

A SYSTEM FOR HANDLING A FAULT OF AN AIRCRAFT AND A METHOD
AND COMPUTER EQUIPMENT FOR ACHIEVING THE SAME

TECHNICAL FIELD

- 5 [1] The present application relates to a system for handling a fault of an aircraft and a method as well as computer equipment for achieving the same.

BACKGROUND

- 10 [2] Since aircraft maintenance cost is an influential actor in the operation of aviation companies, how to reduce the cost has become a cause of concern for all aircraft suppliers. Currently, the major solution focus on the control on routine checks, including minimizing the non-service time of aircrafts, maximizing the time period of aircraft use and the maintenance cycle of aircrafts parts, optimizing the human resources of maintenance personnel and their workload, as well as making full use of facilities and hangars. As to a sudden aircraft fault, there are as yet no better way to control the cost except
15 optimizing the maintenance personnel and their workload.

SUMMARY

- 20 [3] In response to one or more above-mentioned problems, the examples of the present application provide a system and a method for handling a fault of an aircraft.
- [4] According to one aspect of the present application, a system for handling a fault of an aircraft is provided, comprising:
- [5] An interface module for receiving a fault message of an aircraft; and
- 25 [6] A troubleshooting decision-making unit for making a troubleshooting decision against the aircraft faults, wherein the troubleshooting decision is made by the troubleshooting decision-making unit based on fault types and cost estimation.
- [7] In an example, the making of the troubleshooting decision by troubleshooting

decision-making unit based on fault types/safety risks and cost estimation comprises:

[8] Determining whether the fault is retainable or not;

5 [9] In response to that the fault is retainable, calculating the fault retention cost generated for continuing the flight with the fault retained until to a planned maintenance time and/or at a planned maintenance location for repair and calculating the field maintenance cost for said fault;

[10] Comparing the fault retention cost with the field maintenance cost;

10 [11] In response to that the fault retention cost is higher than the field maintenance cost, making a troubleshooting decision for field maintenance on said fault; and

[12] In response to that the fault retention cost is equal to or lower than the field maintenance cost, making a troubleshooting decision for fault retention to continue the flight.

15 [13] In an example, said troubleshooting decision-making unit calculates said field maintenance cost according to one or more of the following: cost of abnormal flight cost, the cost of the changes in other flights disrupted by the fault, the cost of providing the required aviation materials, the cost of urgent maintenance in other places, and the cost of work hour for the maintenance.

20 [14] In an example, said troubleshooting decision-making unit calculates said fault retention cost according to one or more of the following; a cost of the flight operating limitation caused by retaining said fault, and an abnormal flight cost and a fault maintenance cost caused by the non-retainable fault of fault-associated parts during the retention period.

25 [15] In an example, said troubleshooting decision-making unit determines the probability of occurrence for a non-retainable fault developed by the fault-associated parts during the retention period.

[16] In an example, said troubleshooting decision-making unit obtains the weight

value of abnormal flight cost and fault maintenance cost resulting from said non-retainable fault according to said probability of occurrence, calculating said fault retention cost.

5 [17] In an example, said troubleshooting decision-making unit calculates said fault retention cost according to the following formula:

[18] $C = P * (C_L + C_E + C_M) + (1 - P) * C_L,$

[19] Wherein:

[20] C indicates said fault retention cost;

10 [21] C_L indicates said cost of flight operating limitation caused by retaining said fault;

[22] P indicates said weight value obtained according to said probability of occurrence;

[23] C_E indicates the abnormal flight cost generated by said non-retainable fault;

15 [24] C_M indicates the fault maintenance cost generated by said non-retainable fault.

[25] In an example, said weight value is equal to said probability of occurrence.

[26] In an example, said troubleshooting decision-making unit obtains said probability of occurrence by analyzing the performance of said fault-associated parts or the failure probability distribution of said fault-associated parts.

20 [27] In an example, the troubleshooting decision of retaining said fault to continue a flight comprises the planned time and/or planned location for repairing said fault.

25 [28] In an example, said troubleshooting decision-making unit identifies a work-hour period with lower utilization rate for maintenance personnel, and arrange said planned time in said work-hour period with lower utilization rate.

[29] In an example, the system for handling a fault of an aircraft also comprises

a fault diagnosis module communicably coupled with an interface module and configured to find the cause of the fault through diagnosis according to said fault message.

- 5 [30] In an example, the system for handling a fault of an aircraft further comprises a fault-handling solution generation unit to generate a fault-handling solution according to the result of fault diagnosis outputted by the fault diagnosis module, wherein said fault-handling solution comprises: a task, maintenance instruction and/or aviation materials and tools necessary to repair the fault.
- 10 [31] According to another aspect of the present application, a method for handling a fault of an aircraft is provided, comprising:
- [32] receiving an aircraft fault message through an interface module; and
- [33] generating a troubleshooting decision for the fault based on fault types and cost estimation.
- 15 [34] In an example, the generation of troubleshooting decision based on fault types and cost estimation comprises:
- [35] determining whether the fault is retainable or not;
- [36] In response to that the fault is retainable after identification, calculating the fault retention cost generated for continuing the flight with the fault retained
- 20 until to a planned maintenance time and/or at a planned maintenance location for repair and calculating the field maintenance cost for said fault;
- [37] Comparing the fault retention cost with the field maintenance cost;
- [38] In response to that the fault retention cost is higher than the field maintenance cost, making a troubleshooting decision for field maintenance on
- 25 said fault; and
- [39] In response to that the fault retention cost is equal to or lower than the field maintenance cost, making a troubleshooting decision for fault retention to

continue the flight.

