

ระบบฐานข้อมูลสำหรับการซ่อมบำรุงเครื่องยนต์อากาศยาน

Database System for Aircraft Engine Maintenance

โดย

นายชัยวัฒน์ คุณพาณิชย์นันต์

รหัส 43067288

อาจารย์ที่ปรึกษา

รศ.ดร.วิเชียร เปรมชัยสวัสดิ์

H002938

วัน เดือน ปี.....

เลขทะเบียน.....

02938

เลขเรียกหนังสือ.....

จพ. ๕ 4๖2 ร๘๔๕

"ห้องสมุดคณะเทคโนโลยีสารสนเทศ สอ.ศ."

รายงานนี้เป็นส่วนหนึ่งของวิชาโครงการศึกษานิเทศ

หลักสูตรวิทยาศาสตรมหาบัณฑิต สาขาวิชาเทคโนโลยีสารสนเทศ

ภาคเรียนที่ 2 ปีการศึกษา 2545

คณะเทคโนโลยีสารสนเทศ

สถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหารลาดกระบัง

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Title	Database System for Aircraft Engine Maintenance
Student	Mr.Chaiwat Kunpanichanan
Advisor	Assoc. Prof.Wichian Premchaiswadi
Level of Study	Master of Science in Information Technology
Major	Information Technology Management
Academic Year	2002

ABSTRACT

The current data collection of aircraft engine maintenance at Pratt & Whitney's Bangkok field office is done on MS-Excel spreadsheets which yield difficulties because of data redundancies and inconsistencies. This project aims to develop a database system with a graphic user interface that supports ad hoc queries, reports, and can simulate engine management in the real working environment. The database system will reduce data redundancies and make inconsistencies controllable in order to eliminate data anomalies and save time for the data collector's work.

ACKNOWLEDGEMENT

The success of this special study project would not become true without the academic and personal supports from my surrounding people. I would like to take this opportunity to thank Assoc.Prof. Wichian Premchaiswadi who is my advisor and who gives me the guidance to complete this project, and all teachers at FIT, KMITL for your lectures and shared experiences. Big thanks for my ITM8 classmates for the great friendship and supports.

I would like to thank Assoc.Prof.Panida Simaporn at Thammasat University for my English proficiency that is very useful for my study in this post-graduate program. Thanks to Ajarn Martin Pirechio, my guru at Thammasat University whose words always remind me that “I don’t care how much I know, but I care how much I don’t know.”

Million thanks for the tremendous supports from Mr.Peter H. Schenck who is my boss, my colleague and my teacher at Pratt & Whitney. You really teach me how a good boss is. It’s the lesson I cannot find in any schools.

I am thankful for my parents’ support. I am proud that I can go beyond your dreams. Thanks for my friends at Thai Airways for your confidence in me that I can make it.

Last but not at all least, I would like to thank Khun Siriporn Sakdee for your constant encouragement. In the shadow of my success, you are always standing there.

CONTENT

	Page
Abstract	I
Acknowledgement	II
Content	III
Chapter	
1. Background Information	1
1.1. Business Organization	1
1.2. Bangkok Field Office Work	2
1.3. Scope of This Study	3
2. Planning & Analysis	5
2.1. Duties of the Data Collector	5
2.2. As-is Systems and Difficulties	6
2.3. Solutions	7
2.4. Feasibility Analysis	7
2.5. Project Plan	8
3. To-be System Process Modeling	10
4. To-be System Data Modeling	29
4.1. Business Rules	29
4.2. Normalization	32
4.3. Data Dictionary	35
5. System Design	41
5.1. User Interface Design	41
5.2. System Programming	58
6. Testing & Implementation	60
6.1. Database Testing	60
6.2. Program Testing	60
6.3. System Testing	60
6.4. System Implementation	61
7. Summary	62
7.1. Benefits	62
7.2. Problem of the System Development	63
7.3. Future Improvements	63
Bibliography	64
Writer's Profile	65

Chapter 1

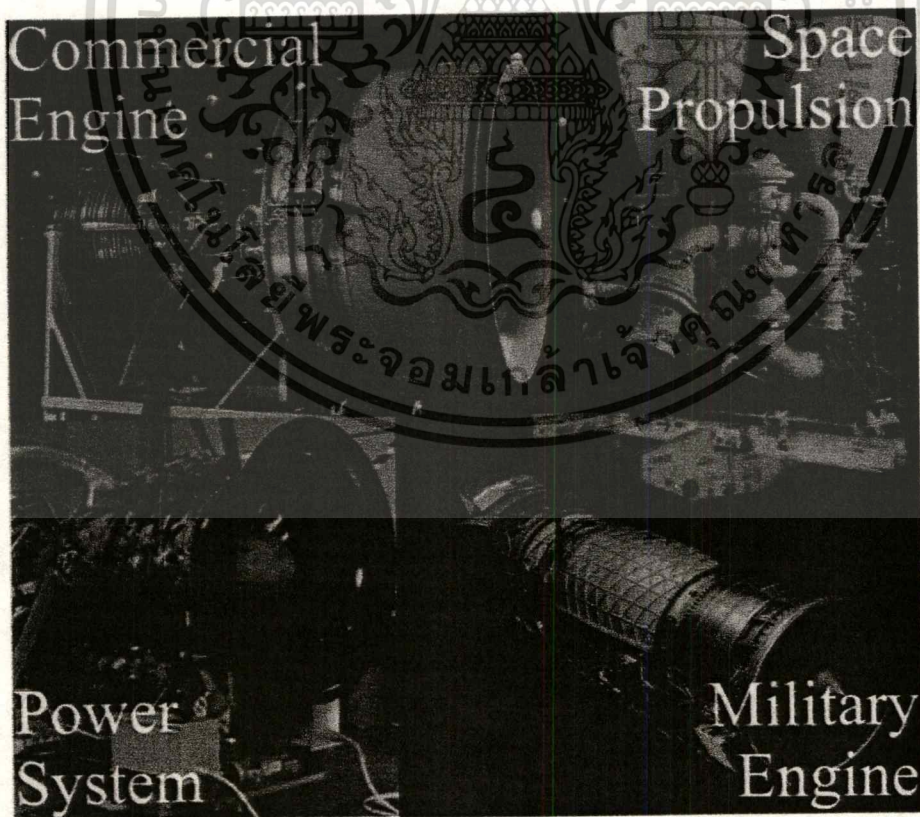
Background Information

Pratt & Whitney is a leading manufacturer of engines for commercial, military, and general aviation aircraft, space propulsion systems and power systems. Its headquarters is located at East Hartford, Connecticut, USA. In today's commercial aviation industry, Pratt & Whitney engines power more than half of the world's fleet. (Pratt & Whitney. 2002a)

Around 18,000 Pratt & Whitney commercial engines are operated by more than 600 airlines in more than 150 countries. All of these engines are supported by Pratt & Whitney's representatives in 76 cities of 47 countries worldwide. (Pratt & Whitney. 2002b)

1.1 Business Organization

Pratt & Whitney consists of 4 major business units that are commercial engines, military engines, space propulsion, and power systems. Each of these business units specializes in its respective cutting-edged technology of design and manufacturing of turbine engines.



Picture 1.1 -- Pratt & Whitney's business units

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Within the commercial engine business unit, which is the main focus of this study, there are several departments as detailed below.

Aftermarket Services	Commercial Engine Programs & Customer Services
Spare Parts	Marketing & Sales

Picture 1.2 -- Commercial engine business units

Customer Services is a department of commercial engine business unit. Its key function is to support airline customers for lowest operating and maintenance costs, highest reliability, and customer satisfaction. Customer services department has several divisions that work together to ensure that all customers' technical and non-technical requirements are fulfilled. Pratt & Whitney has field offices, located in 47 countries, that work closely with airliners to help solve their daily operational problems, provide technical information and publications, convey customers' requirements and inquiries to experts at East Hartford, collect engine utilization, maintenance and problems data, and report to concerning functions at East Hartford.

1.2 Bangkok Field Office Work

Pratt & Whitney's Bangkok field office covers seven airlines in three countries that are Thailand, the Philippines, and Bangladesh. The details of these fleets are described in the following table 1.1.

Table 1.1 -- Fleet Characteristics under Pratt & Whitney's Bangkok field office's coverage

Country	Airliners	A/C Model	No. of A/C	Engine Model	No. of Engine
Thailand	Thai Airways	A300-600	13	PW4158	20
				PW4158-3	11
		A330-300	12	PW4164	19
				PW4168	7
				PW4168A	2
	Royal Thai Air Force	A310	1	PW4152	3
	Orient Thai Airlines	B747-200	2	JT9D-7A	8
The Philippines	Phuket Air	B737-200	3	JT8D	6
	Cebu Pacific	DC9	11	JT8D-9A	24
	Air Philippines	B737-200	8	JT8D-7B	12
				JT8D-9A	7
Bangladesh	Biman Bangladesh	A310	2	PW4156A	5

Pratt & Whitney's Bangkok field office is run by three staffs that are the field office manager, the data collector, and the secretary. Main responsibilities of Bangkok field office are as follows:

- Communicate between airline customers and engineers at East Hartford for technical problems and solutions.
- Provide technical information and publications such as service bulletins that describe procedures of engine maintenance tasks to customers.
- Provide non-technical information such as spare parts inventory status, warranty claims, training classes, and other administrative assistance as requested by customers.
- Collect data of monthly aircraft and engine utilization, engine-related problems, fleet management plans, engine maintenance status, then report all information to headquarters for analysis and statistics.
- Coordinate with engine shops abroad for status of engines that are under repairs or overhauls to achieve shortest turn-around times of repairs and ensure that customers have sufficient serviceable spare engines to support their fleets.
- Convey other special requirements of customers to headquarters for agreements such as on-site training, and on-site experts to assist in maintenance works that are beyond customers' authorized capabilities.

1.3 Scope of This Study

The main objective of this study is the development of a database system that will work as a tool to help the data collector gather and manage information more easily and efficiently through the graphic user interface that simulates engine maintenance work in the real world. This database system as well supports ad hoc queries and composes reports as required by users.

ไม่ว่าการณ์ใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

This study focuses on the work of the data collector with Thai Airways because of the appropriate fleet size, the sufficient data resources and the acceptable standard of work processes.

The development process of this database system follows the system development life cycle, comprising four phases of planning, analysis, design, and implementation. (Dennis and Wixom. 2000: 4) However, only appropriate steps are applied as necessary.



Chapter 2

Planning & Analysis

The first part of this chapter explains general tasks of the data collector that will be covered by the new database system. Concerning tools and computerized systems as well as difficulties of the current working environment are discussed in order to make readers understand the as-is system.

Then the second will offer options for the problems. All solutions will be compared for their strengths and weaknesses. Feasibility analysis will guide for the most appropriate selection.

After the solution is selected, the last part of this chapter will discuss the development plan.

2.1 Duties of the Data Collector

General tasks of the data collector begin with creating records of new aircraft and/or engines once they are inducted into the fleet. He will record aircraft registration, aircraft type, date of induction, aircraft owner aircraft operator, and aircraft flight hours and landings, as known as flight cycles. Data elements of a new engine are similar to those of a new aircraft. That is, engine serial number (ESN), engine model, engine owner, engine operator, date of induction, and engine hours and cycles will be recorded. These flight hours and flight cycles are key indicators of aircraft and engine health and deterioration. Because engine flight hours and cycles are recorded at each time of engine incidents or overhauls, they also serve as milestones in calculation for engine flight hours and cycles at a given date.

When engines and aircraft records exist in the database, the data collector has to identify what engines are installed on what aircraft and what engines are not installed and managed as spare engines. He has to keep records of engine serial number, engine hours, engine cycles, aircraft registration, engine position on the aircraft, aircraft hours, aircraft cycles, and date of engine installation.

While an engine is installed on an aircraft, it might experience problems that lead to delayed or cancelled flights. These problems will be logged, like a health record of a patient, in order to be references for diagnosis of future problems. The engine serial number, engine hours, engine cycles together with date of problem occurrence, aircraft registration, flight number, origin station, destination station, details of the problem, troubleshooting action, total delay time, and flight cancellation data will be recorded.

An aircraft engine is like other mechanical equipment. It deteriorates over time and needs an overhaul to bring it back to normal condition. When an on-wing engine is utilized until it reaches a limited period, the engine will be removed from the aircraft and sent to an engine repair shop for refurbishment. Engine serial number, engine hours and cycles, date of engine removal, aircraft registration, engine position where it is removed from the aircraft, reason of removal, and the engine repair shop, where the repair or overhaul will take place, will be recorded. The dates when the

engine is shipped to the engine shop and when it is returned will as well be tracked in order to reflect engine shop's performance.

If an engine goes through a maintenance job no matter when the engine is installed on wing or removed as an off-wing or a spare engine, the maintenance work incorporation will be recorded. Normally, a maintenance task is created in form of a service bulletin (SB) or an Airworthiness Directive (AD). Therefore, the record of a maintenance task of an engine composes of engine serial number, SB or AD number, date of incorporation, and status of incorporation, that is either finished, partially complete, not yet incorporated, or not applicable.

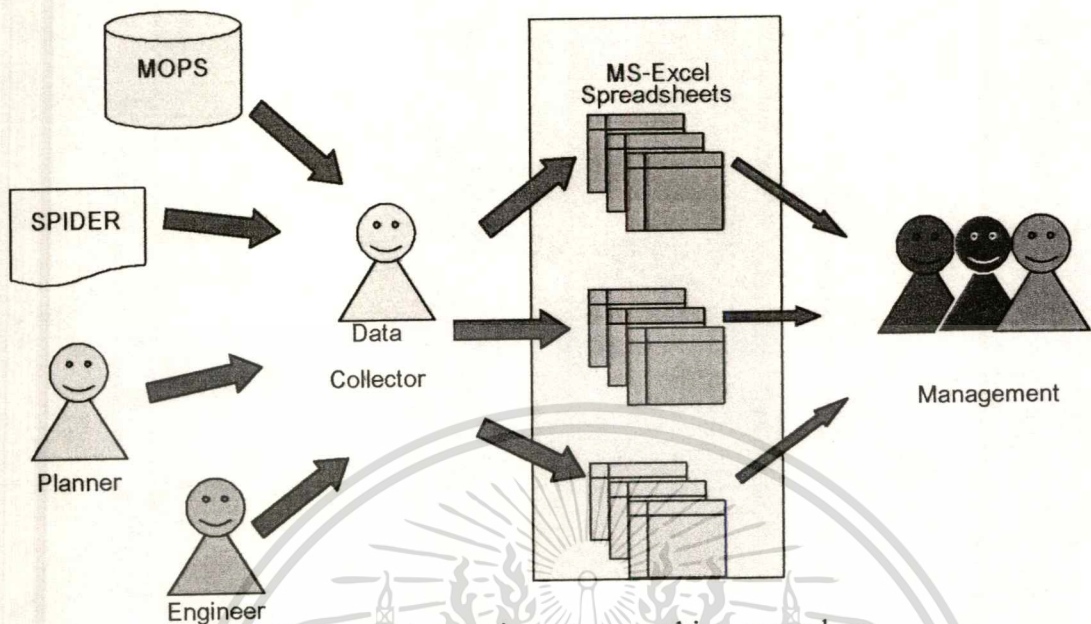
The data of maintenance tasks must be maintained as well. Periodically, new SBs and Ads are issued by Pratt & Whitney's technical publication department and the Federal Aviation Administration (FAA) respectively. Each SB/AD number, revision number, effectivity, and description are kept in the database.

Finally, when an engine or an aircraft is retired from the fleet, the data collector must update the status and termination date, together with the final hours and cycles of the engine or the aircraft. However, the records of terminated engines and aircraft will still be archived in the database for future references.

2.2 As-is Systems and Difficulties

Currently, most data collection is recorded in MS-Excel spreadsheets because of the ease of use and users' familiarity. However, many data elements are duplicated in several spreadsheets that yield data redundancies and inconsistencies when a single update is not made in all related spreadsheets. To maintain data consistencies in all spreadsheets, time consumption is not evitable.

Data redundancies do not occur only in spreadsheets, but in other information systems as well. In addition to spreadsheets, data is collected in Lotus Notes databases, MS-Access databases, and Thai Airways' database system, known as MOPS, which is the abbreviation for Maintenance & Overhaul Planning System. Periodically, the data collector has to gather pieces of information from concerning people, departments and MOPS. Then he has to update data in spreadsheets and databases before reporting the information to Pratt & Whitney's headquarters.



Picture 2.1 -- As-is system working procedure

2.3 Solutions

There are few solutions to manage data redundancies that are prone to errors. The first option is the continued use of spreadsheets. This will cause the least impact to most users, especially managements but the data collector must be very much cautious of any inconsistencies that may happen.

The second choice is a single application that can handle all aspects of a data collector's work as detailed above. This seems to be the best solution but the high cost of development may be a great disadvantage, especially if the application is created by an outsourcer.

The other way-out is the use of an MS-Access database that shares many features with MS-Excel spreadsheets. This can reduce the learning curves of the data collector and his management. MS-Access also supports linkages with other databases of different platforms. This will be very important when the data stored in Thai Airways' MOPS database is automatically reflected in the future. While Pratt & Whitney tends to promote uses of MS-Access databases, the ease of database usage can be boosted with well-designed graphic user interfaces.

2.4 Feasibility Analysis

The three proposed solutions can be compared in table 2.1 below.

Table 2.1 -- Comparison of the three solutions

Criteria	MS-Excel Spreadsheets	Single Application	MS-Access Database with GUI
Technical Feasibility			
- Level of developer (3)	End user **	Programmer	Power user *
- Time for development (1)	Short **	Long	Medium *
- Ad hoc queries (7)	None	Support **	Support **
- Future expansion for added features (6)	None	Hard *	Easy **
Economic Feasibility			
- Development costs (2)	Low **	High	Medium *
Organizational Feasibility			
- Managements' learning curve (4)	Low **	High	Low **
- Data collector's learning curve (5)	Low **	High	Medium *
Scores (number of *)	10	3	10

Considered with the metric above, MS-Excel spreadsheets and MS-Access database seem to be equally preferable. However, if all criteria are weighed from the most (7) to the least (1) importance, MS-Access database gains the highest score for this project because it supports ad hoc queries that can make the greatest benefits from existing stored data. Moreover, it also possesses ability for future expansion to cover more data filtering and possible use as a data warehouse for the future data mining and management information systems. While chances for future expansion to facilitate more complicated uses are feasible, the required learning curves of the two groups of users, that are the data collector and the managements, are not high because MS-Access shares several common features with other MS-Office applications that are well familiar to them. And if complex functions are required by the users, well designed and developed add-in applications that utilize and manage data in the database can help reduce the users' training periods.

