Analatom Inc. • Mountain View, CA
Phone: +1 (650) 796-2472 • Email: info@analatom.com

# 1 Overview

Analatom's **Automated Inspection using Deep Learning (AIDL)** is a cloud-hosted AI solution for rapid, automated defect detection. It enables high-speed, human-in-the-loop inspections across visual and hyperspectral imaging domains. AIDL is adaptable to a wide range of industries, including aerospace, energy, petrochemical, manufacturing, and maritime—by training custom models specific to each application's material, defect type, and imaging conditions. Deployment options include commercial cloud (AWS), Air Force Cloud One, or Docker-based on-edge systems.

### Key Features

- **AI-Driven Defect Detection** – Deep learning-based detection and segmentation of surface/subsurface anomalies
- **Industry-Agnostic System** – Trained per asset/material type with minimal annotation burden
- **High-Speed Inference** – Real-time analysis and QA feedback
- **Flexible Deployment** – Web-based Application hosted on Amazon Web Service (AWS) or Cloud One
- **Human-in-the-Loop Learning** – Inspector corrections integrated to refine model over time
- **Imaging integration** – Supports visible light and hyperspectral imaging

### Target Industries

- **Aerospace** – Visual + SWIR inspections for composite structures, propellers, borescope imagery
- **Energy** – Real-time defect detection on turbines, substations, and battery systems
- **Petrochemical** – Pipeline anomaly classification (deformation, corrosion, obstruction)
- **Manufacturing** – Inline QA and FOD detection on assembly lines and high-throughput processes
- **Maritime** – Hull and weld inspections for ships and offshore structures in harsh environments

# 2 Product Description

Visual inspections are essential for maintaining assets, but traditional methods are slow, labor intensive and prone to human error. Analatom's Automated Inspection using Deep Learning (AIDL) system is an AI-powered tool that enhances the speed and accuracy of defect detection. Although originally developed for aerospace maintenance, repair and overhaul (MRO), AIDL has demonstrated versatility in multiple industries, including aerospace, manufacturing, engineering, and energy since its inception.

Analatom's Automated Inspection using Deep Learning (AIDL) Application is an end-to-end AI driven solution designed to automate and enhance existing nondestructive Inspection (NDI) processes for assets. The system leverages both deep learning models and hyperspectral imaging to enable highly accurate detection of surface and subsurface defects across a wide range of applications. The AIDL platform integrates image acquisition, real-time defect analysis, and data reporting within a secure cloud-based platform, significantly reducing inspection time and human error. AIDL has already proven its impact, reducing inspection times by 75% for Air Force propeller blade assessments. By replacing manual analysis with AI-driven defect recognition, it streamlines processes, reduces costs, and improves reliability. For commercial clients, AIDL operates in a secure cloud environment, while for the Department of Defense (DOD), Analatom is transitioning the system to AF Cloud One as part of a Phase II Option Effort. This ensures a secure and scalable deployment across DOD facilities with real-time accessibility.

## 2.1 Target Applications

The AIDL application offers broad applicability in a wide range of industries where reliability, safety, and process efficiency are critical. AIDL is designed to support use cases ranging from composite structure evaluation in aerospace platforms to foreign object detection and anomaly identification on high-throughput production lines. Its ability to adapt to varying inspection environments and asset types makes it a versatile tool for both operational maintenance and quality assurance workflows. The following sections outline key application areas where AIDL can be integrated to improve inspection accuracy, reduce inspection times, and provide overall time and cost savings.

### 2.1.1 Aircraft Maintenance

The aerospace industry places exceptional demands on inspection systems due to its strict safety standards, high-value components, and the complexity of failure modes in both metallic and composite structures. Analatom's AIDL framework was originally developed for borescope-based inspection of propeller blades within Department of Defense maintenance depots. In this deployment, AIDL enabled automated crack and corrosion detection within confined internal spaces, significantly reducing the manual workload required. The implementation of AIDL in this context resulted in an estimated cost savings of $70,000 per year by streamlining inspection processes, reducing rework, and minimizing inspection bottlenecks.

