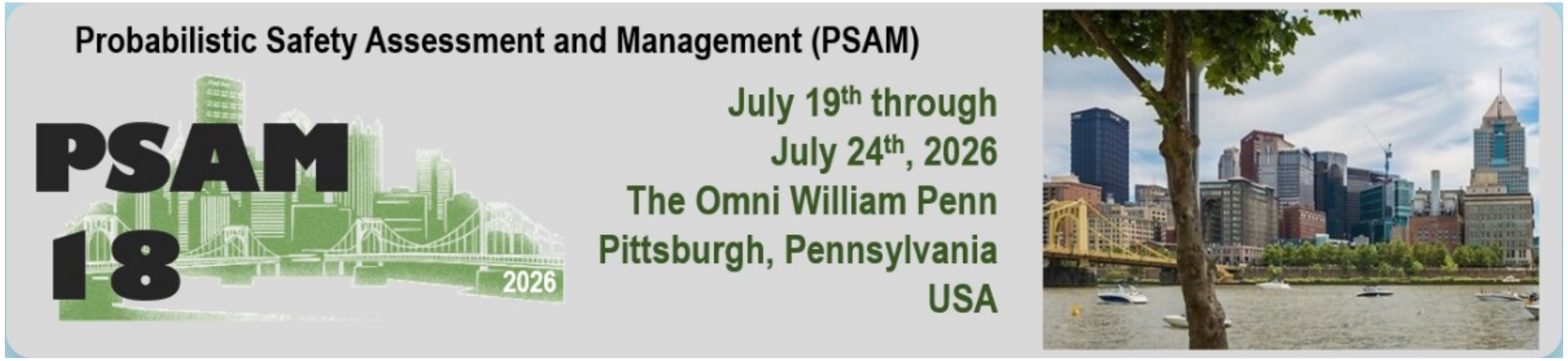

July 22, 2026

Reducing Risks and Time of Inspection of Critical Infrastructures by Means of Light Small-Size Drones

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Contents

Objective of the Research

- Studying the **suitability of flying small drones equipped with RGB cameras** and **processing the recorded images** with the support of **AI algorithms** for **detecting** potentially **damaged structures**

- **Generating valuable insights**, such as georeferenced images for visual inspection, smart 3D reconstructions of affected areas, pattern recognition of damaged zones and location of anomalies, estimation of representative damage indicators
- **Formulating appropriate remediation and corrective measures**, supporting decision making for intervention strategies

Evolving Regulatory Framework - Europe

EU Reg. 2019/947 and **EU Reg. 2019/945** classify civil drone operations into:

- **Open category**: operations without direct supervision or prior approval
- **Specific category**: formal approval process utilising a risk-based approach (SORA)
- **Certified category**: strict safety standards, mirroring those in manned aviation

Specific Operations Risk Assessment (SORA)

Target Level of Safety (TLOS)

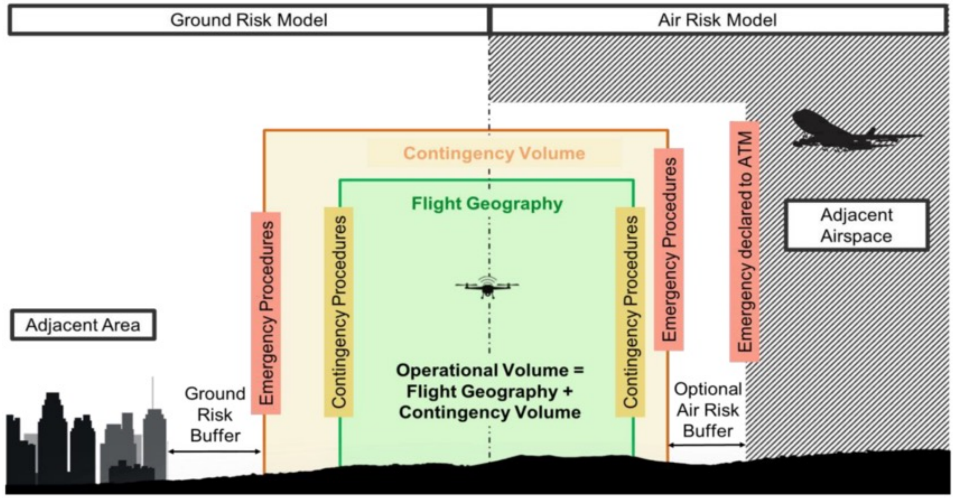
a. **Ground risk**: < 10^{-6} fatalities/FH*

b. **Air risk**: < 10^{-7} MAC**/FH (uncontrolled airspace) or
< 10^{-9} MAC/FH (controlled airspace)

