

Queen Mary University of London
25 October 2024

Training and Simulation in Aerospace

Andy Fawkes
External Lecturer





The Presenter

FIMechE
MRAeS

Before



Ministry
of Defence



Now



Institution of
**MECHANICAL
ENGINEERS**

Outline

- 1. What is, and Why, Simulation?**
- 2. A Short History of Fight Simulation**
- 3. Training & Simulation Developments**
- 4. The Human Dimension of Flight**
- 5. Thoughts on Careers**

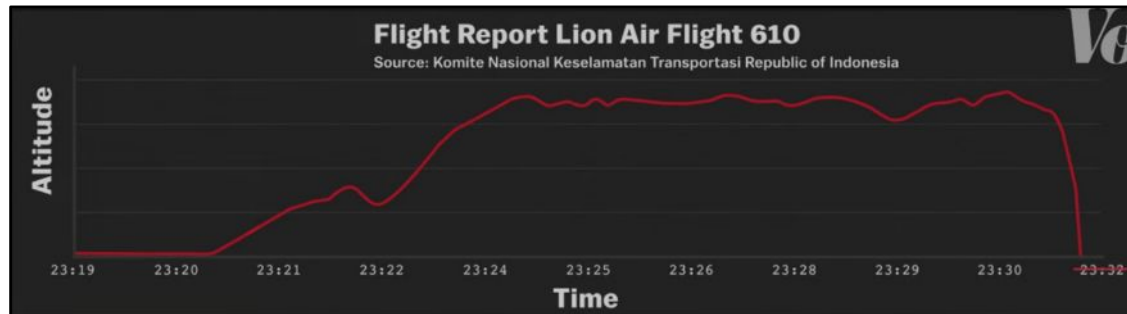
Humans & Flight - 1903



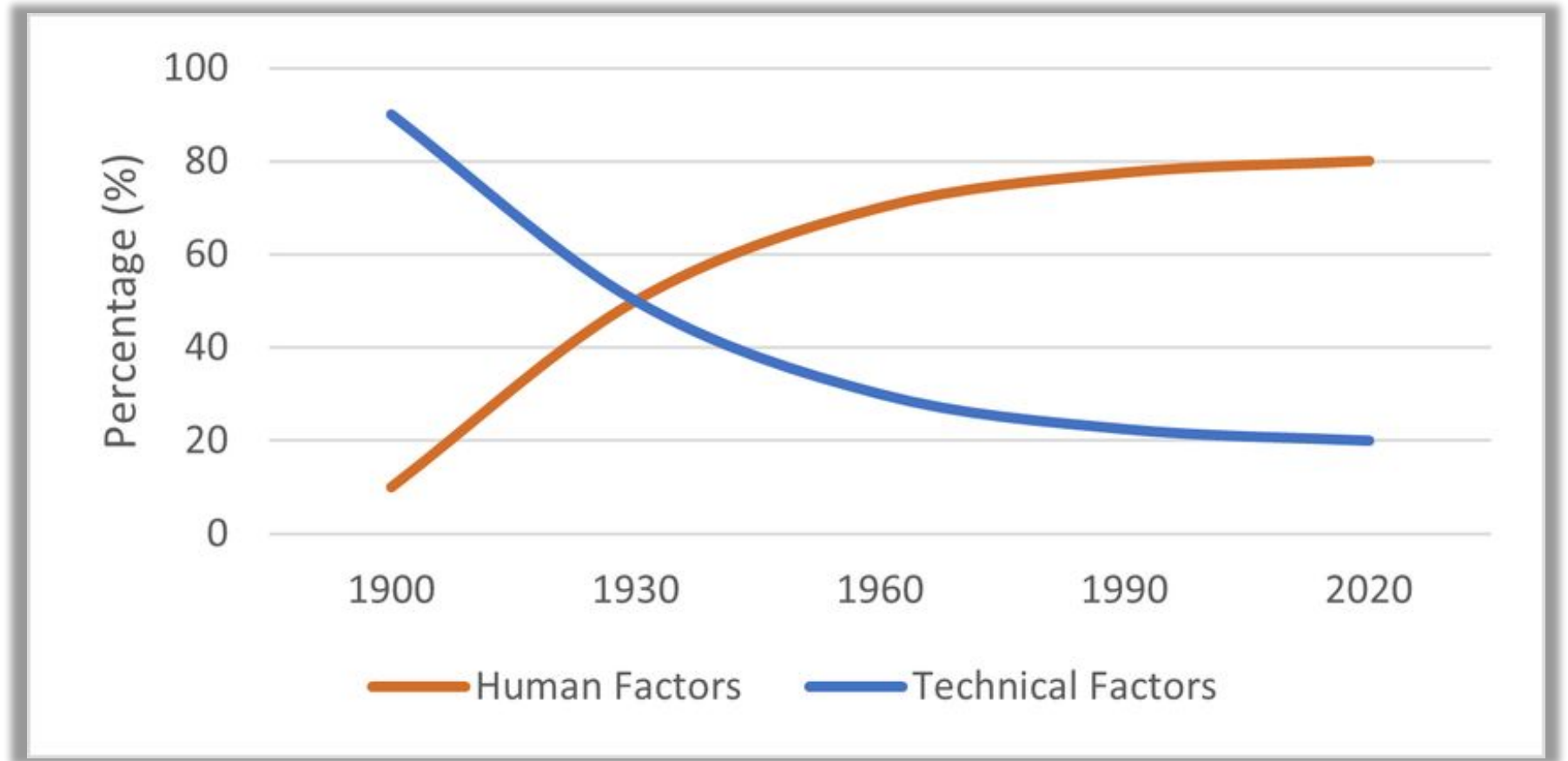
Storm Eunice – Bristol Airport – 18 Feb 22



Boeing 737 MAX (2018 & 2029)



Humans and Aircraft



Drone Racing League (DRL)

&

Drone Racing League Simulator



**Who Owns
the
Technology
Future in this
Space?**

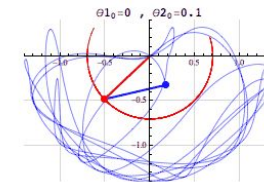
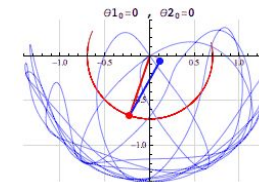
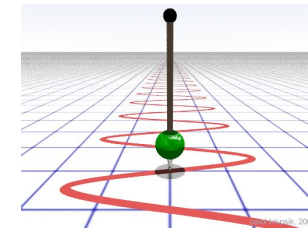
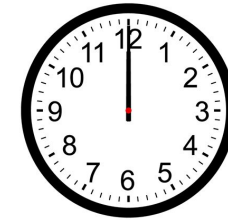
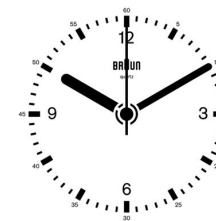
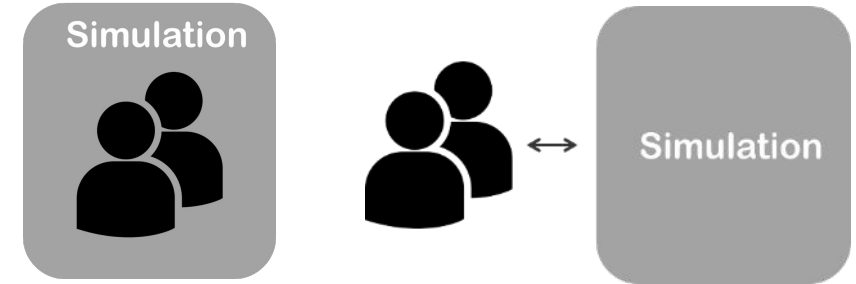
- Military?
- Commerce & Entertainment?

1/5

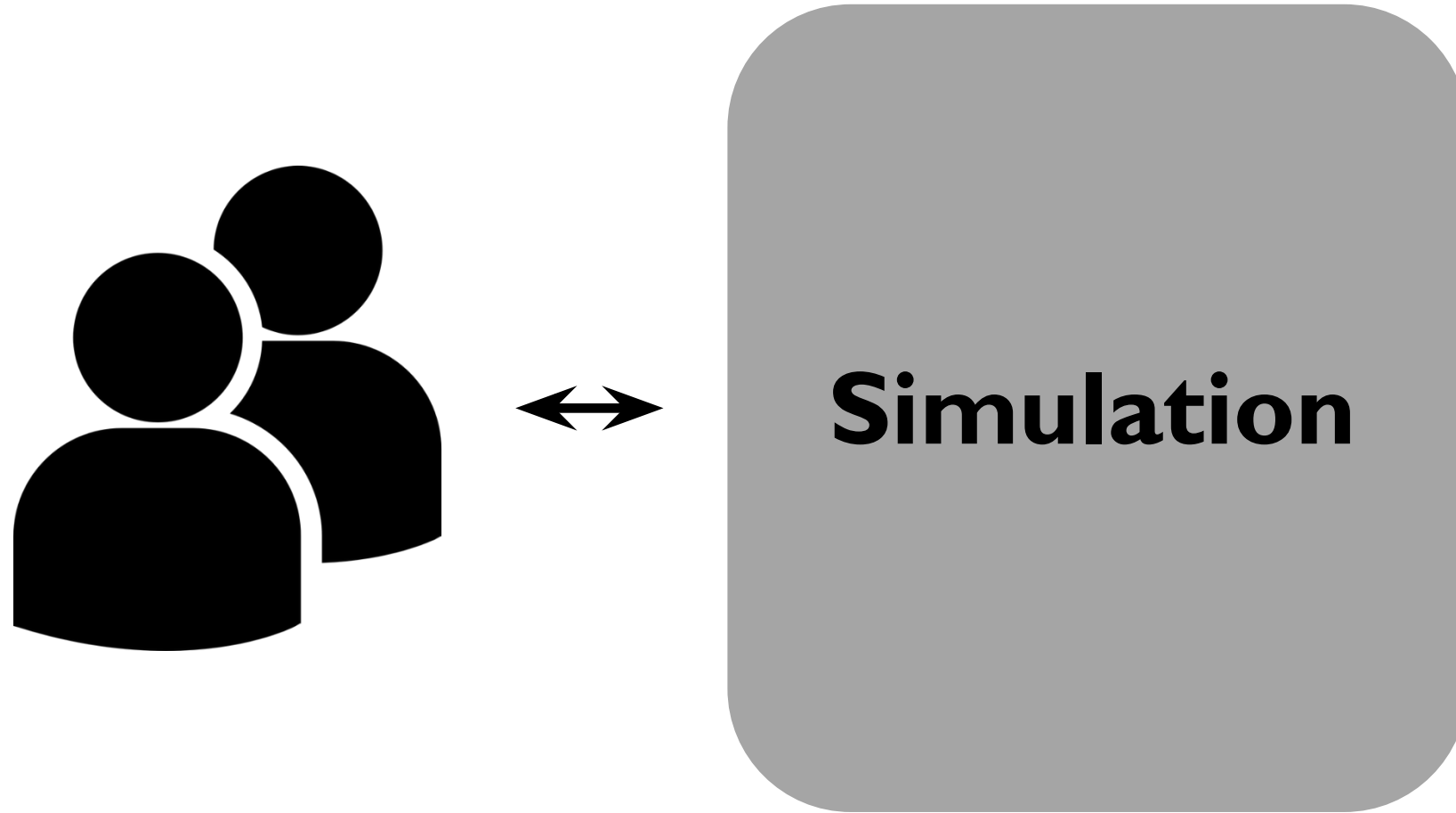
What is, and Why, Simulation?

What is a Simulation?

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

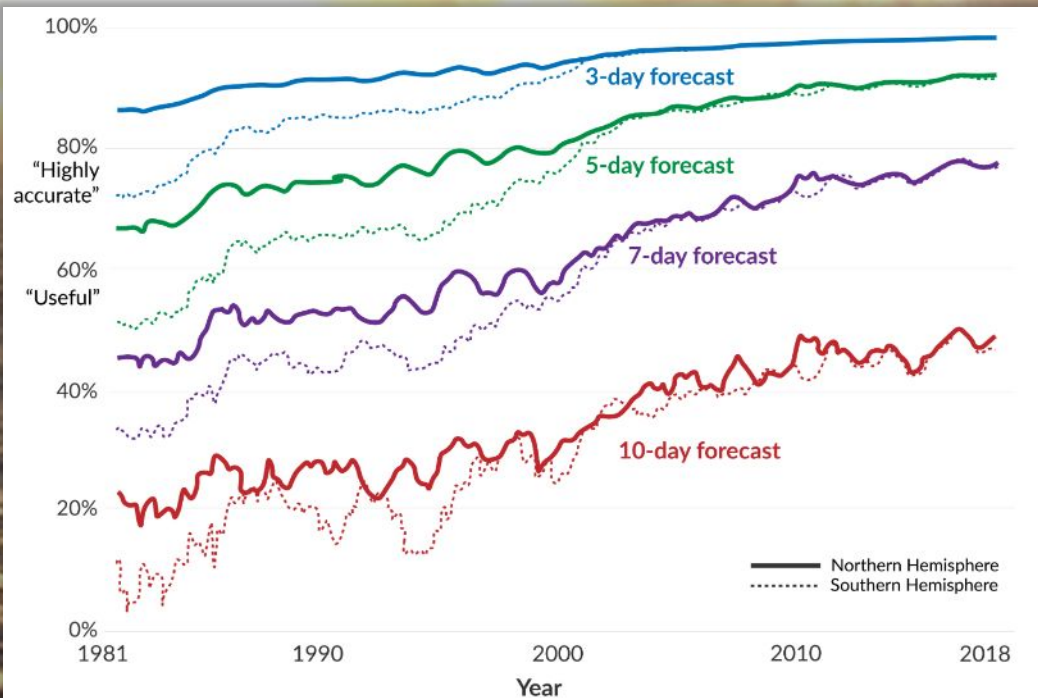


Human(s) Outside the Simulation



"Met Office's 4-day forecast is as accurate as its 1-day forecast was 30 years ago"

Met Office (15 Nov 2023)



Source: European Centre for Medium-Range Weather Forecasts (ECMWF).

Licensed under CC-BY by the author Hannah Ritchie.

Human(s) Inside the Simulation



Flight Simulator



Simulation Technology Drivers

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



Why Flight Simulation?

