



First Regulatory Acceptance of Automated Aircraft Inspection via Drone into an Operator's Maintenance Program

David Piotrowski– Senior Principal Engineer, Technology Development Engineering

Successful Program Implementation Indoors



Delta

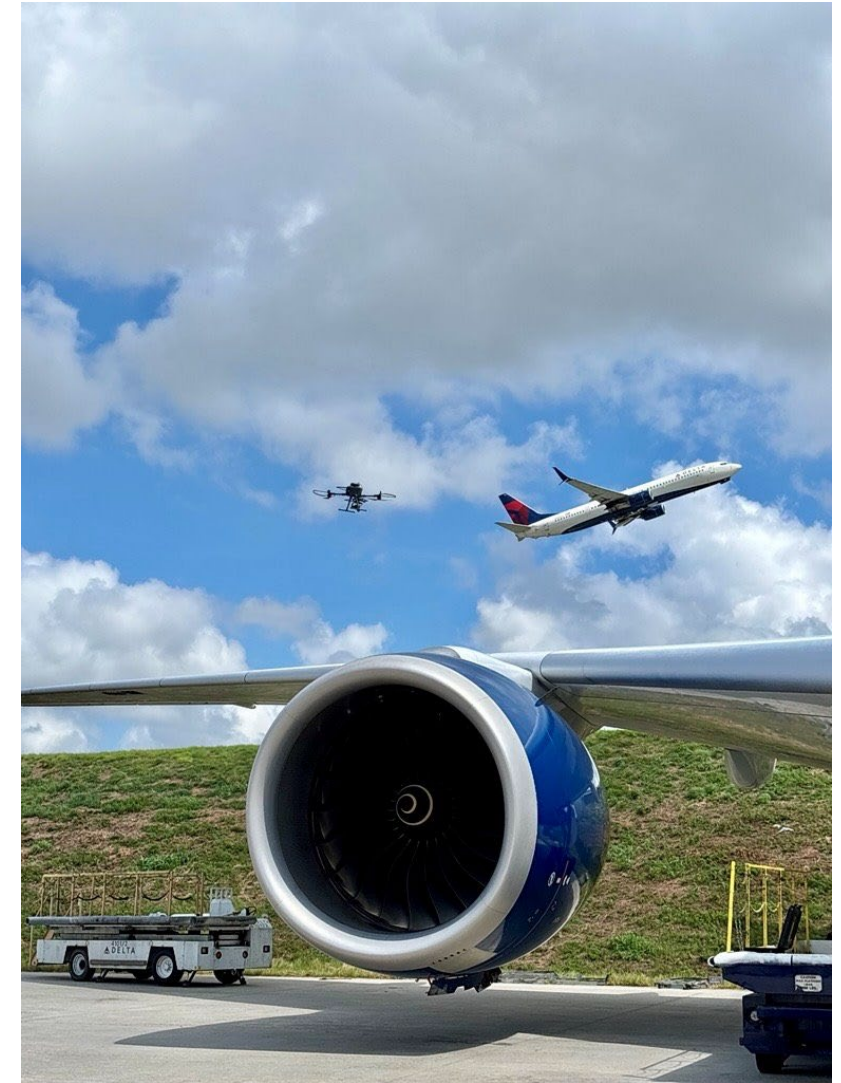
Emma Galarza
David Piotrowski
Alex Melton
John Mathis
Al Harmon

Ed Poole
Mike Holland
Malcolm Berner
Mark Watton
John Bohler

MainBlades

Floris Straver
Dejan Borota
Jochem Verboom

And Outdoors



Impacting The Business



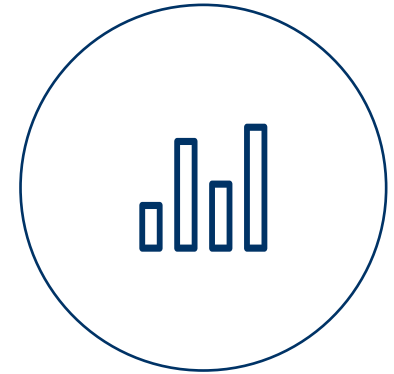
INCREASED A/C AVAILABILITY

Average time to accomplish a full airframe GVI is 8.5 hours.
Autonomous inspection via drone can do the same **inspection in <1 hour for a narrow body and < 2 hours for a widebody**



SAFETY FIRST, ALWAYS

Automated inspection tools, such as the drone, **remove our people inspections at height**; drone comes equipped with full suite of sensors and safety features to prevent run away or impact to an aircraft



NOVEL DATA SOURCE

Inspection via camera technologies provide opportunities to include new data streams into the business; visual data repositories provide **enhanced capabilities to track overall fleet** condition and make more informed engineering decisions

User Priorities – Survey Results

Drone Program Priorities Ranked by Importance

Time of Inspection

Mobility / Ease of Set-Up

Photo Clarify / Resolution

Environmental Needs

If nearby obstacles (ladders / people) need to be removed

Damage Location ID

Photos / damage linked to a frame / stringer location

Mobile Interface For
Damage Review

Battery Swaps
Required

Current GVI Procedure Statistics

16

Man Hours

On average, an upper body
GVI for a lightning strike
inspection requires 4 hours of
work with an average of 4
people

4

People

On average, 4 people are
required to conduct an upper
body GVI

High

Safety Hazard

63% Rated High as a
Safety Hazard while the
77% rated Medium due to
risk of fatality

SVP: 505 instances in 5 years!



Survey included Base Maintenance, Line
Maintenance, IMA, and Inspection (ATL&MSP)

General Visual Inspection Standards



U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

TITLE 14 OF THE CODE OF FEDERAL REGULATIONS (14 CFR) GUIDANCE MATERIAL

**Subject: ACCEPTABLE METHODS,
TECHNIQUES, AND PRACTICES—AIRCRAFT
INSPECTION AND REPAIR**

**Date: 9/8/98
Initiated by: AFS-640**

**AC No: 43.13-1B
Change: 1**

5-15. GENERAL. (extract) *“Visual inspection is the oldest and most common form of NDI for aircraft. [..] This inspection procedure may be greatly enhanced by the use of appropriate combinations of magnifying instruments, borescopes, light sources, video scanners, and other devices discussed in this AC.”*

“The use of optical aids for visual inspections is beneficial and recommended. Optical aids magnify defects that cannot be seen by the unaided eye and also permit visual inspection in inaccessible areas”

An inspection is:

A. GENERAL VISUAL INSPECTION (GVI)

A visual examination of an interior or exterior area, installation or assembly to detect obvious damage, failure or irregularity. This level of inspection is made from within touching distance, unless otherwise specified. A mirror may be necessary to enhance visual access to all exposed surfaces in the inspection area. This level of inspection is made under normally available lighting conditions such as daylight, hangar lighting, flashlight or drop-light and may require removal or opening of access panels or doors. Stands, ladders or platforms may be required to gain proximity to the area being checked.

Experimental Design – Gage R&R



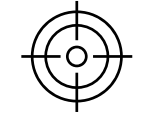
Current GVI Procedure

Inspectors set up to perform standard GVI on A/C and report maximum resolution from the resolution target.



Drone Assisted GVI Procedure

Drone flies autonomous path capturing photos of targets. Inspectors review photos and report maximum resolution from resolution target.



Gage R&R Measurement

Asses the reproducibility and repeatability of current GVI procedures and drone assisted GVI procedures.