Specific Assurance and Integrity Levels (SAIL): maximum allowable loss of control rate [I to VI]

* FH: Flight Hour **MAC: Mid-Air Collisions

Graphical Representation of SORA Semantic Model
(Courtesy of JARUS, [10])



Evolving Regulatory Framework

Ten Ground Risk Class (GRC 1 to 10) based on **UA characteristics** (speed, weight, dimensions) and **at-risk population density** in the operational volume and ground risk buffer

- For **UA weighing < 250g with max speed < 25 m/s** => **intrinsic GRC = 1** regardless of population density => GRC level not influenced by size of ground risk buffer and adjacent area => containment requirements not requested

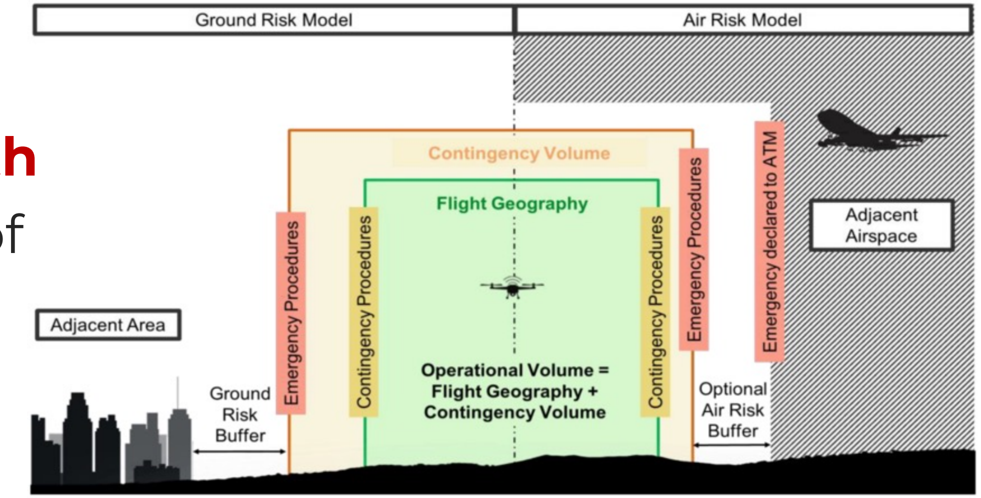
Four Air Collision Class (ARC-a, -b, -c -d) with associated **Tactical Mitigation Performance Requirements** levels (TMPR-no, low, medium, high). For VLOS* and for ARC-a no TMPR requested

- **For UA operated in VLOS weighting < 250g with speed < 25m/s** => **Class** = **ARC-a** with adoption of suitable strategic mitigation measures

SAIL level reasonably **I**

(combination of GRC and ARC)

Graphical Representation of SORA Semantic Model (Courtesy of JARUS, [101])



*VLOS Visual Line Of Sight

Methodological Approach – AI Based Damage Detection by UAV Inspections

Main steps

- **Obtain operational authorisation** for the geographical area of interest
- **Define operational volume and flight geography** for inspection mission
- **Prepare flight plan** for the inspection with sensors installed on the drone
- **Fly the drone according to predefined flight plan** for data capture and recording
- **Transmit or download data** for processing
- **Process data** for **damage detection** using AI-based methods (post-processing)

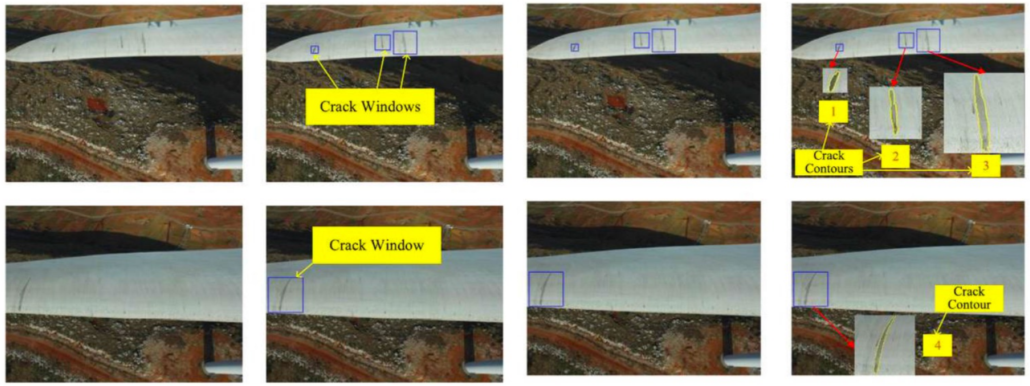
Methodological Approach – Data Post-Processing