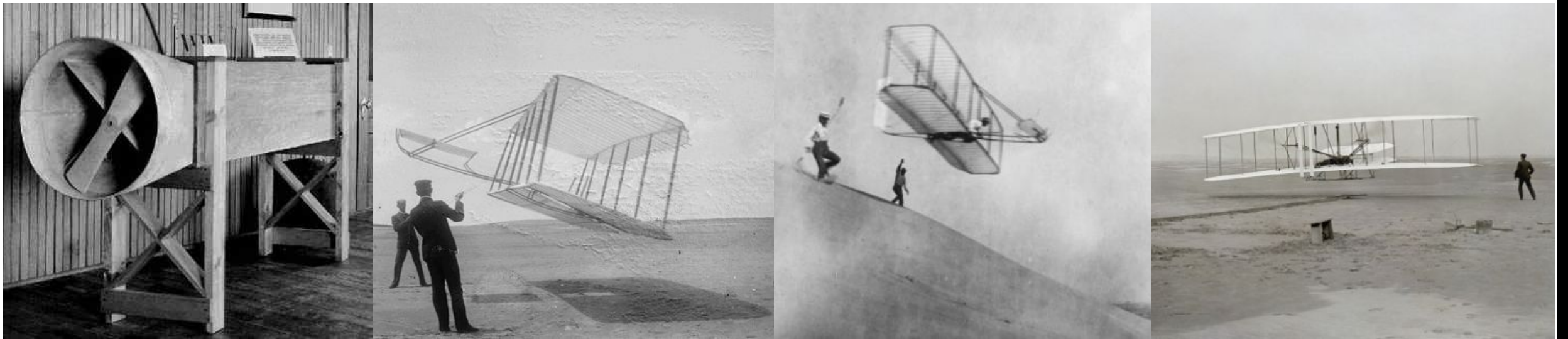


2/5

A History of Flight Simulation

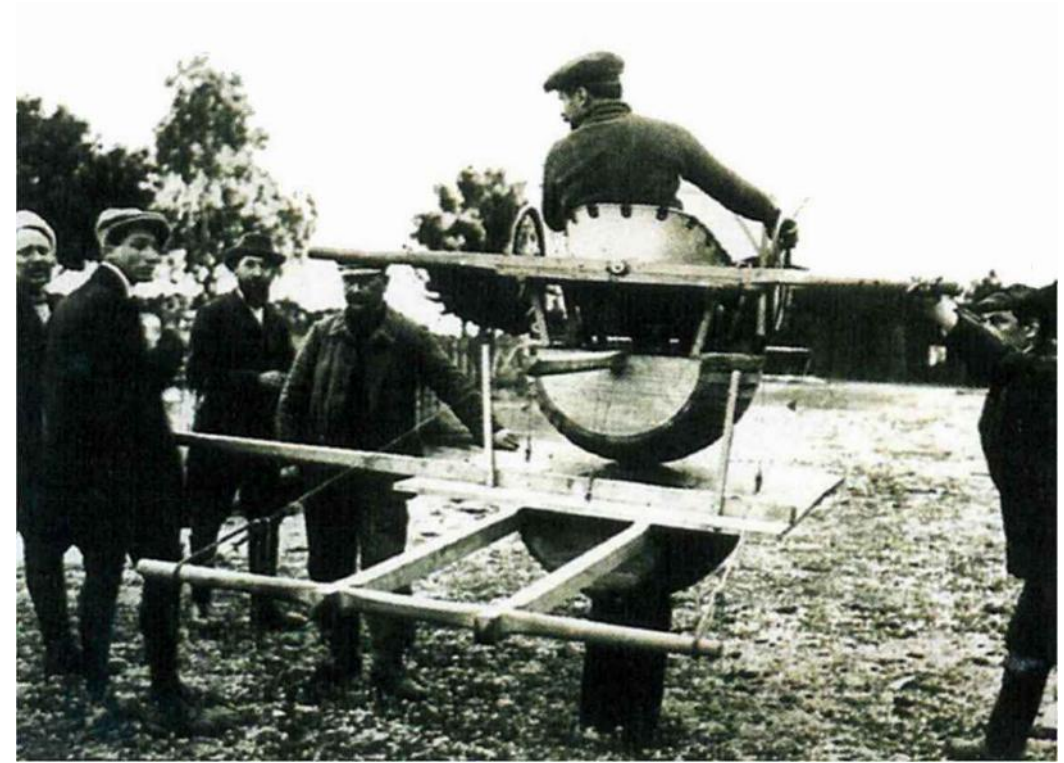
1903 – Wright Brothers

- Test
- Train
- Fly



1910s

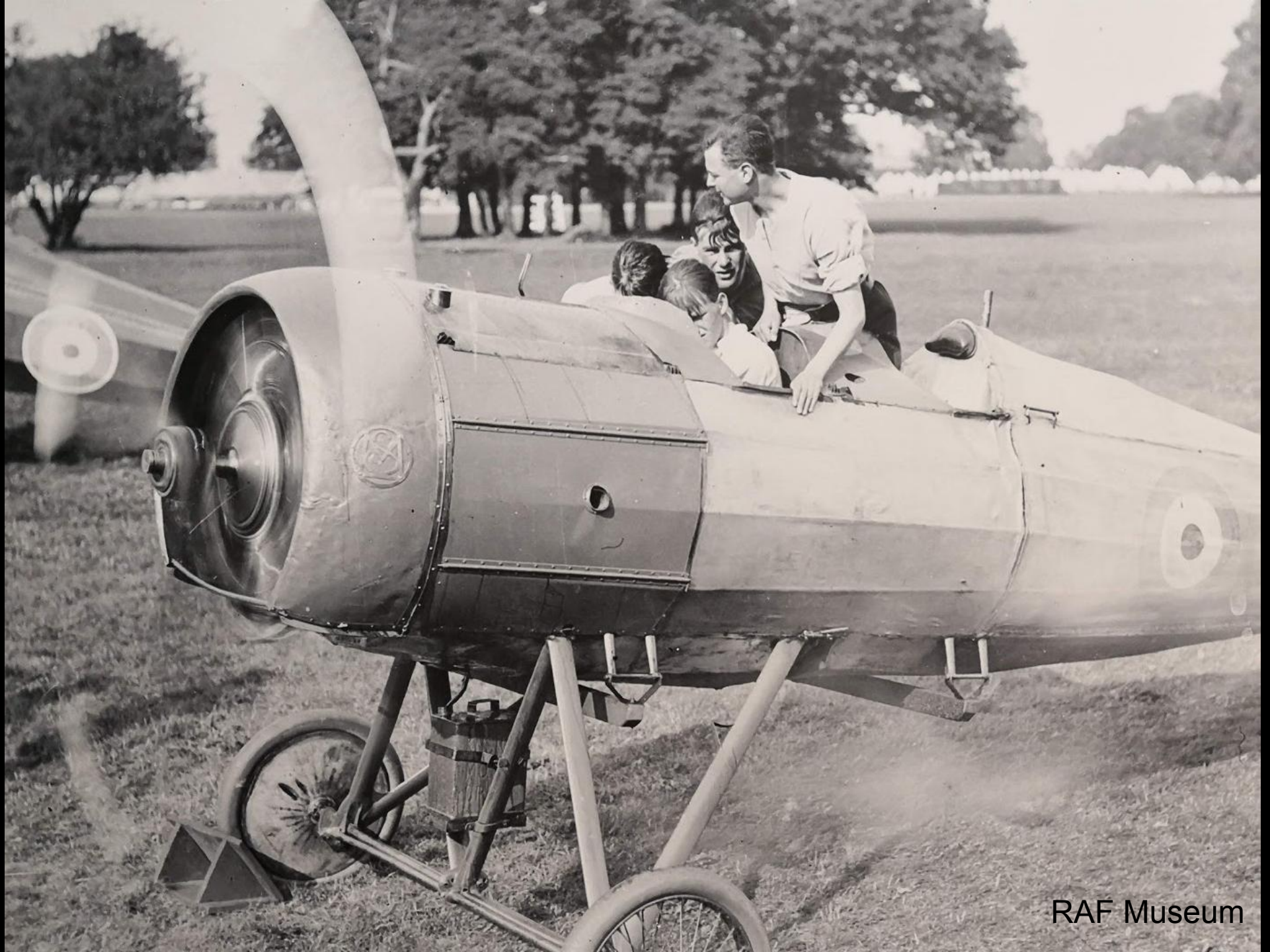
Leon Levavasseur's Antoinette Barrel – France 1910



**1918 -
“Penguin”**

**Cadets and
Instructor**

**No.1 School of
Aeronautics,
Reading**



RAF Museum

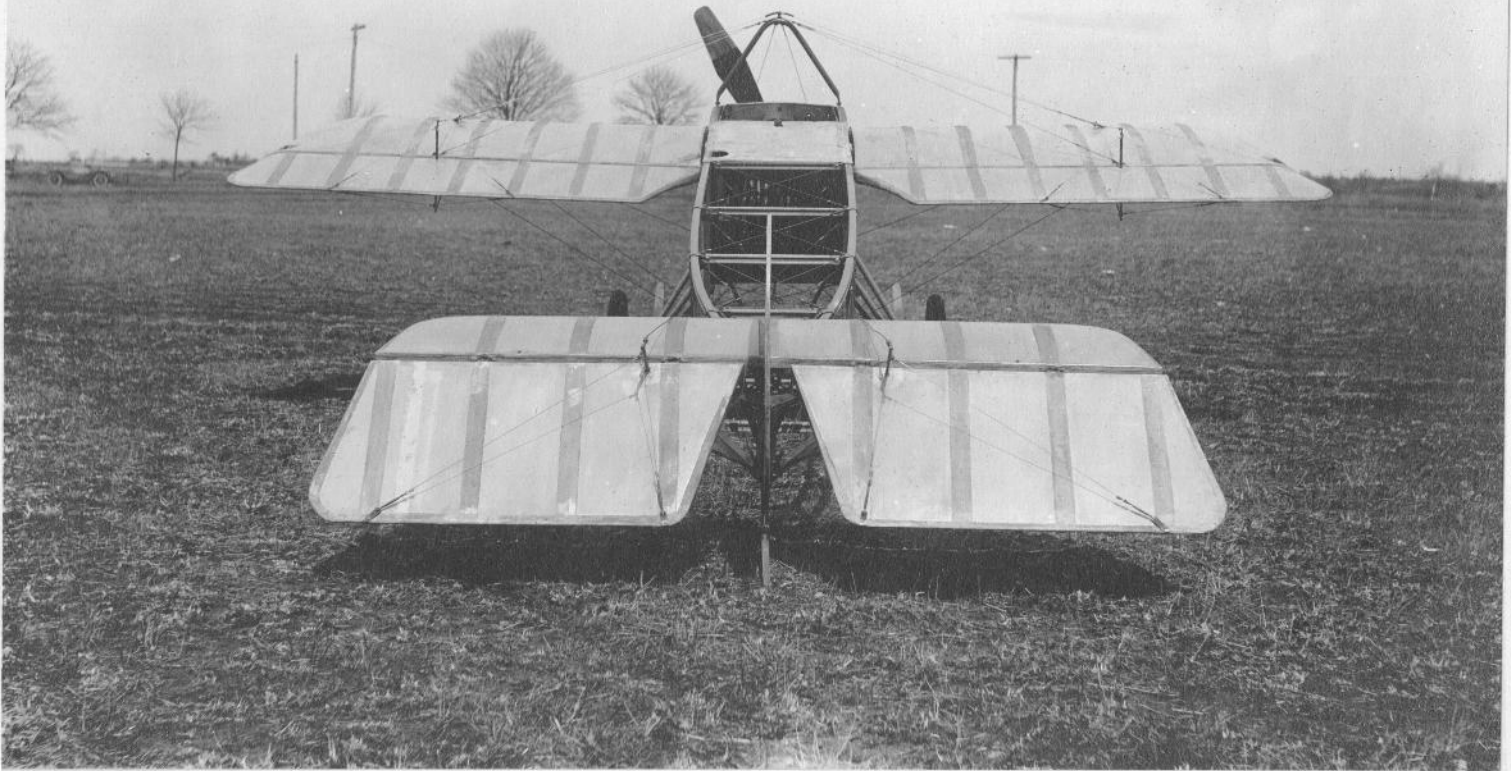
THINKE

US
Breese
Penguin

28HP

300
Made

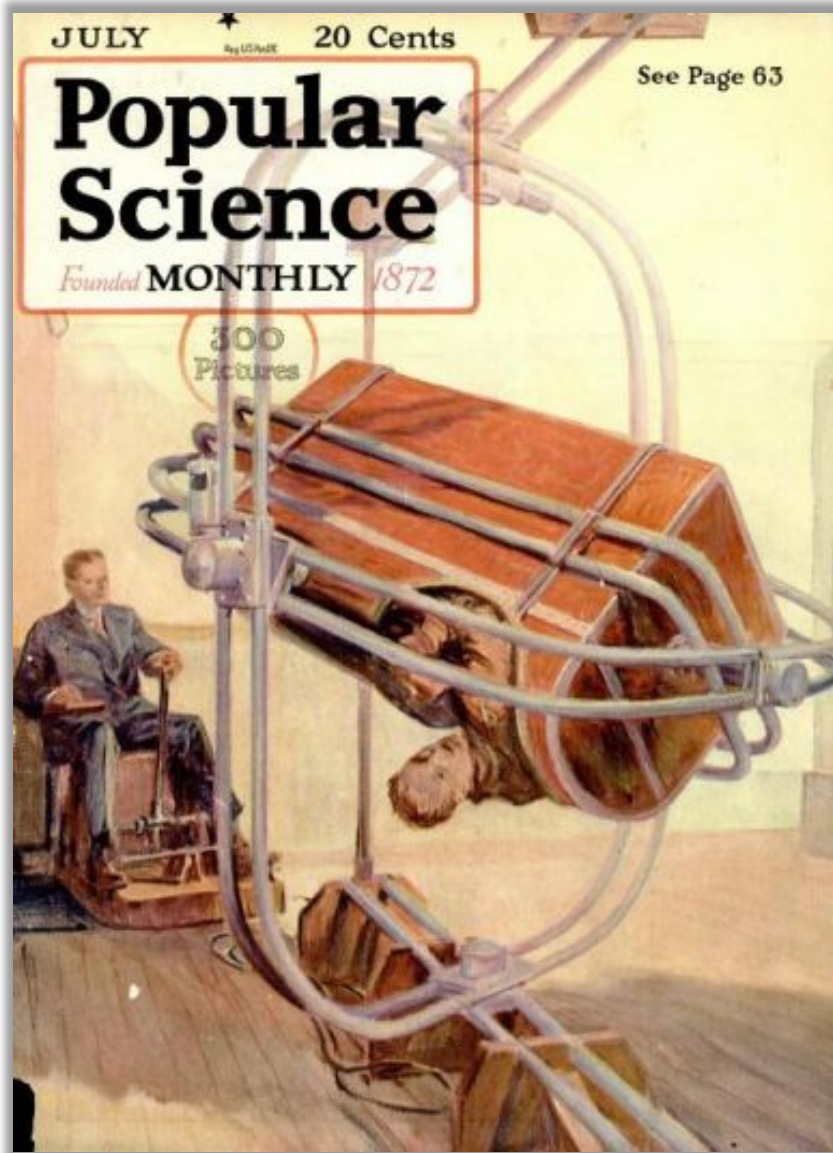
SUBJECT: 165-WW-20G-5		NUMBER AU
165-WW 20G-5		
Edgar Van Sicklen PHOTOGRAPHER		
Aug. 1918	TAKEN	
DESCRIPTION: BRESEE PENGUIN This plane manufactured by the Breese Aircraft Company Inc., Farmingdale, L. I. is supplied the Government for advanced training work for graduating officers in the use of very fast machines. It has the full equipment of the advanced training plane but is not intended for use a great distance from the ground.. The machine was recommended by the Frehch Commission which visited the United States last year.		
20 - 5		
ISSUED	NOTES:	



