WINGMAN

Owen Diede

Christian Lee

Anders Olsen

Matthew Wieberdink

Faculty Advisor: Dr. Todd Letcher

South Dakota State University

GATEWAYS TO BLUESKIES

MEET THE TEAM

Owen Diede

Mechanical Engineer

Christian Lee

Mechanical Engineer

Anders Olsen

Mechanical Engineer

Matthew Wieberdink

Physicist

Dr. Cody Christensen

Design Review Committee

Dr. Ruyi Lian

Design Review Committee

Dr. Todd Letcher

Advisor/Design Review Committee

PRELIMINARY RESEARCH

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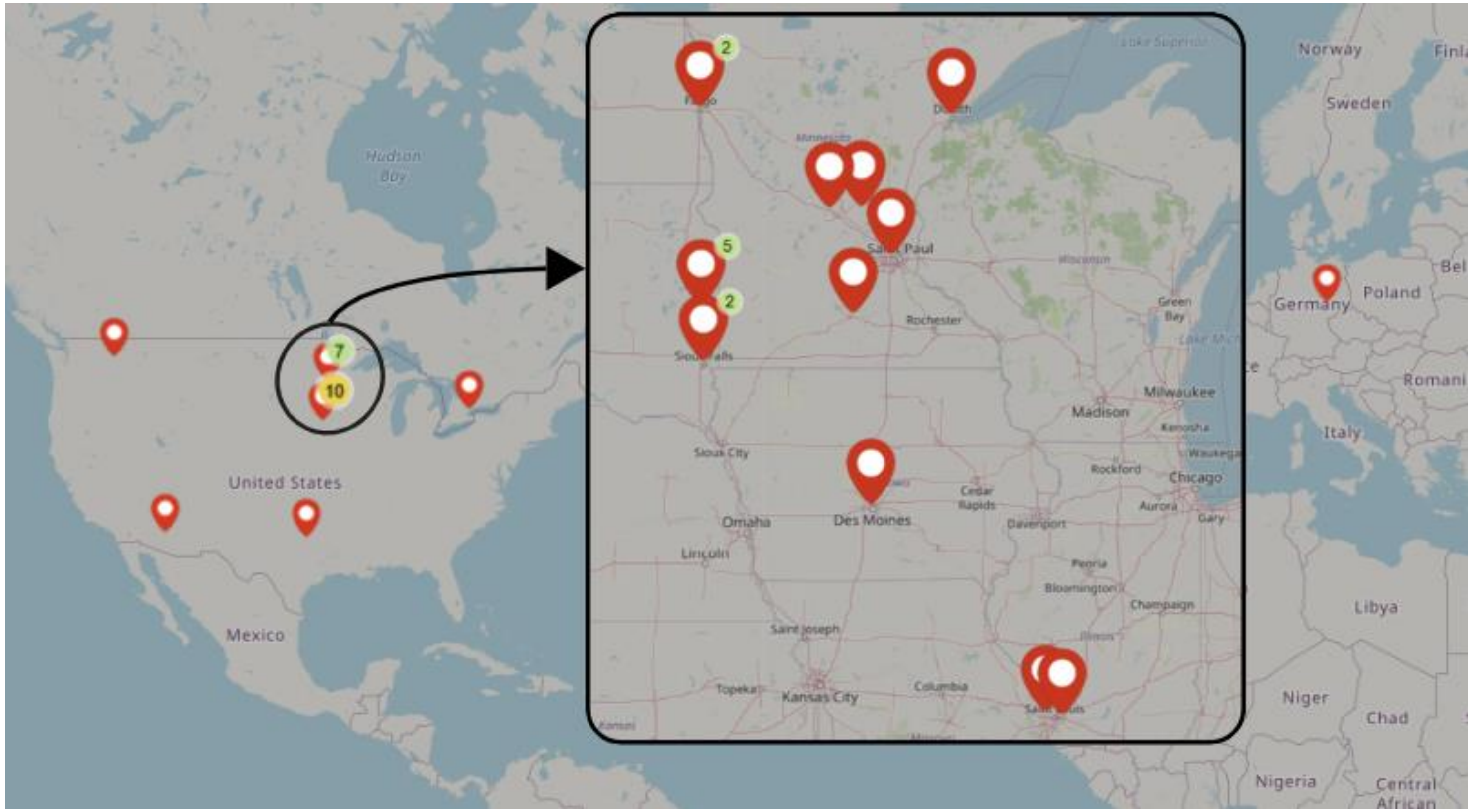
- Participated in the National Science Foundation (NSF) I-Corps Program.
  - 20+ interviews across three countries.
  - Interviewees conducted with commercial aviation line mechanics, a Delta Head-of-Liaison engineer, maintenance instructors, and more.
- About half a mechanics job is reading manuals and blueprints.
- *"Organization [of documentation] is definitely where the industry is behind"* [1].



SITUATION ASSESSMENT

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Industry Context

- Projected commercial fleet growth from **4,500 to 5,700** aircraft by 2035 [2].
- Estimated **shortfall of 48,000** maintenance technicians by late 2020’s [3].
- Daily maintenance and inspections are some of the most prevalent workflows in commercial aviation.