USAF-1951 Resolution Target



Experiment Target Placements

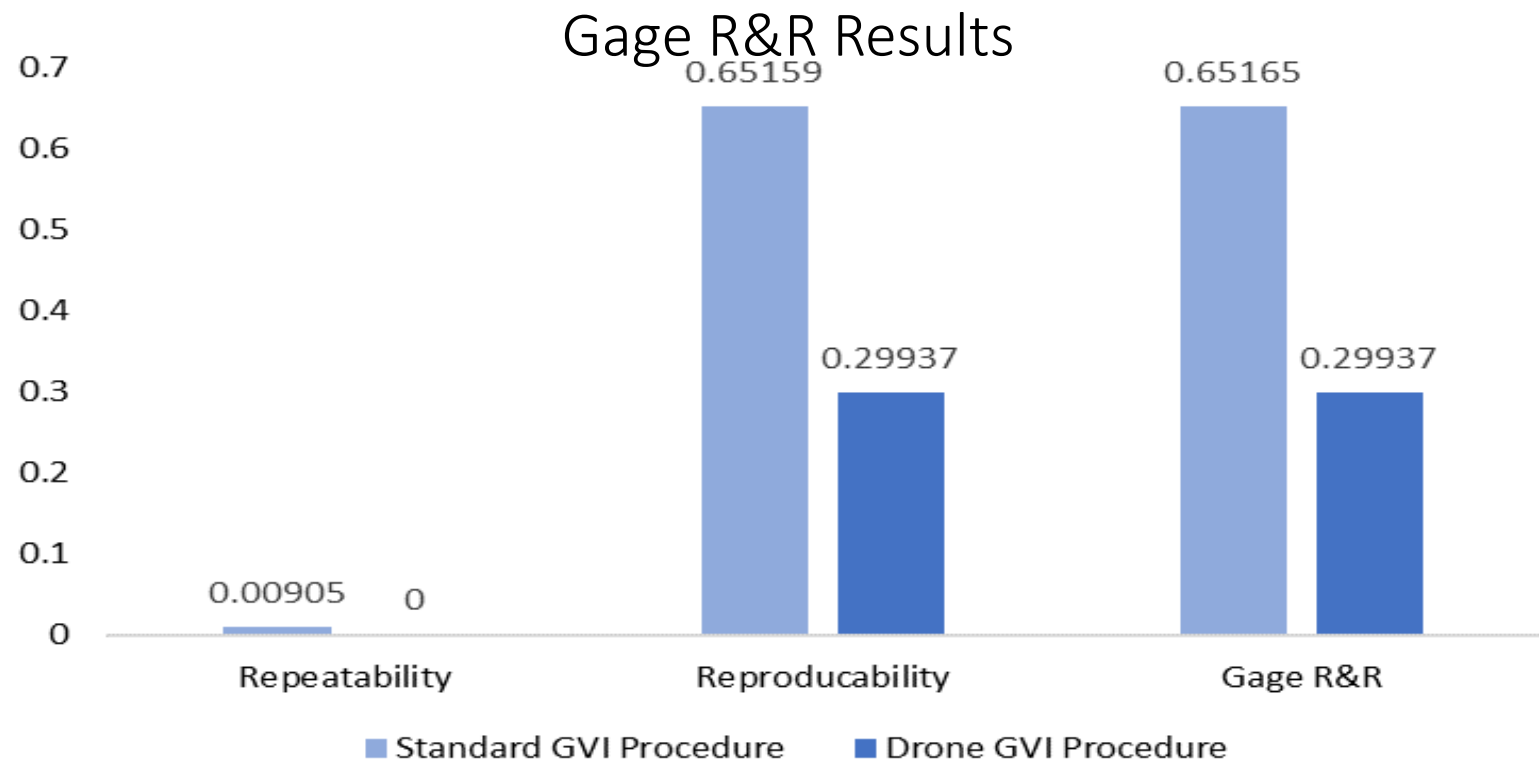


Experimental Results



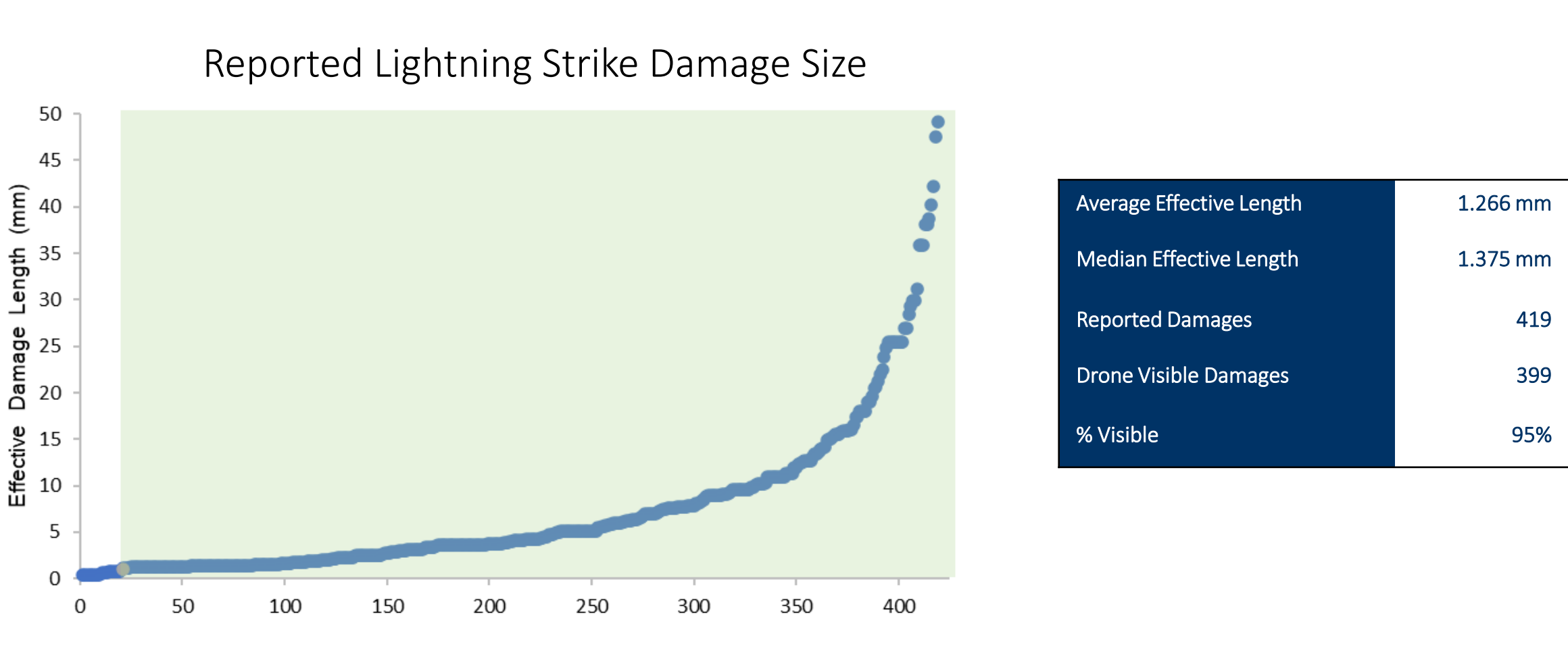
Experimental Results

The drone assisted GVI performed 2x better than current GVI procedures in Repeatability and Reproducibility



Gage R&R Results	Standard GVI Procedure	Drone GVI Procedure
Process Variation Due to Measurement System	65%	30%

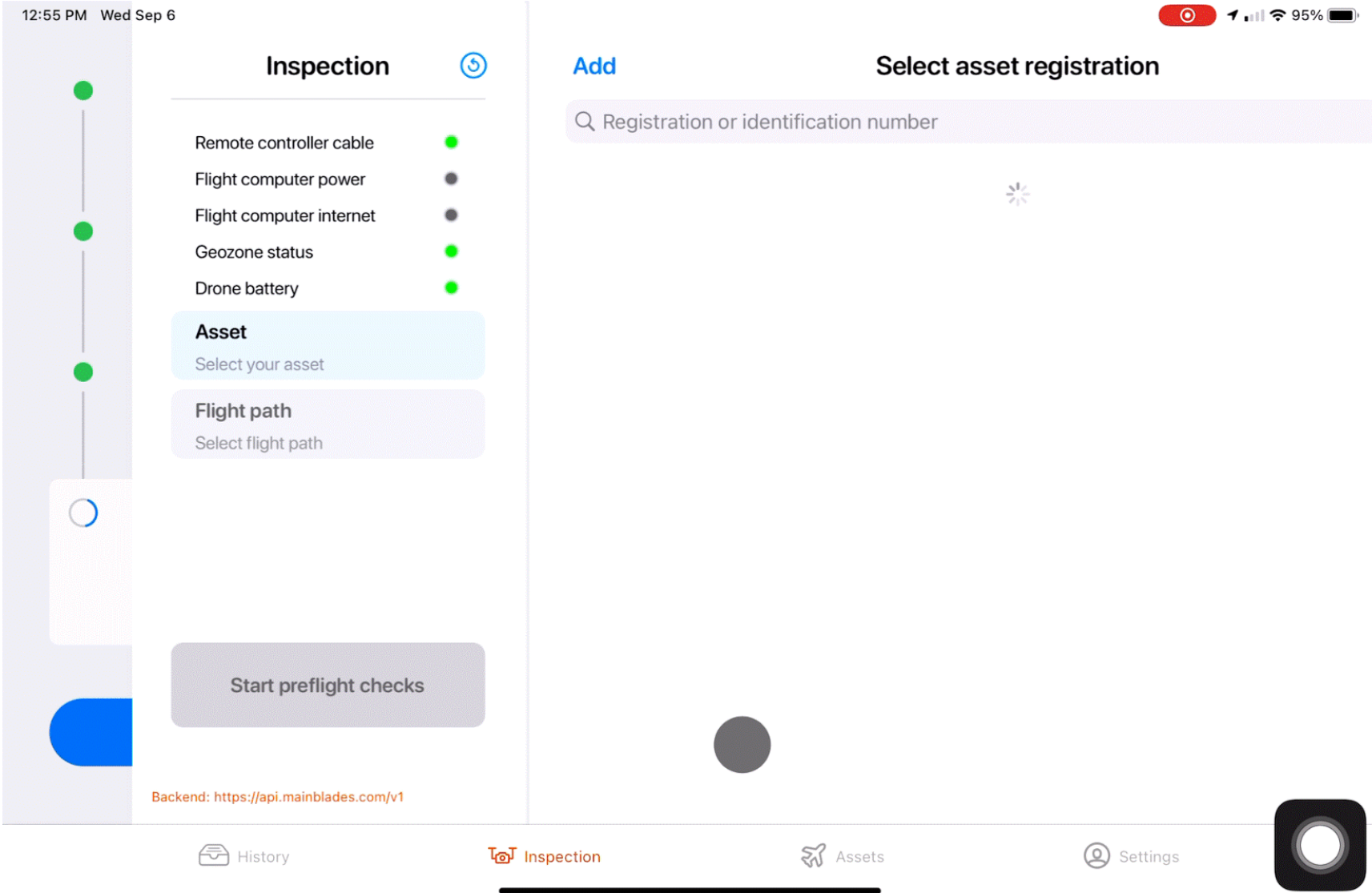
Historical Damage Sizing



Inspection Setup



Inspection Setup



Inspection Setup

12:56 PM Wed Sep 6

94%

Inspection

- Remote controller cable
- Flight computer power
- Flight computer internet
- Geozone status
- Drone battery

Asset
N377NW

Flight path
General visual inspection upp...

