# Course Introduction

Politecnico di Milano

v1

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Marco D. Santambrogio <marco.santambrogio@polimi.it>

# Who am I?

# Who am I?

- An architect


WHAAAAAAAAT?

# Who am I?

- An architect
- Better…

# Who am I?

- An architect
- Better…
- There we go!

# But at the end… Who am I?

# But at the end… Who am I?

Marco Santambrogio
marco.santambrogio@polimi.it
aka Santa

# … and your TA is Alessandro Verosimile

Alessandro Verosimile

alessandro.verosimile@polimi.it

# Course Objectives

- Have each students to familiarize with computer architectures
  - SoC, Multicore systems
  - Heterogeneous architectures
    - GPU, FPGA
  - Programming models
  - Technology factors
  - Performance, Costs
  - Design of computer architectures
  - etc..

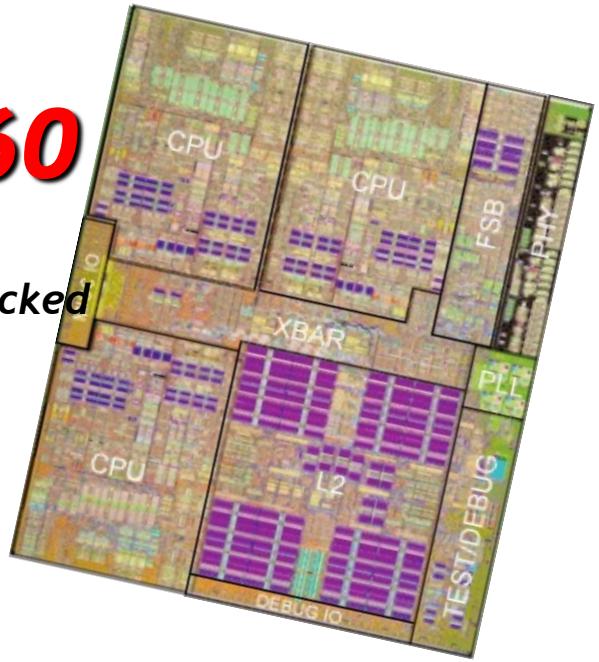

- Envision where/how/why to effectively use computer architectures in students' research

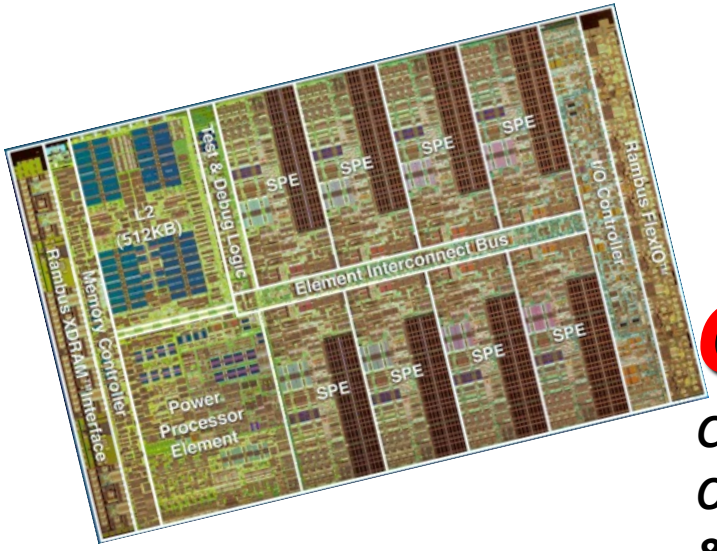
# One core to rule them all

## Xenon: XBOX360

*Three symmetrical cores*

*each two way SMT-capable and clocked at 3.2 GHz*




## Cell: PS3

*Cell is a heterogeneous chip multiprocessor*

*One 64-bit Power core*

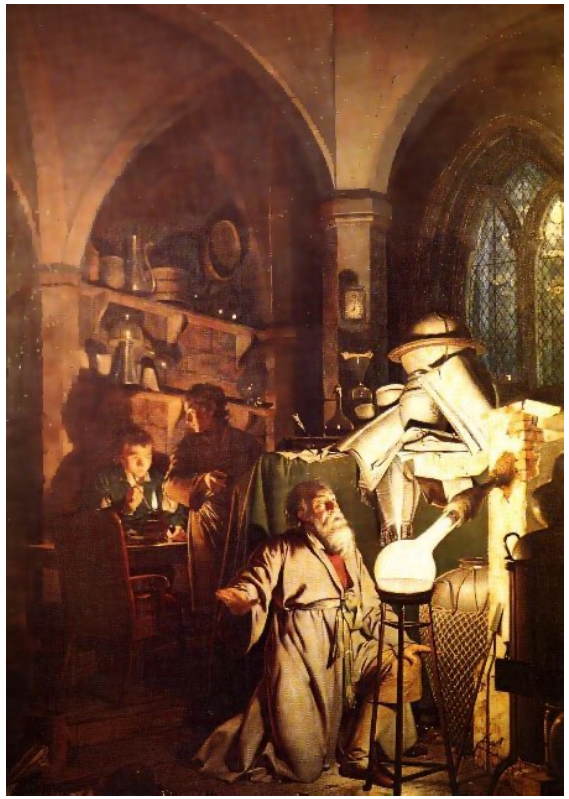
*8 specialized co-processors*

# One core to rule them all

# Outline

- Class Topics: how to turn lead into gold
- Class organization
- End?...