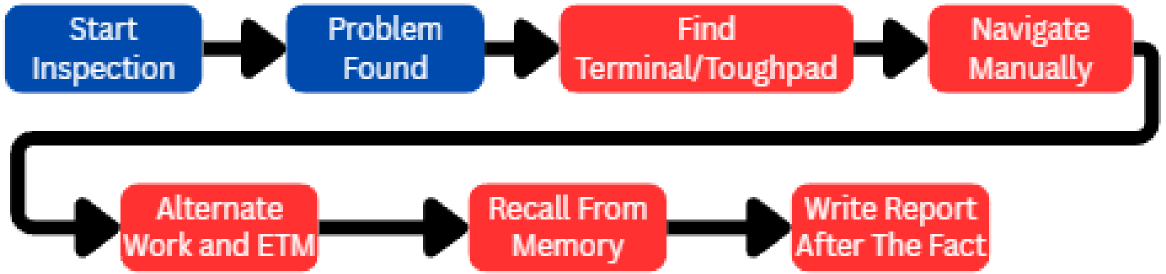
Documentation Issues

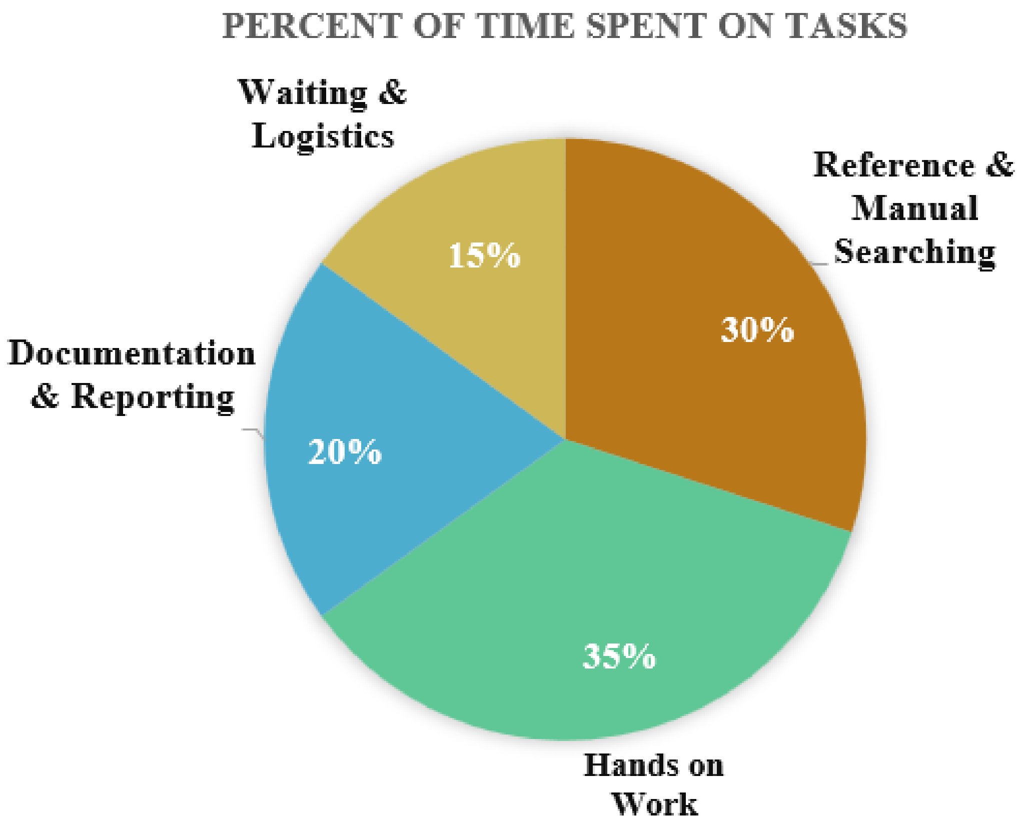
- Lawfully, mechanics must access manual information on handheld devices or fixed terminals to perform their work accurately [4].
- Maintenance logs must be completed for every maintenance event
  - **20.7%** of maintenance-related incidents attributed to incomplete records [5].
  - **35%** of maintenance reporting issues are paperwork-related [4].

Financial Impact

- Cost of maintenance and ground crew errors estimated at **$2B / year** [6].
- **1.2M** delayed flights attributed to maintenance issues annually [7].
- Cost of delays and cancellations up to **$150,000 / hour** [8,9].

CURRENT METHODS





Solution	What it demonstrated	What it misses
Toughpad/Handheld ETM — deployed industry tool	Creates portable, digitized reference material.	Requires stopping hands on work; no reporting aid.
Boeing Project Juggernaut — pilot program	HUD wiring diagrams in assembly. Achieved 25% efficiency gain.	Scoped for structured assembly tasks; no documentation or reporting — not designed for line maintenance variability.
GE Aviation Google Glass — pilot program	Smart glasses used in engine maintenance providing hands free instruction. Achieved 8-12% gain.	Not PPE-compliant; no autonomous reporting or photo-based history retrieval; validated only in controlled factory environments.

MAJOR TAKEAWAYS

- With mechanic shortages and fleet growth on the horizon, there is a need for increased efficiency in line maintenance.
- Current workflows often result in mechanics being taken away from their hands-on work.
- This time is often spent parsing through extensive documentation.
- Recording logs for every maintenance action is tedious and done long after the work, resulting in imprecise and rushed logs.
- Aircraft mechanics choose their profession because they enjoy working on aircraft, not completing paperwork.

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DESIGN SOLUTION

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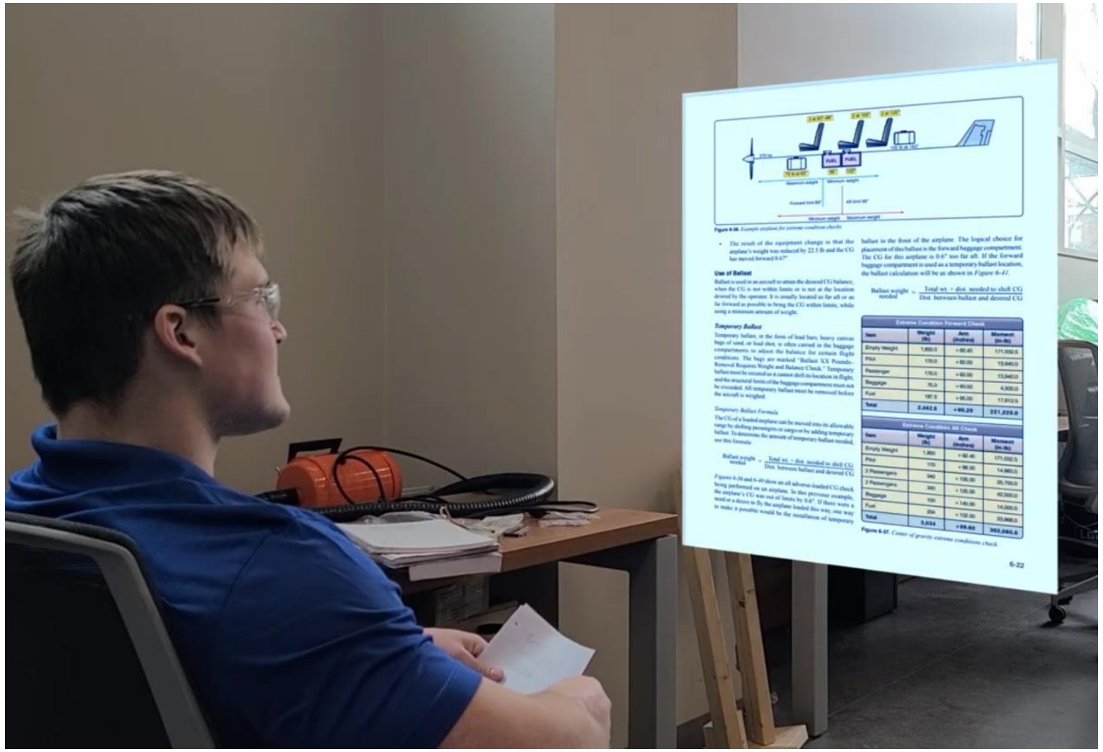
- **Inquiry-based Manual Referencing**
  - Vocal dictation enacts a semantic ETM search to display relevant, hands free, procedures within the AR HUD.
- **Documentation Scrubbing**
  - A mechanic photographs a point of interest, initiating a photo similarity search, returning the 5 most recent and relevant reports with a semantic summary of recurring findings.
- **Autonomous Reporting**
  - Real-time reporting's dictated by the mechanic are compiled into a structured maintenance draft report for later approval and submission.

Key Design Principles

- ANSI Z87.1 compliant
- No aircraft integration
- Offline first operation
- Advisory only

