Adaptive Cockpit

Adaptive cockpit is a level 3 roadmap (3ADC) created by Dave Bertucci (mailto:bertucci@mit.edu) and Tyler Carey (mailto:tcarey4@mit.edu) with the support and mentorship of industry partners.

(NOTE: This roadmap is the sole work of Dave Bertucci and Tyler Carey and does not represent the official position or plan of MIT or any industry partner.)

Contents

Roadmap Overview

An adaptive cockpit is an advanced, AI-driven system designed to enhance aircraft safety and pilot performance during unexpected or high-stress situations. This technology integrates various sensors and intelligent algorithms to monitor both the aircraft's status and the pilot's physiological state in real time. Key features of an adaptive cockpit include:

1. Continuous monitoring of aircraft systems and flight parameters
2. Real-time analysis of pilot biometrics and behavior
3. Detection of sudden, potentially disorienting events or anomalies
4. Intelligent assessment of the pilot's cognitive and emotional state
5. Provision of timely, context-aware assistance and guidance

When the system detects signs of pilot stress, confusion, or delayed responses, it intervenes with appropriate support. This may include a simplified display of critical information, biofeedback to reduce stress, or automated assistance with certain tasks. The adaptive cockpit aims to mitigate the impact of human factors such as the startle effect and cognitive overload. By providing tailored, real-time support, pilots can more quickly regain situational awareness and make informed decisions during critical moments. This technology represents a significant advancement in aviation safety, offering a proactive approach to managing complex scenarios and reducing operational risks. As it continues to evolve, the adaptive cockpit has the potential to revolutionize cockpit design and pilot training, ultimately leading to safer and more efficient flight operations.

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Over time, flight deck crews have evolved from having 5 members (Pilot, Co-pilot, Flight Engineer, Navigator, and Radio Operator) to the modern configuration of Captain and First Officer. This reduction was made possible by technological advances that automated or eliminated certain roles. With the prediction of a massive pilot shortage and the continued advancement in technology, we will explore how **Adaptive Cockpits** may play a role in the journey to Single Pilot Operations.

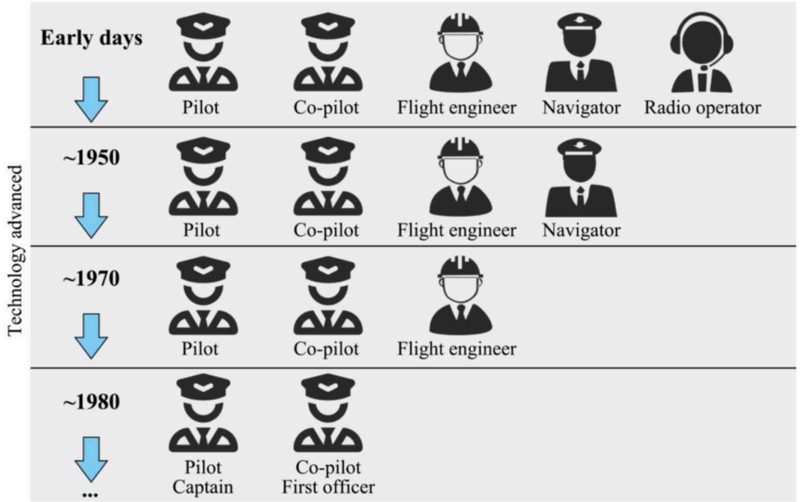
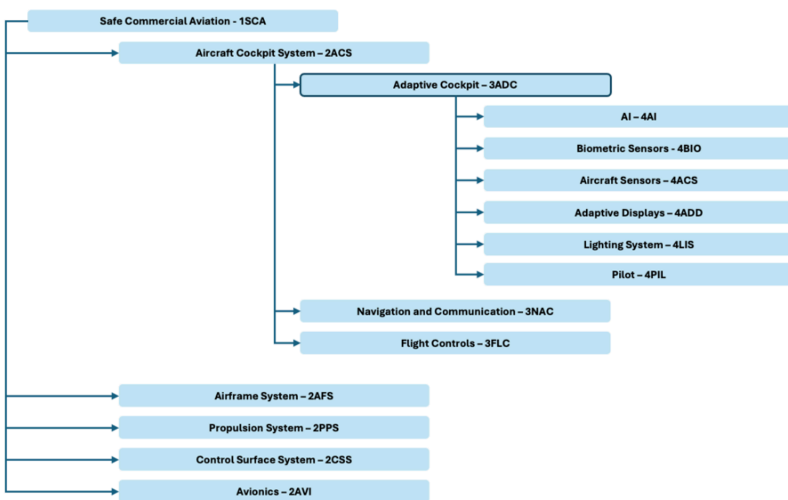
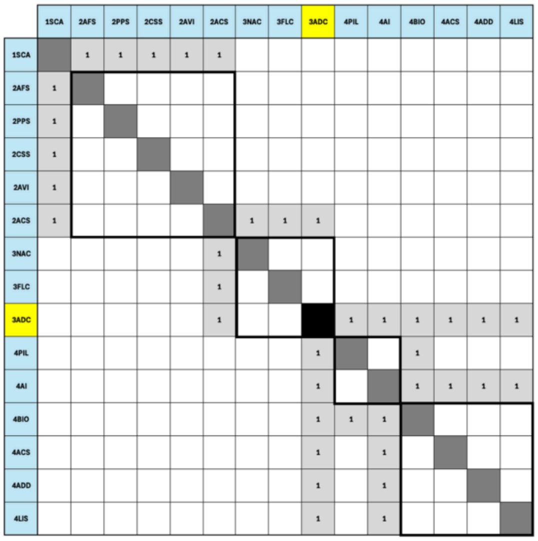


Figure 1-1. The evolution of the flight deck crew.

Design Structure Matrix (DSM) of Roadmap Family

Our technology roadmap focuses on an Adaptive Cockpit (3ADC) at the subsystem level (level 3). Components of the adaptive cockpit are AI for interpreting and modeling data to determine aircraft and pilot status (4AI), Biometric Sensors for measuring pilot status indicators (4BIO), aircraft sensors for detecting aircraft status (4ACS), adaptive displays that can highlight critical information for a pilot (4ADD), a lighting system that assists pilots in maintaining respiratory rates and creating a calming atmosphere (4LIS), and the pilot responsible for flying the aircraft (4PIL). Other subsystems in the cockpit include navigation and communication systems (3NAC), and flight controls (3FLC). We have also listed other level 2 products that support our level 1 market of safe commercial aviation (1SCA).

