

Queen Mary University of London  
20 October 2020

# Simulation in Aerospace

**Andy Fawkes**  
External Lecturer



Carleton University

THINKE





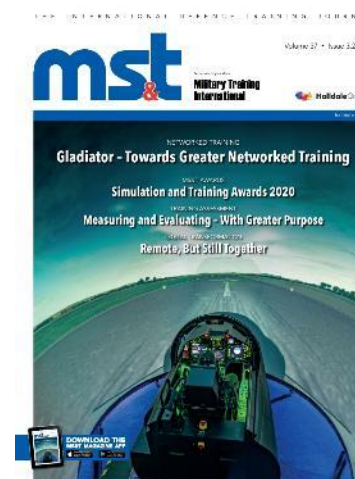
# The Presenter

FIMechE  
MRAeS

## Before



## Now



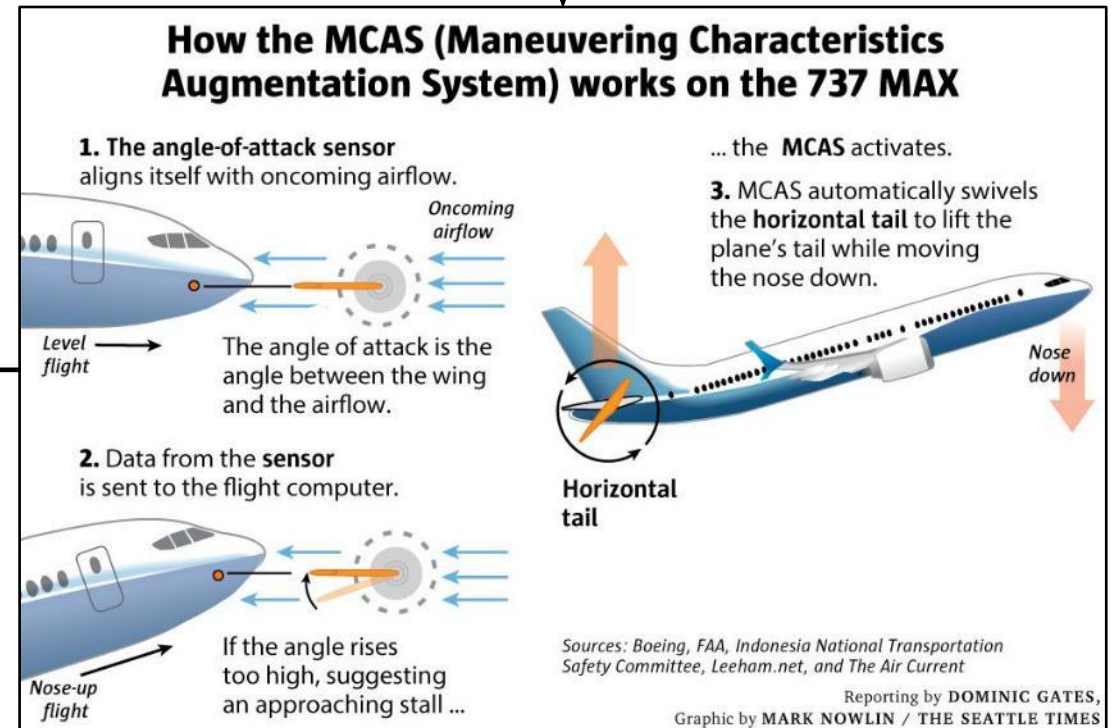
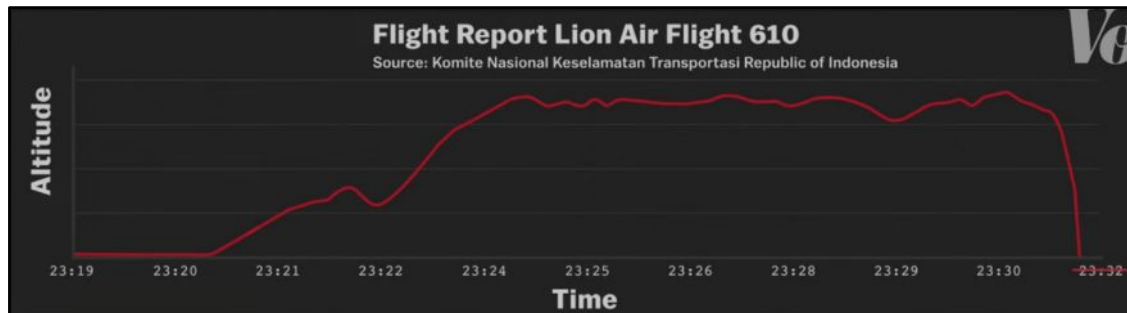
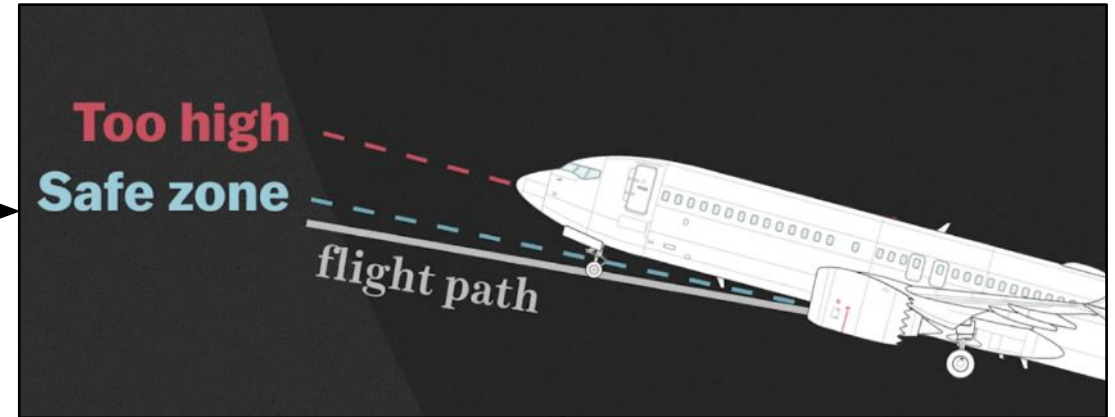
# Outline

1. **What is, and Why, Simulation?**
2. **A Short History of Fight Simulation**
3. **Training, Simulation and Gaming**
4. **The Human Dimension of Flight**
5. **Digital Twins**
6. **Thoughts on Careers**

# Humans & Flight - 1903



# Boeing 737 MAX

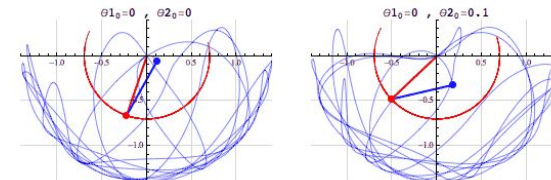
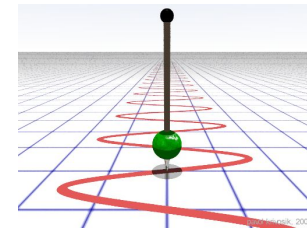
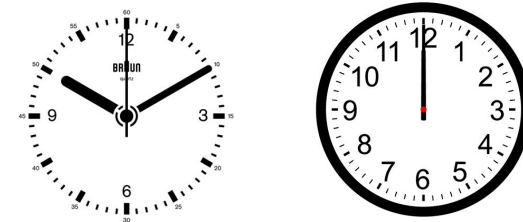
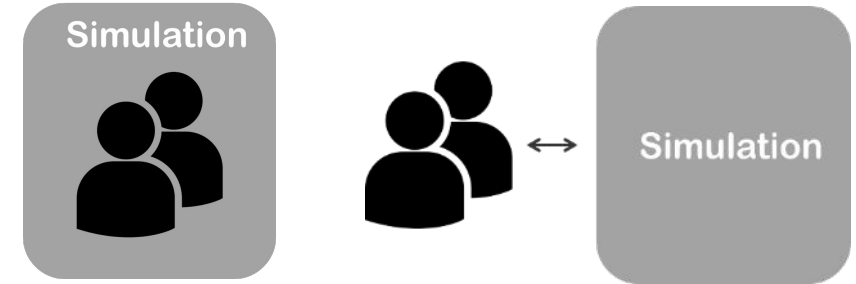


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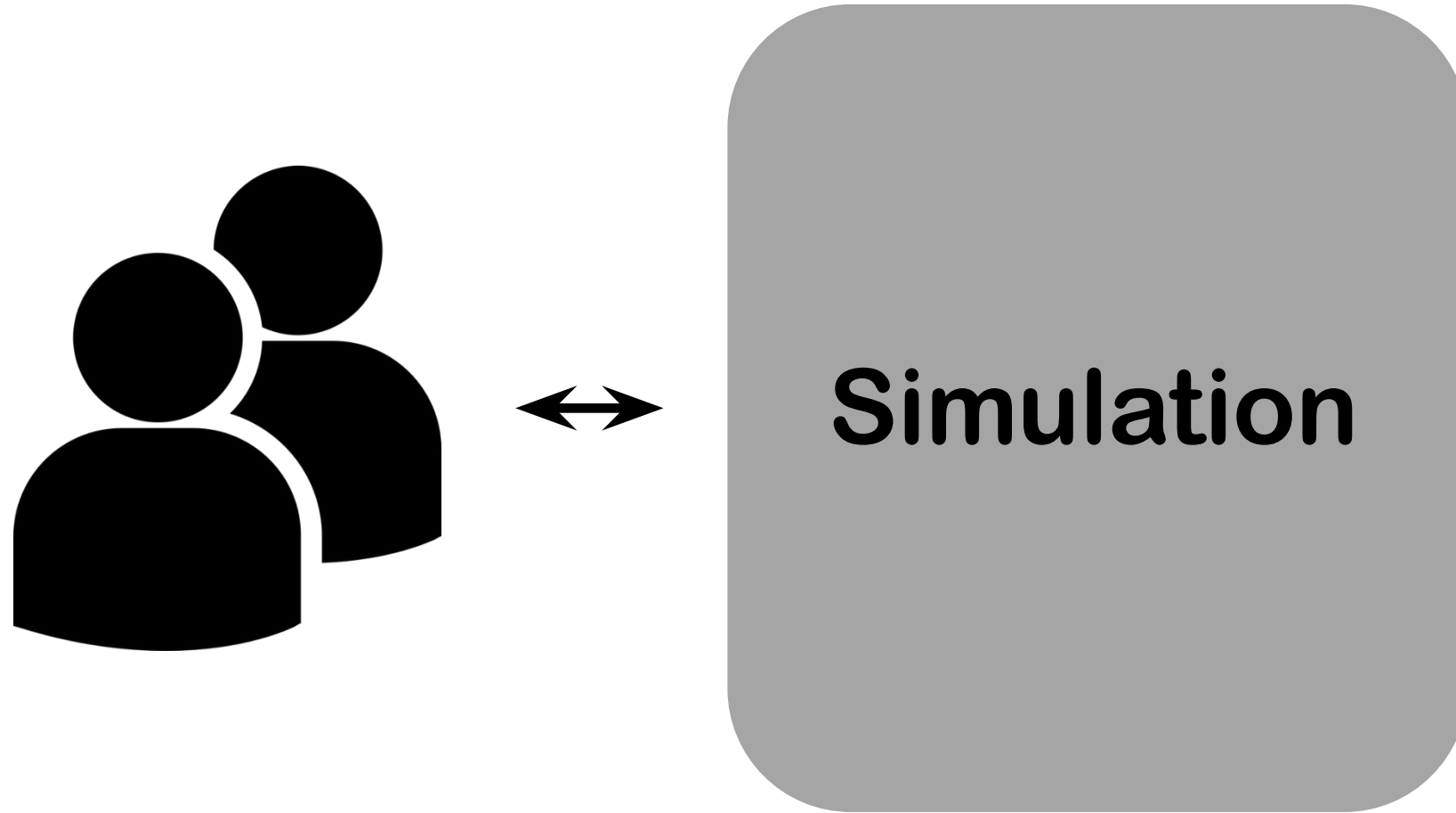
# What is, and Why, Simulation?