2.5 Project Plan

Generally, a typical business application spends 15% of the overall development period in planning, 20% in analysis, 35% in design, and 30% in implementation phase. (Dennis and Wixom. 2002: 54) This special study project is expected to be complete within 4 months from November 2002 to February 2003. Therefore, the rough time estimation for each phase will be as shown in picture 2.1.

	November	December	January	February
Planning	2.5 Wks			
Analysis		3.2 Wks		
Design			5.6 Wks	
Implementation				4.7 Wks

Picture 2.1 -- Typical time estimation for a 4-month application development

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

However, because the database system is developed by the data collector who has worked and been familiar with the problems for more than 4 years, the time spent for planning and analysis phases can be reduced. The design phase as well can take a shorter time than standard estimation because the database design is already completed as the continual part from the seminar study. Then time that is saved in the first three phases will be sacrificed to the programming and the implementation phase that mainly relates to Visual Basic programming that is the least familiar to the developer. System testing and installation are expected to consume a couple of weeks because this database system will be run on the data collector’s computer only as the prototype before it is proposed to be implemented throughout the company in the future. The revised time estimation is shown in picture 2.2 below.



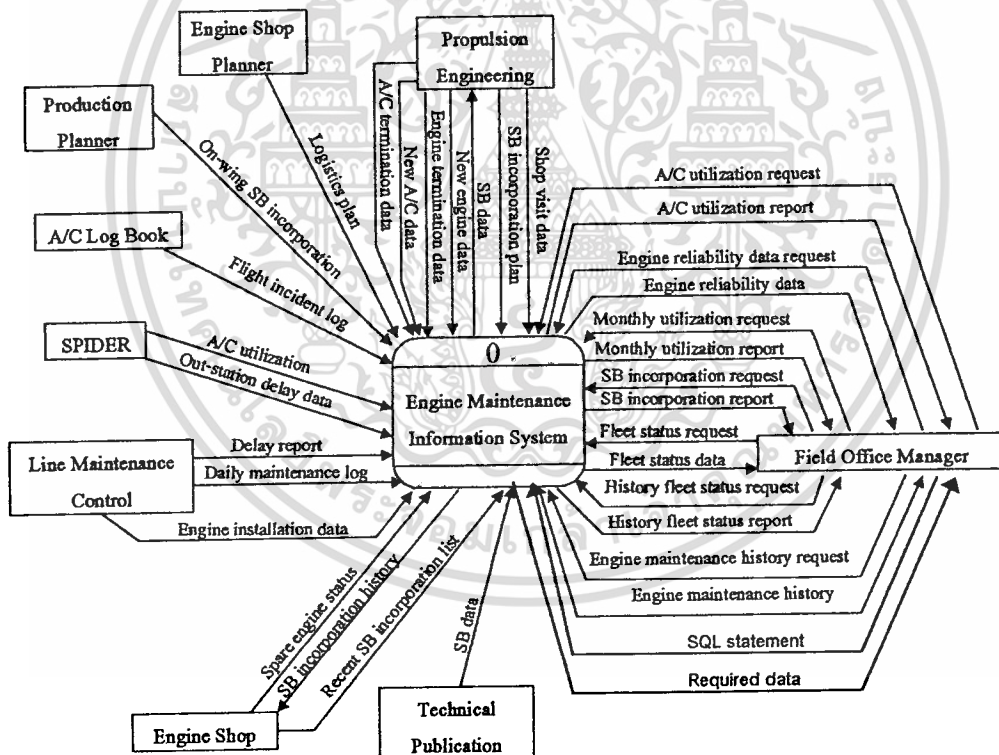
Picture 2.2 – Revised time estimation for Aircraft engine maintenance database

Chapter 3

To-be System Process Modeling

The new system based on MS-Access database works as a collection of data that used to scatter in several spreadsheets. It does not significantly change the process of the current work, Therefore, the development of the to-be system can be considered as a business process automation because it only improves efficiency of the work by centralizing data at a single source to reduce data redundancies while leaving other data collection processes, such as gathering data from concerning people, remain essentially unchanged even though it seems as a new tool. (Dennis and Wixom. 2000: 90)

The overall processes of the to-be system can be represented as process 0 in the context diagram below.



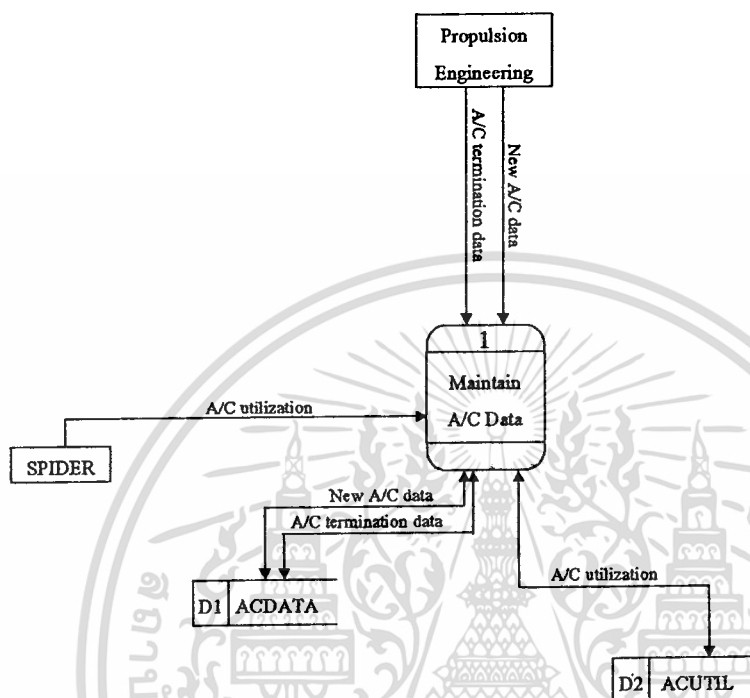
Picture 3.1 – Context diagram of aircraft engine maintenance database system

The system receives inputs from concerning functions that are propulsion engineering, engine technical planners, aircraft log books, air traffic control office -- as known as SPIDER, line maintenance control room, engine repair shops, engine shop planners, production planners, and Pratt & Whitney's Technical Publication. Then it processes inputs and generates reports as requested by the management.

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

From the context diagram above, the system, represented as process 0, is broken down into four groups of level 0 data flow diagrams.

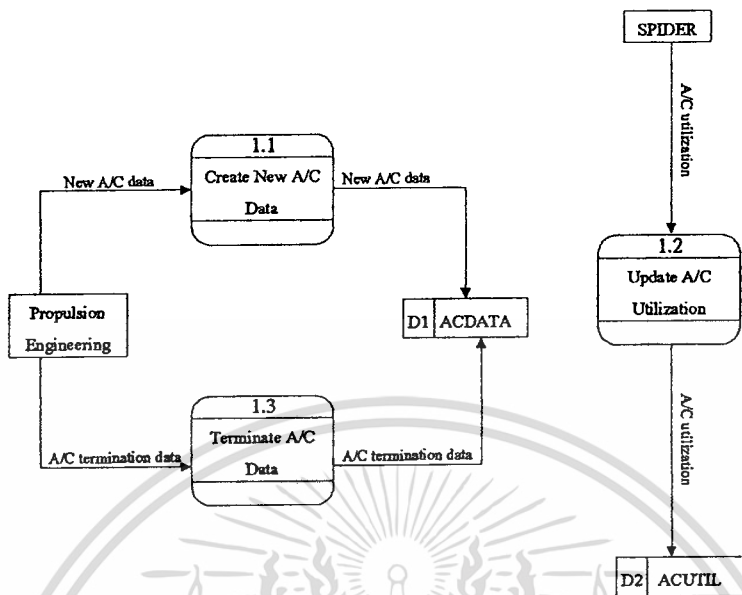
The first group contains process 1 that handles aircraft data.



Picture 3.2 – Process 1: Aircraft data

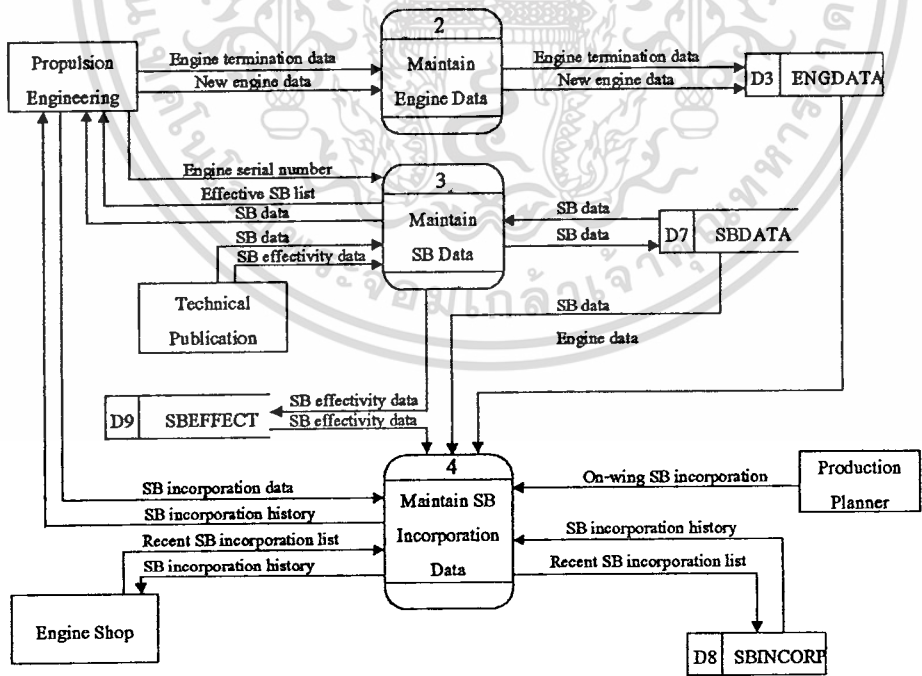
When a new aircraft is inducted into the fleet, the aircraft general information is provided by propulsion engineering. Then the data is recorded into the ACDATA data store. When an aircraft is flown each day, SPIDER will report its utilized flying hours (flight hours) and number of landings (flight cycles) to be appended to the ACUTIL data store. These utilization details will serve as the master file for calculation of an engine age.

Finally, if an aircraft is retired from the fleet, propulsion engineering once again will advise the information of termination that will be added into the ACDATA data store to close the aircraft service record. The whole process of aircraft data maintenance can be depicted as 4 sub-processes in the level 1 data flow diagram below.



Picture 3.3 – Level 1 data flow diagrams of aircraft data maintenance

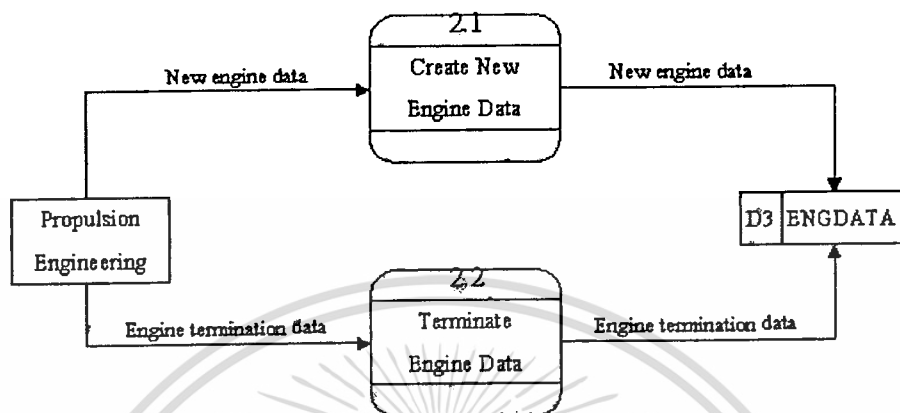
The second group of level 0 data flow diagrams consists of processes 2 – 4 which manage general engine and service bulletin data.



Picture 3.4 – Processes 2 – 4: General engine and service bulletin data

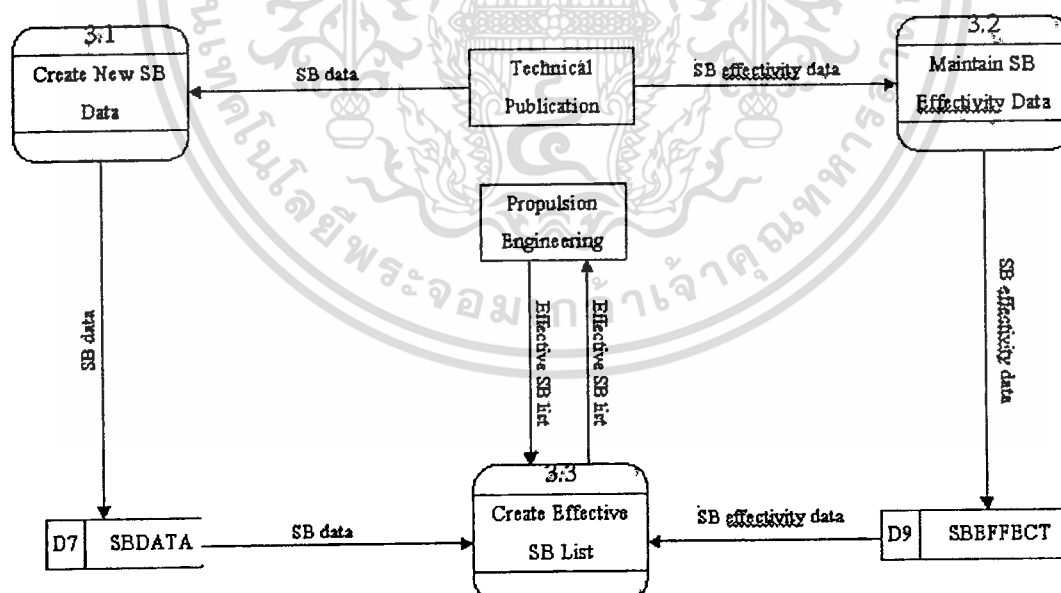
Similarly to an aircraft record, the general details of a new engine introduced into the fleet will be provided by propulsion engineering. Process 2 will record a new engine serial number, effective SB list, SB data, and SB effectivity data. Process 3 will record a new engine serial number, effective SB list, SB data, and SB effectivity data. Process 4 will record a new engine serial number, effective SB list, SB data, and SB effectivity data. Process 4 will record a new engine serial number, effective SB list, SB data, and SB effectivity data.

engine data into the ENGDATA data store. There are two sub-processes underneath process 2 as illustrated as processes 2.1 and 2.2 in the level 1 data flow diagram below.



Picture 3.5 – Level 1 data flow diagram. Processes 2.1 – 2.2: Engine data maintenance

At times, Pratt & Whitney's Technical Publication department will inform updates of new service bulletins. And the data will be manipulated by process 3 and stored in the SBDATA data store.

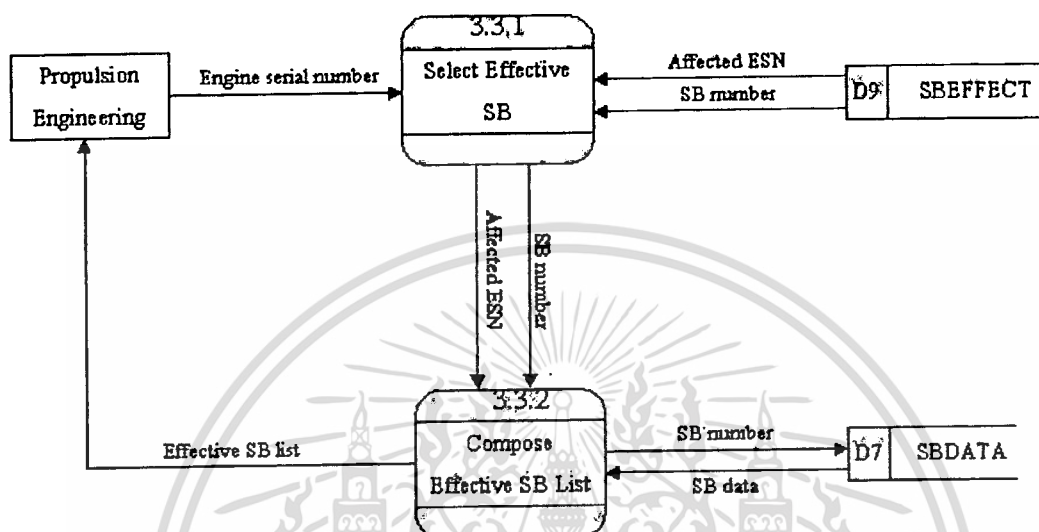


Picture 3.6 – Level 1 data flow diagram. Process 3.1 – 3.3: Service bulletins data maintenance

When a new service bulletin is issued, most of its details such as service bulletin number, title, date of issuance, number of revision, and last revision date will be kept in the SBDATA data store by process 3.1. However, the other portion of service bulletin details, that is effectivity data, will be separately maintained in the

ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ตัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

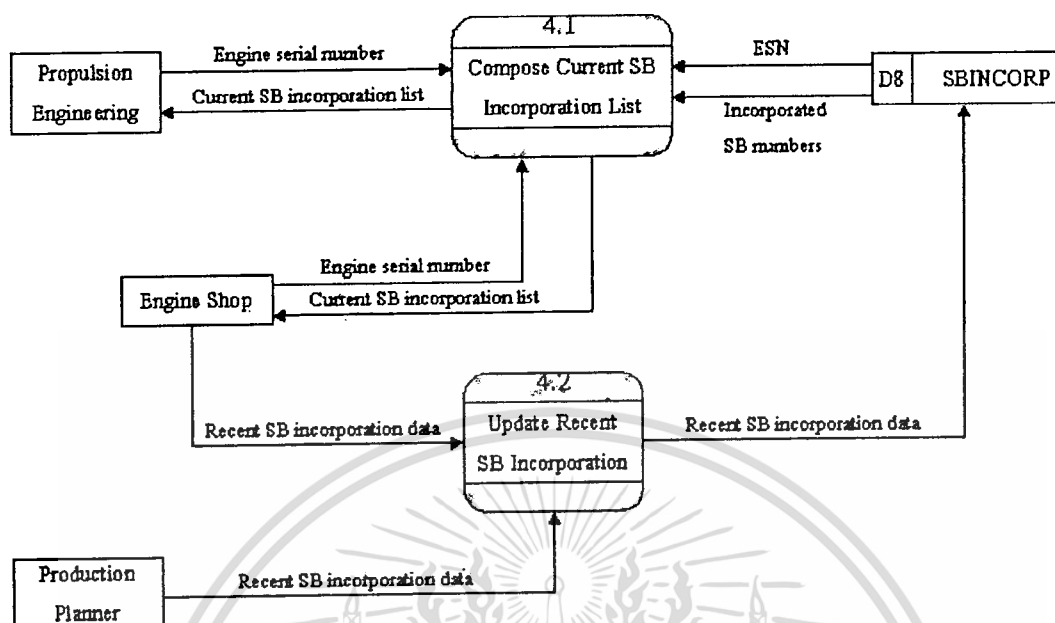
SBEFFECT data store because a service bulletin may affect several engine serial numbers of various engine models. Separation of service bulletin effectivity data not only reduces database size, but it also helps create a list of effective service bulletins for a given engine serial number as in process 3.3.