# How to turn lead into gold



*The Alchemist (1771), Joseph Wright of Derby (Derby Museum and Art Gallery, Derby, UK)*

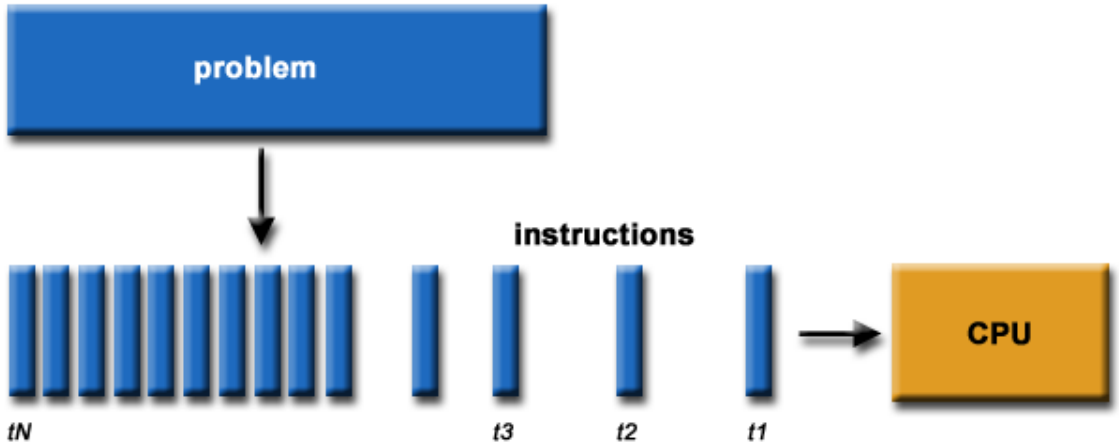
# Flynn Taxonomy (1966)

- SISD - Single Instruction Single Data
  - Uniprocessor systems
- MISD - Multiple Instruction Single Data
  - No practical configuration and no commercial systems
- SIMD - Single Instruction Multiple Data
  - Simple programming model, low overhead, flexibility, custom integrated circuits
- MIMD - Multiple Instruction Multiple Data
  - Scalable, fault tolerant, *off-the-shelf* micros

# "Traditional" Computation

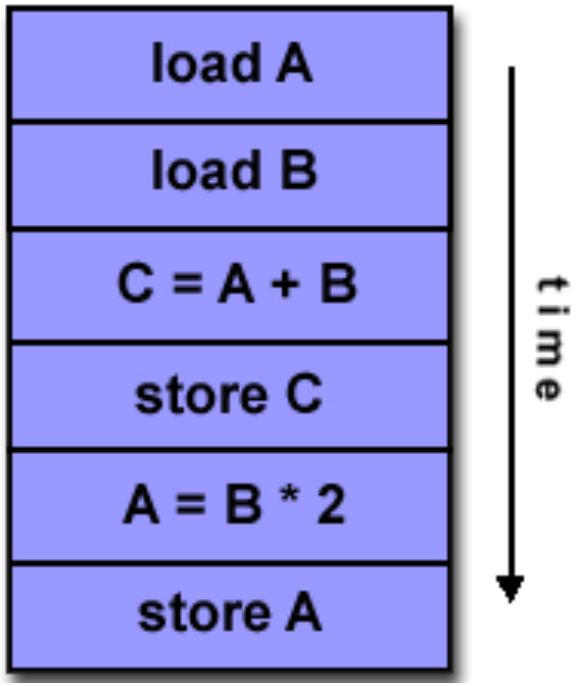
# "Traditional" Computation

- Software is written for serial computation
  - It has to be executed on a single computer having a single Central Processing Unit (CPU)
  - A problem is broken into a discrete series of instructions
    - Instructions are executed one after another
  - Only one instruction may execute at any moment in time



# SISD

- A serial (non-parallel) computer
- Single instruction: only one instruction stream is being acted on by the CPU during any one clock cycle
- Single data: only one data stream is being used as input during any one clock cycle
- Deterministic execution
- This is the oldest and even today, the most common type of computer



# But the world is "parallel"

- Events are happening simultaneously
  - Many complex, interrelated events happening at the same time, yet within a sequence:

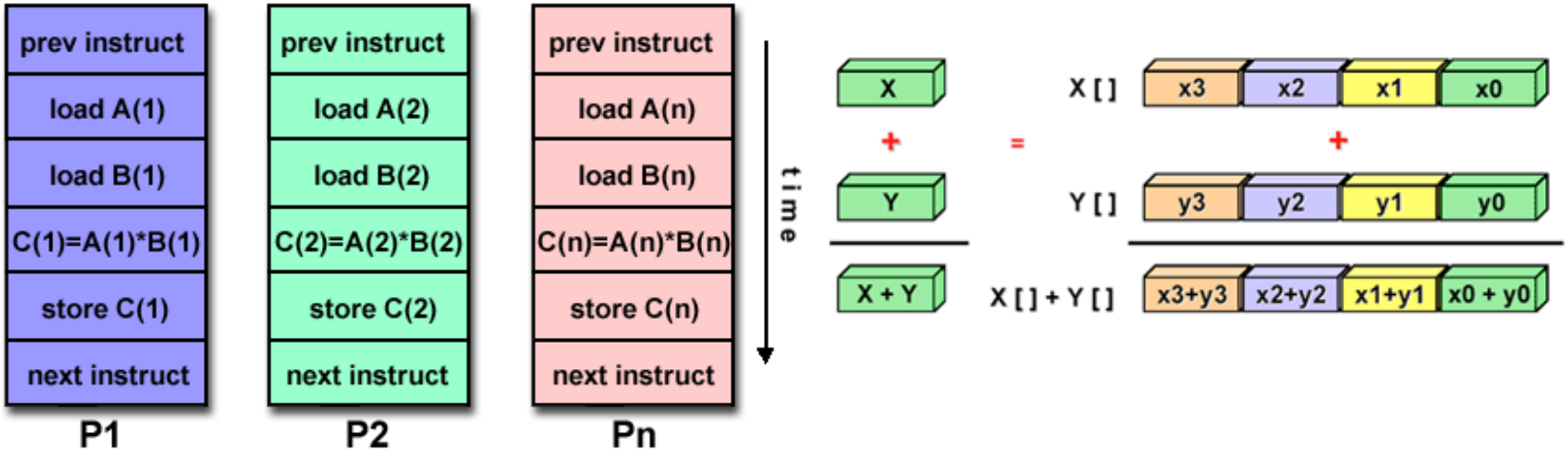

- Some examples:
  - Galaxy formation
  - Planetary movement
  - Tectonic plate drift
  - Rush hour traffic
  - Automobile assembly line
  - Building a space shuttle
  - Ordering a hamburger at the drive through

# Parallelism? Which kind?

# Parallelism? Which kind?

# SIMD

- A type of parallel computer
- Single instruction: all processing units execute the same instruction at any given clock cycle
- Multiple data: each processing unit can operate on a different data element

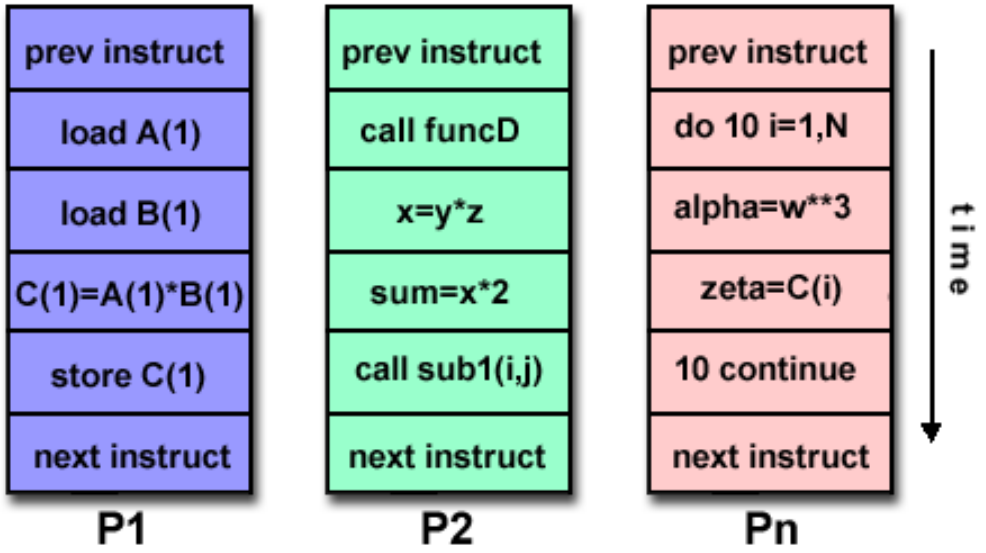



- Best suited for specialized problems characterized by a high degree of regularity, such as graphics/image processing

# Parallelism? Which kind?

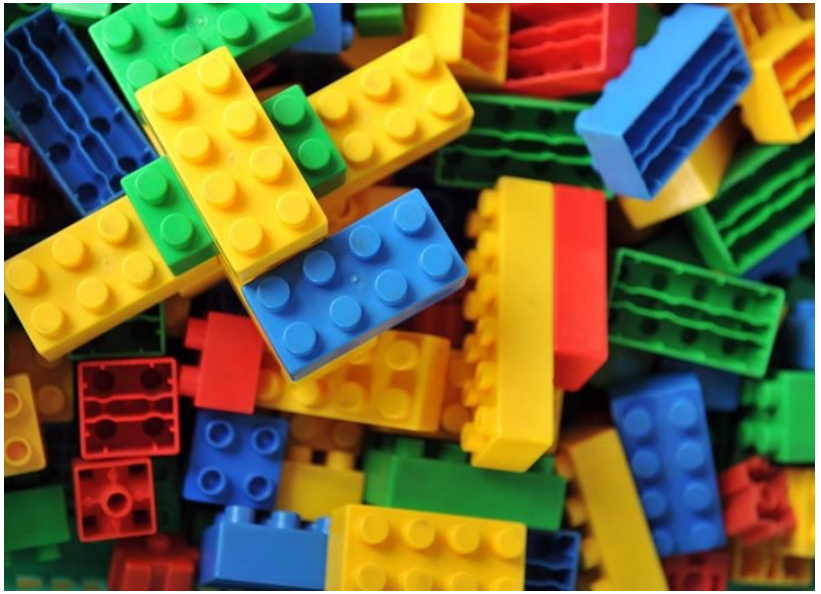
# MIMD

- Nowadays, the most common type of parallel computer
- Multiple Instruction: every processor may be executing a different instruction stream
- Multiple Data: every processor may be working with a different data stream
- Execution can be synchronous or asynchronous, deterministic or non-deterministic



Today…

adaptation and heterogeneity are everywhere…



# Heterogeneous System Architecture


More information available at: http://hsafoundation.com/

# Heterogeneous System Architecture

They all have to deal with energy and power consumption


More information available at: http://hsafoundation.com/


ABOUT WHAT NOW?
Master Yoda


ABOUT WHAT NOW?
Master Yoda
1. CLASS ORGANIZATION

# Classes

- Schedule
  - Monday @10.30am, 2h
    - T.1.1 @ Trifoglio
  - Wednesday @10.30am, 2h
    - 25.S.3 @ Building 25, Via Golgi 40