As aerospace materials continue to evolve, traditional visual inspection techniques face increasing limitations. In particular, composite components, such as glass fiber reinforced polymers (GFRPs) and carbon fiber reinforced polymers (CFRPs), present unique challenges due to their layered structure. Subsurface defects including delamination, core disbonding, honeycomb crush, and water ingression are not easily detectable using visible-spectrum imaging. Conventional nondestructive inspection (NDI) methods such as ultrasonic testing, thermography, or tap testing are time-consuming, operator-dependent, and often require direct contact or surface preparation, reducing their utility in fast-paced maintenance environments.

To address these limitations, Analatom extended the AIDL system to include shortwave infrared (SWIR) imaging capabilities for enhanced composite inspection. SWIR wavelengths (900–1700 nm, Figure 1) are able to penetrate polymer matrices and certain resin systems, making it possible to visualize embedded defects that are invisible in traditional optical images. Analatom's GFRP inspection application leverages SWIR imagery in conjunction with deep learning-based methods to detect anomalies such as internal delamination, moisture ingress (Figure 2), and honeycomb degradation. The technique is non-contact, can be performed in ambient conditions, and requires minimal setup, making it well-suited for integration into both depot and in-field maintenance workflows. While initially designed for GFRP, the same approach generalizes to CFRP components, offering a scalable solution across a broad range of composite aerospace structures.

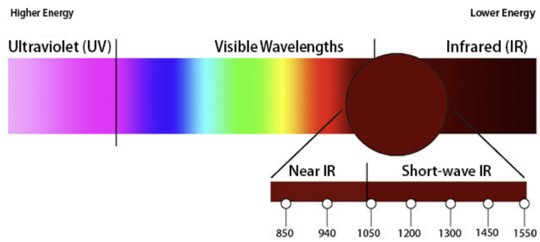


Figure 1: SWIR occupies a spot in the nonvisible light spectrum between near infrared (NIR) and longwave IR. It behaves more like visible light than the thermal energy of the IR spectrum.

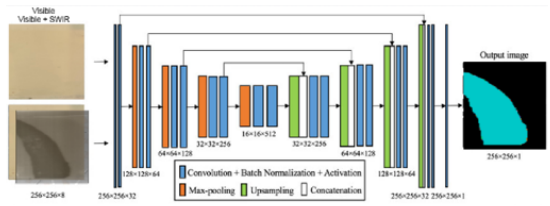


Figure 2: A region of water is detected underneath visible and SWIR spectrum images of fiberglass panels using a deep learning algorithm.

By combining real-time image analysis, subsurface defect visibility, and compatibility with robotic or handheld capture systems, AIDL offers a next-generation solution for aerospace inspection. It addresses the shortcomings of traditional NDI techniques while enhancing reliability, repeatability, and speed. As aircraft designs increasingly rely on composite airframes and bonded assemblies, the need for intelligent, non-invasive inspection systems becomes critical—not only for safety assurance, but also to support predictive maintenance and reduce total lifecycle costs.

### 2.1.2 Energy

Energy infrastructure, including power generation, transmission, and storage systems, is increasingly under pressure to operate with higher efficiency, minimal downtime, and enhanced safety guidelines. Despite this, inspection and maintenance operations across energy assets remain largely manual, fragmented, and reactive in nature. Legacy processes introduce operational bottlenecks, particularly in remote or hazardous environments such as turbine housings, substations, high-voltage switchyards, and battery storage systems. Routine inspections often require physical access, shutdowns, and extensive labor, which increase operational risk and reduce asset availability.

Structural degradation and component failure within the energy sector can stem from a wide range of factors (thermal cycling, corrosion, vibration, material fatigue). These degradation modes are not always visible to the eye and may progress undetected until critical failure occurs. The visual complexity and variation across energy system components introduce significant subjectivity in human-led inspections, resulting in inconsistent defect detection and variability in maintenance outcomes. As energy networks expand and diversify—incorporating renewable sources, distributed storage, and aging legacy systems—the demand for scalable, accurate, and non-invasive inspection solutions continues to grow.