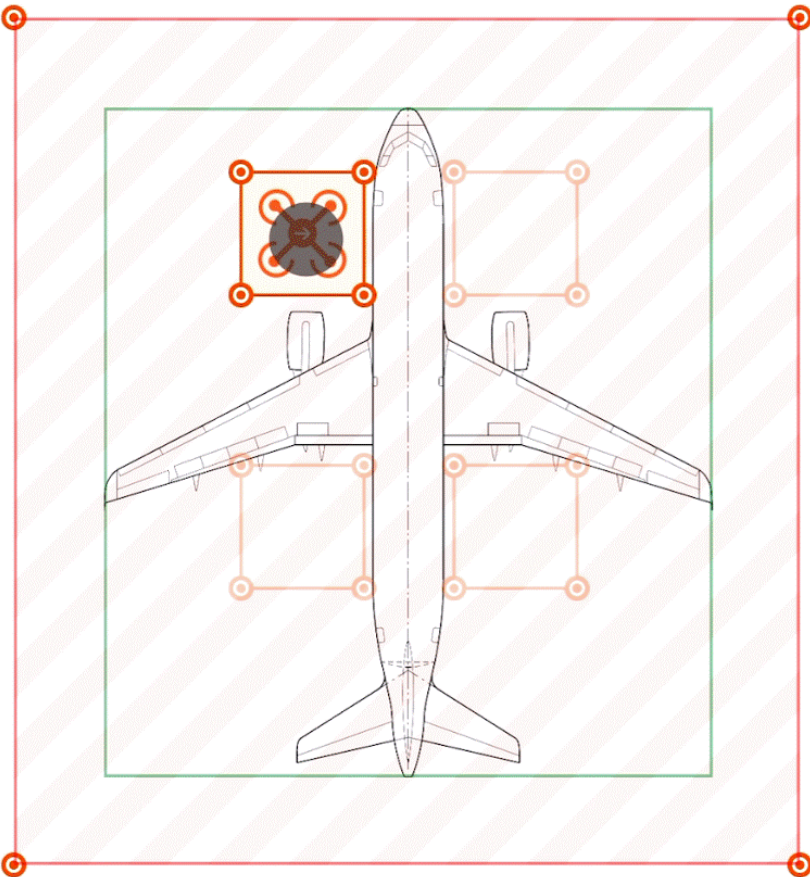
Location
Hangar (indoor)