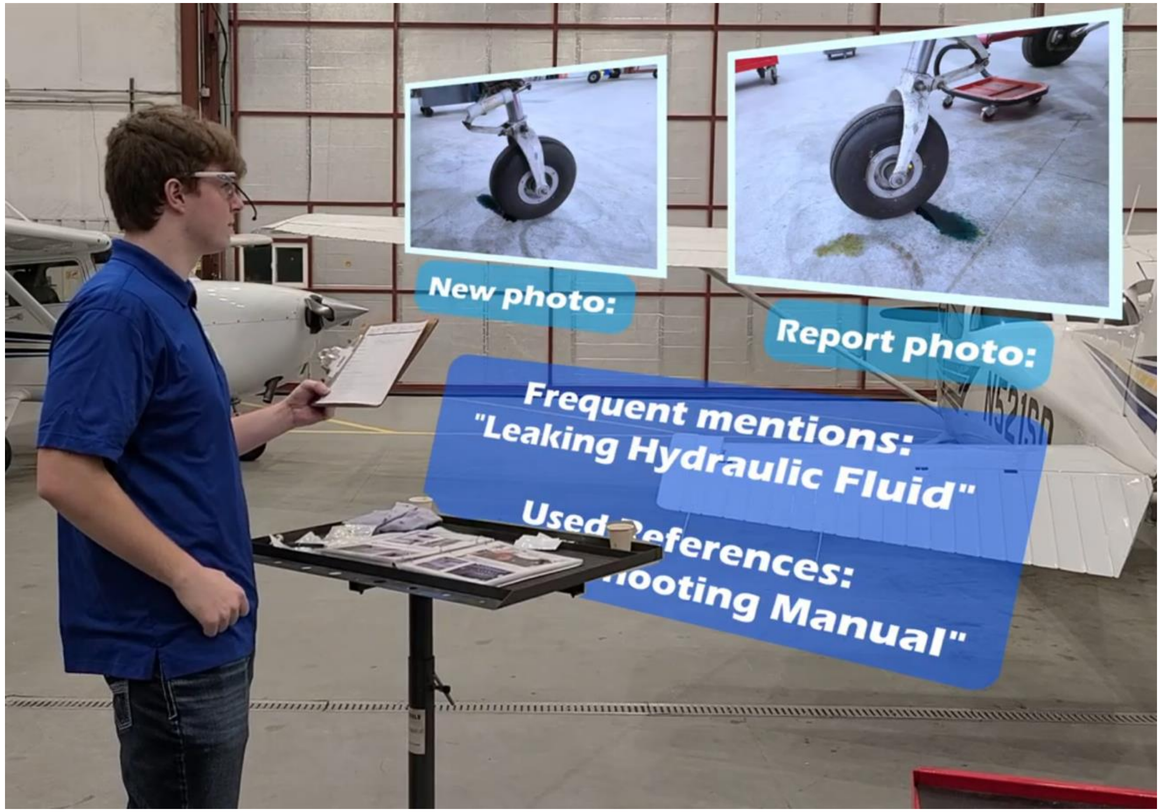
INQUIRY-BASED REFERENCE FUNCTION

- **Problem**
  - Mechanics spend a significant amount of time searching through official references and manuals to validate procedures.
  - Maintenance actions must be supported by approved documentation, which makes document searching a frequent task.
  - *"Sometimes there isn't enough time to find a good reference because of the short time turnarounds."* [1]
- **Summary**
  - Inquiry based referencing allows fast and easy access to aircraft documentation through voice inputs.
  - WINGMAN searches through the onboard database of manuals and official references for the specified aircraft.
- **Solution**
  - Time spent searching through manuals and references is significantly reduced.
  - Workflow efficiency is significantly improved with less back and forth searching and fast access to necessary information.



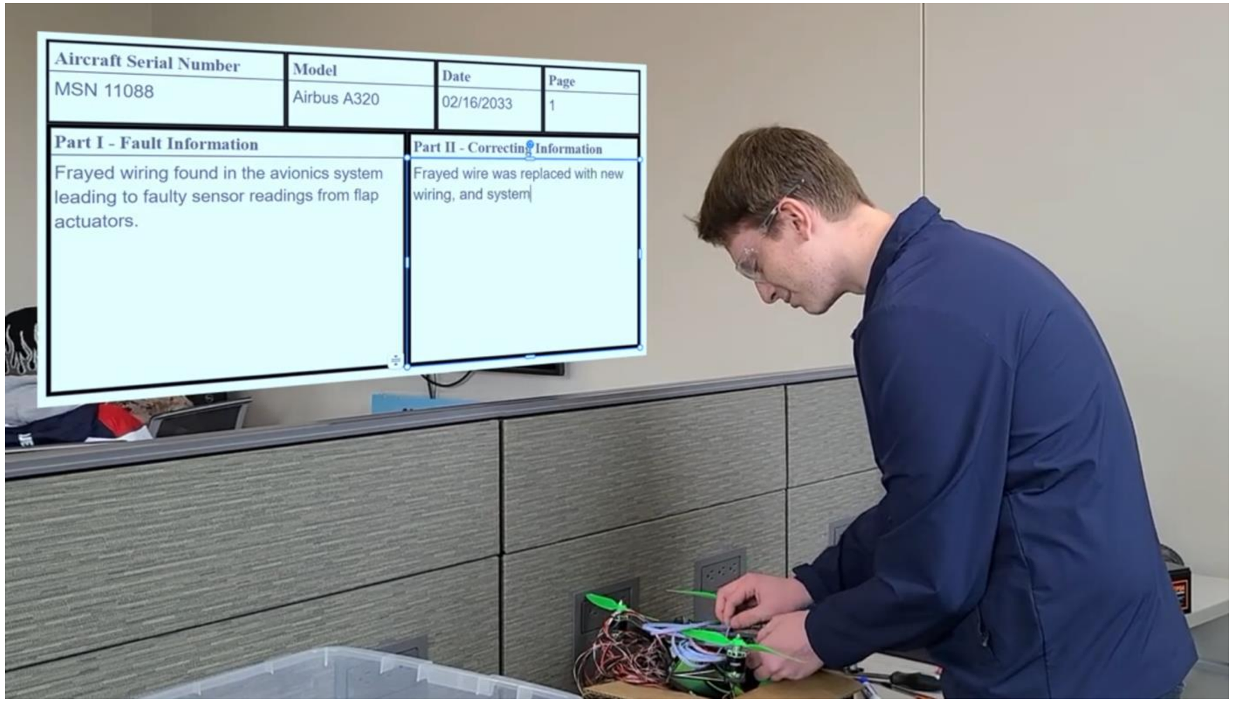
DOCUMENTATION SCRUBBING FUNCTION

- **Problem**
  - Locating information in maintenance logs is often time consuming and inefficient.
  - Some MRO facilities do not utilize photos, only text/diagrams.
  - *"It would be nice if I could just take a photo and have the information."* [1]
- **Summary**
  - Using photo analysis of a targeted component, WINGMAN identifies the part and finds relevant maintenance logs associated with it.
  - Along with historical maintenance logs, a summary of past problems and solutions would be provided alongside past logs.
- **Solution**
  - Time is saved, and human error and incorrect log referencing is reduced.
  - Mechanics gain access to a brief history of the component and have a new starting point for performing their work.