Automated visual inspection solutions present a natural fit for this domain. Analatom's AIDL software offers a robust framework for detecting and segmenting defects across heterogeneous equipment and environments without the need for manual interpretation. Its integration with unmanned inspection platforms such as drones, borescopes, or robotic crawlers allows for coverage of high-risk or difficult-to-access areas without interrupting operations. AIDL's real-time inference capabilities also support integration with predictive analytics platforms, enabling proactive maintenance and minimizing unplanned outages. By reducing the dependency on manual evaluations and allowing for consistent, repeatable assessments, AIDL has the potential to significantly lower operational costs and extend the lifecycle of critical energy assets.

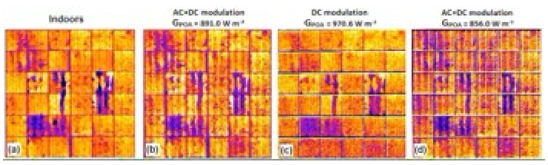


Figure 3: Sample images of PV solar cells under SWIR imaging.

#### 2.1.3 Petrochemical

Existing inspections within the petrochemical infrastructure present challenges because of their time-intensive nature, the reliance on skilled labor, and the inconsistency due to human error. Pipeline integrity inspections traditionally require physical access to hazardous and hard-to-reach areas, resulting in extended downtime and lost operational efficiency. Further, subtle damage such as corrosion, microcracks, and mechanical deformations often go undetected during manual evaluation. Rising labor costs and the growing need for specialized inspection equipment have further exacerbated the economic and operational burden associated with legacy inspection processes.

To evaluate the applicability of AIDL to pipeline inspection tasks, Analatom conducted a feasibility study using a publicly available dataset of pipeline defect imagery. The dataset comprised approximately 22,000 labeled samples representing six classes of damage—four structural (broken, deformation, misalignment, disconnection) and two functional (deposition, obstacle). Images were collected in industrial environments using robotic inspection platforms and had a resolution of 512 x 640 pixels. The dataset was partitioned into 70% training, 20% validation, and 10% test sets.

Analatom used a custom detection-segmentation pipeline, which was applied to this dataset to assess classification and segmentation performance in realistic operating conditions. The detection model was fine-tuned on the training set to localize defect regions via bounding boxes, while the segmentation model operated with default pretrained weights. This approach allowed for the evaluation of zero-shot segmentation performance without the need for time-intensive mask-level annotations. The combined system processed each image in 4.6 milliseconds, enabling near real-time inference suitable for field applications.

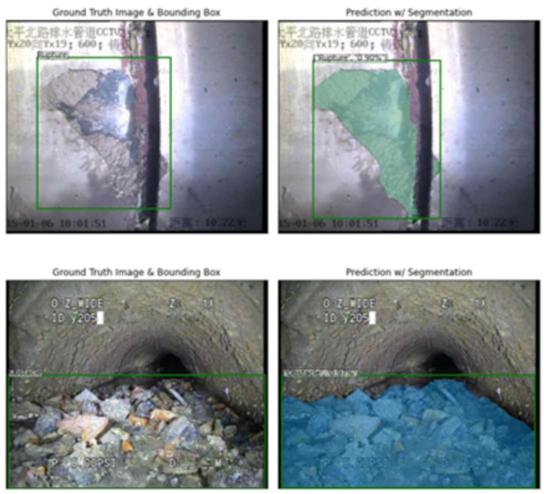


Figure 4: Defect segmentation outputs from Analatom's custom one-shot segmentation framework.

The model demonstrated high fidelity in distinguishing between defect classes and was particularly effective at segmenting complex damage shapes from background elements in cluttered scenes. Visual inspection of segmentation outputs showed that the pipeline was capable of identifying damage features even in visually ambiguous conditions, such as overlapping corrosion patterns or partial occlusions. However, it was observed that class imbalance and the prevalence of background-only samples contributed to a higher false positive rate in background classification. These results suggest that modest improvements to the dataset and further refinement of detection thresholds could yield significant performance gains.

Overall, the feasibility study demonstrated the viability of Analatom's AIDL architecture for pipeline inspection applications. Despite operating on a dataset with class imbalance and minimal fine-tuning, the system achieved robust classification and segmentation performance across diverse damage categories. These findings validate the potential for rapid deployment of AIDL-based inspection pipelines in petrochemical settings and provide a strong foundation for further integration into digital twin systems and predictive maintenance workflows.