Drone setup
Drone home area selected

Start preflight checks

Backend: <https://api.mainblades.com/v1>

Ensure all areas are clear of people and obstacles



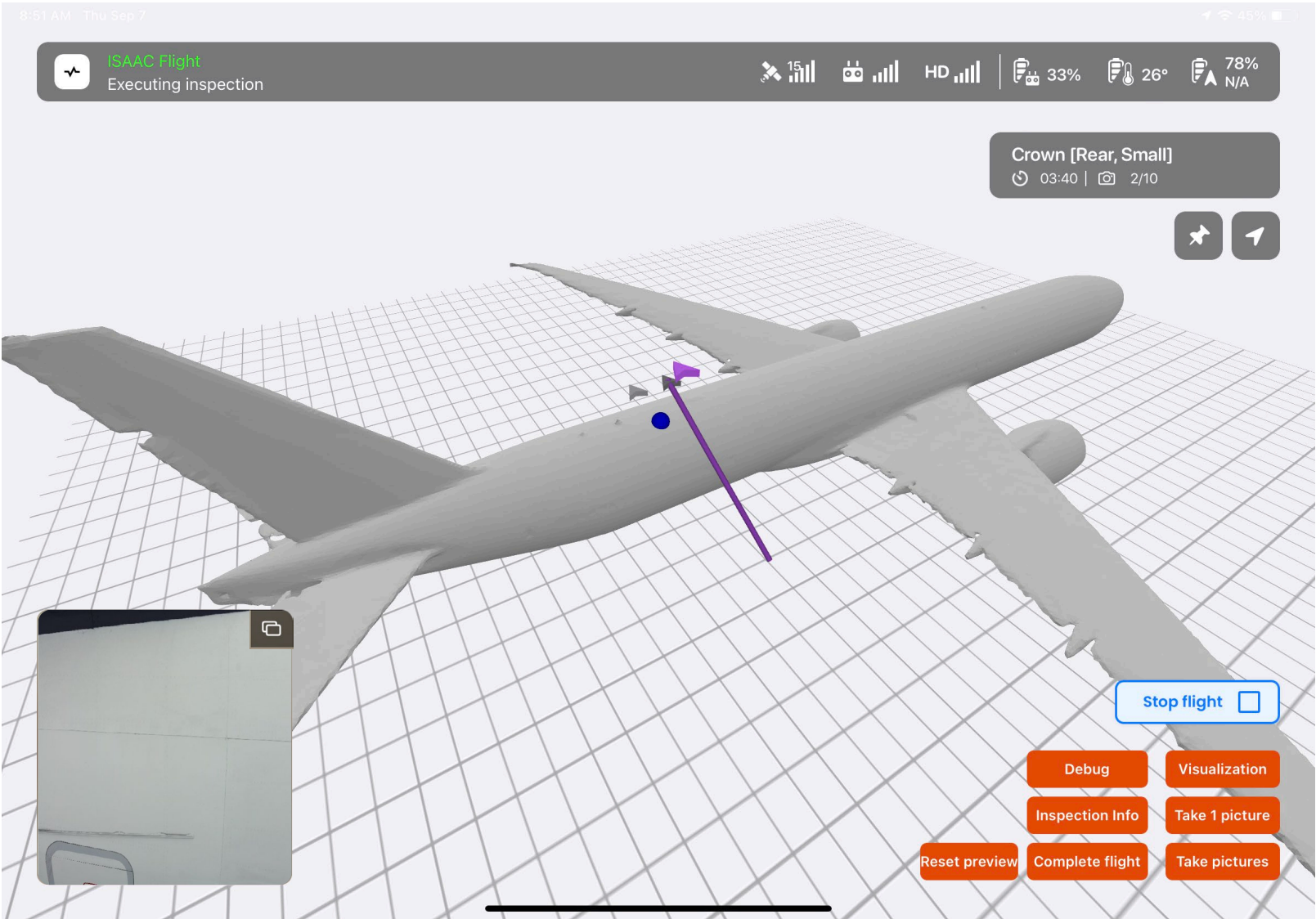
History

Inspection

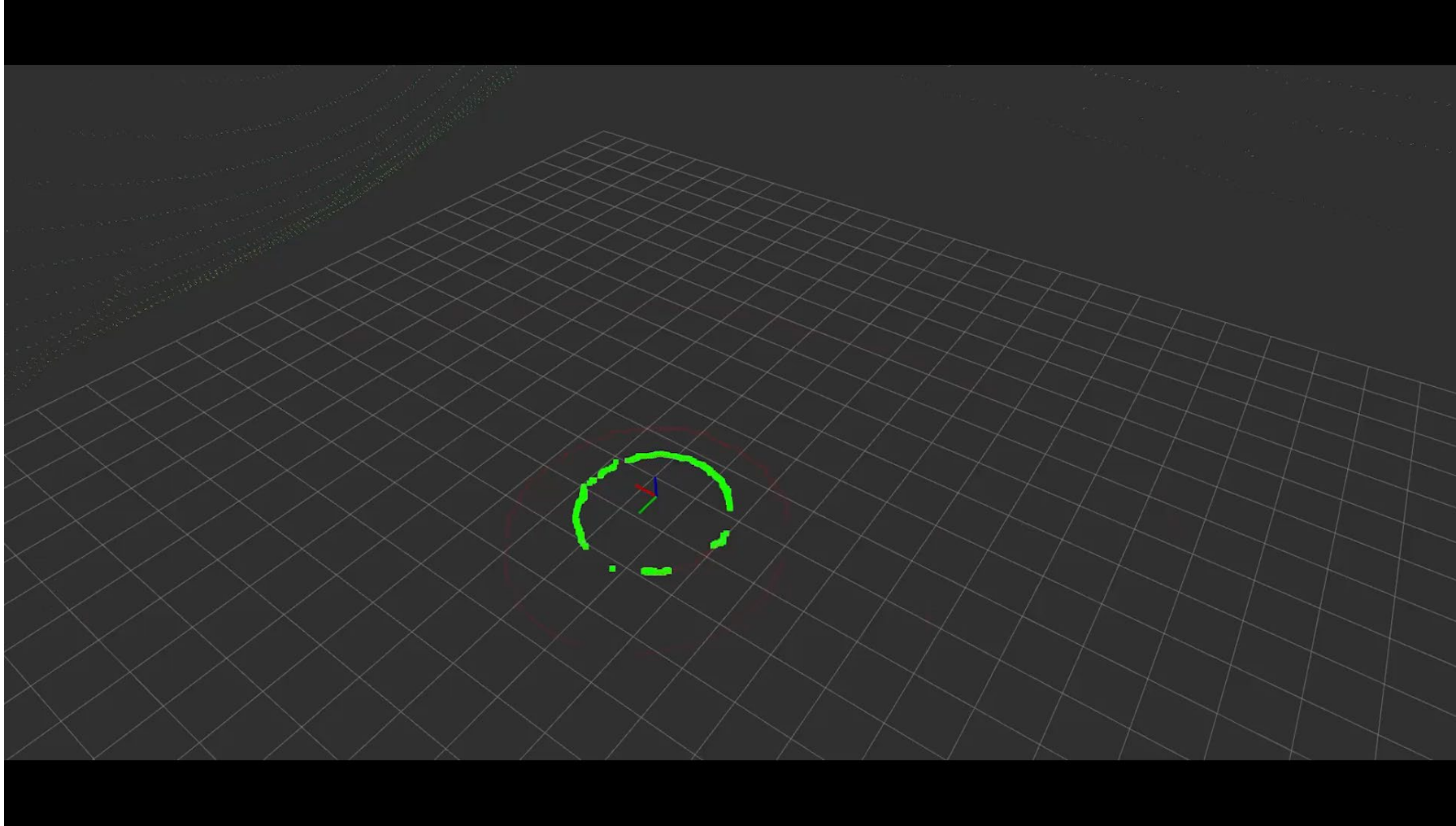
Assets

Settings

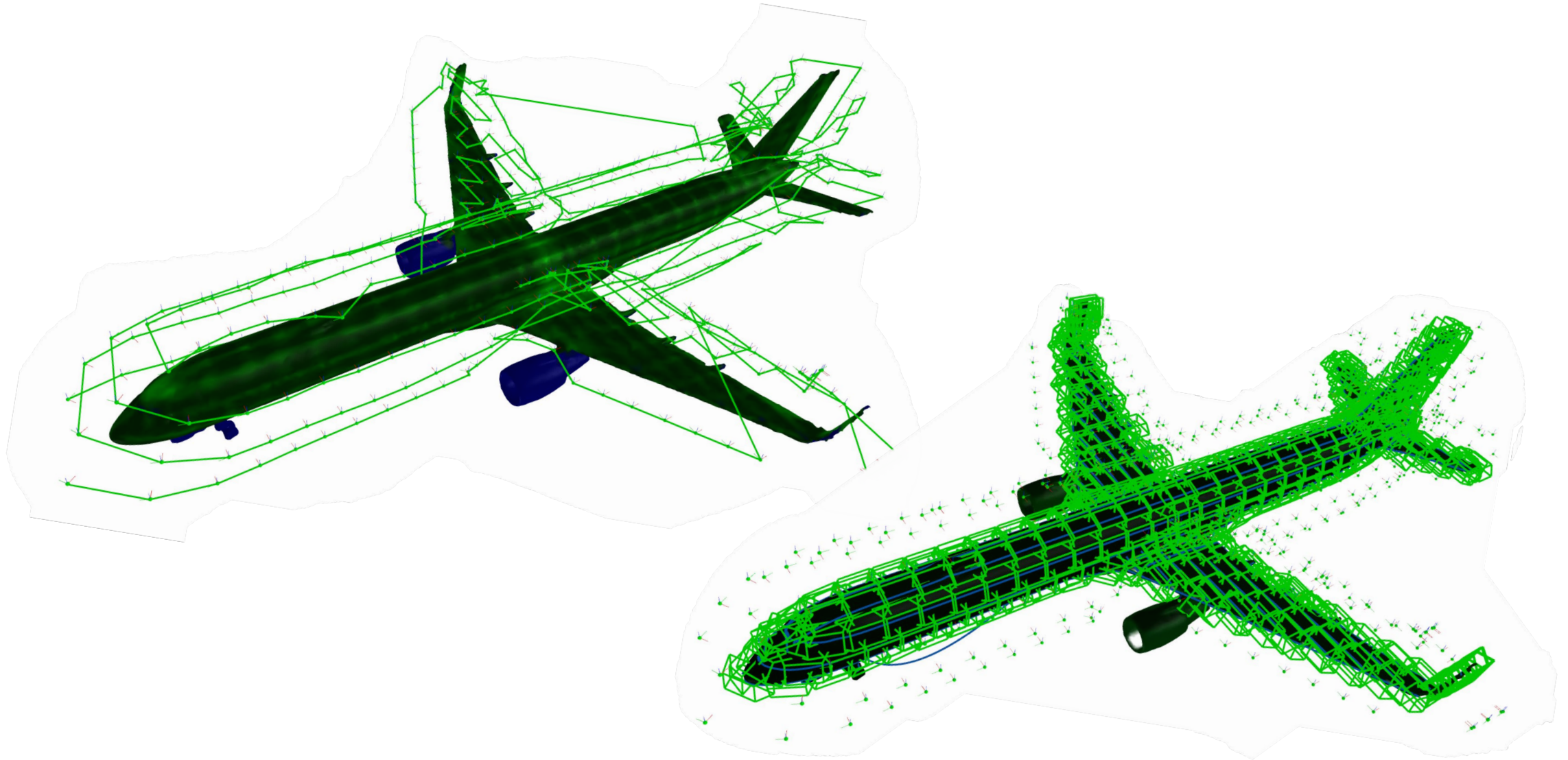
Inspection Flight



Inspection Flight



Flight Path Coverage



Inspection Result

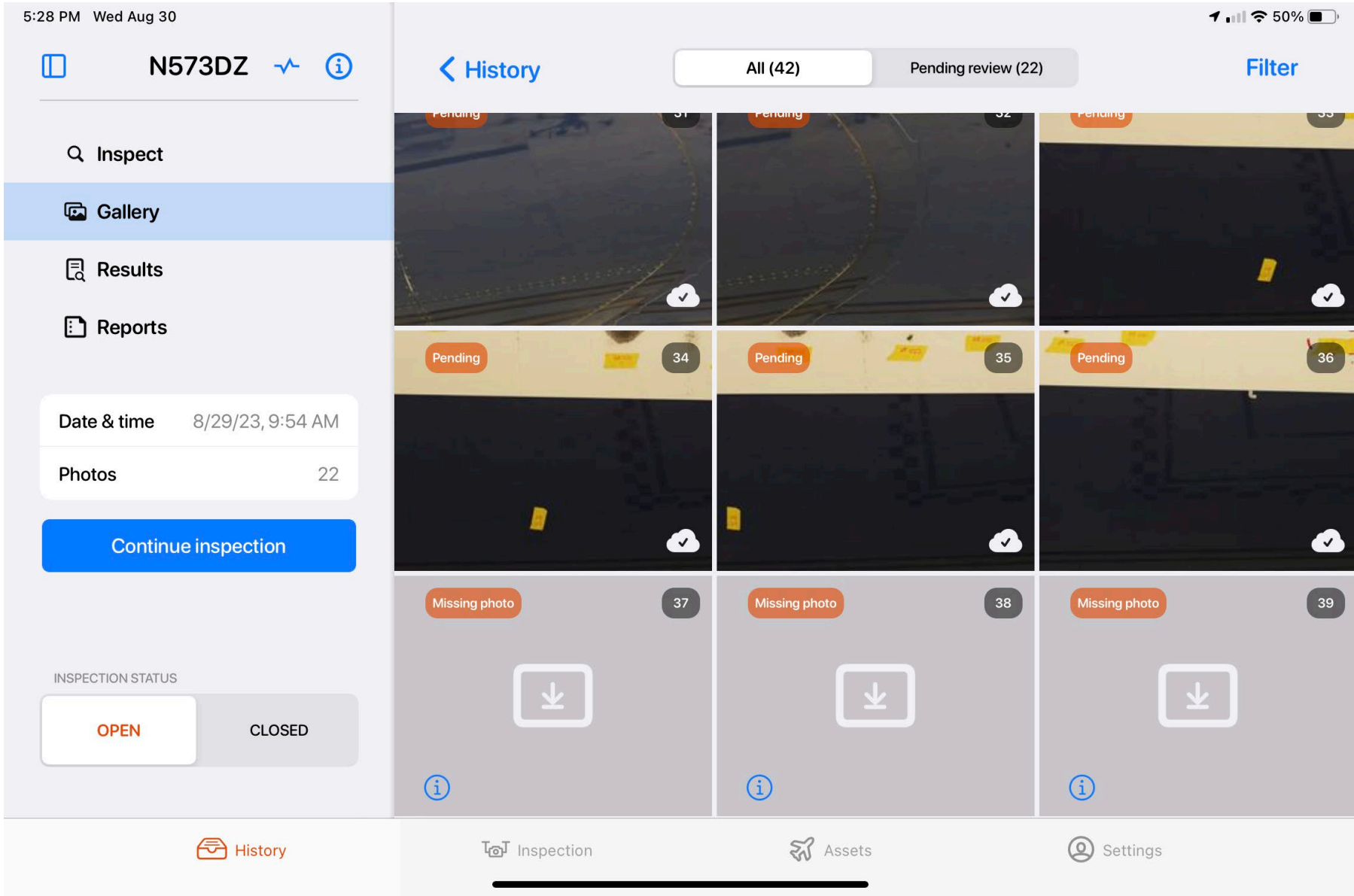


Photo Review

Image 16/40

Pending

Reviewed

Reset

Compute



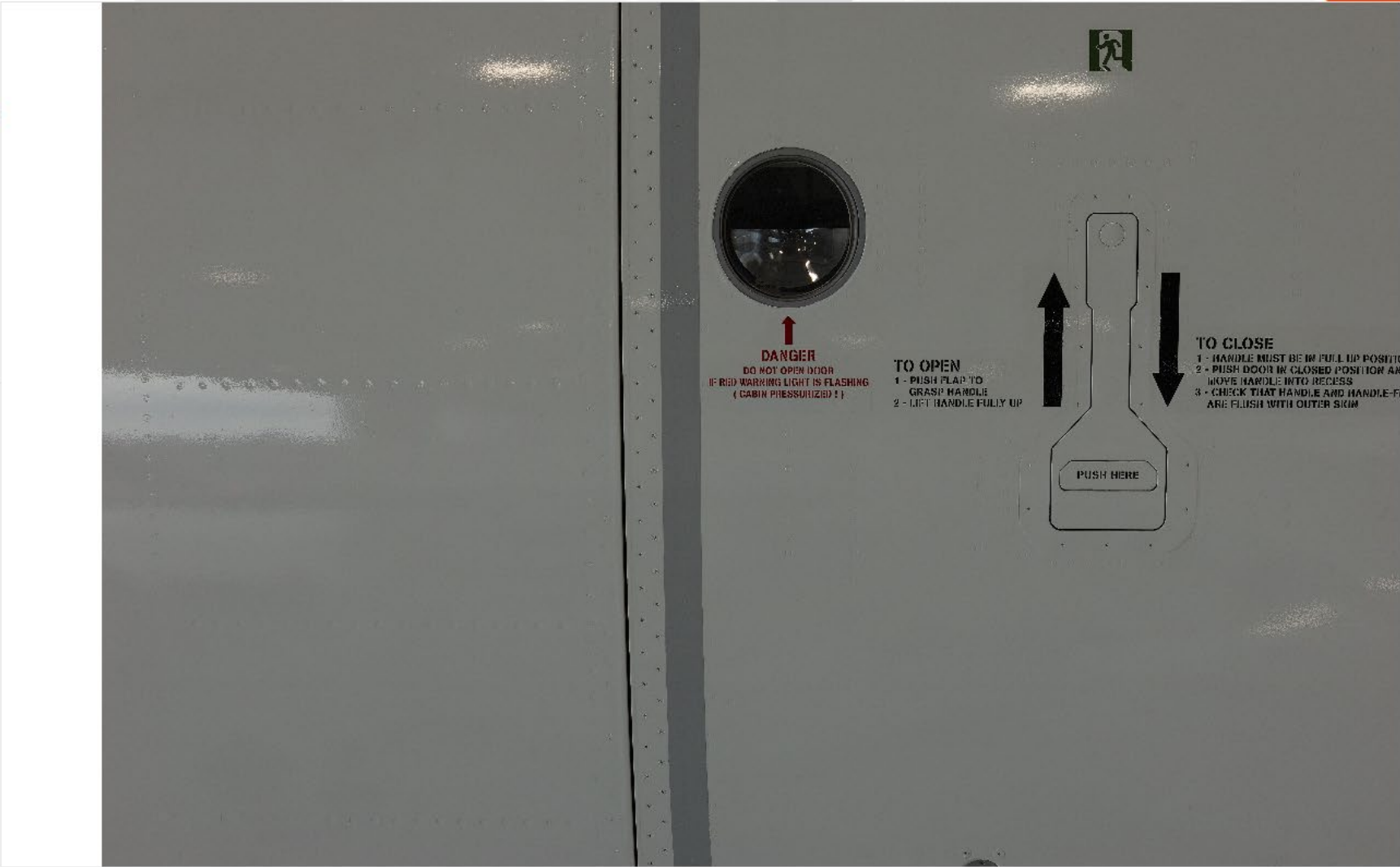
100%



Filter by

Next

Reviewed and next



Floris Straver

1/Sep/2023 8:27

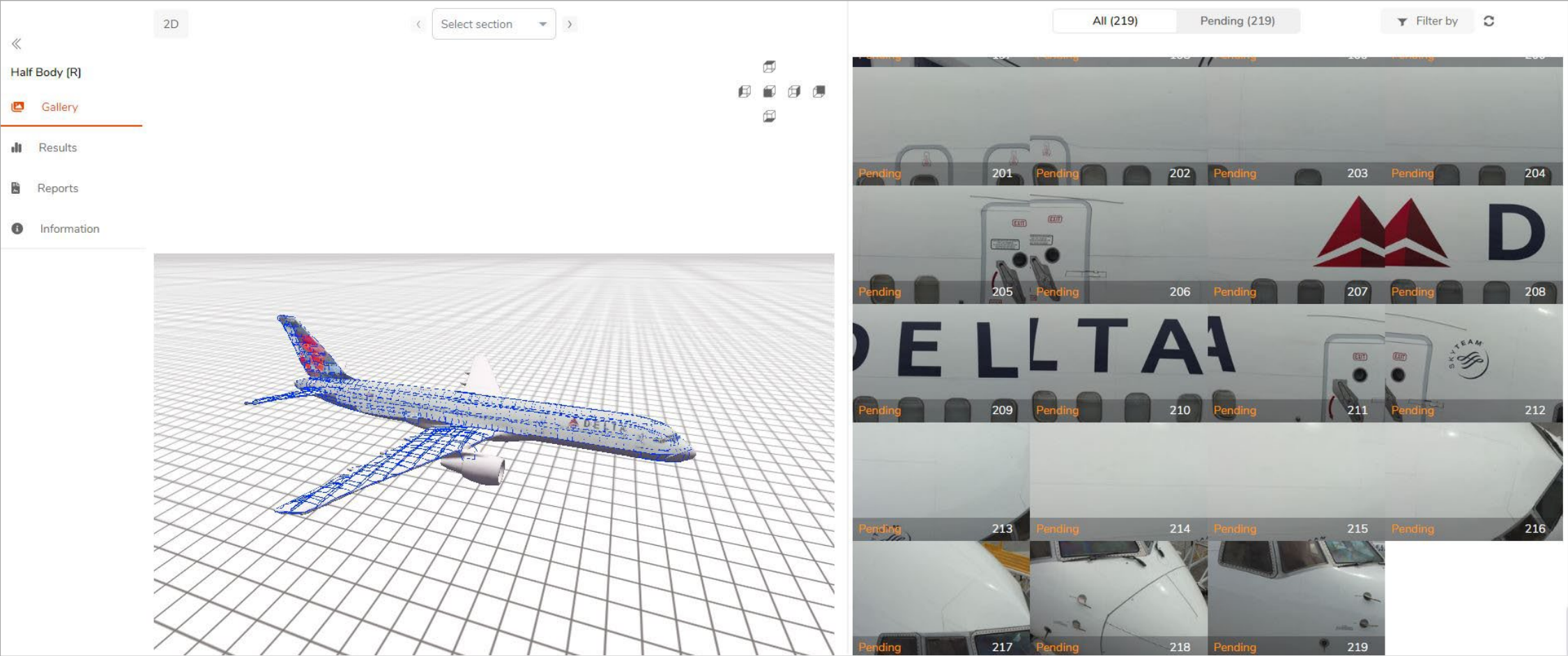
Image center location

RIB 64-65, STGR 21-22

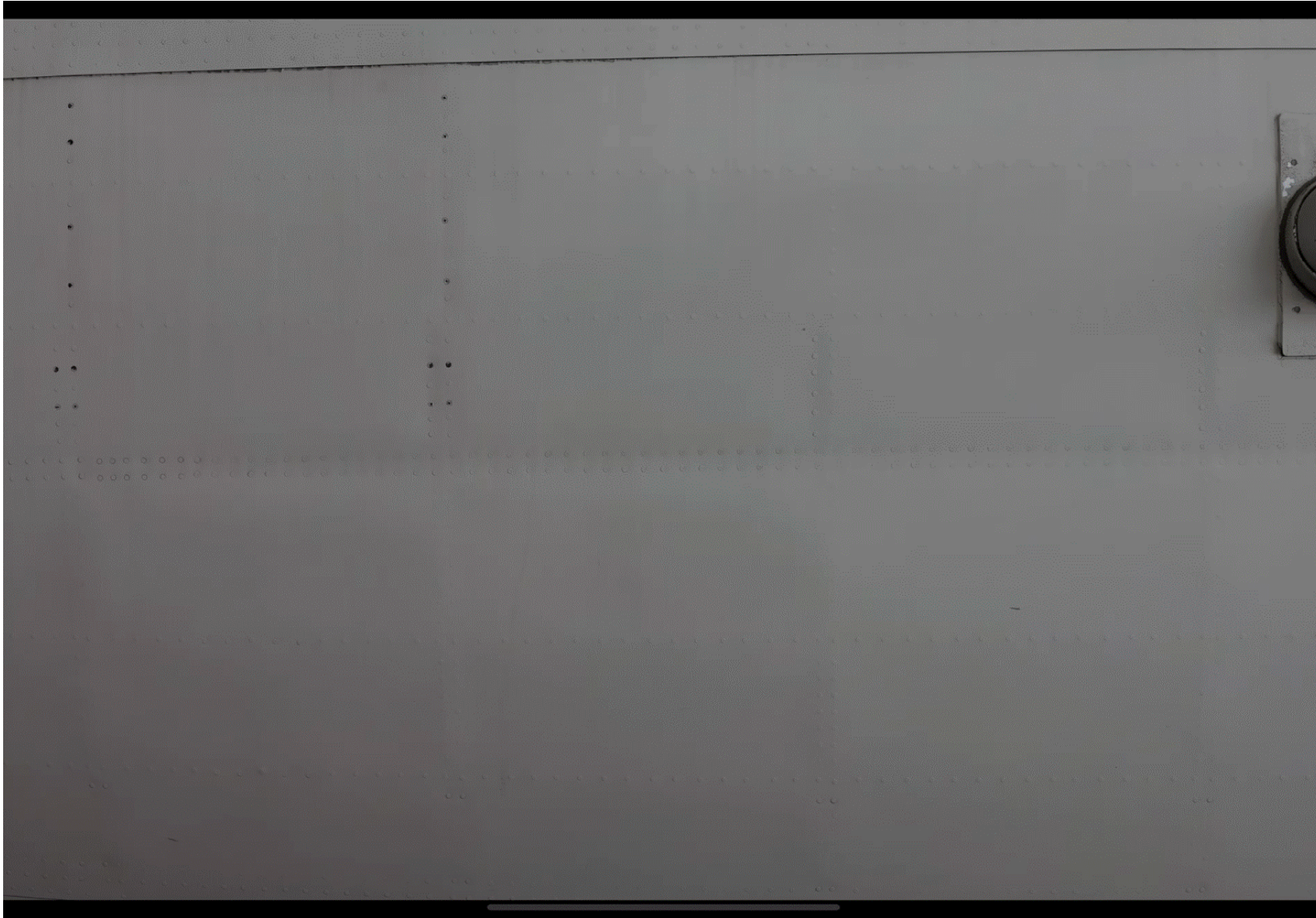
Findings (25)

- 1. Rivet/screw rash
- 2. Light source
- 3. Text
- 4. Rivet/screw rash
- 5. Marking
- 6. Light source
- 7. Marking
- 8. Dirt
- 9. Text
- 10. Sticker
- 11. Text
- 12. Marking
- 13. Rivet/screw rash
- 14. Dirt
- 15. Light source
- 16. Marking
- 17. Light source

Photo Review



Drone Damage Findings



FAA Internal Memo



Federal Aviation Administration

- **Dated:** December 15, 2023