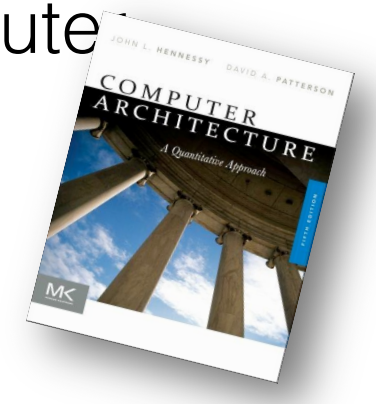
- How to keep informed
  - Google calendar
    - https://tinyurl.com/ACAatPoliMi

# Topics

- Measuring performance: What are the driving measures?
  - Performance (area, time, frequency…..), Power, Cost
- Internal Parallelism in processors:
  - Pipelining
  - Instruction level parallelism inside processors
- Going beyond ILP
- Multiprocessors and multicore systems: taxonomy, topologies, communication management, memory management, cache coherency protocols, example of architectures
- Heterogenous architectures: Vector processors; Graphic Processors, GPGPUs, FPGAs
- Guest Lectures on cutting edge techs/topics

# Topic Coverage

- Textbook: Hennessy and Patterson, Computer Architecture: A Quantitative Approach




- ACA website:

https://santambrogio.faculty.polimi.it/dida/aca/2024/index.htm

- Facebook group
  - https://www.facebook.com/groups/HPPSatPoliMi/

# Calendar



| Date | Topic |
|---|---|
| 17/2 | Course introduction – L1 |
| 19/2 | Introduction to multithreading & parallelism - L2 |
| 24/2 | online classes (via YouTube videos): pipeline, cache, performance – C1, C2, C3<br>Exe on online classes – on C1, C2, C3 |
| 26/2 | Static Branch prediction - L3 |
| 3/3 | Dynamic Branch prediction - L4 |
| 05/3 | Exercises |
| 10/3 | Intruction level parallelism - complex pipeline - L5 |
| 12/3 | Exercises |
| 17/3 | Static scheduling and VLIW architectures - L6 |
| 19/3 | Exercises |
| 24/3 | Dynamic scheduling: Scoreboard – L7 |
| 26/3 | Dynamic scheduling: Tomasulo – L8 |
| 31/3 | Exercises + Dynamic scheduling: advanced – L8b |
| 02/4 | Exercises |

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# Calendar



| Date | Topic |
|---|---|
| 07/4 | online classes (via YouTube videos): Exception handling – C9<br>Hardware Based Speculation – L10 |
| 09/4 | Exercises |
| 14/4 | Explicit Register Renaming – L11 |
| 16/4 | ILP limits and superscalar processors – L12 |
| 23/4 | Exercises |
| 28/4 | Multiprocessor architectures - L13 |
| 30/4 | GPU and heterogeneus Computing Systems – L14 |
| 05/5 | Introduction to CUDA |
| 07/5 | More on CUDA programming |
| 12/5 | Graph ML and ACA projects |
| 14/5 | MIMD – L15 |
| 19/5 | Exercises |
| 21/5 | ACA and Research Projects |
| 26/5 | Exercises |
| 28/5 | Exercises |