### 2.1.4 Manufacturing

Within modern manufacturing environments, the need for rapid, accurate, and automated quality assurance is more critical than ever. Assembly lines and high-throughput fabrication systems operate on strict production timelines where even minor disruptions can propagate into significant delays and cost overruns. Traditional visual inspections, often performed manually or with basic rule-based automation, introduce latency, subjectivity, and error into critical stages of the production cycle. Further, these systems fail to detect subsurface defects or foreign objects embedded within opaque packaging materials, particularly in molded or sealed components.

Analatom's AIDL software is inherently suited for manufacturing applications due to its high-speed inference capability and compatibility with real-time decision systems. The underlying deep learning framework enables consistent, pixel-accurate defect detection with inference times under 5 milliseconds per image—ideal for deployment on high-speed production lines. Whether integrated into existing inspection cameras or deployed via robotic arms and machine vision systems, AIDL supports real-time monitoring, defect flagging, and feedback loops for immediate rejection or downstream tracking of defective parts. Where needed, AIDL can be deployed as an on-edge device to enable even faster inference for high-volume inspections. Its platform-agnostic design allows seamless integration with industrial automation platforms and manufacturing execution systems (MES), facilitating non-intrusive deployment in both legacy and modernized facilities.

A distinguishing capability of the AIDL framework is its support for shortwave-infrared (SWIR) hyperspectral inspection. SWIR cameras can penetrate many common plastics, offering visibility into hidden features or foreign objects beneath the surface of enclosures, housings, or composite layers. This makes SWIR-aided inspection highly effective for quality assurance in electronics and consumer goods manufacturing, where contamination or hidden assembly errors must be caught prior to final packaging. Prior studies have demonstrated the ability of SWIR wavelengths (typically 900–1700 nm) to penetrate polyethylene, polypropylene, and other industrial-grade plastics to reveal embedded anomalies or structural inconsistencies [1, 2]. By pairing AIDL's segmentation framework with SWIR, manufacturers gain access to an automated inspection system that not only assesses surface integrity but also identifies concealed defects that would otherwise be missed in standard visible-spectrum imaging.


Figure 5: A 1550 nm SWIR light can enable a SWIR camera to see through a plastic container and show the fluid level.

As manufacturing continues its transition toward Industry 4.0, the integration of intelligent inspection tools like AIDL offers a path toward improved product quality, reduced waste, and minimized rework. With its ability to generalize across product types and defect classes, AIDL enables a flexible inspection solution that can evolve alongside dynamic manufacturing lines, delivering long-term scalability and value.

### 2.1.5 Maritime

Maritime assets, including naval vessels, commercial shipping fleets, and offshore structures, operate in some of the most demanding and corrosive environments. Prolonged exposure to saltwater, humidity, and temperature fluctuations accelerates structural degradation, weld fatigue, and corrosion onset. These conditions make routine inspection and maintenance of hulls, joints, and coatings essential to operational safety and asset longevity. Traditional maritime inspection methods are often manual, time-consuming, and dependent on physical access to submerged or enclosed compartments. This not only increases labor intensity but also introduces human error in critical assessments, particularly in weld inspections.

Analatom's AIDL software provides an ideal solution for the inspection of maritime assets by allowing for automated inspection in hard-to-reach or hazardous inspection zones. The system supports integration with borescopes, drones, and other remote imaging platforms to access internal compartments, hull structures, and ballast tanks—locations that are traditionally labor-intensive and costly to inspect. The rapid inference speed of the AIDL framework makes it well-suited for inline inspection tasks during dry dock overhauls or live vessel assessments, enabling real-time decision-making and reducing the need for prolonged maintenance windows.

A primary inspection target in the maritime sector is weld integrity. Weld seams are prone to fatigue-related degradation due to the high mechanical and thermal stresses present in maritime operations. NAVSEA standards require rigorous visual examination of weld joints, but manual inspection methods are often inconsistent and heavily dependent on operator experience. AIDL addresses these limitations by automatically identifying weld defects such as cracking, porosity, undercutting, and surface discontinuities with high consistency. This improves inspection repeatability, reduces inspection time, and lowers the risk of missed or misclassified anomalies.