- **From:** AFS-300 to all Flight Standard Offices assigned safety oversight of certificate holders with a Continuous Airworthiness Maintenance Program (CAMP)
- **Subject:** FAA acceptance of Unmanned Aircraft System(s) (UAS) procedures for general visual inspections (GVI) of aircraft in accordance with 14 CFR Part 43.13(c)
- **Details:** *“As a certificate holder with a CAMP operating under 14 CFR Part 121 or 135, certificate holders can change their methods, techniques, and practices for maintenance if the changes are acceptable to the Administrator, reference 14 CFR part 43.13(c). The methods, techniques and practices used by an operator with a CAMP can be different than what is prescribed in a maintenance manual by an original equipment manufacturer. Certificate holders are responsible for their maintenance program, CAMP, in its entirety.”*

Program Acceptance



FAA ACCEPTANCE

Delta earned FAA acceptance of their data package, becoming the first in the industry to have acceptance for the use of a camera-based sUAS inspection for conditional general visual inspections (GVIs) across both Boeing and Airbus fleet types



AMM INSERTION

Fleet wide AMM insertion of camera-based sUAS assisted general visual inspections (GVIs) for conditional lightning strike inspections



U.S. Department
of Transportation
**Federal Aviation
Administration**

Aviation Safety

February 29, 2024

A/W File No.: 202402297000 UAS Drone

This letter is written in response to Delta Air Line's request letter, dated 11/13/2023, regarding, Camera-based Inspection Equivalency for General Visual Inspection.

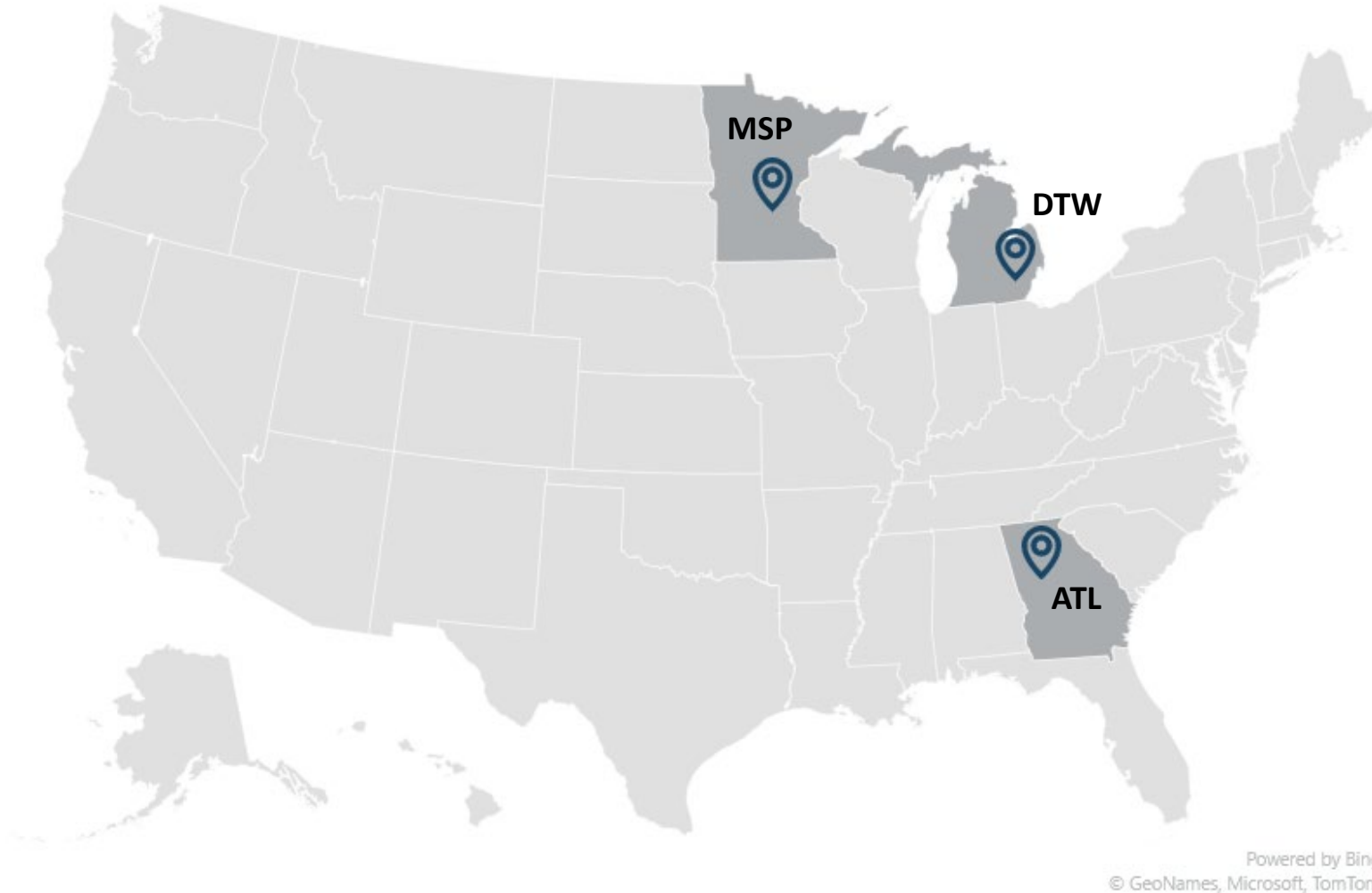
The Delta Certificate Management Office (CMO) has reviewed Delta's Substantiation Report 613599-20, which details Delta's Camera Based sUAS Inspection, as an Equivalent Means of Inspection to Conditional General Visual Inspections, for Airframe Exterior. Based on that review, we have no objections with Delta Air Lines moving to the next step.

This equivalent determination is considered other methods, techniques, or practices acceptable to the Administrator (43.13(a)), as substantiated by your Continuous Airworthiness Maintenance Program (43.13(c)). At the present time, the Delta CMO has no evidence that these maintenance practices are not acceptable. We will continue to evaluate your CAMP as part of routine oversight practices.