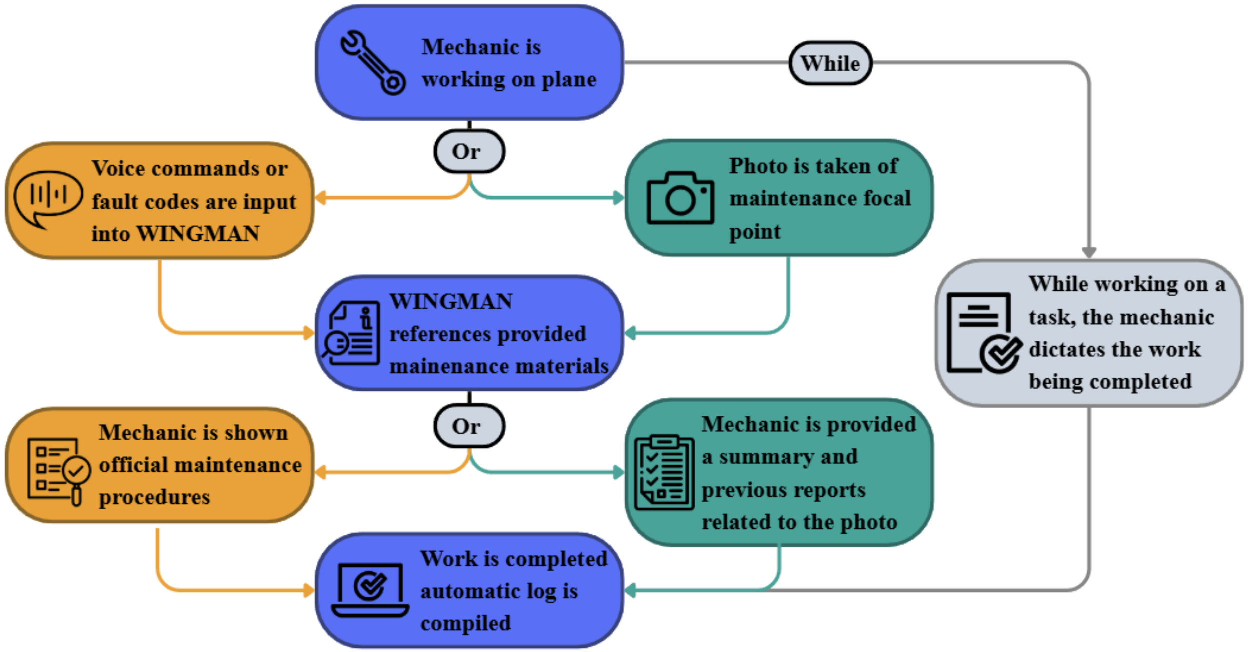
AUTONOMOUS REPORTING FUNCTION

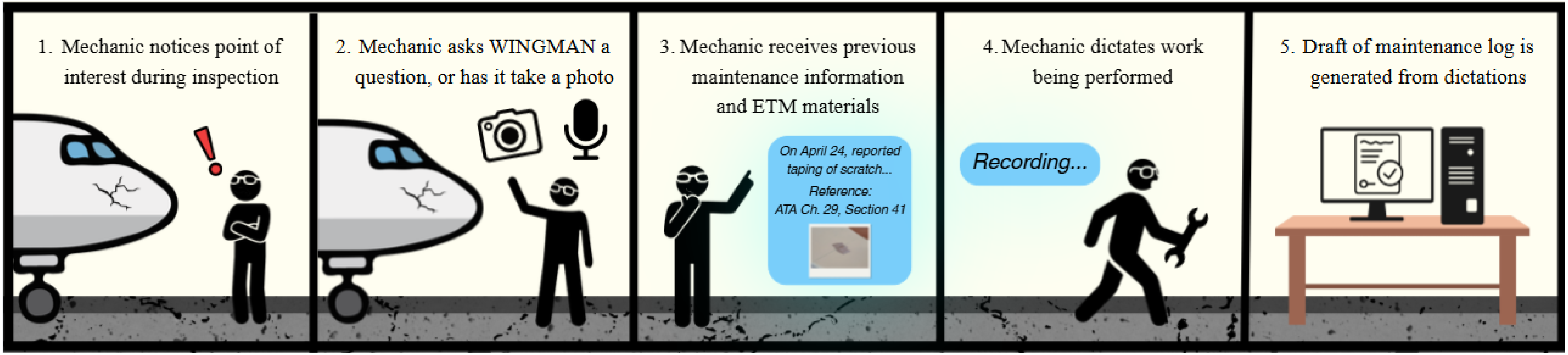
- **Problem**
  - *“Most of my time with the plane on the ground is with reporting.”* [1]
  - Following complex work, important or critical details may be hard to recall accurately.
  - There is no standardization of reporting or logging formats across the industry.
- **Summary**
  - Using voice to text and photos taken, WINGMAN autonomously generates draft reports while the mechanic is working.
  - Captured voice logs and photos are structured into a reporting template for later review and finalizations.
- **Solution**
  - Time is saved by generating the report draft during the maintenance being complete.
  - Standardized documentation, which improves consistency, and ease of use across the industry.



CONCEPT OF OPERATIONS

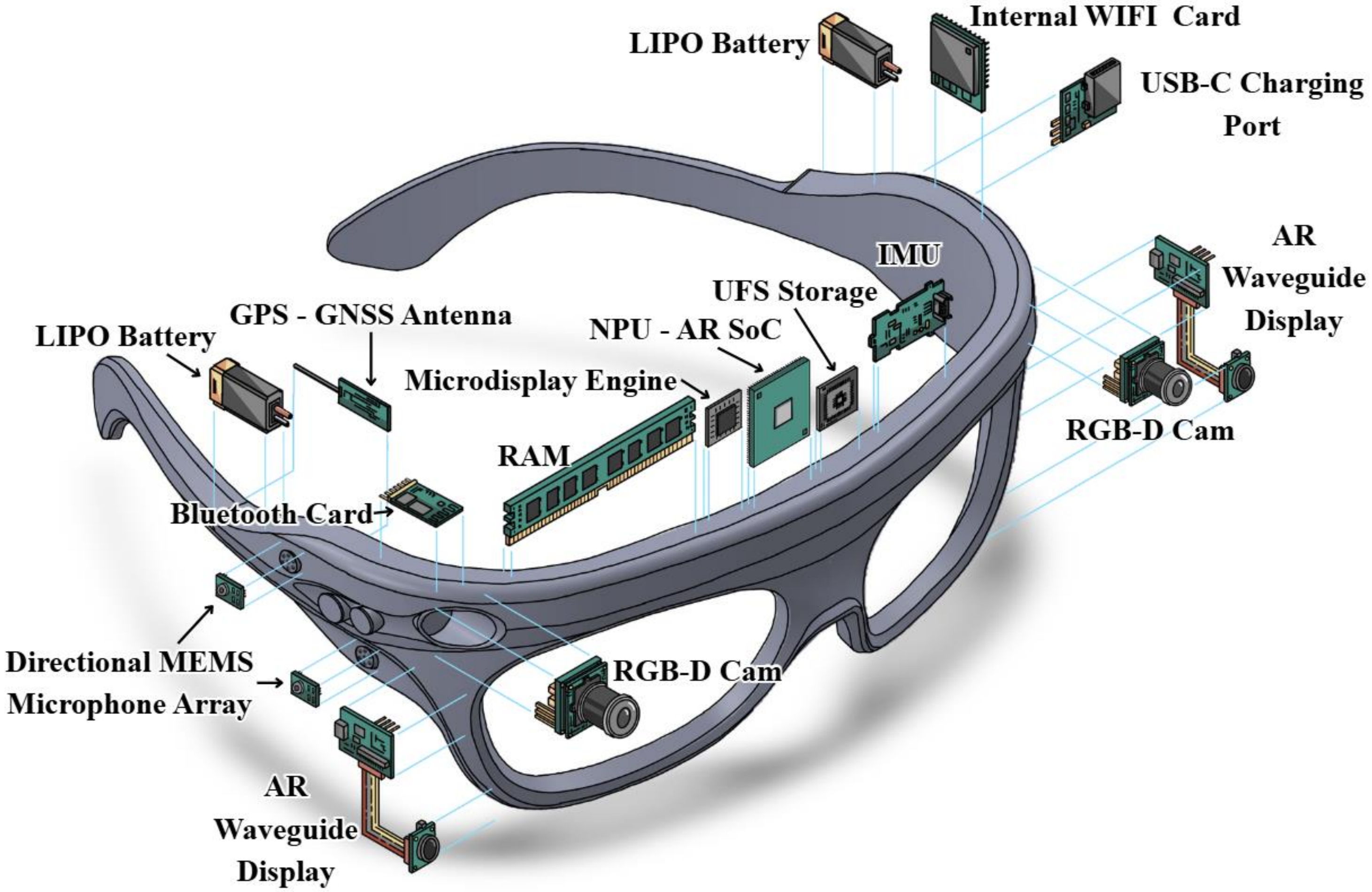
- The proposed workflow is flexible yet improves overall efficiency and accuracy.
- Technicians have improved access to an increased amount of information.
- From problem to documented report, the mechanic never has to stop hands on work.





HARDWARE

- Compliant with ANSI Z87.1 safety standards.
- High visibility display with 5000 nit brightness, ensuring clear vision and readability in direct sunlight.
- Rated IP54 for dust and moisture resistance.
- Prescription lens accommodation, eliminating the need for over glasses solutions.
- >80% waveguide transmittance, maintaining clarity with hands on work.
- On-device SoC, allowing offline functionality of core functions.



