HUMAN–TWIN INTERACTION (HTI)

A Conceptual Approach to Predictive Maintenance in Aviation

Concept note prepared by Dexova Intelligence — September 2025
For inquiries: info@dexova.ai | www.dexova.ai

CONTEXT

Aerospace maintenance faces significant challenges:

- Unplanned downtime leads to high operational and financial costs.
- MRO (Maintenance, Repair, and Overhaul) workflows are complex.

Predictive maintenance powered by Digital Twins (DT) offers:

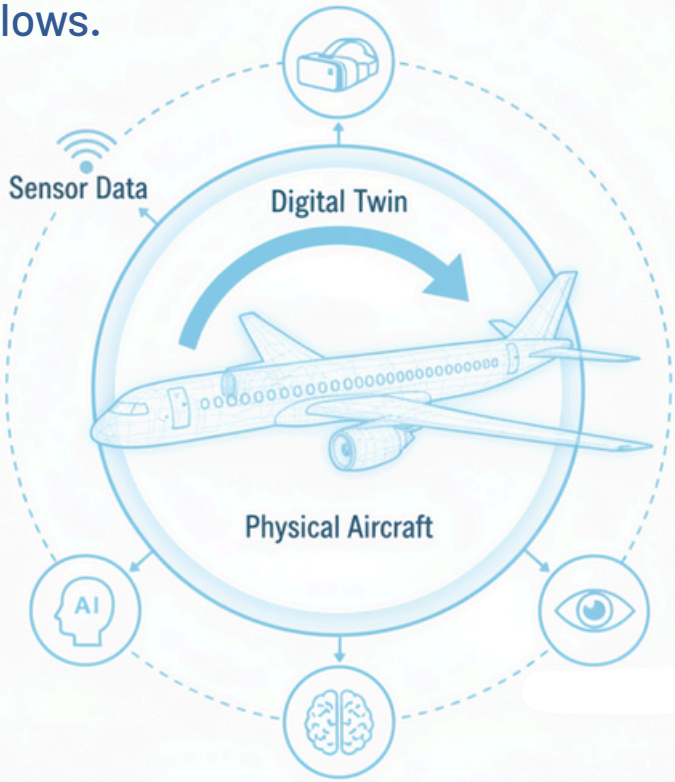
- Real-time monitoring of aircraft systems.
- Early detection of potential faults.
- Streamlined scheduling and maintenance planning.

Human–Twin Interaction (HTI) emphasizes:

- Collaboration between operators and digital twins.
- Ensures predictions are actionable and trustworthy.

DIGITAL TWINS AS A SOLUTION

- Digital Twin (DT): A virtual model of an aircraft system, updated in real-time with sensor and operational data.
- Enables early fault detection and Remaining Useful Life (RUL) predictions.
- Already used by major players (e.g., Airbus, Rolls-Royce) to reduce maintenance costs and disruptions.
- Academic and industrial research has focused heavily on system architectures and algorithms.
- But: most approaches underrepresent the human role in predictive maintenance workflows.



