Review of the ANSV Linate Accident Report

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Overview of the Project

This document is the first report from a review of the Linate accident. The analysis will concentrate on the ANSV report and investigation. The aims of this work are to: 1. to show how the existing recommendations relate to the root causes identified in the existing report. 2. to use recognised accident analysis techniques to identify additional recommendations that might be derived from this accident. 3. to review the existing ANSV report, if necessary, to extend the scope of objective (2).

Executive Summary of this Report

The following pages document the output from an initial analysis of the ANSV report. The investigation began by first constructing a detailed timeline of the events leading to the collision. The ANSV perform a valuable service in promoting the cause of Safety Management Systems but arguably could go further in looking at the specific lessons that Linate offers for the operation of those systems in the future. Any risk-based decision to continue operations must consider not only the likelihood of an accident occurring, for instance under reduced visibility conditions. It must also consider the likelihood of successfully coordinating any emergency activities should an adverse event occur. We show that many of the ANSV's recommendations focussed on establishing conformance with national and international regulations. They also provided high-level guidance on the development of safety management systems. In contrast, we focus on the reasons why the runway and taxiway markings did not conform to ICAO and other requirements. Similarly, we examined the reasons why the Cessna was 'allowed' to fly under low visibility conditions. We also look at the technical and organisational reasons why ATM personnel failed to curtail operations as they faced worsening meteorological conditions and rising workload with minimal ground based technical support. The closing sections analyse the reasons why an inadequate emergency response placed additional lives at risk, including those of other aircrews, passengers and the rescue services.

Twenty-five additional recommendations are proposed from the Linate runway incursion.

Introduction

In the EUROCONTROL Strategic Safety Action Plan (SSAP) framework, informal and more formal reviews of the ANSV Linate Accident Report have been carried out in order to identify safety improvement that might not have emerged from the initial investigation. This report documents a detailed review of the ANSV report by an independent team of accident investigators. The key objectives for this study are:

> *1. to show how existing recommendations relate to root causes identified in the existing report.* The main focus will be to use Events and Causal Factors diagrams to draw out the root causes from the report and then to relate them to the recommendations. This choice of this method is justified because it provides relatively accessible diagrams that can readily be inspected to trace the information in the report back to particular recommendations. EUROCONTROL has used similar diagrams to model human error and systems failure in ATM incidents, for example in HUM.ET1.ST13.3000-REP-02 Human Factors in the Investigation of Accidents and Incidents.
>
> 2. *to use recognised accident analysis techniques to identify further recommendations from this accident.* The ECF model developed in the previous stage of analysis can also be used to help identify additional recommendations. This will be done using the associated reasoning techniques that are part of this method. Additional root causes can be identified by examining each element of the diagram and asking whether or not the accident could have been avoided if that event had not occurred. If the answer is yes then the event or condition becomes a candidate for further inspection.

The ANSV report into the Linate runway incursion and collision identified a number of "immediate and systemic" causes for the accident. These can be summarised as follows, all page numbers in the remainder of this report refer to the official ANSV English language translation of the original Italian report. The ANSV report does not distinguish immediate from systemic. These annotations form part of our subsequent analysis. The numbering system has also been introduced to help this study:

- (Cause 1 - Immediate) "the visibility was low, between 50 and 100 meters". (ANSV page 162)
- (Cause 2 - Immediate) "the traffic volume was high". (ANSV page 162)
- (Cause 3 - Systematic) "the lack of adequate visual aids". (ANSV page 162)
- (Cause 4 - Immediate) "the Cessna crew used the wrong taxiway and entered the runway without specific clearance". (ANSV page 162)
- (Cause 5 - Systematic) "the failure to check the Cessna crew qualification". (ANSV page 162)
- (Cause 6 - Immediate) "the nature of the flight might have exerted certain pressure on the Cessna crew to commence the flight despite the prevailing weather conditions". (ANSV page 162)
- (Cause 7 - Systematic) "the Cessna crew was not aided properly with correct publications (AIP Italy-Jeppsen) lights (red bar lights and taxiway lights), markings (in deformity with standard format and unpublished, S4) and signs (non-existing, TWY R6) to enhance their situational awareness". (ANSV page 163)
- (Cause 8 – Immediate/Systematic) "Official documentation failed to report the presence of unpublished markings (S4, S5 etc) that were unknown to air traffic managers, thus preventing the ATM staff from interpreting the ambiguous information from the Cessna crew, a position report mentioning S4 ". (ANSV page 163)

- (Cause 9 - Immediate) “radio communications were not performed using standard phraseology (read back) or were not consistently adhered to (resulting in untraced misunderstandings in relevant radio communications)”. (ANSV page 163)

- (Cause 10 – Immediate/Systematic) “operational procedures allowing high traffic volume (high number of ground movements) in weather conditions as were current the day of the accident (reduced visibility) and in the absence of technical aids”. (ANSV page 163)

- (Cause 11 - Immediate) “radio communications were performed in Italian and English language”. (ANSV page 163)

- (Cause 12 - Immediate) “ATC personnel did not realize that Cessna was on taxiway R6”. (ANSV page 163)

- (Cause 13 - Immediate) “the ground controller issued a taxi clearance toward ***Main apron*** although the reported position **S4** did not have any meaning to him”. (ANSV page 163)

- (Cause 14 - Systematic) “instructions, training and the prevailing environmental situation prevented the ATC personnel from having full control over the aircraft movements on ground”. (ANSV page 163)

The ANSV also identified the following causes. These are contained in a separate list from those that the ANSV recognize as being either “immediate” or “systemic”. We would argue that these causes are, in contrast, more organizational in nature:

- (Cause 15 - Organizational) “the aerodrome standard did not comply with ICAO Annex 14; required markings lights and signs did not exist (TWY R6) or were in dismal order and were hard to recognize especially under low visibility conditions (R5-R6), other markings were unknown to operators (S4)”. (ANSV, page 163)

- (Cause 16 - Organizational) “no functional Safety Management System was in operation”. (ANSV, page 163)

- (Cause 17 - Organizational) “the competence maintenance and requirements for recent experience for ATC personnel did not comply fully with ICAO Annex 1.” (ANSV, page 163)

- (Cause 18 - Organizational) “The Low Visibility Operations (LVO) implementation by ENAV (DOP 2/97) did not conform with the requirements provided in the corresponding and referenced ICAO DOC 4976.” (ANSV, page 163)

The first stage of our analysis was intended to determine the relationship between this causal analysis and the 18 recommendations that were collated in the ANSV report. Table 1 provides an overview of the results from an initial analysis. It also documents the organisations that each recommendation was directed at. As can be seen, the initial list of 18 recommendations that are listed in the ANSV report can be further subdivided. For example, recommendation ANSV-1/113/15/A/04 was addressed to the Italian Ministry of Internal Affairs and to ENAC. It contained subsections that were given the identifiers from 1) through to g). In order to assess which of the causes were addressed by each recommendation, the following analysis treats each of these sub-parts separately. This yields a total of 36 different interventions identified by the ANSV.

Most of the recommendations are directly related to the organisational causes identified in the ANSV report. For instance, the recommendation ANSV-1/113-7/A/04 was made to the Ministry of Infrastructure and

Transport urging them to work towards the implementation of the European Action Plan for the prevention of runway incursions. This address organisational causes 15 and 16. The aerodrome standard did not comply with ICAO Annex 14 and there was no functional Safety Management System in operation at the Aerodrome at the time of the accident. This example also illustrates the types of inference that must be made when conducting the analysis that is documented in Table 1. In common with most accident reports, there is no explicit attempt to explain the relationship between the causal analysis and the proposed recommendations. Similarly, recommendation ANSV-20-113-4/A/02 was addressed to ENAC and ENAV SpA. It urged increased training and recurrent training for ATM officers. This can be related back to organisational cause 17 "the competence maintenance and requirements for recent experience for ATC personnel did not comply fully with ICAO Annex 1" bit also to systematic cause 14 "instructions, training and the prevailing environmental situation prevented the ATC personnel from having full control over the aircraft movements on ground".

Some of the recommendations are more narrowly focused at the immediate causes of this accident. For instance, the recommendation to standardize the use of English and to follow standard read back procedures are documented in ANSV-17/113-1/A/02. These simply reiterate requirements that should have been recognized before the accident but had been eroded or neglected by the time of this collision. They address specific problems that contributed to the collision rather than the more deep lying systemic or organizational failures that led to the accident. In this case, the recommendation to use English relates to immediate cause 11; "radio communications were performed in Italian and English language". The recommendation to use standard read back procedures relates to immediate cause 9; "radio communications were not performed using standard phraseology (read back) or were not consistently adhered to (resulting in untraced misunderstandings in relevant radio communications)".

Several recommendations do not relate directly to the immediate, systematic or organisational causes identified in the ANSV report. This can be explained in a number of ways. For instance, ANSV-1/113-17/A/04 focuses on the need to better coordinate the emergency response at this aerodrome. Almost half (17 of 36) of the recommendations are directed at post-accident events. This is surprising and can be explained in two ways. Firstly, the distribution of recommendations illustrates the degree of confusion that existed as the Tower and the Fire Service personnel struggled to find out whether there had been a crash and then where the wreckage was located. This confusion stemmed from meteorological conditions and the reduced visibility but was compounded by technical failures in the provision and design of communications equipment as well as organisational failures. The high proportion of post-accident recommendations in the ANSV report also arguably reflects the risk-based approach that seems to dominate the work of this investigation team. Approximately half of the recommendations are intended to reduce the likelihood of similar events occurring in the future. The remaining recommendations are intended to mitigate the consequences of an adverse event should there be any recurrence.

There are some similarities between the ANSV recommendations and those of the BFU in the aftermath of the Ueberlingen accident. For instance, the BFU recommendation 09/2004 focuses on the need to improve audio recording of ATM workstations to support accident investigation. BFU recommendation 13/2004 urges the Swiss Federal Office for Civil Aviation to meet the EUROCONTROL recommendations for data capture and the reconstruction or replay of adverse events and near miss incidents. The ANSV recommendation 1/113-12/A/04 urges the national authorities to petition ICAO so that cockpit voice recorders should be carried in all aircraft under Air Operators Certifications. Such recommendations cannot be directly related to the causes of the accident but are formed in response to problems during the investigation itself.

Reference and Date	No.	Recommendation To	Summary of Recommendation	Cause Addressed?
(9/6/02) ANSV-17/113-1/A/02	1	ENAC and ENAV SpA	ICAO recommendations on use of English language should be enforced.	11:Immediate.
	2		ICAO standard read back procedures should be enforced.	9:Immediate
	3		Enforce new ICAO recommended procedure for explicitly stating runway when crossings are involved.	9:Immediate 13:Immediate
(9/6/02) ANSV-18/113-2/A/02	4	ENAC	Check state of visual aids for all domestic airports and taxi procedures against AIP.	3:Systematic 7:Systematic 8:Immed/System
(9/6/02) ANSV-19/113-3/A/02	5	ENAC and ENAV SpA	Ensure reporting of safety incidents or abnormal operations.	16:Organizational
(9/6/02) ANSV-20/113-4/A/02	6	ENAC and ENAV SpA	Increased training and recurrent training for ATC officers.	17:Organisational 14:Systematic
(9/6/02) ANSV-21/113-5/A/02	7	ENAC and ENAV SpA	Follow ICAO Aerdrome Design Manual for naming of all movement areas.	7: Systematic 8:Immed/System 15:Organisational
	8		Stop bar lights must be controlled by GND controllers.	3: Systematic 7:Systematic 15:Organisational
(9/6/02) ANSV-22/113-56A/02	9	ENAC and ENAV SpA	Apply same regulations from commercial aircraft to all Low Visibility Operations	4: Immediate 6:Immediate
(20/1/04) ANSV-1/113-7/A/04	10	Ministry of Infrastructure and Transport	Work to implement European Action Plan for Prevention of Runway Incursions	15:Organisational 16:Organisational
(20/1/04) ANSV-1/113-8/A/04	11	Ministry of Infrastructure and Transport and ENAC	Ensure design and operation of all aerodromes complies with ICAO Annex 14.	15:Organisational
(20/1/04) ANSV-1/113-9/A/04	12	Ministry of Infrastructure and Transport and ENAC	Ensure all aerodromes in Italy have functioning Safety Management System per ICAO Annex 14.	16:Organisational
(20/1/04) ANSV-1/113-10/A/04	13	Ministry of Infrastructure and Transport and ENAC and ENAV SpA	Ensure competence, maintenance and requirements for recent experience of ATC staff comply with ICAO Annex 1.	17:Organisational 14:Systematic
(20/1/04) ANSV-1/113-11/A/04	14	ENAC and ENAV SpA	All required information to operate safely must be in AIP Italy and updated as needed.	7:Systematic
(20/1/04) ANSV-1/113-12/A/04	15	Ministry of Infrastructure and Transport and ENAC	Forward to ICAO proposals to include Cockpit Voice Recorders for all aircraft under Air Operator Certificate.	**Post-accident**
(20/1/04) ANSV-1/113-13/A/04	16	Ministry of Infrastructure and Transport and ENAC	Work with European Civil Aviation Conference to persuade ICAO to introduce changes in ESARR5.	**Post-accident**

Table 1: Summary of Recommendations Made in the ANSV Report, pages 165-174, (Continued overleaf).