# What is Simulation?

- Humans Inside or Outside
- Runs in Real or Non-Real Time
- Some Systems have Order
- Some Systems are Chaotic
- Some are Random



# Human(s) Outside the Simulation

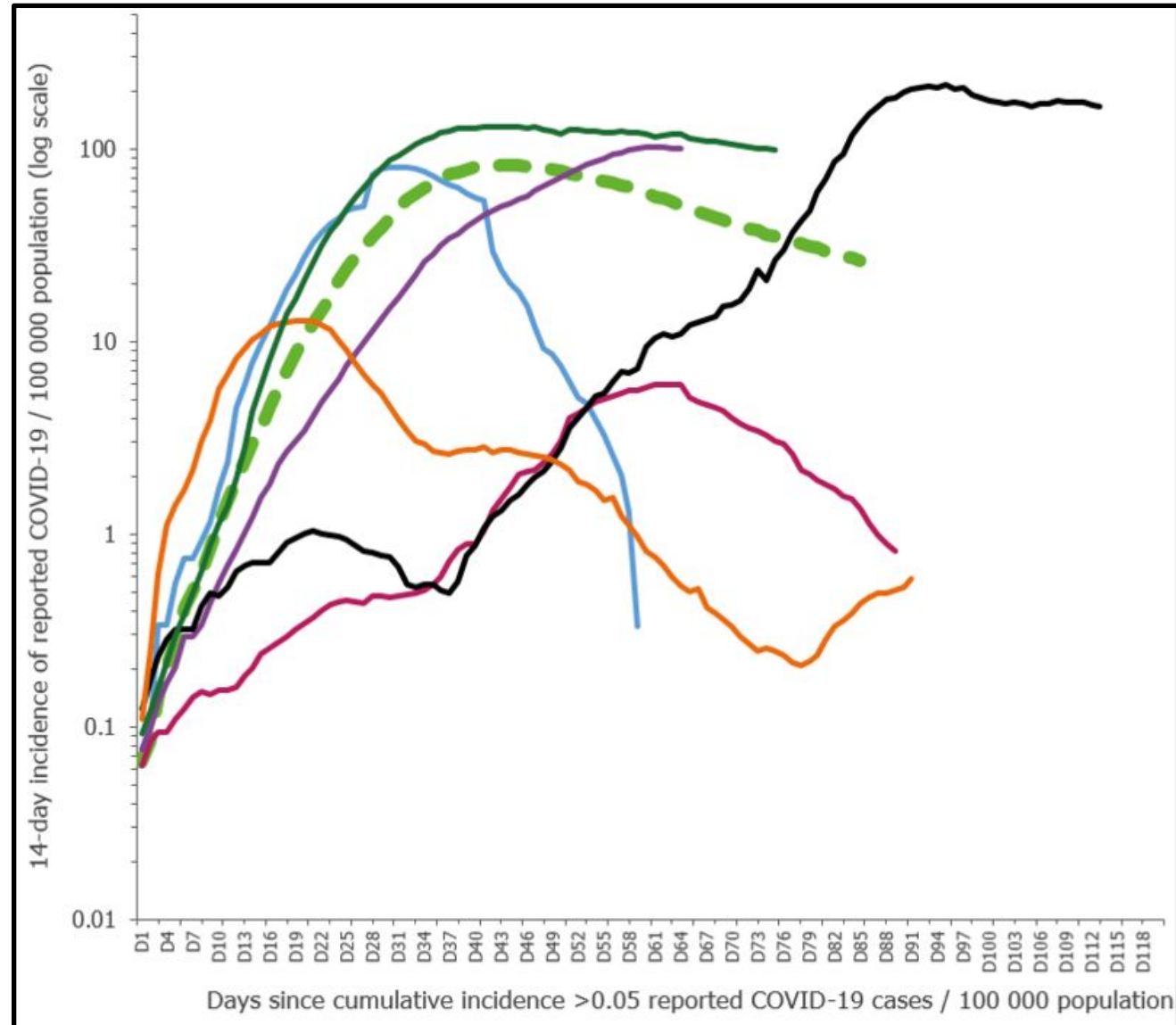


**"Thanks to major investments in research and observations, today's five-day forecast is as reliable as the two-day forecast of 20 years ago"**

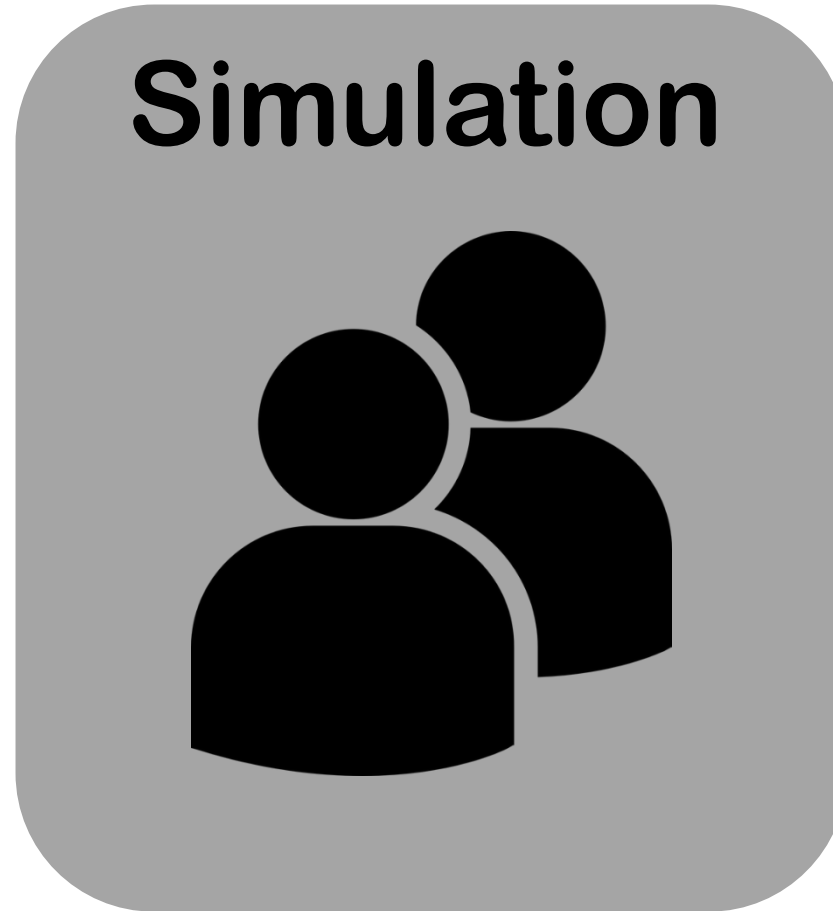
**Michel Jarraud, World Meteorological Organization**



# Simulation Uncertainty



# Human(s) Inside the Simulation



# Flight Simulator



# Simulation Technology Drivers

- Computing
- Games
- Networking
- Graphics
- Audio
- Human Interfaces
- Sensors
- AI



# Why Flight Simulation?

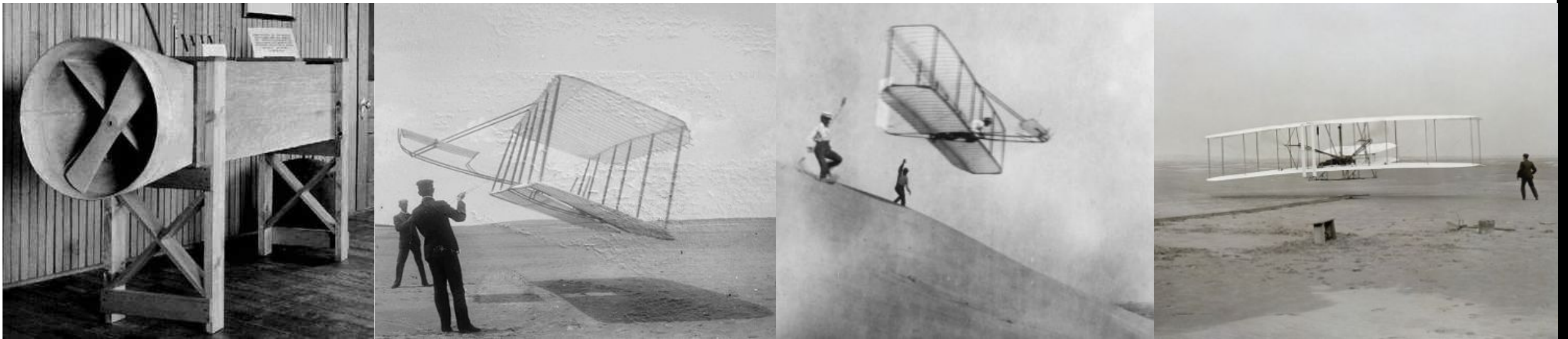


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# A Short History of Flight Simulation