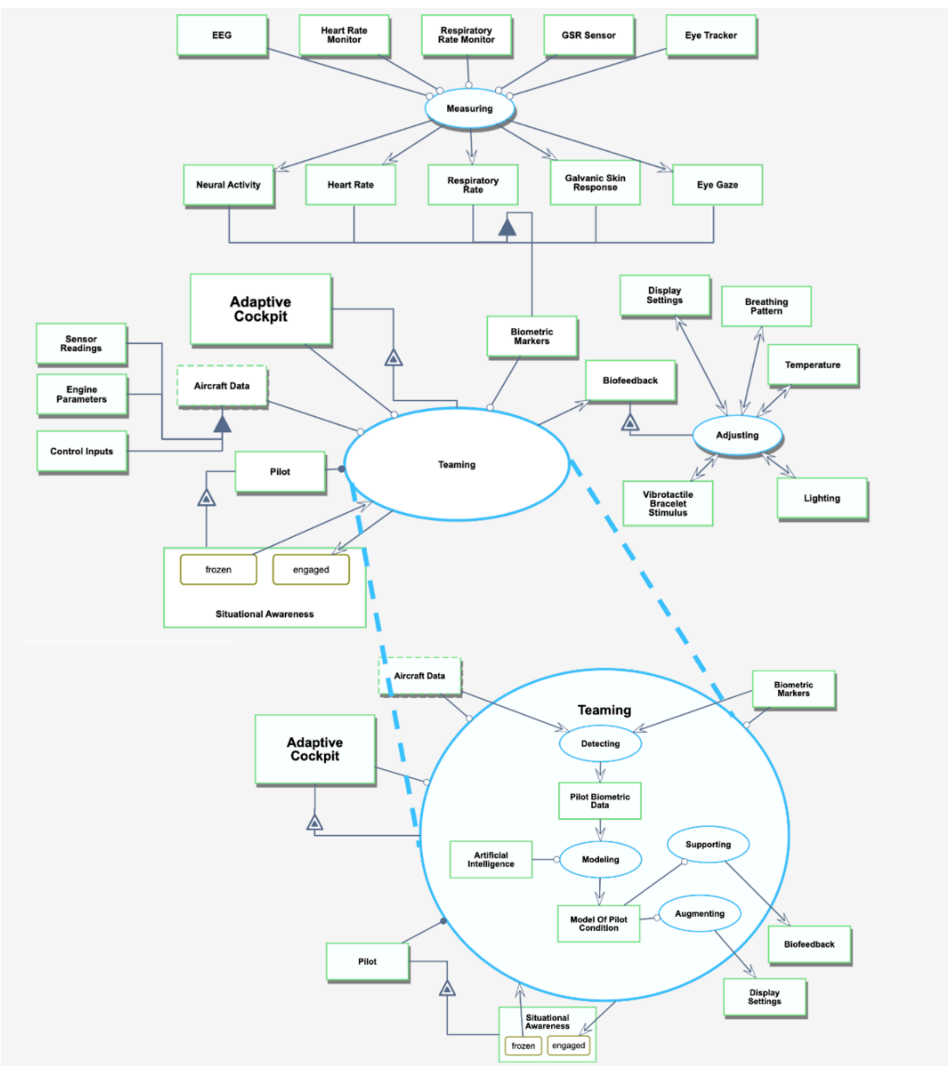




	1SCA	2AFS	2PPS	2CSS	2AVI	2ACS	3NAC	3FLC	3ADC	4PIL	4AI	4BIO	4ACS	4ADD	4LIS
1SCA		1	1	1	1	1									
2AFS	1														
2PPS	1														
2CSS	1														
2AVI	1														
2ACS	1						1	1	1						
3NAC						1									
3FLC						1									
3ADC						1				1	1	1	1	1	1
4PIL									1			1			
4AI									1			1	1	1	1
4BIO									1	1	1				
4ACS									1		1				
4ADD									1		1				
4LIS									1		1				

Object Process Diagram (OPD) of Roadmap Technology

In the figure below, we provide an Object-Process-Diagram (OPD) of the 3ADC roadmap. This diagram captures the main object of the roadmap (Adaptive Cockpit), its main process (Teaming), the various tools required, the sub-processes required for Teaming, and the change in the status of the pilot as a result of Teaming. Additionally, we have included a zoomed-in look into the Temaing process and its four sub-processes (Detecting, Modeling, Supporting, and Augmenting).



The Object Process Language (OPL) below is the auto-generated grammatical version of the OPD above. The first OPL is for the Level 1 OPD, whereas the second OPL is for the decomposition of Teaming into its four sub-processes.

OPL

1. Pilot is a physical and systemic object.
2. Situational Awareness of Pilot is an informatical and systemic object.
3. Situational Awareness of Pilot can be engaged or frozen.
4. Adaptive Cockpit is a physical and systemic object.
5. Biofeedback is a physical and systemic object.
6. Biometric Markers is a physical and systemic object.
7. Aircraft Data is a physical and environmental object.
8. Heart Rate Monitor is a physical and systemic object.
9. Respiratory Rate Monitor is a physical and systemic object.
10. GSR Sensor is a physical and systemic object.
11. Sensor Readings is a physical and systemic object.
12. Heart Rate is an informatical and systemic object.
13. Respiratory Rate is an informatical and systemic object.
14. Galvanic Skin Response is an informatical and systemic object.
15. Eye Gaze is an informatical and systemic object.
16. Eye Tracker is a physical and systemic object.
17. Control Inputs is a physical and systemic object.
18. Engine Parameters is a physical and systemic object.
19. Breathing Pattern is an informatical and systemic object.
20. Temperature is a physical and systemic object.
21. Lighting is a physical and systemic object.
22. Display Settings is a physical and systemic object.
23. EEG is a physical and systemic object.
24. Neural Activity is a physical and systemic object.
25. Vibrotactile Bracelet Stimulus is an informatical and systemic object.
26. Pilot exhibits Situational Awareness.
27. Adaptive Cockpit exhibits Teaming.
28. Biometric Markers consists of Eye Gaze, Galvanic Skin Response, Heart Rate, Neural Activity, and Respiratory Rate.
29. Aircraft Data consists of Control Inputs, Engine Parameters, and Sensor Readings.
30. Biofeedback exhibits Adjusting.
31. Teaming of Adaptive Cockpit is an informatical and systemic process.
32. Teaming of Adaptive Cockpit changes Situational Awareness of Pilot from frozen to engaged.
33. Pilot handles Teaming of Adaptive Cockpit.
34. Teaming of Adaptive Cockpit requires Adaptive Cockpit, Aircraft Data, and Biometric Markers.
35. Teaming of Adaptive Cockpit yields Biofeedback.
36. Measuring is a physical and systemic process.
37. Measuring requires EEG, Eye Tracker, GSR Sensor, Heart Rate Monitor, and Respiratory Rate Monitor.
38. Measuring yields Eye Gaze, Galvanic Skin Response, Heart Rate, Neural Activity, and Respiratory Rate.
39. Adjusting of Biofeedback is a physical and systemic process.
40. Adjusting of Biofeedback affects Breathing Pattern, Display Settings, Lighting, Temperature, and Vibrotactile Bracelet Stimulus.