(20/1/04) ANSV-1/113-14/A/04	17	Ministry of Infrastructure and Transport and ENAC	European Civil Aviation Conference to encourage member states to develop national teams to check air traffic management units.	15:Organisational 16:Organisational 17:Organisational
(20/1/04) ANSV-1/113-15/A/04	18	Ministry of Internal Affairs and ENAC	a) Design airport emergency plans according to ICAO Annex 14 allowing access to all necessary information to allow rescue and fire fighting.	**Post-accident**
	19		b) reference maps to use official naming of key locations to be made public.	**Post-accident**
	20		c) plan to be updated and made public with exercises to test and validate.	**Post-accident**
	21		d) fire crews to inform tower as necessary to support cooperation.	**Post-accident**
	22		e) plan to include radio and telephone links and coded information flow between control centres.	**Post-accident**
	23		f) dedicated telephone line for non-operational information flow to avoid overload of essential channels.	**Post-accident**
	24		g) prepare for updates and maintenance of plan eg new recruit training, personnel staffing times.	**Post-accident**
(20/1/04) ANSV-1/113-16/A/04	25	ENAV SpA and ENAC	a) Tower personnel to be invited to on-site recognition of existing markings etc.	8:Immed/System 12:Immediate
	26		b) Tower airport emergency signal equipment to be recorded and time stamped.	**Post-accident**
	27		c) emergency frequency speaker system positioned to be audible across Tower control room.	**Post-accident**
	28		d) add visual recognition (light source) to ELT activation signal.	**Post-accident**
	29		e) install radio equipment to monitor Fire Service communications	**Post-accident**
	30		f) Tower to have access to all information for rescue personnel before their intervention on accident site…	**Post-accident**
(20/1/04) ANSV-1/113-17/A/04	31	Ministry of Internal Affairs and ENAC	a) in accident ensure Tower and fire station share critical information	**Post-accident**
	32		b) Fire Station Control Center should have access immediately to key information (passengers, fuel etc).	**Post-accident**
	33		c) all communications to fire station should be recorded and time stamped,	**Post-accident**
	34		d) internal fire alarm for fire station to be connected to the Tower	**Post-accident**
	35		e) fixed replenishing tanks should be available to refill several appliances together.	**Post-accident**
(20/1/04) ANSV-1/113-18/A/04	36	ENAC	Aerodrome judicial authorities should increase rate of inspection for licenses and qualifications of pilots under low visibility operations.	5:Systemic

Table 1: Summary of Recommendations Made in the ANSV Report, pages 165-174, (Continued).

Table 1 shows that the ANSV have responded well in drafting recommendations that address the organisational, immediate and systemic causes they identified for the accident. Previous paragraphs have argued that all of the ANSV recommendations are well justified in terms of either the causes of the accident or their analysis of the emergency response. Some of the other recommendations cannot be related back to the causes of the accident because they address problems in the investigation rather than the events that led to the mishap. These include the need to provide Cockpit Voice Recordings in order to determine whether communications between those on-board the Cessna may have contributed to this accident.

A number of causes cannot, however, be linked directly to the recommendations identified in the ANSV report. For instance, it is difficult to determine which proposed interventions address immediate causes 1 and 2. These were that 'visibility was low, between 50 and 100 meters' and that the 'traffic volume was high'. The lack of any recommendations to address these causes can be explained in a number of ways. Firstly, these immediate causes can be seen as environmental issues that lie outside the control of any national regulatory agency. This argument is flawed; it would be possible to reduce traffic flows and to restrict operations during such low visibility conditions. A second explanation is that these causes are not covered by any direct and specific recommendations but are instead addressed by higher-level or more generic interventions. For instance, ANSV-1/113-7/A/04 urges the Italian Ministry of Transport and ENAC to ensure that all aerodromes have a functioning safety management system. An inference could then be made that such a system would address the problems created by high traffic volumes and low visibility operations. Again, there seem to be problems with this argument given that there are few guarantees these issues would be addressed as priorities by any initial management system.

Causes 1 and 2, mentioned above, are immediate and refer directly to the events leading to the Linate accident. They are not the only causes that cannot easily be linked to particular recommendations. Similar comments can be made about immediate and systematic cause 10; "operational procedures allowing high traffic volume (high number of ground movements) in weather conditions as were current the day of the accident (reduced visibility) and in the absence of technical aids". Corresponding recommendations cannot easily be identified for organisational cause 18; "the Low Visibility Operations (LVO) implementation by ENAV (DOP 2/97) did not conform with the requirements provided in the corresponding and referenced ICAO DOC 4976".

The following pages further analyse the evidence that supports the causal analysis in the ANSV report. The aim is to determine whether any additional recommendations might be drawn from the Linate accident. In order to do this it is first necessary to develop a more detailed timeline of the events that led to the collision.

The Linate Timeline

The Linate report does not contain a timeline of the events that led to the collision. Such diagrams or tables provide an overview of an accident. In particular, they can be extended to cover many of the contributory events that created the context in which the accident occurred. It is for these reasons that our analysis began by reconstructing a relatively extended and detailed timeline of events. The reconstructed timeline was deliberately developed to consider the ATM personnel's perspective as well as the circumstances in both cockpits. Figure 1 illustrates the opening events that led to the accident. The remaining timelines are presented in Appendix A. They extend well beyond the point of collision. Later sections will discuss the confusion that arose between Tower and Ground controllers and the emergency services as they tried to understand what had taken place. These subsequent events are critical to our understanding of the accident. The difficulty in determining the aircraft that were involved and their eventual location may delay necessary assistance from being provided to the victims of future accidents.

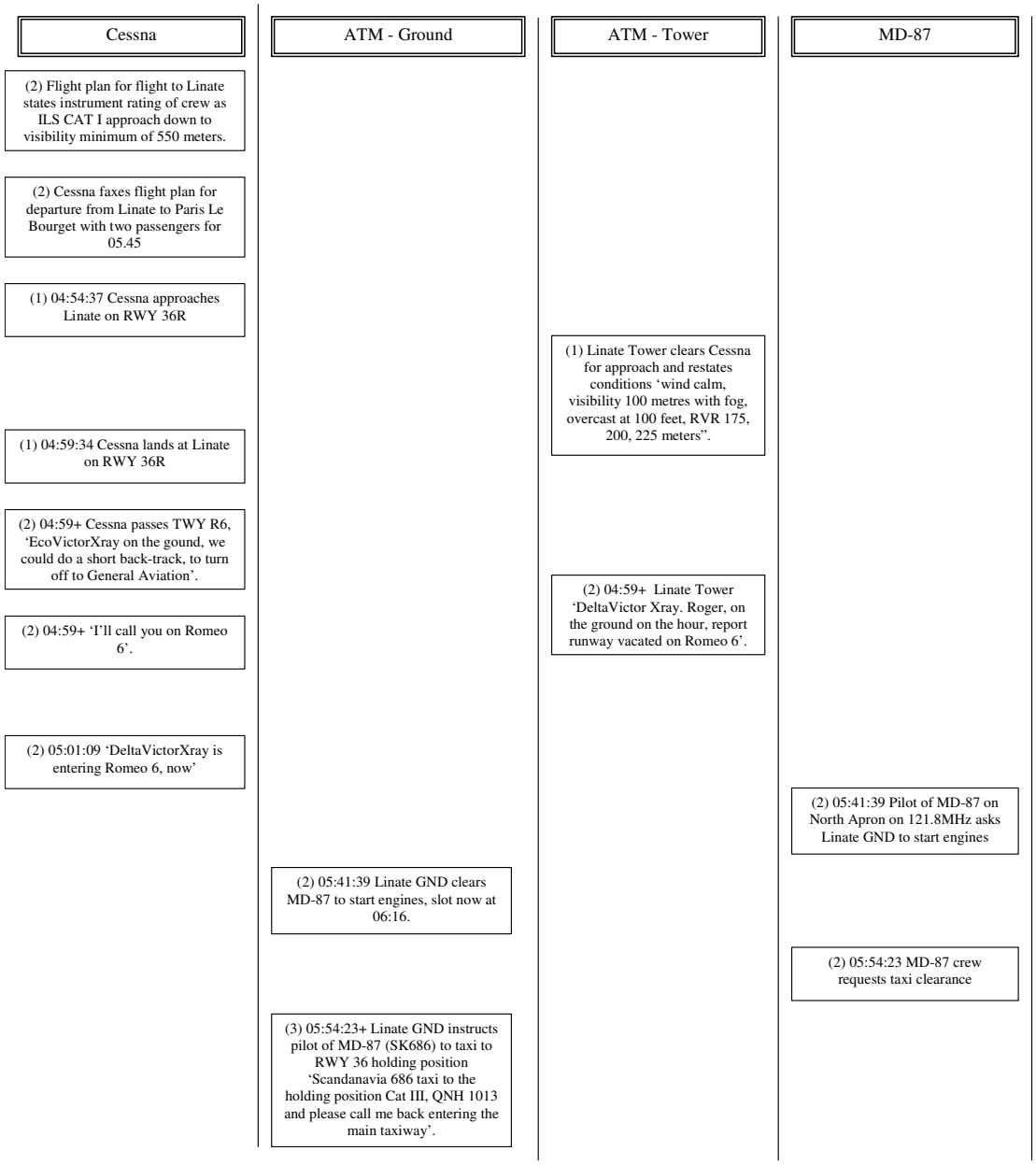

Figure 1: Except from the Revised Timeline of Events

In Figure 1, events are denoted by each rectangle. Time flows from the top to the bottom of the diagram. The left column is used to group events that relate to the Cessna. The middle columns show events associated with the Air Traffic Managers, distinguishing between Ground and Tower. The right column denotes events associated with the crew of the MD-87. The figures in brackets refer to pages in the English language translation of the ANSV report that provide evidence for these events. For instance, "(2) 05:01:09 'DeltaVictorXray is entering Romeo6 now" denotes that the ANSV discuss the communications from the Cessna as it enters taxiway R6 on page 8.

As can be seen, timelines help to map the complex events that lead to many accidents. In Figure 1, we can see how the ATM actions interleaved with those of the two crews in the early stages of the accident. Appendix 2 Figure A2 provides further examples. In particular, it shows the communication between the Ground Air Traffic Managers and the Cessna as the crew confirm the instruction to use taxiway R5 but then depart along taxiway R6. Slightly thicker lines in each of the rectangles have been used to denote these crucial events. This timeline also illustrates some of the limitations of the approach. In particular, the events that describe communication between the ground controllers and the Cessna's crew provide an overview of *what* happened. They do not explain *why*. This is an important distinction. The timelines cannot help us to determine whether the crew of the Cessna had accurately followed the assignment to taxiway R5 and then became confused or lost by the absence of signs and other location information. Similarly, the event-based description provides little insights into alternate explanations. For example, the crew might simply have forgotten the taxiway allocation or mistakenly believed that they were assigned taxiway R6, even though the read-back had been for R5. If this latter explanation is correct then less emphasis might be placed on the role that inadequate signs played in the accident because it assumes the crew knew that they were following taxiway R6.

Having raised these caveats, it is important to stress that the process of developing these timelines can also help to identify potential conflicts, ambiguities and inconsistencies in accident reports. It also helps to begin to map out additional concerns that might not have been covered in depth in the ANSV report. In particular, the initial analysis illustrated the general confusion that was experienced as controllers tried to locate aircraft in Linate under reduced visibility. For example on page 4 of the report there is an account of an initial conversation between the Ground controllers and the crew of LX-PRA in Italian. This is shown in the timeline of Figure 2A:

> "(4) 06:06:15 GND to LX-PRA also parked on West Apron (in Italian) 'OK RomeoAlpha taxi North Romeo 5, QNH 1013, you must follow a Citation (Cessna) marks DeltaIndiaEcoVictorXray who is also taxiing on Romeo 5. Obviously he is not in sight, and the clearance limit for you is the stop bar of the extension of the main runway on Romeo 5'.

The phrase 'obviously he is not in sight' can provide an indication of the reduced visibility on the morning of the collision. This is an important observation because LX-PRA might have seen the Cessna moving off onto taxiway R6 and issued a warning if the visibility had been better. Alternatively, LX-PRA might have seen that the Cessna was not where it should have been on taxiway R5. Conversely,, the Cessna itself might have noticed that LX-PRA was not in position on the same taxiway. However, this last conjecture relies on a number of strong assumptions. Firstly it assumes that the Cessna crew would have been in a position to observe a following aircraft. This raises questions about the line of sight from the Cessna's cockpit. It also assumes that there was sufficient visibility to see the other aircraft. Finally, it assumes that the Cessna's crew could understand the previous instructions, which were given in German. The key issue here is that the reduced visibility was creating operational problems well before the collision. As we shall see, the lack of automated tracking systems including ground radar meant that controllers had to rely on verbal accounts of positioning information and there were early signs that these were insufficient. For example, the timeline in Figure A2 of Appendix 1 records further observations from pages 5 and 6 of the ANSV report. Immediately after the controllers instructed the Cessna to follow taxiway R5 they were involved in the following dialogue with Air One 937:

> "(6) 06:08:55 GND to Air One 937 (in Italian) "Air One 937 where are you?"
>
> "(6) 06:08:55+ Air One 937 to GND (in Italian) "Hmmmm…we…are..on..between the 18 and the Delta".
>
> "(6) 06:08:55+ GND to Air one 937 (in Italian) "Therefore, you are practically in front of the Tower right?"