WW1 Flight Simulation (IWM)



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”

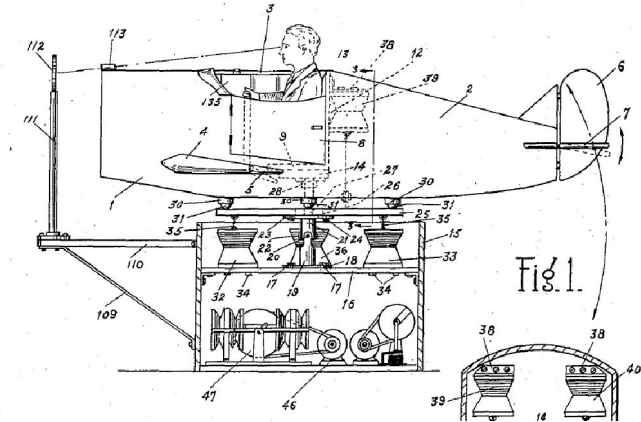
Maj.-Gen. George W. Squier

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



Link Trainer



WW2 Link Trainer



Maritime Link Trainer



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

Queen Bee Drone – 1930s/40s



Anti-Aircraft Training in World War 2

43 “Dome Trainers”

Langham Dome



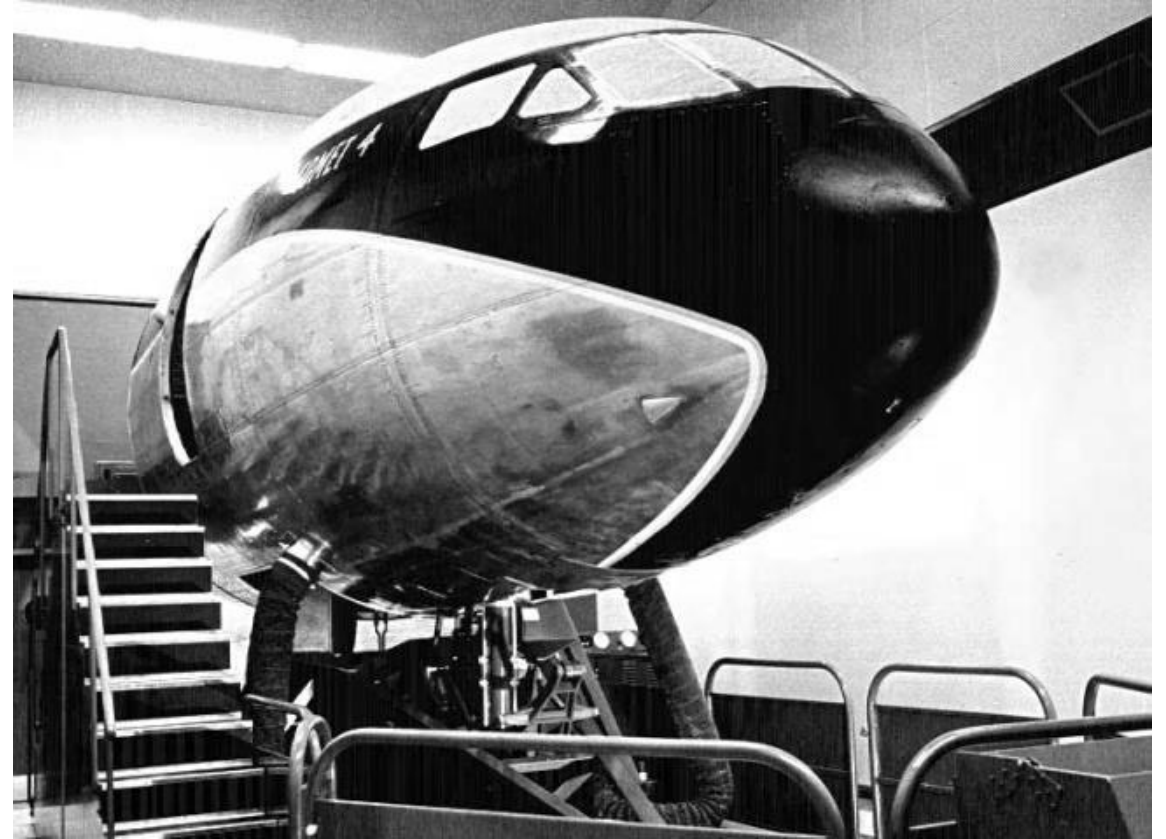


Dome Trainer Portsmouth 1951

Pathé

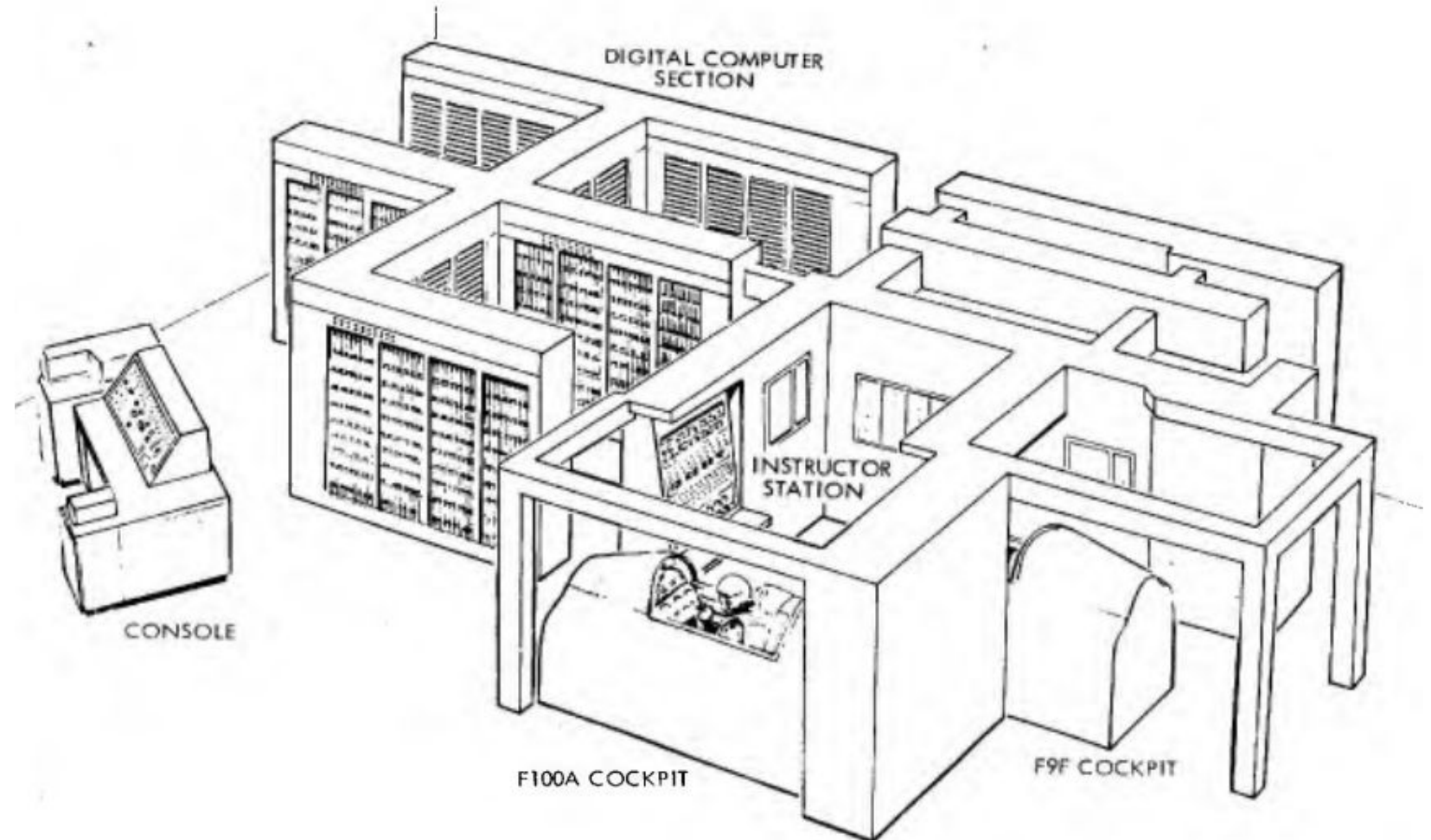
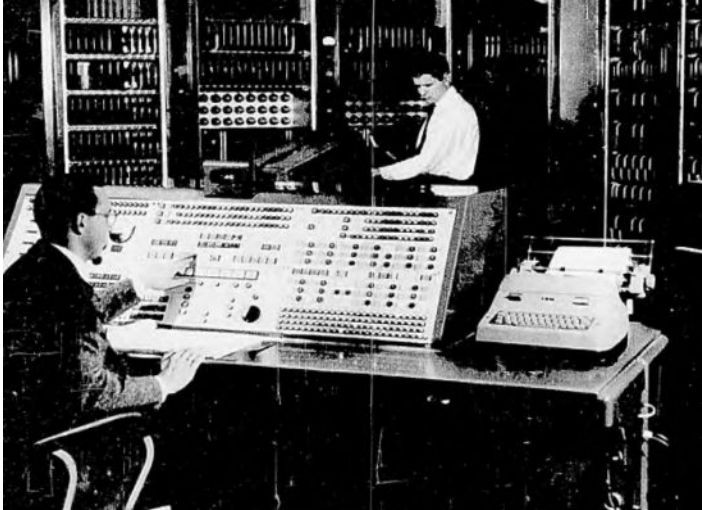
1950s

- Analogue to Digital Computing
- More complete Aircraft Data
- Motion Simulators



1960

USAF/USN Universal Digital Operational Flight Trainer (4 years, \$2m)



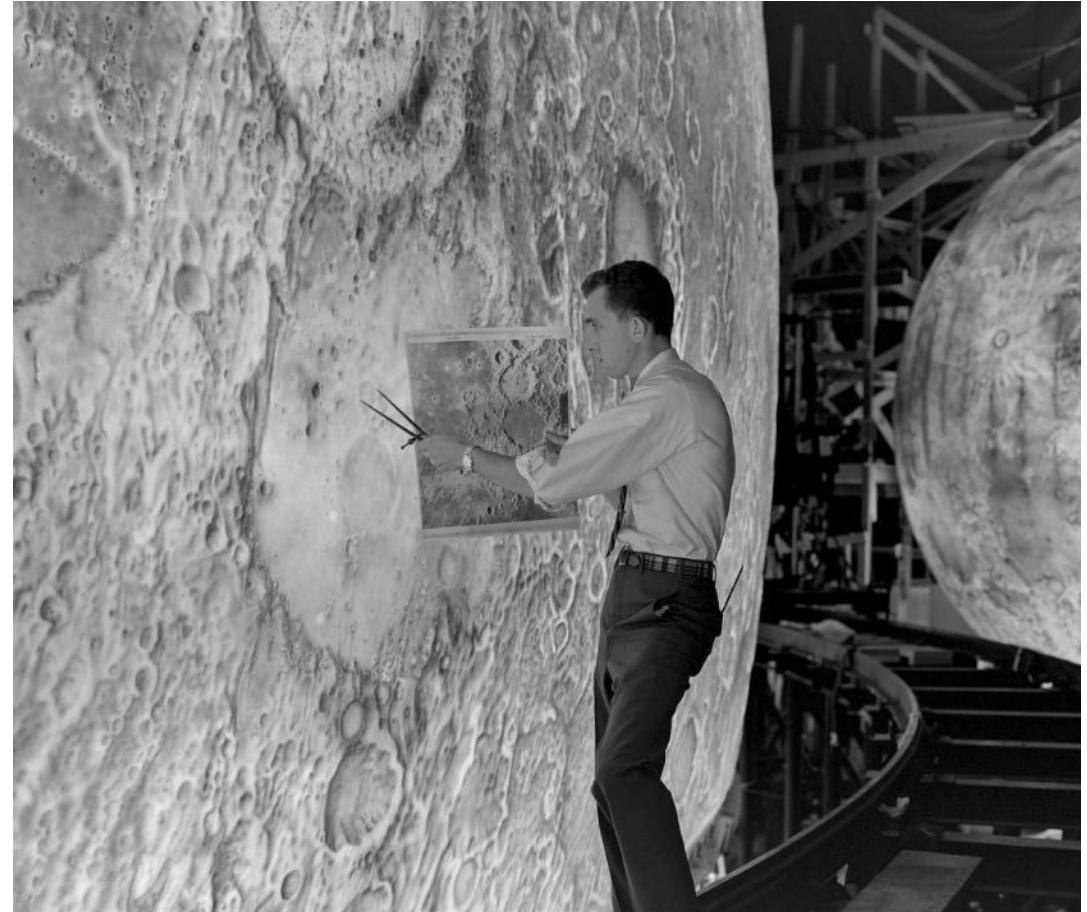
Spacewar! - 1962

- Generally considered the first Shooter game
- The basic PDP-1 model cost US\$120,000 (\$1.25m in 2024)



1960s

NASA Moon Landing Simulator



SR-71 Blackbird

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

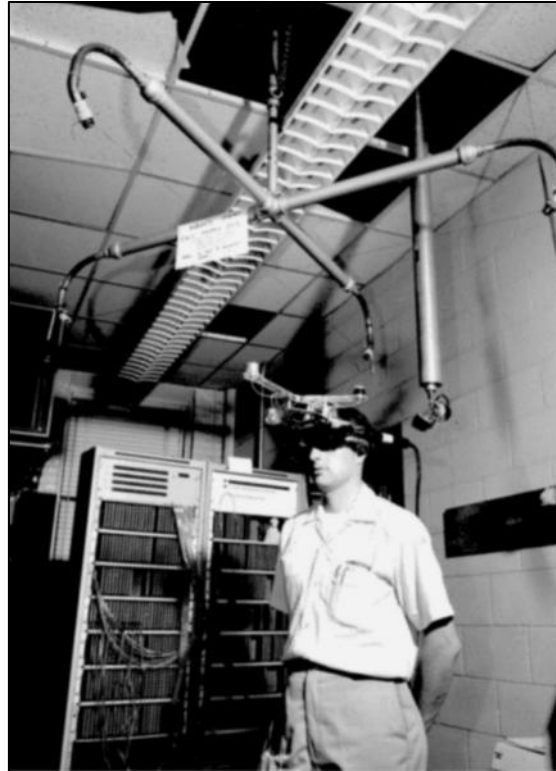
- “They created the mission upstairs, and the tape they produced for the simulator was the same tape used onboard in the aircraft computer.”