SOFTWARE

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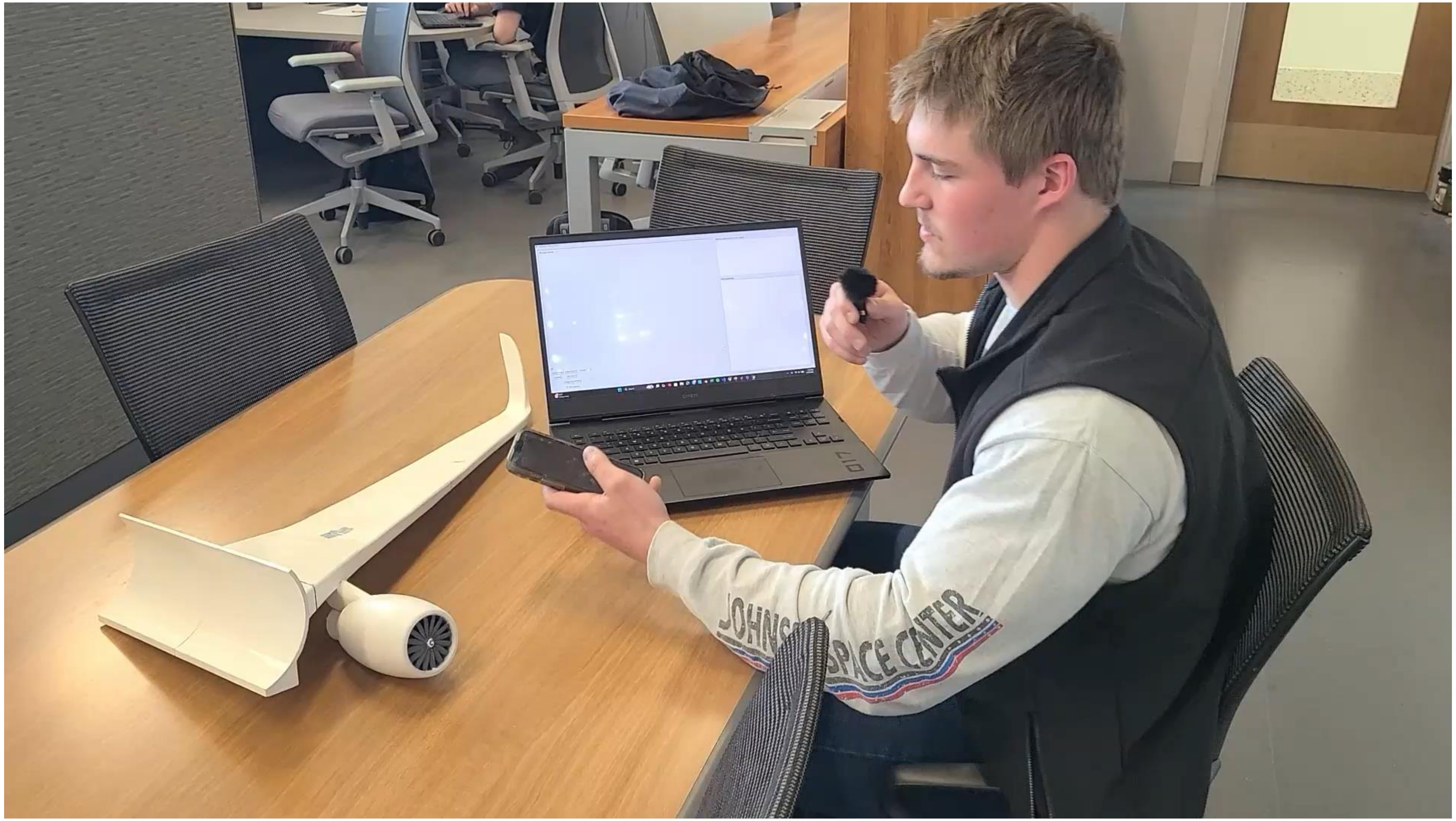
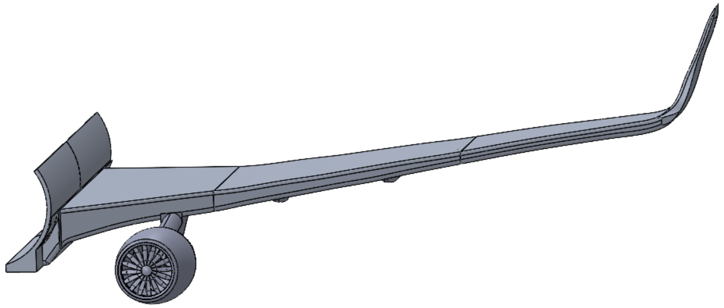
- Built on entirely open-source libraries.
- Three core pipelines: voice, vision, and data.
- **Voice**
  - Offline speech recognition trained for aviation-specific vocabulary.
  - Audio capture and speech-to-text enables voice activated functionality.
- **Vision**
  - Inputted photo translated into vector embeddings used in a similarity search.
- **Data**
  - Database of searchable ETM materials and previous maintenance logs.
  - Semantic vector queries ensure desired data retrieval.

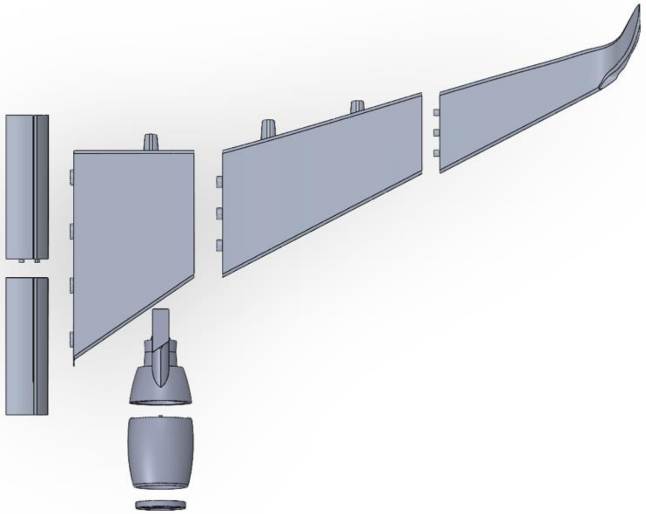
Voice Pipeline				
Component	Description	License	Cost	Source
Vosk	Offline speech recognition engine. Fine-tunable for aviation vocabulary (ATA chapters, aircraft nomenclature). No network connection required at runtime.	Apache 2.0	$ -	alphacephei.com/vosk
PyAudio	Audio I/O library managing microphone capture and speaker output pipeline. Handles raw audio stream from MEMS array.	MIT	$ -	pypi.org/project/PyAudio
pyttsx3	Text-to-speech confirmation output. Provides audible feedback for voice command recognition without cloud dependency.	MIT/BSD	$ -	pypi.org/project/pyttsx3

Vision Pipeline				
Component	Description	License	Cost	Source
MobileNetV3	Lightweight neural network for generating visual feature embeddings from component photos. Optimized for embedded processors. Deployed via ONNX Runtime on Snapdragon NPU.	Apache 2.0	$ -	pytorch.org / torchvision
ONNX Runtime	Cross-platform inference engine. Runs MobileNetV3 on the Snapdragon XR2 Gen 2 NPU for <80ms embedding latency without cloud connectivity.	MIT	$ -	onnxruntime.ai
FAISS	Facebook AI Similarity Search. Vector database for photo-matched maintenance record retrieval. Sub-10ms search across 10M+ vectors. Powers documentation scrubbing function.	MIT	$ -	github.com/facebookresearch/faiss

PROTOTYPES







TECHNOLOGY READINESS LEVEL

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- Every subsystem is **already at TRL 6-7.**
  - No subsystem requires technological breakthrough.
- Reliant on integration and optimization.
  - WINGMAN is not waiting on technological advancements not currently existing.
- The technologies used are currently improving.
  - **8x improvement in AI/NPU performance** in the Snapdragon XR2 Gen 2 over its predecessor. [10]
  - MobileNetV3 uses **143x less energy** on dedicated NPU over CPU [11].
  - Fine-tuning of speech recognition models **reduced error** word rates by up to **30.2%** [12].
- Path to TRL 9 is straightforward.
  - Aviation Environment optimization.
  - On-device edge computing optimization.
  - Vocabulary and semantic finetuning.

