



# ICAO

*International Civil Aviation Organization*

**SEVENTH MEETING OF THE ASIA/PACIFIC AIR  
TRAFFIC MANAGEMENT AUTOMATION SYSTEM  
TASK FORCE (ATMAS TF/7)**

*Bangkok, Thailand 2-4 June 2026*

**Agenda Item 4:** ATM Automation System Implementation Experience by States

4.4 Life cycle management

**SMARTISED MAINTENANCE IN LARGE-SCALE AIR TRAFFIC MANAGEMENT  
AUTOMATION SYSTEM**

(Presented by China)

**SUMMARY**

This paper introduces some data-driven and AI-assisted methods in system maintenance, and emphasizes the advantages of smartised maintenance, compared to traditional ways. Traditional maintenance is time and human-resource costing when dealing with large-scale Air Traffic Management Automation Systems, in the background of continuously-growing air-traffic flow and the increasing system complexity. Experience from CAAC is shared, aiming to provide some viable technology and management ways which can be utilized by other Asian-Pacific partners.

**1. INTRODUCTION**

1.1 Manual inspection and experience from maintenance personnel is the fundamental of traditional system maintenance. When dealing with large-scale and complex-structure Air Traffic Management (ATM) Automation System, its performance is low-efficient, warning-delayed, time-consuming and sometimes relatively risky. Taking an example of a system in Anhui Traffic Management Bureau of CAAC, traditional manual inspection is implemented every two hours; complex trouble-shooting takes one or two hours; and highly-repeated operation needs to be done by technicians. All may lead to mistakes or failure in operation. To solve those, smartised maintenance is utilized, bringing in improvement in four aspects, shown in Table 1.

Table 1 Improvement from Smartised Maintenance

	<b>Traditional Maintenance</b>	<b>Smartised Maintenance</b>	<b>Improvement</b>
<b>System Inspection</b>	Manual	Automatic or Manual	7x24 Automatic Inspection
<b>Fault Localization Capability</b>	Slow and Experience-driven	Precise and Data-driven	More Targeting
<b>Data Backup</b>	Manual	Automatic	Automatic Data Backup
<b>Early Warning</b>	No Early Warning	Early Warning Available	Data-driven Early Warning

1.2 In terms of safety management, smartised maintenance can massively reduce human error by automatic operation. So a management chain from warning, error-analysis, handling to review can be formed.

## 2. DISCUSSION

### Fundamental Principle and Technological Implementation of Smartised Maintenance

2.1 Given the growing complexity, traditional maintenance, relying on threshold alarms and manual inspections, is gradually non-sustainable. The smartised maintenance way, driven by operational data, promotes a shift from passive response to proactive prediction and precise management. The trend can bring in new innovation in maintenance.

#### *Fundamental Principle: Data-Driven Proactive Inspection and Prediction*

2.2 The fundamental principle of smartised maintenance lies in data and the key shift from passive failure-triggered mode to proactive prediction-triggered method. Its technical implementation relies on data flow and data-analysis mechanism. System performance-indicators, including network, process and time-synchronization status, are collected to a platform, via service network in ATM automation system. After being analyzed by algorithm or Artificial General Intelligence(AGI) models, the platform gives feedback, including maintenance recommendation and prediction on system status.

#### *Key Technological Application*

2.3 The smartised maintenance mode, is designed with the capacity of comprehensive system inspection, risk prediction, and tracing of failures. A chain is established, covering data collection, analysis, decision making and automatic implementation. The key techniques have been used are listed as follow:

2.4 **Indicator Prediction and Dynamic Baseline Generation Method Based on Time Series Learning:** this method collects and analyzes data from ATM automation system, such as CPU usage, memory consumption, disk I/O, and network traffic, and trains a time-series learning model with these data. By constructing a dynamic alert baseline, it enables prediction of system-indicator trends and early detection of abnormality. This method overcomes the limitation of traditional maintenance which is mainly alert-triggered and relies heavily on manual inspection, almost eliminates possibility of missed alerts, and provides a life-cycle chain from system-status monitoring, precise anomaly-diagnosis, to trend assessment.

2.5 **Smartised Maintenance Method Based on Log and Text Analyzing:** this method focuses on processing massive, unstructured log text data generated within ATM automation systems. The maintenance platform collects system logs, and transforms them into structured event-sequences. Patterns and possible links are analyzed by AGI models. After analysis, it can provide a comprehensive system status assessment and achieve rapid trouble-shooting if some faults happen.

2.6 Assisted by techniques on system indicators-monitoring and log-analysis, efficiency and accuracy in maintenance will be remarkably improved and Mean Time to Repair (MTTR) can be significantly reduced.

### Application in Large-scale ATM Automation System

2.7 Here takes the example from Anhui Air Traffic Management Bureau of CAAC, to illustrate functions of smartised maintenance platform, such as automatic inspection, automatic backup, early warning and fault-diagnosis.