"(6) 06:08:55+ Air One 937 to GND (in Italian) "Hmmm…yes slightly before, slightly before that".

The construction of a timeline helps to identify the importance of such exchanges. It raises a number of questions that are not fully analyzed in the ANSV report. The reduced visibility was imposing considerable additional overheads on the ATM staff as they tried to confirm positions with the crews, many of whom seem to have experienced considerable uncertainty 'Hmmmm… we… are… on… between…'. There is a danger that hindsight bias will affect the subsequent interpretation of the events in the timeline. It might be argued that the controllers should have taken steps to reduce the traffic until the visibility had improved so that additional measures could be taken to ascertain the location of each aircraft. However, such assertions arguably underestimate the economic and practical consequences of such decisions. After the accident it seems clear that controllers might have suspended or reduced operations. However, the need to take such steps may not have been so obvious during the lead-up to the collision.

Additional Recommendation 1:
The official report does not explicitly consider the various conditions under which Ground Controllers should call for a suspension or reduction in operations. The report largely focuses on Safety Management Systems. It is argued that these might have provided improved runway signage and automated support, for instance through ground radar systems. Ultimately, however, it remains the Controller's responsibility to determine when operating conditions exceed the capacity of the systems that they have available. Lenate provides valuable lessons in when to decide that safe operational bounds have been exceeded.

Extending the analysis to the events after the immediate impact can also help to elicit further insights that were not documented in the ANSV report. As before, some of these relate to the problems that were created by the environmental conditions that faced both controllers and emergency personnel in the aftermath of the collision. For example, Figure A3 includes events that describe the communication between the Airport Traffic Authority (UTC) and the Tower Air Traffic Managers:

"(9) 06:11:00 UTC calls TWR on phone 'Yes, hello this is UTC. We heard a number of bangs like an engine that…'".

"(9) 06:11:00+ TWR to UTC 'Yes…we heard them too but we did not know what it was…'".

"(9) 06:11:00+ UTC to TWR 'You don't have anything abnormal…because, here, I mean the visibility is zero, I cannot see anything…'"

"(9) 06:11:00+ TWR to UTC 'Hmmm…that's it, here too'"

The reduced visibility not only created the context in which a collision was more likely. It also increased the likelihood of communications failures for any subsequent rescue. It can be argued that the ANSV report does address this issue in its recommendations when it supports the adoption of ESARR5 and other advice on the implementation of Safety Management Systems. This is an important and significant contribution by the investigators. However, the Linate accident also provides valuable insights in its own right about how Safety Management Systems ought to function. In this particular instance, any risk-based decision to continue operations must consider not only the likelihood of an accident occurring, for instance under reduced visibility conditions. It must also consider the likelihood of successfully coordinating any emergency activities should an adverse event occur. The ANSV perform a valuable service in promoting the cause of Safety Management Systems but arguably could go further in looking at the specific lessons that Linate offers for the operation of those systems in the future.

Additional Recommendation 2:
One of the lessons from Linate is that Controllers need to understand that the environmental conditions, which make ground-based collision more likely, will also frustrate rescue efforts. It is unlikely that ground-based radar would have provided a panacea for the coordination problems that frustrated immediate attempts to rescue any survivors. It is fortunate in this case that additional lives do not seem to have been lost through the delay in locating the aircraft. The difficulty of mitigating the consequences of adverse events should inform the risk-based management of operations.

Subsequent sections will use a variation on Events and Causal Factors (ECF) analysis to extend the overview provided by timelines. However, the initial reconstructions illustrated in Appendix 1 and cited, in part, above, raise a number of issues that might also have been considered in the ANSV report. As mentioned, the official investigation focused quite narrowly on the provision of ground movement radar as a technical aid for the controllers. However, the confusion that arose in the aftermath of the collision suggests the need to identify other, low cost technical solutions. In particular, the use of image intensification and thermal imaging equipment might have provided valuable assistance to the emergency crews as they attempted to locate the site of the incident.

Additional Recommendation 3:
In addition to the provision of ground movement radar, future investigations might consider the suitability of image intensification and thermal imaging systems for use by emergency personnel. Ground radar systems may help to reduce the likelihood of collision but they cannot eliminate it. If such a collision does occur then the radar should enable the Tower and Ground controllers to locate the site of a potential collision. However, the problem remains that emergency personnel have to navigate in reduced visibility to the site of an accident. As shown in Linate, this site can be extremely difficult to find if one of the aircraft involved is a small commercial or General Aviation aircraft. Night vision devices are now widely available and at relatively low cost. With appropriate training, they might help rescue crews to locate the site of an accident. They might also play a role in helping rescue vehicles avoid other aircraft whose crews are unaware of their presence; this issue is discussed in more detail in the following paragraphs.

It is important to emphasize that these devices have limitations. They do not 'turn the night into day'. They can also increase some operational risks, for instance if relied upon to navigate across broken terrain. However, their reduced cost and widespread military use make it appropriate to consider their deployment to emergency service personnel in situations similar to those that faced the first responders at Linate.

The ANSV report is unusual in the thoroughness with which it explores the events that occurred in the immediate aftermath of the collision. The timelines in Appendix 1, summarize many of their insights. For instance, Figure A4 draws on material towards the middle of the English language version of this document. It describes the confusion that can arise as Air Traffic Management personnel try to coordinate their response and the movements of any other aircraft after an accident has occurred:

> "(81) 06:14:56 TWR orders 1-LUBI to clear RWY 36R, already lined up for takeoff. 'The important thing is that you clear me the runway'"
>
> "(81) 06:15:25 At the same time as the communications with 1-LUBI continue, TWR tells the Fire Control Center on the service radio that fire vehicles can enter the runway and it is 'clear'"
>
> "(82) 06:16:12, Fire Control Centre tells vehicles to enter the runway which is 'closed' but 1-LUBI may still be taxiing on runway to vacate TWY R1. TWR 'clear me the runway is ambiguous'."

As can be seen, the Tower Controllers requested that 1-LUBI clear the runway. However, the ANSV argue that the communications were ambiguous. The Tower's statements might be interpreted as a command to exit the runway as soon as possible, in other words, 'to get clear of the area'. Equally, they might be interpreted as a request to confirm that the runway was 'clear' of any debris. 1-LUBI had vacated the runway and was onto the 36R holding position before the Fire Control Center was able to instruct their crews that they could use the runway. However, the aircraft was not 'clear' at the time when the Tower told the fire personnel that it was safe to enter the runway. The ANSV argue that the consequences of such miscommunication might be more serious in future incidents. In this instance, the timelines have done little more than to provide an overview of material that is already in the official report. However, the process of constructing these models can lead to additional insights. In particular, it can be argues that controllers should be more aware of the dangers that can arise in the aftermath of incidents and accidents. There is a colloquial saying that 'accidents come in threes'. This has a sound scientific and engineering basis. In the aftermath of an accident, individuals and groups will immediately alter their behavior. For instance, first responders often rush to help a victim without due regard for their own safety or that of their colleagues. The knowledge that an accident has happened can create additional stress and distraction that again can also make slips and mistakes more likely.

Additional Recommendation 4:
The events of Linate ought to be publicized more widely to controllers. Not simply to illustrate the importance of Safety Management Systems but also to illustrate the critical need to take additional precautions in the aftermath of adverse events.

Background to the Linate Collision

Appendix A presents a relatively detailed timeline of the LNSV accident. This documents many of the events leading to the collision from the controllers' viewpoint. However, recent systemic approaches to accident investigation have emphasised the need to go further back and consider the events and conditions that created the context for this incident. Figure 2, therefore, extends this initial event-based analysis to consider some of the background and contextual information that was considered by the ANSV in this analysis of the Linate accident.

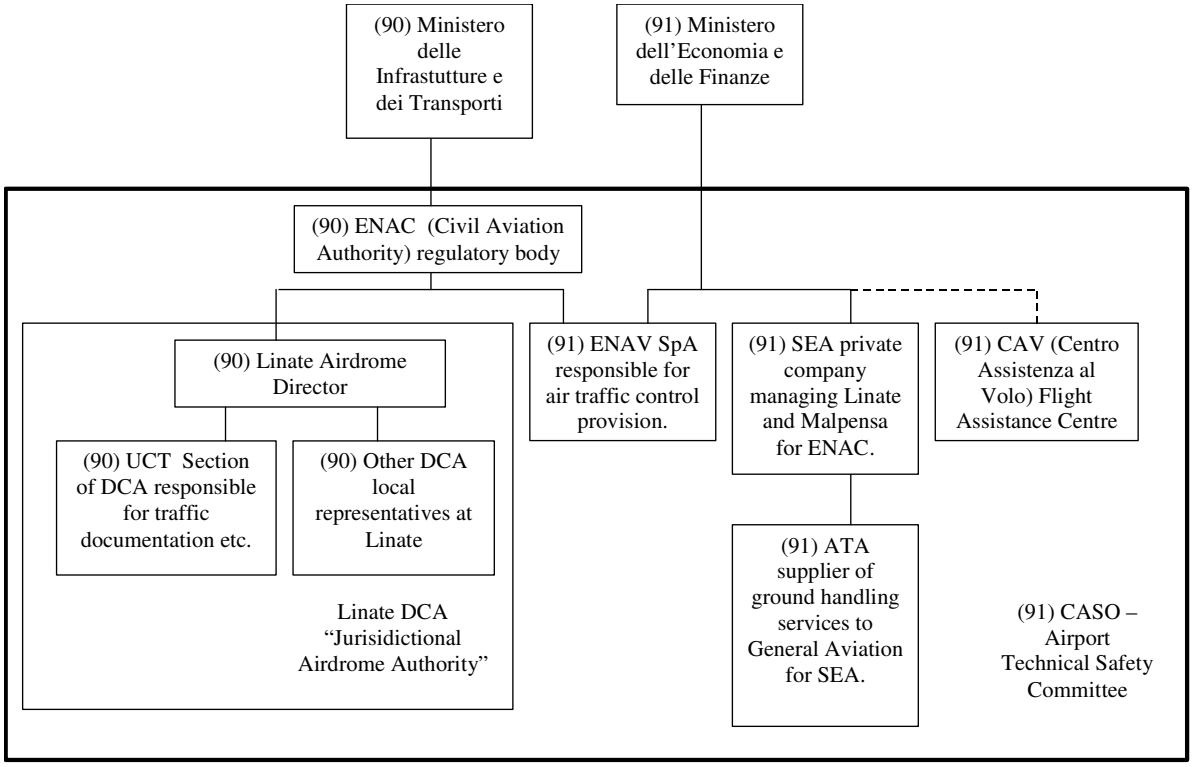

Figure 2: Simplified Organisational Structure Prior to the Linate Accident

As can be seen, this diagram shows some of the organisational relationships that shaped the operation of the aerodrome prior to the collision. As before, the figures in brackets refer to the page numbers in the English language version of the ANSV report. It is important to note that this translation cannot easily be used to derive the organisational structure illustrated in Figure 2. The report uses phrases such as "under the surveillance of" or "with the local CAV is responsible for ATC provision…" These cannot easily be interpreted to produce a clear reporting or management structure. This does not imply that such a structure was not present; it is impossible to tell whether or not the lack of clear organisational guidance was a factor in the accident because it is not made explicit within the ANSV report. One consequence of this is that the depiction of the CAV at the same level as the SEA management company is the result of an assumption based on the current report.

Additional Recommendation 5:
It is important that future accident reports explicitly consider the management and organizational structures that were in place prior to an accident so that readers can clearly identify the impact that they might have had upon the course of an adverse event. As later sections will show, this is particularly important for the credibility of any recommendations that focus on the role of safety management systems. It is difficult to clearly understand the ways in which these systems might

have been improved if readers cannot identify the reporting structures that held when an accident occurred.

A number of insights can be obtained from the control structures sketched in Figure 2. It seems that the operational staff at Linate were caught between the two pressures of economic competition and safety regulation. These are represented by the Ministero delle Infrastutture e dei Transporti and the Ministero dell'Economia e delle Finanze. This is a common tension in modern air traffic management as market forces play an increasing role in former state monopolies. Perceived changes in the priorities associated with economic competitiveness and with safety regulation have also been identified as root causes of accidents in a wide range of industries, as diverse as UK railways and US space missions. Such tensions are hinted at in the ANSV report but are not made explicit.