Main stages of post-processing of images captured during inspection

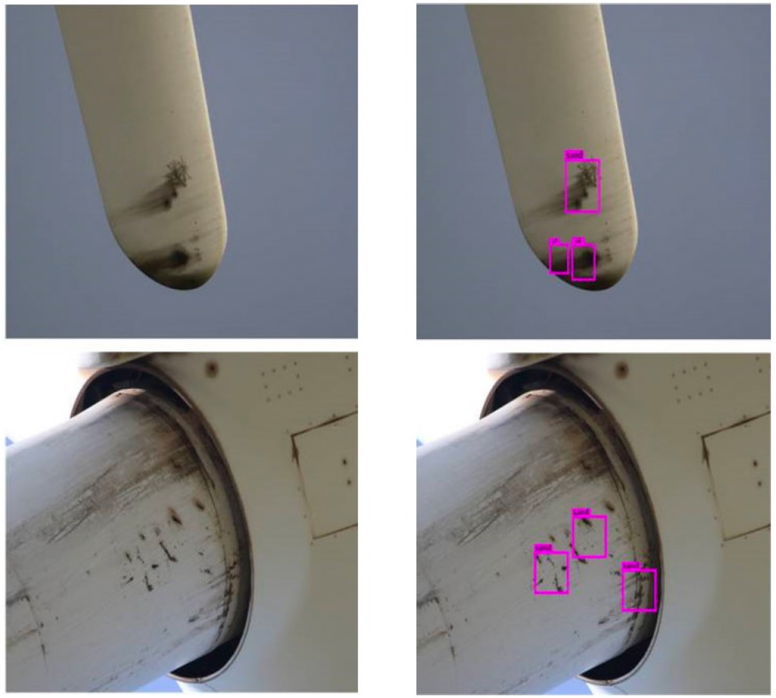
1. **Orthomosaic generation**: Stitching of individual RGB frames into site **georeferenced maps** using **photogrammetry** software (e.g. Pix4D, DroneDeploy or Agisoft Metashape), facilitating production of damage maps and maintenance activities
2. **Anomaly detection and segmentation**: Identification of individual anomalies and their boundaries within the orthomosaic using **machine learning (ML) models** (e.g. U-Net or Mask R-CNN architectures)
3. **Defect recognition and classification**: **1. Classification** of each damage for defect types and severity using **CNNs pretrained** on large datasets for recognising and classifying a series of defects. **2. Defect detection** using CNNs such as YOLO variants particularly suited for their speed, accuracy balance, simultaneous detection of multiple objects
4. **Maintenance intervention planning**: Planning intervention based on **defect class, severity and location**

Example from Wind Turbine Sector*

*Ref. M. Memari , et al. (2024) Review on the Advancements in Wind Turbine Blade Inspection: Integrating Drone and Deep Learning Technologies for Enhanced Defect Detection, IEEE Access, Volume 12, 2024