*Comprehensive Visual Monitoring*

2.8 An integrated monitoring interface is configured, to achieve visual inspection of all system resources. Through the interface, thorough system-inspection time is reduced from the traditional 15 minutes to 1 minute, and device-indicators inspection coverage increases from 80% to 100%. Manual cost in maintenance is greatly reduced, solving the problem of missed inspections.

2.9 **System overview** provides real-time display of key indicators such as CPU load, memory usage , disk usage, and health status for all servers and clients. enabling indicator-ranking and trend predictions. Maintenance personnel can grasp the overall operational status of the system within 1 minute. Shown in Figure 1.

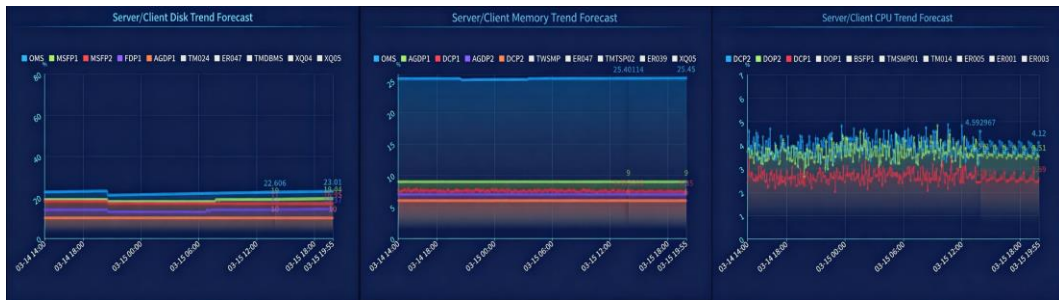


Figure 1 Overview of Disk, Memory and CPU

2.10 **Topology dynamic presentation**, which displays the real-time communication status of servers, network devices, and logical links through dynamic network topology diagrams. It supports visual switch from the topology diagram to device details, achieving control of the entire system's links, as shown in Figure 2.

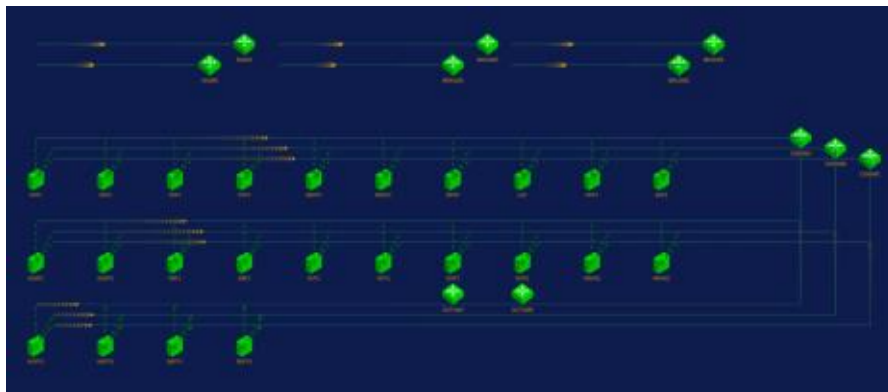


Figure 2 System Topology

2.11 **Device-asset management** includes all equipment assets such as servers, clients, switches, and firewalls, displaying associated device basic information, performance data, alarm status, and health scores to achieve refined and status-based equipment-asset management.

*Early Warning and Closed-loop Handling*

2.12 A full-life cycle early warning management chain is established (shown in Figure3), to implement proactive detection, message sending, and closed-loop event-handling. Based on system data collected already and real-time status, early warning is provided. All the operation of warnings, such as confirmation, suspension, clearance and export, is implemented on the platform. With records of warnings and operation, the smartised platform offers suggestions on maintenance priority and specific

time point for operation. With warning-triggering, recording, analysis, suggestion and review, a closed-loop mechanism is provided.