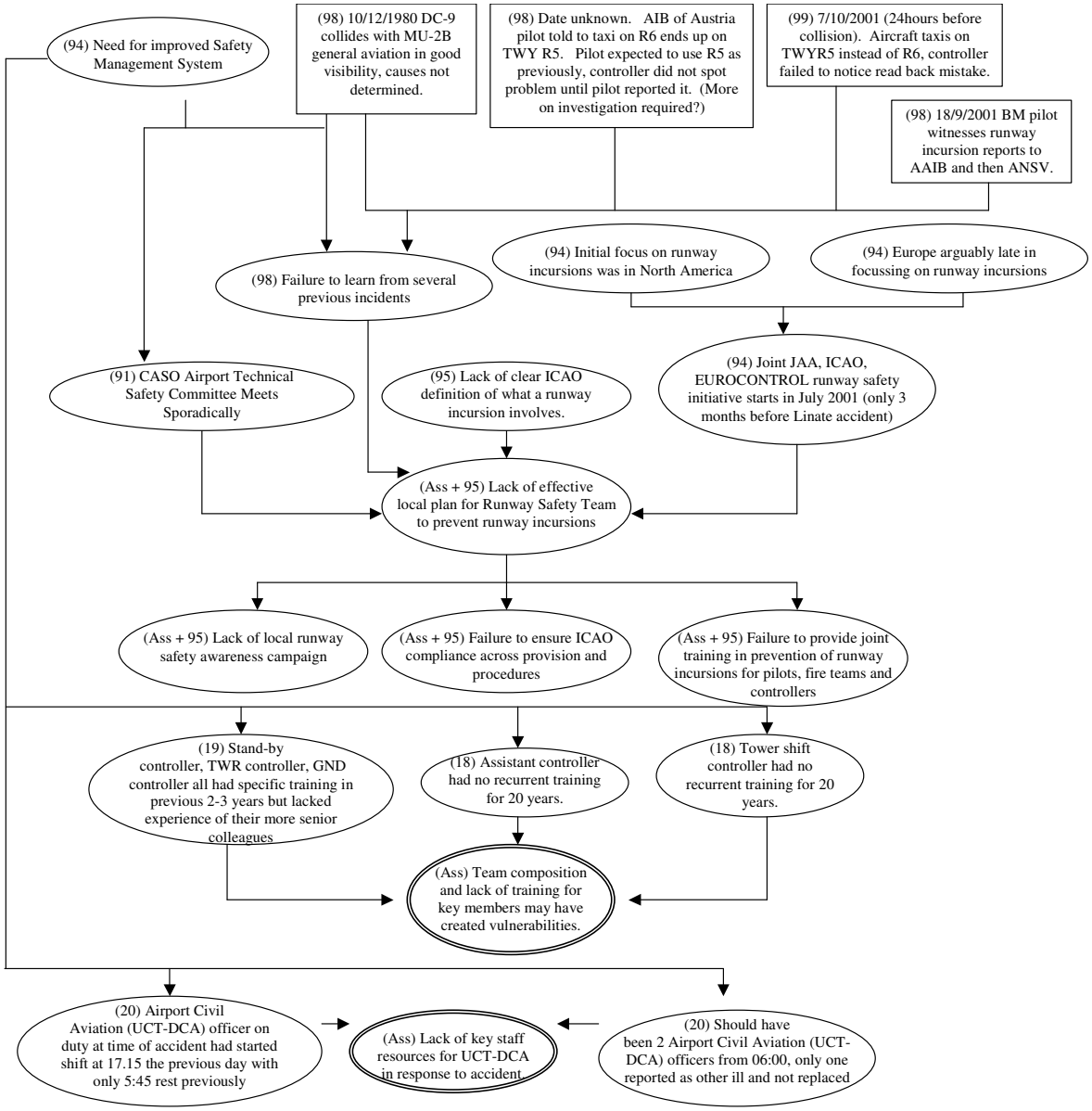

Figure 3: Contextual Factors Stemming from Organisational Issues Prior to the Linate Accident

Figure 3 presents the next stage in our analysis. It represents a simplified form of Events and Causal Factors diagram, initially pioneered by the US Department of Energy. Previous EUROCONTROL projects including the analysis of the Uberlingen mid-air collision have used similar diagrams to model human error and

systems failure in ATM incidents. Ellipses are used to denote contributory factors that combine to make events more likely. Events, as before, are denoted by rectangles. This diagram moves from an initial analysis to look at some of the many ways in which the organizational structure directly affected the context in which the accident occurred. Figure 2 shows how ENAC, the SEA, CAV, DCA etc all contributed to or influenced the CASO, Airport Technical Safety Committee. In contrast, Figure 3 records the observation that this grouping only met sporadically. This is represented by a contributory factor approximately mid-way down the diagram on the left-hand side. One of the factors that led to this was the need to improve the Safety Management Systems in operation at Linate prior to the accident. This apparent shortcoming also partly explains a failure to learn from previous incidents. These are shown as four separate events, including a very similar incident to the collision between the Cessna and the MD-87 which occurred only 24 hours before the accident. In this incident an aircraft taxied along TWY R5 instead of R6; the Controller was only alerted to the incident when the crew realized their potential mistake.

Figure 3 also draws on factors that go beyond the organizations listed in Figure 2. For example, the ANSV argue on page 94 of the report that most of the early concern about runway incursions came from North America rather than Europe. This may partly explain why transatlantic initiatives to address the problem began to make significant progress some three months before the collision leaving insufficient opportunity for many of the subsequent recommendations to be adopted at Linate. These factors combined with the issues that stemmed from the lack of effective Safety Management. Together they contributed to a situation in which there was no effective runway safety plan. The lack of a fully developed runway safety team may also help to explain the absence of runway safety awareness campaigns, of a failure to ensure compliance with ICAO runway requirements and for well integrated plans to deal with runway emergencies. The key point here is that local failures, such as the failure of personnel at Linate to learn from a number of specific previous incidents, combined with higher-level issues, including delays in the development of an international initiative to coordinate efforts to improve runway safety.

Additional Recommendation 6:
There is good reason to believe that the infrastructure at Linate, in terms of technical equipment, operating procedures and signage, might have been improved to a point where the accident would have been prevented if they had followed the recommendations from the European Action Plan for the prevention of runway incursions. However, these were made after the accident. It is, therefore, critical to monitor the manner in which these recommendations have been interpreted and implemented at a local level if we are to be sure that they are to have their intended effect on system safety.

The ECF diagram in Figure 3 includes a link between the need to improve Safety Management Systems and the lack of staff in the DCA (Airdrome Judicial Authority) and the UCT (Traffic documentation section). There would usually have been two UCT officers on duty but only one had turned up for duty. Fortunately, their colleague on the previous shift was still present even though they had worked a continuous total of 13 hours on duty. This had important consequences as Air Traffic Managers and emergency personnel attempted firstly to determine the number of aircraft involved in the accident and then to determine whether any aircraft were missing. Later sections will analyze the consequences of these staffing issues during the immediate aftermath of the collision. For now it is sufficient to observe that page 60 of the ANSV report lists a number of specific “failures to adhere to prescribed obligations”, most seriously including the UCT failure to provide the tower with critical information after the collision. The key point is to identify specific ways in which high-level observations about the operation of Safety Management Systems led to specific vulnerabilities that were exposed during the accident. In this case, the lack of UCT staff and the problems in the shift patterns of those who were on duty, arguably, did little to exacerbate the consequences of the incident. In future accidents, we may not be so fortunate.

Additional Recommendation 7:
Safety management systems often imply the use of risk-based techniques not simply to analyze the barriers that may prevent accidents from happening in the first place, for instance by ensuring adequate signage that complies with ICAO requirements. They can also be used to identify key technical and organizational requirements for mitigating the consequences of any adverse event that does occur. The Linate collision provides numerous examples where inadequate preparation

could have exacerbated the outcome of the accident. The staffing of the UCT-DCA group is one example.

The Runway and Taxiway Infrastructure at Linate before the Accident

Figures 2 and 3 presented an overview of some of the organisational factors that influenced events on the morning of the accident and that were documented in the ANSV report. In contrast, Figure 4 extends the analysis to look more closely at the runway and taxiway infrastructure that ATM personnel had to manage at Linate. Later sections will look at the technical and human factors resources that were available to them.

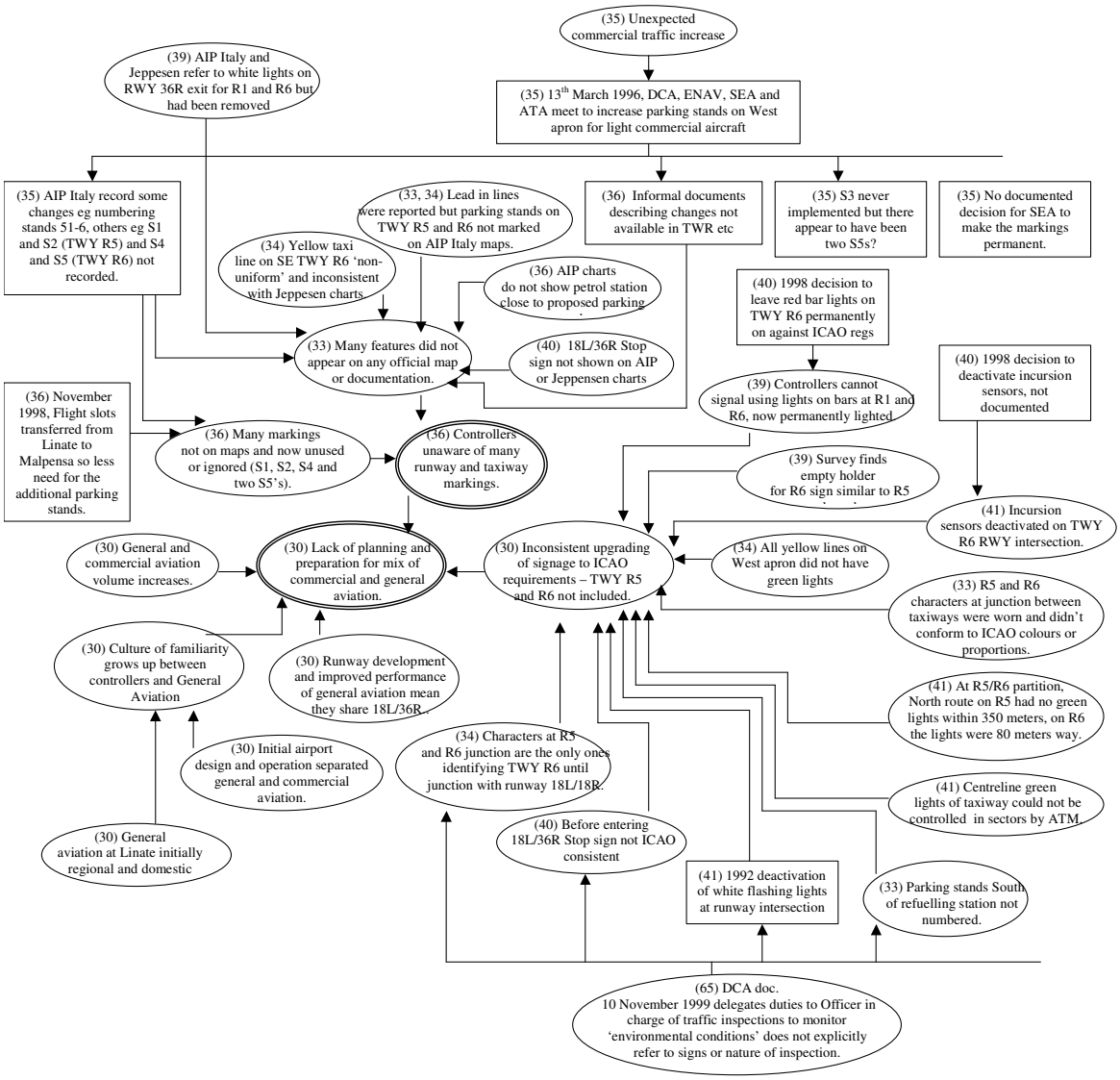

Figure 4: ECF Analysis of the Runway Infrastructure at the Linate Accident

As can be seen, Figure 4 begins with a change in the operating conditions at Linate when there was an unexpected increase in commercial traffic. One consequence of this was that many of the operational groups, identified in Figure 2, met to consider increasing the parking stands on the West Apron to accommodate the increase. The outcomes from this meeting are described on page 36 of the ANSV report. These include the lack of documentation to support the proposed changes in marking that were made as part of this plan. There does not appear to have been a documented decision to make the markings permanent. There were also inconsistencies in the parking stands that were finally developed. For example, the stand S3 never seems to have been implemented and yet there were two S5s. As we shall see, these inconsistent markings created the potential for confusion when controllers were

attempting to locate crews who reported their position in relation to these markings. Further confusion arose because the official AIP charts did not record all of the changes that had been made. These omissions were symptomatic of wider problems in the aerodrome documentation available to aircrews and controllers. For example, the Jeppensen charts did not reflect the yellow taxi lines on TWY R6. The right hand side of Figure 4 also illustrates the consequences of a further change in the operating environment facing ATM personnel before the accident. As can be seen, many of the flight slots at Linate were transferred to Malpensa in November 1998. Figure 2 records that SEA was responsible for operating both airports. This transfer meant that there was less need for the additional parking stands at Linate. Many of the markings close to the taxiways, such as S1, S2, S4 and the two S5's, were now no longer needed and were largely ignored. These changes combined with the lack of accurate and authoritative documentation left ATM personnel unaware of many of the markings that aircrew could see as they moved along the taxiways and onto the runways. In consequence, it was increasingly difficult for ATM staff to understand where aircrews were when they referred to these markers.

Additional Recommendation 8:
ATM personnel at Linate had to control a runway environment that was poorly documented and included markings that were both inconsistent and confusing. The piecemeal decisions to introduce and then 'abandon' the additional parking stands were symptomatic of wider problems that stemmed from the management of change. Linate first had to cope with an expansion of traffic and then adjust as traffic was moved to Malpensa. The ANSV report does not analyze these changes in any detail. However, it seems possible that these changes were seen in purely operational terms without a full analysis of the impact that they might have had both on operating procedures and on the runway environment. In the future, organizations such as EUROCONTROL might invest limited resources to study how other industries take a more systemic approach to change management so that we might avoid the ad hoc and piecemeal changes that were apparent at Linate.