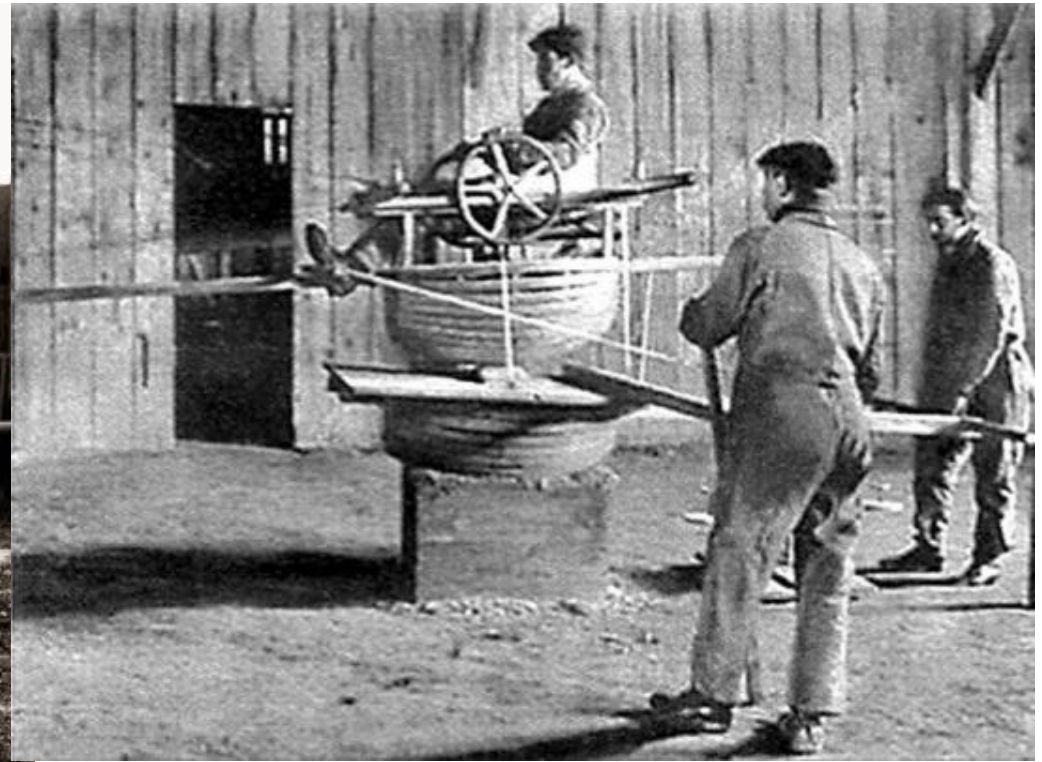
# 1903

- **Wright Brothers**
  - Test
  - Train



# 1910s

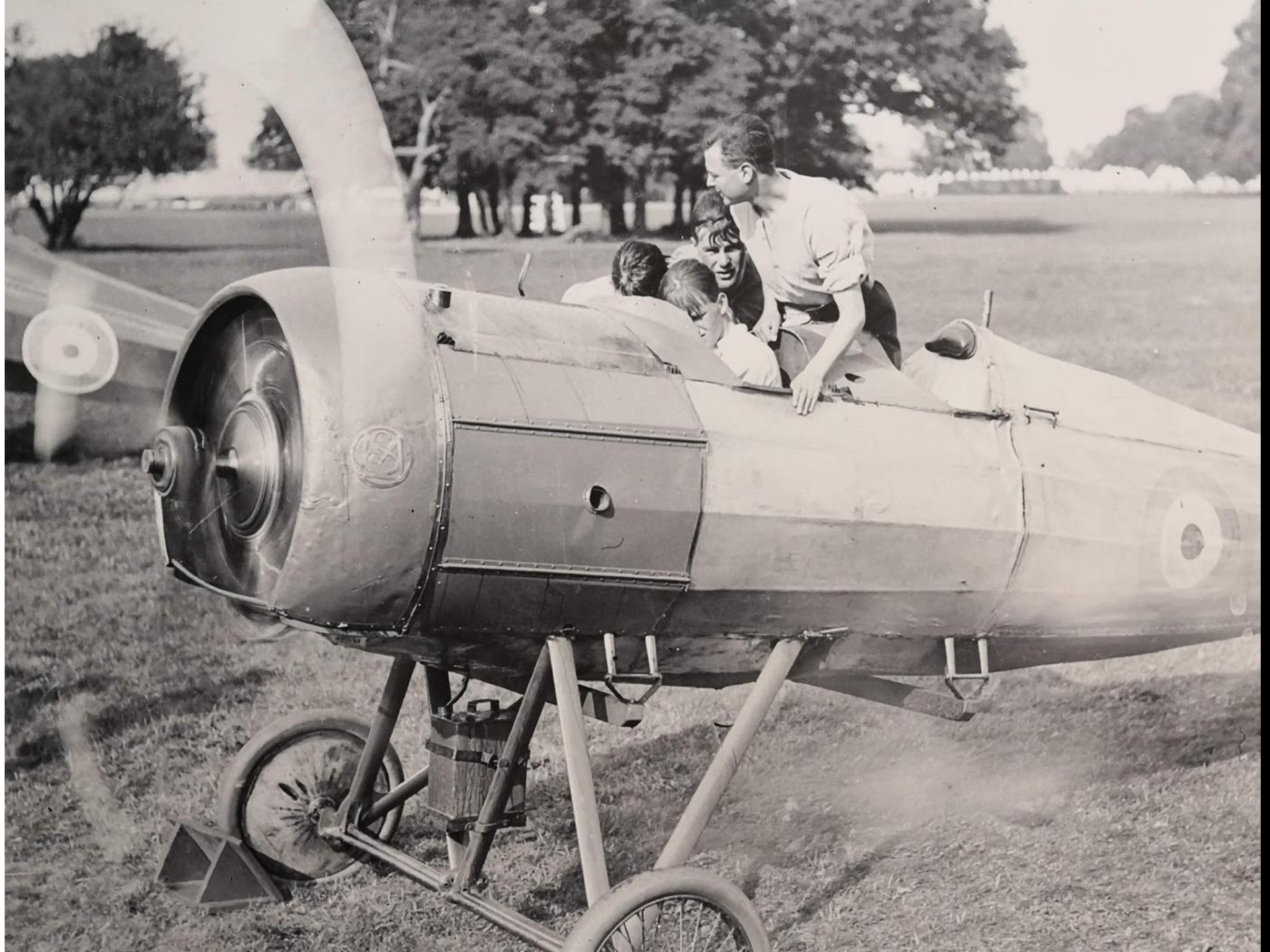
## Leon Levavasseur's Antoinette Barrel – France 1910



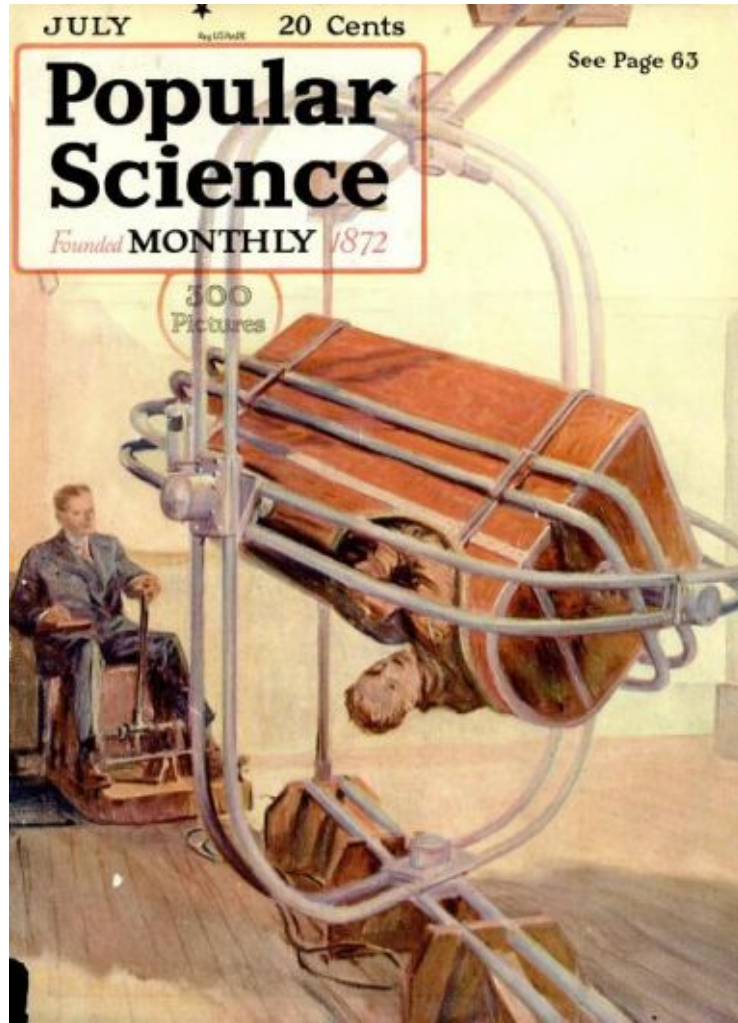
# 1918 - “Penguin”

Cadets and  
Instructor

No.1 School of  
Aeronautics,  
Reading



# Popular Science - July 1919



Ruggles Orientator

**“90% of the flying casualties during the war were caused not by bullets, or badly built machines, but by "the failure of the man”**

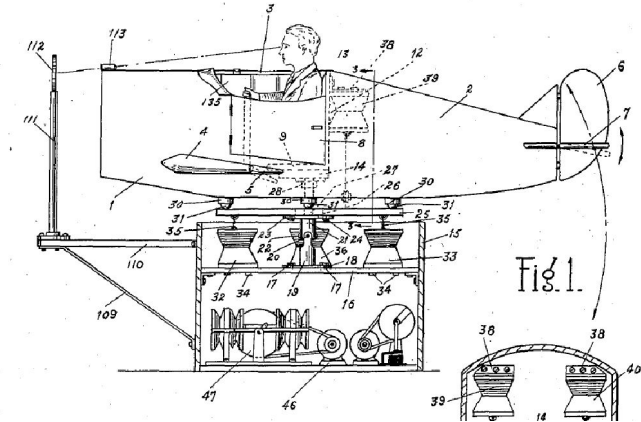
**Maj.-Gen. George W. Squier**

# 1920s/30s – Edwin A Link

- Trainer based on Automatic Piano technology
- 1931 Patent “Combination Training Device for Student Aviators and entertainment Apparatus”
- The Link Trainer came into widespread use during WWII
- 10,000 trainers used to improve safety and shorten training time for over 500,000 pilots

Sept. 29, 1931.

E. A. LINK, JR.  
COMBINATION TRAINING DEVICE FOR STUDENT  
AVIATORS AND ENTERTAINMENT APPARATUS  
Filed March 12, 1930 4 Sheets-Sheet 1



# WW2 Link Trainer



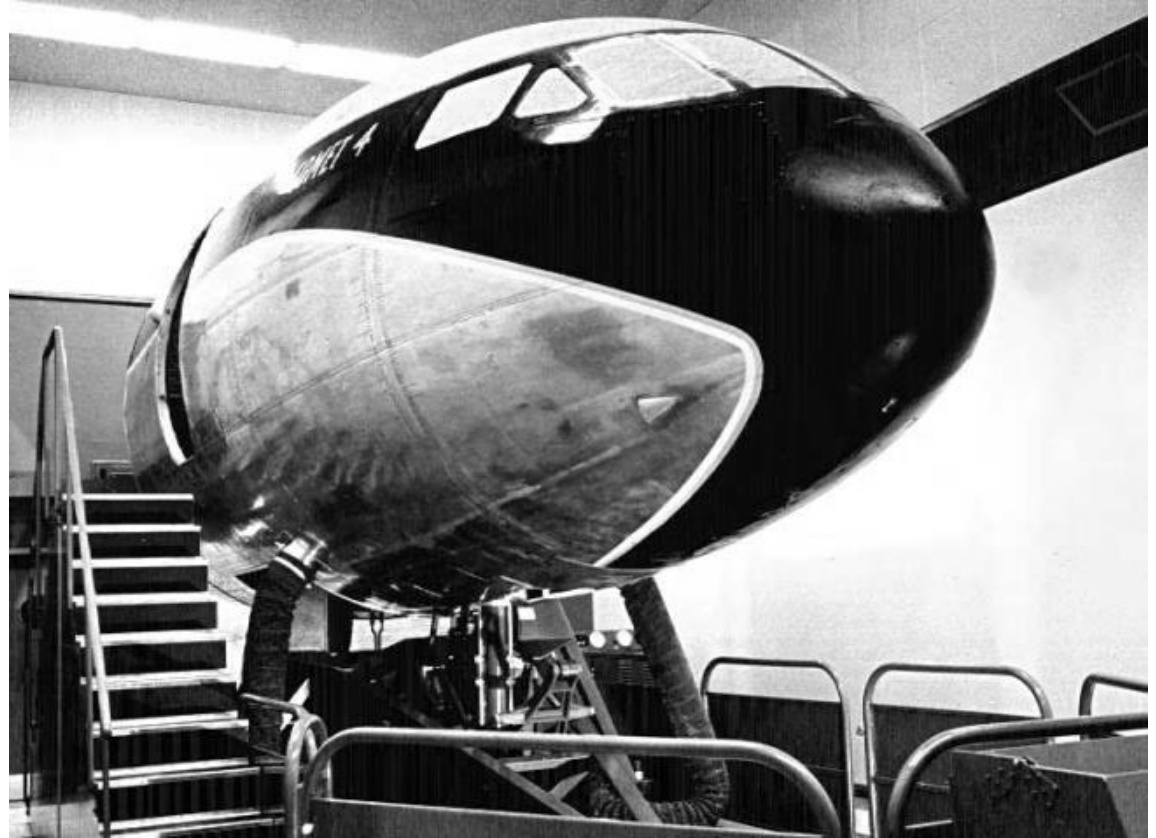
# Maritime Link Trainer



Source - UK Urban Exploitation Forums - Crail  
Airfield [HMS Jackdaw/HMS Bruce/JSSL]

# 1950s

- **Analogue to Digital Computing**
- **More complete aircraft data**
- **Motion Simulators**



# 1960s

## NASA Moon Landing Simulator



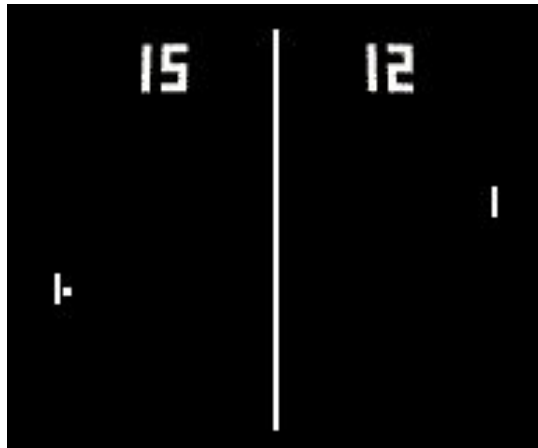
# SR-71 Blackbird

**Fred Forehand, Singer-Link's SR-71 PM:**

- “They created the mission upstairs, and the tape they produced for the simulator was the same tape used onboard in the aircraft computer.”