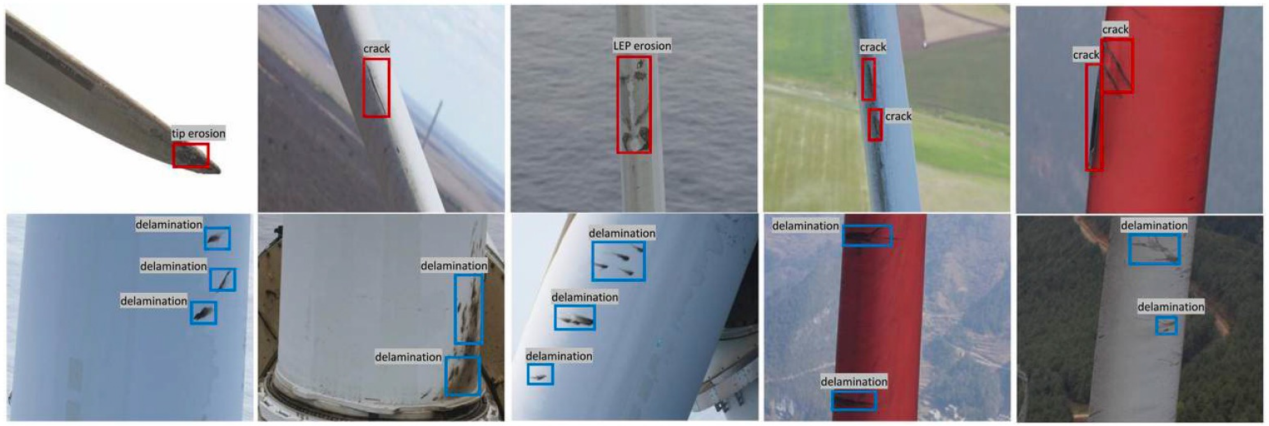
a. Anomaly detection and segmentation



(a) Original

(b) YOLOv3

b. Small damages on blades detected by YOLOv3



c. Defects recognition and classification

Application Areas of AI Based Damage Detection by UAV

Sector	Structures and equipment	Damage
Energy Sector	- Power lines and high-voltage pylons - Wind turbines - Solar farms - Substations	- insulator damage, corrosion, vegetation risks - blade cracks, erosion, structural defects - thermographic detection of defective modules, hot spots, shading - monitoring transformers and electrical components
Infrastructure and Construction	- Bridges - Building façades - Roads and motorways - Tunnels and underpasses	- cracks, concrete spalling, corrosion on steel members - high-rise and industrial structure inspections - automatic detection of potholes and surface damage - structural condition monitoring
Telecommunications	- Mobile masts - Inventory management	- inspection of antennas, cables, and fixings - automatic capture of installed components
Industry and Facilities	- Pipelines - Refineries and chemical plants - Power stations	- corrosion detection and leak monitoring - tanks, pipelines, and process facilities - boilers, cooling towers, and chimneys

Basics for Flight Planning

Flight compliance with mission objectives and local regulations - key criteria

- Ensure **collision-free flight**
- Achieve **full coverage** of the structure to inspect
- Obtain **images of sufficient quality** for feature detection and 3D reconstruction
- **Minimise data volume** by optimising images number and devising efficient flight routes

Flight speed optimisation

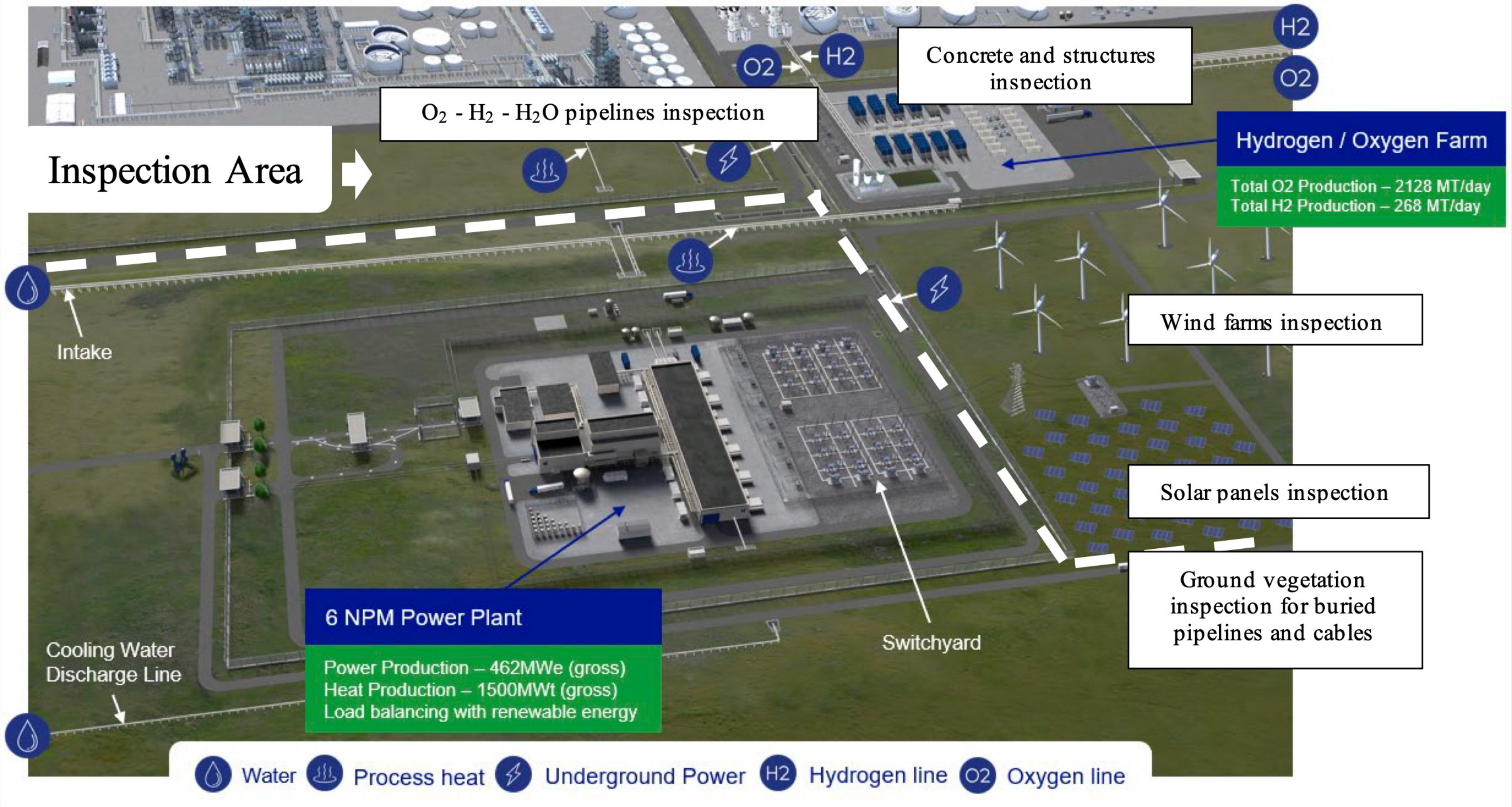
- Maintain **balance between high speed** for battery saving and **slow/moderate speed** for high-quality image collection
- Maintain drone speed aligned with the **camera's capability** to capture sequenced images
- Maintain balance between drone speed and **time required to save** captured images
- Make **exposure time** adequate to avoid taking blurred images

