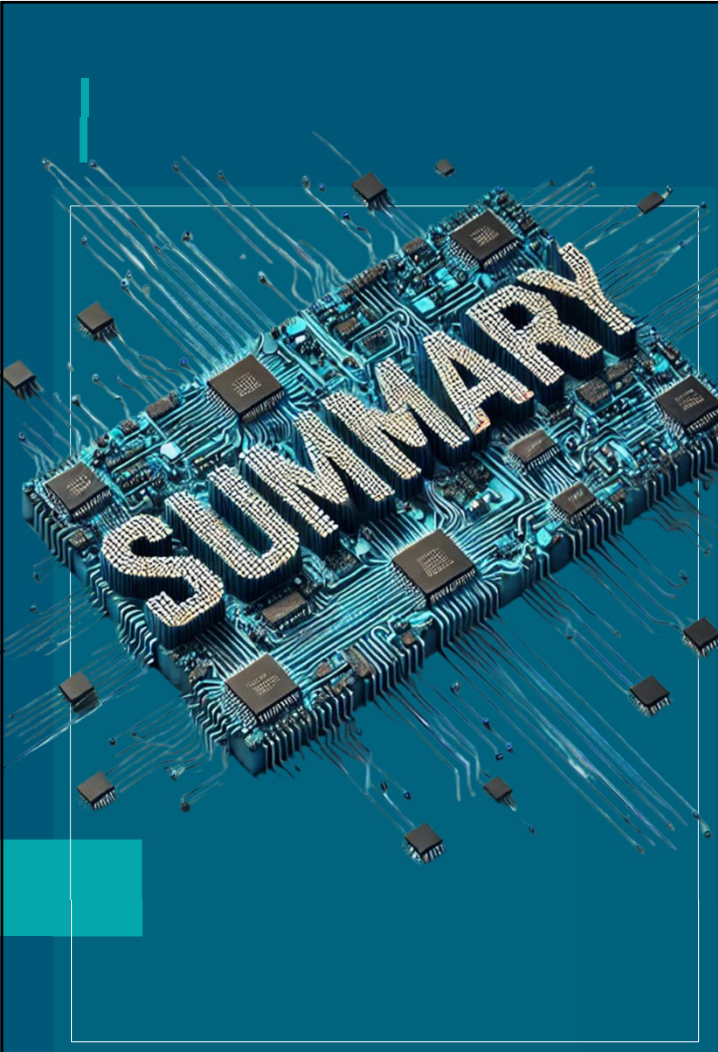
## Conclusions

- › Summary
- › What's Next?
- › LLM Predicts the Future

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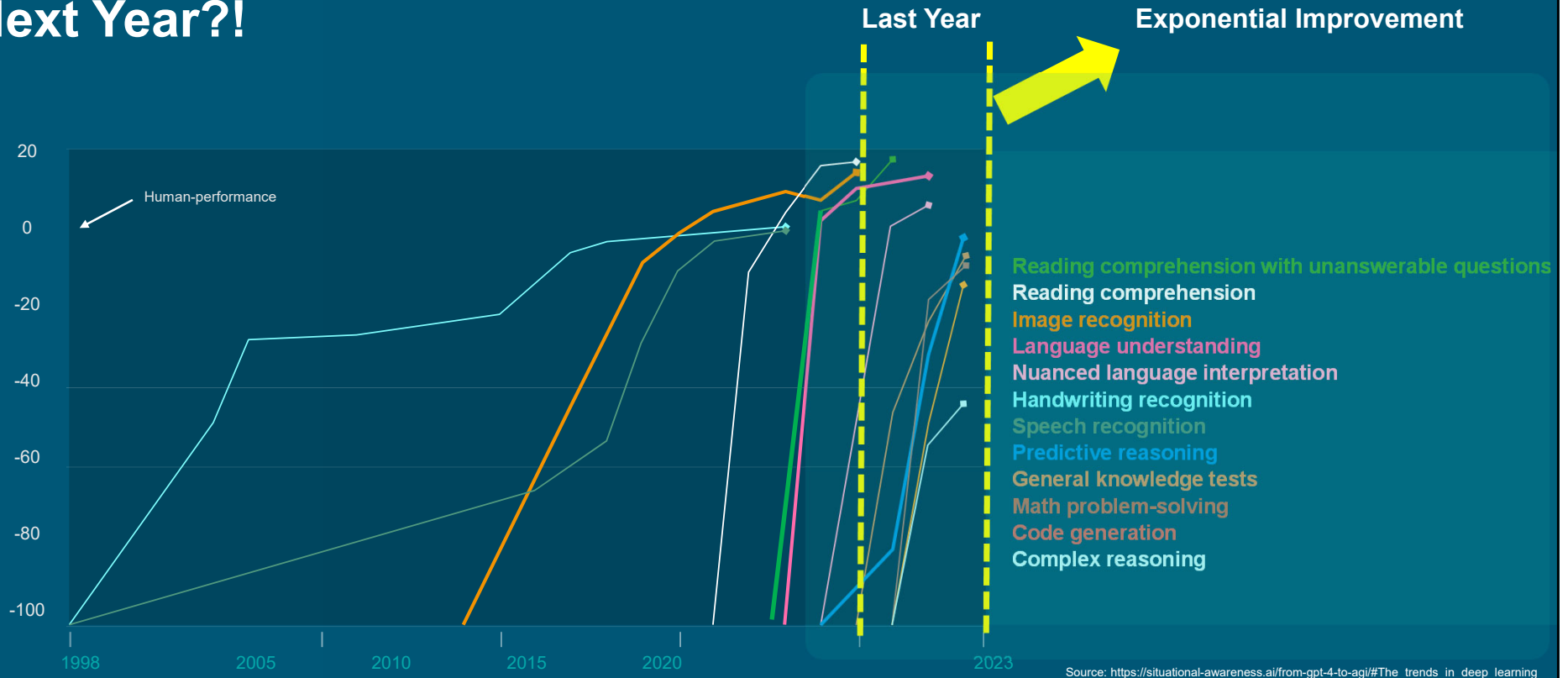
## 2024