OPL

1. Teaming of Adaptive Cockpit from SD zooms in SD1 into Detecting, Modeling, Supporting, and Augmenting, which occur in that time sequence, as well as Artificial Intelligence, Model Of Pilot
2. Situational Awareness of Pilot is an informatical and systemic object.
3. Situational Awareness of Pilot can be engaged or frozen.
4. Pilot is a physical and systemic object.
5. Adaptive Cockpit is a physical and systemic object.
6. Biometric Markers is a physical and systemic object.
7. Aircraft Data is a physical and environmental object.
8. Biofeedback is a physical and systemic object.
9. Display Settings is a physical and systemic object.
10. Model Of Pilot Condition is an informatical and systemic object.
11. Artificial Intelligence is an informatical and systemic object.
12. Pilot Biometric Data is an informatical and systemic object.
13. Pilot exhibits Situational Awareness.
14. Adaptive Cockpit exhibits Teaming.
15. Teaming of Adaptive Cockpit is an informatical and systemic process.
16. Teaming of Adaptive Cockpit changes Situational Awareness of Pilot from frozen to engaged.
17. Pilot handles Teaming of Adaptive Cockpit.
18. Teaming of Adaptive Cockpit requires Adaptive Cockpit, Aircraft Data, and Biometric Markers.
19. Supporting is an informatical and systemic process.
20. Supporting requires Model Of Pilot Condition.
21. Supporting yields Biofeedback.
22. Augmenting is an informatical and systemic process.
23. Augmenting requires Model Of Pilot Condition.
24. Augmenting yields Display Settings.
25. Detecting is an informatical and systemic process.
26. Detecting consumes Aircraft Data and Biometric Markers.
27. Detecting yields Pilot Biometric Data.
28. Modeling is an informatical and systemic process.
29. Modeling requires Artificial Intelligence.
30. Modeling consumes Pilot Biometric Data.
31. Modeling yields Model Of Pilot Condition.

Figures of Merit (FOMs) of Technology

Many figures of merit (FOMs) were considered for this roadmap and are outlined below with more information and current trends on each. The first 3 were found to be especially important for the roadmap and are shown below in **bold**.

Important FOMs for 3ADC

Figure of Merit	Description	Trends	Units
Accident Rate	Rate of accidents normalized by passenger miles or flights	decreasing	$\frac{\text{accidents}}{\text{passenger} * \text{mile}}$ or $\frac{\text{accidents}}{\text{flight}}$
Pilot Efficiency	Measure of how many passengers each pilot is capable of transporting per year	increasing	$\frac{\text{passengers}}{\text{pilot} * \text{year}}$
Biometric Activity Accuracy	Accuracy of best models of pilot pilot metrics to predict attention and startle response	increasing	%
System Maintainability	How much time is spend maintaining aircraft systems, measured by comparing maintenance time per flight time	decreasing	$\frac{\text{maintenance hours}}{\text{passenger} * \text{mile}}$
Response Time	Time required to identify and mitigate safety issues	flat	minutes
System Uptime	Amount of time aircraft is available to be dispatched on a mission as a percentage of wall time	increasing	%
Cognitive Load on Crew	As measured by industry standard NASA TLX score	flat	unitless

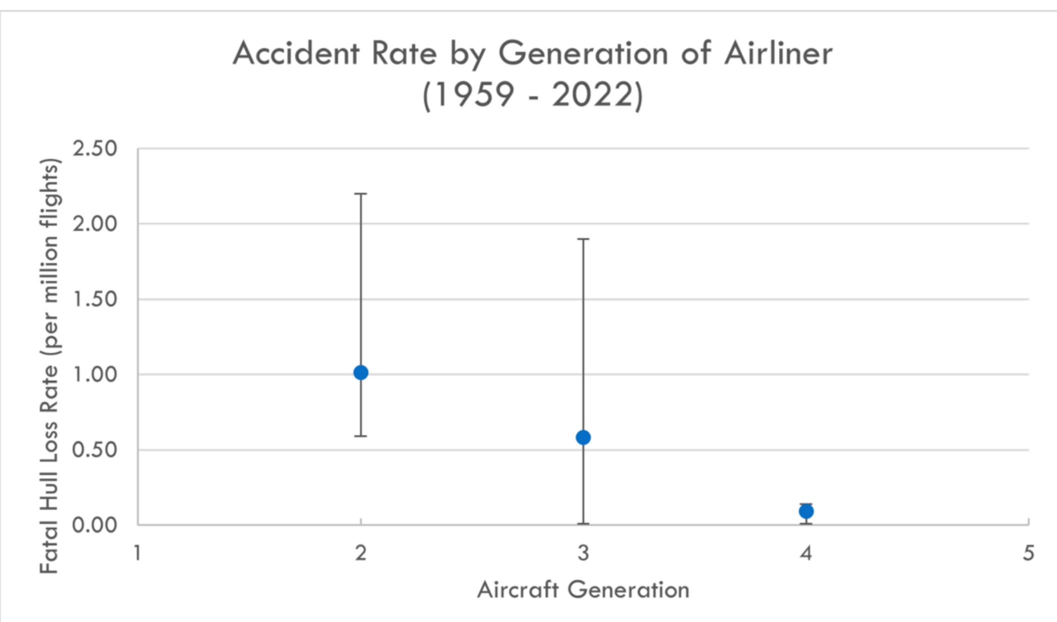
Accident Rate

Detail of Accident Rates (per million flight cycle), 1959 to 2022

Large commercial aircraft have steadily been getting safer. The table below shows accident rates of aircraft organized by the date of their first flights (oldest first). This chart highlights that newer designs have proven to be safer than older designs. Additionally the chart categorizes aircraft by the generation of automation used in each.