Picture 3.7 – Level 2 data flow diagram. Process 3.3.1 – 3.3.2: Creating lists of effective service bulletins

When a propulsion engineer would like to know what service bulletins are effective for a given engine serial number, he inputs the engine serial number into the system. The system then selects effective service bulletins from SBEFFECT data store and coupled with other relative service bulletin details retrieved from SBDATA data store before returns a list of effective service bulletins to the user.

Even though process 3.3 provides a list of effective service bulletins to a user's selected engine serial number, information regarding incorporation of a service bulletin is available through process 4. Detail processes of process 4 are illustrated in the level 1 data flow diagram below.



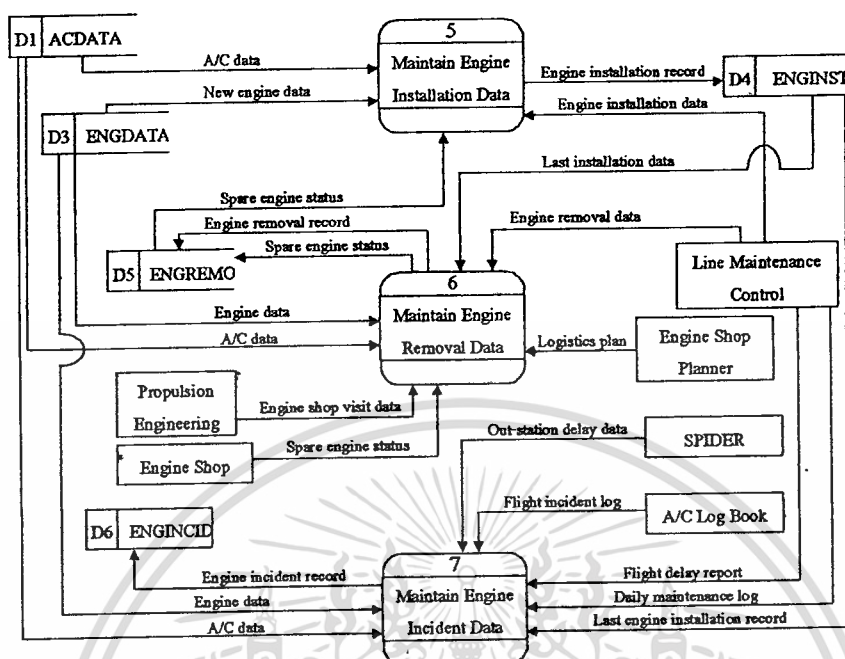
Picture 3.8 – Level 1 data flow diagram. Processes 4.1 – 4.2: Creating service bulletin incorporation list

Generally, many engine maintenance tasks in service bulletins are accomplished at an engine repair shop when an engine is removed for periodical maintenance. After an engine is returned from the shop, a list of service bulletin incorporation is provided to report what service bulletins are performed at the last shop visit.

However, some service bulletins can be incorporated while an engine is installed on an aircraft. Production planner will record all on-wing service bulletin incorporations. When a service bulletin is incorporated, no matter when it is done on wing or in an engine shop, the incorporation data will be recorded in the SBINCORP data store where the latest service bulletin incorporation information will be provided to propulsion engineering and engine shop when they need to determine what service bulletins should be performed and make the maintenance workscope for the next shop visit.

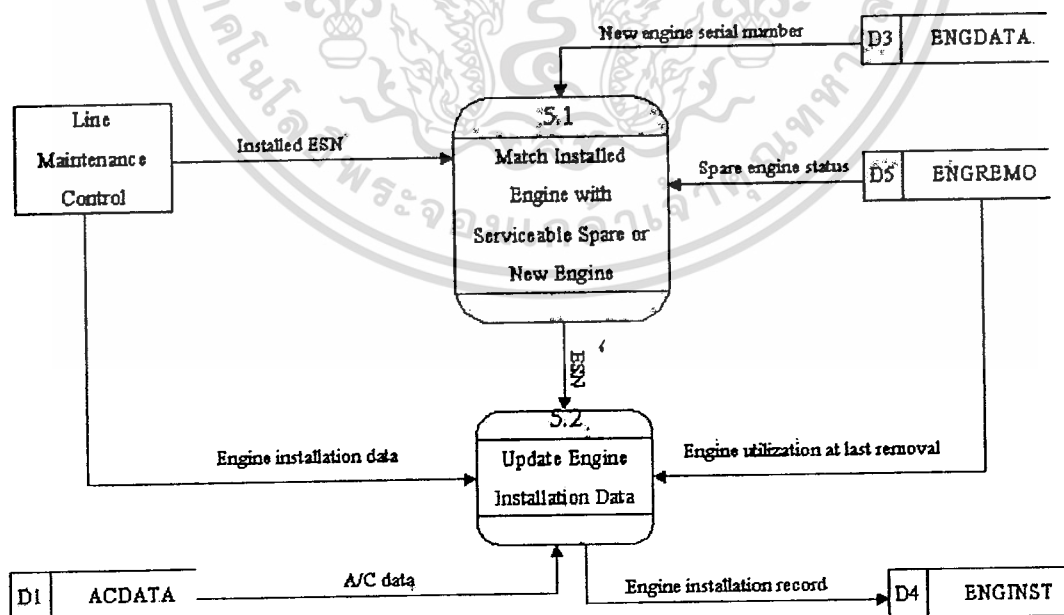
Such data as well serves as a patient's vaccination record. It is used to diagnose symptoms of engine anomalies by reviewing history problems and maintenance events in order to isolate root causes of the problems.

The third group of processes consists of processes 5 – 7 that manipulate data of engine incidents, installations, and removals.



Picture 3.9 – Level 0 data flow diagram. Processes 5 – 7: Engine incidents, installations, and removals

Engine installation process in process 5 can be broken down into two sub-processes as depicted in picture 3.10.

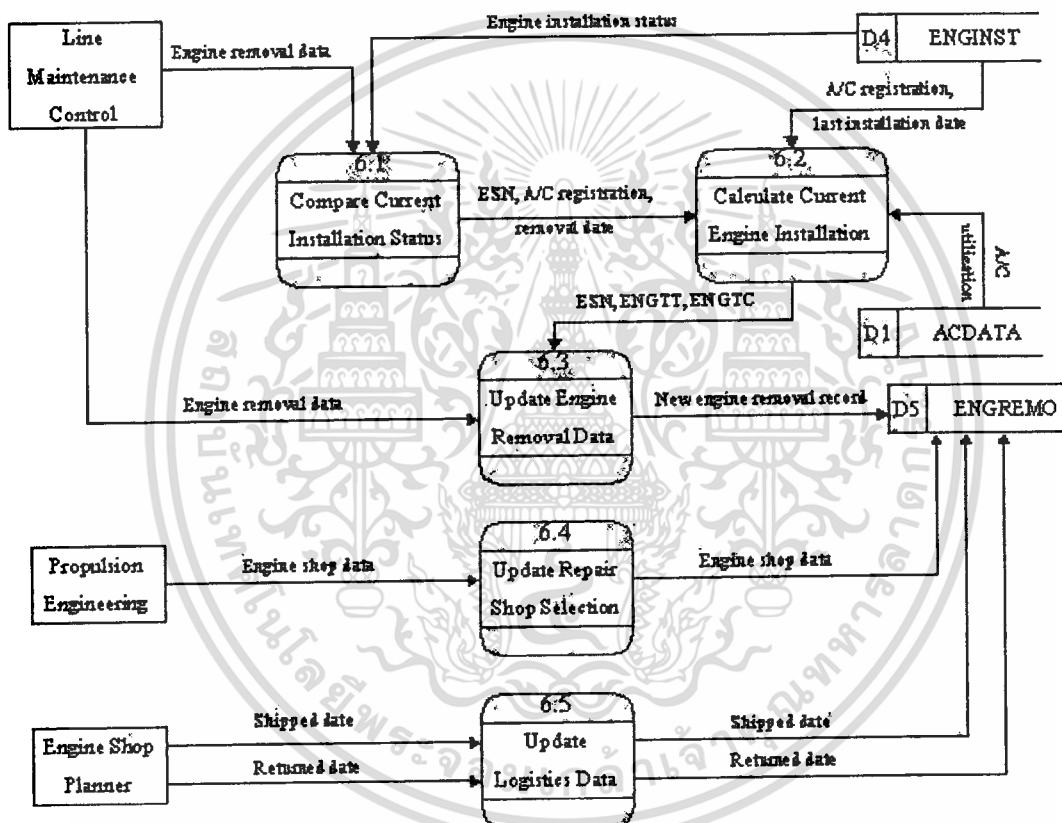


Picture 3.10 – Level 1 data flow diagram. Processes 5.1 – 5.2: Engine installation

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

When an engine is installed on an aircraft, the installed engine serial number will be provided by line maintenance control office. In order to ensure the engine is eligible for installation, the engine serial number will be checked with data from ENGREMO data store and matched with a serviceable spare engine serial number. If the installed engine serial number is not found in ENGREMO data store, it will be matched with an engine serial number in ENGDATA data store because it may be a new engine.

After the installed engine serial number is eligible for installation, other information details such as aircraft registration, engine position, date of installation, engine total hours and cycles will be appended in the ENGINST data store.



Picture 3.11 – Level 1 data flow diagram. Process 6.1 – 6.5: Engine removal

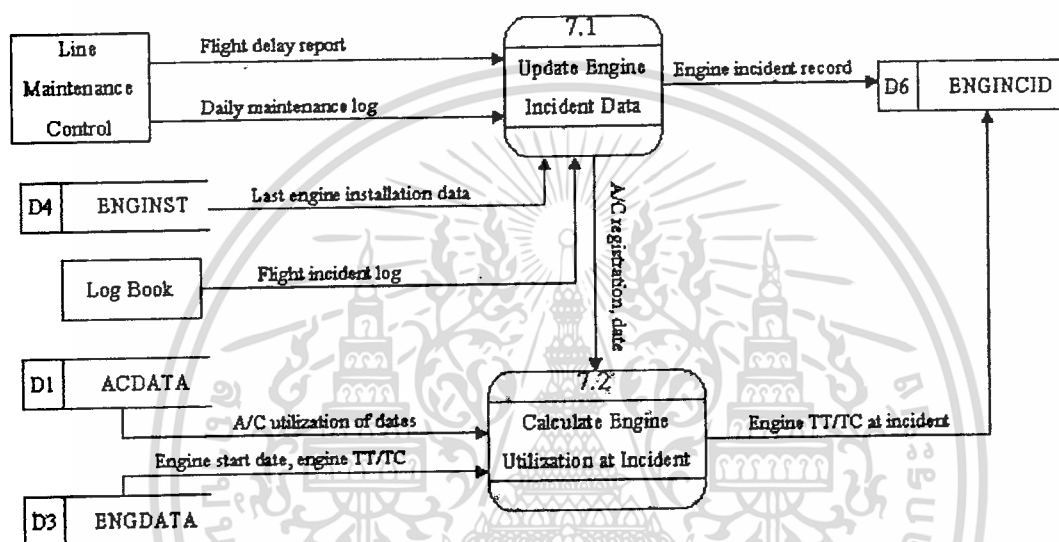
And after an engine is flown for a period of time, it will be due for a maintenance removal. The whole engine removal process starts when line maintenance control office provides engine removal details. The removed engine serial number will be compared with the last installation of that engine serial number. If current installation status agrees with the details from line maintenance control office, the system will retrieve the aircraft total flight hours and cycles at the last installation date and at the current removal date. Then the difference of the aircraft hours and cycles of both dates is calculated to get accumulated engine utilization during the last installation period. All removal data is then recorded in the ENGREMO data store.

Propulsion engineer later advises the selected repair shop for each unserviceable engine and engine shop planner will provide schedule to ship the engine

ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้คัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

to the repair shop. And when the engine repair is completed, the engine will be returned to Thai Airways' engine store. The return date will be input in the ENGREMO data store in order to calculate duration of the repair task. This information can reflect efficiency of the repair shop. Moreover, adding return date into an engine removal record also implies the status of spare engine is changed from unserviceable to serviceable.

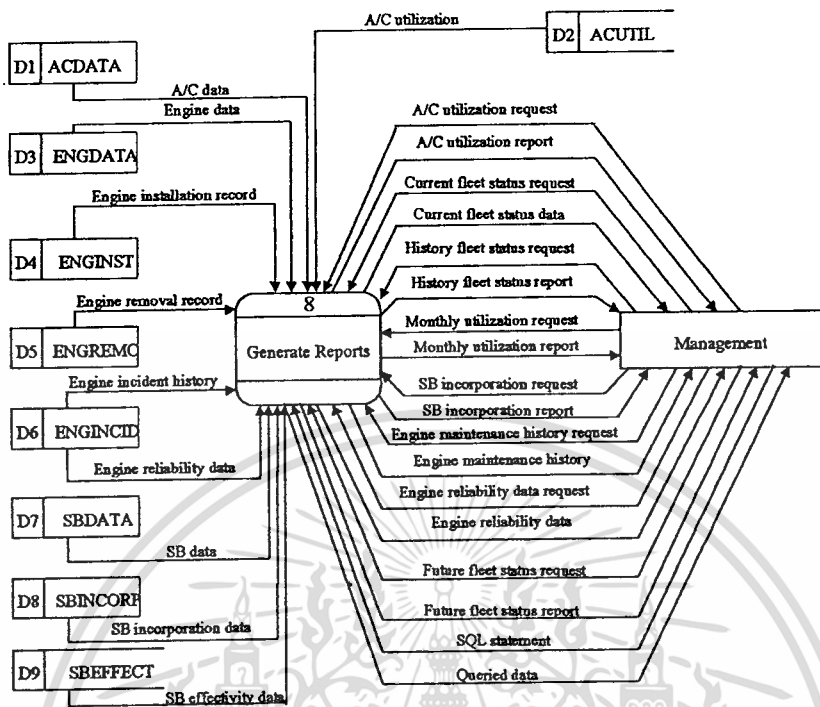
While an engine is installed on an aircraft, it may experience technical problems that lead to flight delays or cancellations. The sub-processes to log engine incidents are illustrated in the picture 3.12 below.



Picture 3.12 – Level 1 data flow diagram. Processes 7.1 – 7.2: Engine incident

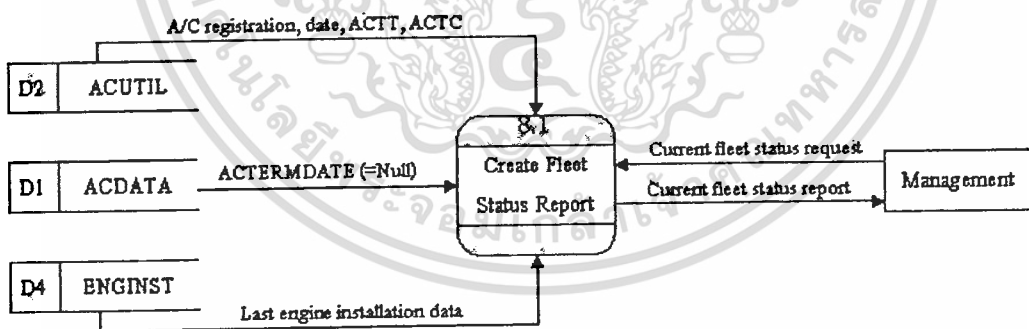
Once a technical problem occurs to an engine, details of the incident will be written up in the aircraft logbook. And if the incident results in a delayed or cancelled flight, a technical delay report will be made at the line maintenance control office. These details will be recorded in the ENGINCID data store while engine total hours and cycles at the incident date will be automatically calculated based on the engine utilization record at the last installation date and on the aircraft accumulated utilization since the last engine installation. The delay and cancellation data can be used further to calculate dispatch reliability rate of the engine fleet while all incident logs tell story of an engine performance. It can give clues for any engine anomalies to help indicate root cause of an engine problem.

The last group of processes contains only one process 8 that is the report generating sub-system. It retrieves data from all data stores, manipulates data according to user's constraints and generates relevant reports.