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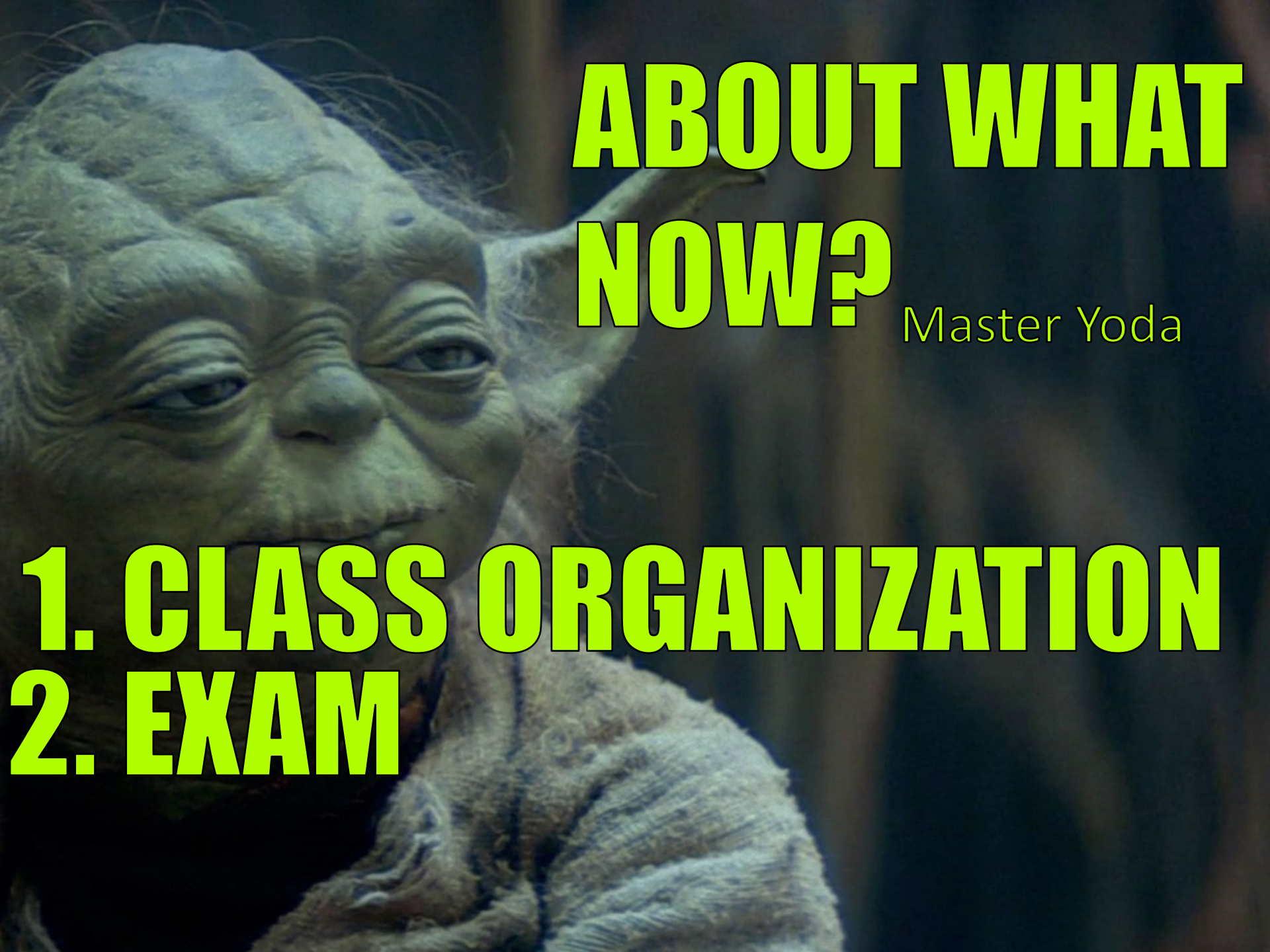
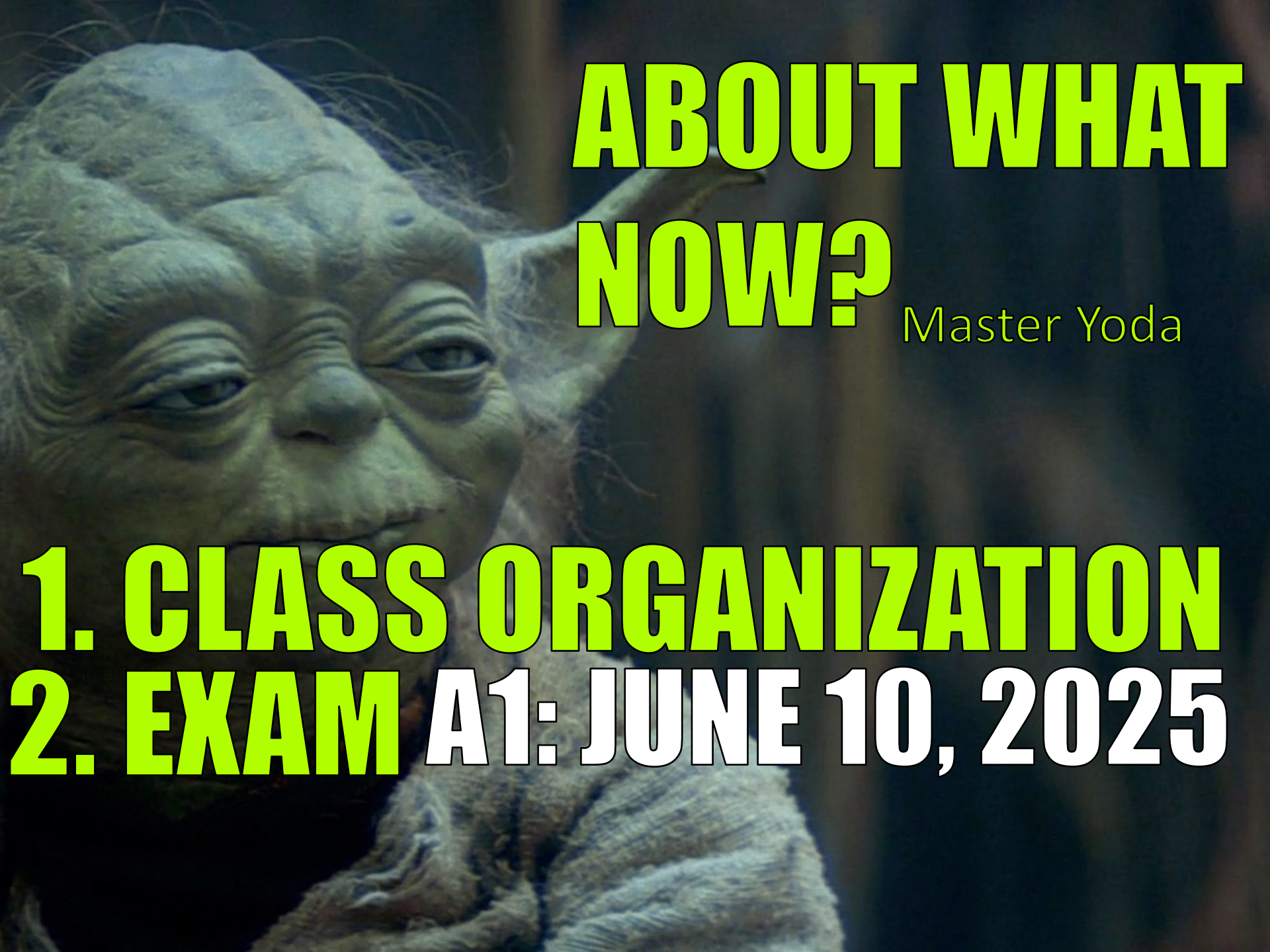