序号	产生时间	更新时间	预警主体	确认时间	预警内容	等级	是否确认	挂起
1	2025-05-13 07:54:09	2025-05-13 07:54:09	SDP1	2025-05-13 09:23:31	CETC_TEST模块内存使用率呈上升趋势, 请予以关注.	中	已确认	
2	2024-01-15 12:38:54	2024-01-15 12:38:54	TM051	2024-09-23 08:27:45	ACEC21上的CETC_POST模块的内存占用率呈增长趋势. 根据回归模型评估, 从2024-01-15 00:40:00到2024-01-15 12:25:00 占用率增长量占全系统内存的0.32%, 预计3小时后的增长量将占全系统内存的0.11%.		已确认	
3	2024-01-15 12:38:54	2024-01-15 12:38:54	TM051	2024-09-23 08:27:45	ACEC21上的CETC_SDD模块的内存占用率呈增长趋势. 根据回归模型评估, 从2024-01-15 00:40:00到2024-01-15 12:25:00 占用率增长量占全系统内存的0.16%, 预计3小时后的增长量将占全系统内存的0.05%.		已确认	
4	2024-01-15 12:38:54	2024-01-15 12:38:54	TM052	2024-09-23 08:27:45	ACPLC21上的CETC_SDD模块的内存占用率呈增长趋势. 根据回归模型评估, 从2024-01-15 00:40:00到2024-01-15 12:25:00 占用率增长量占全系统内存的0.15%, 预计3小时后的增长量将占全系统内存的0.05%.		已确认	
5	2024-01-15 12:38:54	2024-01-15 12:38:54	TM053	2024-09-23 08:27:45	ACEC22上的CETC_POST模块的内存占用率呈增长趋势. 根据回归模型评估, 从2024-01-15 00:40:00到2024-01-15 12:30:00 占用率增长量占全系统内存的0.28%, 预计3小时后的增长量将占全系统内存的0.09%.		已确认	
6	2024-01-15 12:38:54	2024-01-15 12:38:54	TM054	2024-09-23 08:27:45	ACPLC22上的CETC_POST模块的内存占用率呈增长趋势. 根据回归模型评估, 从2024-01-15 00:40:00到2024-01-15 12:30:00 占用率增长量占全系统内存的0.23%, 预计3小时后的增长量将占全系统内存的0.1%.		已确认	

Figure 3 Early Warning

Automatic Operation by Smartised Maintenance

2.13 The system streamlines, standardizes, and automates daily highly repetitive operation , including:

- **Automatic system inspection:** the platform implements automatic inspection, covering server status, client status, link connectivity, database status, and disk health. Traditional inspection takes normally about 10 minutes and scheduled once every two hours. Smartised inspection is almost instantaneous and can be planed or manual done if needed.
- **Automatic configuration backup:** the platform implements scheduled or manual backup for system configuration files within the system (shown in Figure 4). And all configuration files can be exported easily. Compared to traditional manual backup methods, normally costing several hours, automatic-operation time is reduced by 95%, and operation frequency is highly reduced.

Serial Number	Equipment Code	Device Name	IP	Device Type	Backup Completion Status
1	1010400000000	CCT000A	172.30.1.100	Switch	Backup success
2	1010400000000	Approach seat switch A1	172.30.1.118	Switch	Backup success
3	1010400000000	Tower seat switch A	172.30.1.124	Switch	Backup success
4	1010400000000	CCT000B	172.30.1.111	Switch	Backup success
5	1010400000000	Approach seat switch B1	172.30.1.119	Switch	Backup success
6	1010400000000	Tower seat switch B	172.30.1.125	Switch	Backup success
7	1010400000000	Zone control seat switch C1	172.30.1.114	Switch	Backup success
8	1010400000000	Approach seat switch C1	172.30.1.120	Switch	Backup success
9	1010400000000	Tower seat switch C	172.30.1.126	Switch	Backup success
10	1010400000000	Zone control seat switch A2	172.30.1.113	Switch	Backup success
11	1010400000000	Approach seat switch C2	172.30.1.122	Switch	Backup success
12	1010400000000	Zone control seat switch B2	172.30.1.116	Switch	Backup success
13	1010400000000	Approach seat switch A2	172.30.1.121	Switch	Backup success
14	1010400000000	Zone control seat switch C2	172.30.1.117	Switch	Backup success
15	1010400000000	Approach seat switch B2	172.30.1.123	Switch	Backup success

Figure 4 Automatic Backup

- **Standardized operations toolkit:** the maintenance toolkit includes built-in standardized scripts for software package backup, full-system clock synchronization, database error log inspection, ILO alert log export, etc. (shown in Figure 5). It supports manual or scheduled execution, with real-time feedback on execution results, reducing human error to zero.

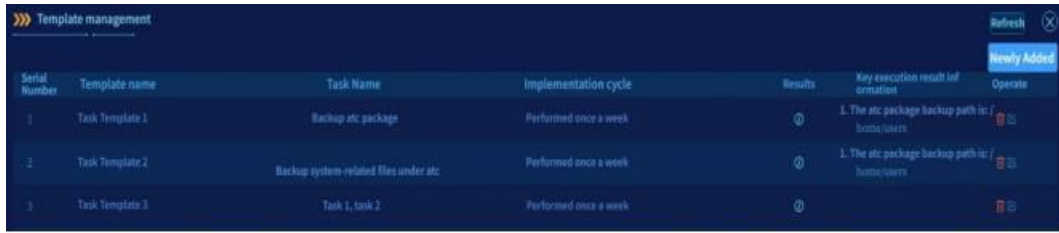


figure 5 Toolkit for Built-in Scripts

*Automatic Report Creation and Log Management*

2.14 With data collected, a system inspection report on system health (shown in Figure 6), can be automatically created. Specific combination of system components, time ranges and indicators can be applied. Paper work on reports normally takes quite long. Great efficiency is achieved.

