



Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation External Investigation – AE-2010-098

Final

**External Assistance to Recreational Aviation Australia –
Fuel Management System Data Recovery
19-4024 Supermarine Mk26, Spitfire Replica**



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Australia – Fuel Management System Data
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Assistance provided by Motec Pty Ltd during the course of the investigation.

Abstract

On 22 October 2010, a replica Supermarine Spitfire MK26 recreational/light sport aircraft (registered 19-4024) collided with terrain near Gympie authorised landing area (ALA), fatally injuring the pilot. Recreational Aviation Australia Inc (RA-Aus) is assisting the Queensland Police in their investigation of the occurrence.

On 17 November 2010, RA-Aus requested technical assistance from the Australian Transport Safety Bureau (ATSB) for the recovery of data from an engine management system (EMS) module recovered from the accident site. To protect the information supplied by RA-Aus and the investigative work undertaken, the ATSB initiated an investigation under the Transport Safety Investigation Act 2003.

Due to the damage to the EMS and the lack of configuration information, the recovery involved extracting the data from the electronic memory components and, using example data provided by the EMS manufacturer, converting the binary extracted data into engineering units.

The full converted data set was provided directly to RA-Aus investigators. This report represents an outline of the process undertaken and a summary of the data obtained.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes appropriate, or to raise general awareness of important safety information in the industry. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

FACTUAL INFORMATION

Introduction

On 22 October 2010, a replica Supermarine Spitfire MK26 recreational/light sport aircraft (registered 19-4024) collided with terrain near Gympie authorised landing area (ALA), fatally injuring the pilot. Recreational Aviation Australia Inc (RA-Aus) is assisting the Queensland Police in their investigation of the occurrence.

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Engine management system (EMS)

Unit details

Manufacturer: MoTeC Pty Ltd

Model: M600 (Figure 1)

Serial number: 13001-03515

Figure 1: Motec M600 Engine Management System provided to the ATSB



Damage to the unit

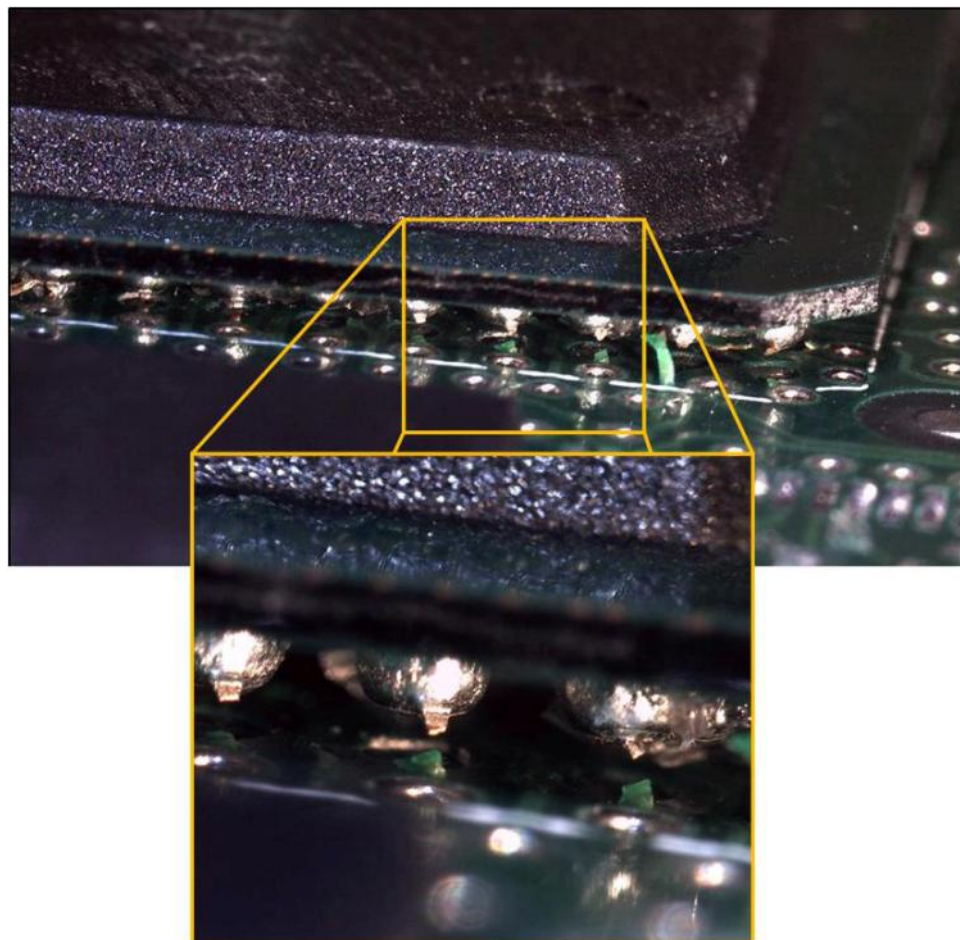
The aluminium case of the unit was visibly deformed (Figure 2). An internal examination revealed that the majority of the electronic components were in good condition: however, as a consequence of the forces exerted on the board, the main