The integration of shortwave infrared (SWIR) imaging within the AIDL system allows for further use in weld inspection. SWIR imaging penetrates coatings and surface contaminants, allowing for the detection of subsurface discontinuities or degradation near the weld interface that may not be visible using conventional imaging techniques. This would allow for early detection of structural anomalies before they progress to critical failure, improving the overall reliability of maritime structures and reducing the frequency of costly, unplanned repairs.

## 2.2 Benefits

Automated inspection systems provide measurable advantages for the maintenance and assessment of high-value assets across industrial sectors. Manual visual inspections, while widely practiced, introduce several challenges: they are inherently time-consuming, operator-dependent, and prone to inconsistencies due to fatigue or subjectivity. These limitations can lead to undetected defects, delayed maintenance actions, or unnecessary rework. By applying computer vision and deep learning techniques to inspection workflows, systems like Analatom's AIDL Application improve detection reliability, reduce variability in results, and enable consistent, repeatable assessments across varying environments and operators.

A key feature of the AIDL architecture is its human-in-the-loop design. Rather than fully automating decision-making, the system allows for operator review and correction of uncertain or edge-case predictions. This hybrid approach retains expert oversight where necessary while offloading repetitive classification and segmentation tasks to the AI system. The result is a reduction in cognitive load for inspectors and improved inspection throughput, without compromising the precision required for critical defect identification.

The inference speed of the AIDL framework enables real-time processing of visual data, making it well suited for integration with automated inspection platforms, robotic systems, or time-constrained workflows. This rapid processing capability supports inline inspection during manufacturing, field-deployable assessments, or integration with digital twin platforms for real-time damage visualization.

In addition to time savings, the use of automated visual inspection significantly increases safety for operators in many cases. An automated system reduces the need for manual access to confined, elevated, or hazardous environments. Inspection platforms such as drones, borescopes, or robotic arms can capture image data from these locations and transmit it to the AIDL system for analysis, minimizing operator exposure and streamlining data collection. As industries continue to prioritize safety and operational efficiency, automated inspection methods offer a technically robust path forward for reducing risk and enhancing defect traceability.

# 3 Technical Specifications

#### 3.0.1 Cloud Architecture

The AIDL application is implemented as a custom web-based application built using microservices. The system leverages cloud infrastructure for secure, scalable deployment. For DOD customers, AIDL has also experience with AF Cloud One for specialized deployments. The following components comprise the production deployment:

## 3.1 Platform Integration

#### 3.1.1 Data Output Options

Inspection results can be exported in standard formats including CSV and XML for compatibility with existing reporting systems. For customers with established data pipelines or legacy documentation workflows, the application supports customized defect mapping outputs. These include structured annotations and coordinate-mapped visualizations that conform to previously used formats, allowing for seamless integration into existing maintenance records or quality assurance protocols.

### 3.2 Hardware Requirements

As the inspection system is cloud-hosted, there are no direct hardware requirements for the end user beyond access to a modern web browser and stable internet connectivity. All computational tasks, including model inference and image processing, are handled within the centralized AWS environment. This deployment strategy supports horizontal scaling to accommodate increased data loads without impacting performance and enables multi-site access with centralized data management.

### 3.3 Learning Capabilities

Each application is supported by a custom-trained model, fine-tuned to specific damage types, material properties, and imaging conditions relevant to the customer's use case. Typical training requires between 100–500 annotated examples to reach acceptable baseline performance. AIDL includes a human-in-the-loop feedback mechanism that allows users to correct model predictions, which can then be selectively incorporated into future training cycles. This enables continuous improvement of model accuracy over time with minimal user input and without the need for full dataset re-annotation.

### 3.4 Data Security

All inspection data and model outputs are stored in encrypted buckets, with access governed by fine-grained IAM policies. Inference requests to the cloud-based models are secured using SSL/TLS encryption. Audit logs of user activity are maintained to support traceability and compliance with internal security protocols or external regulatory requirements. The system is designed to comply with best practices for cloud-native application security in enterprise and defense environments per the Defense Information System Agency's (DSIP) Cloud Computing Security Requirement Guidelines (CC SRG).