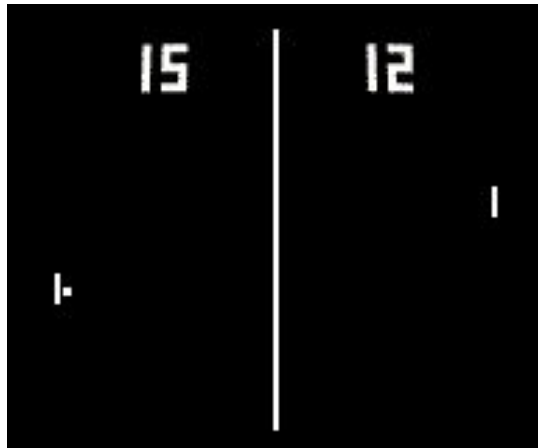
The Sword of Damocles (VR) - 1968

Ivan Sutherland - University of Utah

- The first digital XR HMD
- Displayed a simple 3D virtual wire-frame shape, changing as the user moved their head



PONG - 1972



special **ODYSSEY**™

Free!
a \$3570* value
6 optional
ODYSSEY games
with the purchase of Odyssey

BASEBALL HANDBALL VOLLEYBALL
WIPEOUT INVASION FUN ZOO

Each game is packaged complete with all necessary materials.
*Manufacturer's suggested retail price. Optional with dealers.

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.

the 12
TABLE TENNIS
SKI
CAT AND MOUSE

All for.... \$99⁹⁵
A \$135.65 VALUE

ODYSSEY
ODYSSEY
ODYSSEY
ODYSSEY
ODYSSEY

**GUARANTEED
PARENTS'**
SATISFACTION
OR
REFUND

6

Magnavox Odyssey - world's first
commercial home video game console
(about \$700 at 2024 prices)

1970s/80s Flight Simulation

BBC Open
University
“Million
Pound Man”
(1980)

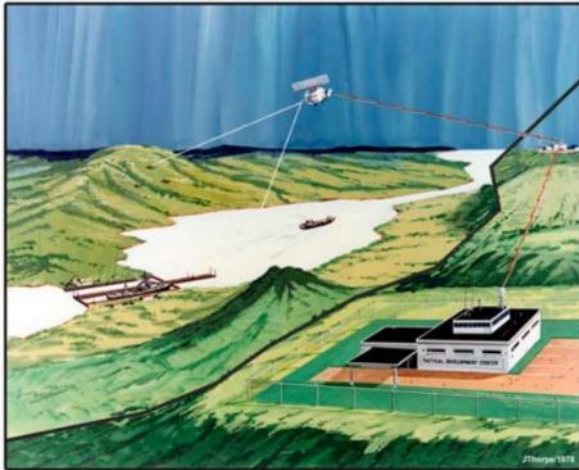
1960/70s

REDIFON



THINKE

USAF Capt Jack Thorpe's White Paper (1978)



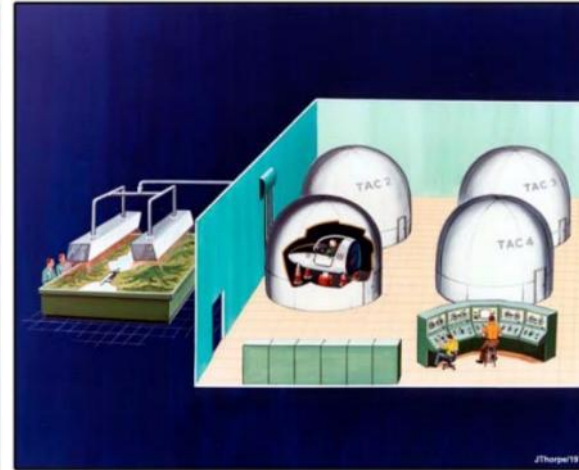
1

Enemy aggression
detected by overhead
sensor



2

Planning a response
using the holographic
electronic sand table



3

Air crews rehearse
the plan and planners
assess suitability



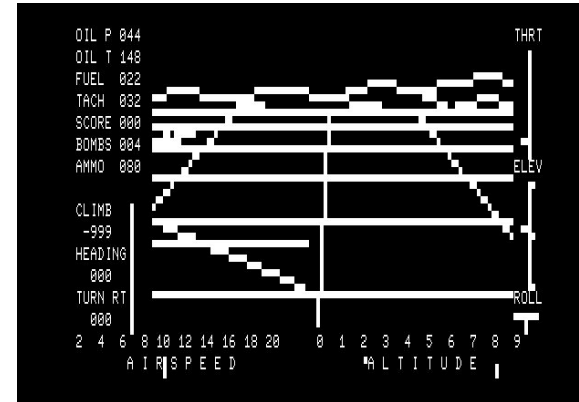
4

Mission execution
with real time
observation

(Microsoft) Flight Simulator



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



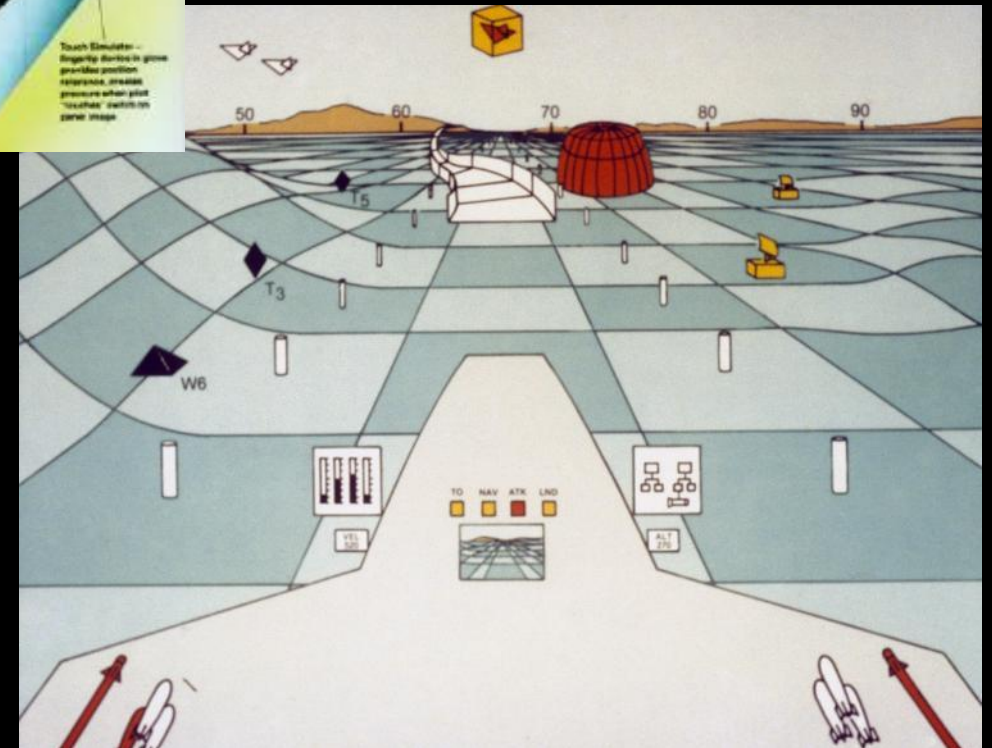
**subLOGIC Flight Simulator 1 for
TRS-80, 1980**



Microsoft Flight Simulator 1.00, 1982



USAF Super Cockpit Program 1986-89

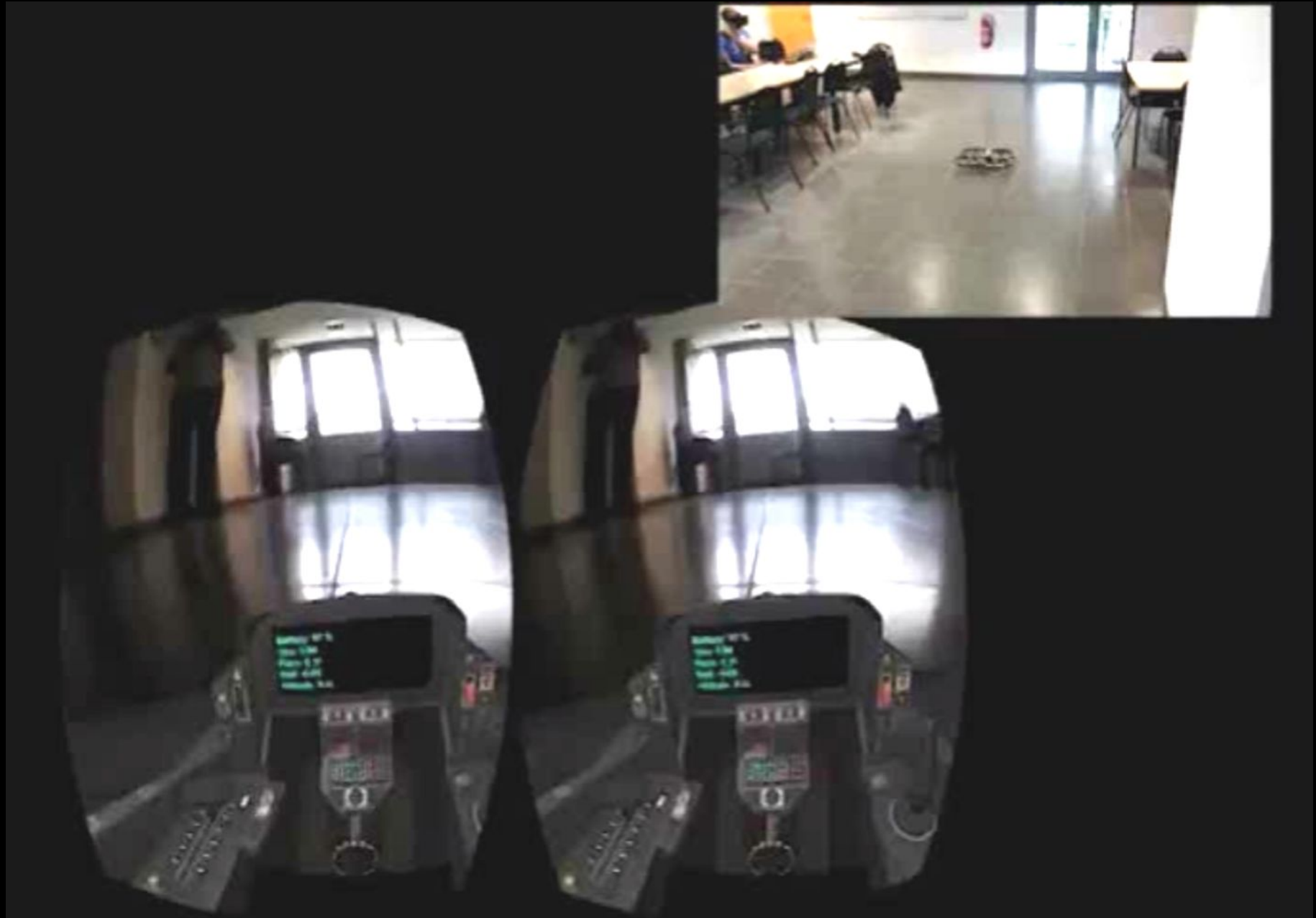


Rift Drone (2014)

AR.Drone 2.0
Oculus Rift
Unity

Xbox 360 Controller
Open-Source Software

<https://github.com/daraosn/oculus-drone>



https://youtu.be/3WmQ1_8ytaM?si=nsmukHRH8IEMII33

Simulation Now - Land, Sea, Air, Anywhere



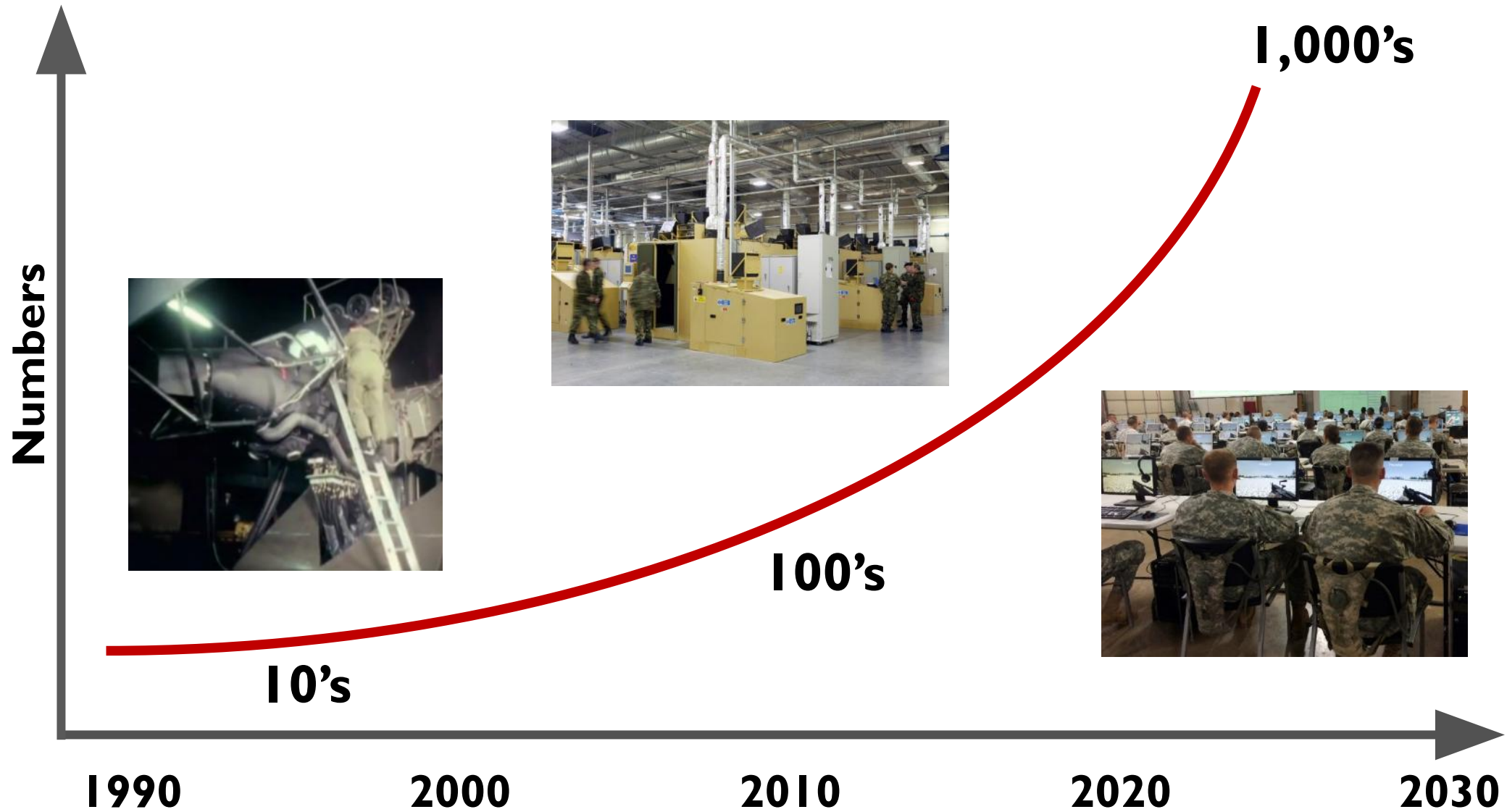
Consumer Flight Simulation Now



Unreal Games Engine Software in CAE Flight Simulator (now)



Military Access to Simulation



3/5

Training and Simulation Developments

Fast Jet Training at RAF Valley (UK)