Generation 1 (Not shown)
Analog gauges and early auto-pilot systems
Generation 2
Integration of auto-pilot and auto-throttle systems
Generation 3
Glass cockpits, improved navigation systems, and terrain avoidance systems
Generation 4
Fly-by-wire and envelope protection systems

As these successive generations of technology have been integrated into aircraft the accident rates have dropped dramatically. Since safety record is a property of the system as a whole and the complexity of an aircraft is so high, generating an analytical model of the contributing factors is very complex, but by comparison to existing vehicles and considering the relative frequency of specific classes of accidents, it is possible to understand what technologies will be able to impact these metrics in the future.



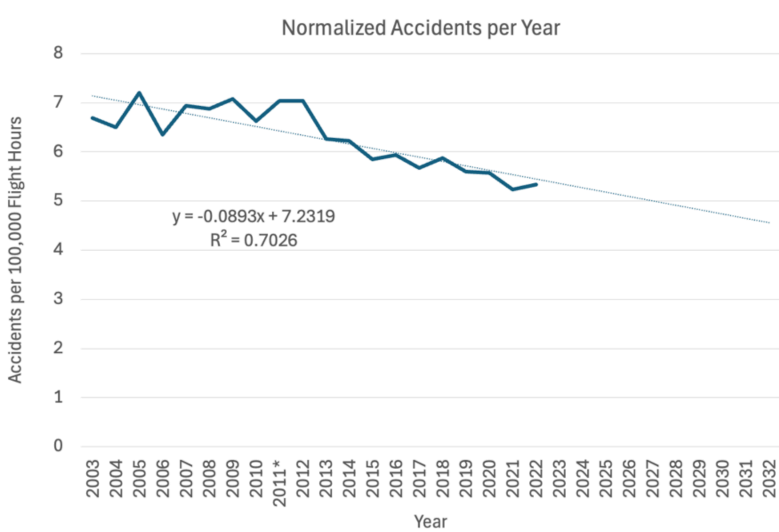
Detailed statistics for each aircraft are in table below.

Accident rates for commercial aircraft from 1959 - 2022 by type, manufacturer and generation (rates per million flights)

Aircraft Sorted by Year of Introduction	Manufacturer	Generation	Fatal Hull Loss Accident Rate	Hull Loss Accident Rate
727	Boeing	Generation 2	0.72	1.22
DC-9	McDonald Douglas	Generation 2	0.77	1.45
737-100/-200	Boeing	Generation 2	0.87	1.78
F-28	Fokker	Generation 2	2.2	4.4
DC-10/MD-10	McDonald Douglas	Generation 2	1.28	2.87
A300	Airbus	Generation 2	0.59	2.52
MD-80/-90	McDonald Douglas	Generation 3	0.32	0.76
767	Boeing	Generation 3	0.14	0.54
757	Boeing	Generation 3	0.22	0.29
BAe 146, RJ-70/-85/-100	British Aerospace	Generation 2	0.67	1.51
A310	Airbus	Generation 3	1.9	2.53
737-300/-400/-500	Boeing	Generation 3	0.26	0.81
A300-600	Airbus	Generation 3	0.54	0.95
A320/321/319/318	Airbus	Generation 4	0.08	0.17
F-100/F-70	Fokker	Generation 3	0.43	1.21
747-400	Boeing	Generation 3	0.55	1.1
MD-11	McDonald Douglas	Generation 3	1.61	3.21
A340	Airbus	Generation 4	0	0.58
A330	Airbus	Generation 4	0.14	0.42
777	Boeing	Generation 4	0.13	0.27
737-600/-700/-800/-900	Boeing	Generation 3	0.08	0.18
EMB-170/-175/-190	Embraer	Generation 3	0.04	0.18
ERJ-135/-140/-145	Embraer	Generation 3	0	0.33
A320/321/319 NEO	Airbus	Generation 4	0.11	0.11
737 MAX	Boeing	Generation 3	1.48	1.48

Detail of Accidents per Passenger Hour (US-based General Aviation fleet)

The general aviation (GA) fleet has steadily gotten safer over the last 20 years and we predict this trend will continue. This fleet is where most aviation accidents occur, due to older aircraft and less trained pilots than then more professional commercial fleet. Because of these features of the GA fleet, it has lots of room to improve with cockpit improvements and attention aids for pilots.



Pilot Efficiency

Pilots are currently a critical part of air transportation systems and making sure they are efficiently transporting passengers is an important figure of merit (FOM) of an airline. The definition of pilot efficiency is below.

$$Efficiency_{Pilot} = \frac{Capacity_{Pass} * LF_{Pass}}{Pilot_{Plane}} * Flight_{Year}$$

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Biometric Activity Accuracy

Biometric Activity Accuracy is a measure of the performance of the system. In this case, biometric activity is used to determine if the pilot becomes startled or suffers from a lack of attention to the activity of flying or other critical actives of controlling the aircraft. The classifier is a binary classifier that either reports normal (attentive) or abnormal (startled or inattentive). This is calculated with the equation below.

$$Accuracy = \frac{correct\ classifications}{all\ classifications} = \frac{TP + TN}{TP + TN + FP + FN}$$

Accuracy in general when applied to a binary classifier of this type is reported as a ratio of correct classifications to all classifications. This is calculated as the sum of true positives (TP) and true negatives (TN) to the total number of classifications, which is the sum of all responses to the classifier, true positive (TP), true negative (TN), false positive (FP) and false negative (FN).