Additional Recommendation 9:
The more detailed analysis of the runway environment prior to the Linate collision shows that a number of decisions seem not to have been properly documented. For example, the ANSV report describes the lack of documentation about the decision to permanently introduce the additional parking stand markings. Similarly, such changes seem not to have been communicated to ATM personnel in documentation that was provided to the Tower. In the future, ATM organizations might reconsider the importance of documentation and traceability within their operational procedures. For example, an increasing number of organizations working in non-safety critical industries are using document management systems and the ISO9000 suite of standards to provide quality and performance metrics.

Figure 4 extends the previous analysis to show that ATM personnel's' lack of information about runway and taxiway markings formed part of wider problems that stemmed form inadequate planning for the mix of commercial and general aviation at Linate. Initially, the design and operation of the airport had separated these different forms of traffic. The general aviation had been largely domestic or regional and the ANSV refer to a 'culture of familiarity' between ATM personnel and the aircrews. However, as we have seen, there had been a gradual increase in traffic at Linate. Runway developments and the increasing power of aircraft used by general aviation pilots created a situation in which runway 18L/36R was shared by an increasingly mixed range of traffic. A further consequence of this was that ATM personnel gradually absorbed the additional overheads associated with synchronizing this mixed-use traffic as they moved from the parking areas, to the taxiways and the runways. These additional demands were exacerbated by the problems in signage mentioned above.

Additional Recommendation 10:

Consideration should be given to the additional workload imposed on ATM personnel operating mixed-mode runways that service both commercial and general aviation. This workload will differ depending on the proportion and total volume of traffic in each category. It will also vary in relation to environmental conditions. It is surprising that existing regulations governing high, medium and low traffic flows in low visibility conditions seem to ignore the characteristics of that traffic. They are purely defined in terms of numbers of 'operations' rather than the mix of traffic and Linate shows that this mix plays a critical role in determining workload when commercial and other forms of traffic must share a runway.

As can be seen from the previous diagram in Figure 4, a DCA document dated the 10th November 1999 delegated responsibility to the officer in charge of traffic inspections to also monitor the 'environmental conditions' associated with the runways and taxiways. However, there is no explicit mention of the signage or of the types of inspections that might be appropriate to meet this objective. Partly in consequence, there was a range of modifications to the runway and taxiway infrastructure at Linate that did not meet ICAO requirements. These included the stop sign before 18L/36R, the 1992 deactivation of white flashing lights at the runway intersection, the 1998 decision to deactivate incursion detectors etc. It should be noted that this last modification was not properly documented and this reinforced the comments made in additional recommendation 8. The inconsistent signage created problems for the aircrews that had to navigate onto appropriate runways. It may explain the previous runway incursion incidents mentioned in previous paragraphs. Further problems were created by the lack of control over critical sections of runway and taxiway lighting. ATM personnel could no longer alter the configuration of these light sources to provide positional cues to aircrew. Some of the inconsistencies with ICAO regulations and wider safety provisions stemmed from decisions made 7 or 8 years before the accident. The fact that they had not been addressed after previous incidents arguably reinforces the need for improved Safety Management Systems, identified by the ANSV. It also underlines the need to provide better support for the responsible individuals, such as the 'officer in charge of traffic inspections', and groups, including the 'runway safety teams' anticipated by the working groups on runway incursion. The runway environment at Linate evolved over many years. Hence, it would be useful if regulatory organizations provided specific guidance for responsible individuals and groups on how to identify existing problems when they take up their post. This is a non-trivial problem. It seems clear that many of the deficiencies at Linate had been accepted as 'normal' prior to the accident. Management could argue that there had been no serious accidents even with the current marking problems, the lack of lighting control and the deactivated incursion sensors. The key recommendation here is, therefore, to provide guidance on how to expose the potential consequences of these 'normal operational circumstances' before an accident takes place.

Additional Recommendation 11:

In addition to the high-level guidance provided by the ANSV report and by the various international working groups on the prevention of runway incursions, there is a need for very specific and detailed guidelines on how to assess the environment for ATM staff who are responsible for the safe operation of runways and taxiway. These guidelines should not simply be devolved to line management or to the runway safety groups that have been proposed. There must also be some line for appeals to be made to a higher authority should a review reveal the need for more sustained 'root and branch' reform of current working practices, signage and technical equipment.

Figure 4 looked at some of the key factors that influenced the evolution of the taxiway and runway infrastructure in the years and months leading up to the Linate accident. Figure 5 extends this analysis by looking more directly at the technological environment that ATM personnel had to exploit. As can be seen from events on the right of the extended ECF diagram, some of the decisions involving ground movement radar and incursion detection systems can be partly ascribed to the sporadic role of the airport technical safety committee, as described on page 91 of the ANSV report. As can be seen, the existing

Aerodrome Surface Movement Indicator (ASMI) radar at Linate was analogue. The traffic increase mentioned in previous paragraphs exposed the reliability and low definition of this system to a point at which ATM personnel began to look for an alternative. This again emphasizes the points made in Additional Recommendations 8 and 9 about the need to provide explicit support for the management and documentation of structural changes in ATM operations. As we shall see, the technical decisions that were made as a consequence of the increase in traffic were not followed through in a systematic manner. Change management systems and associated documentation support tools, similar to those advocated under ISO9000, might have an important role to play in reducing the likelihood of such problems recurring.

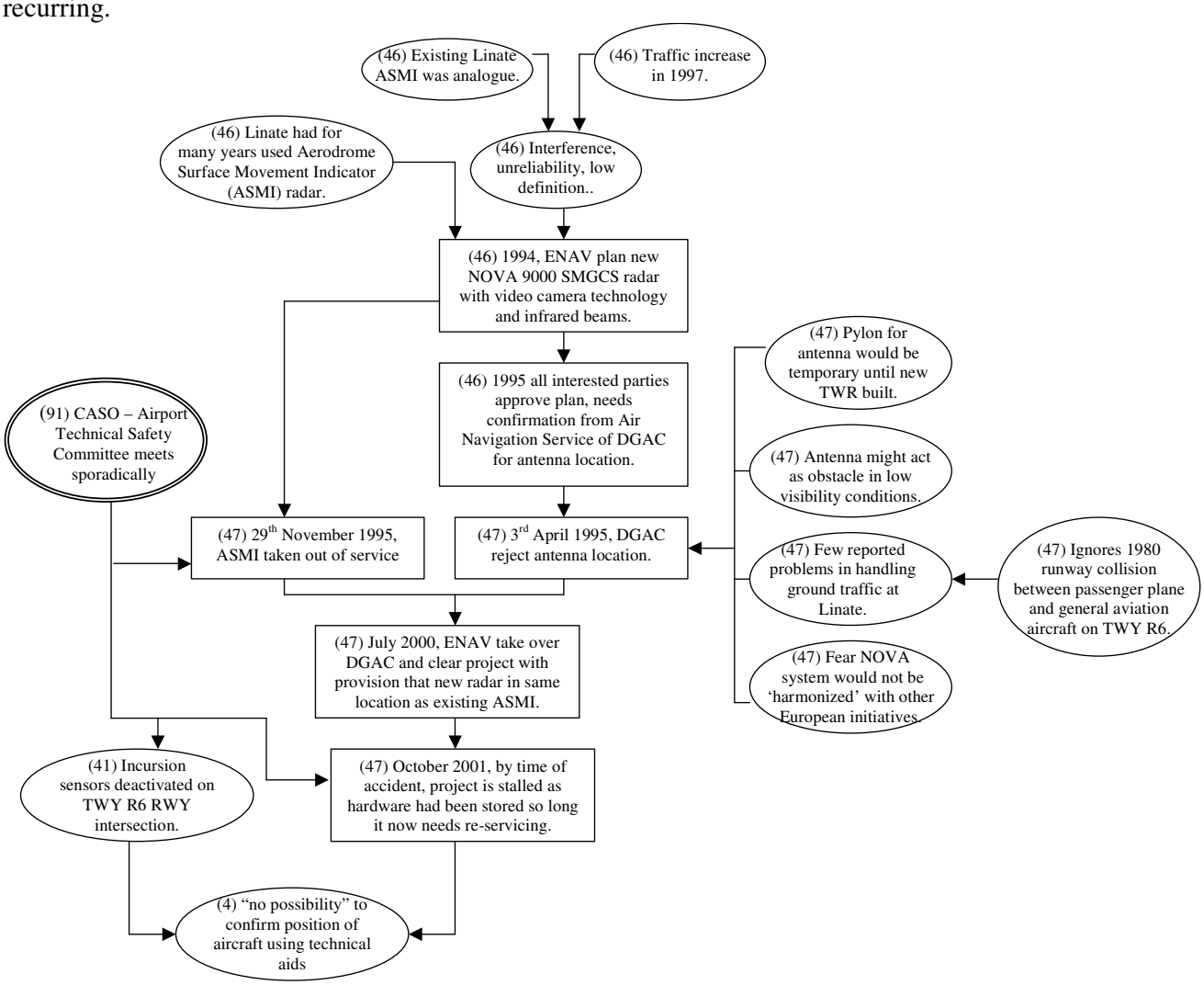

Figure 5: ECF Analysis of Technological Infrastructure at the Linate Accident

Figure 5 specifically shows how there was a plan to introduce a NOVA 9000 Surface Movement Guidance and Control System (SMGCS) using video camera technology and so the old AMSI system was taken out of service some three years before the accident. The plans to install the new system were jeopardized when the predecessor of ENAC objected to the antenna location. They argued that this would involve additional expense by constructing a temporary structure that would then be moved once a new Tower was built. It was also argued that the proposed structure might hinder visibility and that there were few reported problems in handling ground traffic at Linate. The ANSV do not explicitly consider the relevance or strength of this argument given the previous incidents noted in this report. Equally, the DGAC precursor of ENAC might not have been told about such previous incidents and hence would, from their point of view, have been justified in reaching this conclusion. The ECF diagram in Figure 5

notes this possible objection by showing the 1980 collision between a passenger aircraft and a commercial plane as a counter example. Finally, the previous diagram also illustrates the DGAC's concern that the new system would not harmonize with other European initiatives. This last point is particularly interesting as a reason to delay expenditure on a significant component of a ground-based safety net. It seems to be counter-intuitive that ATM personnel would be deprived of an important tool so that the eventual system would be consistent with a European initiative that was intended to harmonize safety provision. It could be argued that this valuable and important safety initiative had the unintended effect of exposing the ATM personnel to greater risk.

Additional Recommendation 12:

Advice should be provided by organizations such as EUROCONTROL about what to do when national organizations postpone safety improvements in anticipation of European or other international initiatives. A risk-based approach could be advocated where national operators must explicitly document and justify the decision to postpone the introduction of a safety critical system, such as the NOVA SMGCS radar. It seems clear that the desire to conform or harmonize with wider European initiatives should not place passengers lives at undue risk.

The lower portion of Figure 5 uses the ECF formalism to continue the analysis. In July 2000, ENAV assumed many of the previous responsibilities held by DGAC. One side effect of this hand-over was that approval was finally granted for the development of the new Surface Movement Guidance and Control System. The antenna was to be located in the same position as the previous Aerodrome Surface Movement Indicator (ASMI) radar. The ECF diagram also shows that at the time of the project this upgrade project was further stalled as mothballed hardware had to be re-serviced before the new system could be delivered. As we have seen from Figure 4, the runway incursion sensors had already been deactivated on TWY R6. In consequence the ANSV argued that there was "no possibility" to confirm the positions of the various aircraft on the morning of the collision using technical aids.

It is worth pausing to consider some of the similarities between the technical environment at Linate and the erosion of systems support prior to the Überlingen mid-air collision. Changes in the sectorisation of Air Traffic services at Zurich following the introduction of Revised Vertical Separation Minima had led to a number of planned upgrades. On the night of the accident, automatic flight plan and radar correlation (ADAPT) support had been disabled as part of the SYCO flight plan processing system upgrade. In consequence, the controllers had to work in fallback mode without a visual Short Term Conflict Alert but with a delayed audible warning. The upgrade work also caused an interruption to the SWI-02 communications system with neighbouring control centres. There are strong similarities here with the problems described in Figure 5. The level of technical support provided to ATM staff had been degraded. These problems were compounded by particular working practices in the two centres. At Zurich, a practice had been established of allowing a Controller to rest during quiet periods. At Linate, it can be argued there was no tradition of recurrent training in key tasks for experienced staff. These organisational and human factors issues interacted with the degraded technical systems that were available prior to the accident. It can, therefore, be argued that we might repeat a previous recommendation that was identified in the previous report on the BFU investigation:

Uberlingen Recommendation 2:
Additional emphasis should be paid to a risk-based approach to the identification and dissemination of information about the impact of necessary upgrades on the ATM infrastructure

In the context of Linate, such a risk assessment would have focused on providing ATM personnel with additional information about the danger of runway incursions in low visibility conditions without the support of ground movement radar. Such a risk-based initiative could have been triggered by delays in the replacement of the former systems or by the earlier Linate incursion incidents that have been mentioned in previous paragraphs. There are, of course, important differences between the two

accidents. ATM personnel at Zurich were forced to cope with a relatively rapid degradation in technical systems support as the SYCO upgrade work was scheduled for the night of the accident. In contrast, the Linate ground controllers' had faced prolonged periods without either the former Aerodrome Surface Movement Indicator radar or the proposed Surface Movement Guidance and Control system. Rather than repeating the former recommendation based on the BFU report, it is possible to identify a more detailed proposal based directly on the observations of the ANSV investigators but extending their findings beyond those in the existing report:

Additional Recommendation 13:
The Überlingen accident illustrates the importance of conducting explicit risk assessments when planning major upgrades to ATM infrastructure. The European and international working groups have also argued that risk assessments should be made at regular intervals to assess the likelihood of runway incursion. Our analysis of Linate also suggests that risk assessments should be required whenever a planned upgrade is postponed. Such an analysis would ensure that the temporary erosion of technical support does not create an undue risk during the transition between old and new systems.

