DAEDALEAN

Flight control systems for the autonomous electric light personal-transport aircraft of the near future.

Can Artificial Intelligence pass the CPL(H) Skill Test?

ICAS Workshop 2017-09-11

Dr. Luuk van Dijk -- Anna Chernova

Contact: info@daedalean.ai

1 Why?

2 What?

3 How?

4 Yes?

1. **Why?**
2. What?
3. How?
4. Yes?

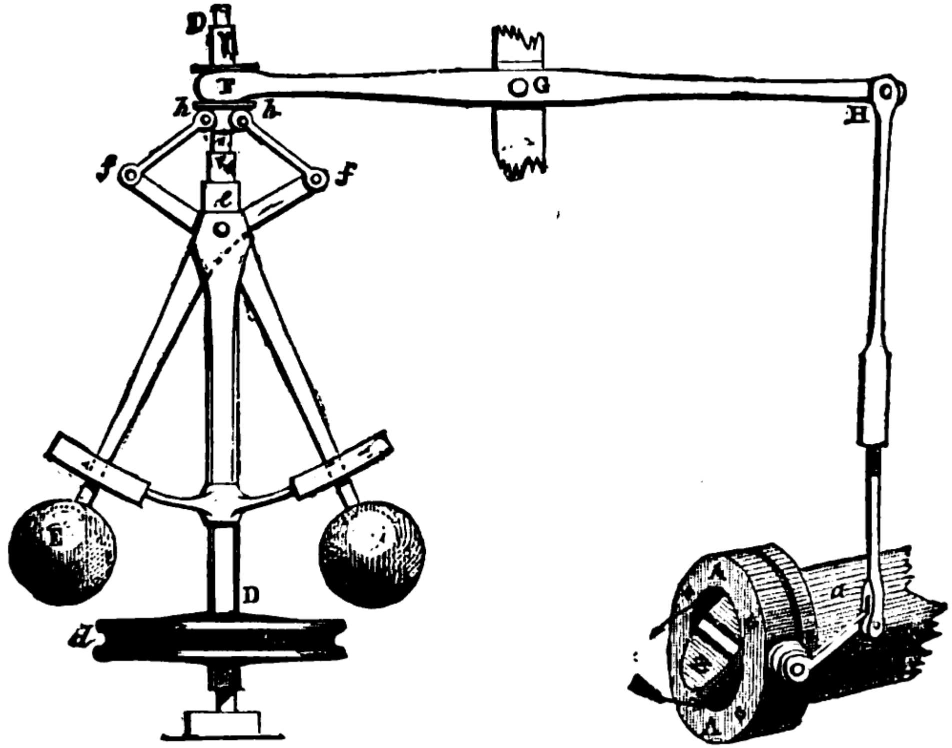
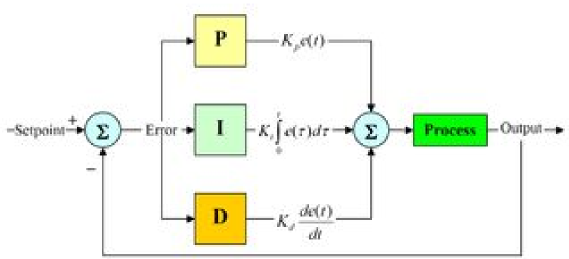
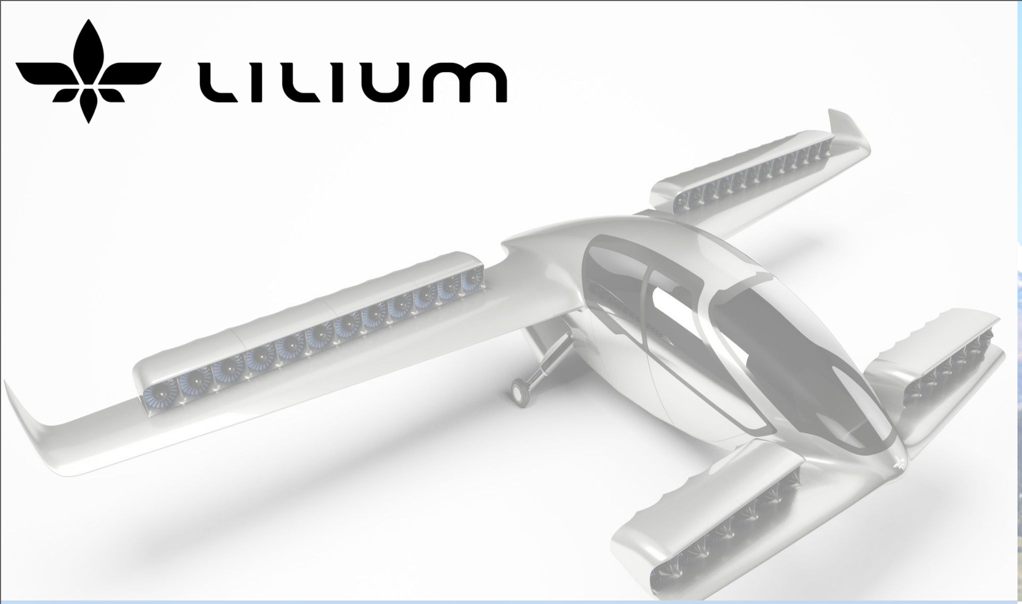
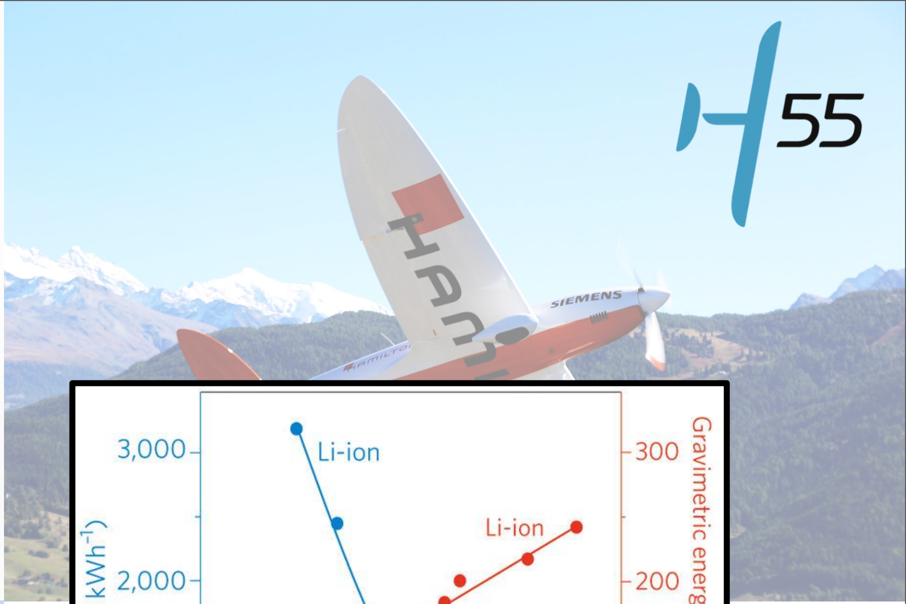
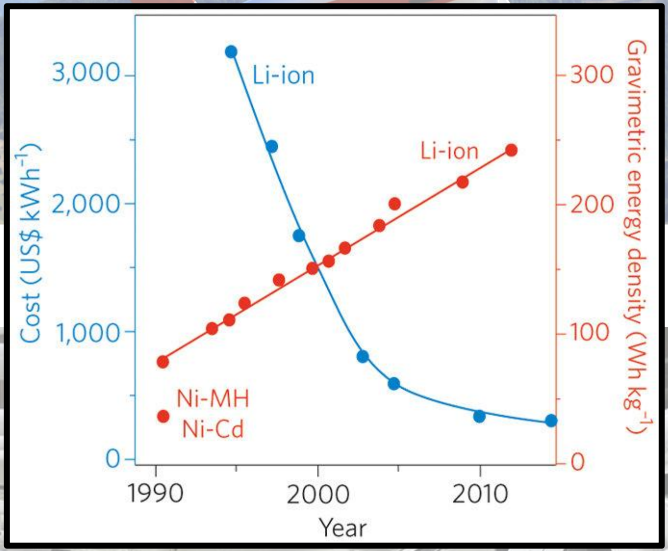