[40] In an example, said field maintenance cost is calculated according to one or more of the following: cost of abnormal flights, cost of the changes in other flights disrupted by the fault, the cost of providing the required aviation materials, the cost of urgent maintenance in other places, and the cost of work hour for the maintenance.

[41] In an example, said fault retention cost is calculated according to one or more of the following: cost of the flight operating limitation as a result of retention of said fault, or the cost of an abnormal flight and the fault maintenance cost incurred by the non-retainable fault of fault-associated parts during a retention period.

[42] In an example, the method for handling a fault of an aircraft further comprises determining the probability of occurrence for a non-retainable fault developed by the fault-associated parts during the retention period.

[43] In an example, the weight value of abnormal flight cost and fault maintenance cost resulting from said non-retainable fault is obtained according to said probability of occurrence for calculating said fault retention cost.

[44] In an example, said fault retention cost is calculated according to the following formula:

[45] $C = P * (C_L + C_E + C_M) + (1 - P) * C_L$,

[46] Wherein:

[47] C indicates said fault retention cost;

[48] C_L indicates said cost of flight operating limitation caused by retaining said fault;

[49] P indicates said weight value obtained according to said probability of occurrence;

[50] C_E indicates the abnormal flight cost generated by said non-retainable fault;

- [51] C_M indicates the fault maintenance cost generated by said non-retainable fault.
- [52] In an example, said weight value is equal to said probability of occurrence.
- [53] In an example, said probability of occurrence is obtained by analyzing the performance of said fault-associated parts or the failure probability distribution of said fault-associated parts.
- [54] In an example, the troubleshooting decision of retaining said fault to continue a flight comprises the planned time and/or planned location for repairing said fault.
- [55] In an example, the method for handling a fault of an aircraft comprises determining a work-hour period with lower utilization rate for maintenance personnel, and arrange said planned time in said work-hour period with lower utilization rate.
- [56] In an example, the method for handling a fault of an aircraft further comprises finding the cause of the fault through diagnosis according to said fault message.
- [57] In an example, the method for handling a fault of an aircraft further comprises generating a fault-handling solution according to the result of fault diagnosis, wherein said fault-handling solution comprises: a task, maintenance instruction and/or aviation materials and tools necessary to repair the fault.
- [58] According to another aspect of the present application, a method for handling a fault of an aircraft is provided, comprising:
- [59] determining whether the fault can be retained or not;
- [60] In response to that the fault is retainable, calculating the fault retention cost generated for continuing the flight with the fault retained until to a planned maintenance time and/or at a planned maintenance location for repair and calculating the field maintenance cost for said fault;

[61] Comparing the fault retention cost with the field maintenance cost; and

[62] In response to that the fault retention cost is higher than the field maintenance cost, making a troubleshooting decision for field maintenance on said fault.

5 [63] According to another aspect of the present application, a method for handling a fault of an aircraft is provided, comprising:

[64] determining whether the fault is retainable or not;

[65] In response to that the fault is retainable, calculating the fault retention cost generated for continuing the flight with the fault retained until to a planned
10 maintenance time and/or at a planned maintenance location for repair and calculating the field maintenance cost for said fault;

[66] Comparing the fault retention cost with the field maintenance cost; and

[67] In response to that the fault retention cost is equal to or lower than the field maintenance cost, making a troubleshooting decision for fault retention to
15 continue the flight.

[68] In an example, said field maintenance cost is calculated according to one or more of the following: cost of an abnormal flight, the cost of changes in other flights disrupted by the fault, the cost of providing the required aviation materials, the cost of urgent maintenance in other places, and the cost of work
20 hour for the maintenance.

[69] In an example, said fault retention cost is calculated according to one or more of the following: a cost of flight operating limitation as a result of retention of said fault, and an abnormal flight cost and a fault maintenance cost caused by the non-retainable fault of fault-associated parts during the retention
25 period.

[70] In an example, the method for handling a fault of an aircraft further comprises determining the probability of occurrence for a non-retainable fault developed by the fault-associated parts during the retention period.

- [71] In an example, the weight value of abnormal flight cost and fault maintenance cost resulting from said non-retainable fault is obtained according to said probability of occurrence for calculating said fault retention cost.
- [72] In an example, said fault retention cost is calculated according to the following formula:
- [73] $C = P * (C_L + C_E + C_M) + (1 - P) * C_L$,
- [74] Wherein:
- [75] C indicates said fault retention cost;
- [76] C_L indicates said cost of flight operating limitation caused by retaining said fault;
- [77] P indicates said weight value obtained according to said probability of occurrence;
- [78] C_E indicates the abnormal flight cost generated by said non-retainable fault;
- [79] C_M indicates the fault maintenance cost generated by said non-retainable fault.
- [80] In an example, said weight value is equal to said probability of occurrence.
- [81] In an example, said probability of occurrence is obtained by analyzing the performance of said fault-associated parts or the failure probability distribution of said fault-associated parts.
- [82] In an example, the troubleshooting decision of retaining said fault to continue a flight comprises the planned time and/or planned location for repairing said fault.
- [83] In an example, the method for handling a fault of an aircraft comprises determining a work-hour period with lower utilization rate for maintenance personnel, and arrange said planned time in said work-hour period with lower utilization rate.