The Immediate Events Leading to the Linate Accident

The previous pages have used ECF diagrams to analyse the organisational and technical context that led to the Linate collision. These have linked problems in the formation and operation of key safety committees through to delays in the implementation of specific technical aids that might have reduced the burdens on individual controllers. In contrast, the following pages extend this analysis to identify some of the ways that these contextual factors helped to shape specific events on the morning of the accident.

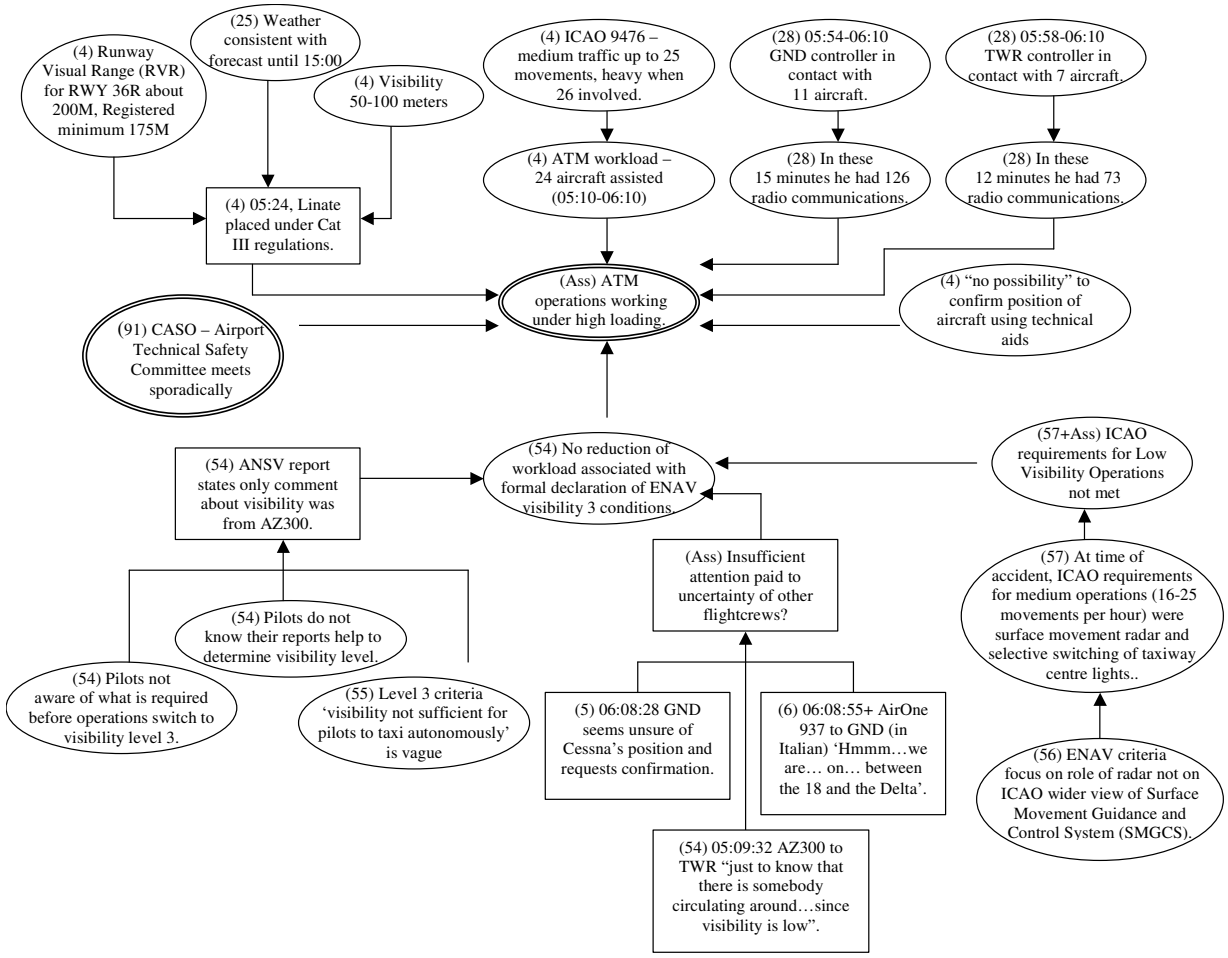

Figure 6: ECF Analysis of the Linate Accident Linking Organisational Issues to Specific Events

Figure 6 illustrates the way in which ECF diagrams can bridge between the previous organisational and contextual issues to focus more narrowly on the events in the timeline that led to the accident. As can be seen, this diagram focuses on those factors that contributed to the loading on ATM personnel. Some of the contributory factors have been analysed before, such as "no possibility to confirm position of aircraft using technical aids". Analysts can, therefore, use previous diagrams such as Figure 5 to trace back the underlying organisation and technical issues that are summarised by the inclusion of this node in Figure 6. The left-hand side of the previous diagram deals with meteorological conditions that can be seen as the catalyst for the accident. The ANSV report describes the low visibility conditions that held on the morning of the crash. The observed conditions were consistent with the forecast until approximately 15:00 and, as can be seen, the airport was therefore placed under Cat III regulations at 05:24. During the interval from 05:10 to 06:10 when the collision occurred the controllers assisted 24 aircraft. 21 taxied from the North and West apron. 3 more had landed and were moving from the runway areas. During the 15 minutes before the accident, the GND controller was in contact with 11 different aircraft and had

approximately 126 radio communications. Over the last 12 minutes before the accident the TWR controller contacted 7 aircraft and had 73 radio communications. ICAO DOC 9476 defines medium traffic to be up to 25 movements. Anything beyond this is classified as heavy traffic. The analysis of the upper portion of Figure 6 leads to conclusions that are similar to those voiced in recommendation 10. This urged regulatory organisations to consider the workload imposed by mixed mode operations, combining general and commercial aviation, rather than simply defining workload in terms of the total number of movements or aircraft. Our analysis of the previous ECF diagram suggests that a number of other factors should also be considered.

Additional Recommendation 14:
The level of traffic should be determined by a combination of the mode balance, commercial or civil, the total number of movements *and* the prevailing meteorological conditions. Current distinctions between low, medium and high traffic movements are relatively meaningless without this additional contextual information. Further research might be conducted to provide controllers and supervisors with simple mnemonics and other aide-memoires that could help them to make decisions about workload when they are faced with changes in their operational environment.

The lower portion of Figure 6 focuses on the reasons why measures were not taken to reduce the workload on ATM personnel in the interval leading up to the Linate runway incursion. ENAV technical document DOP 2/97, in accordance with ICAO DOC 9476-AN/927, identifies situations in which the categorisation of an airport can be downgraded or movements limited if it is not equipped with operational Aerodrome Surface Movement Indicator radar. This ENAV document identified three visibility conditions. The first level dealt with situations in which crews and controllers could coordinate their actions by direct visual observations. This was clearly not the case on the morning of the Linate accident. Level two conditions exist when the crews can use visual observations to coordinate their movements even when controllers cannot make direct visual observations. Level three conditions involve "visibility not sufficient for pilots to taxi autonomously and for ATC operators to exercise visual control of all such traffic" (page 54). Under this final level, departing traffic could be cleared to begin taxiing only when any landing aircraft was reported to be at their assigned parking bay and any departing traffic before them had already taken off. It seems clear that the decision to declare level 3 visibility, had it been made at Linate, would have led to a profound decrease in workload on ATM staff. However, Figure 6 illustrates some of the reasons that the ANSV used to explain why this decision was not made. Pilots were unaware that the decision to make this transition depended on their assessment of the conditions on the taxiways and runways. Although there are many comments that can be interpreted as references by the crews to poor visibility, none of these can be interpreted as a direct request to consider the visibility categorization. There are further issues that are not considered by the ANSV. In particular, crews would have to be sufficiently well motivated to make visibility reports that might have severe operational consequences both for themselves and their colleagues. The ANSV do, however, recognize that the official classification of "visibility not sufficient to taxi autonomously" was "generic, subjective and dependent from undefined variables" (page 55).

The ANSV report agues that there was only one example of a comment from an aircrew that might have prompted ATM staff to declare level 3 visibility. Figure 6 uses an event symbol to denote "05:09:32 AZ300 to TWR 'just to know that there is somebody circulating around…since visibility is low'". However, further analysis of the GND transcripts shows that the crews made a number of other comments that relate to visibility problems. AirOne 937 seemed to be very uncertain about their precise location after a GND prompt. ATM personnel also seemed unsure about the location of the Cessna as they sought clarification at 06:08:28. The ANSV were justified in not considering these comments because they illustrate uncertainty over the location of aircraft. They cannot be directly interpreted as explicit statements about poor visibility. However, the crews were unaware of the need to make these concerns

explicit. Two weeks after the accident the ENAC amended the visibility regulations to state that level 3 conditions exist when RVR is less than 400 meters.

Additional Recommendation 15:
Aircrews are a 'last resort' for objective information about prevailing meteorological conditions. Automated instruments and standardised metrics should be used wherever possible. If this is impracticable then aircrews must be explicitly told about the criteria to be applied when making such judgements. ATM personnel must also ensure that aircrews are prompted to provide this information.

Figure 6 also includes information on the ICAO requirements for low visibility operations. Page 57 of the ANSV report includes the observation that for medium operations (16-25 movements per hour) there is an assumption that surface movement radar would be available and that controllers should be able to perform the selective switching of taxiway centre lights. As we have seen, ATM personnel were not supported by these infrastructure facilities prior to the Linate collision.

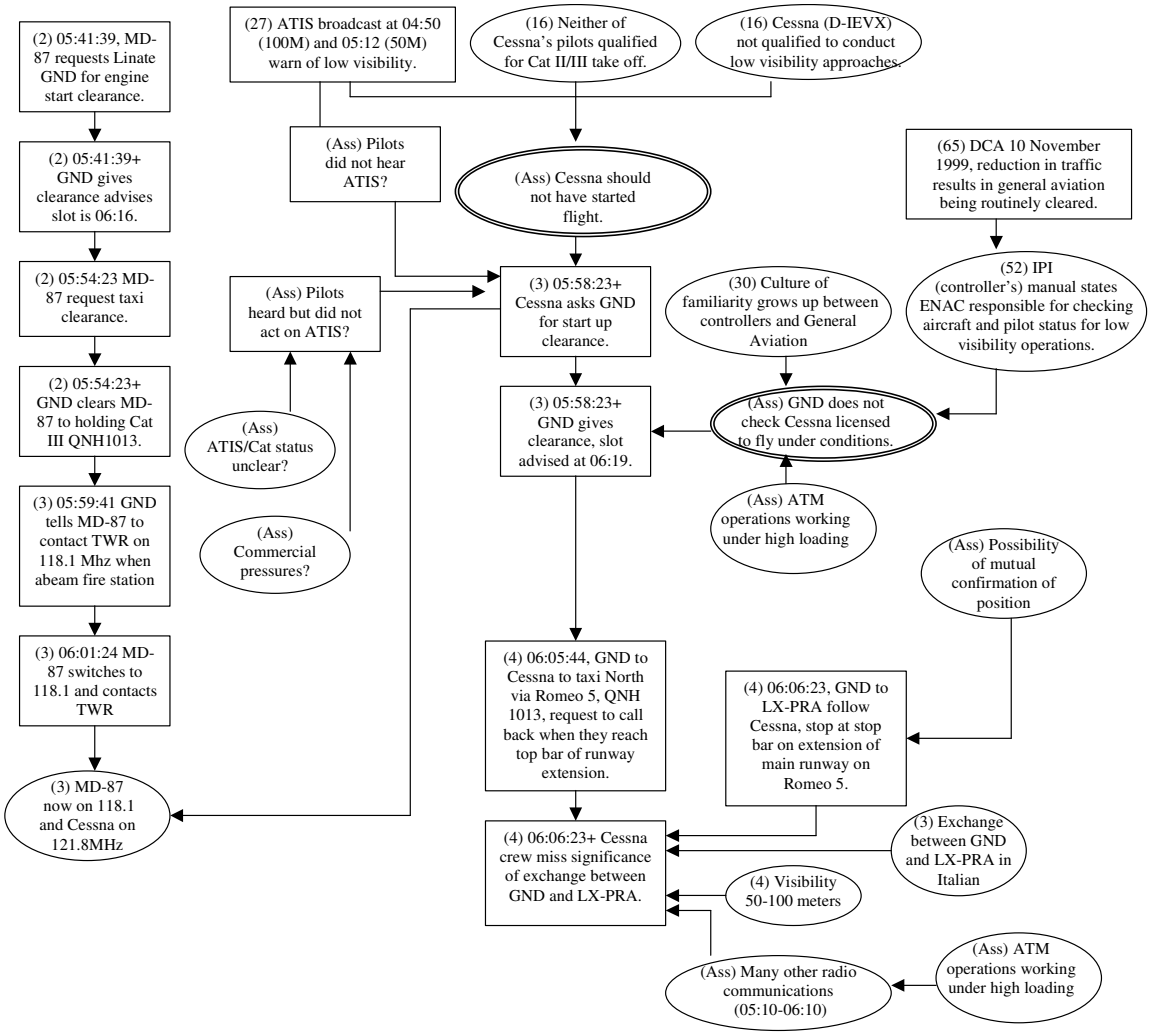

Figure 7: ECF Analysis of the Linate Accident – Initial Events on the Morning of the Accident