Alignment with Company Strategic Drivers

Strategic drivers and targets

ID	Strategic Driver	Alignment Targets
1	Reduce perceived stress/workload after adverse events in cockpit.	This roadmap aims to develop a technology that will accurately measure pilot physiological parameters, model the status of pilot and aircraft, and augment the pilot's environment to reduce stress after adverse events. This strategic driver is strongly aligned with our roadmap. **Target:** Reduction in pilot stress by 35% in single pilot operations as measured by standard physiological markers (such as HR and HRV).
2	Improve detection of stress and workload from real time physiological sensing.	This roadmap requires accurate assessment of pilot state to allow for useful intervention to improve performance. Both false positives (nuisince interventions) and false negatives (missed interventions) will erode trust in the system and reduce its effectiveness. **Target:** Detect stress response and increased workload with 90% accuracy with less than 5% false positive rate.
3	Provide framework that reduces the number of pilots required for flight to meet projected demand of commercial aviation. *"Demand for pilots is likely to soar. Projections indicate that, over the next 20 years, 602,000 new pilots will be needed to meet demand from commercial operators." – Boeing Pilot and Technician Outlook 2022-2041*	This roadmap focuses on developing technology that identifies and adjusts pilot operation conditions to reduce perceived workload after adverse events. If this technology is successful, it will help to create a case for safe single pilot operations. Single pilot operations are not the primary purpose of the technology but is a possible outcome that assists in demand drivers. Therefore, this strategic driver is aligned with our technology roadmap, but isn't the primary focus of our roadmap. **Target:** Reduction in pilot workload by 50% during critical flight phases as measured by standard workload metrics (such as NASA TLX score).

Positioning of Company vs. Competition

The chart below summarizes some key metrics for the major players in aircraft manufacturing. There is a clear difference in market share, with Boeing and Airbus demonstrating a duopoly over commercial aviation. Embraer and Bombardier have focused their efforts on commercial aviation's regional and business segments.

Summary of Aircraft Manufacturers

Manufacturer	Number of Aircraft in Service	Number of Models	Primary Segment	Range of Crew Sizes	Number of Single Pilot Aircraft
Embraer	1,800	6	Regional / Short Haul	2	1 (Pheonom 300E, Part 23)
Airbus	13,890	8	Commercial Wide / Narrow Body	2-3	0
Boeing	11,000	10	Commercial Wide / Narrow Body	2-3	0
Bombardier	5,000	4	Business	2	0

Aircraft are incredibly complex systems that impart a tremendous demand on pilots. We will look at some characteristics and traits of various aircraft and use them as a proxy for complexity. The chart below highlights the various levels of complexity in commercial aviation across segments and manufacturers.

Complexity of Aircraft as Measured by Cost, Parts, and Maintenance Man-Hours per Flight Hour

Manufacturer	Aircraft Model	Maximum PAX	Average Cost	Approximate Parts	Maintenance Man-Hours per flight hour (MMH/FH)	Cost / Passenger Seat
Embraer	E175	88	$54 million	500,000	.95	$614,000
Airbus	A320neo	240	$110 million	1.2 million	1.75	$458,000
Airbus	A350	410	$317 million	2.5 million	2.35	$773,000
Boeing	737 Max	210	$121 million	1.3 million	1.50	$576,000
Boeing	787 Dreamliner	318	$292 million	2.3 million	2.25	$918,000
Bombardier	CRJ900	90	$75 million	300,000	1.2	$833,000

The chart below shows that Airbus is the only major manufacturer that shows public-facing activity in RDO / SPO R&D. There is an opportunity for companies to differentiate their architectures and provide a solution that will assist the industry in generating safer aircraft and eventually meet pilot demands in the future by providing single-pilot aircraft.

Development of Reduced Crew Operations (RCO) / Single Pilot Operations (SPO) by Manufacturer

Manufacturer	RCO / SPO in Development? (Y/N) - Name	Estimated Implementation Date	Aircraft	Segment	Technology
Airbus	Y – Project Morgan and Project DISCO	2026/2027 (RCO), 2030 (SPO)	A350F / A321F	Freight	Eye Tracking, voice recognition, Pilot health monitoring, CAS, etc.
Embraer	N	-	-	-	-
Boeing	N	-	-	-	-
Bombardier	N	-	-	-	-

Technical Model

The development of an adaptive cockpit involves several key design considerations, particularly regarding bio-feedback devices. These devices play a crucial role in monitoring pilot physiological states, but their implementation requires careful balancing of accuracy and practicality.

Key Issues

1. Accuracy vs. Practicality: More accurate bio-feedback devices often come at the cost of being more cumbersome and potentially distracting for pilots.
2. Cognitive Load: Highly accurate devices may inadvertently create unnecessary cognitive burden, which could counteract their intended benefits.
3. Obtrusiveness: The most accurate devices are designed for a lab environment so likely would be too intrusive for use in real time while operating an aircraft.
4. R&D Focus: Future research and development efforts should prioritize creating bio-feedback devices that maintain high accuracy while minimizing invasiveness and pilot discomfort.