electronic control unit (ECU) device had lifted from the circuit board. Closer inspection revealed that the pads from the board were lifted with the ECU (Figure 3). Given this damage, the manufacturer advised that a normal download would not be possible.

Figure 2: Motec system with visible deformation



Figure 3: Image of the lifted ECU and zoom of damage to the pads and circuit board



Data recovery

Recovery plan

A data recovery plan was developed in consultation with the manufacturer. The plan comprised the physical recovery of the data and the subsequent decoding of this data into engineering parameters by writing the raw data to a new circuit board and completing a conventional download.

In the event that this method was unsuccessful, a process for reverse engineering was planned to be undertaken, using control data provided by the manufacturer.

Physical data recovery

The manufacturer advised that the logged data was stored in the flash memory device identified in Figure 4¹.

A procedure was developed for the removal of the flash memory device from the damaged circuit board. The procedure involved the removal of the conformal board coating as per the manufacturer's instructions, then the removal of the flash memory from the circuit board using a hot-air rework station² in accordance with IPC³ standard 7711/21B-K⁴. Following this, the data was to be downloaded from the flash device via a universal flash memory reader⁵.

The procedure was tested successfully on an example circuit board provided by the manufacturer. The physical recovery was then performed on the accident board and the binary data was recovered successfully on 2 May 2011.

¹ The flash device is ST Microelectronics, part number M29F080D, density of 8 Mbit (or 1 MB).

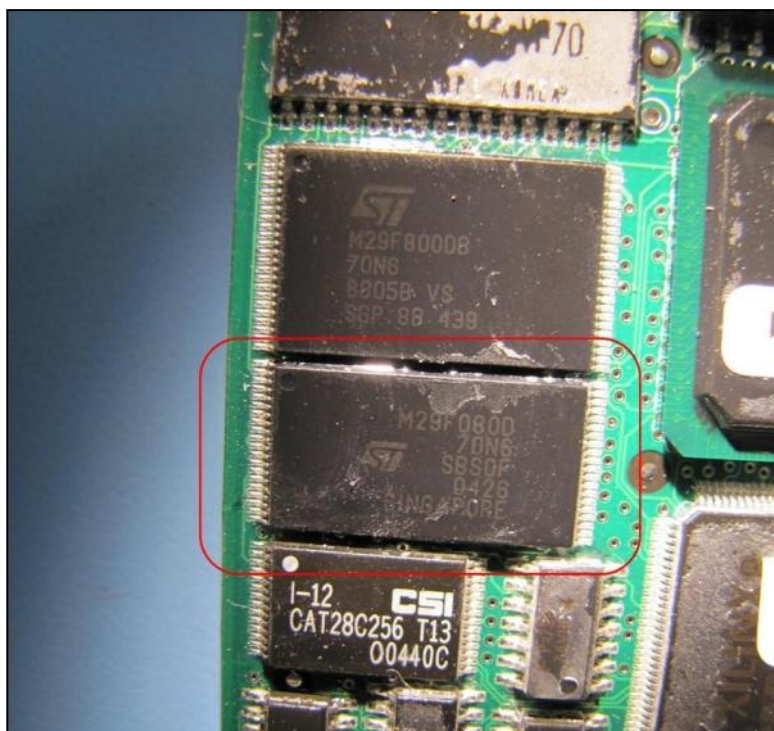
² The ATSB uses a Hakko FR803-B hot air rework station.