- [84] In an example, the method for handling a fault of an aircraft comprises finding the cause of the fault through diagnosis according to said fault message.
- [85] In an example, the method for handling a fault of an aircraft further comprises generating a fault-handling solution according to the result of fault diagnosis, wherein said fault-handling solution comprises: a task, maintenance instruction and/or aviation materials and tools necessary to repair the fault.
- [86] According to another aspect of the present application, computer equipment for handling a fault of an aircraft is provided, comprising:
- [87] A memory for storing instructions executable by a computer;
- [88] A processor for accessing said memory and executing said instructions executable by said computer stored in said memory; the execution of said instructions executable by said computer by said processor enables said computer equipment to perform said method for handling a fault of an aircraft.
- [89] According to another aspect of the present application, a system for handling a fault of an aircraft is provided, comprising:
- [90] A unit for determining whether the fault is retainable or not;
- [91] A unit, in response to that the fault is retainable, for calculating the fault retention cost generated for continuing the flight with the fault retained until to a planned maintenance time and/or at a planned maintenance location for repair and calculating the field maintenance cost for said fault;
- [92] A unit for comparing the fault retention cost with the field maintenance cost; and
- [93] A unit, in response to that the fault retention cost is higher than the field maintenance cost, for making a troubleshooting decision of field maintenance on said fault.
- [94] According to another aspect of the present application, a system for handling a fault of an aircraft is provided, comprising:

[95] A unit for determining whether the fault is retainable or not;

[96] A unit, in response to that the fault is retainable, for calculating the fault retention cost generated for continuing the flight with the fault retained until to a planned maintenance time and/or at a planned maintenance location for repair and calculating the field maintenance cost for said fault;

[97] A unit for comparing the fault retention cost with the field maintenance cost; and

[98] A unit for making a troubleshooting decision of fault retention to continue the flight in response to that the fault retention cost is equal to or lower than the field maintenance cost.

[99] The examples of the present application allow a cost control on the aircraft fault handling based on safety concerns. In other words, it lowers the operating cost of aircraft while ensuring its flight safety.

BRIEF DESCRIPTION OF THE DRAWINGS

[100] In these figures, unless otherwise specified, same reference sign indicates the same or similar part or component. The figures, through examples, generally illustrate, rather than limit, the examples of the present application. These figures may not be provided on a pro rata basis.

[101] Fig. 1 is a schematic diagram showing the composition of a module of the system for handling a fault of an aircraft according to one example of the present application.

[102] Fig. 2 is a flow diagram showing the method for handling a fault of an aircraft according to one example of the present application.

[103] Fig.3 is a composition diagram showing the network environment of the system for handling a fault of an aircraft according to one example of the present application.

DETAILED DESCRIPTION OF THE INVENTION

[104] In the following detailed description, only certain exemplary embodiments of the present invention have been shown and described, simply by way of illustration. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present invention. Accordingly, the drawings and description are to be regarded as illustrative in nature and not restrictive.

[105] Before a detailed description about typical examples, it should be noted that some exemplary examples are illustrated as an arrangement or a method as shown in the flow charts. Although the flow charts describe each operation in sequence, many operations may be implemented concurrently or simultaneously. In addition, the sequence for the implementation of each operation may be rearranged. Said arrangement may be ended when the operations complete, but it may include additional steps not present in the Figures. Such an arrangement may correspond to a method, a function, a regulation, a subroutine, a subprogram, etc.

[106] The methods discussed below (some are illustrated by flow chart) can be implemented by hardware, software, firmware, middleware, microcode, hardware description language or any combination thereof. When software, firmware, middleware or microcode is employed, the procedure code or code segment used to perform the necessary tasks can be stored in the readable medium (e.g. memory medium) in a machine or computer. One or more processors are able to perform necessary tasks.

[107] Fig. 1 is a schematic diagram showing the composition of a module of the system for handling a fault of an aircraft according to one example of the present application. Such modules can be achieved by operating one or more software programs in a computer/computer system, hardware/firmware parts and/or the combination thereof of a computer/computing equipment. The computer/computing equipment may comprise a local memory device and/or a remotely-accessible memory device connected to a network.

[108] As shown in Fig.1, the system 100 for handling a fault of an aircraft

comprises various interface modules(such as onboard data interface 103, fault report interface 104, WIFI/bluetooth interface 105 and software interface 102) and a decision-making module 101. The interface modules are used to receive or acquire fault-related data and/or messages. For example, the onboard data interface 103 of the system 100 for handling a fault of an aircraft requests or receives such onboard data as real-time fault, ACMS report, QAR and fault maintenance sheet through an aviation telecommunication network/mobile communication network 108, e.g. the system 100 for handling a fault of an aircraft can be directly or indirectly connected to the aviation telecommunication network/mobile communication network 108 through a Ethernet network interface, a WIFI interface and a mobile communication interface. As an interactive interface between the system 100 for handling a fault of an aircraft and the users, the fault report interface 104 can be applied by the users to input fault report or other fault messages to the system 100 for handling a fault of an aircraft. The fault report interface can be a mouse, a keyboard, a displayer or a combinations thereof. The WIFI/bluetooth interface 105 is the interface between the system 100 for handling a fault of an aircraft and various measuring tools/equipment, through which the system 100 sends a measuring request to the measuring tools/equipment and receives the measuring results therefrom. The software interface 102 is an interactive interface that links the system 100 for handling a fault of an aircraft with other software applications or software modules, for example, the system 100 for handling a fault of an aircraft can check the devices and tools required by the repair of the fault through the software interface 102 as well as receive other status messages sent by other related software systems. Also, system 100 may receive the fault maintenance sheets from other software systems through the software interface. The decision-making module 101 generates a troubleshooting decision based on fault types/safety risks and cost estimation. In an example, a field maintenance or fault retention decision is generated by the decision-making module 101 based on safety risks and cost estimation. In regard to the fault retention decision, a fault retention arrangement will be

implemented on the aircraft. Regarding the field maintenance decision, a field fault report is generated and/or a fault is recorded in the ELB for maintenance personnel's reference. In another example, the decision-making module 101 may calculate the cost of operating limitation or abnormal flight cost based on the supplementary decision-making information of software interface 102, e.g. the flight scheduling information, in the course of making a troubleshooting decision. The process conducted by the decision-making module 101 is elaborated in Fig. 2.