Morphological matrix

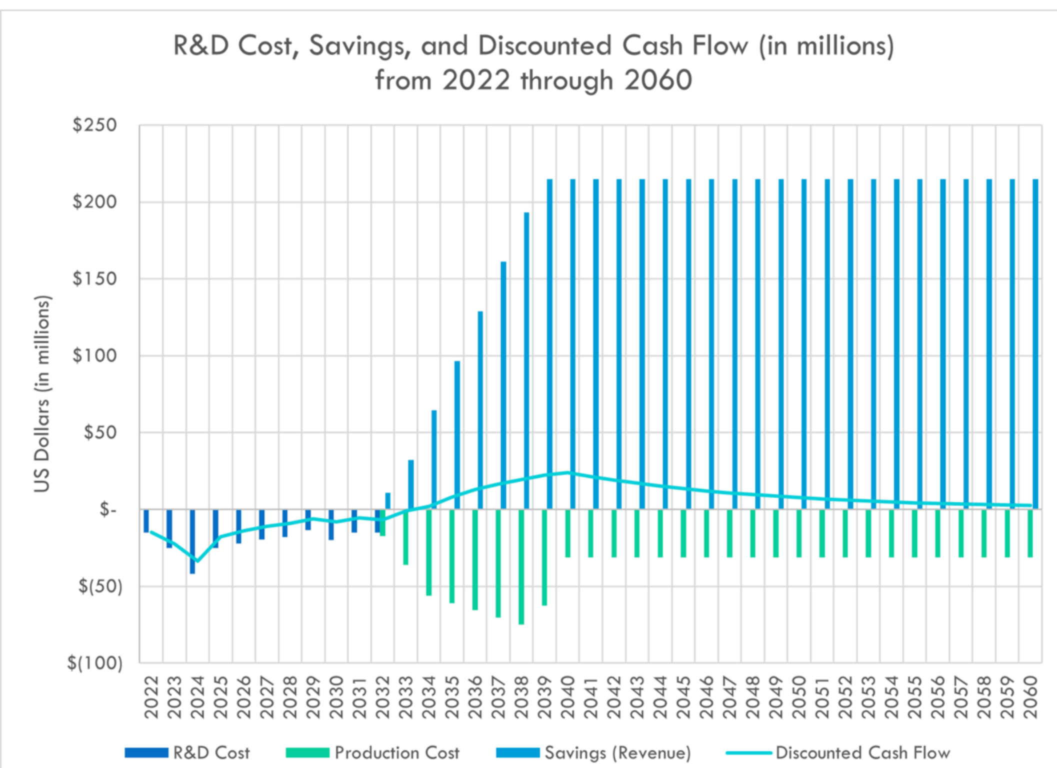
Categories	Decision Variables	1	2	3	Status
Sensors	**Heart Rate / Heart Rate Variability (HR/HRV)**	Single-Lead Electrocardiogram (ECG)	Chest Strap	PPG	**Promising**
	Electroencephalogram (EEG)	High Density Array (>64 channel)	Conventional Array (~32 channel)	Consumer Array (~4 channel)	**Promising, but Obtrusive**
	Galvanic Skin Response (GSR)	Electrodes	Wearables (wrist or watch)		**Needs more study**
	Eye Tracking	Point Cloud	Head Mounted		**Promising, but Obtrusive**
	Respiratory Rate	Spirometer	Chest Strap	Resistive Sensors	**Promising**
	Blood Oxygen (VO2)	Pulse Oximeter	Arterial Blood Gas Test		**Needs more study**
Compute	**Algorithm Type**	Random Forest	Support Vector Machines	Deep Neural Networks (DNNs)	
Output Target	**Level of Automation (LoA)**	Minimal	Management by Consent	Management by Exception	

Financial Model

Based on a reduction of accidents by 75% of the Embraer commercial fleet of 11% of the total, mean accident cost to industry of $170M, and discount rate of 12% the financial model of the value of this project is below. Additionally the project has an assumption of a rollout of the system to the global fleet over 7 years.

- Embraer commands 11% of the commercial fleet worldwide
- Improving pilot cognition can reduce accident rate by 60%
  - 80% accidents from pilot error today
  - Reduction of 75% of this class of accident
- The mean cost for a catastrophic accident to industry is $170M
- Discount rate of 12%
- R&D spend is allocated over the schedule in the R&D Projects section
- Retrofit into the fleet is over 7 years after conclusion of R&D effort

As shown below this shows the Net Present Value of the effort at ~$133M.



List of R&D Projects

The R&D project timeline has been developed based on limited information about competitors' progress in Single Pilot and Reduced Crew Operations. Airbus' Project Morgan and Project DISCO, which aim to implement single pilot operations in Fedex freight aircraft by 2030, provide the only publicly available insights. To maintain competitiveness with major manufacturers like Airbus, Embraer targets R&D completion by 2032, with the subsequent availability of aircraft and training for customers. The R&D trajectory begins by enhancing component-level technologies that best indicate pilot status, then advances to developing precise modeling algorithms and automation. The final phase of R&D projects focuses on human factors research, design, prototyping, and training development. This strategic approach ensures Embraer remains at the forefront of aviation technology while addressing the complex challenges of reduced crew operations.

Project #	Status	Project Title	Start	Finish	FOM Improvement	Anticipated Cost ($)	Cost Breakdown
1	In Progress	Eye Tracking Improvement with unobstructive hardware	2022	2024	Biometric Activity Accuracy (%) Cognitive Load	~30 Million	Hardware - $3,500,000 Software - $6,500,000 V&V – $10M Personnel - $5,000,000 Regulatory - $5,000,000
2	In Progress	EEG improvement with unobstructive hardware	2022	2024	Biometric Activity Accuracy (%) Cognitive Load	~20 Million	Hardware - $2,000,000 Software - $5,000,000 V&V – $5,000,000 Personnel - $3,000,000 Regulatory - $5,000,000
3	In Progress	Pilot Modeling Improvement	2023	2025	Pilot Model Prediction Accuracy (%) Response Time	~25 Million	Data Collection - $2,000,000 Model Development - $5,000,000 Hardware Integration - $3,000,000 V&V – $10M Regulatory - $5,000,000
4	In Progress	Automation analysis and improvement for decision making	2024	2027	Response Time Incident Rate	~40 Million	Based on SMARTS and COAST projects, which are focused on AI and automation in aviation. Expanded to capture additional costs associated with larger freight aircraft.
5	Planned	Human Factors Research for Cockpit Design	2025	2027	Response Time Cognitive Load Incident Rate	~20 Million	Personnel – $10M Hardware - $4,000,000 Software - $3,000,000 V&V - $3,000,000
6	Planned	Prototype Development	2027	2030	No FOM improvements **Prototyping**	~45 Million	Avionics – $15M Mockup and Integration – $15M V&V – $15M
7	Planned	Advanced Training Program	2030	2032	Incident Rate Cognitive Load	~50 Million	Personnel - $35M Equipment – $15M

Key Publications and Patents

Publications

Masi, G.; Amprimo, G.; Ferraris, C.; Priano, L. Stress and Workload Assessment in Aviation—A Narrative Review. Sensors 2023, 23, 3556. https://doi.org/10.3390/s23073556

This paper reviews various workload and stress assessment tools used within the military and civilian aviation sector. Stress and workload are key indicators of pilot performance, but measuring these conditions is not straightforward. Some of the highlighted indicators used for determining stress and workload are neurophysical (heart rate (HR) and heart rate variability (HRV)), respiratory rate, electrodermal activity (EDA), body temperature, eye movements and dilation, etc. Subjective measures such as the NASA-TLX can also be used to determine workload. One of the major conclusions was that there is no positive indicator for stress and workload in pilots. All the indicators mentioned above are only potential indicators for stress, so a comprehensive approach must be taken to model the status of the pilot. Most of the studies reviewed in this analysis used a combination of assessments to deduce stress and workload. The most common neurophysical used in the studies was HR and HRV. The authors comment on the feasibility of taking these measurements during flight, recommending that the devices should be light and not encumber the pilot's ability to function by using single-lead wearables or smart devices.