FIG. 4.—*Governor and Throttle-Valve.*



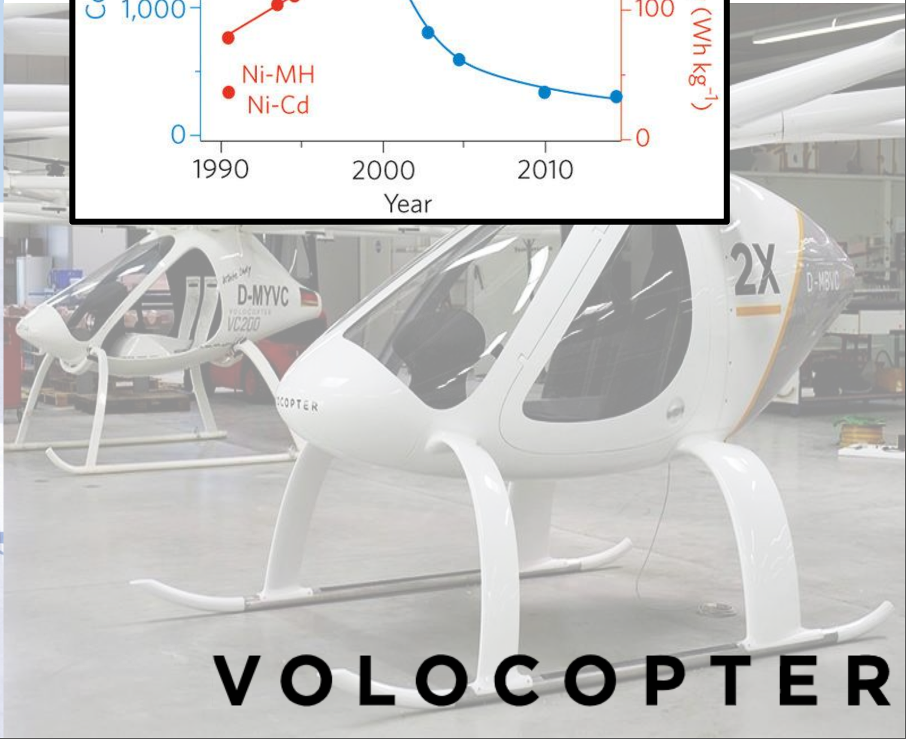

LILIUM


H55
SIEMENS


3,000
2,000
1,000
0
Cost (US$ kWh^{-1})
300
200
100
0
Gravimetric energy density (Wh kg^{-1})
Li-ion
Li-ion
Ni-MH
Ni-Cd
1990
2000
2010
Year


Aurora®
FLIGHT SCIENCES


JOBY®
AVIATION


2X
D-MYVC
VC200
VOLOCOPTER

*"To fast-forward to the **safest** possible operational state for VTOL vehicles, network operators will be interested in the path that realizes **full autonomy as quickly as possible**."* (source)

UBER

*"Electrically operated aerial vehicles combined with more **autonomous operation** and data-driven business models could herald the **biggest change in aviation in decades**."* (source)

AIRBUS

"Pilotless planes are technically feasible, and could bring material benefits" (source)

UBS

Machine Age Lamps Company
by Royal64Crown CCarling #17
Machine Age Lamps Company
by Royal64Crown CCarling #18
ALT
CLIMB
R.P.M.
CYL TEMP
FUEL/AIR RATIO
PPH

1 Why?

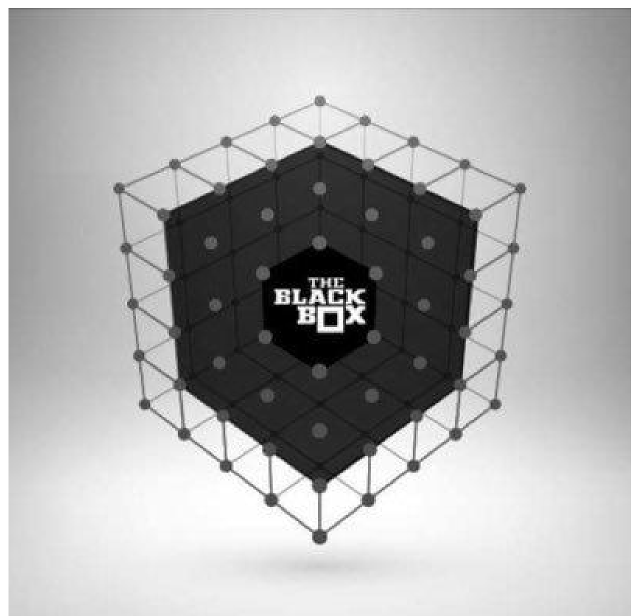
2 What?