[109] As shown in Fig.1, the system 100 for handling a fault of an aircraft also comprises a fault diagnosis module 106, a solution generating module 107 for handling fault, an aircraft configuration database 109, a fault classification and statistical module 110 and a fault database 111. The fault diagnosis module 106 is communicably coupled with the interface module and configured to find the cause of the fault through a fault diagnosis according to said fault message. The aircraft configuration database 109 records the type, hardware configuration and set membership (the relationship between aircraft system and its components), functional position of hardware, limitation of interchangeability, aircraft performance and cabin layout of each aircraft. The fault database 111 keeps fault handling records, including fault feature of each fault (for example, one or more of fault description, fault code, text message, light message and indication message), steps for locating the fault, and identified cause of the fault. The fault classification and statistical module 110 classifies the fault handling records in the fault database to find out the possible fault causes for the same or similar faults and the probability of occurrence for each possible fault cause. In the course of fault diagnosis, the fault diagnosis module 106 acquires the fault message and the required fault-associated data from the interface module by interacting with users, test equipment or other software systems. The fault diagnosis module 106 can further search the aircraft configuration database 109 for acquiring the configuration data of the aircraft and based on which to find the fault statistical data corresponding to aircraft configuration and fault information from the fault classification and statistical

module 110, then finding the fault cause according to the fault statistical data. In an example, the fault diagnosis module 106 is configured as: in response to the fault indication from the fault data in the interface module and the aircraft configuration data from the aircraft configuration database, search one or more
5 fault causes corresponding to the obtained fault indication and aircraft configuration data by accessing the fault classification and statistical module 110, foster the steps for locating the fault corresponding to the potential fault cause according to the probability of occurrence relevant to each possible fault cause, and identify the fault cause. The probability of occurrence corresponding
10 to each possible fault cause is acquired by an analysis of a large number of statistical data. Such probability of occurrence may possess a defaulted or pre-estimated initial value and is updated on a real-time basis according to the resultant location of each fault.

[110] According to an example of the present application, the fault diagnosis
15 module 106 is configured to facilitate the implementation of fault location steps corresponding to each associated possible fault cause on the basis of a high-to-low probability of occurrence until the fault cause is located. For example, the fault diagnosis module 106 may be configured to identify the first possible fault cause with the highest probability of occurrence from one or more searched
20 possible fault causes and promote the implementation of fault location steps corresponding to the first possible fault cause. If the result shows that the fault is not caused by the first possible fault cause, the fault diagnosis module 106 maybe further configured to identify the fault cause with the second highest probability of occurrence from the remaining searched fault causes and
25 promote the implementation of fault location steps corresponding to the second possible fault cause. The procedures can be repeated until the real fault cause is found. In response to that the probability of occurrence of the plurality of possible fault causes is the same or non-existent (for example, the system is in an original state without using data), the fault diagnosis module 106 is
30 configured to promote the implementation of fault location steps corresponding to each of said possible fault causes randomly. According to another example,

the fault diagnosis module 106 can also be configured to provide one or more possible fault causes and their probabilities of occurrence for user altogether for selection and promote the implementation of fault location steps corresponding to the selected fault cause by users.

5 [111] In the examples described above, the implementation of fault location steps promoted by fault diagnosis module 106 may comprise the following: the fault diagnosis module 106 is configured to indicate the users to implement relevant fault location steps and send the feedback about the resultant fault location steps to the interface module 106 through the interface module, that is, if the
10 possible fault cause is the true fault cause. Alternatively, the fault diagnosis module 106 can further be configured to automatically complete the fault location steps through the exchange with the test center connected to the faulted device, and the implementation results of fault location steps are sent back to fault diagnosis module 106 through the interface module.

15 [112] According to another example, the fault diagnosis module 106 is also configured to indicate users to find the fault cause on their own if the implementation results of fault location steps show that all the possible fault causes included in the relevant fault location records are not true fault causes. In response to the fault causes found and input by the users themselves, the
20 fault diagnosis module 106 guides the users to input the identified fault cause and determines the fault location steps required by said fault causes.

[113] The fault location steps corresponding to possible fault causes in the examples above can either be acquired by the fault diagnosis module 106 through the fault classification and statistical module 110, or by the fault
25 diagnosis module 106 accessing other databases (such as FIM service database), or be input by the users.