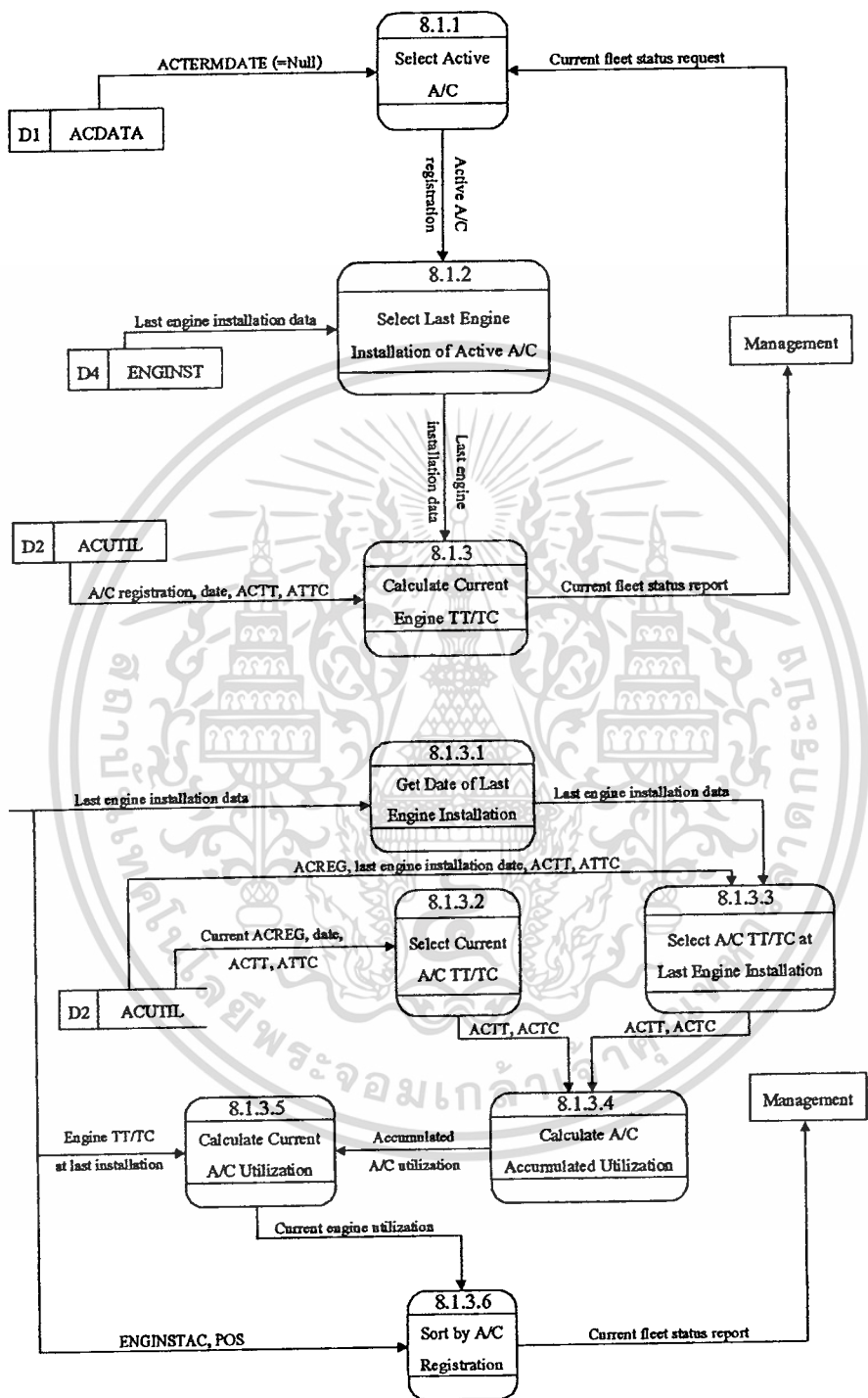
Picture 3.13 – Level 0 data flow diagram. Process 8: Reports generation

Process 8 consists of 8 detailed reports that can be illustrated as 8 level-1 data flow diagrams.



Picture 3.14 – Level 1 data flow diagram. Process 8.1: Current fleet status report

When a user requests for a current engine fleet status report, the sub-process 8.1 will gather all concerning data from ACDATA, ACUTIL, and ENGINCID data stores.



Picture 3.15 – Level 2 – 3 data flow diagrams. Process 8.1.1 – 8.1.3: Current fleet status report

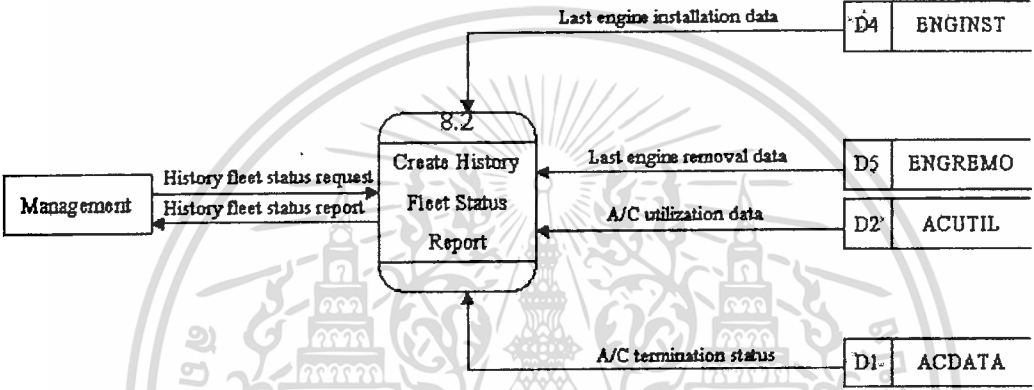
The processes start with checking status of aircraft by looking for termination dates for all aircraft. Any aircraft with a termination date will be considered as inactive aircraft. On the other hand, any aircraft records that have termination data as

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

null will be active aircraft and the aircraft registrations will be listed in the current fleet status report.

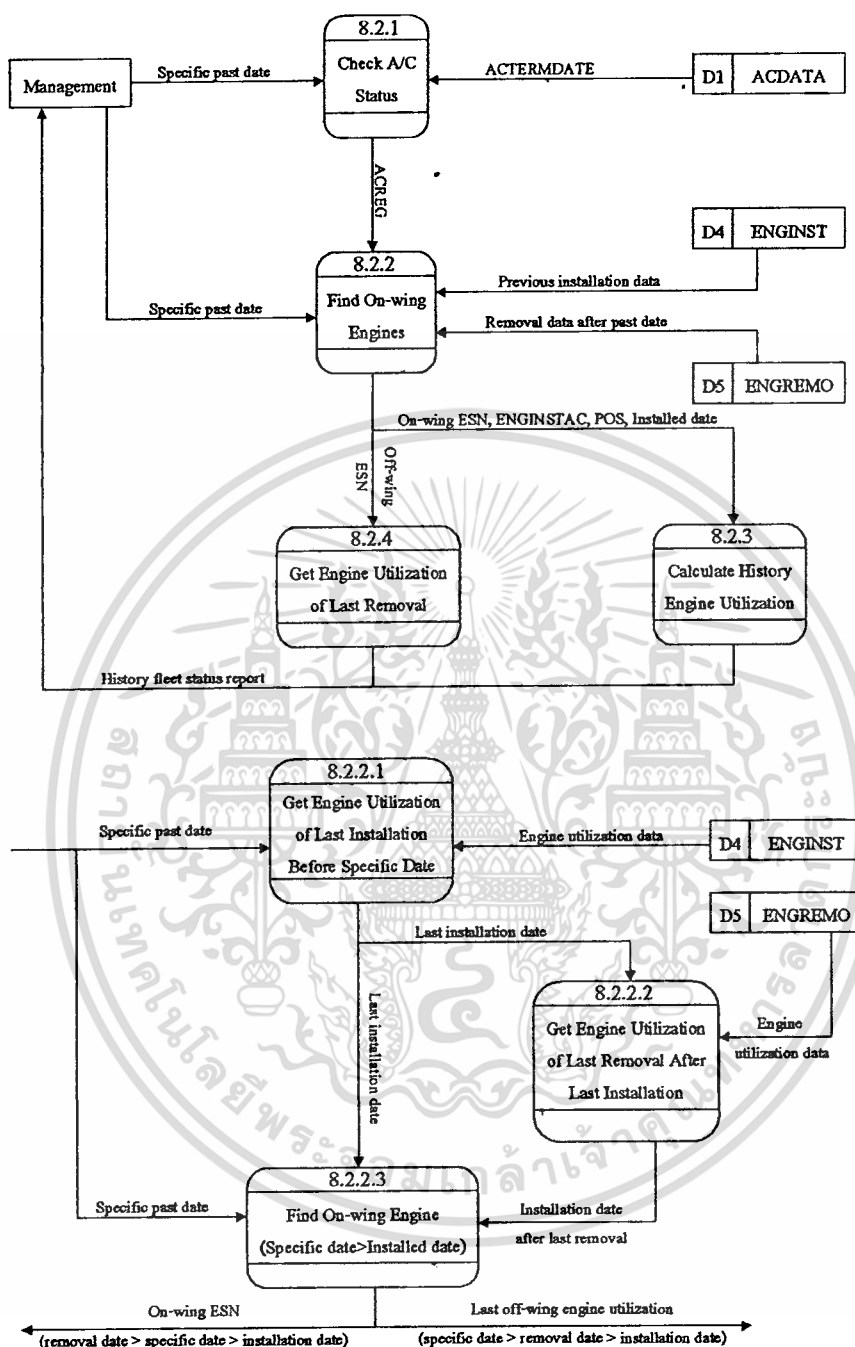
Then the last engine installation records of the active aircraft registrations from the previous step will be selected. The last installation date of each engine will be used to calculate aircraft accumulated hours and cycles since the last installation and then add the numbers to engine hours and cycles at the last installation to get current age of the engine.

Once all current aircraft and engine data is ready, it will be sorted by aircraft registrations and engine positions respectively before being shown in the current fleet status report.

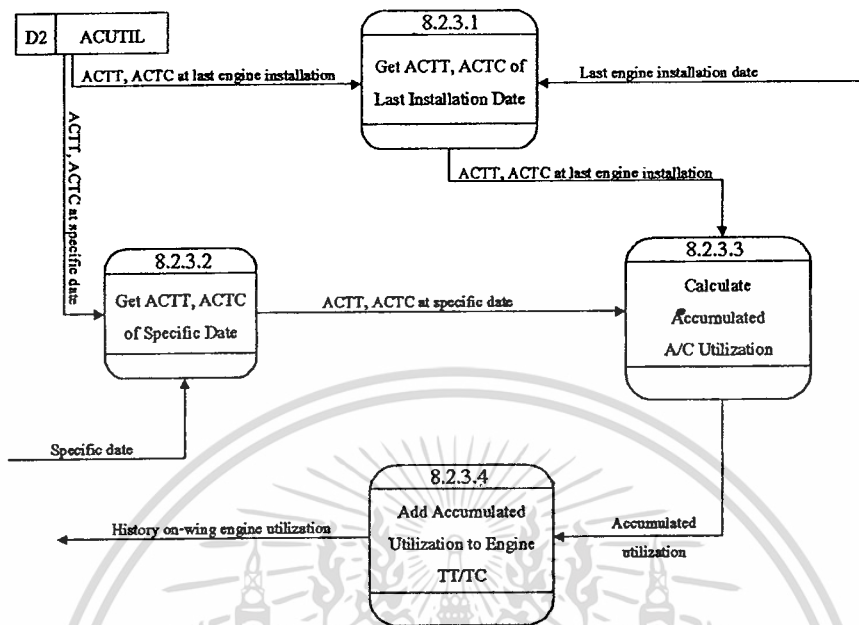


Picture 3.16 – Level 1 data flow diagram. Process 8.2: History fleet status

An advantage that the to-be system has over the as-is system is the creation of history fleet status. To create fleet status at a given date in the past using MS-Excel spreadsheet is a complicated and time-consuming task while engine installation and removal records in an MS-Access database can be used to facilitate this requirement.



Picture 3.17 – Level 2 – 3 data flow diagram. Processes 8.2.1 – 8.2.4: History fleet status



Picture 3.18 – Level 3 data flow diagram. Processes 8.2.3.1 – 8.2.3.4: History fleet status

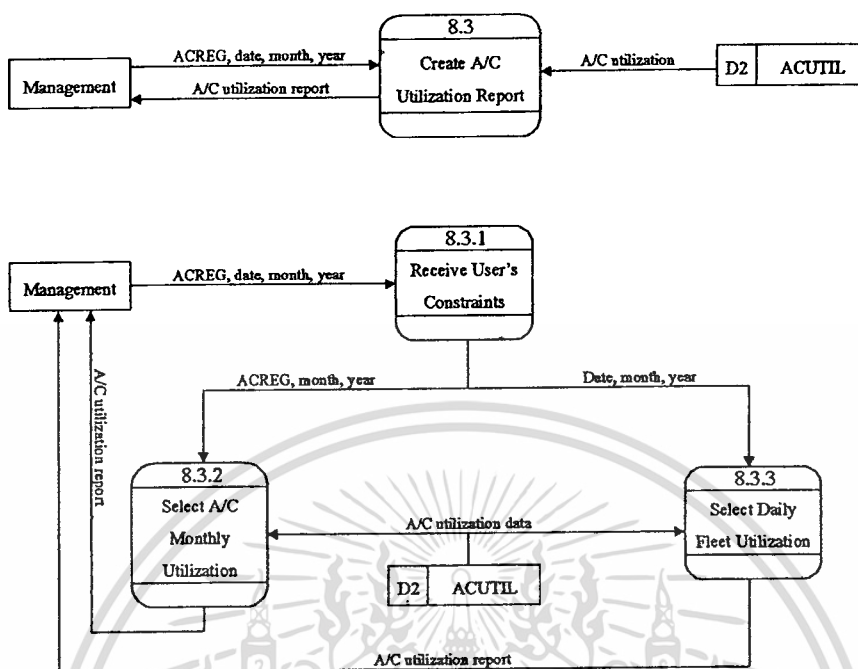
When a user needs to know the fleet status of a specific date in the past, he just enters the required date into the system. Then the system will check for active aircraft registrations on that date by comparing the given date with aircraft termination dates.

Then the last installation record of each engine on those active aircraft will be selected. The first engine removal record after the last installation date is as well selected. When the system has three dates for each engine, it can identify what engines are on-wing or off-wing on the user's given date. The rules to specify on-wing and off-wing engines are as follows:

- Installation date < Removal date < User's date = Off-wing engine
- Installation date <= User's date < Removal date = On-wing engine

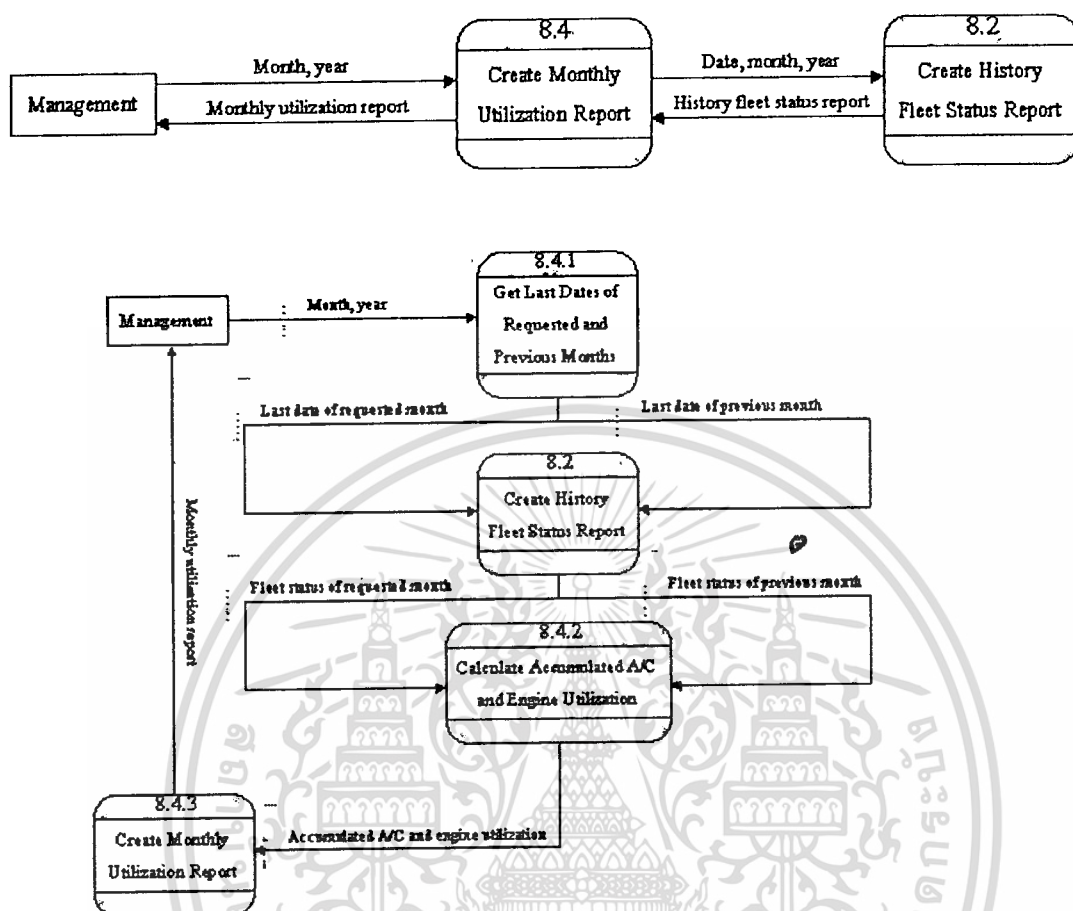
After the system can identify each engine status at the date, engine total hours and cycles at the last removal will be used as utilization data for all off-wing engines. And for all on-wing engines, calculating engine utilization at the user's date is similar to the process in current fleet status. Aircraft accumulated utilization from the last engine installation date until the user's date will be added to each engine total hours and cycles of the last installation to get the engine utilization at the user's date.

When all on-wing and off-wing engine status at the user's date is available, the history fleet status will be reported to the user.