The authors suggest that more research should be done on eye tracking, near-infrared spectroscopy, grip strength during flight, and other parameters. Lastly, the author recommends further research into adaptive cockpits.

This review is an excellent source of background science regarding safety in aviation as it relates to pilot performance. The review's conclusion suggests that a combination of assessments is required, that there is still work to do to establish a reliable model for pilot stress and workload, and that adaptive cockpits would be the potential practical application of these findings.

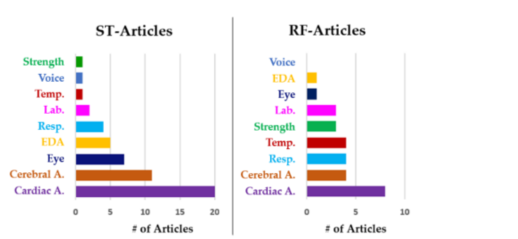


Figure 3. Objective measures employed in ST articles (with simulated flight task) and RF articles (real flight task).

Li, Qinbiao & Chen, Chun-Hsien & Ng, Kam K.H. & Yuan, Xin & Yiu, Cho Yin. (2024). Single-pilot operations in commercial flight: Effects on neural activity and visual behaviour under abnormalities and emergencies. Chinese Journal of Aeronautics. 37. 10.1016/j.cja.2024.04.007.

This study explores the feasibility and safety of single-pilot operations (SPO) in commercial aviation. Using a flight simulator, 20 licensed pilots were tested in dual-pilot (DPO) and SPO scenarios. Findings reveal that neural activity, particularly in the frontal, parietal, and temporal brain regions, increased significantly during complex emergencies in SPO, indicating higher cognitive demands. Eye-tracking data showed that pilots in SPO focused less on the primary flight display (PFD) and more on secondary displays, reflecting dispersed attention and increased workload. Pilots made more operational errors in SPO, especially during complex scenarios like dual-engine failures and single-engine fires. Subjective feedback highlighted that pilots perceived SPO as having higher workload, reduced performance, and greater safety risks compared to DPO. The study identified specific physiological patterns, such as heightened cortical activity and altered visual scanning behaviors, which correlated with operational errors in SPO. To mitigate these risks, the study recommends integrating ground-based support systems and SPO-oriented intelligent flight systems to provide real-time assistance and maintain situational awareness. Additionally, improved cockpit design, such as head-up displays (HUD), is suggested to streamline information and reduce workload. Technological advancements, regulatory changes, and tailored training for single-pilot scenarios are critical to addressing these challenges. While SPO shows potential, its safe implementation depends on overcoming significant human performance and safety concerns.

This thesis directly supports the need for the technology we are roadmapping. The author provides the context surrounding the shift to SPO, and the risks associated with this transition.

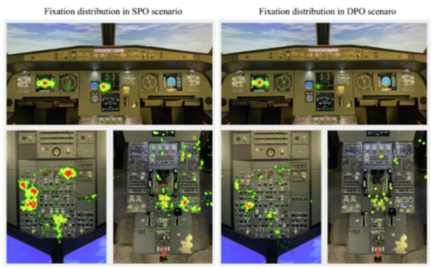


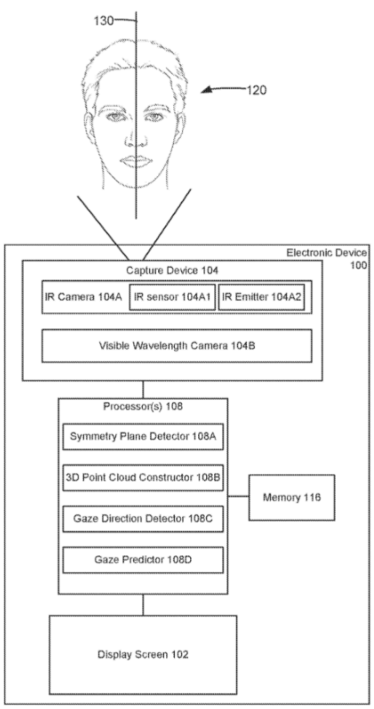
Fig. 5 Heat map of fixation distribution of all emergencies over main panel, pedestal, and overhead panel during two different scenarios from all participants.

Patents

Eye Gaze Tracking – US Patent No. US11899837B2 – CPC G06F

The Eye Gaze patent shows a new way to detect and track eye gaze. The primary components of the patent are a visible wavelength camera, an infrared camera, and processors. It works by using the IR cameras to develop a 3D point cloud of a person's face. It also creates a 2D image of the face with the visible wavelength camera. The processors take this data and create symmetry planes, which can be used to determine where the person is looking.

This technology is relevant because the publication review suggested that eye-tracking is a great indicator of pilot status. However, wearing devices that obstruct vision or could bounce around during flight is not ideal. This technology addresses both of those concerns.



Smart Ring System for Monitoring Sleep Patterns And Using Machine Learning Techniques To Predict High-Risk Driving Behavior – US Patent No. US12077193B1– CPC B60W

The patent above is for a smart ring that monitors sleep patterns in users and predicts high-risk behaviors through machine learning. The device is a ring, similar to an Oura ring, that tracks HR/HRV, body temperature, motion, etc. This data can be used in conjunction with vehicle data to predict high-risk behavior.

While this patent is centered around sleep and performance of an automobile driver, the general concept can be applied in other domains. It shows that small, non-obstructive devices can be used to collect data, transmit data, and inform models that could improve people's performance in control of transportation systems.