ABOUT WHAT NOW?
Master Yoda
1. CLASS ORGANIZATION
2. EXAM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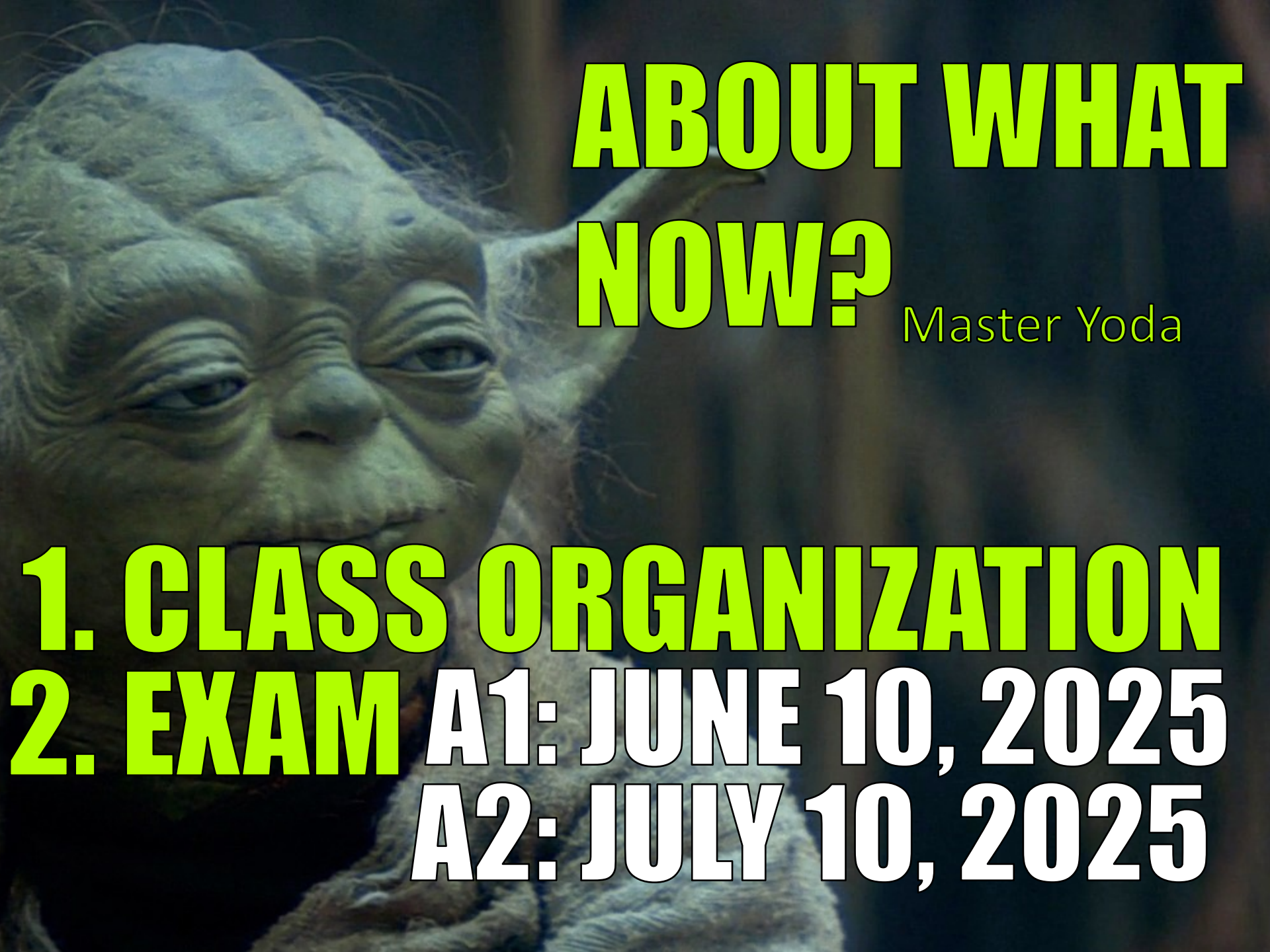
ABOUT WHAT NOW?
Master Yoda
1. CLASS ORGANIZATION
2. EXAM
A1: JUNE 10, 2025
A2: JULY 10, 2025

# ACA Exam (Live)

- The final exam consists of a 90’ written exam
  - No: PC/Laptop, notes, books

- For each written exam (6 problems), a max score of 33 pts (equal to 30L)
  - Exercises part [Practice]
    - 3 exercises, ~15 pts
  - Theoretical part [Theory]
    - 3 questions, ~18pts

# ACA Exam (Live)

- The final exam consists of a written exam

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- The final exam consists of a written exam

- Oral exams
  - We will randomly sample students to go through an oral exams
    - Highest probability to be selected with grades in arrange from 27 to 30L
    - If selected, it is not a choice, it is MANDATORY