Subsystem	Key Components	TRL	Primary Remaining Work
AR and Human Interface	OLED micro-display, IMU head tracking, Bluetooth	6	Extended-wear ergonomic validation; depth sensing and tracking refinement for active maintenance environments
Computer Vison	RGB-D stereo camera array, 3D depth mapping, object recognition, visual embedding, image similarity retrieval	6	Aviation-specific lighting calibration, angle variability testing, and industrial deployment validation
System Infrastructure	Offline operation, server/cloud sync, FAISS vector database, edge computing, offline-first architecture	7	Wearable form factor optimization for edge compute; FAISS specialization for aviation maintenance datasets
Information and AI	Vosk speech recognition, NLP, OCR, PDF/document ingestion, ATA chapter search, autonomous report drafting, voice-editable log entry	7	Aviation vocabulary specialization, FAA documentation format compliance, and manual revision currency

TRL Timeline

Subsystem	2026	2027	2028	2029	2030	2031	2032
AR and Human Interface	6	6	7	7	8	8	9
Computer Vison	6	7	7	7	8	8	9
System Infrastructure	7	7	7	8	8	8	9
Information and AI	7	7	8	8	8	8	9

TIMELINE

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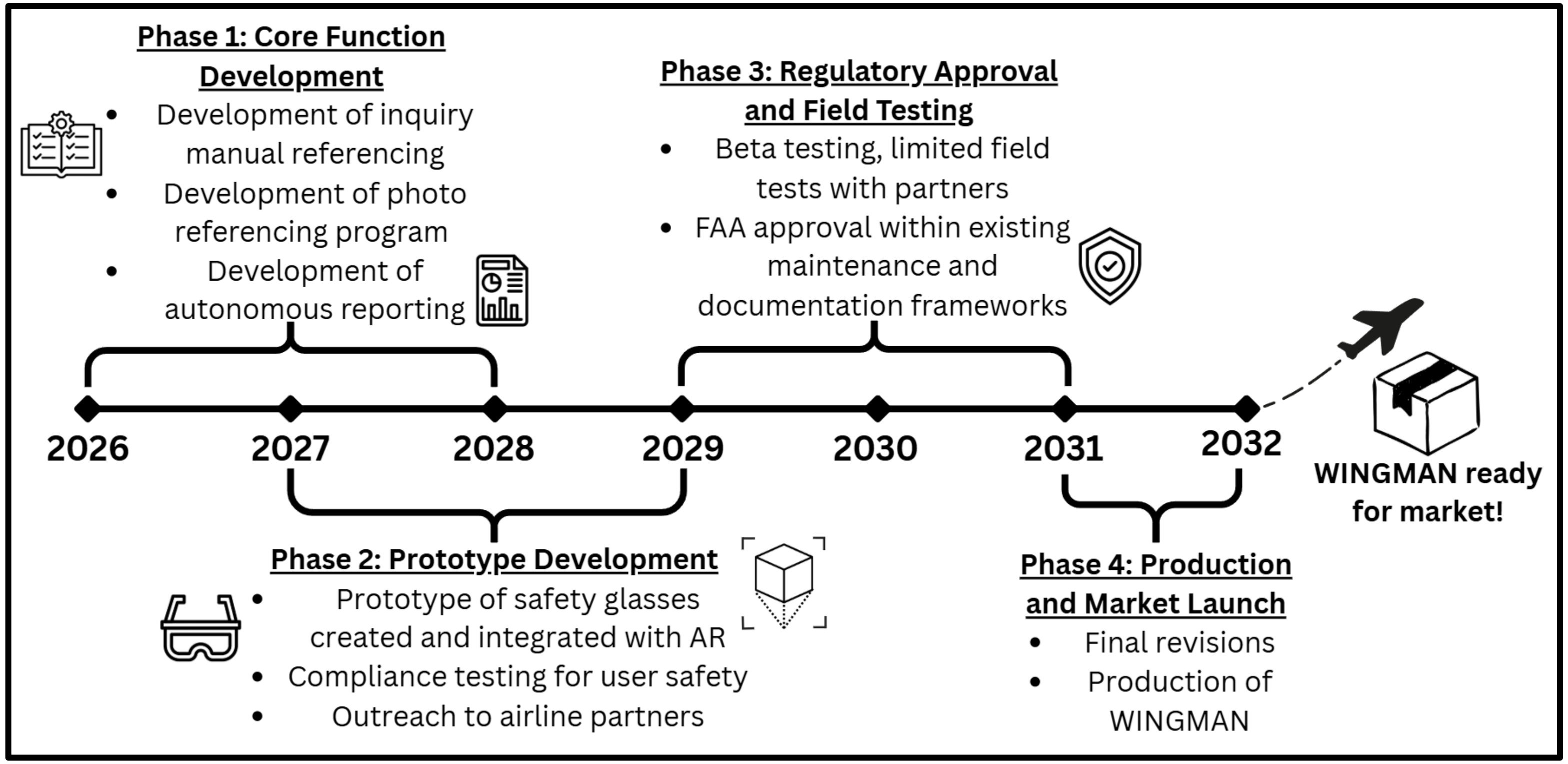
- **Phase 1 (2026-28):**
  - Open-source software shows that the technology is already developed but still must be adapted for AR and aviation uses.
- **Phase 2 (2027-29):**
  - With the software developed, this time is spent ensuring WINGMAN's functionality as a safety device and tool.
  - Outreach to FAA and partners is done early, in preparation for Phase 3.
- **Phase 3 (2029-31):**
  - With proper documentation, A025 amendment approval is acquired quickly.
  - Two years of operational testing provides valuable feedback on necessary improvements.
- **Phase 4 (2031-32):**
  - By this point, WINGMAN has been validated in operational environments and is ready to be produced.



REGULATORY PATHWAY

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WINGMAN requires no device-level FAA certification.

WINGMAN's architecture places it outside the certification pathways that typically block the deployment of aviation technology.

Only: A025 amendment

Ground-worn device — outside of FAA airborne standards

No Supplemental Type Certificate required: 14 CFR § 21.113 applies only to devices that physically interact with the aircraft [13]; Takes 6+ months on a finished product.

No aircraft systems connection: DO-178C/DO-254 governs airborne systems only [14,15]. WINGMAN has zero aircraft integration.

Advisory-only design slots into existing frameworks

Records satisfy 14 CFR § 43.9: Reports capture required fields such as work description, date, mechanic name, and certificate number [16].

A025 Amendment Only: A025 is the required FAA approval for electronic maintenance records — existing process requiring simple amendment [17].

Licensing and security requirements met

No OEM licensing required: WINGMAN reads from the airlines' already licensed ETM library, like a Toughpad or desktop in current deployment.

TSA/SIDA Compliant: Mechanic-initiated capture with no continuous recording; fits within existing frameworks without additional approval [18].

FAA confirmation:
Outreach to the Fargo Flight Standards Office confirmed **no specific FAA regulation governs AR wearable devices in a maintenance support context** — the glasses require no approval to operate.