Autonomous Flight Capabilities



Outdoor Flight Approvals



Approved Airports:

- Hartsfield-Jackson Atlanta International Airport (ATL)
- Minneapolis-Saint Paul International Airport (MSP)
- Detroit Metropolitan Wayne County Airport (DTW)

Regulatory Approvals:

- Federal Aviation Administration
- Department of Transportation
- Airport Authorities
- Transportation Security Administration
- City Authorities

Training Program

Session 1

Drone Pilot Training:

- Hardware familiarization
- Battery and equipment handling
- Flight theory: flight dynamics and flight modes
- Drone Discipline and best practices for piloting and handling
- General safety practices

Test: Pilots are turned around while drone is moved into new location. Pilot must take control, determine flight direction, and fly back to home for landing

Session 2

Delta Program Training:

- Drone unpacking and setup procedures
- Camera setup
- First flight of the day and pre-flight checklist procedures
- Flight program execution
- Emergency landing procedures
- General troubleshooting tips
- Bug reporting

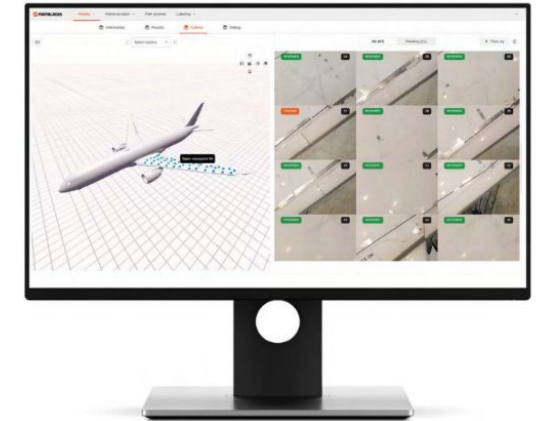
Test: Pilots setup drone from start to finish, run program, and take over autonomous flight for emergency landing

Session 3

Photo Review Training:

- Create a Mainblades account and login
- Selecting a completed inspection / navigating the portal
- Photo navigation tools and information
- Photo review process and standards
- Tagging found damages

Test: Find an inspection, inspect 10 photos, find predetermined damages, tag damages using portal



Operationalization

TASK A350-C-05-51-18-90001-281A-A

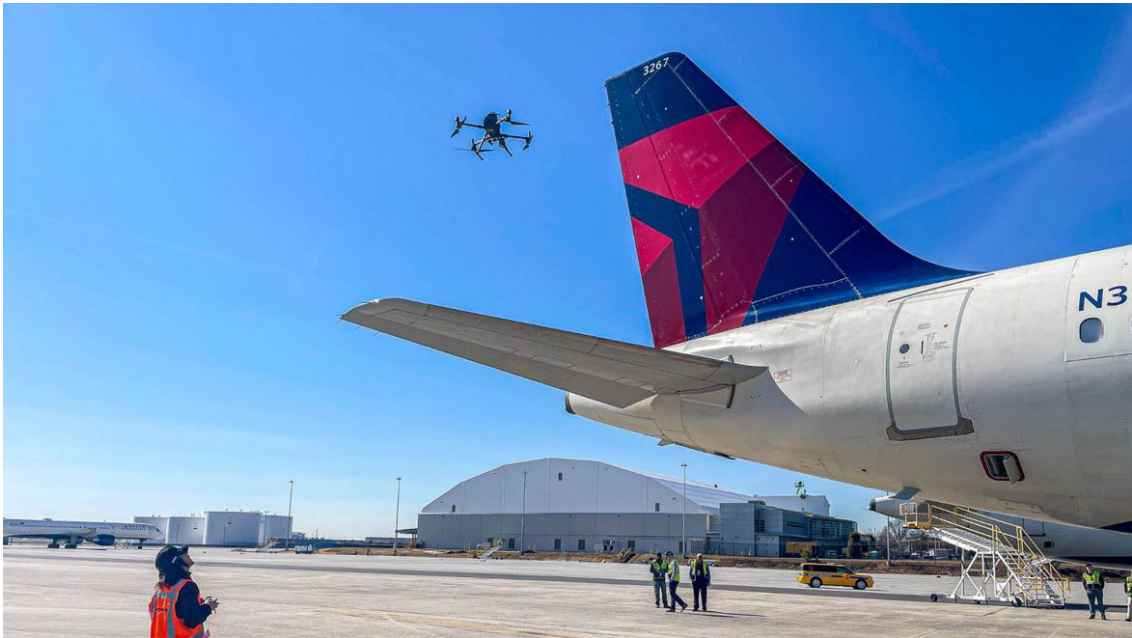
Inspection - Camera Based Drone Inspection for Portions of the
External Check

ON A/C ALL

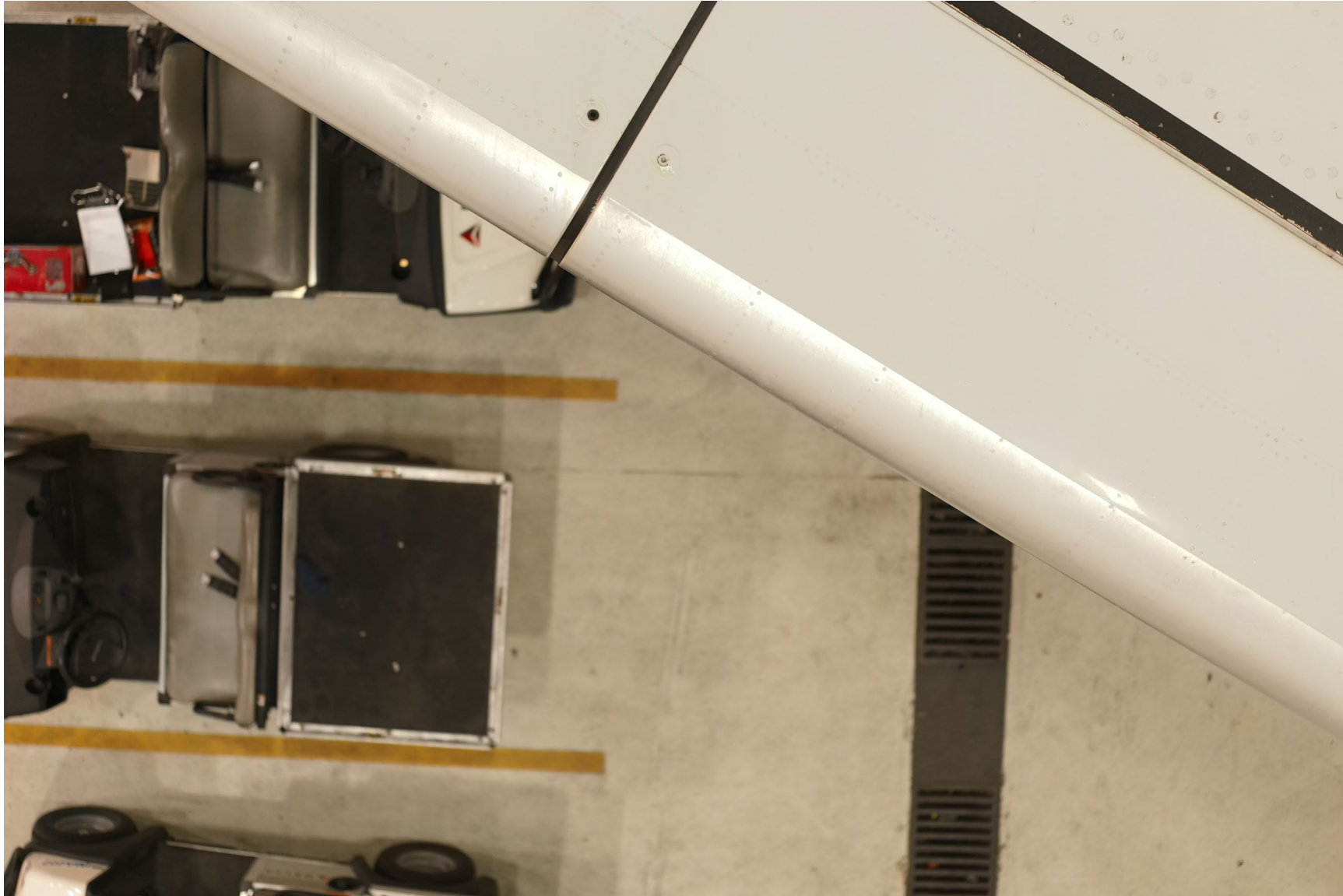
References

Table 1 References

<i>Data module/Technical Publication</i>	<i>Title</i>
<u>A350-A-05-51-18-00001-282A-A</u>	<i>Unscheduled Maintenance Checks - Inspections – Inspection After Lightning Strike</i>
<u>A350-C-05-51-18-90001-281A-A</u>	<i>Inspection - Camera Based Drone Inspection for Portions of the</i>