## 4 Customer Success Stories

### 4.1 Reducing Borescope Inspection Time by 70%

Previously, MRO technicians at Robins Air Force Base relied on a time-consuming process for borescope inspections. They inserted the borescope into the engine or component, captured dozens of images, and then painstakingly reviewed each one by hand, marking any defects on paper forms. With the introduction of AIDL software, this entire workflow was transformed. Using computer vision, AIDL automatically identifies and flags defects within the inspection images (Figure 6), allowing technicians to focus their attention on only the most critical or ambiguous cases. Their feedback on these edge cases is then fed back into the model, continuously improving its accuracy over time. The digital output of AIDL allows users to quickly export inspection results or generate a digital damage map that mirrors the manually created versions. By reducing the manual workload and improving accuracy, Robins AFB reported a remarkable 70% reduction in inspection time, highlighting the efficiency gains and reduced labor cost achieved through this AI-powered solution.

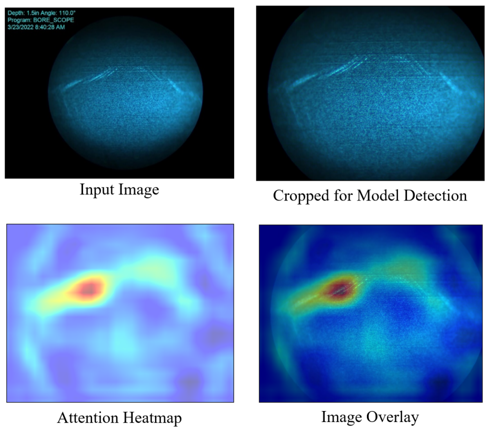


Figure 6: Computer vision model heatmap visualizes where identified borescope defect is found.

### 4.2 Identifying Hidden Defects in Composite Aircraft

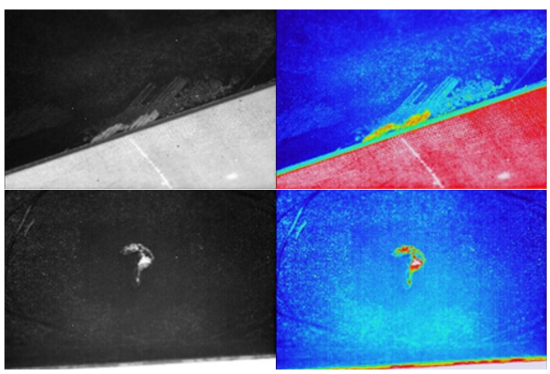

Figure 7: SWIR imaging highlights hidden surface and subsurface defects, which can be easily found by AI models.

AIDL has also proved highly effective in detecting defects on F-15 GFRP (Glass Fiber Reinforced Polymer) rudder blades (Figure 7). Traditional visual inspection methods often fail to catch hidden flaws, especially subsurface defects that are not visible to the naked eye. By integrating SWIR (Short-Wave Infrared) imaging with the AIDL software, inspections could detect potential problem areas that standard inspection methods missed. The AI-driven system identified both surface-level and deeper structural defects, significantly improving both the thoroughness and reliability of the inspection process. This advanced approach not only reduces the risk of costly oversights but also strengthens the overall safety and longevity of critical aircraft components.

## 5 List of Abbreviations

| | |
|---|---|
| **AI** | Artificial Intelligence |
| **AIDL** | Automated Inspection using Deep Learning |
| **AWS** | Amazon Web Services |
| **CC SRG** | Cloud Computing Security Requirements Guide |
| **CFRP** | Carbon-fiber Reinforced Polymer |
| **DISA** | Defense Information Systems Agency |
| **DOD** | Department of Defense (U.S.) |
| **GFRP** | Glass-fiber Reinforced Polymer |
| **HSI** | Hyperspectral Imaging |
| **MRO** | Maintenance, Repair, and Overhaul |
| **NDI** | Non-destructive Inspection |
| **SWIR** | Shortwave Infrared |

## References

[1] R. Morikawa et al., "Evaluation of Plastic Material Using SWIR Imaging for Automated Sorting," *IEEE Sensors Journal*, vol. 19, no. 24, pp. 11887–11893, 2019.

[2] T. Takatani et al., "Short-Wave Infrared Imaging for Identification of Foreign Substances in Plastic Products," *SPIE Proceedings*, vol. 10656, 2018.