USAF Predator Mission Aircrew Training System

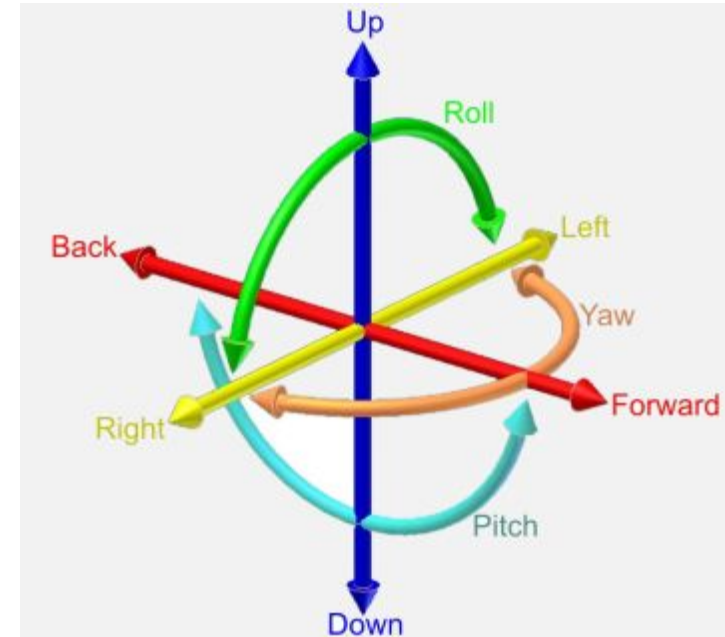
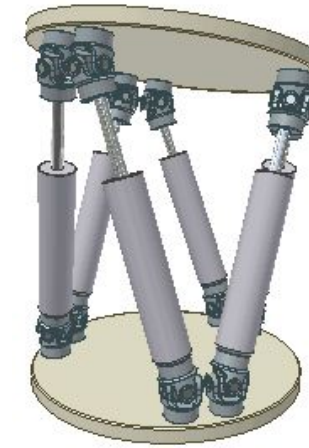


Full Flight Simulator (FFS)

- 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
- 1795 Fixed and Rotary FFSs in 2023



Stewart Platform - 6 Degrees-of-Freedom



High-G Motion Simulator v Zero-G Simulator

Flight Simulation Without Physiological Stresses...
Is Not Flight Training

With Stress		VS	Without Stress	
Aircraft	Pilot		Pilot	Aircraft
2.15 G	2.15 G		1.00 G	1.8 G
				

The image compares two flight simulation environments. On the left, a 'With Stress' scenario shows a pilot and aircraft both experiencing 2.15 G. The pilot's face is shown in a close-up, appearing strained. On the right, a 'Without Stress' scenario shows a pilot at 1.00 G and an aircraft at 1.8 G. The pilot's face is shown in a close-up, appearing relaxed. A central 'VS' graphic separates the two scenarios. Below the 'VS' is a 'Battlepace' diagram showing a yellow arrow (high-G) and a blue arrow (low-G) in a circular path. The text 'Flight Simulation Without Physiological Stresses... Is Not Flight Training' is at the top.

Some Trends in Interactive 3D Digital Technology



Terminology

- **Metaverse?**

- A future evolution of the Internet where the physical and cyber domains achieve convergence.

- **Spatial Computing?**

- Techniques focused on blending digital content with the physical world.

- **Immersive Technology?**

- Digital tools that create engaging, interactive experiences, often making users feel part of a virtual environment.

- **Web 4.0?**

- A more intelligent, personalized, immersive, and decentralised Internet.

- **Extended Reality?**

- The spectrum from physical reality to virtual reality

Themes

XR

Virtual Worlds

Digital Twins

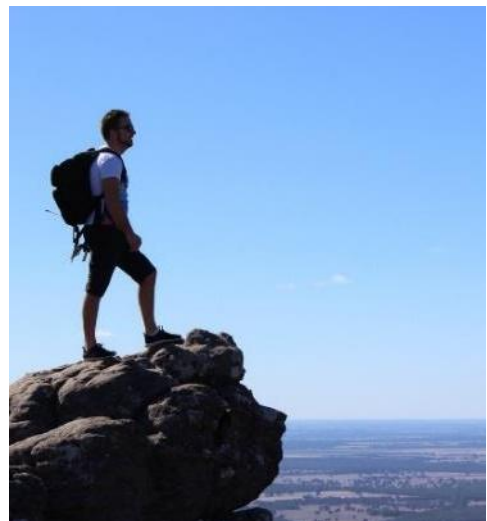
**Open
Ecosystems &
Standards**

AI

eXtended Reality (XR)

Reality

The physical world



Augmented Reality

Information layered over physical world



Mixed Reality

Blend of real & digital information



Virtual Reality

Fully virtual world



XR in Warfare



https://youtu.be/4vWuEKhE6Xc?si=EoS_9x1qEuNdlb8j

XR Gaming Skills

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[Breaking News](#) | [Australia](#) | [Video](#) | [University Guide](#) | [China](#) | [Debate](#) | [Meghan Markle](#) | [Prince Harry](#) | [King Charles](#)

Call of Duty: Defence secretary John Healy wants online gamers to join up for real to become drone pilots as he plans to ease entry requirements for 'console warriors'

By [DAVID WILCOCK](#), DEPUTY POLITICAL EDITOR FOR MAILONLINE

PUBLISHED: 14:28, 22 September 2024 | **UPDATED:** 14:28, 22 September 2024



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51
shares

129
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VR for Professional Use



HalldaleGroup

Pioneering simulation training, education, and learning

[Shop](#)

[Civil Aviation](#) ▾

[Defence](#) ▾

[Safety Critical Training](#) ▾

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EASA Qualifies World's First VR Flight Training Device



EASA calls the VRM Switzerland Virtual Reality FSTD qualification "a further step towards Agency and industry objectives to improve overall rotorcraft safety by 50% by 2028." Image credit: VRM Switzerland.

[RICK ADAMS](#)

APRIL 26, 2021

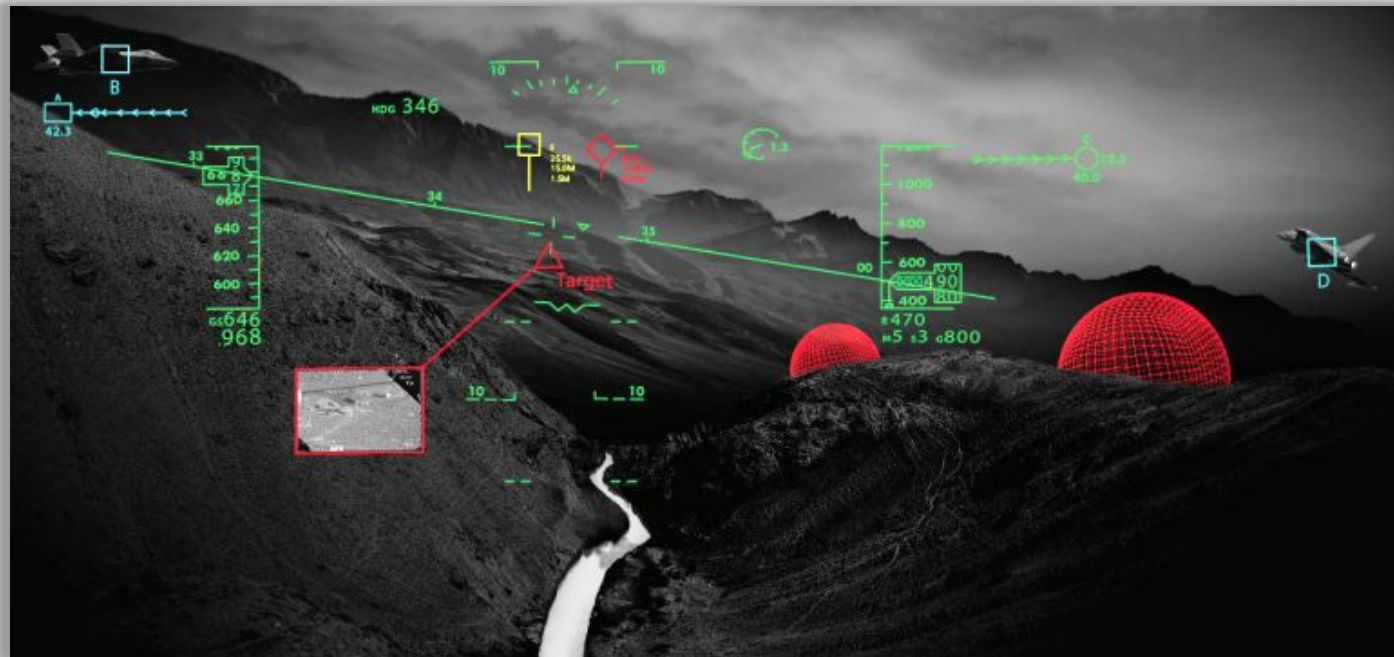
VRM Switzerland has received approval from the European Union Aviation Safety Agency (EASA) for pilot training credits in a type-specific Robinson R22 virtual reality flight simulation training device, the world's first VR-driven FSTD to receive approval from an aviation regulatory authority.

Other Crew (CAE)



XR

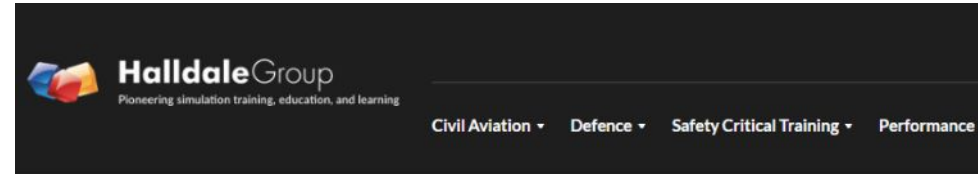
BAE Systems Striker® II



Support



Credit – Kognitiv Spark



RAAF Test Microsoft HoloLens



Image credit: RAAF.

MIKE RAJKUMAR

SEPTEMBER 4, 2020

The Royal Australian Air Force (RAAF) recently commenced a trial initiative for maintenance of its C-17A Globemaster III transport aircraft using Microsoft HoloLens mixed-reality devices with software developed by Boeing. The trials commenced in July with aircraft technicians from No. 36 Squadron at RAAF Base Amberley, the service announced in a statement.

Eye Tracking



XR

Meta Project Orion



Emteq Labs “Sense”

Facial Expression Smart Glasses

-  Eating behaviour
-  Attention
-  Engagement & Valence
-  Facial expressivity
-  Activity (walking, sitting, reading etc.)
-  Regulatory Compliance CE mark, RoHS, WEE.

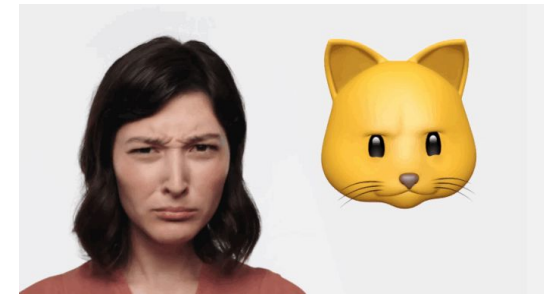
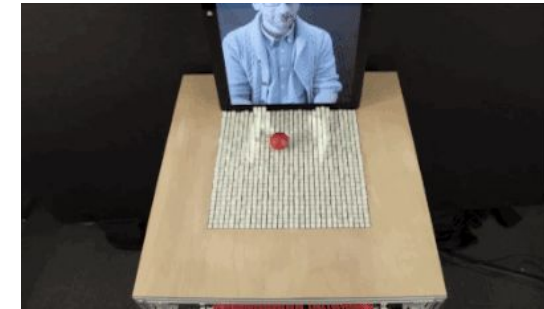


XR - BMW M Mixed Reality



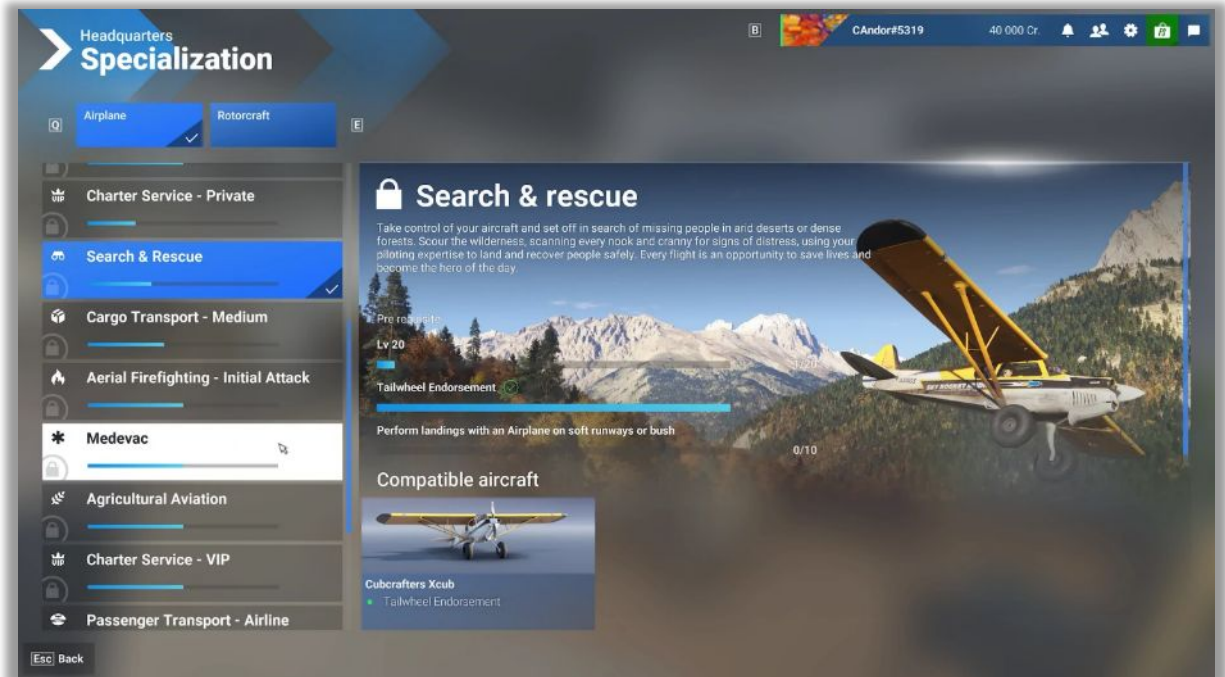
Next-Generation User Interfaces

- Gesture Interfaces
- Tangible User Interface
- Emotion Sensing
- Brain-Computer Interface