3 How?

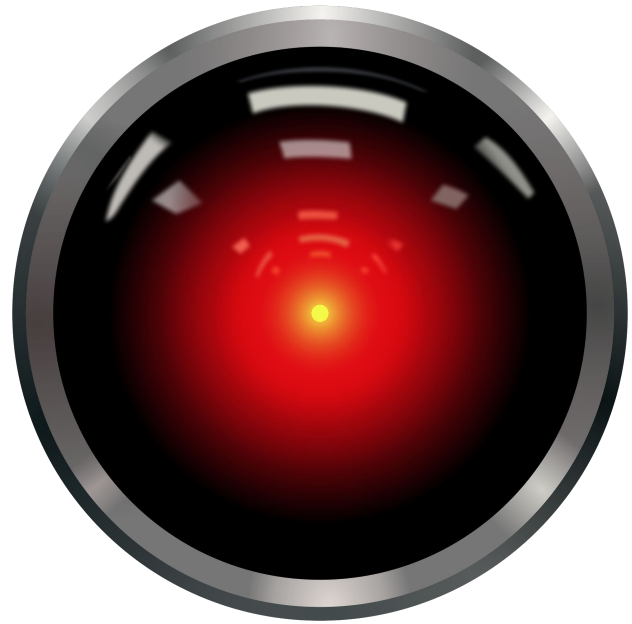
4 Yes?

Every other startup idea since 2015

1. Collect BIG DATA
2. Apply magic-AI-black-box
3. Profit!



What is this "AI" you speak of?



(depends on who you ask)

The science and engineering to create machines (computer programs) that use understanding of the world to achieve goals.

A broad range of CS techniques

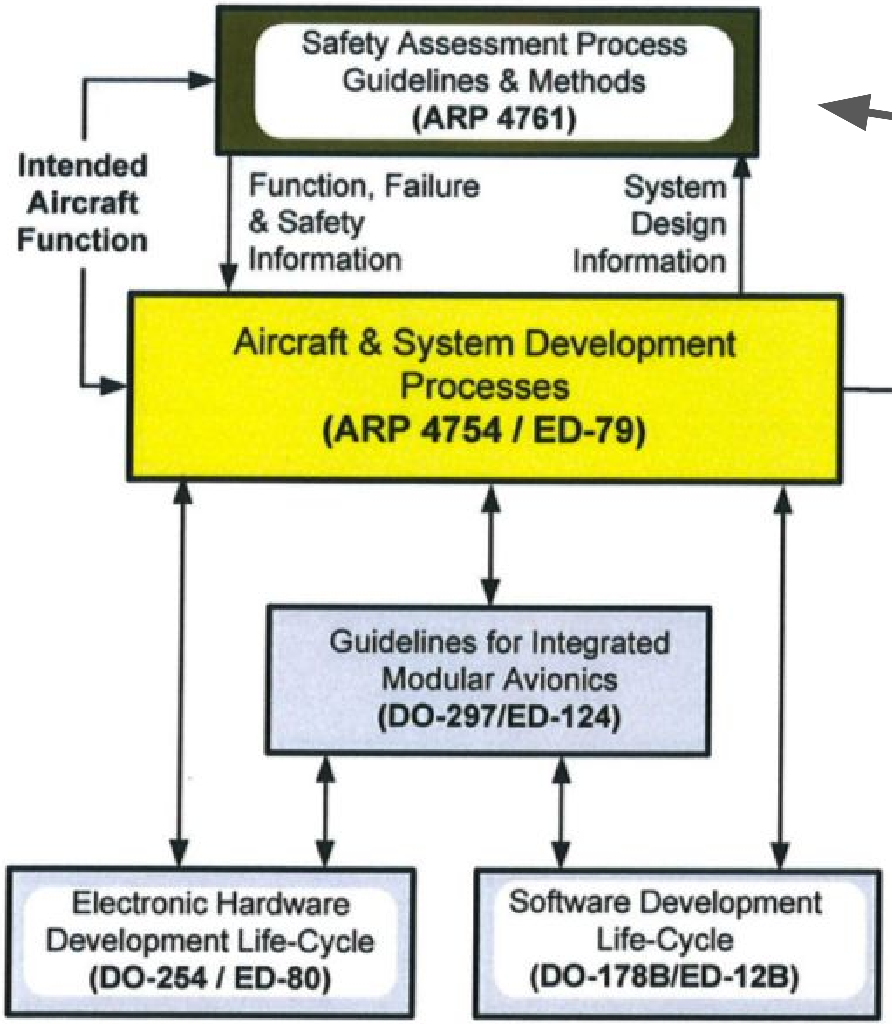
- Computer Vision
- Robotics
- Statistics on Big Data
- Machine Learning
- “Deep” neural networks
- Reinforcement Learning
- Adaptive (learn on the job)

New algorithms are made possible by strides in computational capacity.

1996

=

2016



Require the wrong things to be not there

Require the right things to be there

Build what you require

14 CFR Ch. I

...