[114] Now “BLEED TRIP OFF” is used as an example to illustrate the operation of fault diagnosis module 106. After receiving the fault indication of “BLEED TRIP OFF” through the interface module, the fault diagnosis module 106
30 acquires the following possible fault causes and their probability of occurrence

that corresponding to aircraft configuration data and fault indications from the fault classification and statistical module 110:

- | | | | |
|----|-------|--|-----|
| | [115] | Fault of precooler control valve | 10% |
| | [116] | Fault of precooler controlling valve sensor | 15% |
| 5 | [117] | Fault of 450 °F thermometer | 3% |
| | [118] | Fault of high-pressure bleed air regulator | 5% |
| | [119] | Fault of high-pressure bleed air valve | 8% |
| | [120] | Fault of bleed air regulator | 12% |
| | [121] | Fault of sense line | 7% |
| 10 | [122] | Fault of precooler sealing gasket | 6% |
| | [123] | Fault of precooler | 20% |
| | [124] | Fault of 490 °F overheating switch of Engine 1(Engine 2) | 14% |
- [125] It can be seen that the fault with the highest probability of occurrence corresponds to the possible cause of (9) Fault of precooler. In other words, the fault diagnosis module 106 determines the strategy to address the fault based on the searching results of fault location. For example, it can indicate users to execute the fault location steps corresponding to (9) Fault of precooler or provide the possible fault causes above on the basis of a high-to-low probability of occurrence to the users for selection.
- [126] After the fault cause is diagnosed by the fault diagnosis module 106, the fault cause, together with the required work task, equipment and relevant Minimum Equipment List, will be sent to the solution generating module 107 for handling fault. The solution generating module 107 for handling fault generates relevant fault handling solutions according to the information provided by the fault diagnosis module 106 and sends the fault causes and solutions to the decision-making module 101. The fault handling solutions comprise: the work task involved in the fault maintenance, maintenance

instructions and/or conditions of required aviation materials and tools. It is noted that the fault diagnosis module 106 and the solution generating module 107 for handling fault are not indispensable in the present invention. For example, the fault causes can also be input or sent to the decision-making module 101 after identified by users or other personnel or equipment. With respect to the work tasks involved in the fault maintenance, maintenance instructions and conditions of required aviation materials and tools, they also can be manually input or acquired by the decision-making module 101 from other equipment, modules, database or software applications. Although the example in Figure 1 shows that the system for handling a fault of an aircraft comprises a fault diagnosis module 106, a solution generating module 107 for handling fault, an aircraft configuration database 109, a fault classification and statistical module 110 and a fault database 111, it is understandable that one or more of the modules can also be applied in other equipment or systems.

[127] Fig. 2 is a flow diagram showing how the decision-making module 101 makes a decision.

[128] Step S201 determines whether a fault is retainable or not.

[129] In an example, the faults can be divided into retainable or non-retainable faults based on safety concerns. The retainable fault means that air safety will not be affected if the flight continues with this fault. Put differently, the retainable fault allows the aircraft to fly without handling the fault. If the fault is a non-retainable one, a field maintenance is required instead of keeping the fault while the flight is not allowed to continue. In an example, whether the fault is retainable may be determined according to MEL. In another example, a NO GO fault, a short-term fault or a long-term fault is also included into a retainable fault. For instance, Full Authority Digital Engine Control (FADEC) of Boeing 737-NG diagnoses such maintenance information as 150 and 750 flight hours limits, they are also regarded as short-term faults as they have to be handled within the time limit. As to the long-term fault, troubleshooting is allowed to be conducted in the next Check. In another example, any fault that

causes no safety risk can be deemed as a retainable fault. Once the fault cause is identified, a reference to Minimum Equipment List and/or other methods can be used to determine whether the fault is retainable. This step can be either performed by the decision-making module 101 or by the fault diagnosis module 5 106 or other modules which then send the result to the decision-making module 101. In another example, some faults can be identified directly whether they are retainable ones in light of their features instead of the fault causes. For example, if an alarm of “CABIN ALT AUTO L” is given by EICAS of Boeing 777, the relevant fault is determined as “Auto Cabin Pressure Control L/R” and 10 identified as a retainable fault according to 21-31-01 of MEL. Another example is that, according to the descriptions about Precooler Controlling Valve of the MEL for Boeing 737-800, if an alarm of “BLEED SYSTEM DISENGAGEMENT” is issued by the cockpit, the disengagement cause has to be ruled out if the description is used to support the retention of the fault. If the 15 fault belongs to the one that cannot be retained, it is identified as a non-retainable fault.

[130] In response to a non-retainable fault determined in step S201, step S202 follows, calculating the fault retention cost C_K generated for continuing the flight with the fault retained until to a planned maintenance time and/or at a 20 planned maintenance location for repair and calculating the field maintenance cost C_M for said fault.

[131] The field maintenance cost C_M is calculated by one or more of the following: cost of the abnormal flight cost incurred by fault maintenance, the cost of the changes in other flights disrupted by the fault, the cost of providing the required 25 aviation materials, the cost of urgent maintenance in other places, and the cost of work hour for the maintenance. The abnormal flight cost incurred by fault maintenance and the cost of the changes in other flights disrupted by the fault can be measured, for example, by the product of the delayed flight hours and the predetermined cost per hour. The cost of providing the required aviation 30 materials can be divided into material repairing cost and material renting cost

according to the conditions of the current aviation materials. The cost of urgent maintenance in other places refers to cost generated in the travel by maintenance personnel between different places, and the cost of work hour for the maintenance means the time consumed by the maintenance personnel in the field maintenance.

[132] The fault retention cost C_K is calculated based on one or more following factors: the flight operating limitation cost as a result of retention of said fault, the abnormal flight cost incurred by the non-retainable fault of fault-associated parts during the retention period, and the fault maintenance cost. The flight operating limitation cost refers to the loss caused by load reduction for safety considerations for an aircraft while the fault is retainable. Meanwhile, the flight operating limitation cost should be measured based on the configuration data of the aircraft, for instance, the same load reduction limitation that works for a large-configuration aircraft may become out of operation for small-configuration ones.