Picture 3.19 – Level 1 – 2 data flow diagrams. Process 8.3: Aircraft utilization report

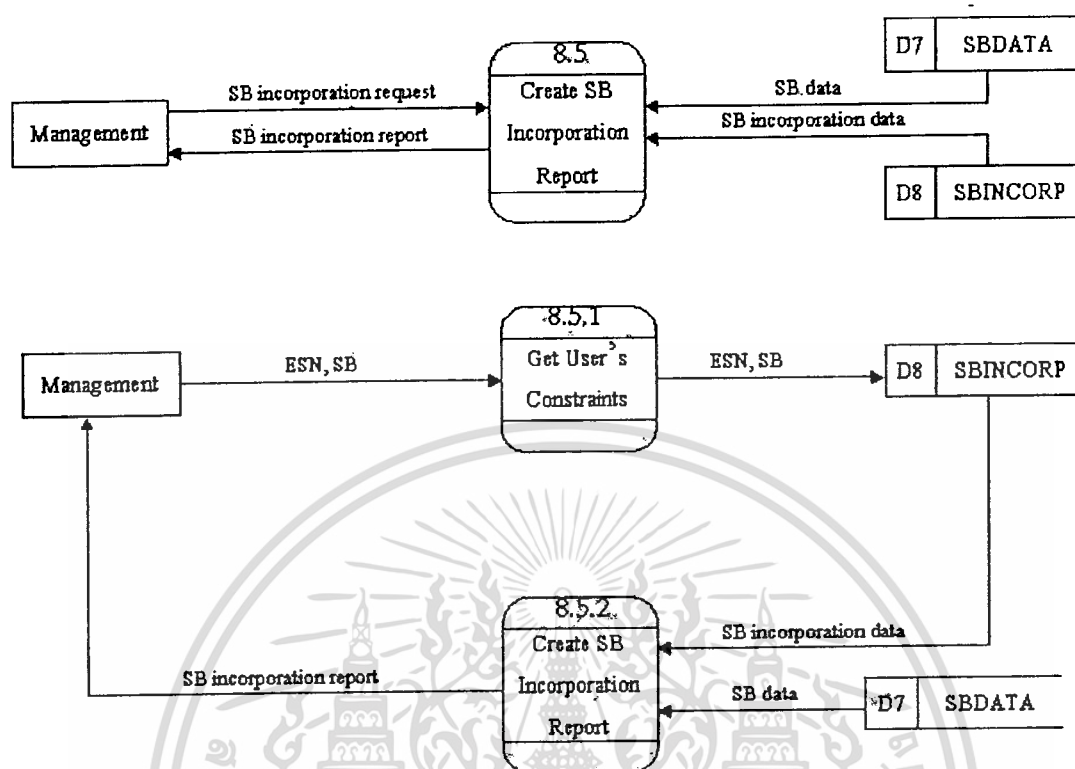
A user can see aircraft utilization by aircraft registration or by date. If he enters an aircraft registration, month, and year, the system will retrieve aircraft utilization records from ACUTIL data store and generate a daily total hours and cycles of the aircraft for the selected month. But if the user inputs a date, month, and year, he will get the utilization of each aircraft of the date.



Picture 3.20 – Level 1 – 2 data flow diagrams. Process 8.4:
Monthly utilization report

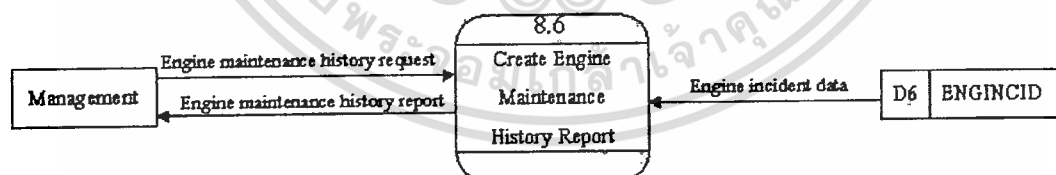
The fourth type of reports is the most important in the as-is system. The to-be system is capable to create this report as well and it reduces the effort of users to create the report because the system will retrieve data from concerning data stores and automatically conduct the monthly utilization report.

This process takes benefit from history fleet status reports in process 8.2. Starting when the user inputs his desired month and year, the system will launch process 8.2 twice. The first time is to create the fleet status of the last date of the user's given month. The second launch is for the fleet status of the last date of one previous month. Each aircraft and engine utilization accumulated between two months will be calculated and then the monthly utilization report will be conducted.



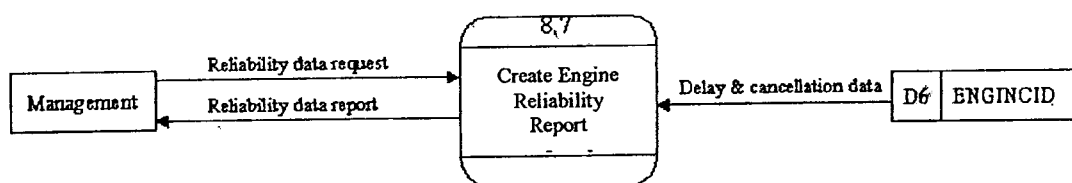
Picture 3.21 – Level 1 – 2 data flow diagram. Process 8.5: Service bulletin incorporation report

A user can get information on service bulletin incorporations. Process 8.5 offers the user two options. If he inputs a service bulletin number, the system will display the incorporation status of all engines for that specific service bulletin. However, if the user enters an engine serial number, he then is provided with all incorporated service bulletins of the selected engine serial number.



Picture 3.22 – Level 1 data flow diagram. Process 8.6: Engine maintenance history report

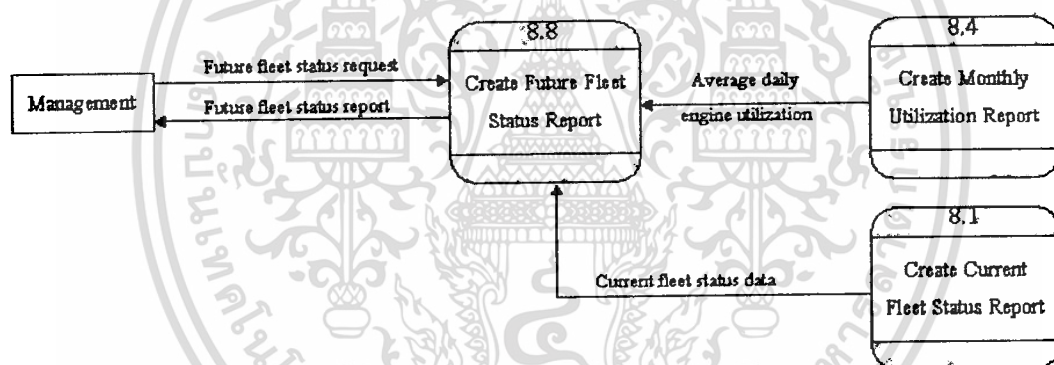
Sometime, when an engine experiences an abnormal performance, the user may need to trace back for any correlation of previous incidents or possible origin of the problem. Process 8.6 is a simple and straight forward step that receives an engine serial number and the required period of incident logs from the user. Then the system selects all engine incidents and maintenance that happen to the specified engine serial number during the period and create an engine maintenance history report.



Picture 3.23 – Level 1 data flow diagram. Process 8.7: Engine reliability report

The ENGINCID data store not only provides data for engine maintenance history reports, it also contains data regarding flight delays and cancellations that result from engine problems. Delay and cancellation data can be used further together with other aircraft operation data to calculate dispatch reliability rate for an aircraft type and an engine model. However, such rating calculation is not yet included in this project version, but may be added in a future improvement.

When the user provides an engine serial number, and the preferred duration, the system selects all relative delay and cancellation records before making a reliability report for the user.



Picture 3.24 – Level 1 data flow diagram. Process 8.8: Future fleet status report

The to-be system has another advantage over the as-is system. It does not only provide current and history fleet status, but it as well has the capability to forecast aircraft and engines total hours and cycles at a given date in the future.

The user inputs a future date on which he would like to know the fleet status. The system then calculates the interval between today and the user's date. It as well counts the amount of days since the last month end. At this point the system knows how many days the user's date is ahead of the last month end. The system will multiply the total number of days to the average daily engine and aircraft utilization taken from the last month's fleet status report that is generated by the process 8.4.

Up to this step, the system gets the tentatively accumulated aircraft and engine utilization that will occur at the user's specific date. The last monthly report is generated. The future accumulated utilization from the process 8.8.4 is added to the current aircraft and engine total hours and cycles. All predicted utilization will be included in the future fleet utilization report. This forecast is based on the assumption that each engine will not be removed before the user's date. The use of this report is to

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า

ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

give the user rough information on engine ages at a future date so that he can plan properly for maintenance tasks when an engine reaches its life limit.



เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Chapter 4

To-be System Data Modeling

Even though the processes of this system have been already designed, the data itself needs to be properly modeled as well because a well designed database can essentially yield good response time, easy data management, and better control over data consistencies and integrity. Entity-relationship diagram is a popular tool for data modeling.

4.1 Business Rules

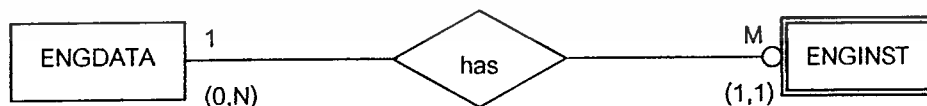
The first step of data modeling for this database system starts with listing all business rules that are practiced in the current working environment. Business rules will define data entities that are necessary for the database system and the relationships among them. And the business rules of the current data collection work are as follows:

1. An aircraft may be flown on more than one day, but each daily aircraft utilization record must belong to only one aircraft.
2. No aircraft utilization records can exist with any aircraft that are not inducted into the fleet.



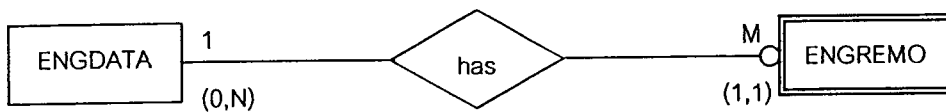
Picture 4.1 – Entity-relationship diagram: ACDATA & ACUTIL

3. An engine may be installed on many aircraft at many occasions, but each engine installation must belong to only one engine serial number.
4. Only engine serial numbers that are inducted into the fleet can be installed on an aircraft.



Picture 4.2 – Entity-relationship diagram: ENGDATA & ENGINST

5. An engine may be removed from many aircraft at many times, but each engine removal record must pertain to only one engine serial number.
6. Only engine serial numbers that are inducted into the fleet can be removed from an aircraft.



Picture 4.3 – Entity-relationship diagram: ENGDATA & ENGREGMO

7. An engine may experience many incidents, but each incident record must belong to only one engine.
8. Each engine incident must be logged with only engine serial numbers that are inducted into the fleet.



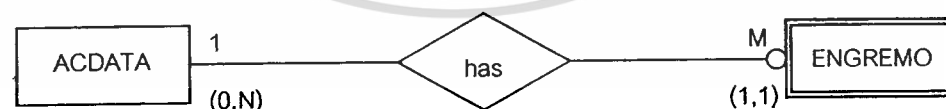
Picture 4.4 – Entity-relationship diagram: ENGDATA & ENGINCID

9. An aircraft registration may have many engines installed at different times, but each engine installation must be done on only one aircraft.
10. No engine installations can be performed on any aircraft that are not inducted into the fleet.



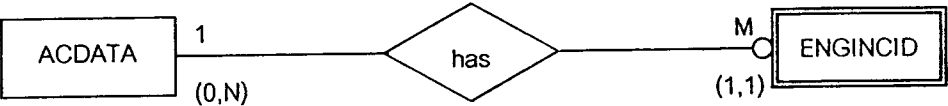
Picture 4.5 – Entity-relationship diagram: ACDATA & ENGINST

11. An aircraft registration may experience in many engine removals at many occasions, but each engine removal must be done on only one aircraft.
12. No engine removals can be performed on any aircraft that are not inducted into the fleet.



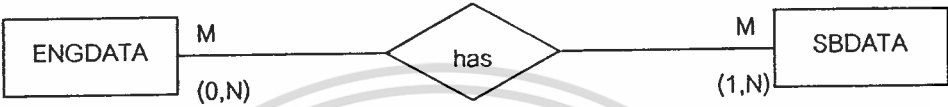
Picture 4.6 – Entity-relationship diagram: ACDATA & ENGREGMO

13. An aircraft may be involved in many engine incidents at various occasions, but each engine incident record must belong to only one aircraft registration.
14. Each engine incident record must be logged with only aircraft registrations that are inducted into the fleet.



Picture 4.7 – Entity-relationship diagram: ACDATA & ENGINCID

- 15. An engine may be incorporated with many service bulletins.
- 16. Each service bulletin may affect many engine serial numbers.



Picture 4.8 – Entity-relationship diagram: ENGDATA & SBADATA

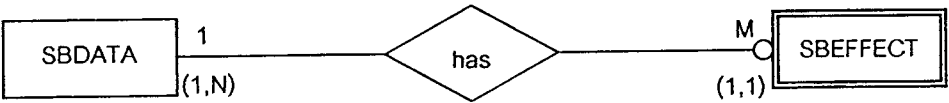
The relationship connectivity between these two entities is many-to-many which is not preferable because it can produce data inconsistencies. The solution for this type of relationship is adding a composite entity to change the connectivity to one-to-many.



Picture 4.9 – Entity-relationship diagram: ENGDATA & SBADATA with composite entity

With the added SBINCORP composite entity, the business rules 15 and 16 need to be revised as follows:

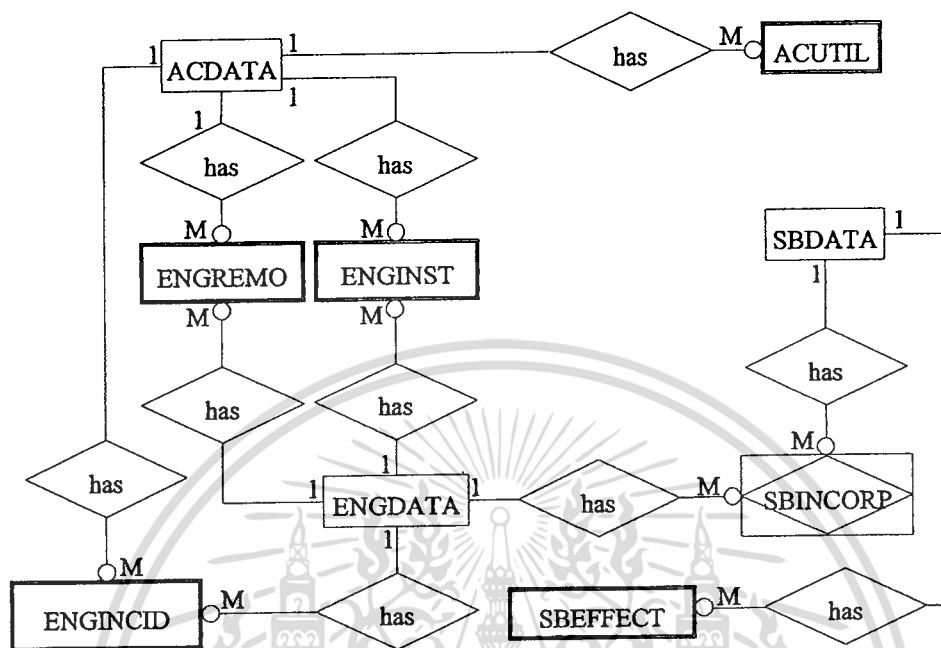
- 15a. An engine may have many service bulletin incorporation records, but each service bulletin incorporation record must pertain to only one engine serial number.
- 16a. A service bulletin may appear in many incorporation records, but each service bulletin incorporation record must belong to only one service bulletin number.
- 17. A service bulletin may have many effectivity records, but each effectivity record must pertain to only one service bulletin number.
- 18. An effectivity data can exist only when its referenced service bulletin exists.



Picture 4.10 – Entity-relationship diagram: SBADATA & SBEFFECT

All pairs of entity relationships can be joined in the overall entity-relationship diagram below.

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้



Picture 4.11 – Overall entity-relationship diagram

4.2 Normalization

Each entity in the entity-relationship diagram above represents a group of interested data. However, all pieces of data to form the database, that are attributes, need to be assigned to their appropriate entities based on their relevance. In other word, all attributes need to be normalized in order to eliminate repeating groups, partial dependencies, and transitive dependencies. Normalization helps reduce data redundancies and make them controllable which leads to elimination of data anomalies. (Rob and Coronel. 2000: 254)

From the E-R diagram, each entity can be listed with its key coverage as follows:

ACDATA:	General aircraft data
ACUTIL:	Daily aircraft utilization data
ENGDATA:	General engine data
ENGINCID:	Engine incident data
ENGINST:	Engine installation data
ENGREMO:	Engine removal data
SBDATA:	Service bulletin data
SBEFFECT:	Service bulletin effectivity data
SBINCORP:	Service bulletin incorporation data

And attributes are assigned to their relevant entities. Each block in the diagram below represents an attribute. All attributes names that are underlined serve as the primary keys in their entities. The combination of all primary keys in an individual entity can determine uniqueness of each record in the entity. The determinations are shown as arrows from primary keys to other attributes.