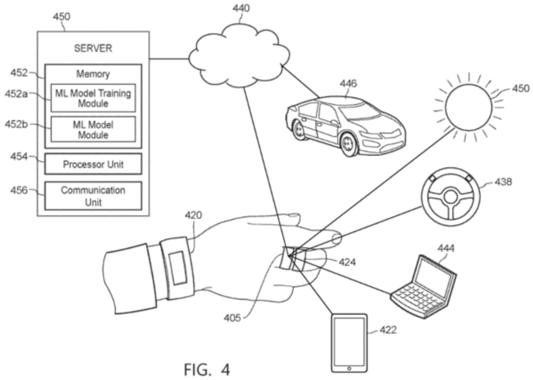
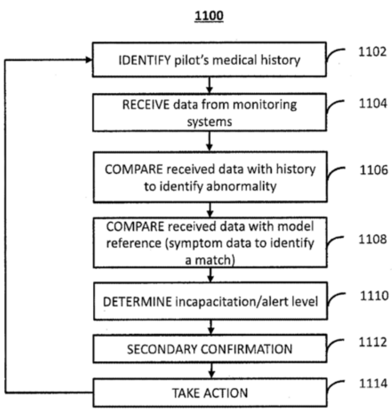


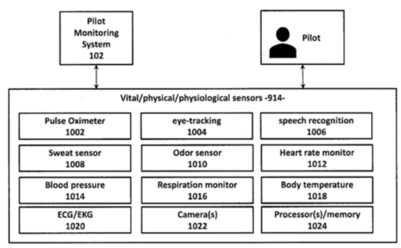
FIG. 4

Systems And Methods for Monitoring Pilot Health – US Patent No. US20190090800A1– CPC A61B

This patent outlines a system for monitoring the health of a pilot and status of the aircraft. It also contains a way to analyze the pilot status and interface with them. Lastly, this patent also includes an actuator to take control of the aircraft if necessary.

This patent is incredibly relevant as it is nearly identical to our technology with a few exceptions. The main difference is our technology aims to provide biofeedback to get the pilot back into normal operating conditions. In contrast, this patent utilizes a robot-pilot to manually control the aircraft in an emergency. The process up until that point is nearly identical.





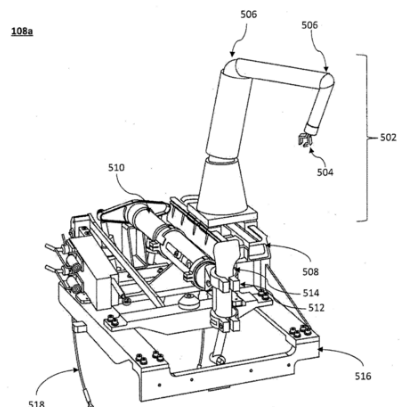


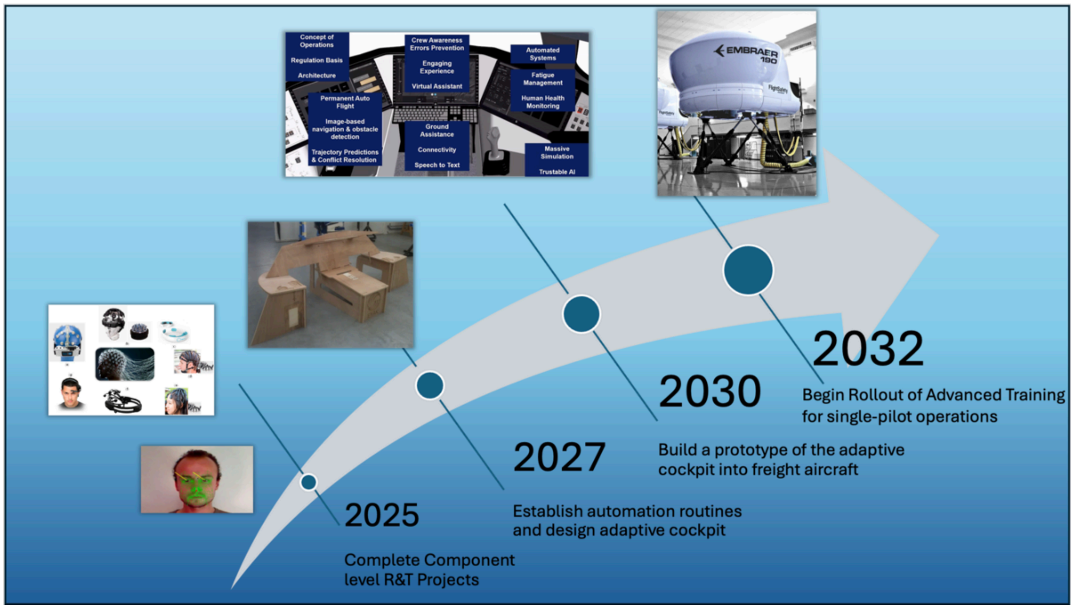
Figure 5a

Related Projects

- Haiku Project - Use Case 1 - Intelligent Assistant (https://haikuproject.eu/use-case-1/)
- Embraer Pulse Concept Jet (https://executive.embraer.com/global/en/pulse)
- Aerospace Testing International - Building an autonomous business jet (https://www.aerospacetestinginternational.com/features/building-an-autonomous-business-jet.html)

Technology Strategy Statement

The aviation industry faces a significant challenge as the demand for pilots continues to outpace the available supply. By 2029, a global shortage of 50,000 pilots is anticipated, necessitating alternative solutions to address this growing gap. One promising approach to mitigate this shortage is to reduce the number of pilots required to operate aircraft. This strategy involves a phased implementation, starting with reduced crew operations, progressing to single-pilot operations for cargo aircraft (which pose no risk to passengers), and eventually extending to commercial aircraft. To achieve this goal, a comprehensive plan for research and development is proposed, focusing initially on improving component-level systems and enhancing accuracy-related figures of merit. These foundational projects are slated for completion by 2025. Following this, the development of an adaptive cockpit will progress through stages of modeling, human factors analysis, design, and prototyping. A fully functional prototype is expected to be ready by 2030, with pilot training commencing immediately thereafter. The ultimate objective of this roadmap is to have single-pilot capable aircraft available for sale to freight companies by 2032, marking a significant milestone in aviation technology and addressing the critical pilot shortage. Of course, all of these developments are dependent on this technology being equal to, or safer than, the existing architecture.



Concept of Operations
Regulation Basis
Architecture
Permanent Auto Flight
Image-based navigation & obstacle detection
Trajectory Predictions & Conflict Resolution
Crew Awareness Errors Prevention
Engaging Experience
Virtual Assistant
Ground Assistance
Connectivity
Speech to Text
Automated Systems
Fatigue Management
Human Health Monitoring
Massive Simulation
Trustable AI
EMBRAER 190
2032
Begin Rollout of Advanced Training for single-pilot operations
2030
Build a prototype of the adaptive cockpit into freight aircraft
2027
Establish automation routines and design adaptive cockpit
2025
Complete Component level R&T Projects