[133] During the fault retention period, if the fault-associated parts break down, a field maintenance may be implemented according to MEL as the fault may not be retained. The resultant field maintenance cost comprises the possible cost of work hour for the maintenance, the possible cost of providing the required aviation materials, and the possible cost of urgent maintenance in other places. The possibility here means the probability for associated parts to develop a fault within the fault retention period. The “associated parts” refers to the parts associated with the retainable faults, and the retainable faults will turn to be non-retainable ones if the associated parts also break down in the fault retention period. The identification of associated parts is based on MEL and/or historical data. For a retainable fault, MEL recites its associated parts and describes the conditions for a fault developed by associated parts turning into a non-retainable one. Besides MEL, historical data are also used to determine the associated parts with a retainable fault. MEL may not predict or find all associated parts. If a retainable fault turns into a non-retainable one as MEL

repeatedly finds a part in failure or having a fault, the fault can be determined as a part associated with the fault according to historical records. While calculating the fault retention cost C_K , the decision-making module determines the probability of occurrence for the fault-associated part to develop a non-retainable fault during the fault retention period. According to an example, the decision-making unit is able to obtain the probability of occurrence for a non-retainable fault through a performance analysis on the fault-associated part or an analysis on the failure probability distribution of the fault-associated part. For example, for the parts suitable for performance analysis, the decision-making module calculates the probability of occurrence of a fault according to the decline rate of main performance indexes. For the parts unsuitable for performance analysis, the decision-making module calculates the probability of occurrence of a fault according to the failure probability distribution during the fault retention period.

[134] The decision-making module can further obtain the weight value of abnormal flight cost and fault maintenance cost resulting from the non-retainable fault of associated parts for calculating the fault retention cost C_K . In an example, the decision-making module calculates the fault retention cost according to the following formula:

[135] $C_K = P * (C_L + C_{EP} + C_{MP}) + (1 - P) * C_L$,

[136] Wherein:

[137] C_K indicates said fault retention cost;

[138] C_L indicates said cost of flight operating limitation caused by retaining said fault;

[139] P indicates the weight value obtained according to the probability of occurrence; in one example, the weight value equals the probability of occurrence;

[140] C_{EP} indicates the abnormal flight cost generated by the non-retainable fault;

and

[141] C_{MP} indicates the fault maintenance cost generated by the non-retainable fault.

[142] Then compare the field maintenance cost C_M with the fault retention cost C_K
5 in step S203.

[143] If $C_K > C_M$, step S204 follows and the troubleshooting decision of field maintenance is made; and

[144] If $C_K \leq C_M$, step S205 follows and the troubleshooting decision of fault retention is made to continue the flight. The troubleshooting decision of fault
10 retention to continue the flight comprises the planned time and/or place for fault maintenance that are determined by the decision-making unit based on the principle of a minimum cost. For example, in determining the planned time, the decision module identifies a work-hour period with lower utilization rate for maintenance personnel so as to arrange the planned time within said period.

15 [145] In response to a non-retainable fault determined in step S201, step S204 follows to make a troubleshooting decision of field maintenance for the fault.

[146] Fig.3 is a composition diagram showing the network environment of the system for handling a fault of an aircraft according to one example of the
20 present application. The system for handling a fault of an aircraft in the examples of the present application can be applied in an individual computing device 101, or several computing devices 101 and 103 that are communicated with each other through network 104, or a server 102 and/or one or more computing devices 101 and 103 that are communicated with the server 102
25 through network 104. The one or more computing devices 101 and 103 or the server 102 of the system for handling a fault of an aircraft in the examples of the present application may comprise a memory for storing instructions executable by a computer, and a processor for accessing the memory and executing the instructions executable by the computer stored in said memory.

The execution of the instructions executable by said computer by said processor enables the computing devices 101 and 103 or the server 102 to perform said method for handling a fault of an aircraft.

5 [147] Computing devices 101 and 103 can be any suitable terminal devices, including but not limited to personal computer, laptop, desktop computer, tablet PC, personal digital assistant, server, and mobile, wherein the present invention can be realized either by operating said terminal device and/or computing device separated or by the interactive operation between said terminal device and/or computing device after accessing network and other
10 computers in the network, wherein the network of said terminal device/computing device includes but not limited to network, mobile communication network, WAN, MAN, LAN and VPN. The devices in the network include but not limited to a single network server, a network server group consisting of a plurality of network servers, or the cloud consisting of a
15 number of computers or network servers on the basis of cloud computing, wherein the cloud computing, as one of distributed computings, is a super virtual computer consisting of a group of loosely-coupled computer set.

[148] It should be noted that said terminal device, computing device, network device and network are only recited as examples. Other present or
20 future possible computing device or network, if applicable, should also be included under the protection scope of the present invention and cited herein as reference.

[149] It should be understood that the method, system and device disclosed in the examples of the present application can be achieved by other approaches.
25 The device examples as described above are only schematic, for example, the division of modules or units is only made only on the basis of logics. There are other possible divisions in the practical operation, for instance, a plurality of modules or components may be combined together or integrated into another system, some features may be neglected or not performed. The components
30 showed or described may be coupled or directly coupled or connected

communicably together through an indirect coupling or communicable connection among some interfaces, devices or modules. Such coupling can be made possible electronically, mechanically or in other form.

5 [150] In the description, the module or unit “is configured to” means that such modules or units take form of hardware (e.g. a processor and a memorizer) or software or firmware when the process unit of a processor performs software (application) or firmware instruction.

10 [151] The module or unit as a separate part described above can selectively be physically separate, so do the parts as a module or a unit display. That is, they can either be arranged in one place or in a plurality of network units. The goal of examples can be achieved by some of the units or all units according to practical requirements.