# PONG - 1972



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a \$3570\* value  
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**ODYSSEY** the exciting TV  
Electronic Game Center

This year give the gift that makes TV more than something to just sit and watch. Odyssey easily attaches to any TV—black and white or color, 17" diagonal or larger—and transforms it into a challenging electronic playground of fun and learning for the entire family. Like Hockey and Tennis. Arithmetic games, like Analogic. Geography games, like States. And pure fun games, like Simon Says and Haunted House. And, now, just in time for the holidays, you get six extra games free! So give Odyssey by Magnavox. Odyssey is thought, action and reaction. It's a play and learning experience for all ages. Odyssey—model TL200.

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TABLE TENNIS  
SKI  
CAT AND MOUSE

**All for.... \$99<sup>95</sup>**  
A \$135.65 VALUE

**ODYSSEY**  
ODYSSEY  
ODYSSEY  
ODYSSEY  
ODYSSEY

6

Magnavox Odyssey - world's first  
commercial home video game console  
(\$500 at 2020 prices)

# 1960/70s

## Redifon's Laser Revolution

Advances in the technology of visual simulation in recent years has been dramatic. Computer generated image visuals for example have in the space of just seven years revolutionised the entire business of flight simulation.

In civil simulation especially, CGI is undoubtedly the way ahead with future development geared to improving scene content in general and daylight display techniques in particular. But what else does the future hold in visual simulation?

That's a question that could well be answered by a development programme currently underway at Redifon's Cranley research and development facility. It's a programme in which Redifon, with American Airlines is probing the use of laser technology to produce a wide angle high resolution visual display.

The systems relevance lies



An artist's impression of how a scanned laser visual system may be applied to simulators in the future.

primarily in the area of tactical military mission simulation where a high degree of scene detail is essential to promote low altitude perception. Current generation visual systems whilst addressing some of the problems of scene content and resolution are severely limited in terms of continuous field of view.

In assessing these limitations Redifon engineers, as long ago as 1964, proposed a visual system that would be capable of combining high scene content and picture resolution with a wide angle display. The proposal was revolutionary in that it used scanned laser beams as a medium to generate and display the image.

Simulator News is the quarterly news magazine of Redifon Simulation Ltd. Published by the Public Relations Department. Redifon Simulation Ltd., Gatwick Road, Cranley, West Sussex. Publication No. 4. Produced and printed by Newman-Thornhill, 13 Albion Street, Brighton, Sussex.



The laser camera operates here on a 'map of the earth' scene scaled at 1000:1

also represents a major advance in the whole area of technology associated with laser based optical systems.

The development programme is currently entering its final stage to build a full colour production prototype equipment. On the basis of results so far, however, it is quite realistic



# SIMNET Vision - 1978

Networks of simulators that would be used for combat planning, rehearsal & execution

1



Enemy aggression detected

2



Planning a response

3



Rehearsal and analysis

4

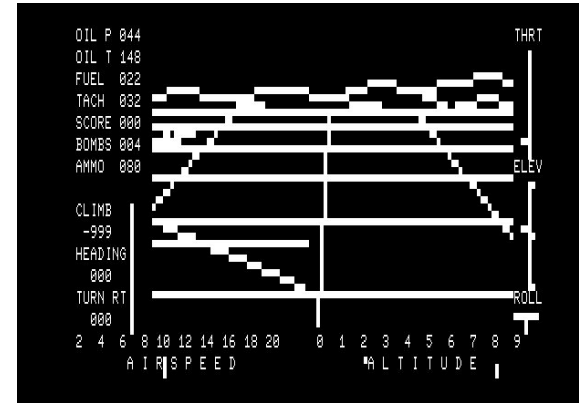


Real time mission observation

# (Microsoft) Flight Simulator



**subLOGIC Flight Simulator 1 for  
Apple II, 1979  
(sold Jan 80)**



**subLOGIC Flight Simulator 1 for  
TRS-80, 1980**



**Microsoft Flight Simulator 1.00, 1982**



# Multiplayer Games! - 2000



Source – Half life Counter-Strike - <http://youtu.be/mex00PAACyk?t=4m13s>

# Consumer Flight Simulation Now



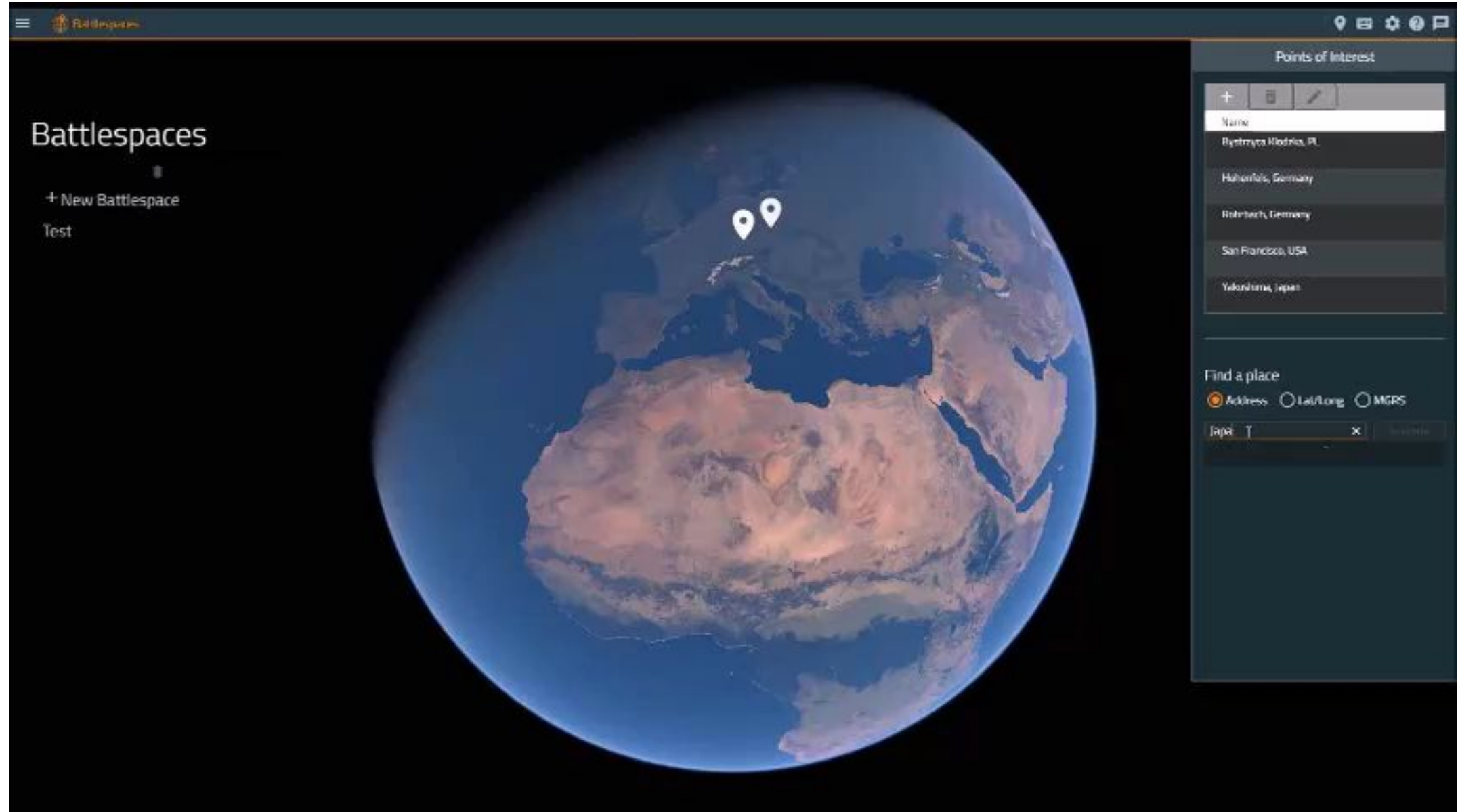
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# Training, Simulation and Gaming

