Advanced Technologies

Artificial Intelligence(AI)/Machine Learning (ML)
in
Pharmaceutical Manufacturing

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The PIC/S GMP Guide Annex 22 referenced in this presentation is currently in draft form. The views and opinions expressed are those of the speaker alone and do not necessarily reflect the views, advice, or official guidance of Health Sciences Authority.

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Introduction – Overview of Artificial Intelligence in Pharmaceutical Manufacturing

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Artificial intelligence (AI) has transformed many industries and is increasingly being adopted in pharmaceutical manufacturing to improve **efficiency, product quality, process reliability.**

Quality Control:
Utilizing advanced image recognition to detect and preempt deviations in real time.

Quality Assurance:
Recognizing deviation patterns to identify root causes and apply effective Corrective and Preventive Actions (CAPAs).

Process Monitoring:
Early identification of potential issues to reduce downtime, alongside predictive performance monitoring on Critical Quality Attributes (CQA) and Critical Process Parameters (CPP).

Predictive Maintenance:
Early anomaly detection in equipment performance to optimize yield and output reliability.

✓ **We need a structured framework to govern the use of AI in Pharmaceutical Manufacturing**

Introduction to the Draft Annex 22 of the PIC/S GMP Guide

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Establish a new GMP guideline on Artificial Intelligence in Pharmaceutical Manufacturing

1 **Annex 22: Artificial Intelligence**

2 **Reasons for changes:** Not applicable (new annex).

3 **Document map**

1. Scope
2. Principles
3. Intended Use
4. Acceptance Criteria
5. Test Data
6. Test Data Independency
7. Test Execution
8. Explainability
9. Confidence
10. Operation

Glossary

- The draft was published in July 2025
- Public consultation closed on: 7 Oct 2025
- Being revised based on industry feedback
- **Final version still in development**

Introduction to the Draft Annex 22 of the PIC/S GMP Guide

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Annex 22 – Artificial Intelligence in Pharmaceutical Manufacturing

First AI-Specific GMP Framework	Focuses on AI systems in **critical applications** affecting **product quality, data integrity**, and **patient safety**
Restricted Scope	Applies to **Static, Deterministic Artificial Intelligence (AI) / Machine Learning (ML) Models**
Complementary to Annex 11	Designed to **complement**, not replace, **Annex 11** (Computerised Systems) of the PIC/S GMP Guide
Full GMP Lifecycle Controls	Requires adherence to **validation, change management, documentation, traceability**, and **ongoing monitoring**
Regulatory Compliance	Ensures **reproducible, explainable**, and **traceable** decision-making

Scope of the Draft Annex 22

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What Annex 22 Really Controls?

Does the AI influence a GMP decision or directly affect product quality, patient safety, or data integrity?

Yes (Critical AI Application)

- Automated Visual Inspection (sterility)
- Real-Time Release Testing
- In-Process Control of Critical Parameters
- Automated quality decisions & deviation classification
- Predictive maintenance for equipment

No (Non-Critical AI Application)

- SOP drafting and training content
- Historical analysis and knowledge management

Scope of the Draft Annex 22

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Understanding the Restrictions in Annex 22

Permitted : Static Models Only
Mechanism : Models do not adapt their performance based on new data during use

Restricted : Dynamic Continuous Learning
The rationale : Continuous learning introduces the risk of parameter drift triggered by abnormal or contaminated data (e.g., automatically adjusting sterilisation temperatures erroneously), leading to highly unstable production outcomes

Permitted : Deterministic Models Only
Mechanism : Models must produce the same output every time when given identical inputs

Restricted : Probabilistic Models
The rationale : Probabilistic models introduce unacceptable uncertainty. Deterministic predictability is fundamentally essential for GMP reproducibility and maintaining consistent, stable processes