Flight timing

- Select **time slots** appropriate to **avoid overexposure** due to daylight and solar radiation

Example: SMR and H_2 System Integration Options

Figure 2: Flight operation boundaries for small drones and inspection types.
Conceptual Layout of a 6 NPM Power Plant Integrated with an SOEC Hydrogen Production Plant
(Courtesy of NuScale, [15])



Discussion - Advantages

- **Efficiency gains and time savings**: AI-powered drone inspections faster than manual inspections (hours vs days)
- **Enhanced safety**: No personnel sent to dangerous locations or hard-to-reach areas reducing accident risk and supporting HSE standards
- **Cost reduction**: Overall costs reduced, particularly with small-size drones, by lowering personnel demand, avoiding asset downtime, enabling early detection, anticipating costly failures and optimising maintenance planning
- **Precision and objectivity**: Reproducible and objective results obtained without need for repetitive tasks. Recorded data used to retrain models and enhance anomaly detection precision
- **Scalability**: Approach scalable across various typologies of facilities and sites

Discussion – Limitations and Suggestions

Suggestions to overcome current limitations

- Advanced knowledge of **UAV's stability properties** to withstand wind gusts
- Flights automated with an **adequate percentage of image overlay** (75–80%) to eliminate flaws and occlusions
- **Adequate computing capacity** of the equipment used for image processing to avoid long processing times
- **Pilots** continuous **training and development**, and frequent updates of advances in UAV technology
- Identification of potential **adverse weather conditions** and provision of directions for possible flight postponement
- Selection of **AI models** balancing **complexity** and **computational time** to achieve the desired precision of the results

Future Challenges and Research Areas

- **Regulatory framework**. **Authorisation processes** to be simplified based on further studies demonstrating high safety levels for air and ground risks
- **AI models**. **Data bases** to be enriched with new open data, training AI models specifically for damage detection, recognition and classification
- **Hardware**. **Battery performance** to be enhanced and **equipment weight** to be reduced (e.g. light high-precision sensors necessary for installation on small-size UAVs). Dedicated equipment to be designed to elaborate and transmit data in real-time
- **Data processing and transmission**. **Advanced technologies** for transmitting high volumes of data in real-time to be studied (e.g. improvement of transmission and remote-control capabilities)

THANK YOU FOR YOUR ATTENTION

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