³ Association Connecting Electronics Industries (formerly Institute of Interconnecting and Packaging Electronics Circuits)

⁴ 7711/21B-K: Rework, Modification and Repair of Electronic Assemblies.

⁵ The ATSB uses a Xeltek SuperPro 5000 reader/programmer.

Figure 4: Section of MoTeC M600 circuit board (memory device with logged data indicated by red rectangle)



Decoding of engineering parameters

The EMS unit manufacturer advised that the most appropriate method to recover the data directly into engineering parameters was via a conventional download using the user interface of the EMS system. To perform this, it was planned that the recovered data would be written to another serviceable unit and, using a configuration file for the engine, downloaded using the user interface and software.

The manufacturer stated that the configuration file, which determined the parameters logged and their frequency, would need to match the recorded data exactly for the download to complete.

Rather than mount the accident flash memory device on a new memory board, in order to minimise the risk to the original flash memory device, data was written to an identical flash memory device and checked for consistency. This device was sent to the manufacturer for mounting on another serviceable board.

On 8 June 2011 the manufacturer installed the identical flash memory device onto an appropriately tested serviceable unit and attempted a download using the configuration file (V6 3.5l Spitfire engine early std inj 50psi fuel pres.e23) provided by the engine tuner. The download was not successful and the manufacturer was unable to retrieve the engineering data log file.

It was later determined that the configuration file provided by the engine tuner did not match the format of the data on the device. This was the likely explanation for the unsuccessful download attempted by the manufacturer.

Reverse engineering of recording method

Due to the unsuccessful download attempt, a reverse engineering process of the data recording method was undertaken to decode the key engine parameters.

To assist the ATSB, the manufacturer recorded some simulation data and provided to the ATSB the log of the data and the flash memory device containing the binary data.

Through examination of the supplied data, the following recording method information was determined:

- logged data was recorded consecutively as 16 bit words
- the simulation data was recorded at sample rates of 1, 2, 5 or 10 Hz defined by the configuration file
- the order of the recorded parameters was a combination of the EMS priority listing and the sample rate
- there were no parameter names or time parameters recorded
- the number of parameters recorded (as per the configuration file)
- some parameters required scaling by factors of 1/10, 1/100 or 1/1000
- the most highly sampled (10 Hz) parameters were identified as engine revolutions per minute (RPM), manifold pressure, and throttle position.

Application to the recovered data

The recovered binary data was similar to the simulated data recording, however there were some differences. The following key differences were identified in respect of the recovered (accident) data:

- the highest sample rate was 20 Hz
- the parameters recorded were not identical.

These differences implied that the configuration of the EMS unit used to collect the simulation data was different to that used on the accident aircraft EMS. This introduced a level of uncertainty in the identification of parameters, and meant that direct analysis of the raw unscaled data would be required to determine the represented parameters and the appropriate scaling.

Despite the EMS configuration differences identified, examination of the data did reveal that there were 36 parameters recorded at various sampling rates (Table 1). Using this information, the total number of 16 bit words in 1 second was calculated:

$$(1 \times 18) + (2 \times 4) + (5 \times 7) + (10 \times 4) + (20 \times 3) = 161$$

This enabled the data to be broken up into one second frames and provided a method for determining elapsed time. Accordingly, the total recording was 3,119 seconds long (approximately 52 minutes).

Table 1: Number of parameters recorded at a sample rate

Sample Rate (Hz)	Number of Parameters
1	18
2	4
5	7
10	4
20	3

The raw, unscaled data was exported into a table and was provided to RA-Aus.

ANALYSIS

Determination of key engine parameters

Although the sample rate was different, the most highly sampled parameters from the simulated data showed a correlation with the most highly sampled parameters from the recovered data.

Further analysis corroborated this view, with the following supporting evidence:

- the values for all three parameters were in the correct ranges when scaled appropriately
- the parameters related to each other in an expected, regular manner
- at elapsed time 2,115 seconds, the throttle parameter was recorded at 100% for 24 seconds, which would correspond with take-off power being selected

Although the ATSB has a high level of confidence in the attribution of these parameters, this data, being unverified, should be confirmed with the engine tuner or against previous logs from the aircraft if attainable during the investigation.