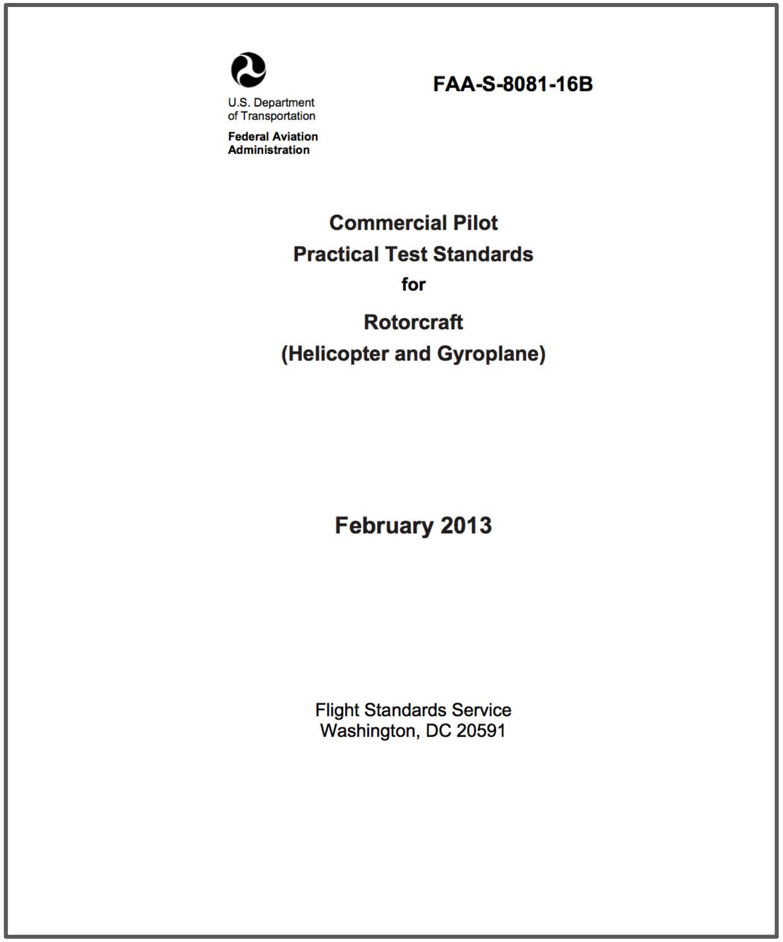
§ 23.1329 Automatic pilot system.

If an automatic pilot system is installed, it must meet the following:

(a) Each system must be designed so that the automatic pilot can—

(1) Be quickly and positively disengaged by the pilots to prevent it from interfering with their control of the airplane; or

(2) Be sufficiently overpowered by one pilot to let him control the airplane.


U.S. Department of Transportation
Federal Aviation Administration

FAA-S-8081-16B

Commercial Pilot
Practical Test Standards
for
Rotorcraft
(Helicopter and Gyroplane)

February 2013

Flight Standards Service
Washington, DC 20591


Chapter 3

Helicopter Flight Controls

Introduction

There are three major controls in a helicopter that the pilot must use during flight. They are the collective pitch control, the cyclic pitch control, and the antitorque pedals or tail rotor control. In addition to these major controls, the pilot must also use the throttle control, which is usually mounted directly to the collective pitch control in order to fly the helicopter.

In this chapter, the control systems described are not limited to the single main rotor type helicopter but are employed in one form or another in most helicopter configurations. All examples in this chapter refer to a counterclockwise main rotor blade rotation as viewed from above. If flying a helicopter with a clockwise rotation, left and right references must be reversed, particularly in the areas of rotor blade pitch change, antitorque pedal movement, and tail rotor thrust.

if rpm is	and manifold pressure is	Solution
LOW	LOW	Increasing the throttle increases manifold pressure and rpm
LOW	HIGH	Lowering the collective pitch decreases manifold pressure and increases rpm
HIGH	LOW	Raising the collective pitch increases manifold pressure and decreases rpm
HIGH	HIGH	Reducing the throttle decreases manifold pressure and rpm

Adaptive AI systems face 3 layers of challenges

- Sufficiently reliable hard- and software
- Regulatory capture
- **Actually Solving The (Hard) Problems of Flying!**
  - **Dealing with the unexpected**

1 Why?

2 What?

3 How?

4 Yes?

Modern AI & the unexpected?

