Chapter 2
Factual Description of Accident and Available Information

The detailed chronological factual statement of known information about flight MH370 is given at [35]. A brief summary is given here sufficient to put the analysis in the rest of the book in context.

On 7 March 2014 at 16:42, flight MH370 departed from KL bound for Beijing; this is marked as event 1 in Fig. 2.1. Initially, everything about the flight proceeded as normal. The Mode S transponder system on-board the aircraft was responding as expected to interrogation from the ATC Secondary Surveillance Radar up to the time when it was lost on the ATC radar screen at 17:21:13, marked as event 4. No message was received from the aircraft to report a system failure. Similarly the on-board Aircraft Communications Addressing and Reporting System (ACARS) reported as expected at 17:07:29, this event is marked as 2 in Fig. 2.1. This message contained a collation of six reports generated at five minute intervals by the system from 16:41:43 until 17:06:43. These reports contained information about the aircraft position and motion such as latitude, longitude, altitude, air temperature, air speed, wind direction, wind speed, and true heading. The ACARS position reports are scheduled to be transmitted at thirty minute intervals during cruise. The next scheduled report at 17:37 was not received. The last recorded radio transmission with the crew of MH370 occurred at 17:19:30 as the aircraft was instructed to contact Vietnamese ATC on leaving the Malaysian Flight Information Region. This communication is marked as event 3. At 17:39:06 Vietnamese ATC contacted KL ATC to query the whereabouts of MH370, who initiated the efforts of several countries' ATC to establish the location, without success. Malaysian military radars were subsequently able to show primary radar returns associated with MH370 deviating from the flight plan almost immediately after the loss of Secondary Surveillance Radar at 17:21:13 by making a left turn to end up travelling in a South Westerly direction. Radar returns show the aircraft travelling back across Malaysia before turning near Penang Island and travelling in a North Westerly direction up the Straits of Malacca. The final primary radar return was recorded at 18:22:12, which is marked as event 5 in Fig. 2.1.

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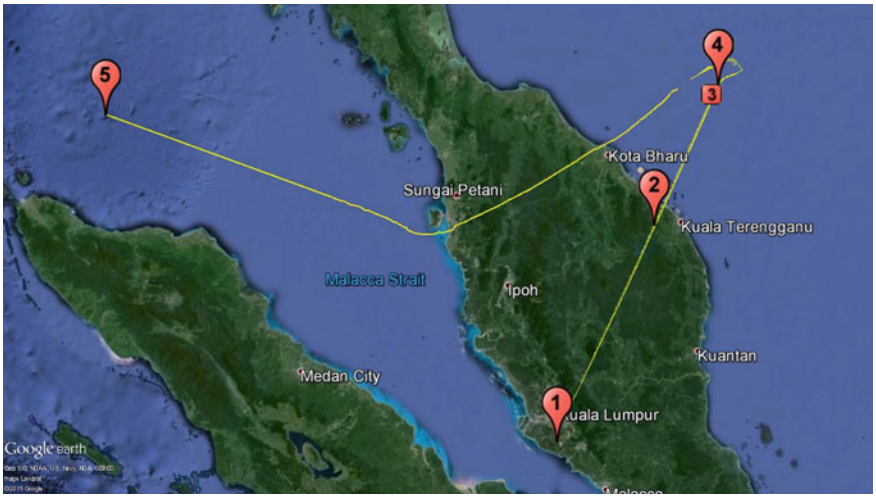

Fig. 2.1 Chronological sequence of events in MH370 disappearance. *1* = Take off; *2* = Final ACARS transmission; *3* = Final radio contact; *4* = Final Mode S transmission; *5* = Final primary radar detection

The ACARS system also provides message communication between the aircraft and its ground base. At 18:03:23 Malaysian Airlines Operations Centre sent a message asking the crew to contact Vietnamese ATC immediately. The downlink message showed that this failed to reach the aircraft. The message was auto transmitted every two minutes until 18:43:33 with no success [35]. The next communication on the SATCOM system was a log-on request from the aircraft at 18:25. This communication contains no location information from the aircraft but it does however contain timing and frequency metadata which turn out to be crucial in estimating where MH370 went after the final radar return at 18:22:12. The timing measurement is called the Burst Timing Offset (BTO) and the frequency measurement the Burst Frequency Offset (BFO). At 18:39:52 there was an unanswered attempt to call the aircraft from ATC on the ground to air telephone link. The failed communication data log contains frequency but not timing metadata.

If there has been no SATCOM activity for sixty minutes then the ground station automatically initiates a handshake confirming presence of the aircraft. If the aircraft receives this query then an automatic response is sent indicating that it is still logged on to the SATCOM network. These handshake responses contain both timing and frequency metadata. Handshake messages occurred at 19:41:00, 20:41:02, 21:41:24 and 22:41:19. At 23:15:58 there was a second unanswered attempt at a satellite telephone call, again giving frequency metadata. There was a ground station initiated handshake at 00:10:58 (timing and frequency metadata). Finally, at 00:19:29 the aircraft SATCOM system initiated another log-on request and this was the last SATCOM transmission received from the aircraft. Due to its timing, this log-on request is believed to correspond to fuel exhaustion and subsequent

Table 2.1 Summary of SATCOM data available for MH370

Event	Time (UTC)	BTO	BFO
Aircraft departed KL	16:42	Y	Y
Last ACARS transmission	17:07	Y	Y
AES initiated log on	18:25	Y	N*
AES access request	18:28	Y	Y
Unanswered ground to air telephone call	18:39	N	Y
GES initiated handshake	19:41	Y	Y
GES initiated handshake	20:41	Y	Y
GES initiated handshake	21:41	Y	Y
GES initiated handshake	22:41	Y	Y
Unanswered ground to air telephone call	23:15	N	Y
GES initiated handshake	00:10	Y	Y
AES initiated logon	00:19	Y	N*

Measurements marked with an *asterisk* are available but cannot be used as discussed in the text

activation of the auxiliary power unit [5]. There was no response to the ground station initiated handshake request at 01:15:56. The log-on messages at 18:25 and 00:19 contain BFO measurements but the equipment was not in steady state. The values of the BFO measurements were deemed to be unreliable at these times and cannot be used.

The key pieces of information available to us to estimate the MH370 flight path are the final radar detection at 18:22:12 and the timing and frequency metadata associated with the infrequent SATCOM messaging that subsequently occurred up until 00:19. Table 2.1 summarises the available measurement data. The messages at 18:25 and 00:19 occurred during transient phases of operation for the SATCOM equipment so the BFO values reported for these times cannot be used. In the next two chapters we describe the Bayesian approach, and then how the satellite communication system works and how the timing and frequency metadata can be related to aircraft location, allowing us to build a likelihood function for our Bayesian analysis.