The complete decoding/detection/deciphering of the parameters was outside the scope of the ATSB assistance to the investigation.

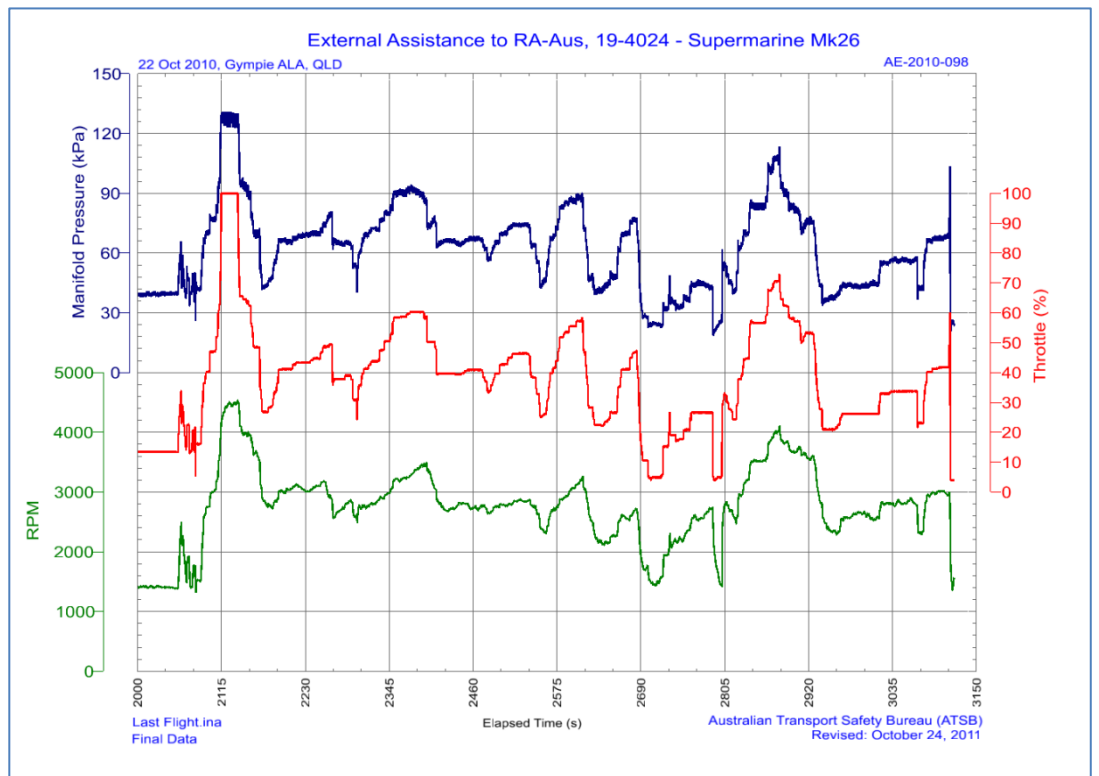
Tabular data of these scaled parameters was provided to Recreational Aviation Australia (RA-Aus).

Length of final flight

On the basis of the identified parameters, one takeoff was identified in the data (Figure 5), at approximately 2,115 seconds elapsed time. This was characterised by the recording of 100% throttle for 24 seconds.