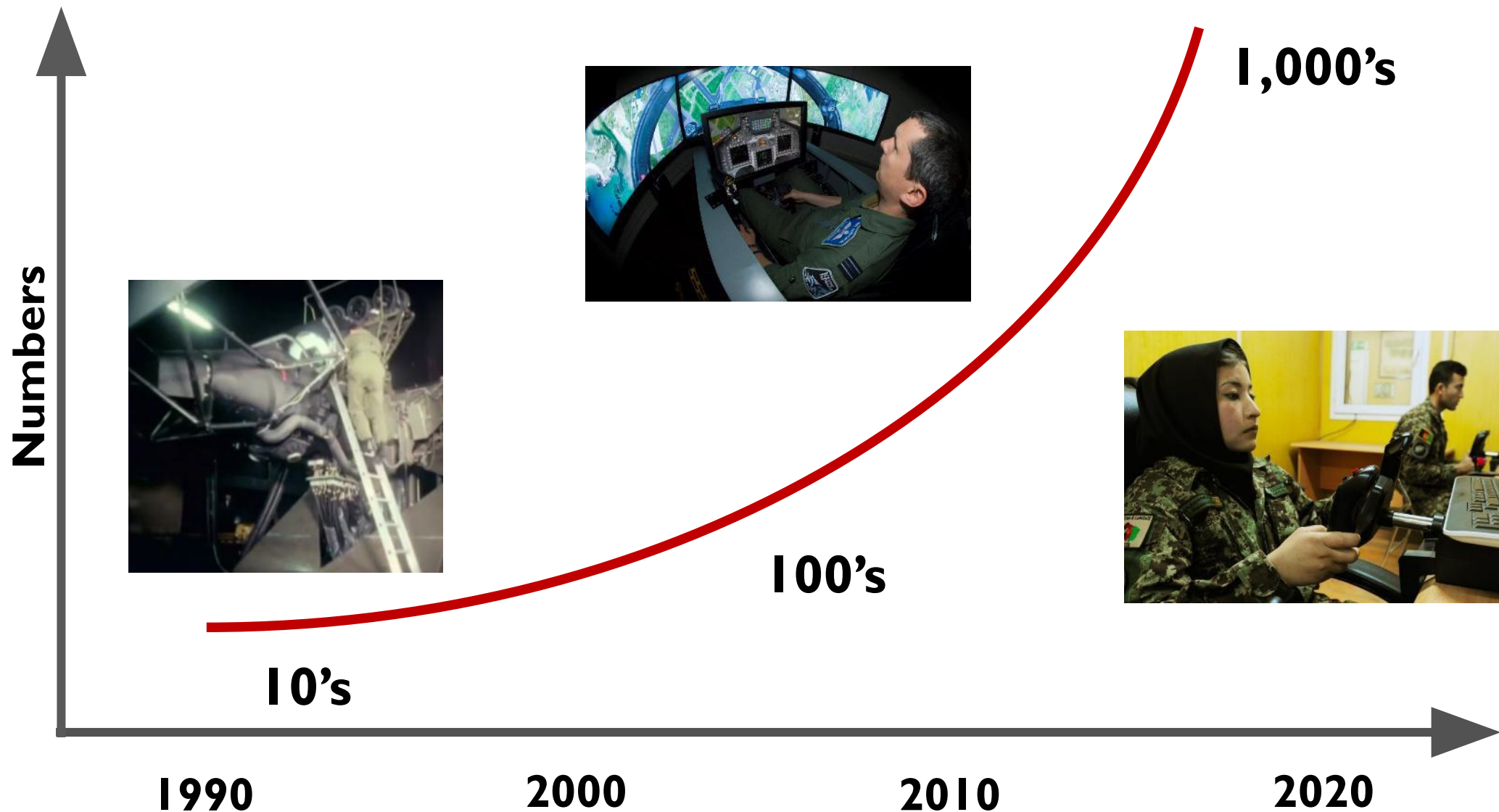
# Simulation Now - Land, Sea, Air, Anywhere



# Whole Earth Simulation



# Military Access to Simulation



# Fast Jet Training at RAF Valley (UK)



# Predator UAV Training Simulator (L-3)

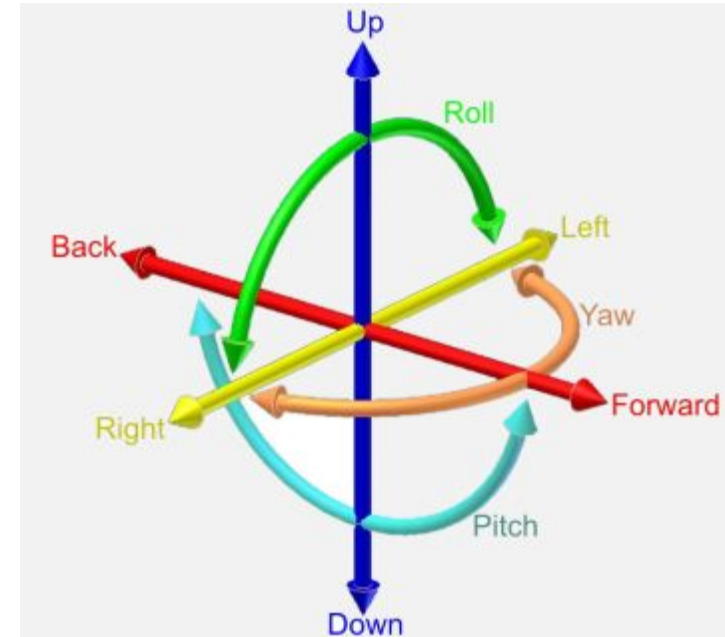
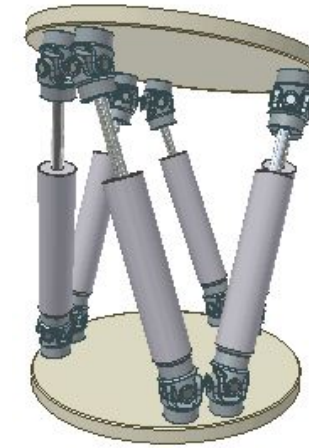


# Full Flight Simulator (FFD)

- Supports conversion to a new aircraft type
- Airline flight crews train 2 days every 6 months
- 40-50 Level D FFS simulator purchased per year



# Stewart Platform - 6 Degrees-of-Freedom



**XR**

# **eXtended Reality (XR)**

| Reality                                                                            | Augmented Reality                                                                   | Mixed Reality                                                                        | Virtual Reality                                                                      |
|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| The real world                                                                     | Information layered over vision                                                     | Blend of real & digital information to enhance reality                               | Fully virtual world                                                                  |
|  |  |  |  |

# Huey Flight Simulator with Oculus Rift





Olli43  
1.46M subscribers

# Microsoft Flight Simulator 2020

YouTube

Search



Microsoft Flight Simulator 2020 - London Update Pack & Viewer Suggestions!

114,410 views • Streamed live on 18 Aug 2020

3K 95 SHARE SAVE ...

Live chat replay ▾



Fly through tower bridge



Craig Davies HIGH END CPU : Ryzen 7 Pro 2700X or Intel i7 9800X GPU : Radeon VII or Nvidia RTX 2080 VRAM : 8 Gb RAM : 32 Gb SSD : 150 Gb Solid State Drive Bandwidth: 50 Mbps



Navdeep Singh @Olli43 disable Hpet on your computer for smoother gameplay look it up on YouTube.



Siddhant Bhurud thats me



Jackson Scaletta do a roll



Hunt3r - Fly over some stadiums in london



SpursFan214 omg i found you



Kentucky Fried-Chicken Who else live near southampton



DodgeGt6 such a cool gamer moment!



SpLiT pErSoNaLiTy GTA 5 car meet



TheGamingBluejay Did he download London or is this streamed?



Slow mode was enabled



HIDE CHAT REPLAY

THINKE



UNREAL ENGINE 5  
FIRST LOOK

# Simulation Trends

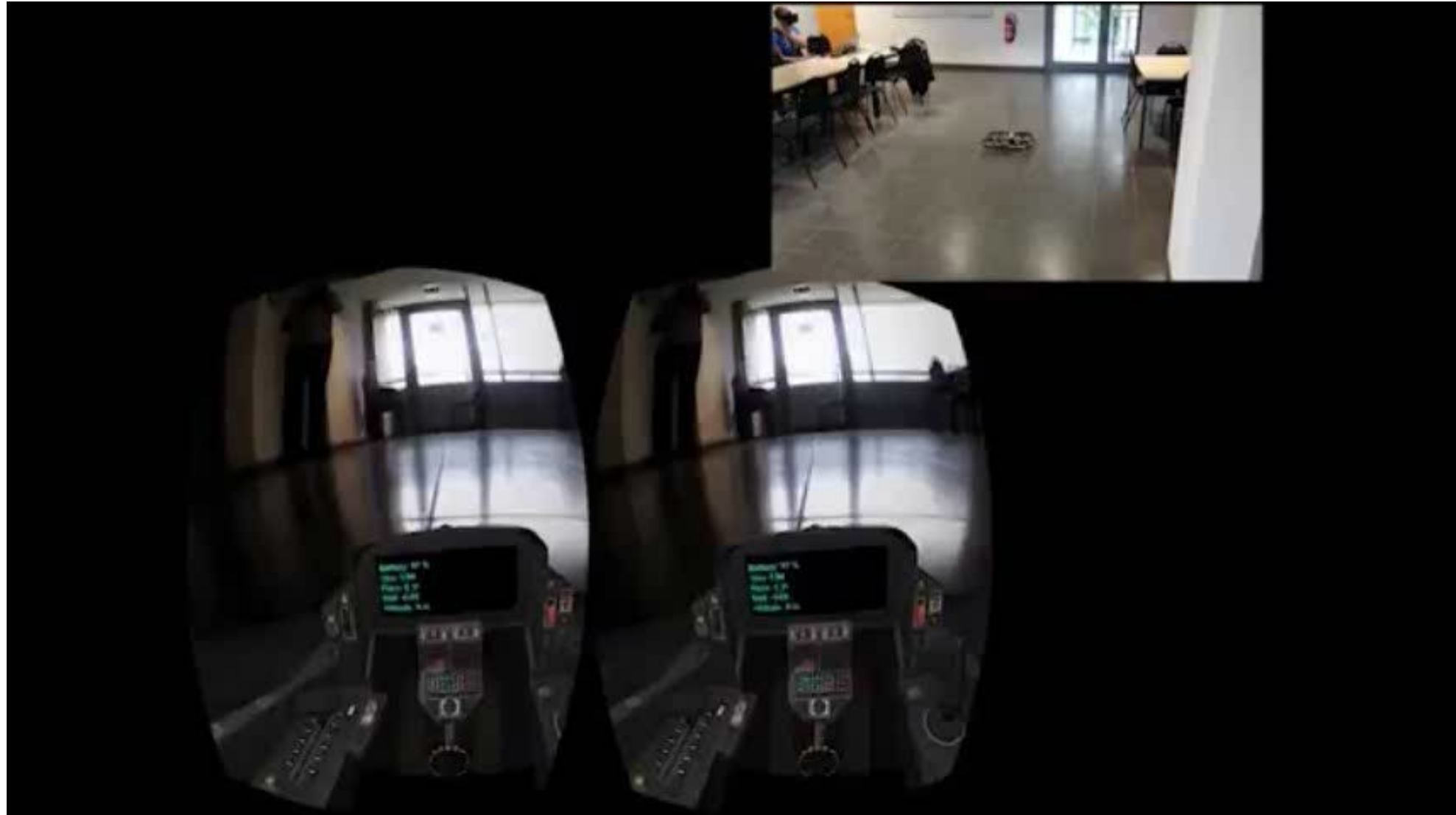
## Unreal 5 (2021)



[youtu.be/qC5KtatMcUw](https://youtu.be/qC5KtatMcUw)