เอกสารนี้เป็นทรัพย์สินของกองทัพอากาศไทย ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Table 4.1 – ACDATA

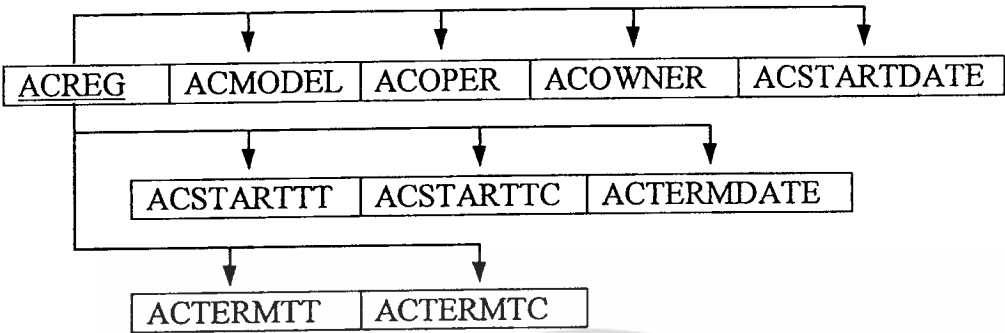


Table 4.2 – ACUTIL



Table 4.3 – ENGDATA

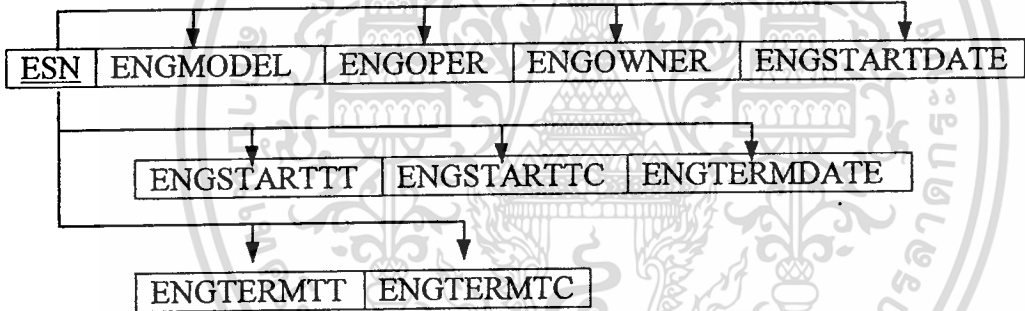


Table 4.4 – ENGINCID

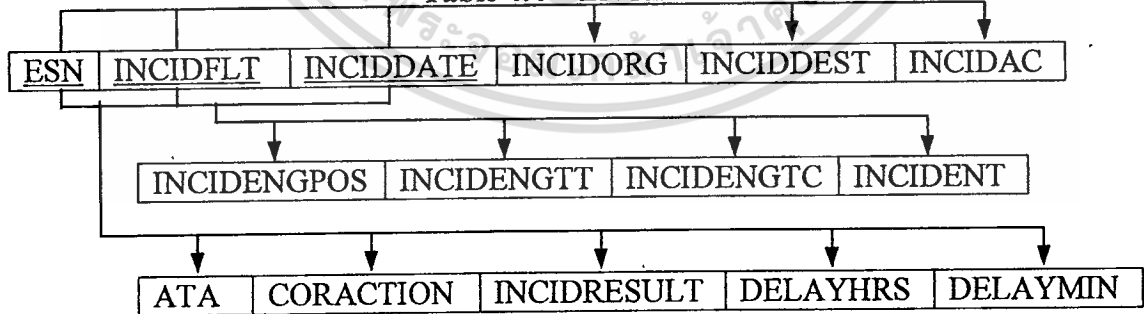
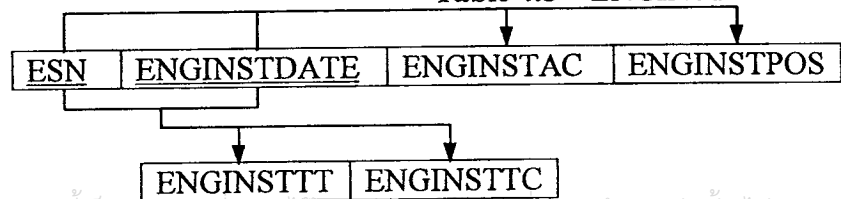


Table 4.5 – ENGINST



เอกสารนี้เป็นเอกสารทสงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Table 4.6 – ENGREMO

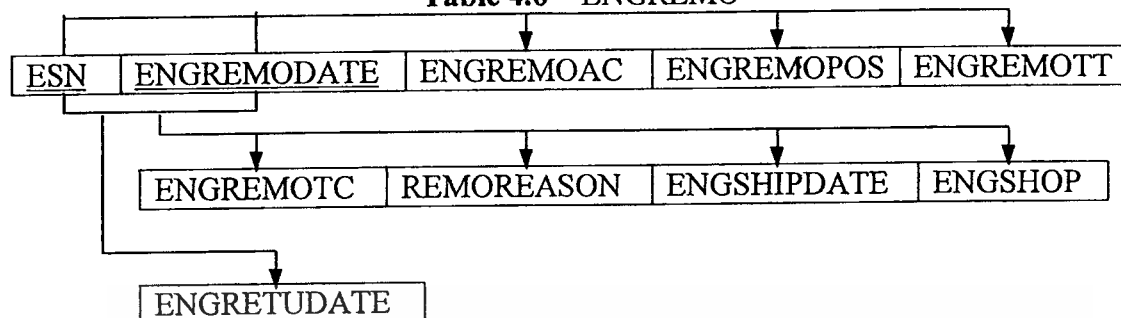


Table 4.7 – SBDATA

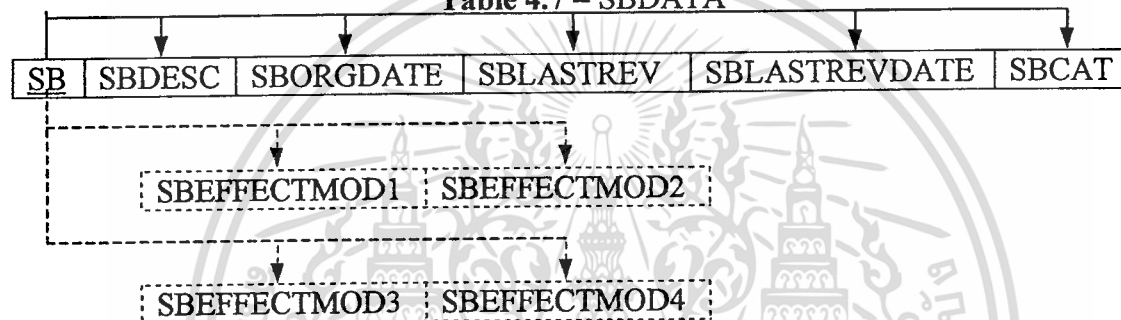


Table 4.8 – SBEFFECT



Practically, a service bulletin may affect more than one engine model and many engine serial numbers, some are in order such as engine serial numbers 999001 up to 999060, and sometimes the affected engine serial numbers are not at all in order such as 999001, 999023, 999157 and 999390. During the initial design of the data model, service bulletin effectivity data was included as a memo-typed attribute in the SBDATA entity. However, a subsequent refinement was made with the effectivity data split off as a new entity. This SBEFFECT entity has three attributes, that are service bulletin number, affected engine model, and affected engine serial number, all of which work as primary keys to create uniqueness of each record. It would be a waste of data storage and slow response time if the effectivity data was included in the SBDATA entity because if a service bulletin effected only one engine model, the data space reserved for the other three engine models would not be used.

Furthermore, the memo-typed attribute could not facilitate ad hoc queries if the user needed to find whether or not an engine serial number was affected by a service bulletin because the affected engine serial numbers may be input as ranges such as 999001 to 999060, 999187 to 999189, etc. Any engine serial numbers that fell in between the ranges would not be searchable. Therefore, the separation of the effectivity data as another entity optimizes the use of data storage and yields better data manipulation.

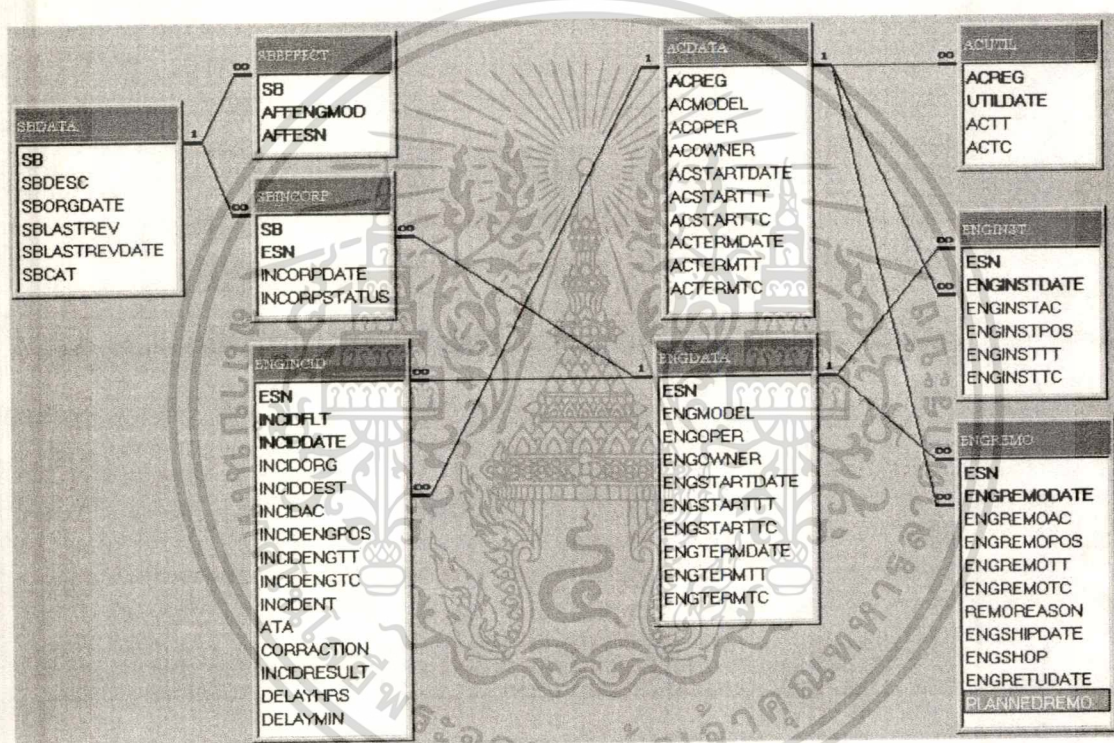
เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Table 4.9 – SBINCORP

SB	ESN	INCORPDATE	INCORPSTATUS
----	-----	------------	--------------

After the normalization process, all entities do not contain repeating groups, partial dependencies, and transitive dependencies. This means all entities are in third normal forms. All data inconsistencies are prevented and data redundancies are under control with the use of referential integrity, that is the correlation between primary keys and foreign keys. Hence, data anomalies are controlled and should not happen.

The relational schema below represents the relationships between entities and their attributes.



Picture 4.12 – Relational schema

4.3 Data Dictionary

Data dictionary contains data about data, that are entity names, attribute names, data types, data sizes, descriptions, keys and referenced entities. The data dictionary for this aircraft engine maintenance database is detailed in the following tables.

Table 4.10 – Data dictionary: ACDATA entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
ACREG	Text	6	Aircraft registration number	PK	
ACMODEL	Text	8	Aircraft model		
ACOPER	Text	4	Aircraft operator (Airliner)		
ACOWNER	Text	4	Aircraft owner		
ACSTARTDATE	Date/Time		Aircraft operation start date		
ACSTARTTT	Long Integer		Aircraft total utilized hours at start date		
ACSTARTTC	Long Integer		Aircraft total utilized cycles at start date		
ACTERMDATE	Date/Time		Aircraft termination date		
ACTERMTT	Long Integer		Aircraft total utilized hours at termination		
ACTERMTC	Long Integer		Aircraft total utilized cycles at termination		

Table 4.11 – Data dictionary: ACUTIL entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
ACREG	Text	6	Aircraft registration number	PK, FK	ACDATA
DATE	Date/Time		Date of aircraft utilization data	PK	
ACTT	Long Integer		Aircraft total utilized hours at a specific date		
ACTC	Long Integer		Aircraft total utilized cycles at a specific date		

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Table 4.12 – Data dictionary: ENGDATA entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
ESN	Long Integer		Engine serial number	PK	
ENGMODEL	Text	16	Engine Model		
ENGOPER	Text	4	Engine operator (Airliner)		
ENGOWNER	Text	4	Engine owner		
ENGSTARTDATE	Date/Time		Start date of engine operation		
ENGSTARTTTT	Long Integer		Engine total utilized hours at start date		
ENGSTARTTTC	Long Integer		Engine total utilized cycles at start date		
ENGTERMDATE	Date/Time		Termination date of engine operation		
ENGTERMTT	Long Integer		Engine total utilized hours at termination date		
ENGTERMTC	Long Integer		Engine total utilized cycles at termination date		

Table 4.13 – Data dictionary: ENGINCID entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
ESN	Long Integer		Engine serial number	PK, FK	ENGDATA
INCIDFLT	Text	6	Flight number of incident	PK	
INCIDDATE	Date/Time		Incident date	PK	
INCIDORG	Text	30	Origin station of incident flight		
INCIDDEST	Text	30	Destination station of incident flight		
INCIDAC	Text	6	Aircraft registration number of incident flight		
INCIDENGPOS	Text	2	Engine position on incident flight		
INCIDENGTT	Long Integer		Engine total utilized hours at incident		
INCIDENGTC	Long Integer		Engine total utilized cycles at incident		
INCIDENT	Memo		Incident detail		
ATA	Text	2	ATA chapter of problem		
CORRACTION	Memo		Corrective action performed		
INCIDRESULT	Text	4	Result of incident : TD, CNL, TC, IFSD (Delay, Cancellation, A/C change, IFSD)		
DELAYHRS	Integer		Total delay hours		
DELAYMIN	Integer		Total delay minutes		

Table 4.14 – Data dictionary: ENGINST entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
ESN	Long Integer		Engine serial number	PK, FK	ENGDATA
ENGINSTDATE	Date/Time		Installation date	PK	
ENGINSTAC	Text	6	A/C on which engine is installed		
ENGINSTPOS	Text	2	Position at which engine is installed		
ENGINSTTT	Long Integer		Engine total utilized hours at installation		
ENGINSTTC	Long Integer		Engine total utilized cycles at installation		

Table 4.15 – Data dictionary: ENGREMO entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
ESN	Long Integer		Engine serial number	PK, FK	ENGDATA
ENGREMODATE	Date/Time		Date of engine removal	PK	
ENGREMOAC	Text	6	A/C on which engine is removed		
ENGREMOPOS	Text	2	Position at which engine is removed		
ENGREMOTT	Long Integer		Engine total utilized hours at removal		
ENGREMOTC	Long Integer		Engine total utilized cycles at removal		
REMOREASON	Memo		Removal reason		
ENGSHIPDATE	Date/Time		Engine shipped date to engine shop		
ENGSHOP	Text	16	Engine shop code/name		
ENGRETUDATE	Date/Time		Date when engine returns to operator		
PLANNEDREMO	Yes/No		Planned engine removal		

Table 4.16 – Data dictionary: SBDATA entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
SB	Text	16	Service bulletin number	PK	
SBDESC	Memo		SB description		
SBORGDATE	Date/Time		SB original revision date		
SBLASTREV	Byte		SB last revision number		
SBLASTREVDATE	Date/Time		SB last revision date		
SBCAT	Text	2	SB category		

Table 4.17 – Data dictionary: SBEFFECT entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
SB	Text	16	Service bulletin number	PK, FK	SBDATA
AFFENGMOD	Text	16	Affected engine model	PK	
AFFESN	Long Integer		Affected engine serial number	PK	

Table 4.18 – Data dictionary: SBINCORP entity

Attribute	Data Type	Size	Description	Key	Referenced Entity
SB	Text	16	Service bulletin number	PK, FK	SBDATA
ESN	Long Integer		Engine serial number	PK, FK	ENGDATA
INCORPDATE	Date/Time		SB incorporation date		
INCORPSTATUS	Text	2	Status of SB incorporation : F, P, NA (Finished, Partial, Not Applicable)		

Chapter 5

System Design

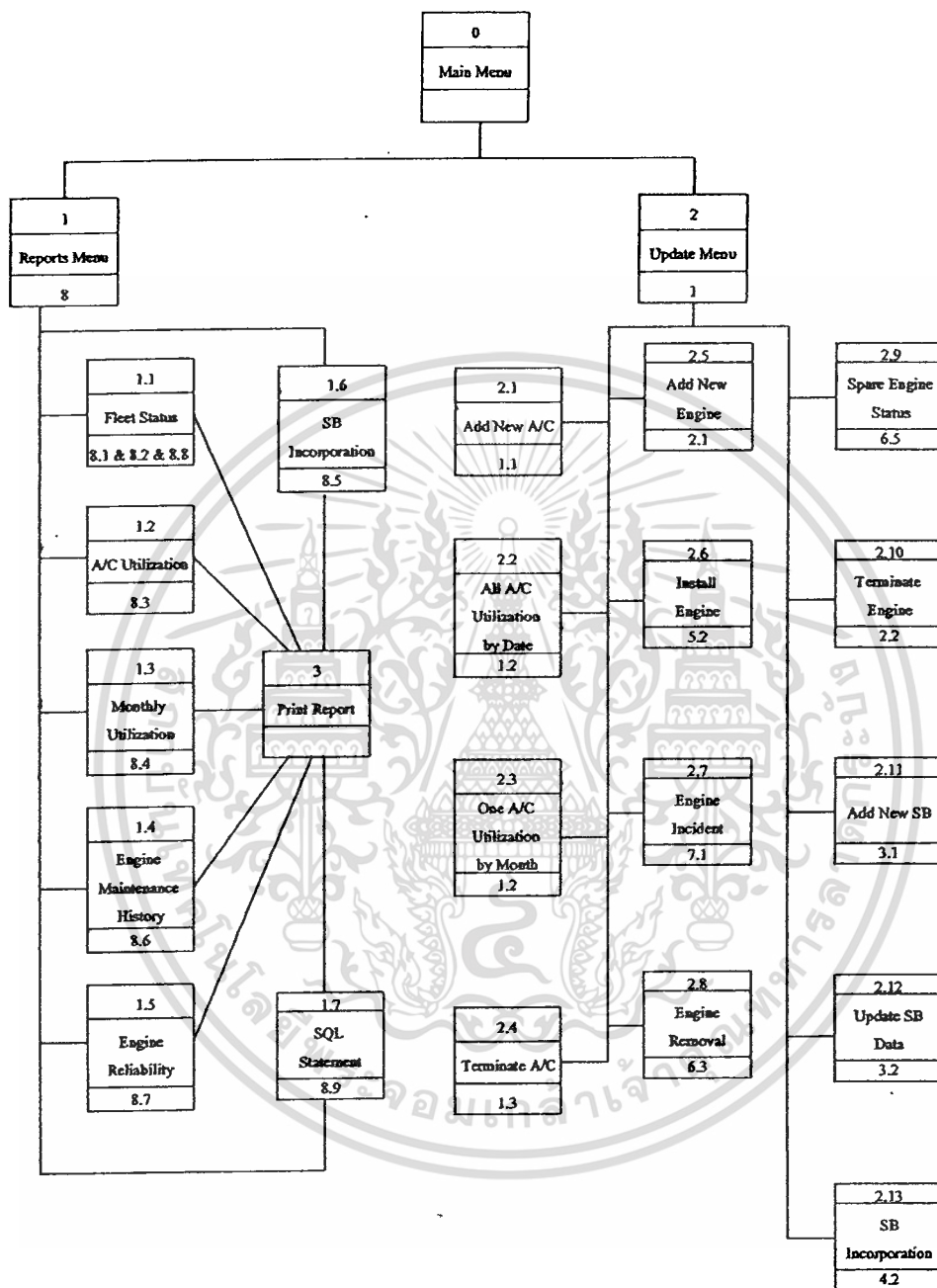
After the database is created and all necessary processes are diagrammed, the next step is to build the system accordingly. This chapter will discuss the concept of user interface design and how the processes are transformed from the data flow diagrams into the real application.