2.15 The platform supports cross-device log management, allowing batch-export by time, host, keywords, and other criteria. Problem troubleshooting time is reduced from 60 minutes to within 20 minutes, with efficiency improved.

2.16 In terms of hardware maintenance, the platform can statistically analyzes the average disk service time, read/write rates, and anomaly points. After analysis, it identifies trends in storage hardware in advance, thus to provide a suggestion for preventive maintenance of hardware.

Serial Number	Machine Name	Machine Number	Equipment Operation	Software Operation	CPU Utilization (%)	Memory Usage (%)	Disk Utilization (%)	A-Browser Status	B-Browser Status	C-Browser Status
1	TS001	TS00101	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
2	TS002	TS00201	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
3	TS003	TS00301	Normal	Normal	2.22%	11%	11%	Normal	Normal	Normal
4	TS004	TS00401	Normal	Normal	2.15%	11%	11%	Normal	Normal	Normal
5	TS005	TS00501	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
6	TS006	TS00601	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
7	TS007	TS00701	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
8	TS008	TS00801	Normal	Normal	2.15%	11%	11%	Normal	Normal	Normal
9	TS009	TS00901	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
10	TS010	TS01001	Normal	Normal	2.14%	11%	11%	Normal	Normal	Normal
11	TS011	TS01101	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
12	TS012	TS01201	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
13	TS013	TS01301	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
14	TS014	TS01401	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
15	TS015	TS01501	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
16	TS016	TS01601	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
17	TS017	TS01701	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
18	TS018	TS01801	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
19	TS019	TS01901	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal
20	TS020	TS02001	Normal	Normal	2.12%	11%	11%	Normal	Normal	Normal

Figure 6 Inspection Report

Experience and Benefits of Smartised Maintenance

2.17 China's experimental practice in smartised maintenance of large-scale Air Traffic Management Automation Systems provides valuable experience for civil aviation authorities and air traffic service providers in the Asia-Pacific region.

*Standard-based Systematic Plan and Implementation*

2.18 The smartised maintenance system is not a mere box of isolated tools, but a systematic project that is planned in accordance with ATM Automation Systems, and must comply with security regulations and industry standards.

*Modular and Scalable Technology Architecture*

2.19 Air traffic in the Asia-Pacific region continues to grow, and the scale of Air Traffic Management Automation Systems is gradually expanding with increasingly complex functions. The

new generation of maintenance tools plays a positive role in maintenance. Despite differences in scales, manufacturers, and techniques among Air Traffic Management Automation Systems in different countries and regions, the strategy of platform plus customized functional modules can still be adopted to assist traditional maintenance.

*Focus on Data-driven Approach*

2.20 The key practice of smartised maintenance is to establish a data-driven strategy. When promoting the strategy, it is essential to guide maintenance teams to shift their focus from whether alarms are triggered to data trends and correlations. By smartised maintenance tools, data can be transformed into assets that support operations, continuously optimize maintenance procedures, and assist system planning and management.

*Maintenance Powered by AI*

2.21 In terms of log analysis, AI-powered tools can play an important role. In traditional mode, logs are analyzed by maintenance staff. The work is time- and energy- costing. If assisted by AI, it could be quick and precise. Most logs in ATM automation systems, have its own patterns and can be analyzed. AGI models, such as GPT-4, Gemini2.0 and DeepSeek-R1, has the capacity to boost our maintenance capacity.

**CONCLUSION**

2.22 Smartised maintenance is an innovative attempt to address the challenges of maintenance on complex systems. Based on industry standards and advanced technologies, China has made an attempt to build a platform integrating comprehensive system-monitoring, early warning, intelligent diagnosis, and automatic operation. Beyond transforming maintenance models from reactive to proactive and from experience-driven to data-driven, this platform continuously collects full-lifecycle operational data to support system lifecycle management, enabling data-driven decisions for system iteration, risk prediction, and performance optimization. This practice can enhance safety and efficiency of China's ATM automation systems, and also provide the Asia-Pacific region with proven, implementable technical solutions and management approaches.

2.23 Going forward, further experimental work on system maintenance will be carried out, with a focus on AGI applications and data utilization. New use cases will be explored for flight plan, weather, and surveillance data to improve operational efficiency and safety. AGI models will be deployed for log and operational data analysis, and the resulting data assets will continuously feed back into system lifecycle management, creating a closed loop of “operation, analysis, and optimization” .

**3. ACTION BY THE MEETING**

3.1 The meeting is invited to:

- a) note the information contained in this paper; and
- b) discuss any relevant matter as appropriate

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