# Rift Drone

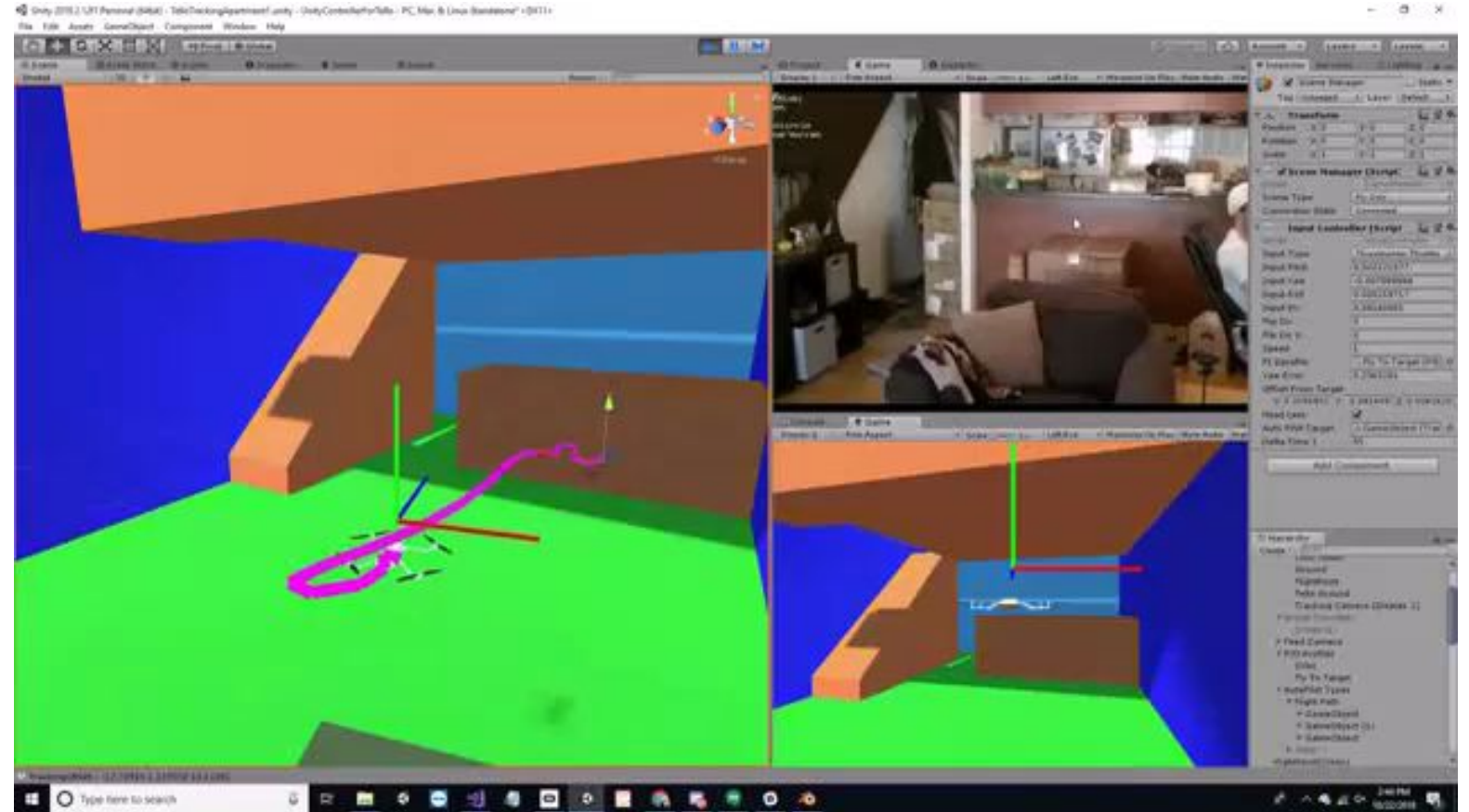
AR.Drone 2.0 + Oculus Rift + Unity + Xbox 360 Controller



Rift Drone is open source: <https://youtu.be/nD2a0OHRmoM>

# Command and Control

# Flight Path Programmed in, and Controlled by, Unity Game Engine

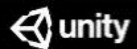




## Machine Learning Agents



# Unity Games Engine Machine Learning Agents *AI Training*



## Machine Learning Agents

Simultaneous Training Demo

Imitation learning



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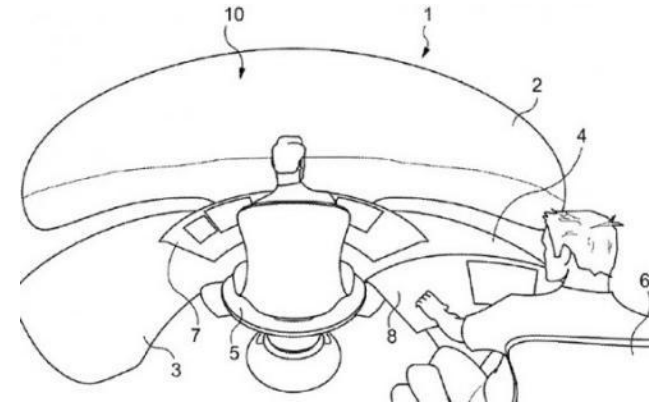
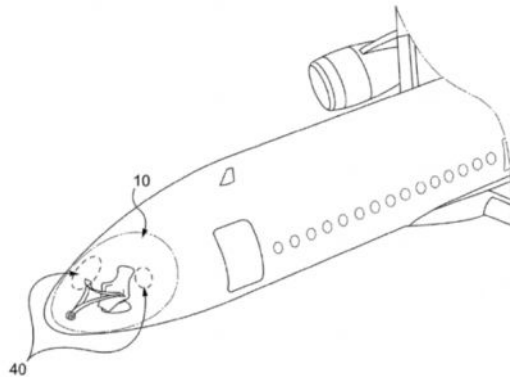
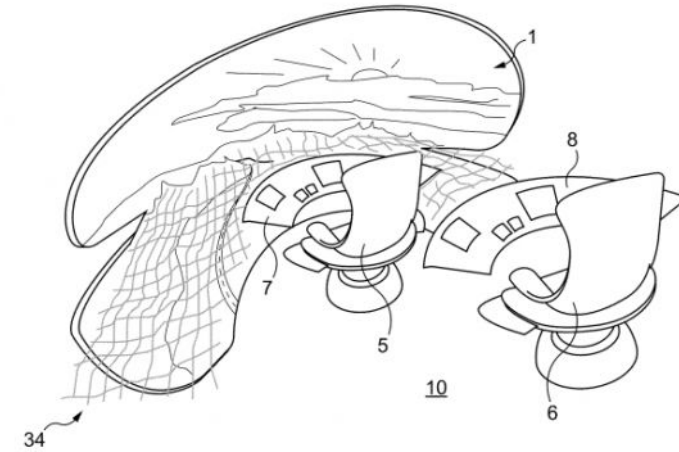
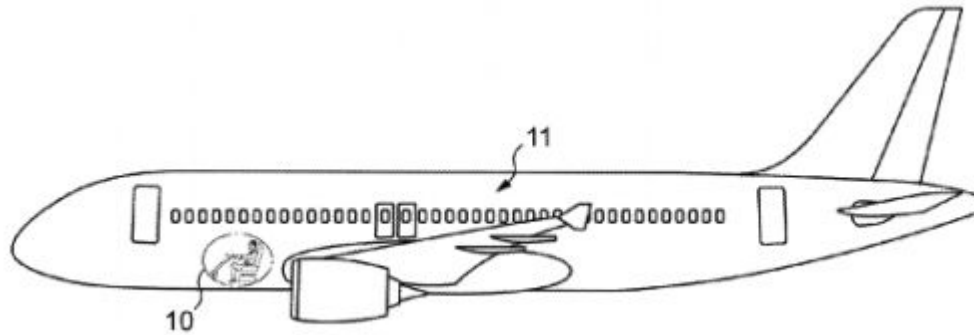
# The Human Dimension of Flight

# Pilots of the Future?



- What will they do?
- Who will they be?
- Where will they be?
- How will they train?
- Will we need them?

# Airbus Windowless Cockpit Patent



**Air Chief Marshal  
Sir Stephen Hillier  
Jan 18**

**“teenagers playing on  
their Xbox at home  
should take their  
gaming to the next  
level and join the RAF  
to operate real drones”**

**MailOnline** News

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## Join the RAF for the real thing, Xbox teenagers are told: Head of the air force says young gamers should take it to the next level by operating drones

- Air Chief Marshal Sir Stephen Hillier wants more young people to join the RAF
- The service will be celebrating their 100th anniversary with events this year
- Among the major events planned is a flypast along the Mall before the Queen
- RAF chiefs hope a display of military might could provide a boost to recruitment

By LARISA BROWN FOR THE DAILY MAIL  
PUBLISHED: 00:32, 12 January 2018 | UPDATED: 00:53, 12 January 2018

387 shares 194 View comments

Teenagers playing on their Xbox at home should take their gaming to the next level and join the RAF to operate real drones, the head of the air force said yesterday.

Air Chief Marshal Sir Stephen Hillier said the RAF's next 100 years will see a huge shift towards unmanned flying machines as he outlined plans for centenary celebrations.



# Queen Bee Drone – 1930s/40s



# BOAC VC10 Automatic Landing (1968)

Source – Pathe



THINKE

# Google DeepMind 2019

GAMING / TECH / ARTIFICIAL INTELLIGENCE

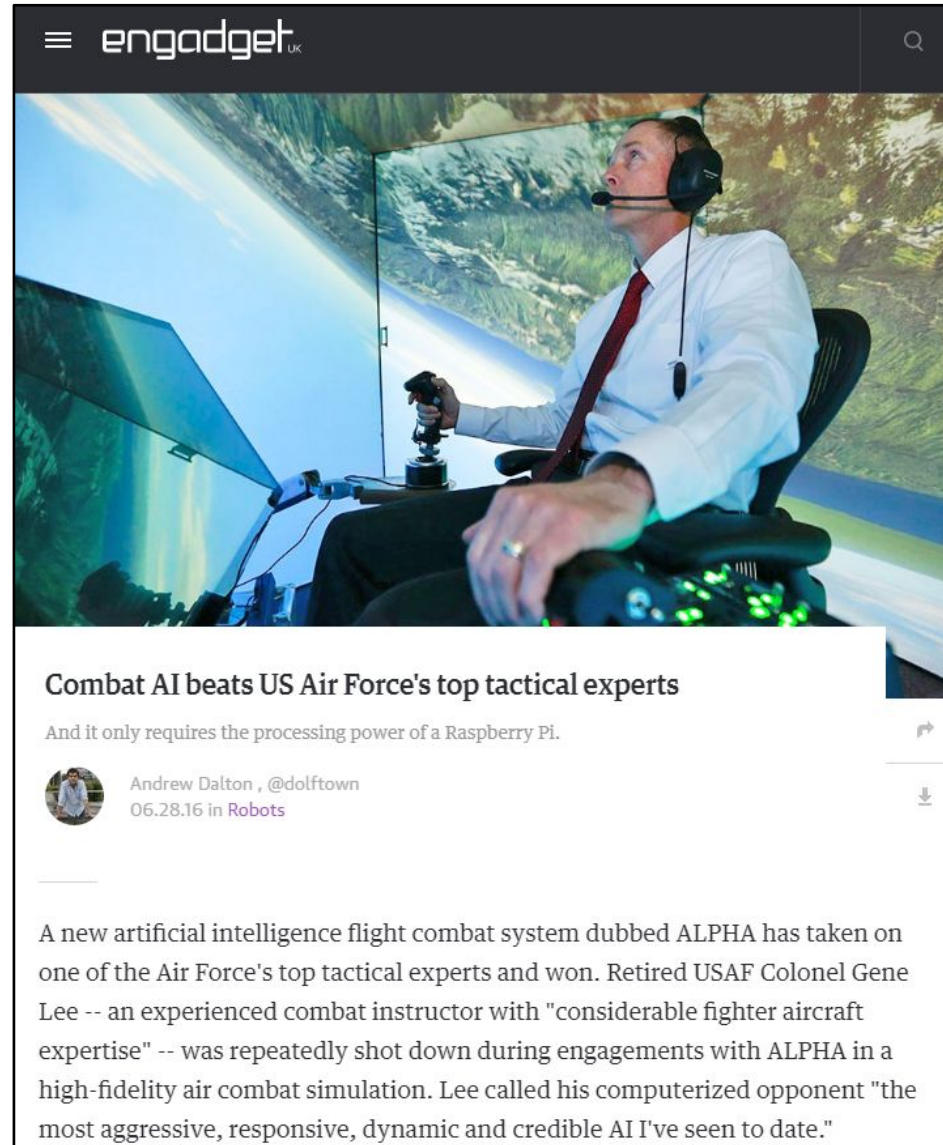
# DeepMind's StarCraft 2 AI is now better than 99.8 percent of all human players