Virtual Worlds

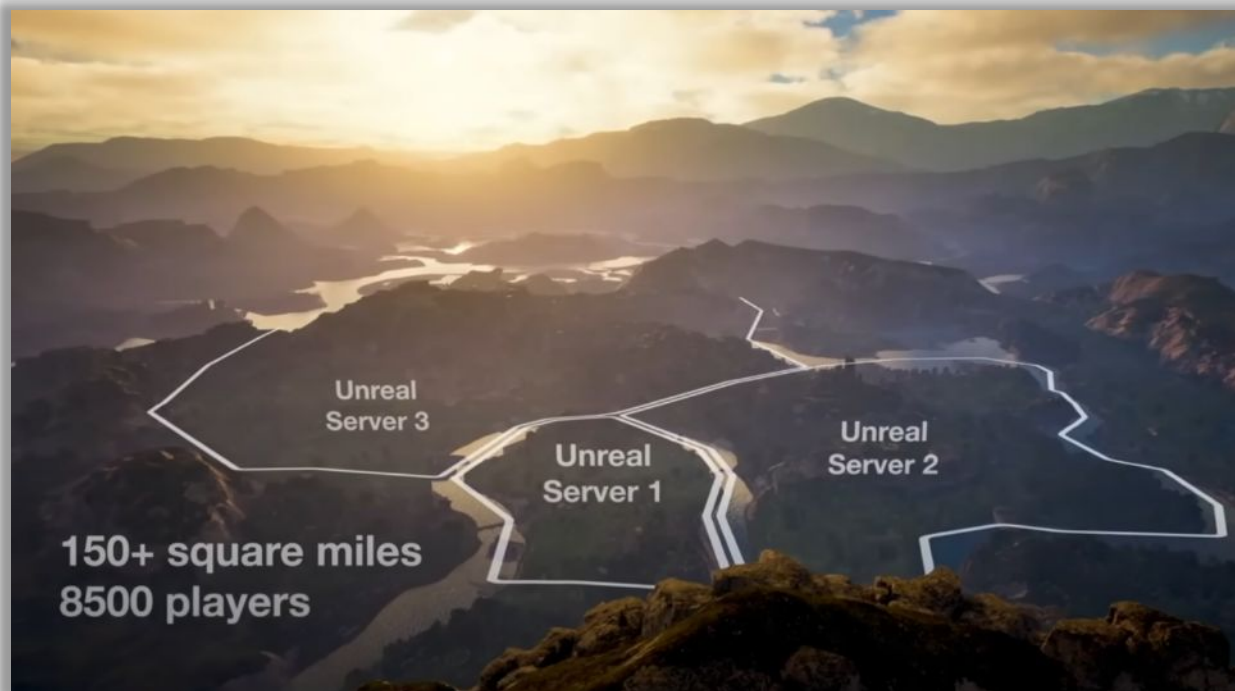
Microsoft Flight Simulator 2024 Career Mode



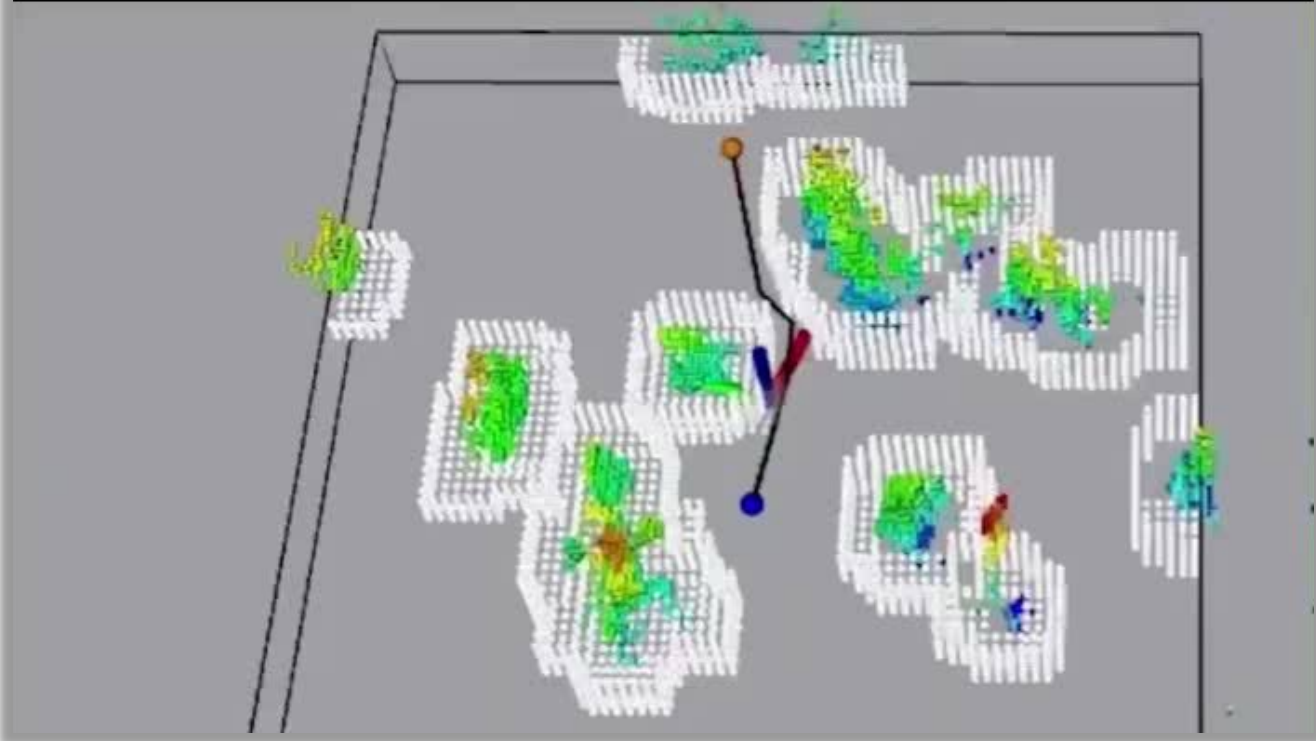
Virtual Worlds

Dynamic Server Meshing

Epic Games Unreal 5.5

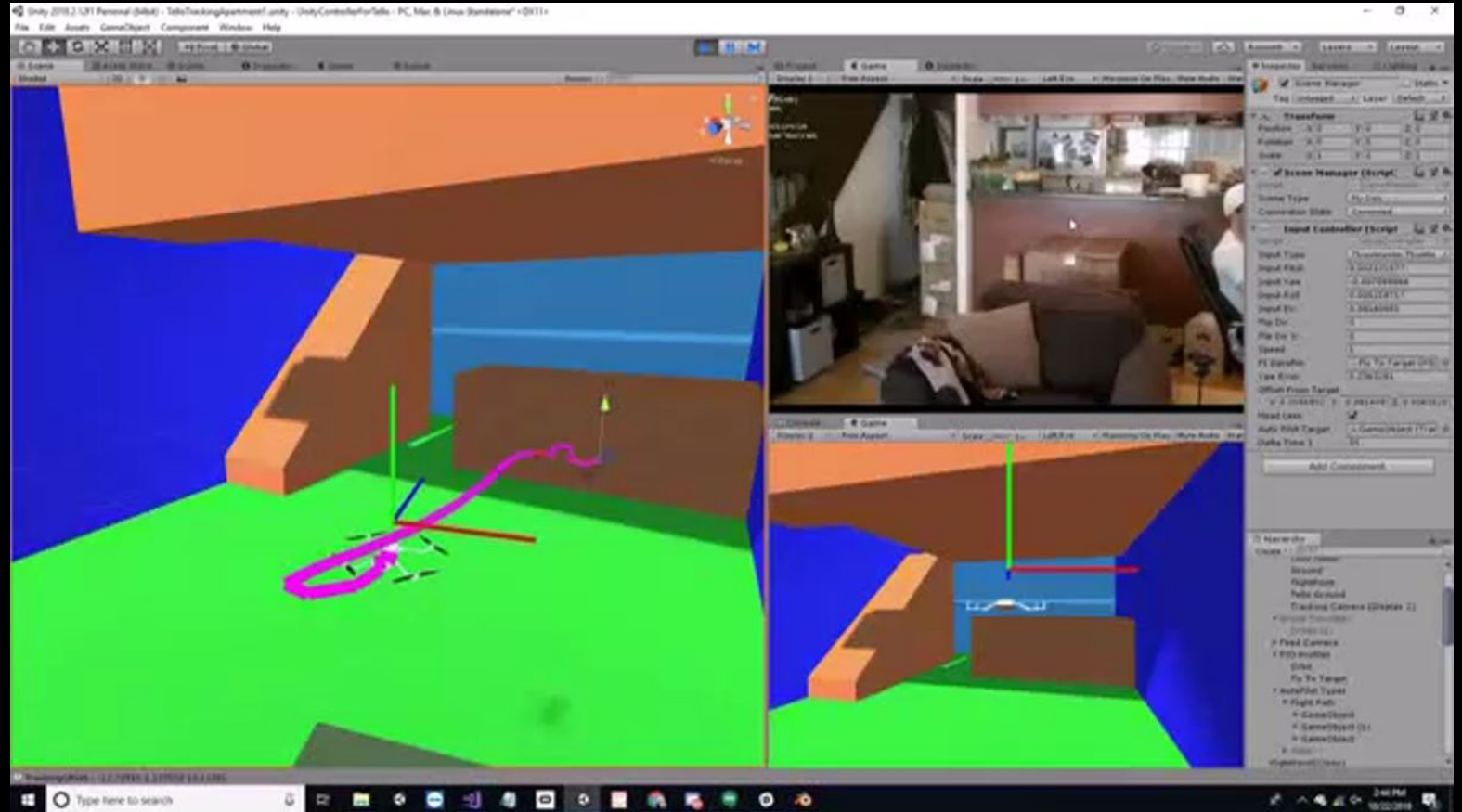


Performance Drone Works (PDW)



Command and Control

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



Digital Twins are Intrinsic to the Metaverse

digital twins connect the physical and virtual realms



Digital Twins + Simulation creating a connected industrial digital platform

Digital
Twins

Industrial
Metaverse



Image -
Siemens

The Price of Data



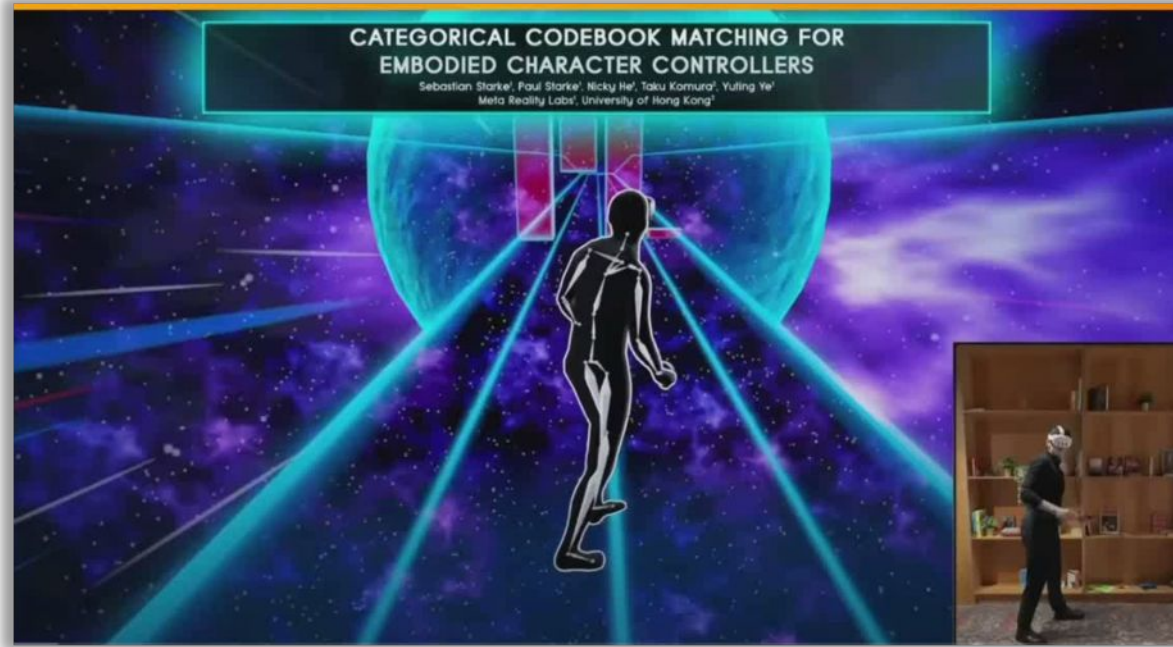
AI

Unity 6

“Sentis” AI

(9 Oct 24)

<https://youtu.be/T-sbHvDF6Bw?si=6BBJmWnWPJRXtM-U>



3D Digital Standards

XR

OpenXR

Virtual Worlds

OpenUSD

Digital Twins

**Open
Ecosystems &
Standards**

AI

**Converging
Themes**

XR

Virtual Worlds

Digital Twins

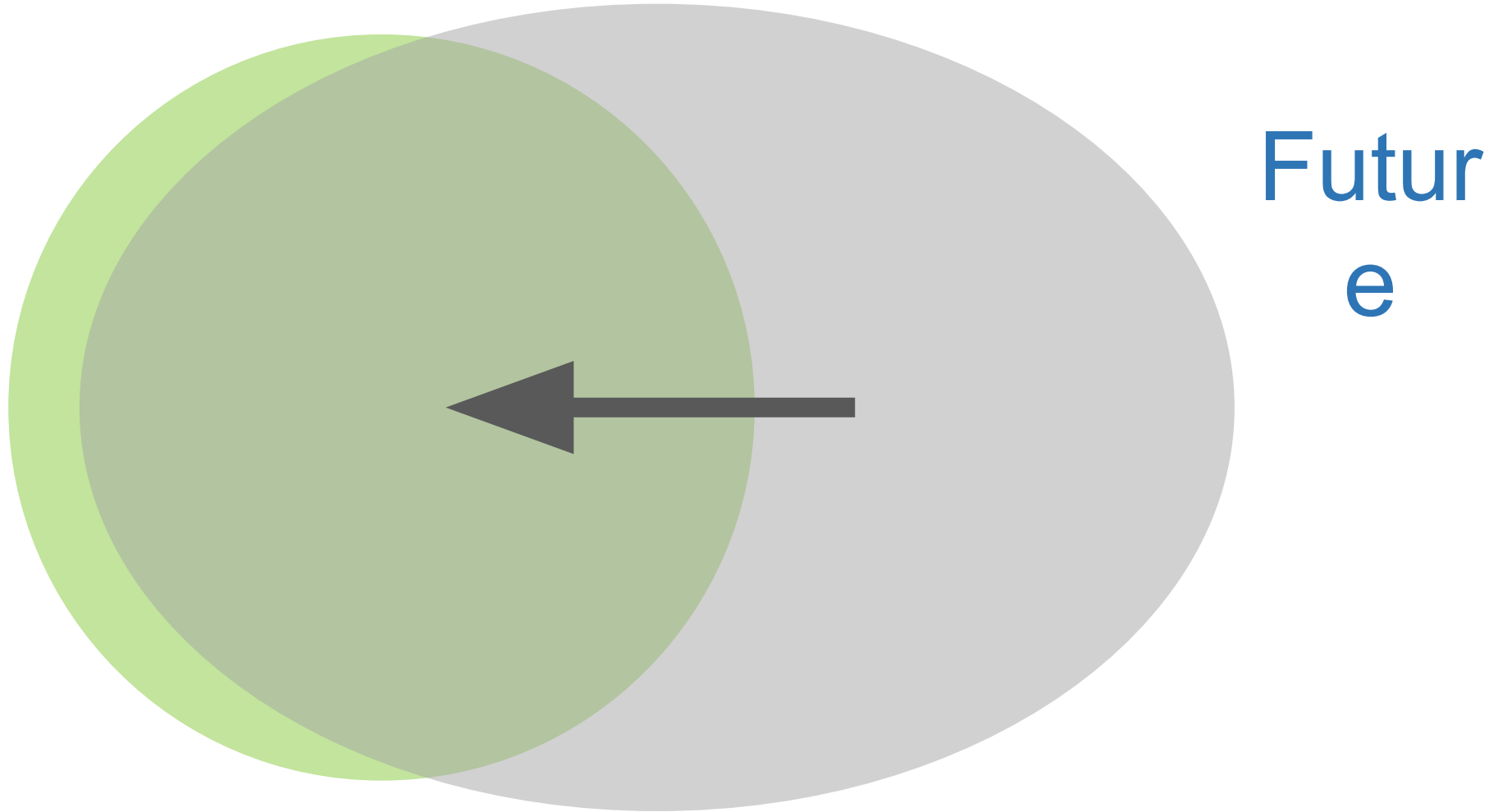
**Open
Ecosystems &
Standards**

AI

The Digital World Trends (?)