Content of the Draft Annex 22

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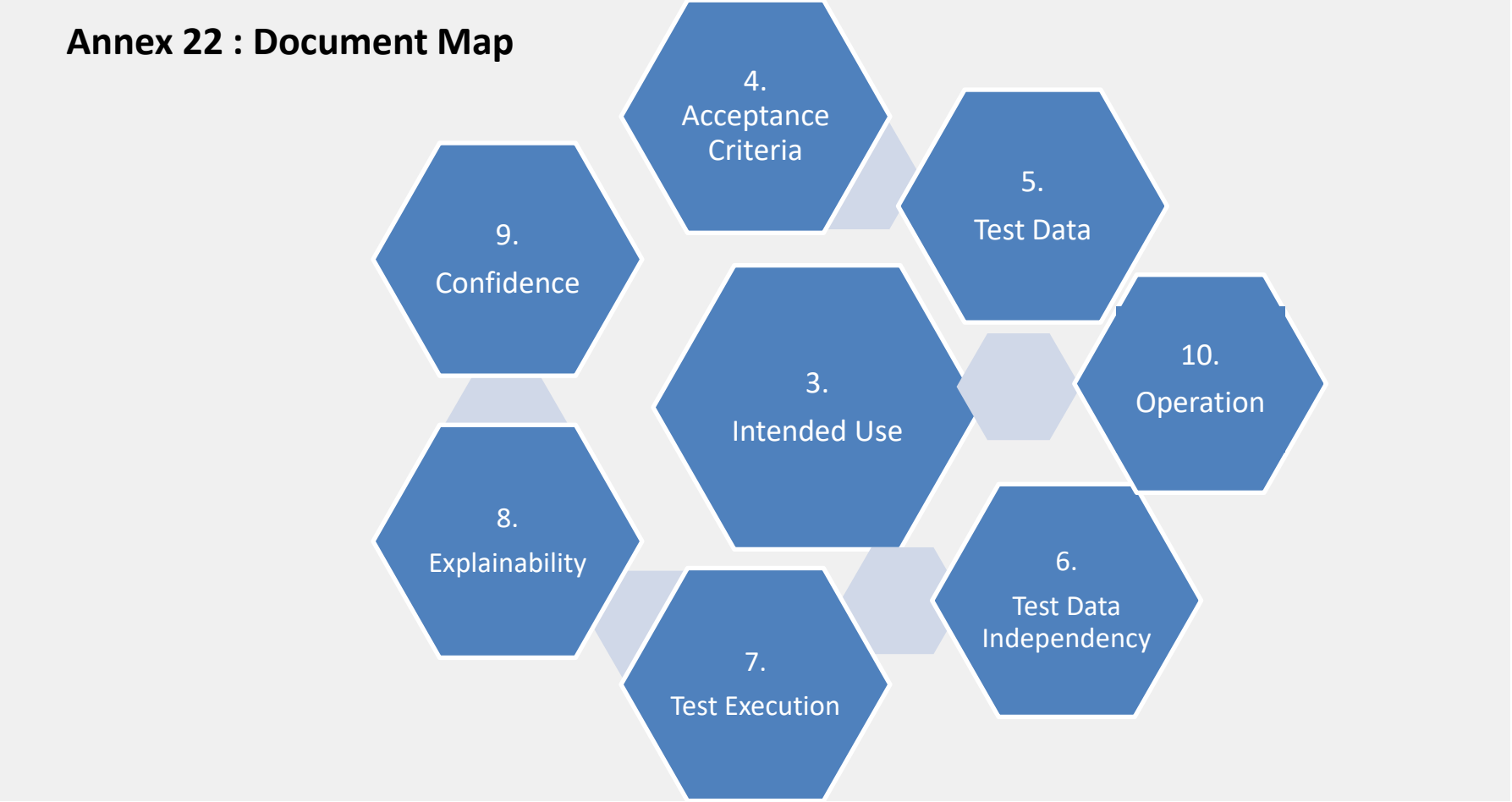
The AI/ML Lifecycle for GMP-Critical Systems

Treats AI like any other GMP system—**designed, tested, validated, and controlled across its entire lifecycle**.