15 [152] In addition, each functional module or unit in the examples of the present invention can be integrated all in one processing module or unit, or used as one module or unit. In other cases, two or more modules or units can be integrated into one module or unit. Such integrated modules or units can be achieved by hardware or the functional module or unit of hardware, software, firmware or the combination thereof.

20 [153] A person skilled in the art can understand the present invention as follows: all or part of steps defined in the method examples of the present application can be realized by hardware with programmed-instruction. Such programs can be stored in a storage medium readable by a computer. The steps in the method examples above are performed in the implementation of such programs. The storage medium above comprises mobile storage device, read-
25 only memory, random access memory, disk, compact disc and other medium that stores program identifier.

[154] Alternatively, in case that the integrated units above take form of software functional module and are sold or used as separate products, they can also be stored in a storage medium readable by a computer. On this basis, the

contribution of the technical solution in the examples over the prior art substantially is a software product in a sense. The computer software product is stored in a storage medium, including some instructions to enable a computer (as a personal computer, server, or network device, etc.) to perform part of or
5 all the method in the examples. Said storage medium comprises mobile storage device, ROM, RAM, disk, compact disc and other medium that stores program code.

[155] The examples of the present application allow a cost control on the aircraft fault. Specifically, the present application ensures a safe flight while
10 minimizing the cost of fault maintenance, thereby lowering the cost of aircraft operations.

[156] The descriptions above only represent the specific examples of the present invention, but the protection scope is not limited here. Based on the disclosure above, any person skilled in the art is easily aware that a change or substitution
15 about the contents above will also fall into the protection scope of the present invention. Therefore, the protection scope thereof should be subject to the claims.

20

CLAIMS

We claim:

1. A system for handling a fault of an aircraft, comprising:
 - 5 an interface module configured to receive a fault message of the aircraft; and
 - a troubleshooting decision-making unit configured to make a troubleshooting decision against the fault, wherein said troubleshooting decision-making unit is configured to make the troubleshooting decision based on a type of the fault and a cost estimation.
- 10 2. The system for handling a fault of an aircraft according to Claim 1, wherein said troubleshooting decision-making unit is configured to make the troubleshooting decision based on a type of the fault and a cost estimation in the following way:
 - determining whether the fault is retainable or not;
 - 15 in response to that the fault is retainable, calculating a fault retention cost generated for continuing the flight with the fault retained until to a planned maintenance time and/or at a planned maintenance location for repair and calculating a field maintenance cost for said fault;
 - comparing the fault retention cost with the field maintenance cost;
 - 20 in response to that the fault retention cost is higher than the field maintenance cost, making a troubleshooting decision for making a field maintenance on said fault; and
 - in response to that the fault retention cost is equal to or lower than the field maintenance cost, making a troubleshooting decision for retaining the fault to

continue a flight.

3. The system for handling a fault of an aircraft according to Claim 2, wherein said troubleshooting decision-making unit is configured to:

calculate said field maintenance cost according to one or more of following items:

5 a cost of abnormal flight caused by the fault, a cost of change in other flights disrupted by the fault, a cost of providing required aviation materials, a cost of urgent maintenance in other places, and a cost of work hour for a maintenance; and/or.

calculate said fault retention cost according to one or more of following items: a

10 cost of flight operating limitation caused by retaining said fault, and an abnormal flight cost and a fault maintenance cost caused by a non-retainable fault of fault-associated parts during a retention period of said fault.

4. The system for handling a fault of an aircraft according to Claim 3, wherein said troubleshooting decision-making unit is configured to determine a probability
15 of occurrence for a non-retainable fault developed by fault-associated parts during a retention period of the fault; and obtain a weight value for the abnormal flight cost and the fault maintenance cost resulted from said non-retainable fault based on said probability of occurrence so as to calculate said fault retention cost;

preferably, said troubleshooting decision-making unit is configured to obtain said
20 probability of occurrence by analyzing a performance of said fault-associated parts or a failure probability distribution of said fault-associated parts.

5. The system for handling a fault of an aircraft according to Claim 4, wherein said troubleshooting decision-making unit is configured to calculate said fault retention cost according to:

25 $C = P * (C_L + C_E + C_M) + (1 - P) * C_L,$

Wherein:

C indicates said fault retention cost;

C_L indicates said cost of flight operating limitation caused by retaining said fault;

P indicates said weight value obtained based on said probability of occurrence;

5 C_E indicates the abnormal flight cost caused by said non-retainable fault;

C_M indicates the fault maintenance cost caused by said non-retainable fault;

preferably, said weight value is equal to said probability of occurrence.

6. The system for handling a fault of an aircraft according to Claim 2, wherein the troubleshooting decision for retaining said fault to continue a flight comprises
10 a planned time and/or a planned location for repairing said fault;

preferably, said troubleshooting decision-making unit is configured to identify a work-hour period with lower utilization rate for maintenance personnel, and arrange said planned time in said work-hour period with lower utilization rate.

7. The system for handling a fault of an aircraft according to any of Claims 1-
15 6, further comprising:

a fault diagnosis module communicatively coupled with an interface module and configured to make a fault diagnosis according to said fault message so as to find a cause of the fault;

a fault-handling solution generation unit configured to generate a fault-handling
20 solution according to result of the fault diagnosis outputted by the fault diagnosis module, wherein said fault-handling solution comprises: a task, maintenance instructions and/or aviation materials and tools necessary to repair the fault.

8. A method for handling a fault of an aircraft, comprising:

receiving a fault message of the aircraft through an interface module; and

generating a troubleshooting decision for the fault based on a type of the fault and a cost estimation.