Figure 7 moves the ECF analysis from the contextual and background factors to the specific events that occurred on the morning of the accident. It begins with the observation that there was an Automatic Terminal Information System (ATIS) broadcast at 04:50 advising of low visibility. This broadcast was updated at 05:20, 05:24, 05:25, 05:50 and 06:20 (post accident) repeating the warning. Figure 7 also

captures the observation that neither the aircraft nor the pilots were qualified to take-off under the Cat II/III conditions that held on the morning of the accident. It follows that the Cessna should not have started the flight. However, the ANSV report does not provide a detailed analysis of the reasons why the Cessna did attempt to take off. This omission can be justified in a number of ways. Firstly, the Cessna was not obliged to carry a cockpit voice recorder and so we have very little evidence of the discussions that took place before the crew requested permission to start their engines. A number of other considerations justify the lack of explicit causal analysis in the official accident report. In particular, the ANSV provide an implicit analysis of the pressures that might have helped to shape the crews' decision when they consider the personal and commercial incentives to complete the flight. It is difficult to be sure of the precise motivations that influenced the crews' decisions. Hence figure 7 considers two possible explanations. Firstly, the crew may not have checked the ATIS announcements. This is marked as an assumption in the diagram and can only provide a partial explanation. The crews' own assessment of the prevailing meteorological conditions should also have alerted them to the possible dangers. Figure 7 also considers the possibility that they heard the ATIS announcement but failed to act on it, either because of the commercial and personal pressures mentioned above or because the ATIS announcement did not spell out the Cat status of the aerodrome under the prevailing meteorological conditions.

Additional Recommendation 16:
Our analysis of the ANSV report has shown how difficult it was to determine the visibility levels. This, in turn, made it difficult to identify what levels of traffic and equipment provision could safely be tolerated . ICAO and ENAV recommended different approaches. This previous analysis focused on the ATM perspective. Further analysis should also be conducted to determine whether aircrews could use existing ATIS and other information resources to unambiguously determine the operational status of runways, including Cat level.

Figure 7 goes on to show that the Cessna requested start-up clearance at shortly after 05:58. GND control then provided permission to the crew. It can be argued that ATM personnel should have checked the licence conditions of the aircraft to ensure that they were permitted to operate in the low visibility conditions that currently held at Linate. As we have seen from Figure 6, ATM staff were working under a relatively heavy loading. In addition, Figure 4 has described how the initial dominance of local and regional general aviation at Linate may have led to the development of a culture of familiarity between ATM personnel and these crews. The ECF diagrams in Figure 7 not only explain the controller's actions in terms of the contextual factors that were introduced in our previous it also provides new insights. As can be send, the reduction in traffic following the movement of slots to Malpensa may also have contributed to working practices that routinely cleared general aviation operations even though the controller's manual stated that ENAC was responsible for checking aircraft and pilots for low visibility operations.

Additional Recommendation 17:
The onus should be on the crews to ensure eligibility at the point at which they make a request as they are in the best position to understand their classification and license status. Aircrews could usefully be reminded of this obligation and greater effort should be made to ensure that they can unambiguously determine their rights and responsibilities from information sources such as ATIS (see recommendation 16). The intervention of operational ATM personnel to check such permissions should only be relied upon as a last resort.

Additional Recommendation 18:
The onus is currently on ATM and ground personnel to check the eligibility of aircrews to perform the operations that they request. It is unrealistic to expect reduced number of ATM personnel to conduct such checks while controlling large numbers of other aircraft. Spot checks made by other ground personnel prior to flight are of only limited value; crews argue that they would not fly if the

meteorological conditions changed. This is analogous to asking a motorist if they intend to break the speed limit. Hence, spot checks should also be made on the basis of *previous flights*. Enforcement actions can be taken if crews can be shown to have violated their licence conditions.

The left-hand sequence of events in Figure 7 describes how the MD-87 commenced its departure. This included the comment that the aircraft was to taxi to the 'holding position Cat III, QNH 1013". This analysis continues to the point at which the MD-87 transferred their radio frequency to the TWR on 118.1 while the Cessna continued to communicate with GND control on 121.1MHz. It is important to remember that some nine minutes elapsed between this handover to the TWR and the time of the collision. It might be argued that the protocols used for such handovers should be re-examined given that the opportunity for GND, TWR and the two crews to coordinate their actions was now significantly reduced. The common channel of communication between the GND controllers, the MD-87 and the Cessna diverged into two separate and distinct communications channels between GND and the Cessna and between the TWR and the MD-87 from 06:01:24 onwards. The previous ECF diagram also describes how GND personnel cleared another aircraft LX-PRA to follow the Cessna until the stop bar on the extension of the main runway on taxiway R5. As we have seen, this exchange was in Italian. This may partly explain why neither crew was able to use this clearance to provide information on their relative positions. Equally, however, the crew of LX-PRA may not have been able to see that the Cessna was no longer in front of them given the reduced visibility on the taxiways.

Figure 8 extends the analysis to look at the events that occurred and the contextual factors that made them more likely as the Cessna taxied onto R6. As can be seen, GND requested the crew to taxi North via R5 and to call back when they reach the top of the runway extension bar. However, the crew took a Southeasterly direction. Figure 8 identifies two possible explanations that are considered at several points in the ANSV report. We know from the communications transcripts that the crew correctly read back the R5 assignment, see page 4 of the official report. It can, therefore, be argued that they formed the correct intention to head along R5 but that they were disoriented by the lack of appropriate visual cues. This interpretation is supported by our analysis of the taxiway and runway infrastructure in the ECF of Figure 4. The characters identifying R5 and R6 at their junction were worn and did not conform to ICAO requirements. Similarly, the route North on R5 had no green lights within 350 meters of the junction while the route Southeast on R6 had more salient cues with lighting only 80 meters away. Figure 8 also provides a further explanation. The crew correctly confirmed the allocation of R5 at 06:05:44. Other factors such as workload or distraction led the crew to miss-remember this allocation. In this interpretation the signage and lighting were less significant as causes of the incident that is suggested by the ANSV report. It seems clear by the unequal allocation of analytical resources that the official investigation favours the first of these explanations. This is justified; Linate clearly was in violation of several ICAO requirements for signage and lighting. The ANSV assumption that the crew intended to taxi on R5 is also supported by the lack of any cockpit transcripts for the Cessna. In other words, there is no reason to assume that the crew miss-remembered the instruction for R6 and deliberately headed out on the wrong taxiway. If, however, we consider the possibility that the crew did intend to follow R5 then more attention needs to be paid to the possible factors that might have led them to forget the initial allocation to R6. These might include the stresses associated with preparing for a flight in low visibility conditions that they were not licensed to undertake. It is also important to remember that the alternate explanations shown in Figure 8 could be too simplistic. For instance, stress, high-workload and distractions might have combined with the inadequate signage to create doubt about **both** the assignment of the taxiway and the actual route to be taken. My personal view is that this is the most probable explanation. Hence it is this uncertainty that explains why the Cessna crew spontaneously report their position approaching 'Sierra 4' at 06:08:28.

Additional Recommendation 19:
Current CRM techniques often focus on airborne operations. Arguably too little attention is paid to the problems that uncertainty and confusion can create for runway operations. This is

confirmed by the lack of integrated training for aircrew, ATM personnel and fire crews on the problems of runway incursion at Linate. It seems unlikely that in the short term we will be able to ensure that all maps and information resources provide unambiguous and suffienet cues for aircrews to determine their location on most runways in low visibility operations. Hence aircrews should be trained to recognise and communicate any uncertainty over their location on a taxiway so that appropriate help can be provided.

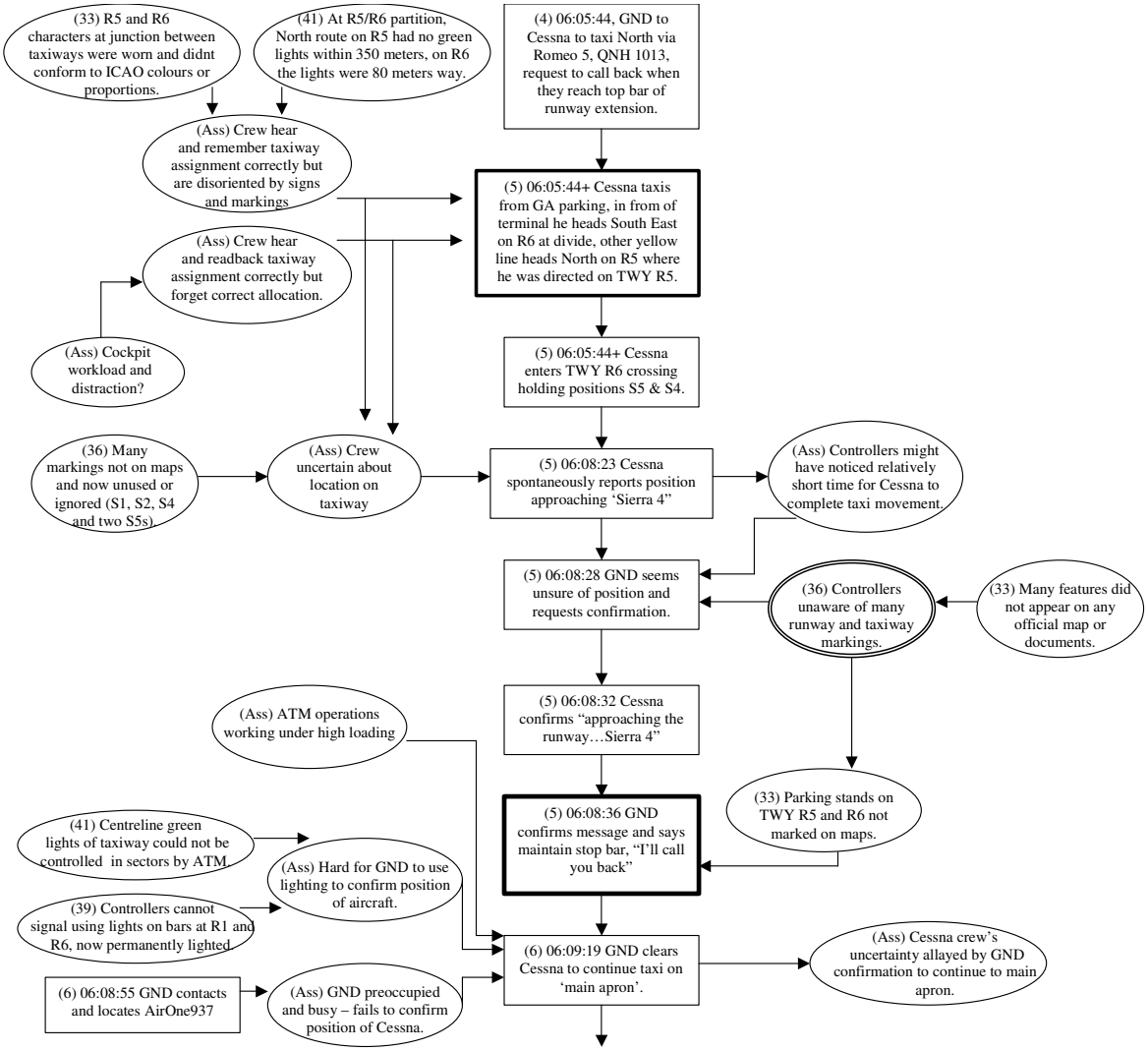

Figure 8: ECF Analysis of the Linate Accident – Problems with the Taxiway Signage and Markings

As mentioned, the crew of the Cessna made an unexpected report of their position near 'Sierra 4' at 06:08:23. This provided one of the few opportunities for ATM personnel to detect the potential runway incursion. These are two different lessons to be learned from this opportunity. Firstly, we must understand the potential reasons why the crew made this report so that we can encourage these observations and provide similar opportunities for the detection of incursions in the future. Secondly, we must also understand the reasons why the ATM personnel did not identify the potential problem once the report had been made. Figure 8 builds on the previous analysis of recommendation 19 were it was argued that aircrews need to identify and communicate uncertainty over their location on a taxiway. As can be seen, this uncertainty was based on the lack of sufficient markings and signage and may also arguably have been compounded by uncertainty over the initial allocation to R5. In either case, the lack of markings for S1, S2, S4 and the two S5's may well have compounded any apparent confusion for the aircrew. The reasons for the lack of documentation and the disuse of these markings were analysed in

Figure 4. From the controllers' perspective, several aspects of the Cessna's report might have alerted them to a potential problem. The report was made relatively soon after the initial instruction to R5 and certainly well before ATM personnel might have expected a call back from the runway extension. The report also referred to markings 'Sierra 4' that were unused and unmarked in official maps and documentation. In consequence, GND seems to have questioned the report by asking for confirmation. They respond by saying 'I'll call you back' at 06:08:36. Under a minute later, GND responds by clearing the Cessna to the main apron. This decision is arguably just as important as the aircrews' decision to follow the line towards R6 rather than R5. The GND clearance can be explained in terms of the workload issues for low visibility operations that were introduced in Figure 6. In particular, their attention was at least partly taken by requests from another aircraft (AirOne 937). Their dilemma was compounded by the difficulty of taking active measures to determine the location of the Cessna at 'Sierra 4'. The light bars at R1 and R6 were no longer in their control and remained permanently lit. Similarly, the green centre lights of the taxiways could not be controlled in sectors. These issues are well covered in the ANSV report. However, it is also important not simply to ask why these facilities were not available (see Figure 6) but also to question what would have happened if these systems had been functioning correctly. In particular, there is no guarantee that ATM staff would have decided to use a lengthy trial and error process to determine the location of the Cessna given that the aircrew would not have been able to see the initial lighting changes at their expected location on R5.