Content of the Draft Annex 22

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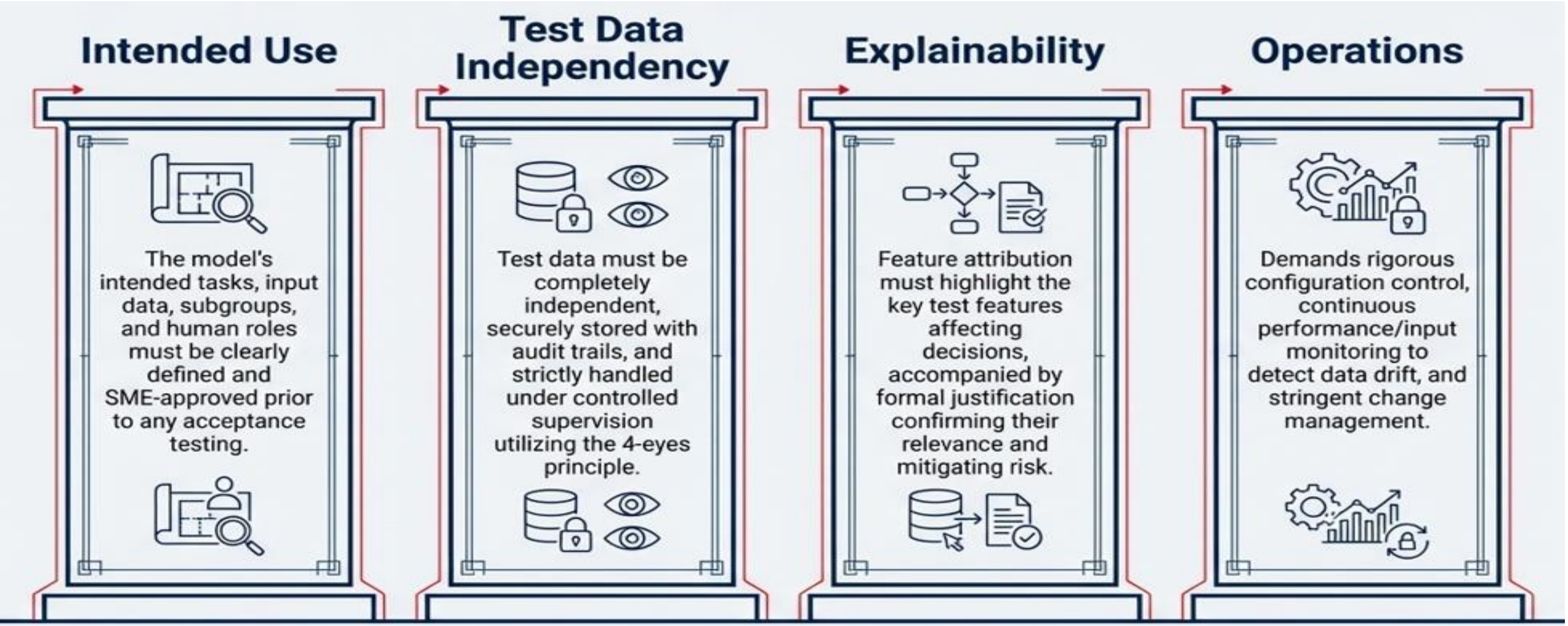
The 4 pillars in Annex 22



Key GMP Principles under Draft Annex 22

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Integrating AI/ML under GMP Controls

PIC/S GMP Guide — Chapter 1: Pharmaceutical Quality System

Change Management

- Formal change control for all *AI/ML modifications*
- Impact assessment *before implementation*
- Changes *documented, approved, and justified*
- Re-validation for GMP impact

Quality Risk Management

- Patient safety, Product quality, Data integrity
- Risk-based AI decisions
- Aligned with ICH Q9 (R1)

Performance Monitoring

- Monitor validated metrics
- Detect performance drift
- Escalate to QA if needed

AI/ML systems are managed within the Pharmaceutical Quality System using risk-based control and continuous oversight

Key GMP Principles under Draft Annex 22

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Integrating AI/ML under GMP Controls

PIC/S GMP Guide – Chapter 2: Personnel

Multidisciplinary Governance

- Cross-functional collaboration *is mandatory*
- (SMEs, QA, IT, Data Science)
- Clear *roles, responsibilities, and qualifications* for every contributor

Competency & Qualification

- Trained & qualified personnel
- GMP-aligned *responsibilities*

AI/ML systems under GMP require qualified people, clear roles, and effective cross-functional collaboration

Key GMP Principles under Draft Annex 22

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Integrating AI/ML under GMP Controls

PIC/S GMP Guide – Chapter 4: Documentation & Annex 11

Configuration Management

- Version control of models
- Control of training scripts

Data Integrity

- Audit trails & data checks
- ALCOA principles enforced

Access & Accountability

- Role-based access control
- Defined responsibility

Documentation & Traceability

- Complete lifecycle records
- Full validation & audit trails

AI/ML systems require complete documentation, controlled access, and full lifecycle traceability under GMP

Conclusion

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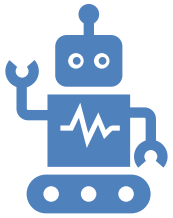
Annex 22 - The Blueprint for Controlled Innovation in Pharmaceutical Manufacturing



Clear Regulatory Framework

Provides the industry with a highly structured, predictable approach for the development, validation, and lifecycle management of AI system.

Enabling Responsible AI

Acts as an enabler - encourage pharmaceutical manufacturing toward responsible, documented, and controlled adoption

Compliance-integrated Innovation

Embedding these compliance boundaries early in the innovation strategy builds resilient, auditable, and trusted platforms that meet regulatory expectations and ensure alignment across the industry

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