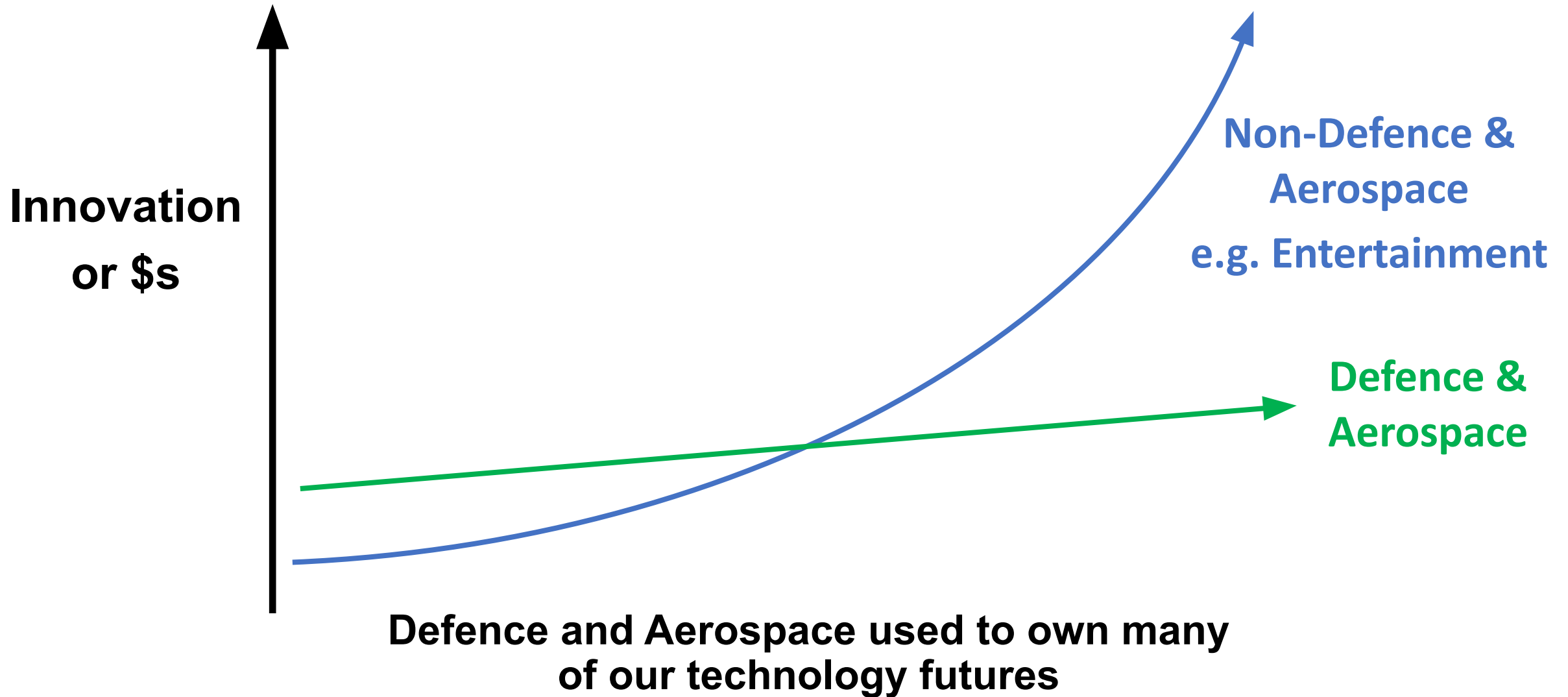
Fact
Driven Immersive
Fake Democratised
Physical Connected
Ubiquitous Worlds
Intuitive
Persistent Data
Intelligent 3Dimensional

The 3D Digital World Expanding & Moving into the Physical World



Physical & Digital Worlds

Who's Driving Metaverse Technologies?



4/5

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?**

New Pilots

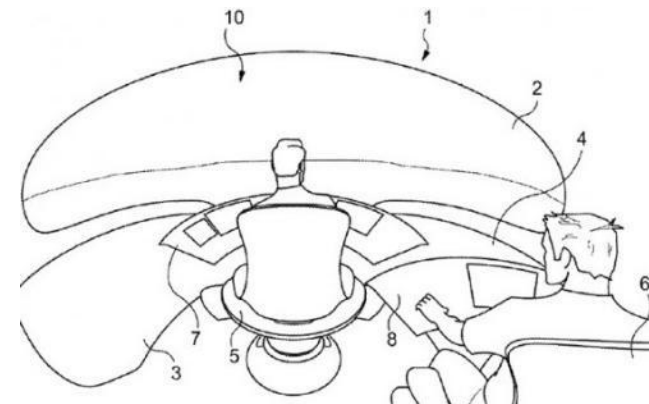
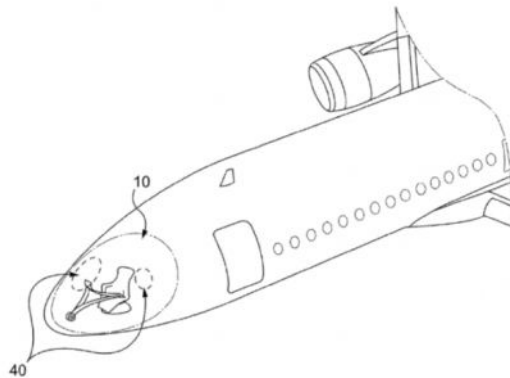
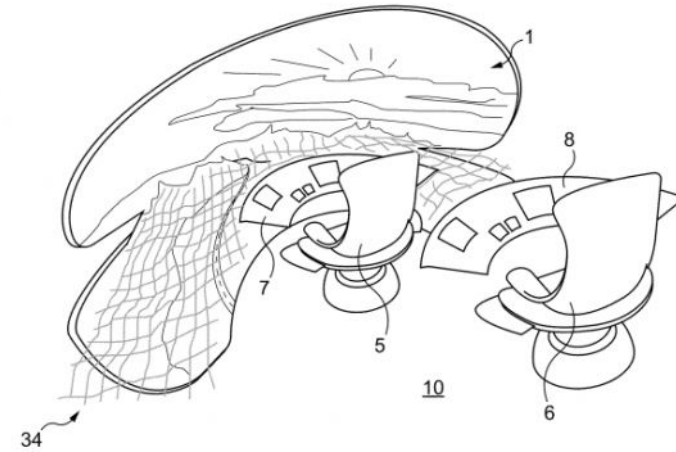
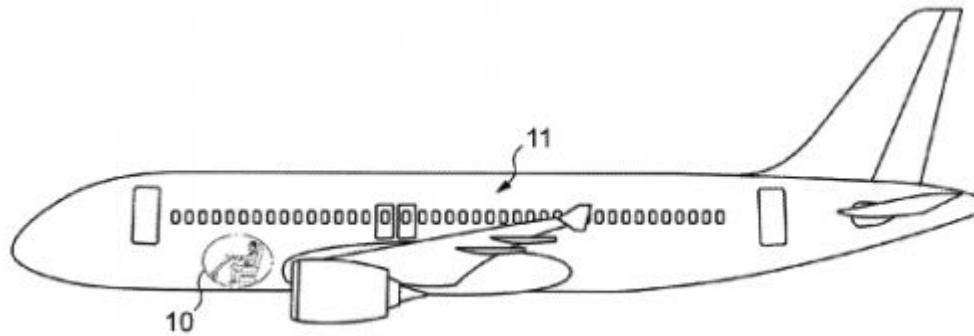


https://youtu.be/4vWuEKhE6Xc?si=EoS_9x1qEuNdlb8j

New Pilots (KTV)



Airbus Windowless Cockpit Patent



BOAC VC10 Automatic Landing (1968)

Source – Pathe



THINKE

Redundant Pilots?



Combat AI beats US Air Force's top tactical experts

And it only requires the processing power of a Raspberry Pi.

Andrew Dalton , @dolftown
06.28.16 in Robots

A new artificial intelligence flight combat system dubbed ALPHA has taken on one of the Air Force's top tactical experts and won. Retired USAF Colonel Gene Lee -- an experienced combat instructor with "considerable fighter aircraft expertise" -- was repeatedly shot down during engagements with ALPHA in a high-fidelity air combat simulation. Lee called his computerized opponent "the most aggressive, responsive, dynamic and credible AI I've seen to date."

2016



AIR WARFARE, NETWORKS / CYBER

AI Slays Top F-16 Pilot In DARPA Dogfight Simulation

"It's a giant leap," said DARPA's Justin (call sign "Glock") Mock.

By THERESA HITCHENS on August 20, 2020 at 6:03 PM

3.6k    
SHARES



Heron Systems' AI pilot scores the final kill against AF F-16 instructor "Banger" in AlphaDogfight Trials

WASHINGTON: In a 5 to 0 sweep, an AI 'pilot' developed by Heron Systems beat one of the Air Force's top F-16 fighter pilots in DARPA's simulated aerial dogfight contest today.

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.

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.

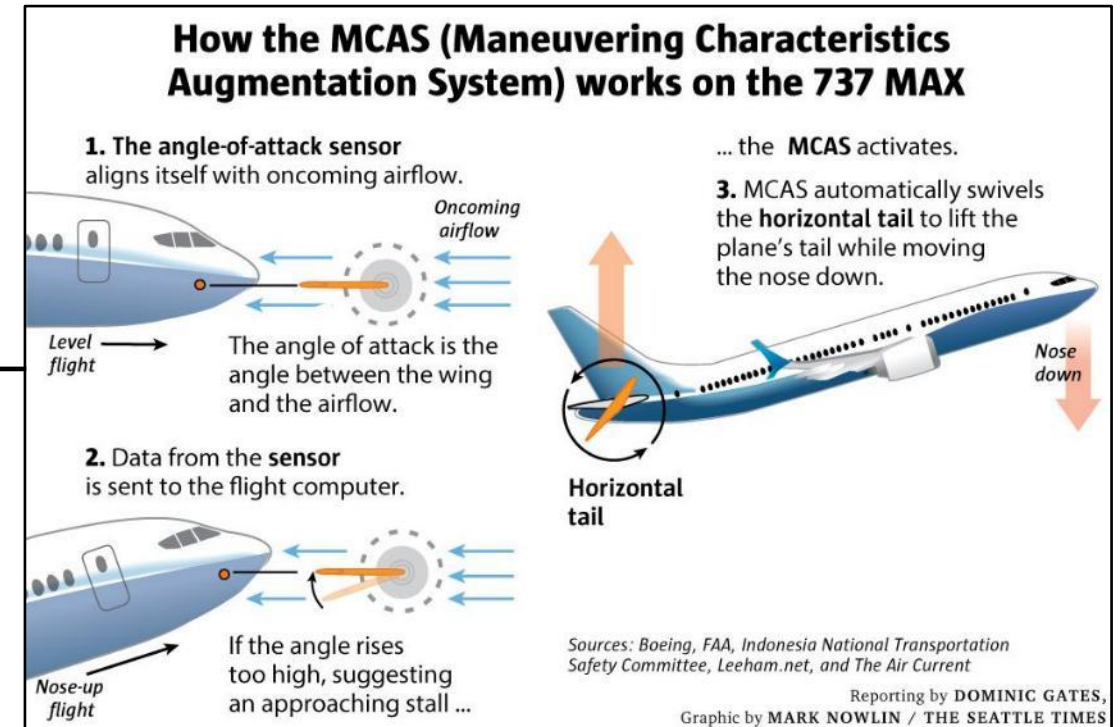
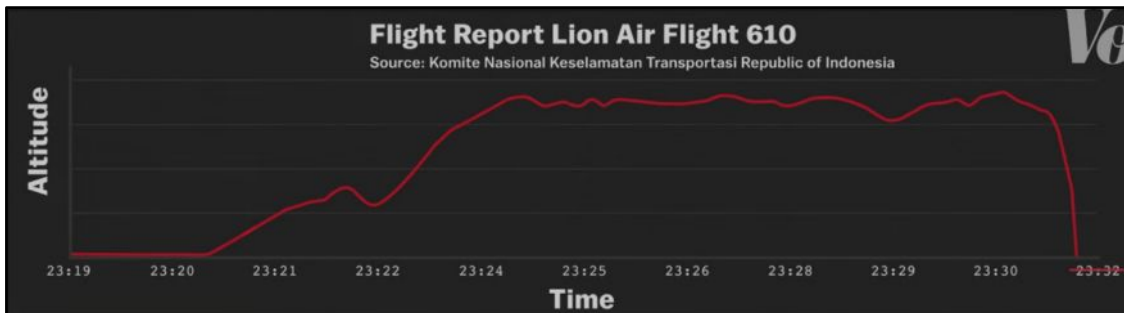
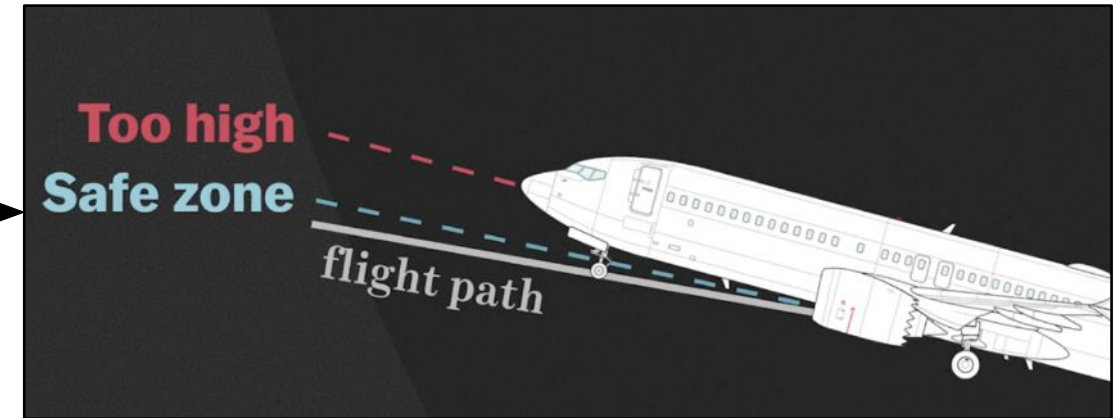
The report, dated February 2019, was [published online](#) by the MoD after the BBC made a Freedom of Information request for it, leading to [news reports](#) over the past few weeks.