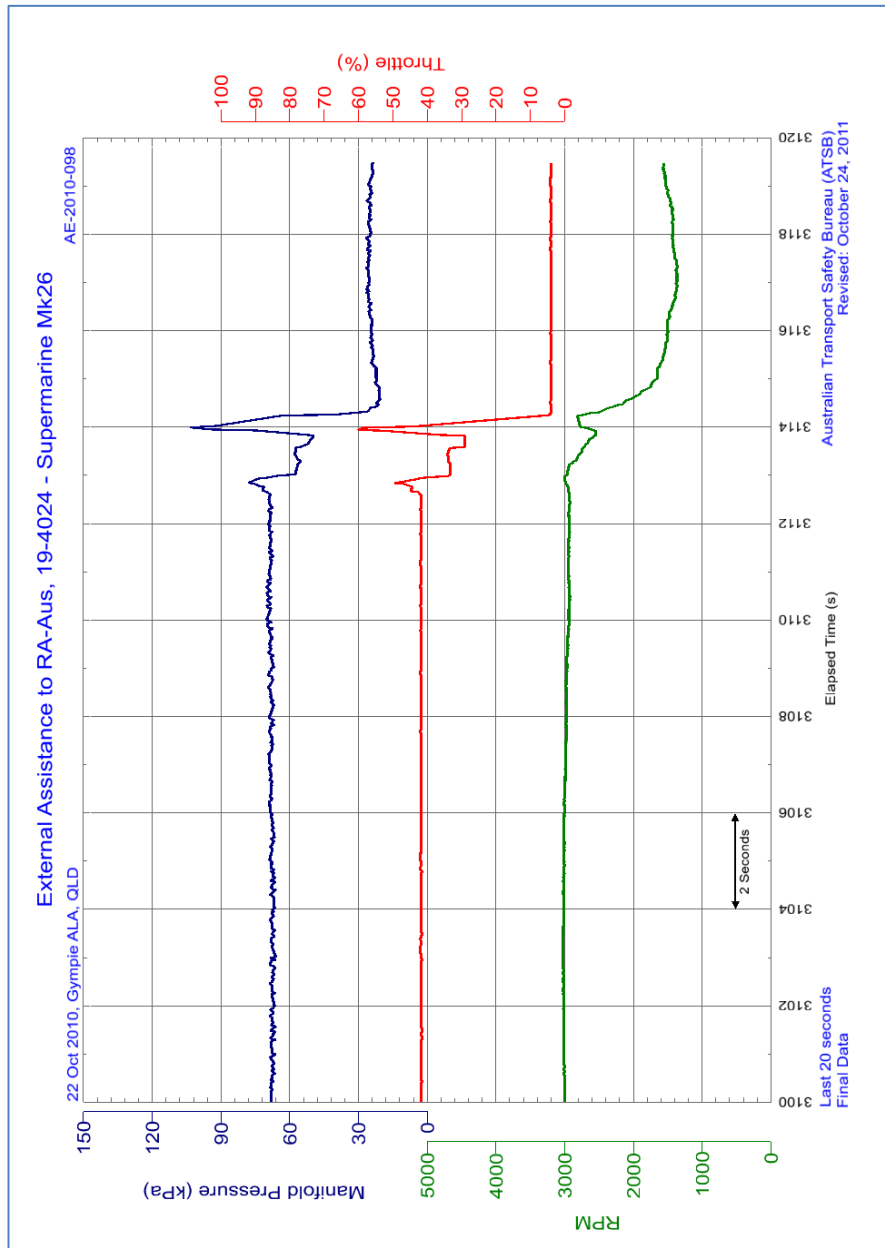
The elapsed time between the takeoff and the end of the data was 1004 seconds (16 minutes and 44 seconds) and the end of the flight is the end of the recorded data recovered.

Figure 5: Flight identified in the data



The flight ends with an abrupt reduction in throttle (Figure 6) with a corresponding reduction in RPM and Manifold pressure. Due to the lack of data from previous flights, it was not possible to determine if this was in line with normal operation for the given phase of flight.

Figure 6: Last 20 seconds of recorded data



CONCLUSIONS

The following conclusions were made in relation to the engine management system (EMS) data recovered:

- 3,119 seconds of data was recovered
- 36 parameters were recorded
- no time or date parameters were recorded
- no parameter names were recorded in the data
- the likely values of revolutions per minute (RPM), manifold pressure and throttle position were determined during the analysis
- on the basis of the above engine parameters it appears as though only one flight was recorded in the data
- the recorded flight was 16 minutes, 44 seconds long.

APPENDIX A: ACKNOWLEDGMENTS

Assistance provided by the manufacturer

The EMS manufacturer provided the following assistance to the investigation:

- information on the function of the damaged components and the operability of the damaged EMU
- location of the memory components used to store the logged engine data
- assistance to the development of the physical recovery procedure
- an example circuit board in order to test the physical recovery procedure
- a copy of the software to view the configuration and data from the EMS analysing the log files
- simulated data and associated log file for reverse engineering of the data recording method.