Full Compliance Citations:
14 CFR Part 21 §113, 14 CFR §43.9, 14 CFR §121.369, 14 CFR §121.380, 49 CFR Part 1542, AC 120-78B, AC 20-115D, AC 20-152A, 18 U.S.C. §2511, ANSI Z87.1

BARRIERS, RISKS, AND RELIABILITY

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Risk/Barrier		Mitigations
Cybersecurity: Access to proprietary ETM's, maintenance records, and component photographs creates data security exposure.	→	**Addressed Architecturally:** HTTPS/TLS 1.3 on all data; API key tied to device. Mechanic initiated audio processed on-device [19].
Environmental Conditions: Line maintenance occurs in direct sunlight, rain, dust, and high noise environments.	→	**Designed for field conditions:** 5000 nit display, IP54 dust and moisture resistance, MEMS beamforming microphone allows for high hanger noise, PPE compliant [20, 21].
Workflow Resistance: Mechanics follow precise, incrementally revised procedures — any new tool risks adoption friction.	→	**Supplement, not replacement:** No procedural changes required. No modifications to approved documentation systems. Phase 3 field testing before fleet-wide rollout.

Training and Reliability

Durability: PPE frame. Dust and moisture resistant. ANSI Z87.1 Compliant.

Repairability: Modular repairability: battery, microphone, and camera.

Onboarding: Train-the-trainer model; single-shift covering core functions and symbology.

Prescription Accommodation: Prescription-fitted bonded lens option — no second pair of glasses required.

RETURN ON INVESTMENT

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- At $2,500 per unit, a single WINGMAN user generates **$60,835** in annual savings.
- Recovers **138 hours** of technician work per year.
- 24.3x return on investment per year.

Savings Category	Time Savings (Hours)	Annual Savings
Inspection & Reporting Time	90	$4,174.20
Reworks	18	$834.84
Delays	1.5	$9,028.10
AOG Duration	0.6	$48,000.00
Unnecessary Movement	36	$1,669.68
Cost of Glasses	N/A	-$2,500.00
Onboarding	-8	-$371.04
TOTAL ANNUAL SAVINGS	138.1	$60,835.78

Savings that scale:

For a modest regional airline (200 mechanics): **$12.2M/yr**

A larger airline like Delta (6,647 mechanics): **$402M/yr**

U.S. addressable market (75,000 mechanics): **$187.5M revenue**

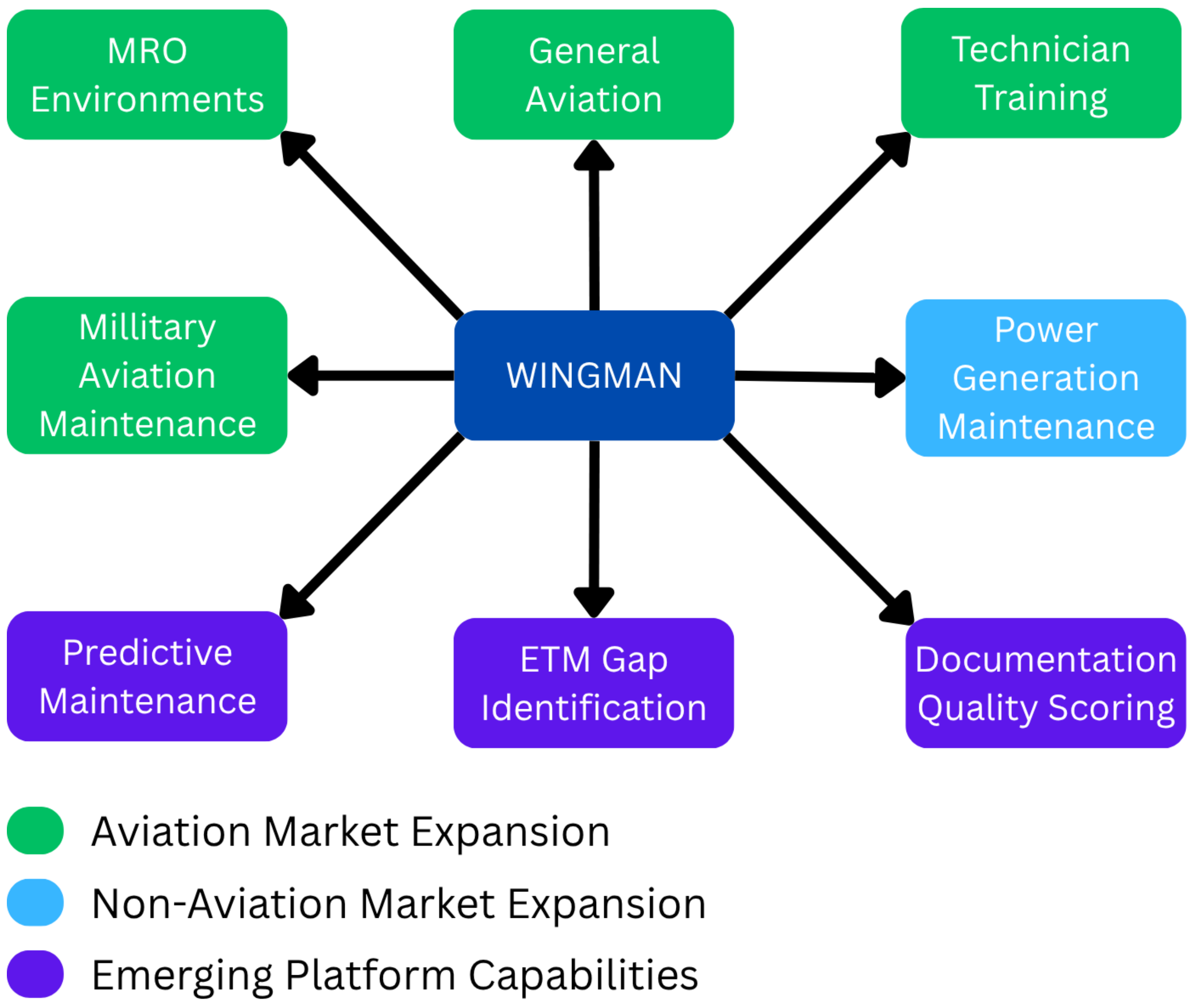
Conservative saving estimates:

- Published AR maintenance deployments document gains of 40% in efficiency and 75% reduction in procedural errors [22].
  - A conservative **20% improvement** is used for ROI calculations.

Simple payback period:

$2,500/$60,835 = 0.047 years or **15 days**

WHAT'S NEXT?



Anticipated Optimizations

- Object Recognition
  - Auto-identify components to trigger documentation scrubbing.
- AI-Structured Reporting
  - Restructure reported findings within text box.
- Desktop Integration
  - Display relevant fault codes, schedules, and work orders into AR HUD.

Product Continuation

- Invention disclosure filed.
  - Provisional patent being pursued.
- Seeking industry partnerships to advance towards prototype.
- Two team members pursuing graduate school in engineering fields.

CONCLUSIONS

30% of shift lost to manual referencing. → Hands-free AR eliminates task interruption during inspection and reporting.

1.2 million delayed flights. → Reduced documentation time and AOG duration directly cuts maintenance delays.

48,000 projected technician shortage. → 138 hours recovered per technician annually—multiplying workforce capacity.

Significant Returns: **$60,835 annual savings** per technician — 15-day payback on $2,500 unit.

Clear Regulatory Path: **No device-level FAA certification**. A025 amendment only, zero disruption of current procedures.

Ready to build: Built on commercially available components — proven concepts requiring no breakthrough, **TRL 9 by 2032**.

Massive Upside: $187.5M U.S. addressable market. Scales to **$402M/yr** with a major carrier such as Delta. **Extensive applicability**: MRO, GA, and predictive maintenance.