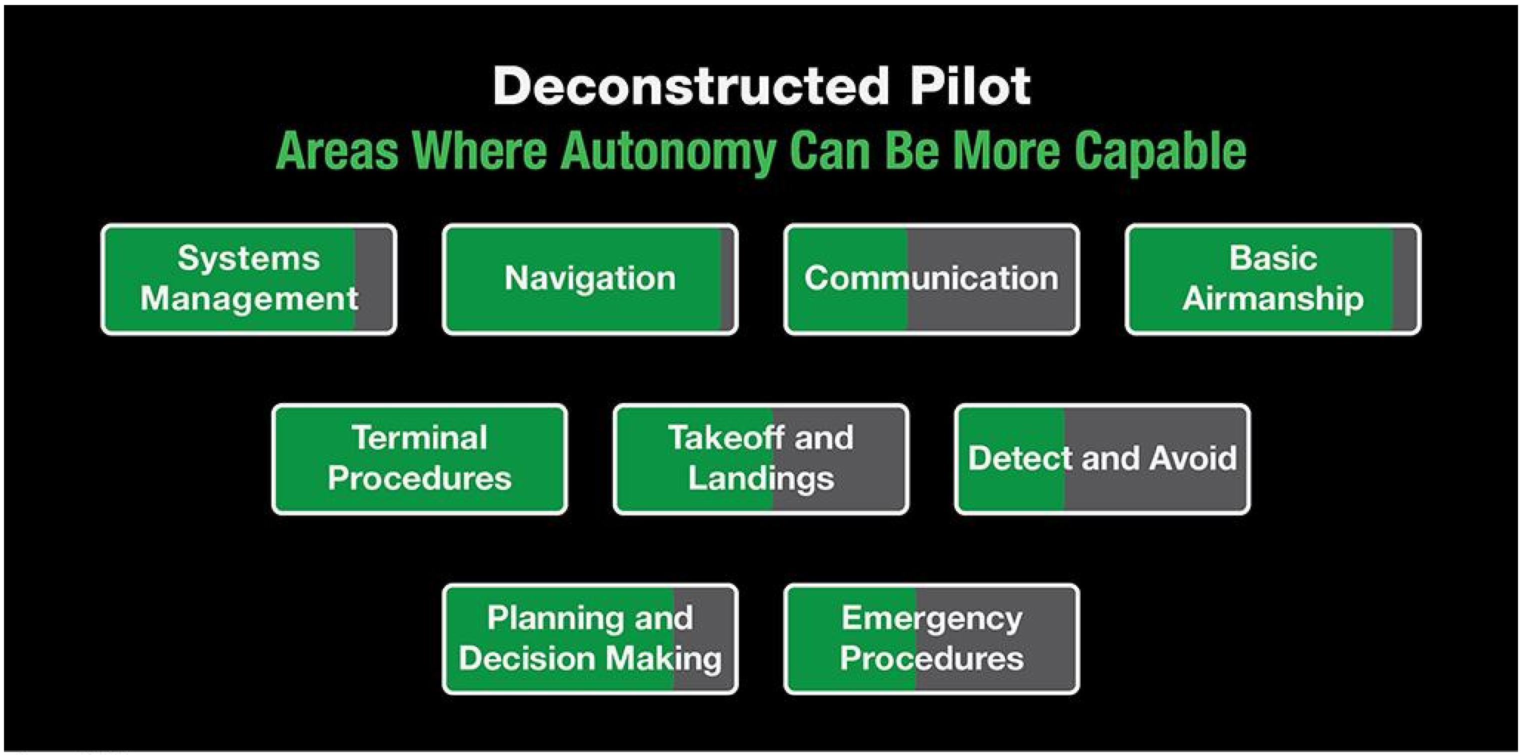
- Pool flight hours
  - Copies of our systems can share their learnings
- Simulations
  - Generate much more data than you could ever train a human on!
  - Take 10^4 Hours of real data,
  - …. multiply by 10^8 scenarios...

What if we created an autopilot
*with **10^{12} hours** of PIC time in Day, Night, IFR...*

The real art of flying

I. Preflight preparation
II. Preflight procedures
III. Airport operations
IV. Hovering maneuvers
V. Takeoffs, landings and go-arounds
VI. Performance maneuvers
VII. Navigation
VIII. Emergency operations
IX. Special Operations
X. Postflight procedures

industry assessment of autonomy's current ability



Source: GAMA

Source: recent report by NASA Autonomy Incubator

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Reconnaissance for confined area landings

- High reconnaissance
  - Wind direction and speed
  - Find touchdown point
  - Forced landing options
  - Approach/departure axes
- Low reconnaissance
  - Reconfirm earlier observations
  - Wires, poles
  - Surface conditions: dust, sand, snow, debris and obstacles
    - Anything that is dangerous
  - Slope