AlphaStar is now grandmaster level in the real-time strategy game

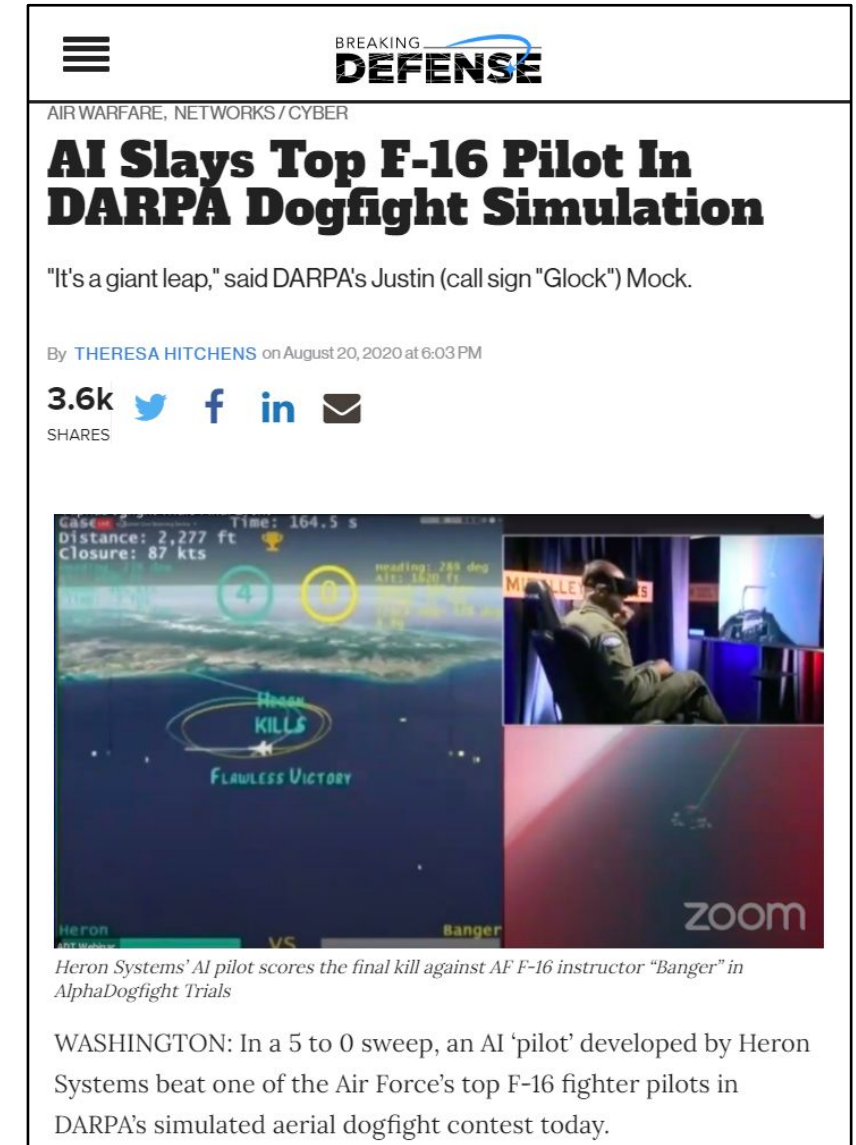
By **Nick Statt** | [@nickstatt](#) | Oct 30, 2019, 2:00pm EDT



# Redundant Pilots?



2016



2020

# Cautionary Tales



# Algorithms...

## Security

### Brit Watchkeeper drone fell in the sea because blocked sensor made algorithms flip out

Report scolds maker Thales for poorly understood software

By Gareth Corfield 15 Apr 2019 at 13:58

120 SHARE ▼



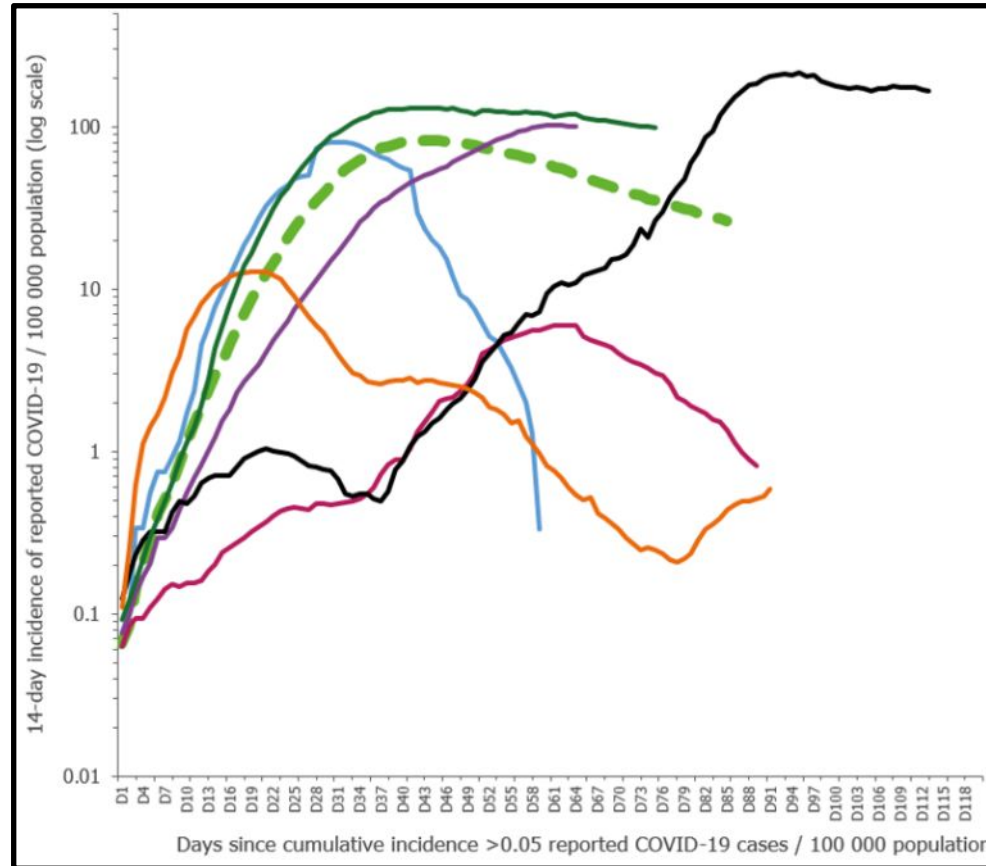
A Thales Watchkeeper drone. File pic, Crown copyright

A British Army Watchkeeper drone stalled itself and crashed into the sea on a bad weather flight test, military investigators have said – though most of the wreckage was never found.

Investigators concluded that one of its pitot probes used for reading the aircraft's speed and angle of attack (AOA) became blocked, causing the Watchkeeper's onboard flight control logic to enter an erratic series of climbs and dives until it stalled itself and flopped into the sea. They criticised the craft's maker, Thales, for not fully understanding how its algorithms responded to loss of accurate sensor data.

Air Marshal Susan Gray, director general of the Defence Safety Authority, criticised the Ministry of Defence and Thales for their "incomplete level of detailed technical understanding" regarding the drone and its systems.

# AI Limitations



Artificial intelligence / Machine learning

## Our weird behavior during the pandemic is messing with AI models

Machine-learning models trained on normal behavior are showing cracks —forcing humans to step in to set them straight.

by Will Douglas Heaven

MIT  
Technology  
Review

May 11, 2020

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In the week of April 12-18, the top 10 search terms on Amazon.com were: toilet paper, face mask, hand sanitizer, paper towels, Lysol spray, Clorox wipes, mask, Lysol, masks for germ protection, and N95 mask. People weren't just searching, they were buying too—and in bulk. The majority of people looking for masks ended up buying the new Amazon #1 Best Seller, “Face Mask, Pack of 50”.

When covid-19 hit, we started buying things we'd never bought before. The shift was sudden: the mainstays of Amazon's top ten—phone cases, phone chargers, Lego—were knocked off the charts in just a few days. Nozzle, a London-based consultancy specializing in algorithmic advertising for Amazon sellers, captured the rapid change in this simple graph.

# Issues with Automation



# Monitoring Systems



The Register

{\* INTERNET OF THINGS \*}

## Army Watchkeeper drone flopped into tree because crew were gazing backwards

Live footage of runway and grass verge more compelling than actual flight instruments

Thu 29 Aug 2019 // 10:11 UTC

98 GOT TIPS?

Gareth Corfield BIO EMAIL TWITTER

SHARE

The latest British Army Watchkeeper drone crash happened because its crew became fixated on live footage from an onboard camera instead of their instruments, a Ministry of Defence report has revealed.

An internal Defence Accident Investigation Branch (DAIB) report detailed why the semi-autonomous aircraft, tail number WK050 and flown on the day by two Royal Artillery operators, crashed in June 2018.

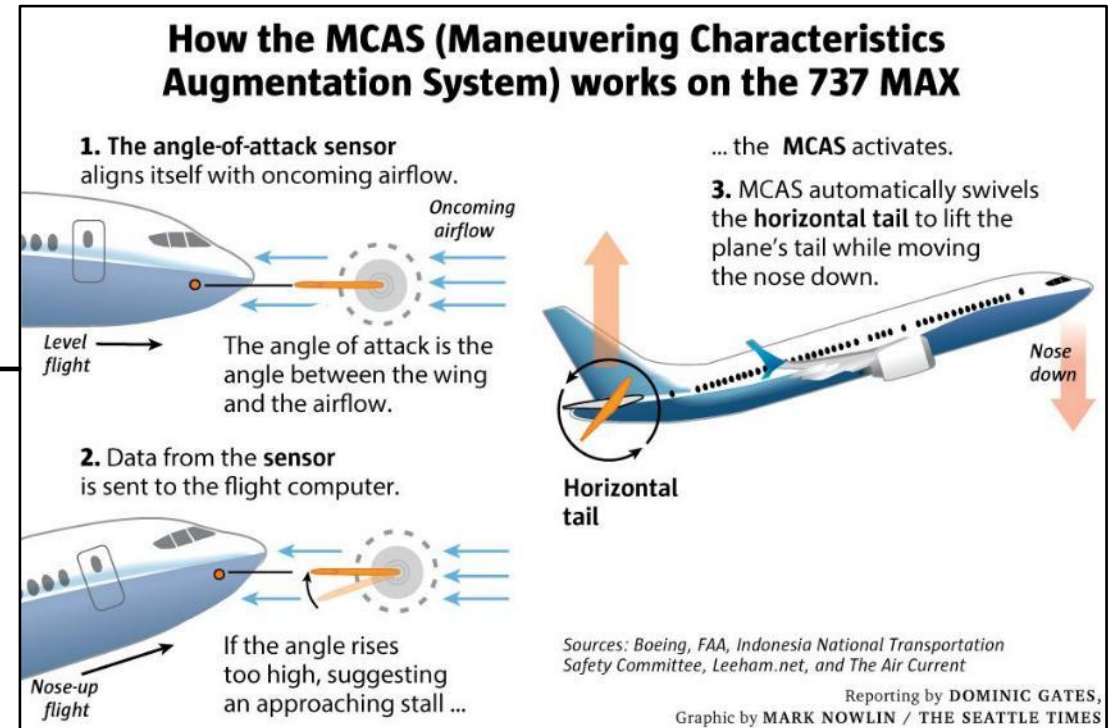
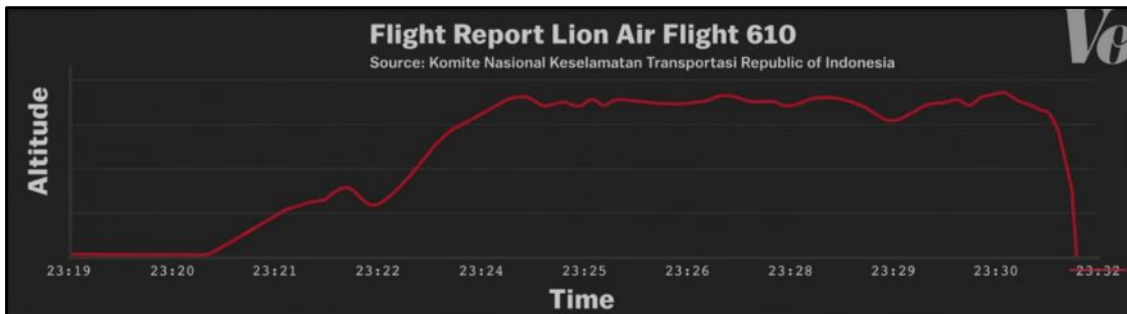
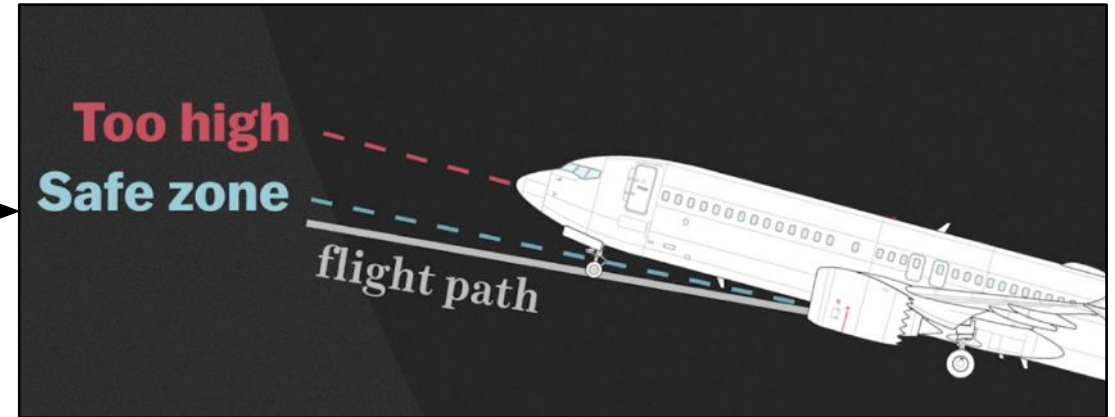
The report, dated February 2019, was [published online](#) by the MoD after the BBC made a Freedom of Information request for it, leading to [news reports](#) over the past few weeks.