WINGMAN presents a long-overdue upgrade for the commercial maintenance industry, keeping authority in the hands of the certified mechanic while positioning aviation for a data-driven future.

Thank you!

Questions?

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APPENDIX A: HARDWARE AND SOFTWARE

Input Capture		
Component	Function	Cost
RGB-D Camera array	Depth perception for AR displaying and image capure	$ 169.00
Four-element MEMS microphone array	Captures voice commands and dictated reports	$ 20.00

Power and Connectivity		
Component	Function	Cost
2x 3.7 V, 5000 mAh lithium-polymer battery	Battery for system	$ 44.00
Power Management IC	Charging and component power distribution	$ 6.00
USB-C port	Charging and data transfer	$ 2.00
WiFi/Bluetooth antenna	Wireless capability	$ 7.00

Display and Form Factor		
Component	Function	Cost
OLED waveguide module	AR display system	$ 899.00
Nylon frame + polycarb lens	Safety, comfort, and ANSI compliant	$ 20.00

Processing and Memory		
Component	Function	Cost
Qualcomm Snapdragon XR2 Gen 2 System-on-Chip	CPU, GPU, image signal processor, and dedicated Neural Processing Unit	$ 84.00
Samsung Flash UFS 3.1 Storage (256 GB)	Storage for offline ETM index, FAISS vector database, draft reports, and photo captures	$ 15.00
NVTEK System Memory - RAM (16 GB)	Quick access processing storage	$ 44.00

APPENDIX B: TRL OF HARDWARE

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System Component	TRL	Reasoning
Micro Display (OLED)	8	Commonly used in phones, cameras, AR, and VR.
Depth Sensing (Stereo vision)	6	Used in AR and VR components.
Eye / Head Tracking	7	Used in VR for years now. Getting more advanced with AR.
Text to Speech	8	Text to speech is commonly used, but has not been specialized for maintenance environments.
Wireless Communication (Bluetooth)	9	Used commercially and in consumer products.
Offline Operation and Information Sync	9	Mature technology, used commercially and by consumers.
Server Backing / Cloud Backing	9	Common practice in many industries.
Edge Computing	7	Used in industry, would need optimization for wearable technology.
Object Recognition	6	Technology exists, but needs more development and optimization.
3D Depth Mapping	6	Technology exists, but is not fully developed / optimized for any use case.
3D Location Tracking	6	Technology exists, works in controlled environments. Testing for commercial aviation needed.
Advanced Search and AI Referencing	7	AI referencing is a proven concept.
Image Similarity Identification	6	Proven, but lighting and angles play factors.
Photo Embedding and Data Tagging	7	Commonly used for a few years in face scanning recognition.
Natural Language Processing	8	Already been used in Python for some time.

APPENDIX C: TRL OF SOFTWARE

System Component	TRL	Reasoning
Vosk Offline Speech Recognition	8	Vosk is already used in many devices, but has not been specialized to the aviation environment and use cases.
Local Audio Pipeline	8–9	Mature technology with several libraries specializing in proximity text to speech.
PDF / Document Ingestion (pypdf, PyMuPDF, python-docx)	9	Mature capability with many libraries supporting it.
Optical Character Recognition	7–8	OCR is nearly a matured technology. It currently is used in many industry applications, but OCR still has some areas where issues can occur.
Embedding-Based Document Searching	7	This technology is proven, but validation and precision of searches may need further development.
ATA Chapter / Reference Searching	7	Straightforward and practical, but has issues in keeping up to date with yearly manuals / revisions.
MobileNetV3 Component Recognition	8	The MobileNetV3 software is proven and ready for use upon purchase, may need further specialization and development for aviation environments.
XR2 Edge Inference	8–9	Edge inference is used in many applications, and is a mature technology. Has not been specialized to our use cases.
3D / Visual Embedding-Based Part Identification	6	3D mapping technology has been proven with prototypes, but the technology needs further development before efficient industrial use.
FAISS Vector Database Search	8	FAISS is commonly used in many industry applications. Mature technology that is capable of large datasets. Has not been specialized for our uses yet.
Maintenance History Visual Match Retrieval	6	Visual photo embedding has been proven in prototypes and specific environments, but needs further development for consistent use and success.
AR HUD Record Display	6–7	AR displays are under development. They are seeing use in industry but have not been developed for long term comfortable easy use.
Autonomous Report Drafting Engine	7–8	Autonomous drafting technology is proven and used in many industries. The technology needs further specialization and verification for the aviation industry.
Voice-Editable Log Entry Creation	7	These technologies are mature, but have not been specialized for the aviation environment. Autonomously meeting FAA standards for documentation may be an issue.
Offline-First Edge Architecture	8–9	Local computing is commonly used and practiced, especially in the defense industry. Technology is mature.

APPENDIX D: COST AND ROI CALCULATIONS

South Dakota State University

Savings Category	Assumption (Per Single User)	Time Savings (Hours)	Annual Savings
Inspection & Reporting Time	1,800 tasks a year, 15 minutes per task, 20% time reduction, average mechanic salary of $46.38 / hr	90	$4,174.20
Reworks	1,800 tasks, 5% of tasks require rework, 20% time reduction, reworks take 1 hr, average mechanic salary of $46.38 / hr	18	$834.84
Delays	$100.76/ minute cost for delay, avg delay 28 min, 16 delays per maintenance worker * 20% reduction	1.5	$9,028.10
AOG Duration	Each mechanic contributes to 3 hours annually reduced by 20%, $80,000 per hour AOG,	0.6	$48,000.00
Unnecessary Movement	Conservatively 40% of tasks require movement to access reference data, 1800 annual tasks (720 trips), 3 mins round trip, $46.38 / hr	36	$1,669.68
Cost of Glasses	See cost calculation; adding approx. $1300 for manufacturing processes and profit margin	N/A	-$2,500.00
Onboarding	8 hour program for the mechanic	-8	-$371.10
TOTAL ANNUAL SAVINGS		138.1	$60,835.71

APPENDIX D: COST AND ROI CALCULATIONS

a) Inspection & Reporting Time savings

$$\left(\frac{1800\ tasks * 15\ minutes * 0.2\ percentage}{60\ \frac{minutes}{hour}}\right) * \$46.38\ hourly\ wage = \$4{,}174.20$$

b) Reworks savings

$$(1800\ tasks * 0.05\ percentage\ of\ tasks\ require\ rework * 1\ hour * 0.2\ percentage\ savings) * \$46.38\ hourly\ wage = \$834.84$$

c) Number of delays per mechanic

$$\frac{1{,}200{,}000\ flights\ delayed\ due\ to\ maintenance}{75{,}000\ commercial\ mechanics} = 16\ delays/mechanic$$

d) Delays savings

$$\frac{\$100.76}{min} * \frac{28\ mins}{delay\ task} * \frac{16\ delay\ tasks}{person * year} * 0.2\ percentage\ reduction = \$9{,}028.10$$

e) AOG Duration savings

$$\$80{,}000\ per\ hour\ AOG\ cost * 0.2\ percentage\ savings * 3\ hours\ of\ AOG\ contribution = \$48{,}000$$

f) Unnecessary Movement savings

$$\left(\frac{1800\ tasks * 3\ minutes * 0.4\ percentage\ walking}{60\ \frac{minutes}{hour}}\right) * \$46.38\ hourly\ wage = \$1{,}669.68$$

g) Cost of glasses

$$\$1{,}266\ component\ costs + \$300\ assembly\ costs + \$934\ (37\ \%)\ profit\ margin = \$2500$$

h) Onboarding Losses

$$8\ hour\ program\ x\ \$46.38\ hourly\ wage = \$371.10$$