- Human-like responses revolutionizing user interactions
- Navigates complex and nuanced queries; previously posed significant challenges
- Unmatched fluency, coherence, and depth of understanding
- Accuracy soaring

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## Next Year?!



Source: [https://situational-awareness.ai/from-gpt-4-to-agi/#The\\_trends\\_in\\_deep\\_learning](https://situational-awareness.ai/from-gpt-4-to-agi/#The_trends_in_deep_learning)

# Let's ask GPT-4o1 to Predict the Future

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**Anticipate models exhibiting cognitive reasoning akin to human thought processes**

**Not just language, but underlying concepts and emotions**

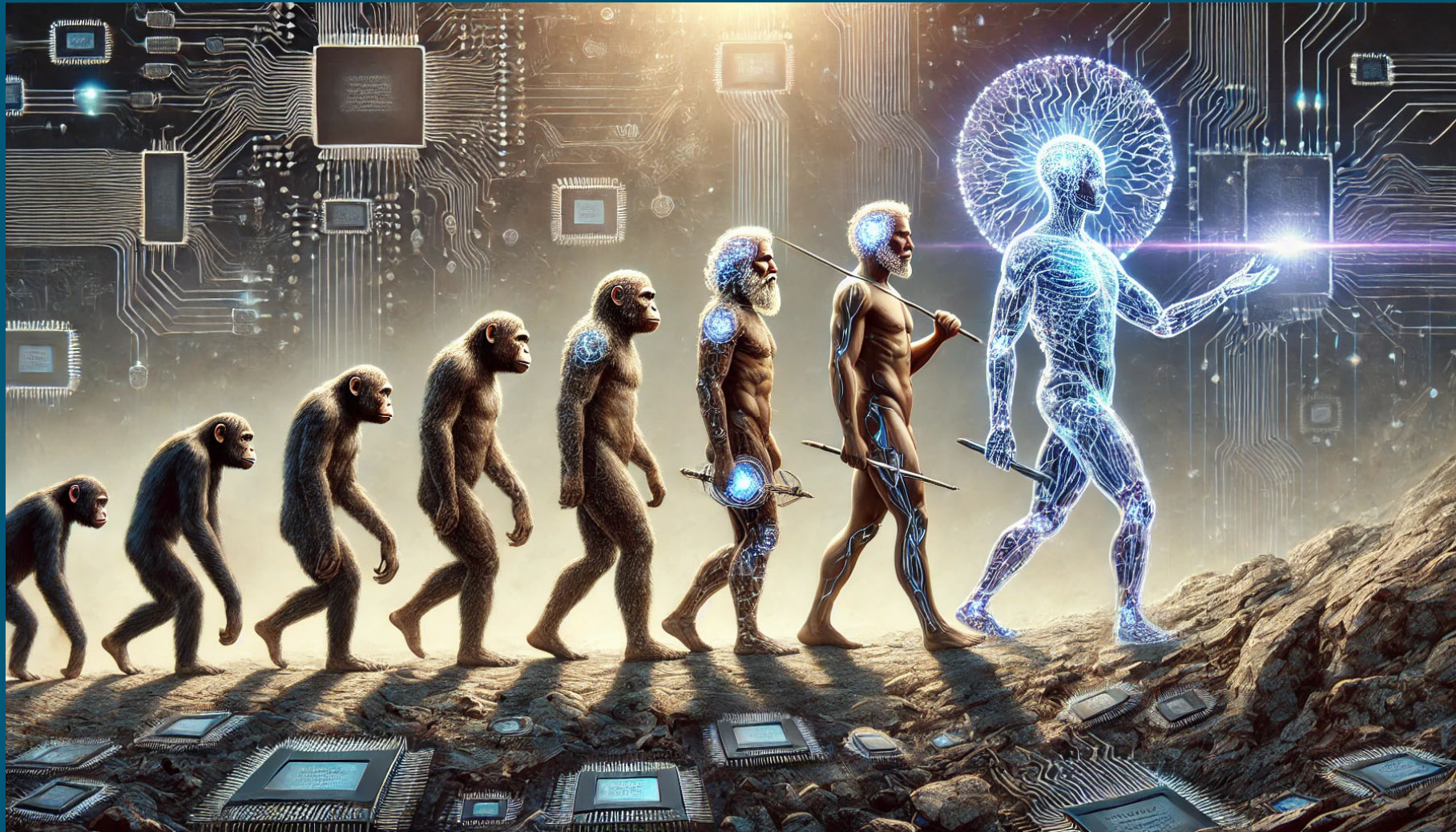
**Imagine genuine creativity and abstract thinking seamlessly integrating and enhancing human capabilities**

**Would you like me to show you?**

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**Keith Schaub**

Vice President of Technology and Strategy  
Advantest America Inc.  
July 2024

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