5.1 User Interface Design

The key concept to design screens of this system is to serve the two groups of users that are the management and the data collector. However, these two groups of users are different in their requirements and computer skills. The management have less technical competency in computer and database structure so they need a system that is easy to use and can generate reports that they require.

On the other hand, the data collector has more understanding in database structure and more experience with computer applications. He mainly uses the system to update and maintain data as well as assist the management to create reports.

Therefore, the user interface structure is divided into two parts. The first part contains screens that receive parameters from the users to generate reports. The other part of the screens is for the data collector to update and manage data. Below is the user interface structure diagram of this system. Each interface box contains its number at the top, its name in the middle, and its related DFD process number at the bottom. The interfaces are linked by lines that show how the user can move from one screen to another.

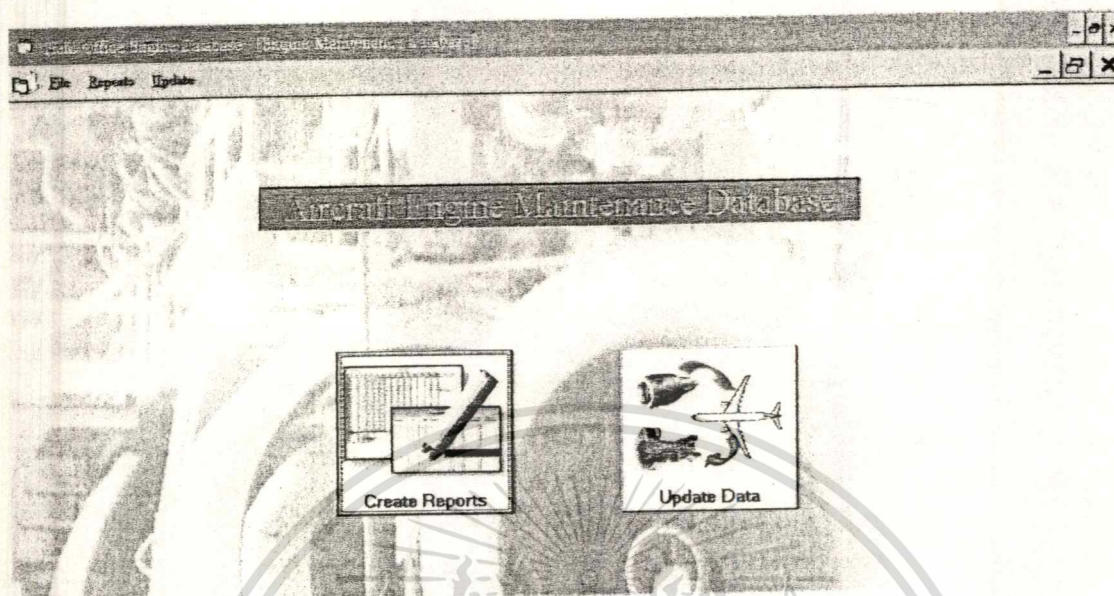


Picture 5.1 – User interface structure diagram

Because all screens in this system are categorized for two groups of users, in order to help the users know where they are in the system, different background colors are used for two groups of the screens. The green background is for report mode and the blue background is for the update mode.

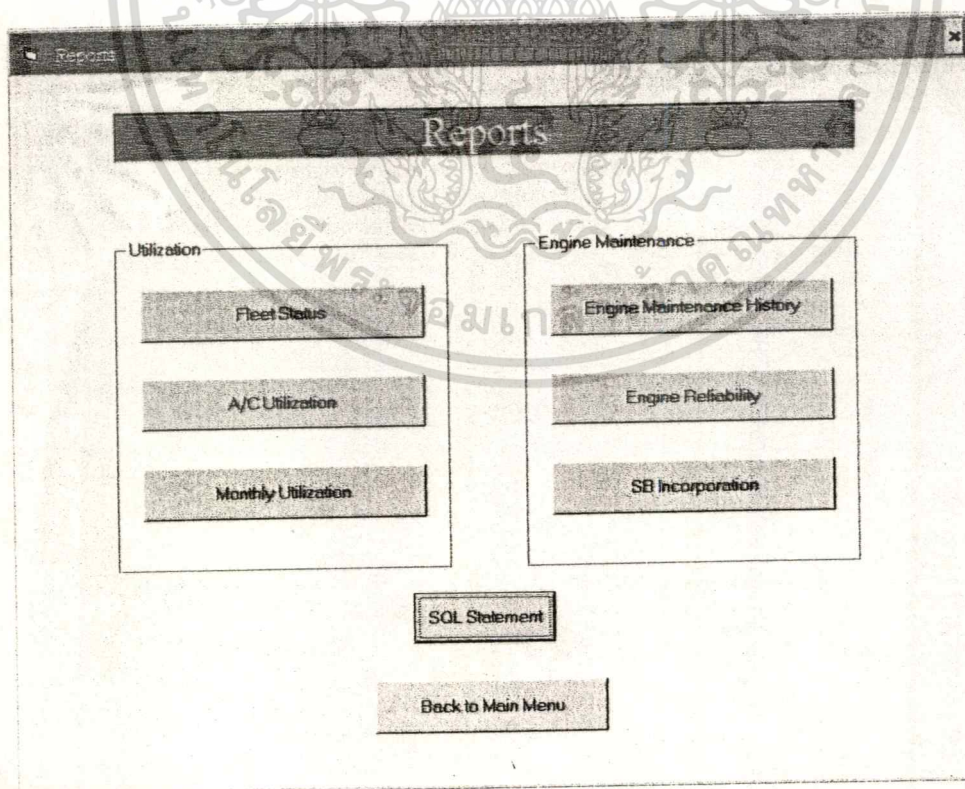
The system starts working with the main menu that offers two choices to the users. The first button is to create reports and the other button is to update data.

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้



Picture 5.2 – Main menu screen

The “Create Reports” button is placed first in order to assist the non-technical group of management to spend the least effort to use this program. When a user presses this button, the next screen will come up with two groups of seven report buttons.



Picture 5.3 – Report menu screen

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

The first group of reports is about utilization of aircraft and engines while the other group of reports is about engine maintenance work and problems history.

The first button brings up the fleet status screen where the user needs to input a date to get the report that tells what engine is installed on what aircraft and what is its flying hours and cycles on that date.

Picture 5.4 – Fleet status screen

A/C	TT	TC	Pos.	ESN	TT	TC
HS-TXA	17998	7995	1	724001	12215	6791
			2	724002	10427	7578
HS-TXB	3238	1072	1	724051	3238	1072
			2	724052	3238	1072
HS-TXC	239	77	1	724105	239	77
			2	724106	239	77

Picture 5.5 – Fleet status report

The second button displays the aircraft utilization screen. On this screen, the user has two options to create the report. The first option is to create the utilization report of one aircraft within one-month period. The other option is to create the utilization report of all aircraft on one given date.

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า ไม่วิจารณ์ใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Aircraft Utilization Report

☒ All aircraft by date (mm/dd/yyyy)

☐ One aircraft by Month Year (yyyy)

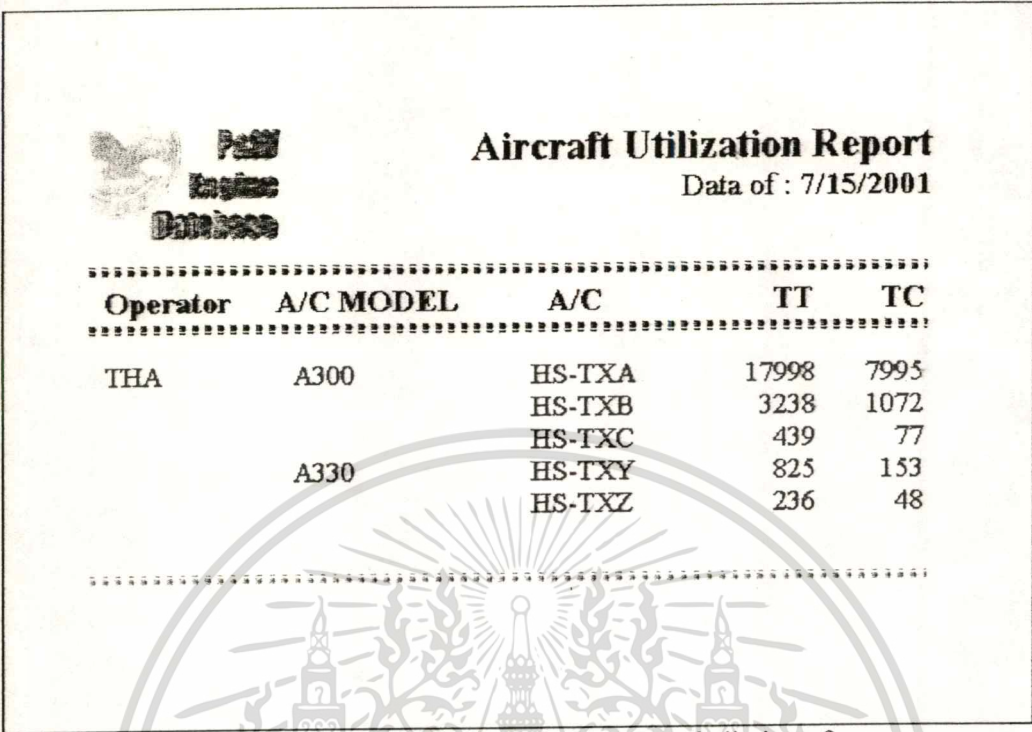
Picture 5.6 – Aircraft utilization screen

Aircraft Utilization Report
A/C Registration: HS-TXA
Data of: July 2001

Date	TT	TC	Date	TT	TC
1	17882	7947	17	18021	8004
2	17893	7952	18	18030	8007
3	17903	7955	19	18041	8012
4	17909	7957	20	18052	8017
5	17921	7960	21	18062	8021
6	17926	7962	22	18078	8026
7	17935	7966	23	18087	8029
8	17942	7970	24	18094	8032
9	17949	7973	25	18101	8035
10	17957	7975	26	18101	8035
11	17964	7979	27	18101	8035
12	17971	7982	28	18101	8035
13	17981	7987	29	18103	8036
14	17991	7991	30	18111	8041
15	17998	7995	31	18115	8045
16	18005	8000			

Picture 5.7 – Aircraft utilization report of one aircraft

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

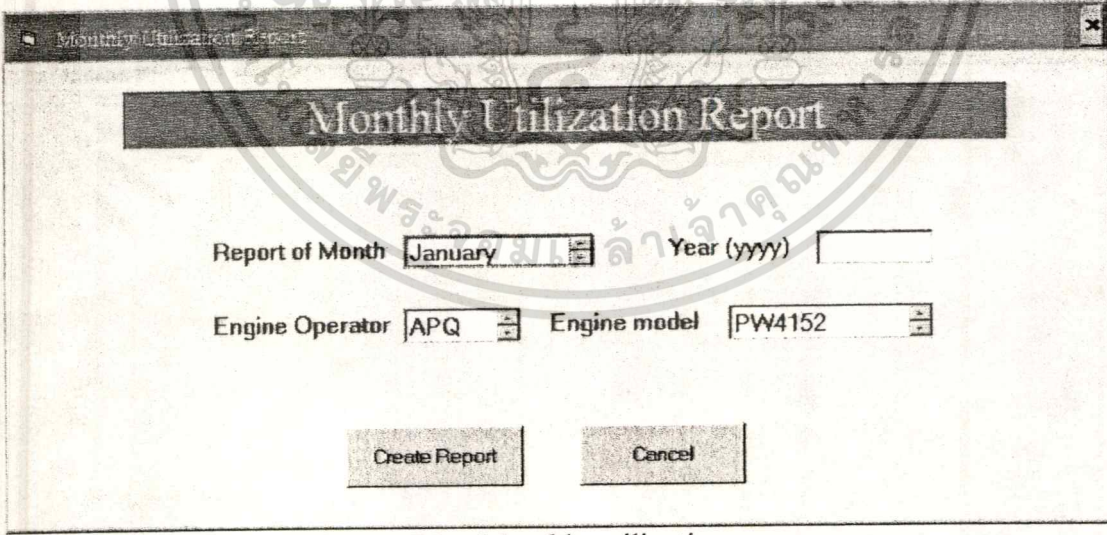


The screenshot shows a window titled 'Aircraft Utilization Report' with a date of 7/15/2001. It contains a table with columns: Operator, A/C MODEL, A/C, TT, and TC. The data is as follows:

Operator	A/C MODEL	A/C	TT	TC
THA	A300	HS-TXA	17998	7995
		HS-TXB	3238	1072
	A330	HS-TXC	439	77
		HS-TXY	825	153
		HS-TXZ	236	48

Picture 5.8 – Aircraft utilization report of all aircraft

The third button is for monthly utilization report of both aircraft and engines. The user just selects a month and an engine model then the system will show the report on the screen.



The screenshot shows a window titled 'Monthly Utilization Report'. It contains the following fields and buttons:

- Report of Month: Year (yyyy):
- Engine Operator: Engine model:
- Buttons:

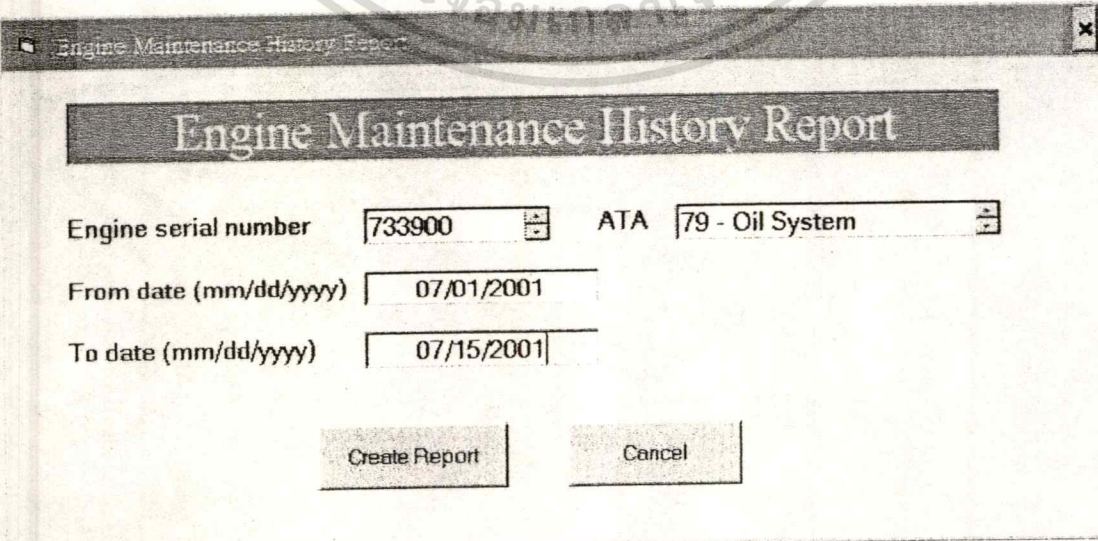
Picture 5.9 – Monthly utilization screen

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

 Thai Engine Database		Monthly Utilization Report Operator: THA Engine model: PW4158 Month of : July 2001			
A/C	TT	TC	Monthly Hours	Monthly Cycles	
HS-TXA	18115	8045	387	143	
724001	13124	6923	387	143	
724002	10645	7697	387	143	
HS-TXB	3487	1166	304	118	
724051	3487	1166	304	118	
724052	3487	1166	304	118	
HS-TXC	342	104	342	104	
724105	342	104	342	104	
724106	342	104	342	104	
Total A/C monthly utilization :			1033 hours	365 cycles	
Average A/C monthly utilization :			344 hours	122 cycles	
Total engine monthly utilization :			2066 hours	730 cycles	
Average daily engine utilization :			11.11 hours	3.92 cycles	

Picture 5.10 – Monthly utilization report

The fourth button generates engine maintenance history report. The user inputs a selected engine serial number, the first and the last dates, and, optionally, the ATA number. Then the system will show a list of related problems and maintenance tasks of that engine during that period.



Engine Maintenance History Report

Engine serial number ATA

From date (mm/dd/yyyy)

To date (mm/dd/yyyy)

Picture 5.11 Engine maintenance history screen

เอกสารนี้เป็นเอกสารที่สงวนลิขสิทธิ์สำหรับการใช้งานภายในเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Engine Maintenance History				
ESN: 724001 ATA: 77				
From : 07/02/2001 To : 07/08/2001				
Date	Flight	A/C	Engine TT	Engine TC
07/03/2001	TG102	HS-TXA	12065	6747
	Detail :	Oil leak from engine no. 1 air oil heat exchanger.		
	Action :	Air oil heat exchanger B-nuts tightened. Leak chk perf w/o remark		
07/04/2001	TG420	HS-TXA	12084	6753
	Detail :	Found engine 2 oil dirty at lower cowling.		
	Action :	Engine 2 crank was checked and no leak found. Lower cowling was cleaned.		
07/06/2001	MPC	HS-TXA	12113	6772
	Detail :	Engine 2 found oil leak from fan case at drain port under transfer gear box.		
	Action :	Replace oil tube at air oil heat exchanger. Engine run-up check was normal.		

Picture 5.12 – Engine maintenance history report

The fifth button is for engine reliability. When the user selects an engine serial number and inputs the start and the last dates of his interest, the system will list all delayed and cancelled flights relating to that engine.