Drone Damage Findings



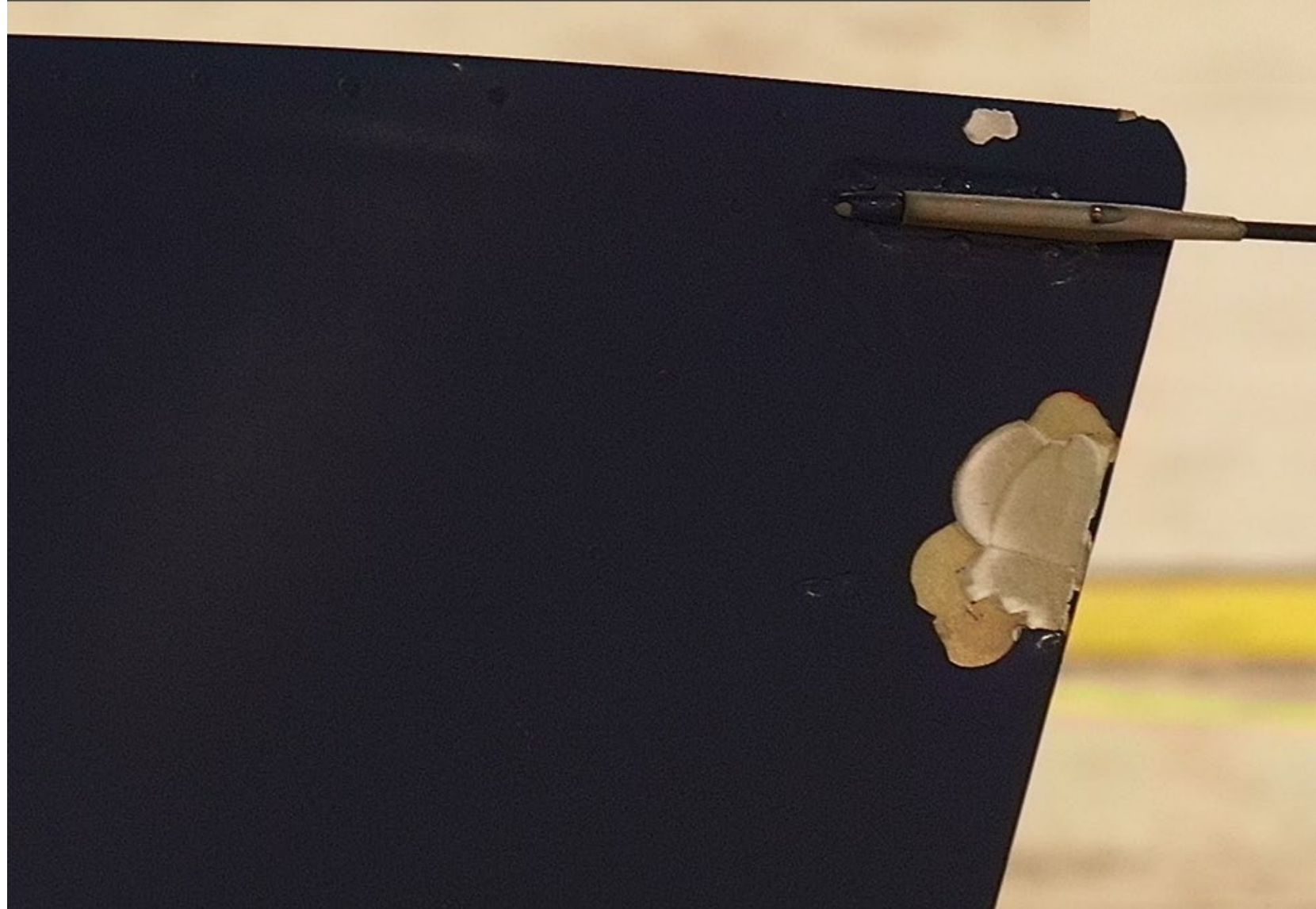
Drone Damage Findings



Drone Damage – Exposed Surface



Drone Damage Findings – Exposed Surface



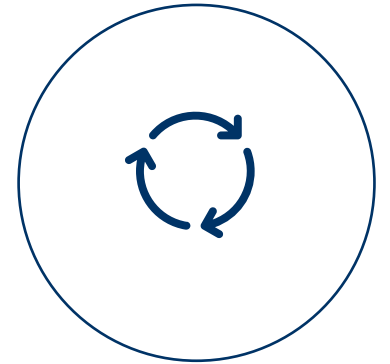
Next steps

- *Continued rollout: Additional bases*
- *Paint quality/priority*
- *Expansion of conditional GVI: Hail*
- *SAE G-38 Committee Collaboration*
 - *See Walt's presentation tomorrow*
 - *GVI vs Zonal*



COLLABORATION

Delta and Boeing lead SAE's G-38 Exterior Aircraft Inspection Committee; Working approvals and implementation of conditional general visual inspections (GVIs), moving to Zonal inspection



SCALING

Delta is determining appropriate number of drones and geographic locations to support conditional GVIs; additional locations will be required if future implementation is allowed for Zonal inspections

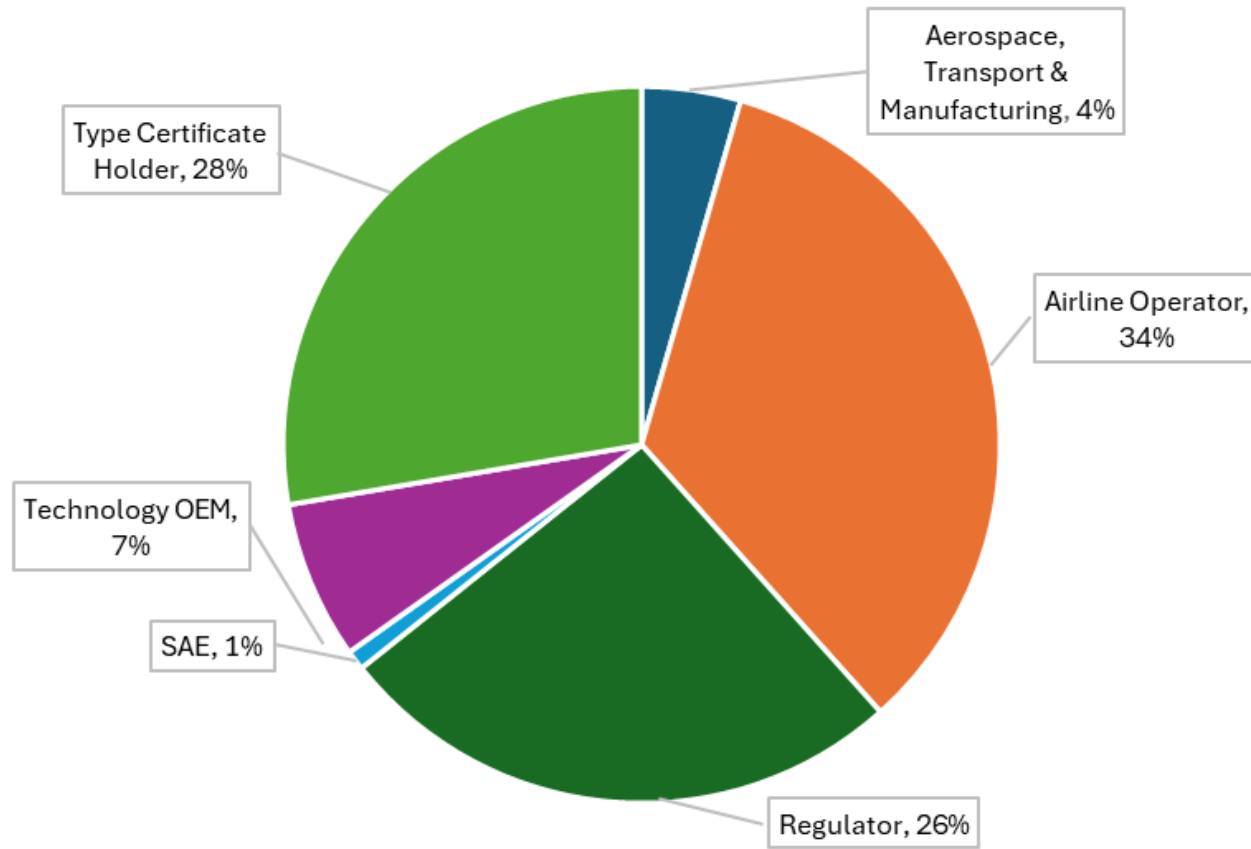
SAE G-38 COMMITTEE

- *Exterior Aircraft Inspection*
- *Chair = Greg Swears (Boeing)*
- *Vice = Emma Galarza (DL)*
- *Secretary = Don Munasinghe (Emirates)*



SAE G-38 COMMITTEE

Participant Interest - Categories



Category	Participant Interest
Aerospace, Transport & Manufacturing	5
Airline Operator	38
Regulator	29
SAE	1
Technology OEM	2
Type Certificate Holder	31

Category	Participant Interest
Australia	2
Brazil	2
Canada	2
China	2
Europe	4
FAA	10
Hong Kong	2
Japan	2
Singapore	2
UAE	1

Assisted Damage Detection - Future

Image 16/40

Pending

Reviewed

Reset

Compute

100%

Filter by

Next

Reviewed and next

Florin Straver

1/Sep/2023 8:27

Image center location

RIB 64-65, STGR 21-22

Findings (25)

1. Rivet/screw rash

2. Light source

3. Text

Type:

Text

Depth:

N/A

Width:

5mm

Length:

25.1mm

Area:

125.8mm²

Location:

RIB 64-66, STGR 20-21

4. Rivet/screw rash

5. Marking

6. Light source