# ACA 4 Erasmus

```
If (Erasmus)
    ACAExam = Live;
    if (!in Italy)
        ACAExam = ORAL via Zoom;
```

# ACA through other possibilities?

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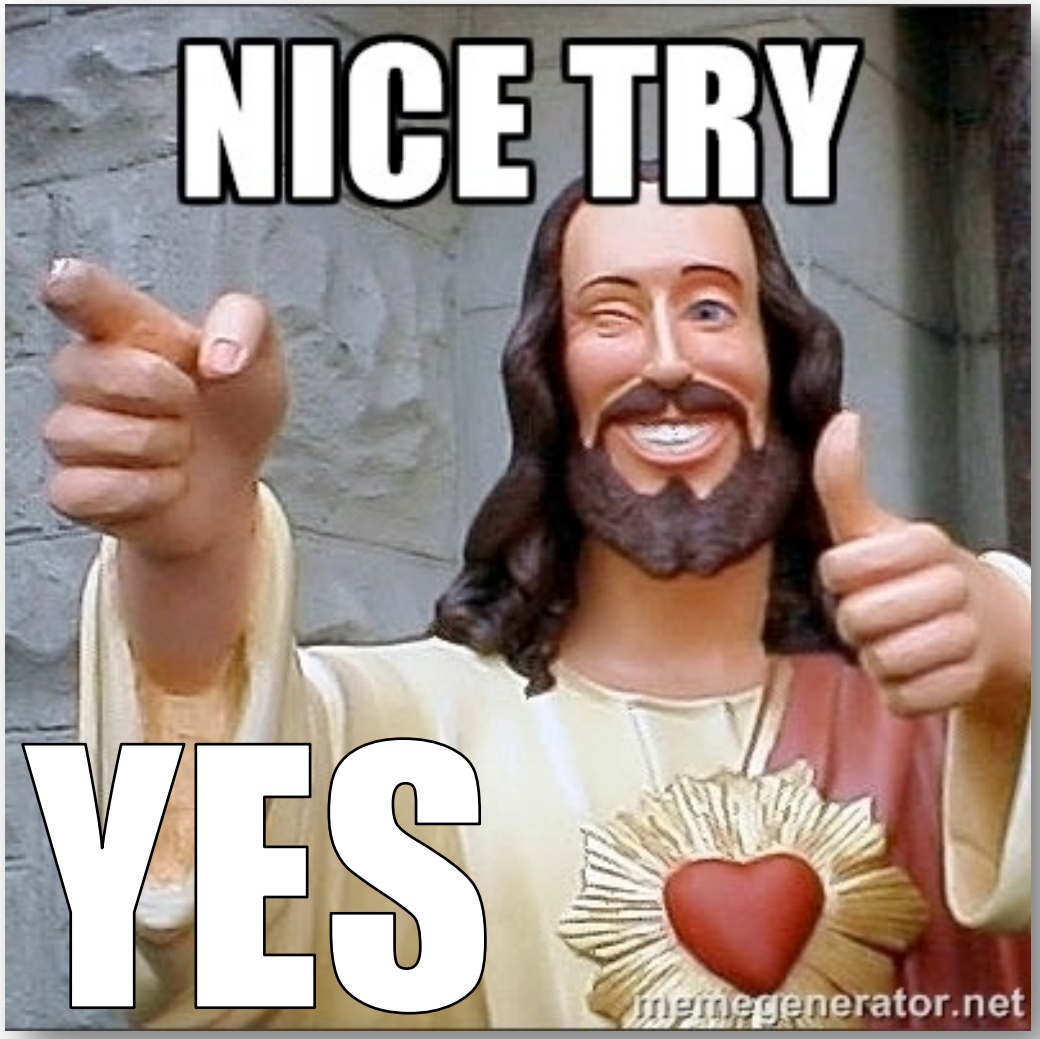

# ACA (as HPPS **have** to!)

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  A. 1 Written test in the first half of May: max 15 pts
     - Evaluated through the course via written tests (e.g. quizzes, exercises, theoretical questions, etc)
       – No: PC/Laptop, notes, books

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  A. 1 Written test in the first half of May: max 15 pts
     - Evaluated through the course via written tests (e.g. quizzes, exercises, theoretical questions, etc)
       – No: PC/Laptop, notes, books
  B. Project: max18 pts
     - Project presentation and oral

# ACA (as HPPS **have** to!)

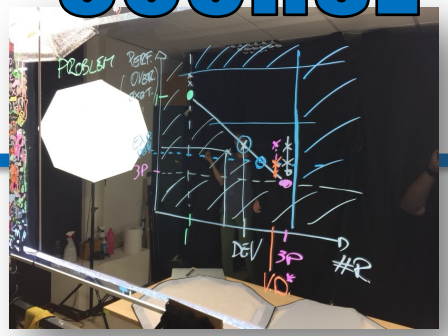
- Max score of 33 pts (equal to 30L)
  - To pass the exam:
    1. at least 18 pts overall
    2. at least 8 pts from A (written test)
    3. at least 10 pts from B (Project)
  - To pass the exam: 1 AND 2 AND 3

- HPPS-way
  - valid ONLY for the SUMMER session
  - Students will "*trade*" the first "appello" to access this
    (trade = seating and seeing the written test)

# ACA Exams

**ACA @20.2**


**COURSE**




**EXAMS A1, A2**


**A1: JUNE 10, 2025**

**A2: JULY 10, 2025**

# ACA Project Rules

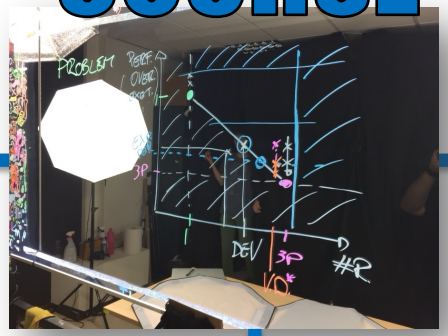
- Project presented on Monday 12.5.2025
  - Where: ACA Class (T.1.1)
  - When: @ 2pm
  - What: Two tracks will be presented during the 12.5.25 class

- Teams and projects
  - Teams up 2 members
  - Each team has to pick/select one of the two tracks (share the decision via email to the instructors) – Deadline: 18.5.2025
  - Starting: May 12, 2025 - Deadline: June 30, 2025
  - Each project will be presented to Prof. Santambrogio
    - The date will be discussed/agreed with him
    - It's an ACA **project**, **questions** wrt to all the ACA topics will be asked during the project presentation!