Source: Helicopter Flying Handbook ch 10 "Advanced Maneuvers"


rotation errors
translation errors

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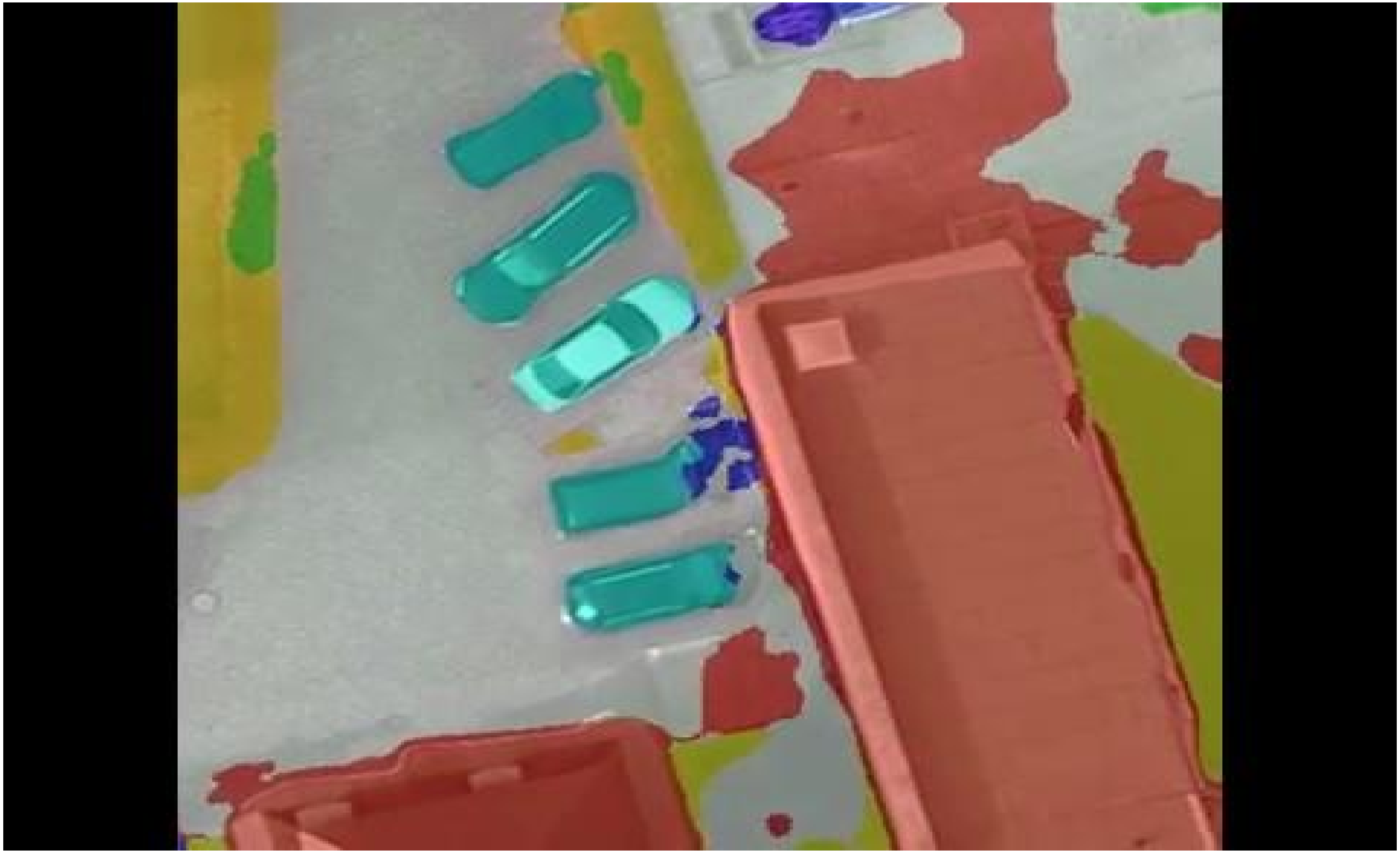


How to outperform the human

- The easy bits
  - Permanent attention for everything
  - Always a plan ready
  - Look in all directions always
  - Superior control over the airframe
  - Should we pull the parachute?