WK050 flopped into a tree just beyond the runway of Aberporth airport on the Welsh coast after its Army operators, under the supervision of contractors from a Thales joint venture company, cut its throttle immediately after the drone had landed and lifted off again.

"Had no action been taken, the [Watchkeeper] would have completed its automatic go-around from which it could have been commanded to conduct a further approach," said the DAIB in its Safety Investigation Report, which was written by a major and a Warrant Officer 1 (WO1).

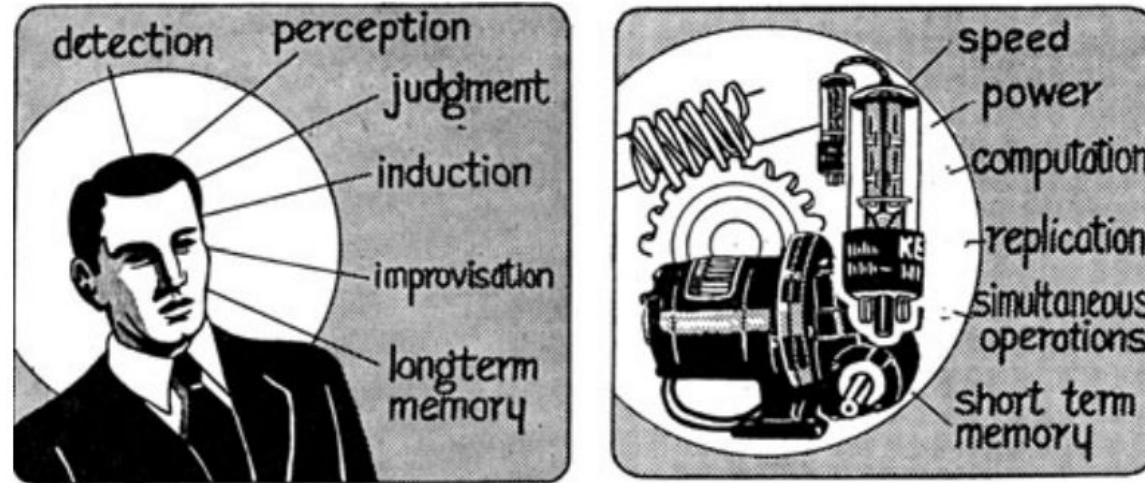


# Boeing 737 MAX



# Paul M Fitts (1951)

## Human Engineering for an Effective Air Navigation and Traffic Control System



- “great caution be exercised in assuming that men can successfully monitor complex automatic machines and take over if the machines break down”
- “engineers should seriously consider systems in which machines would monitor men and prevent them from making dangerous



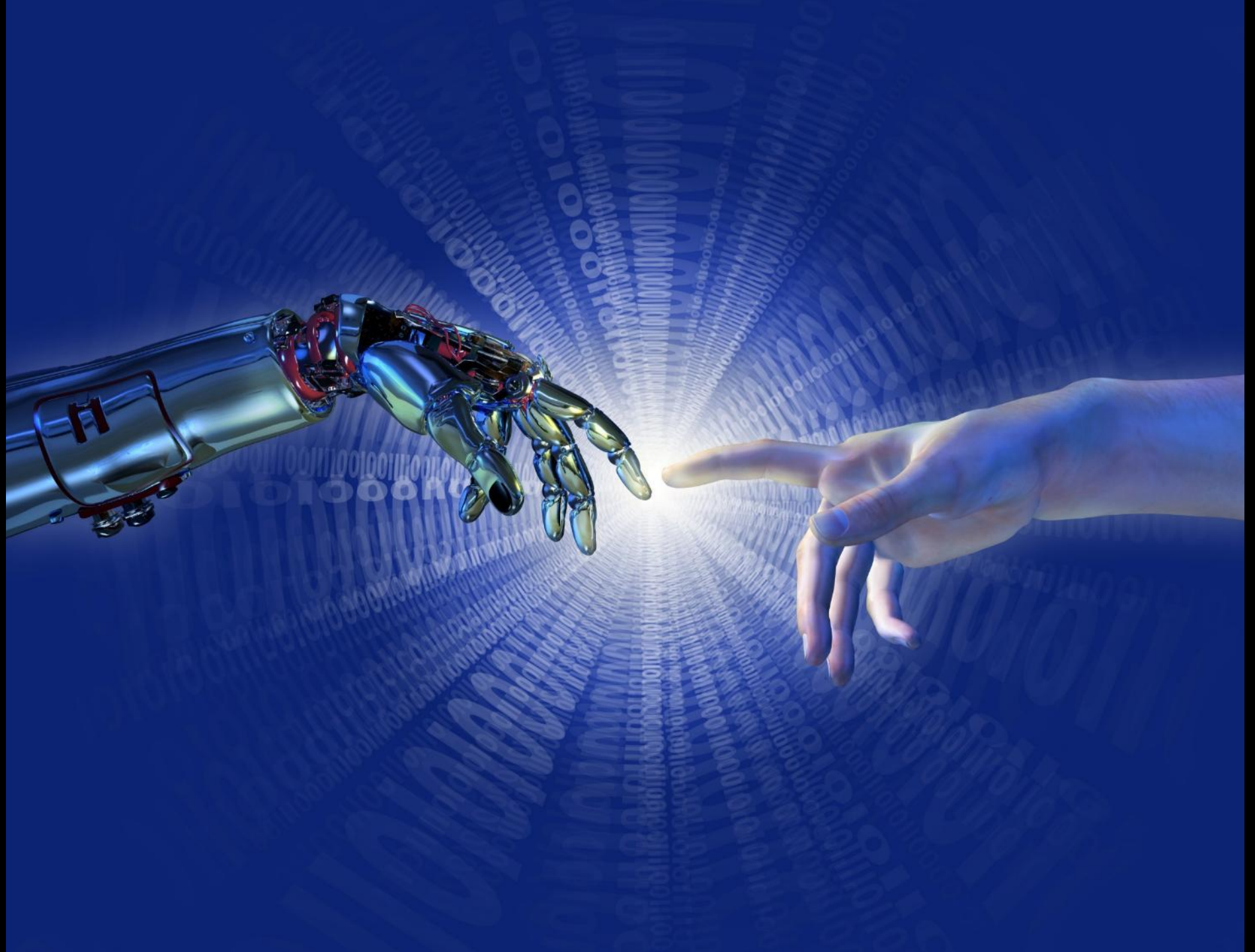
# Responding...

**"If I'm in the loop mentally I can respond more quickly than if I have to watch an automatic system and take over and then get my mind into the loop.**

**So I was more comfortable in flying a manual descent than an automatic descent... my mental computer is already running at full speed."**

**David Scott  
Apollo 15 Commander (1971)**

**Maximise  
the  
Strengths  
of Both**



5/6

# Digital Twins

# “Digital Thread” & “Digital Twin”



Credit: Boeing

AVIATION WEEK  
NETWORK

AVIATIONWEEK  
& SPACE TECHNOLOGY

Step **INSIDE** the next evolution

## USAF Selects Lead Programs For ‘Digital Twin’ Initiative

*Aviation Week & Space Technology*

**Graham Warwick**

Jan 26, 2015

Digital system models are seen as key to regaining understanding of complex systems

### Threading the Needle

Over the years, the U.S. Air Force has come to rely more and more on industry for its technical understanding of the systems it acquires. To reverse that process and bring costs and risks more under its control, the service is experimenting with creating and carrying digital system models through the entire life cycle of a program.

The acquisition process now being piloted has two key elements: the “digital thread,” a model of the system that begins at conceptualization and evolves through its life to retirement; and the “digital twin,” a model of the system as built, including any manufacturing discrepancies, that is used to support the system in service.

# Tupolev Tu-160M2 Digital Twin



# The Price of Data



6/6

# Thoughts on Careers

# Thoughts on Careers

- Have Passion & Purpose
- Be Good to People
- Professionalism trumps Talent
- Don't worry
  - It's mostly beyond your/our control
  - Go to the next interesting job





**ROYAL  
AERONAUTICAL  
SOCIETY**

# Royal Aeronautical Society (RAeS)

# RAeS Student Affiliate Membership

- **Free** Student Affiliate membership, if in full-time study and intending to follow a career in aerospace
- **Benefits:**
  - Online access to the monthly magazine, AEROSPACE
  - Free attendance to over 400 lectures and events worldwide and often at a branch or Division near you
  - Free places at RAeS Conferences (subject to demand)
  - Free 1-2-1 careers guidance for UK-based students
  - Support towards professional registration (EngTech, IEng and CEng) with Engineering Council
  - A Young Persons Network with over 8,000 like-minded young professionals worldwide
  - Access to Scholarship Schemes
  - Use of the National Aerospace Library
  - Access to the Members' area of the Society's website



# Questions?

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[andy.fawkes@thinke.co.uk](mailto:andy.fawkes@thinke.co.uk)



Hélène Dutrieu c. 1911