# ACA Exams

## ACA @17.2


## COURSE




## EXAMS A1, A2


## MID-EVALUATIONS


@MAY

## ACA Prj


## PROJECTS 12.5 - 30.6

@ 30.6

## PRJ SUBMISSION

# HPPS Project Rules

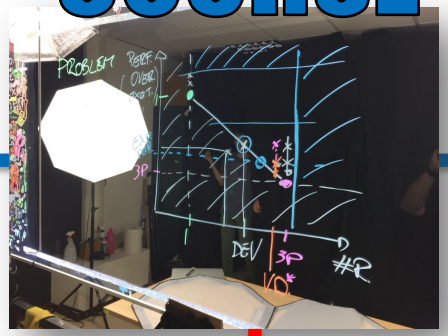
- Project presented on Friday 21.2.2025
  - Where: NECSTLab Meeting Room
  - When: @ 2pm

- Teams and projects
  - No team (aka 1 project = 1 student)
  - The mapping will be done during the meeting @21.2.2025
  - Starting: Feb 21, 2025 - Deadline: June 30, 2025
  - Each project will be presented to Prof. Santambrogio
    - The date will be discussed/agreed with him
    - It's an HPPS **project**, **questions** wrt to all the HPPS topics will be asked during the project presentation!

# ACA Exams

**ACA @17.2**


**COURSE**



**EXAMS A1, A2**


**HPPS**

**PROJECTS 21.2- 30.6**

**@MAY**


**MID-EVALUATIONS**

**@ 30.6**

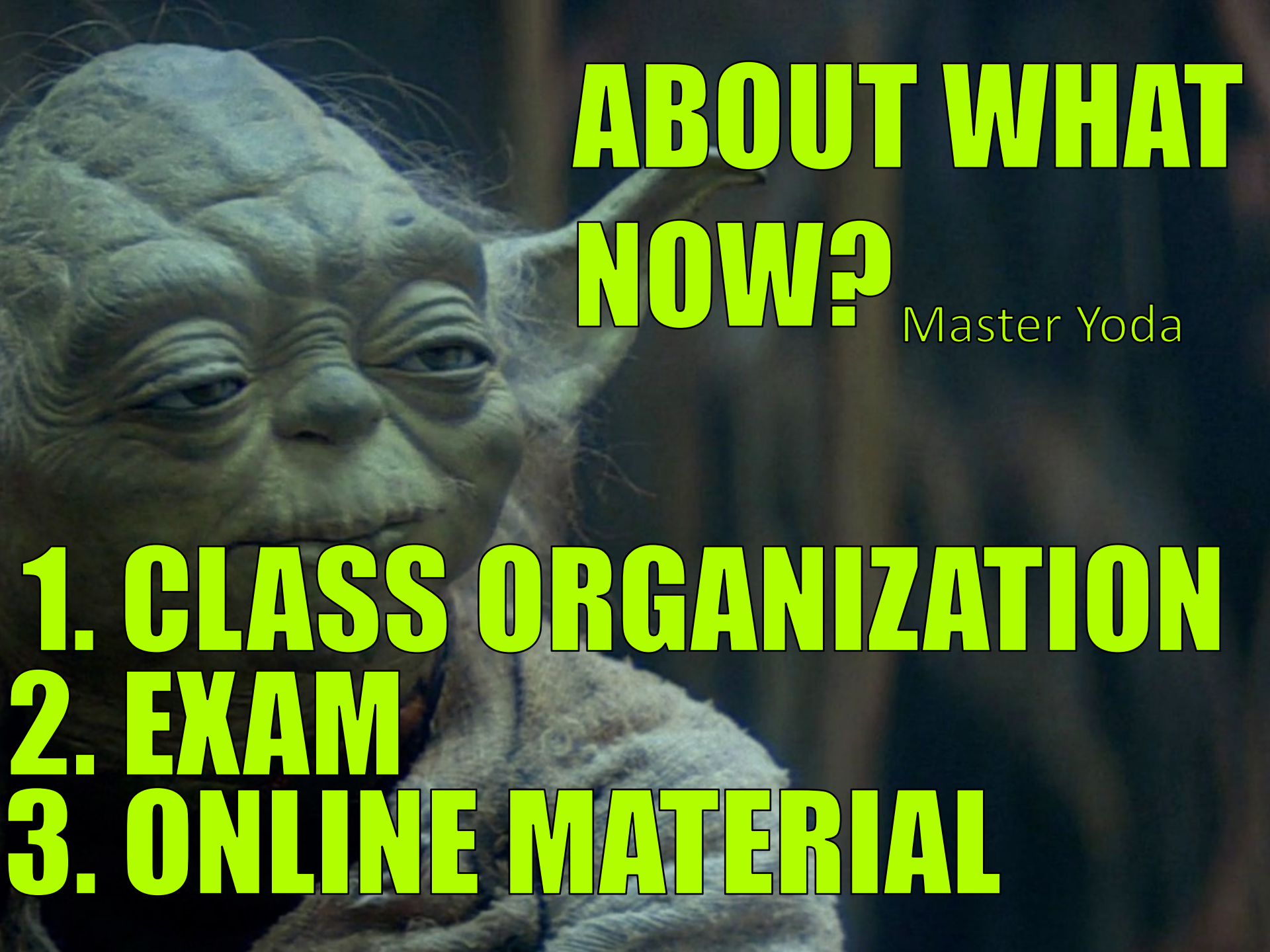
**PRJ SUBMISSION**

# How To ACA

Let us know how you'll complete the ACA course

https://tinyurl.com/HowToACA2025

Deadline March 7, 2025


ABOUT WHAT NOW?
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3. ONLINE MATERIAL

# Useful online material

- Slides and videos provided via the ACA website through Dropbox
- ACA website: @https://santambrogio.faculty.polimi.it/dida/aca/2025/index.htm
- Online Classes: @https://tinyurl.com/video-ACA-polimi
- Google Calendar: @https://tinyurl.com/ACAatPoliMi

# Instructors

Alessandro Verosimile
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  - email: alessandro.verosimile@polimi.it
  - office: 3564 (NECST Lab, -1 @ Bld.20)


Marco D. Santambrogio
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# Questions…

# Course Introduction

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