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).

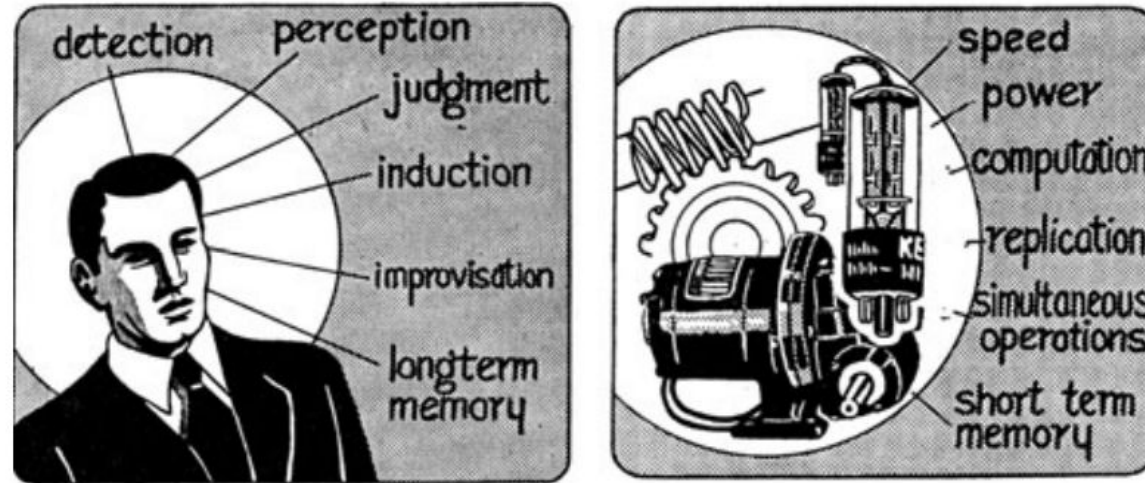


Boeing 737 MAX



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 mistakes”

In the Loop ...

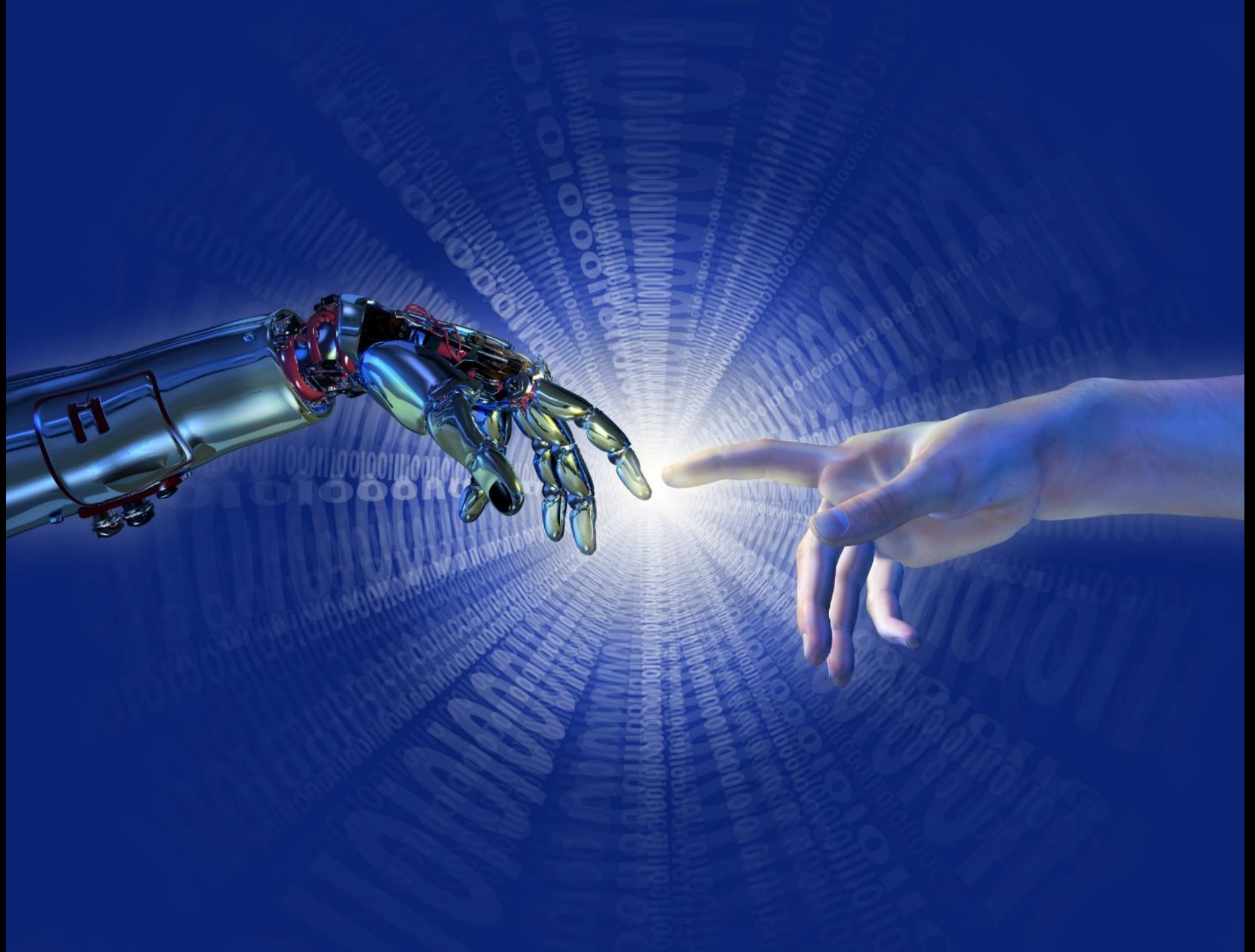


"If I'm in the loop mentally I can respond more quickly than if I have to watch an automatic system and take over and then get my mind into the loop.

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**



... and Human Teams?

The High and the Mighty (1954)



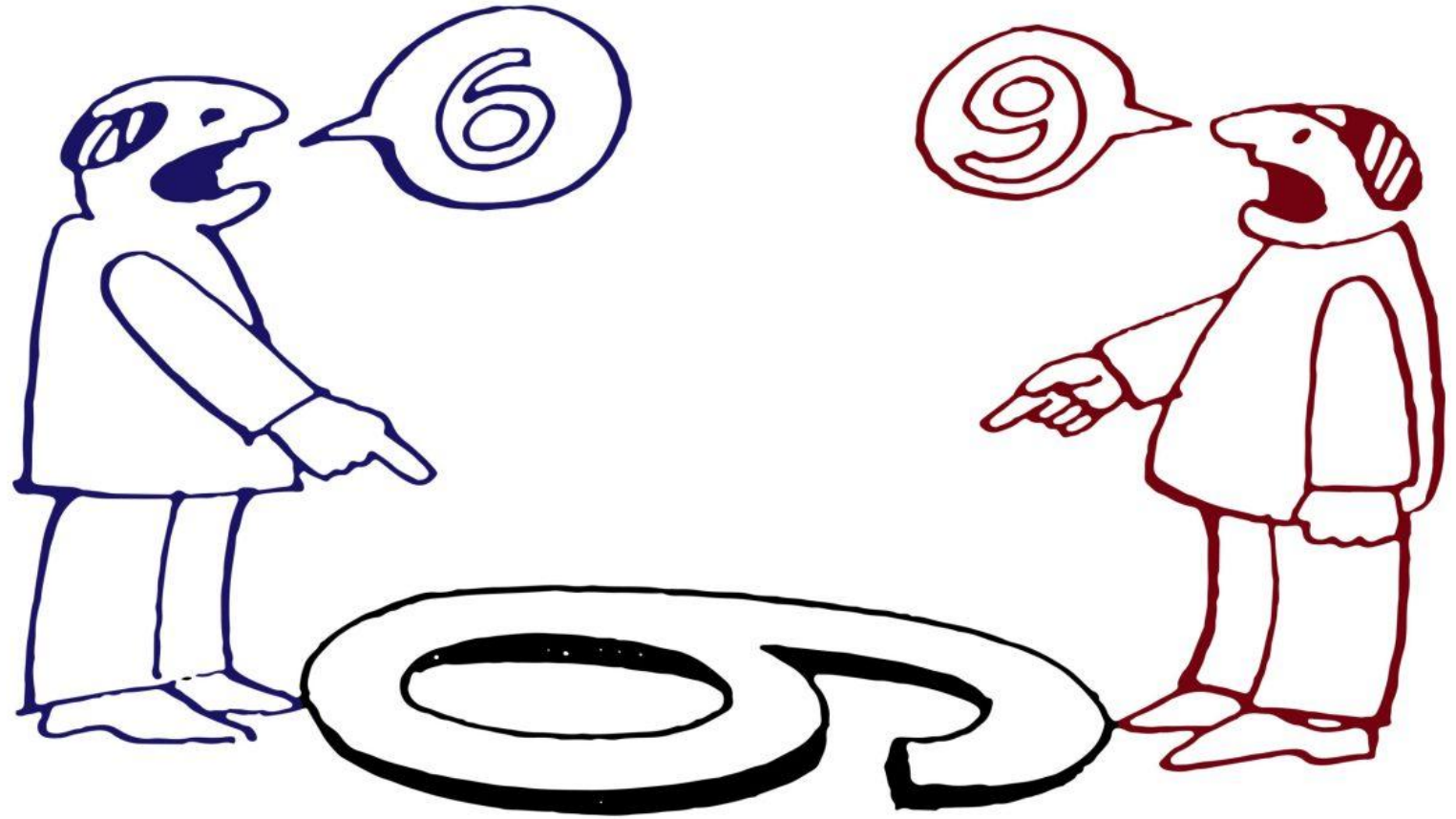
Air France Flight 447 (2009)



Based on Endsley's SA Three Level Model



Differences of Perception



Airplane! (1980)





What Makes an Expert?



Harvard
Business
Review

Managing People

The Making of an Expert

by K. Anders Ericsson, Michael J. Prietula, and Edward T. Cokely

From the Magazine (July–August 2007)

- “a person who is very knowledgeable about or skilful in a particular area”
- *experts are always made, not born*
- Superb performers have:
 - Practiced intensively, on tasks that they can, and that they *can't* do well
 - Studied with devoted teachers/mentors
 - Been supported enthusiastically

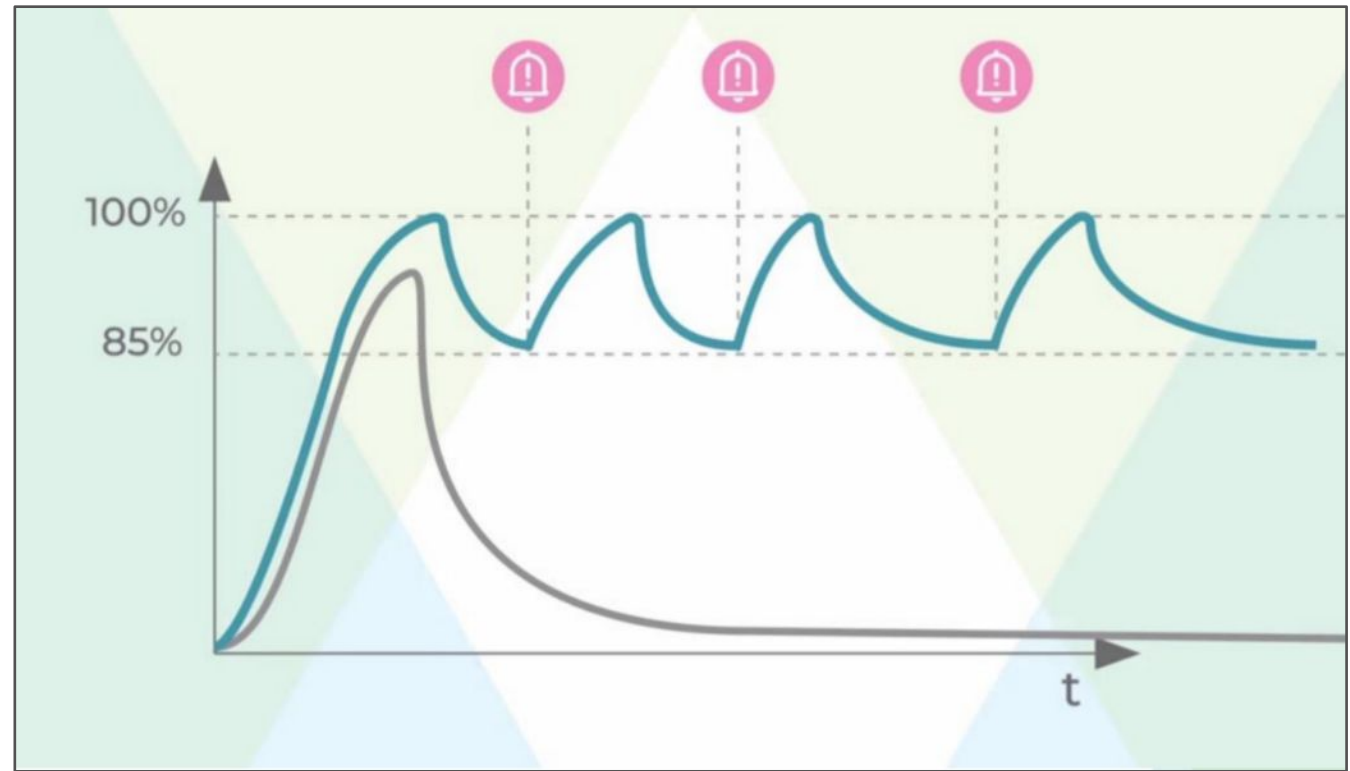


What About an Expert Team?



- An **expert team**, consists of individuals who have expertise, but more important, they have the ability to work effectively with others, resulting in a high-performing team
- For a team to succeed, team members need to be skilful in teamwork competencies such as knowing how to correctly **coordinate** and **communicate**

Skill Fade



**Humans need to
Practice, Practice, Practice!
Individually and in Teams**



5/5

Thoughts on Careers





**It is an Exciting &
Important Time of
Change in Aerospace**

- **AI**
- **Autonomous Flight**
- **Digital Twins and Digitisation**
- **Drones**
- **Electrification**
- **Space**
- **Sustainability**

Professional Engineer Competences

- A. Knowledge and understanding**
- B. Design, development and solving engineering problems**
- C. Responsibility, management and leadership**
- D. Communication and interpersonal skills**
- E. Professional commitment**



Professional Engineer

- Chartered Engineer
- Incorporated Engineer



Some Professional Organisations



**ROYAL
AERONAUTICAL
SOCIETY**



Thoughts on Careers

- **Be Good to People**
- **Don't worry too much...**
 - **It's mostly beyond our control**
 - **Go to the next interesting job**



Questions?

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Hélène Dutrieu c. 1911