- The harder bits
  - Recognizing water, debris, snow
  - Visual clues for the wind
  - “anything dangerous”

1 Why?

2 What?

3 How?

4 Yes?

Engineering is the art of solving problems within constraints

In the Aerospace sector we like to see those formulated as **requirements**

U.S. Department of Transportation
Federal Aviation Administration

FAA-S-8081-16B

Commercial Pilot
Practical Test Standards
for
Rotorcraft
(Helicopter and Gyroplane)

February 2013

Flight Standards Service
Washington, DC 20591

By humans, for humans

AUTOMATED DRIVING

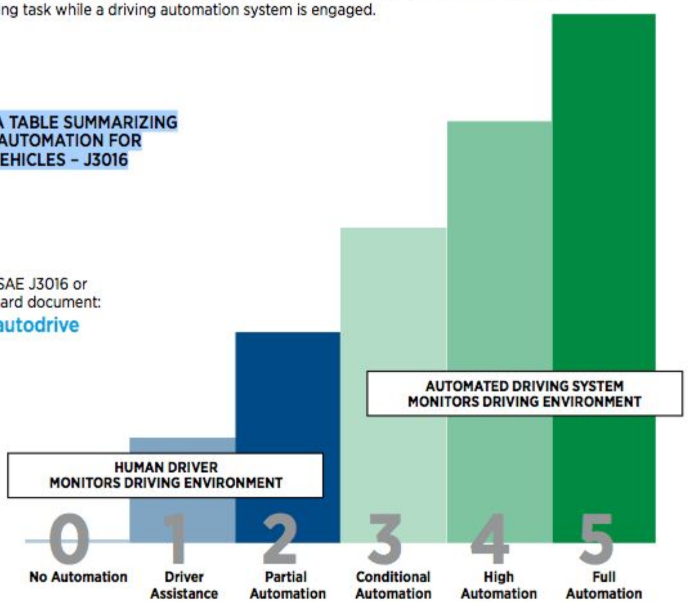
LEVELS OF DRIVING AUTOMATION ARE DEFINED IN NEW SAE INTERNATIONAL STANDARD J3016

With the goal of providing common terminology for automated driving, SAE International's new standard J3016: **Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems**, delivers a harmonized classification system and supporting definitions that:

- Identify six levels of driving automation from "no automation" to "full automation".
- Base definitions and levels on functional aspects of technology.
- Describe categorical distinctions for a step-wise progression through the levels.
- Are consistent with current industry practice.
- Eliminate confusion and are useful across numerous disciplines (engineering, legal, media, and public discourse).
- Educate a wider community by clarifying for each level what role (if any) drivers have in performing the dynamic driving task while a driving automation system is engaged.

OVER FOR A TABLE SUMMARIZING LEVELS OF AUTOMATION FOR ON-ROAD VEHICLES – J3016

Learn more about SAE J3016 or purchase the standard document:
www.sae.org/autodrive



SUMMARY OF SAE INTERNATIONAL'S LEVELS OF DRIVING AUTOMATION FOR ON-ROAD VEHICLES

Issued January 2014, **SAE International's J3016** provides a common taxonomy and definitions for automated driving in order to simplify communication and facilitate collaboration within technical and policy domains. It defines more than a **dozen key terms**, including those italicized below, and provides **full descriptions and examples** for each level.

The report's **six levels of driving automation** span from *no automation* to *full automation*. A **key distinction** is between level 2, where the *human driver* performs part of the *dynamic driving task*, and level 3, where the *automated driving system* performs the entire *dynamic driving task*.

These levels are **descriptive** rather than normative and **technical** rather than legal. They imply **no particular order** of market introduction. Elements indicate **minimum** rather than maximum system capabilities for each level. A particular vehicle may have multiple driving automation features such that it could operate at **different levels** depending upon the feature(s) that are engaged.

System refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*. **Excluded** are **warning and momentary intervention systems**, which do not automate any part of the *dynamic driving task* on a sustained basis and therefore do not change the *human driver's* role in performing the *dynamic driving task*.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Key definitions in J3016 include (among others):

Dynamic driving task includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task.

Driving mode is a type of driving scenario with characteristic *dynamic driving task* requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.).

Request to intervene is notification by the *automated driving system* to a *human driver* that s/he should promptly begin or resume performance of the *dynamic driving task*.

Contact: SAE INTERNATIONAL +1.724.776.4841 • Global Ground Vehicle Standards +1.248.273.2455 • Asia+86.21.61577368

P141661

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
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Dynamic driving task includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task.

A modest proposal

- Define **descriptive** levels 0...5 cf. the SAE for a comprehensive set of tasks
    - Not necessarily the CPL(H) ones
- For each task, level define **normative** metrics that would constitute sufficient and convincing bars of compliance
- …..
- Profit!

1 Why?

2 What?

3 How?

4 Yes?

www.daedalean.ai