Engine Reliability Report

Engine serial number

733900

From date (mm/dd/yyyy)

07/01/2001

To date (mm/dd/yyyy)

07/15/2001

Create Report

Cancel

Picture 5.13 – Engine reliability screen

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้



Engine Reliability Report

ESN: 724001

From : 07/02/2001 To : 08/01/2001

Date	Flight	A/C	Org	Dest	Result	Dly Hrs.	Min
07/03/2001	TG102	HS-TXA	BKK	CNX	TD	0	34
07/04/2001	TG420	HS-TXA	KUL	BKK	TD	1	12
07/23/2001	TG116	HS-TXA	BKK	HKT	TC	0	0
07/28/2001	TG124	HS-TXA	BKK	HDY	CNL	0	0
Total delay time :						1	46

Picture 5.14 – Engine reliability report

The sixth button brings up the service bulletin incorporation screen. The user inputs an engine model, a service bulletin number, and an engine serial number. Then the incorporation status will be displayed. If the user leaves engine serial number blank, the incorporation status of all affected engines will be shown.

Service Bulletin Incorporation Report

SB Incorporation Report

Engine model

SB No. - - -

Engine serial number

Picture 5.15 – Service bulletin incorporation screen

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้



Service Bulletin Incorporation

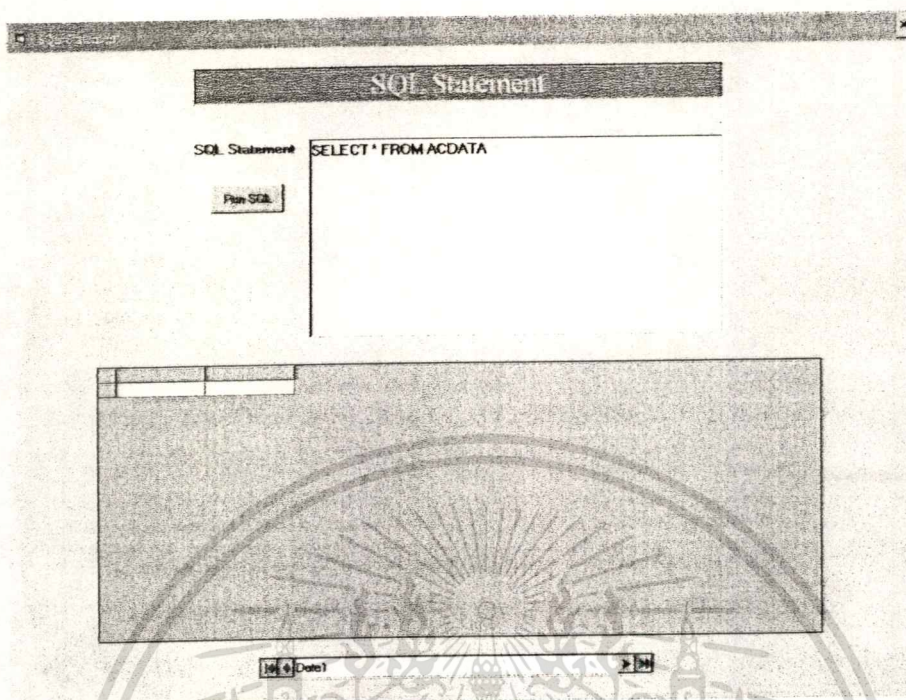
SB: PW4ENG-72-125

Engine model: PW4158 Operator: THA

ESN	Status	Incorp. Date
724001	F	3/2/2001
724002	F	3/2/2001
724051	P	3/27/2001
724052	P	3/27/2001
724105	NA	
724106	NA	
Total engines : 6		
Total affected engines : 4		
Total finished engines : 2		
Incorporation rate : 50%		

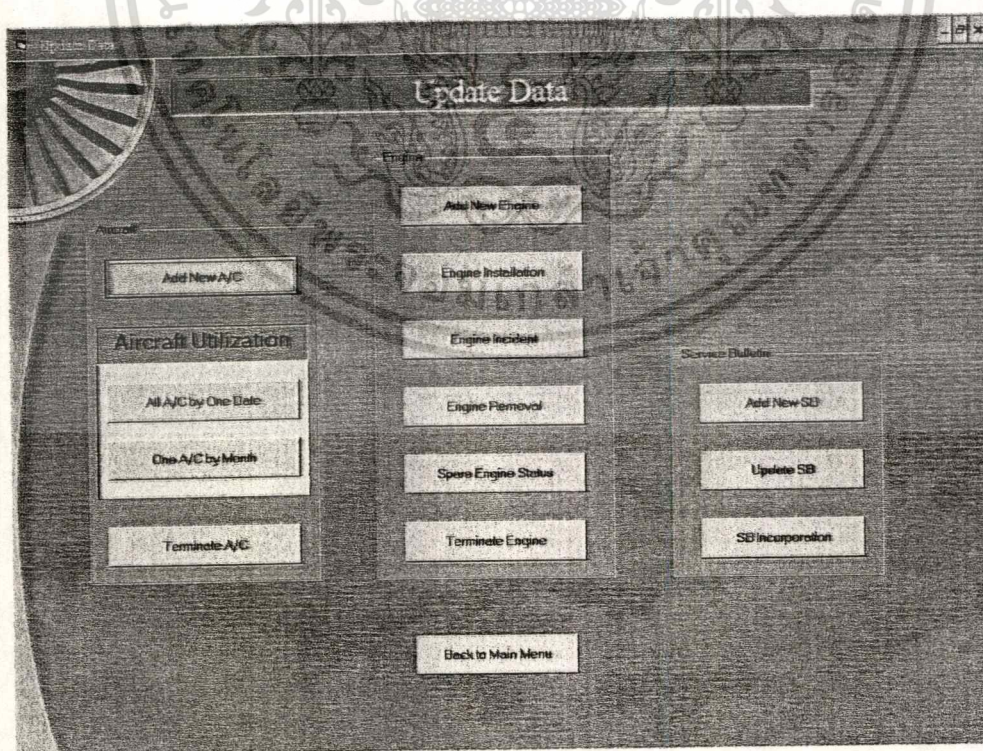
Picture 5.16 – Service bulletin incorporation report

The last button of the report screen is mainly dedicated to the data collector. Sometimes, the management may want to know a specific data from the database but such data is not available through the use of the previous six buttons. This “SQL Statement” button will provide a text box for the data collector to input an SQL statement to retrieve the specifically required data.



Picture 5.17 – SQL statement screen

These are all the screens for report generation mode. On the main menu screen, if the user presses the “Update Data” button, the next screen will provide him three groups of buttons for data manipulation.



Picture 5.18 – Update menu screen

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

The first group of buttons is about aircraft data update. The four buttons in this group are ordered by the sequence of the real aircraft maintenance cycle.

Start with “Add New A/C” button. This button will bring up a screen where the user can input a new aircraft data to activate the aircraft registration into the fleet.

Picture 5.19 – Add new aircraft screen

The second and the third buttons are for updating aircraft utilization. The user can select either to update the utilization data of one aircraft within one-month period or to update all aircraft utilization on a specific date. The former scenario is suitable when the data collector has not updated an aircraft utilization for several days and would like to update all data at once. The latter scenario is more appropriate when the data collector updates the utilization of all aircraft everyday.

Update Aircraft Utilization by Date

Update A/C Utilization by A/C Registration

* Red fields are optional

A/C Registration: Month: Year:

1	24879	11956	17		
2	24885	11960	18		
3	24894	11965	19		
4	24901	11969	20		
5	24908	11974	21		
6	24915	11978	22		
7	24922	11985	23		
8	24930	11990	24		
9			25		
10			26		
11			27		
12			28		
13			29		
14			30		
15			31		

Picture 5.20 – Aircraft utilization update screen. Update one aircraft in one month

Update Aircraft Utilization by Date

Update A/C Utilization by Date

* Red fields are optional

Date: Month: Year:

HS-TXA	24907	11976
HS-DXB	2564	1343
HS-DXC	879	427
HS-TXY	96	43
HS-TXZ	45	21

Picture 5.21 – Aircraft utilization update screen. Update all aircraft on one date

The fourth button is for aircraft termination. When an aircraft is retired from the fleet, the data collector will push this button to complete the aircraft record with termination data.

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Picture 5.22 – Aircraft termination screen

The second group of buttons relates to engine data. Like the first groups of buttons, these buttons are ordered by the sequence of activities that happen to an engine in the real world.

The first button is to add a new engine into the fleet. The record of a new engine will be input here with all necessary data for future reference.

Picture 5.23 – Add new engine screen

After a new engine record is available in the database, that engine is ready for installation on an aircraft. The second button will open a window for the data collector to record all details of an engine installation. ไม่นานพอที่จะนำไปใช้ประโยชน์ด้านการค้า ไม่ว่าจะเป็นใด ๆ ทั้งสิ้น อีกทั้งห้ามมิให้ตัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Picture 5.24 – Engine installation screen

While an engine is installed on an aircraft, it may experience some problems. The third button will show a screen to collect any flight delays and cancellation as well as details of the problems and the corrective actions.

Picture 5.25 – Engine incident screen

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

When an engine is removed from an aircraft, the data collector will press the fourth button to record the engine removal data. He can leave the repair shop and engine shipping details blank because this data is not available until the engine has been removed for few days and the engineer decides where to repair the engine and the planner plans when to ship the engine.

Picture 5.26 – Engine removal screen

However, when the engineer selects the engine repair shop and the planner schedules the shipment, the data collector can press the fifth button to add more details of the spare engine.

Picture 5.27 – Spare engine status screen

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า
ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

The life cycle of an engine will be stopped when the engine is retired from the fleet. The sixth button opens the window to complete engine termination data.

Picture 5.28 – Engine termination screen

The last group of buttons relates to service bulletin data. The first button of this group is for adding a new service bulletin data. The data collector needs to input all necessary details of a service bulletin into the database.

Picture 5.29 – Add new service bulletin screen

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Sometimes, a service bulletin may be revised. The data collector may press the second button to update the existing service bulletin data.

Picture 5.30 – Update service bulletin data screen

When an engine is incorporated with a service bulletin, pressing the third button will bring up the screen where the data collector can record the incorporation status of the engine.

Picture 5.31 – Service bulletin incorporation screen

5.2 System Programming

The user interface of this system is designed on the design screen of Visual Basic 6.0. The connection from the application to the MS-Access database is made through the Data Access Object technology (DAO), which has the Microsoft Jet Database Engine. All data control objects on the application screens such as text boxes, combo boxes, radio buttons, and check boxes, are bound to the relative database fields. The input data will be submitted from the application screens to be appended and updated in the database with the use of predefined SQL statements.

Then, the source data may need to be calculated by the program in Visual Basic 6.0.

ไม่ว่ากรณีใดๆทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Finally, the information is displayed on report screens that are created with the Data Report Designer, which is a tool to help design reports on Visual Basic.

The Data Report Designer works with Data Environment Designer. The Data Environment Designer makes connection to the database, retrieves and manipulates data. Then the data is displayed on the report that is designed with the Data Report Designer.



Chapter 6

Testing & Implementation

After the system is developed, it need to be tested to verify that it can work with no errors and the system is what the users need (validation.) The testing phase of this system is done at three levels: database testing, program testing, and system testing.

6.1 Database Testing

The database was tested with both correct and fault test data to ensure the errors were detected. Referential integrity was as well tested and found that the database successfully did not allow any deletion of a referenced record and an insertion or an update with references to non-existing data.

6.2 Program Testing

The programs of all objects in the application were tested to ensure they worked as expected and open the correct forms. The shortcut keys were tested in the same way and the tab index sequence on each form were examined as well to verify the user would get smooth transition from one control to another.

6.3 System Testing

Finally, the whole system was tested. Several parameters were input into the system to check whether it could calculate correctly and generated the desired reports. All tests are summarized in the table 6.1 below.

Table 6.1 – Test summary

Test type	Result	Remark
Database Test		
- Data types	Pass	
- Data ranges	Pass	
- Deletion anomalies	Pass	
- Insertion anomalies	Pass	
- Update anomalies	Pass	
Program Test		
- Tab index sequences	Pass	
- Shortcut keys	Pass	
- Data object functions	Pass	
System Test		
- Data update	Pass	
- Report generation	Pass	

6.4 System Implementation

This system is installed on the data collector's computer as planned. There were no problems found during the installation. However, the system will not yet be used in production. The plan to implement this system is to use it in parallel with the current systems. This new system will be proposed to the management level and the information technology team at the headquarters as a prototype for worldwide use. Hence, the implementation at Bangkok field office will be the test bed for the future implementation.



Chapter 7

Summary

This chapter will discuss the evaluation of the new system in three parts. Firstly, the values and benefits of the new system will be covered. Then, the problems that were found during the system development will be discussed. This chapter will be concluded with the recommendation for future improvements of the system.

7.1 Benefits

The first advantage that this new system has over the current system is the elimination of data redundancy. The new system uses the database as the single source of information. It gathers data that used to be in various MS-Excel spreadsheets into one place. This helps the data collector save his time to update data and reduce data inconsistency.

The second benefit of the new system is the ease of use. The user interface on the new application is user-friendlier than the old spreadsheet environment. The users just select what they want to do with data and the screens will guide them what to do. The data collector may need to learn more within a database environment but the ease of use is much improved in the view of the management because they can select reports they want and input their parameters to get the reports. They can get the required reports themselves with minimal assistance from the data collector.

The third benefit comes from the automatic calculation of engine status and utilization. Previously in the old system, if the management would like to know an engine status on a given date in the past, the data collector must track from the current status of the engine back to the required date. If the engine was rotated around few aircraft during the period, the calculation of an engine utilization on that date will be more complicated and error-prone. The new system takes over this manual calculation. It does not only automatically calculate the utilization and get the status of an engine, but it also provide the status of all engines in the fleet and show the report to help users see the fleet status of that date.

Last but not least, the new system database contains a great deal of data that is useful to the management. This database can be queried differently to yield different views or scenarios. The data collector no longer needs input the same pieces of data several times for different report layouts like before. With the new system, the data is more widely utilized with only single data entry.

7.2 Problem of the System Development

One problem that occurred during the implementation of the new system was the difficulty in data migration from the existing spreadsheets and other data sources into the new database. Even though MS-Access database has a feature to import data from MS-Excel spreadsheets, it only helps a little because the biggest part of the source data is the aircraft utilization since 1990 that is stored in Thai Airways' MOPS database. At the time of this report, the automatic link between these two databases is not possible due to no mutual agreement on data exchange policies of both organizations. Therefore, data migration may take a long time to be completed and make the new system fully launched in production environment.

7.3 Future Improvements

Because of the short period to develop this system, all possible features cannot be included in this version. The followings are additional features suggested for future improvements.

1. *Better user interface.* The system will be user-friendlier if the user interface is equipped with drag-and-drop capability. The main screen may come up with the current fleet status with a graphical layout that simulates an airport ramp with aircraft icons and their registration number. On each wing of an aircraft, there is an engine serial number to indicate what engine is installed on what aircraft. On one side of the screen located the areas of engine shop and engine store for spare engine icons. When an engine serial number is dragged from an aircraft and dropped at the engine shop block, the screen of engine removal will be launched for the user to fill out the removal data. Likewise, when an engine icon is dragged from the engine store to be dropped on an aircraft wing, the engine installation window will be displayed for data update. This drag-and-drop capability can better simulate the real movement of engine in the field and be an user-friendlier interface.

2. *Link to MOPS database.* Thai Airways' database is an important source of data. The direct link from MOPS database can eliminate the manual data entry process. This yields fewer errors and less time consumption.

3. *Expanded use of existing data.* The existing data can be further utilized in various reports. More queries can be created to match the users' needs. Graphical data presentations in forms of charts and summarized data are as well recommended.

Bibliography

- Dennis, A. and Wixom, B. H. 2000. **System Analysis and Design**. New York: John Wiley and Sons.
- Lockman, D. 1997. **Teach Yourself Oracle8 Database Development in 21 Days**. Indiana: Sams.
- Pratt & Whitney. 2002a. **Company Profile**. [Online]. Available: <http://www.pratt-whitney.com/2b/html/company-profile.html>.
- Pratt & Whitney. 2002b. **Fast Facts**. [Online]. Available: <http://www.pratt-whitney.com/3b/html/company-fastfact.html>.
- Rob, P. and Coronel, C. 2000. **Database Systems: Design, Implementation, and Management**. Massachusetts: Course Technology.
- กิตติ ภัคดีพัฒนกุล และจำลอง คุรุอุตสาหกรรม. 2544. **Visual Basic 6 ฉบับฐานข้อมูล**. กรุงเทพฯ: ไทยเจริญการพิมพ์.
- ฉันทวุฒิ พิษผล และพิชิต สันติกุลานนท์. 2544. **คู่มือเรียน Visual Basic 6**. กรุงเทพฯ: โปรวิชั่น.
- นันทนี แขวงโสภา. 2544. **อินไซต์ Visual Basic และ VB.NET ฉบับ Database**. กรุงเทพฯ: โปรวิชั่น.
- พัฒนพงศ์ พันธะดิวงค์. 2545. **การเขียนโปรแกรมคอมพิวเตอร์ด้วย Visual Basic**. กรุงเทพฯ: ซอฟท์เพรส.
- วุฒิพงศ์ พงศ์สุวรรณ และคณะ. 2543. **How to Learn Visual Basic 6.0**. พระนครศรีอยุธยา: ซอฟต์แวร์ ปาร์ค.
- ศุภชัย สมพานิช. 2545. **สร้างระบบงานฐานข้อมูลด้วย Visual Basic ฉบับปรับปรุง**. นนทบุรี: อินโฟเพรส.
- ฮาลเวอร์สัน, ไมเคิล. 2542. **Microsoft Visual Basic Professional 6.0 Step by Step**. แปลโดย สุทธา ศรีวิจิตรจารย์. กรุงเทพฯ: ซีเอ็ดยูเคชั่น.

Writer's Profile

Chaiwat Kunpanichanan graduated in 1995 from the faculty of Liberal Arts, Thammasat University, majoring in English. He worked at Kodak (Thailand) Ltd. as an Inventory Planning Assistant before moving to Air France as a Cargo Handling Personnel.

In 1998, he started working for Pratt & Whitney as the Data Collector who handled the engine maintenance data and was responsible for computer system maintenance at Pratt and Whitney's Bangkok field office.

Currently, he is working as the Associate Customer Service Representative and pursuing a Master's degree in Information Technology Management at King Mongkut's Institute of Technology Ladkrabang.