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THE HTI CONCEPT

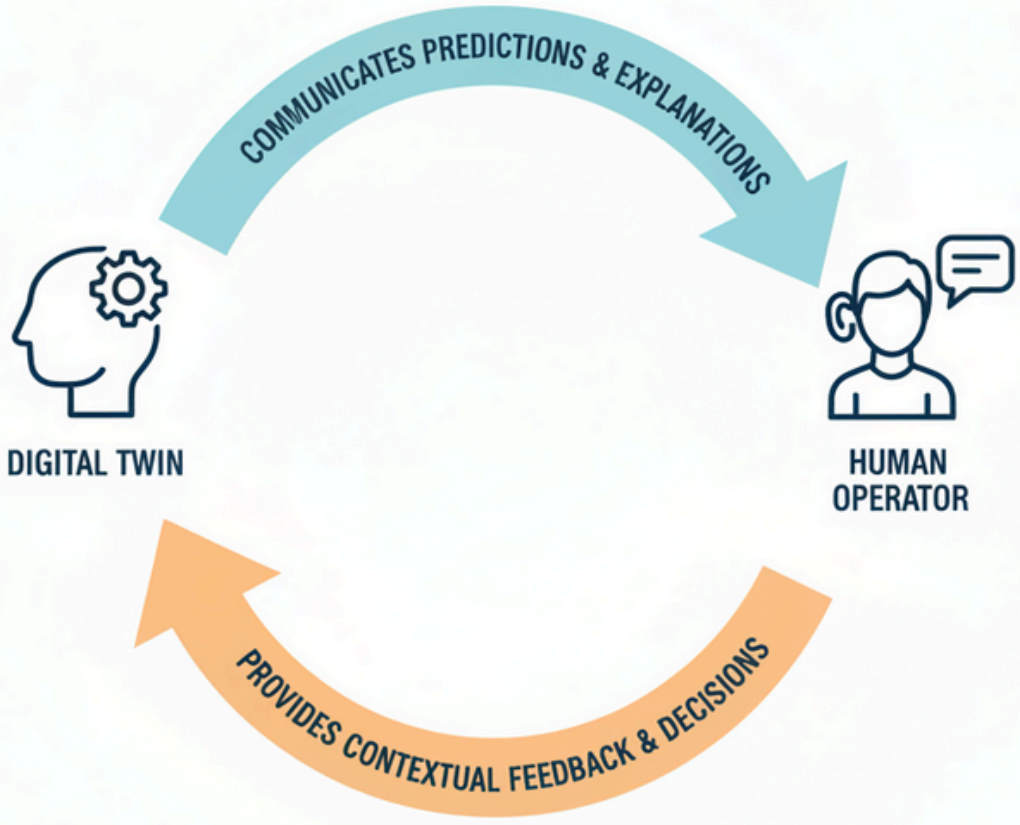
HTI focuses on the human–technology interface in predictive maintenance.

Bidirectional interaction:

- DT communicates predictions and explanations.
- Operators provide contextual feedback and decisions.

Benefits:

- Improved situational awareness
- Higher trust in predictive outputs
- Enhanced decision-making confidence



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WHY IT MATTERS

HTI bridges technical predictive maintenance tools with operator expertise.

Builds trust, usability, and adoption in real-world MRO settings. Benefits include:

- Reduced downtime through proactive interventions
- Increased safety via early fault detection
- Cost efficiency by optimizing spare parts and schedules.

Scalable for both large airline fleets and regional MROs.

A conceptual direction that sets the stage for future applied research and development

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HOW HTI HELPS MRO TEAMS

Explainability:

- Shows why predictions were made (key parameters, confidence levels).
- Links outputs to standard MRO procedures.

Visualization:

- 3D models with health overlays.
- Heatmaps of stress/wear.
- Trend charts for RUL and component degradation.

Conversational Interaction:

- Natural language queries: “What caused this fault?”
- “What-if” scenarios: simulate different maintenance actions.
- Engineers log observations back into the twin.

Adaptability:

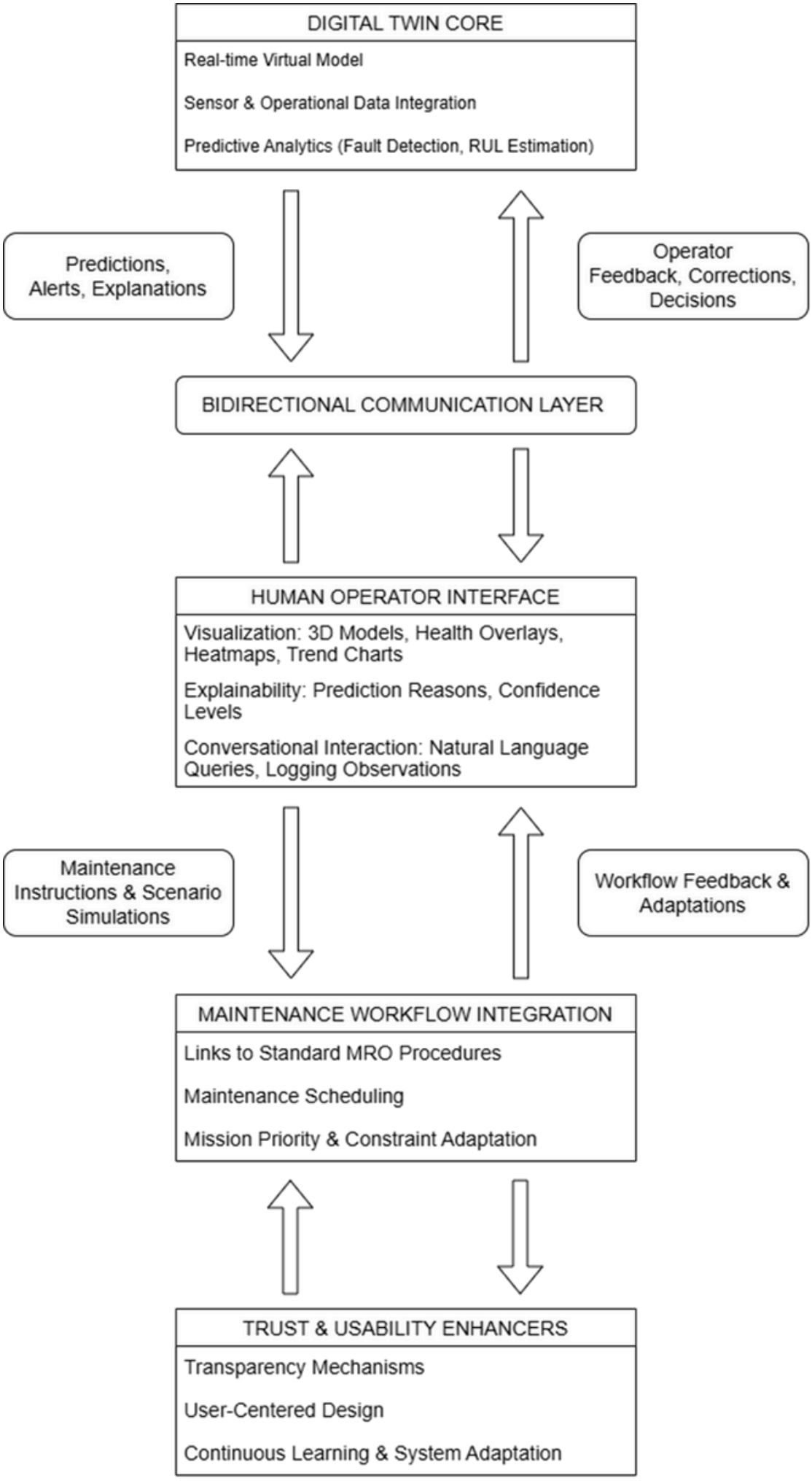
- Learns from operator corrections.
- Adjusts thresholds based on real-world reliability.
- Tailors recommendations to mission priorities and constraints.

CONCEPTUAL HTI FRAMEWORK

The framework highlights a collaborative, adaptive relationship where human expertise and digital insights combine to:

- Optimize maintenance processes
- Reduce downtime
- Enhance safety

The figure illustrates the data cycle — from sensors to the Digital Twin, to operator interaction, and back as feedback for refinement.


DIGITAL TWIN CORE
Real-time Virtual Model
Sensor & Operational Data Integration
Predictive Analytics (Fault Detection, RUL Estimation)
Predictions, Alerts, Explanations
Operator Feedback, Corrections, Decisions
BIDIRECTIONAL COMMUNICATION LAYER
HUMAN OPERATOR INTERFACE
Visualization: 3D Models, Health Overlays, Heatmaps, Trend Charts
Explainability: Prediction Reasons, Confidence Levels
Conversational Interaction: Natural Language Queries, Logging Observations
Maintenance Instructions & Scenario Simulations
Workflow Feedback & Adaptations
MAINTENANCE WORKFLOW INTEGRATION
Links to Standard MRO Procedures
Maintenance Scheduling
Mission Priority & Constraint Adaptation
TRUST & USABILITY ENHANCERS
Transparency Mechanisms
User-Centered Design
Continuous Learning & System Adaptation

INSIDE THE HTI FRAMEWORK

- Digital Twin Core – Models the aircraft system in real time, generating predictions and alerts.
- Bidirectional Communication Layer – Enables feedback between the twin and operator for contextual decisions.
- Human Operator Interface – Provides visualization, explainability, and conversational interaction to aid understanding.
- Maintenance Workflow Integration – Links outputs to MRO processes, scheduling, and operational priorities.
- Trust & Usability Enhancers – Ensure transparency, intuitiveness, and adaptive learning from user interactions.