9. The method for handling a fault of an aircraft according to Claim 8, wherein
5 generating a troubleshooting decision based on a type of the fault and a cost estimation comprises:

in response to that the fault is retainable, calculating a fault retention cost generated for continuing the flight with the fault retained until to a planned maintenance time and/or at a planned maintenance location for repair and calculating a field
10 maintenance cost for said fault;

comparing the fault retention cost with the field maintenance cost;

in response to that the fault retention cost is higher than the field maintenance cost, making a troubleshooting decision for making a field maintenance on said fault; and

15 in response to that the fault retention cost is equal to or lower than the field maintenance cost, making a troubleshooting decision for retaining the fault to continue a flight.

10. The method for handling a fault of an aircraft according to Claim 9, wherein said field maintenance cost is calculated according to one or more of following
20 items: a cost of abnormal flight caused by the fault, a cost of change in other flights disrupted by the fault, a cost of providing required aviation materials, a cost of urgent maintenance in other places, and a cost of work hour for a maintenance; and/or

said fault retention cost is calculated according to one or more of following items:
25 a cost of flight operating limitation caused by retaining said fault, and an abnormal

flight cost and a fault maintenance cost caused by a non-retainable fault of fault-associated parts during a retention period of said fault.

11. The method for handling a fault of an aircraft according to Claim 10, further comprising:

5 determining a probability of occurrence for a non-retainable fault developed by fault-associated parts during a retention period of the fault; and

obtaining a weight value for the abnormal flight cost and the fault maintenance cost resulted from said non-retainable fault based on said probability of occurrence so as to calculate said fault retention cost;

10 preferably, said probability of occurrence is obtained by analyzing a performance of said fault-associated parts or a failure probability distribution of said fault-associated parts.

12. The method for handling a fault of an aircraft according to Claim 11, wherein said fault retention cost is calculated according to:

15 $C = P * (C_L + C_E + C_M) + (1 - P) * C_L,$

Wherein:

C indicates said fault retention cost;

C_L indicates said cost of flight operating limitation caused by retaining said fault;

P indicates said weight value obtained based on said probability of occurrence;

20 C_E indicates the abnormal flight cost caused by said non-retainable fault;

C_M indicates the fault maintenance cost caused by said non-retainable fault;

preferably, said weight value is equal to said probability of occurrence.

13. The method for handling a fault of an aircraft according to Claim 9, wherein

the troubleshooting decision for retaining said fault to continue a flight comprises a planned time and/or a planned location for repairing said fault;

preferably, the method further comprising determining a work-hour period with a lower utilization rate for maintenance personnel, and arranging said planned time
5 in said work-hour period with lower utilization rate.

14. The method for handling a fault of an aircraft according to any of Claims 8-13, further comprising:

making a fault diagnosis according to said fault message so as to find a cause of the fault; and

10 generating a fault-handling solution according to result of the fault diagnosis outputted by the fault diagnosis module, wherein said fault-handling solution comprises: a task, maintenance instructions and/or aviation materials and tools necessary to repair the fault.

15. A method for handling a fault of an aircraft, comprising:

15 determining whether the fault is retainable or not;

in response to that the fault is retainable, calculating a fault retention cost generated for continuing the flight with the fault retained until to a planned maintenance time and/or at a planned maintenance location for repair and calculating a field maintenance cost for said fault;

20 comparing the fault retention cost with the field maintenance cost; and

in response to that the fault retention cost is higher than the field maintenance cost, making a troubleshooting decision for field maintenance on said fault.

16. The method for handling a fault of an aircraft according to Claim 15, further comprising:

in response to that the fault retention cost is equal to or lower than the field maintenance cost, making a troubleshooting decision for retaining the fault to continue a flight.

17. The method for handling a fault of an aircraft according to Claim 15 or 16,
5 wherein,

said field maintenance cost is calculated according to one or more of following items: a cost of abnormal flight caused by the fault, a cost of change in other flights disrupted by the fault, a cost of providing required aviation materials, a cost of urgent maintenance in other places, and a cost of work hour for a maintenance;
10 and/or

said fault retention cost is calculated according to one or more of the following: a cost of flight operating limitation caused by retaining said fault, and an abnormal flight cost and a fault maintenance cost caused by the non-retainable fault of fault-associated parts during the retention period.

15 18. The method for handling a fault of an aircraft according to Claim 17, further comprising:

determining a probability of occurrence for the non-retainable fault developed by the fault-associated parts during the retention period; and

obtaining a weight value for the abnormal flight cost and the fault maintenance cost
20 resulted from said non-retainable fault based on said probability of occurrence so as to calculate said fault retention cost.

19. The method for handling a fault of an aircraft according to Claim 18, wherein said fault retention cost is calculated according to:

$$C=P*(C_L+C_E+C_M) +(1-P)* C_L,$$

Wherein:

C indicates said fault retention cost;

C_L indicates said cost of flight operating limitation caused by retaining said fault;

P indicates said weight value obtained based on said probability of occurrence;

5 C_E indicates the abnormal flight cost caused by said non-retainable fault;

C_M indicates the fault maintenance cost caused by said non-retainable fault;

preferably, said weight value is equal to said probability of occurrence.

20. The method for handling a fault of an aircraft according to any of Claims 15-19, further comprising:

10 making a fault diagnosis according to said fault message so as to find a cause of the fault; and

generating a fault-handling solution according to a result of the fault diagnosis outputted by the fault diagnosis module, wherein said fault-handling solution comprises: a task, maintenance instructions and/or aviation materials and tools

15 necessary to repair the fault.