Additional Recommendation 20:
When confusion exists there should be a clear verbal protocol for ensuring that both the crew and the ATM personnel know their location before any permission is given to proceed. Greater consideration should also be given to the mechanisms that might be used to determine the location of an aircraft under low visibility conditions. In such circumstances, the trial and error use of lighting systems may increase the risks of runway incursions or of other operational incidents given the associated increases in workload. If lighting systems are to be used in this fashion then studies need to be conducted to ensure that this is regarded as a distinct and potentially dangerous mode of operation where ATM staff may need additional support from supervisory or other ATM personnel.

The final element in Figure 8 denotes that the Cessna's initial uncertainty over their location, which arguably prompted their spontaneous report to GND at Sierra 4, was answered by the controllers' confirmation to continue towards the 'main apron'. Figure 9 builds on this analysis to show the impact that it might have had immediately before the collision. As can be seen, the Cessna crew confirmed the clearance and reported that they would call back before entering the main taxiway. This appears to have been the last communication between ATM personnel and the crew. Figure 9 includes the assumption that the Cessna's pilot and co-pilot did not question whether they were on the correct taxiway at this stage because the GND control had just given them permission to continue taxiing. This reiterates the importance of recommendation 20, without some protocol for the explicit confirmation of location information the potential concerns of a pilot or controller may be overlooked by the inadvertent cooments of other aircrew or ATM staff. The ECF diagram again includes insights from the previous analysis of the environment at Linate in Figure 4. In this case, the crew did not question their position because there were no external prompts to indicate that they might have been on R6 rather than R5. There may have been a missing placard similar to one that was found for R5 and there were no other markings to indicate the identity of their taxiway other than the characters at the junction, mentioned previously.

Figure 9 also illustrates another key moment in the events leading to the accident. In this case, the Cessna's crew crossed the STOP markings 180 meters before RWY 18L/18R onto TWY R6. The ECF diagram reiterates points from Figure 4 that the STOP sign was not ICAO compliant. The sign was not shown on AIP or Jeppensen charts even though ENAV regulations required that the TWR should stop all aircraft at the signal on TWY R6. If it is true that neither the aircrew nor the ATM personnel knew the true location of the Cessna at this point then these last two comments are irrelevant and might arguably be

excluded from the analysis. Neither the aircrew nor the ATM staff would have known to check the maps to check for the signs in their location. The TWR was not expecting the Cessna to be on R6 and so was unlikely to enforce the STOP regulations. Equally, if the GND proceed command had allayed the aircrew's lingering concerns then they too are likely to have missed the inconsistent STOP signs because they were not expecting them to be there.

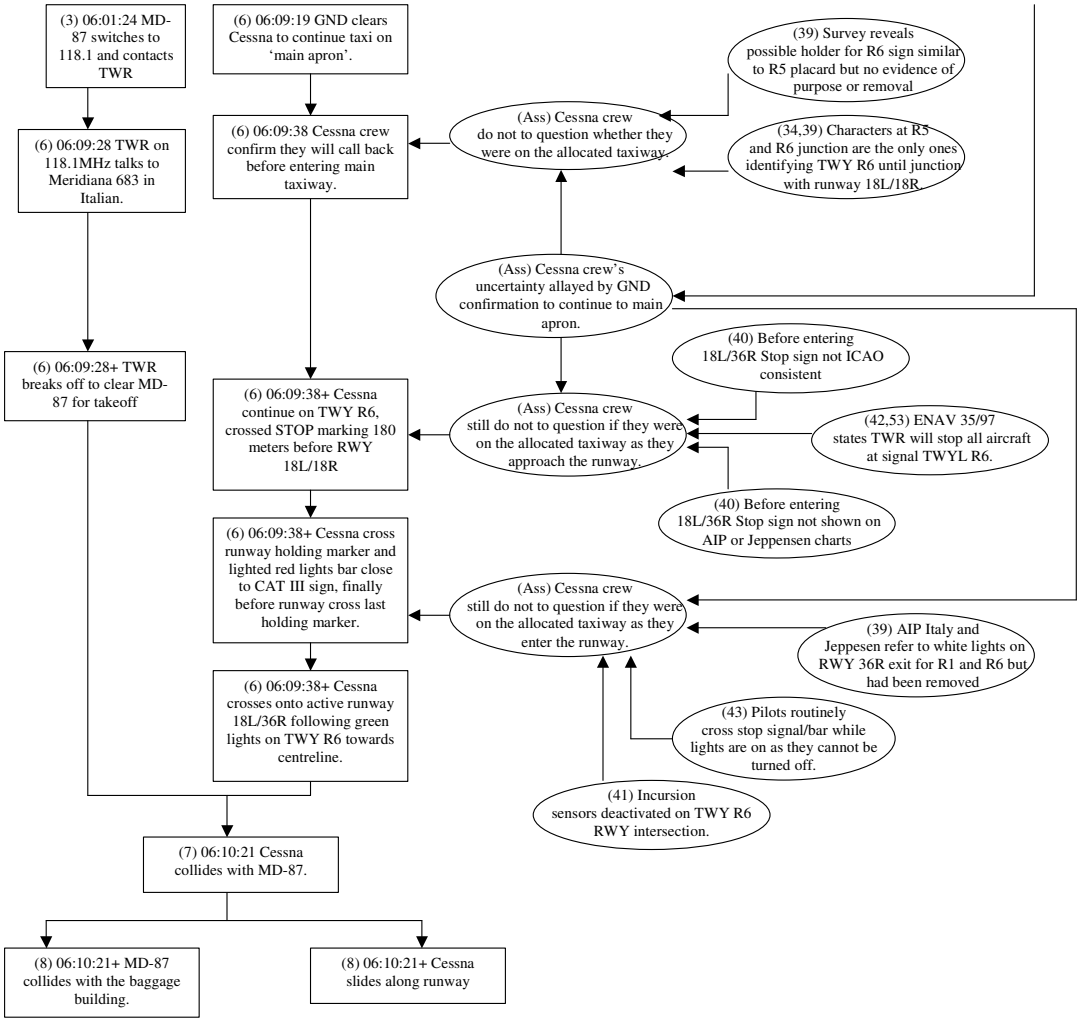

Figure 9: ECF Analysis of the Linate Accident – Events Immediately Prior to the Collision

AT some time shortly after 06:09:38, the Cessna crossed the runway holding marker. They passed an illuminated red light bar close to a Cat III sign. Again it must be assumed that they were disoriented and did not at this stage question their assumed location on the appropriate taxiway short of the runway. The ANSV provide some information about the reasons why this final set of defences might have been broached when they argue that pilots routinely had to pass illuminated stop signals because ATM personnel could not routinely turn them off. Figure 9 also includes further observations on inconsistencies between the signage and official documentation. As before, however, it is uncertain whether there inconsistencies were immediate causes of the accident. There is no evidence that the Cessna crew attempted to use this documentation to trace their position on the taxiway at this relatively late stage in the accident. Their decision to cross onto the active runway may also have been influenced by the path of the green lights on TWY R6 that led onto the centreline of 18L/36R.

Events Following the Linate Collision

The Linate accident has many unusual and worrying features. One of these is the lack of coordination that characterised the immediate response to the collision. There are many reasons for this. Clearly, the adverse meteorological conditions that were an important cause of the incursion also served to exacerbate the problems of responding to the accident. Other organisational factors may not have helped. For instance, the ANSV report argues that the response was hindered by a failure to learn from previous drills that had been organised to prepare for future incidents. Figure 10 provides an overview of the immediate response to the Linate collision.

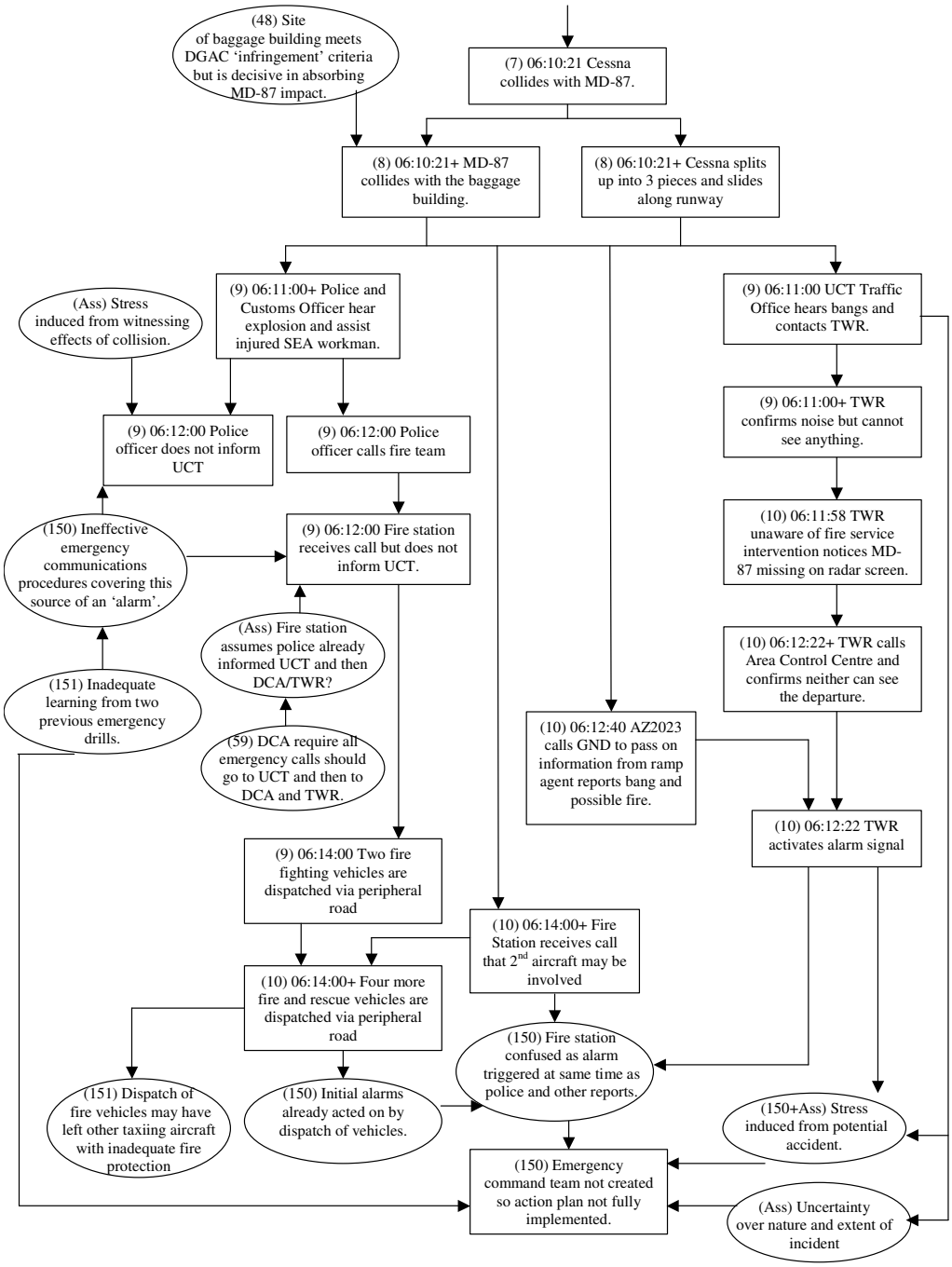

Figure 10: ECF Analysis of the Linate Accident – Events Immediately After the Collision

As can be seen, the MD-87 collided with a baggage building that was situated close to the runway. The location of this structure conformed to the relevant DGAC infringement criteria. Although a previous ENAV survey had shown that it encroached the permitted area by around 1 metre and additional warning lights had subsequently been added to the structure. The ANSV report concluded that the position of the building was 'decisive' in absorbing the violent impact of the aircraft (page 48) and was 'instrumental in the catastrophic sudden and violent stoppage of the aircraft' (page 160). The official report does not speculate whether the consequences of the incident would have been less severe if the baggage handling facility had not been placed so close to the runway. The ANSV report does not list the location of the baggage facility as one of the factors that caused the adverse outcome to this incident once the collision had occurred. None of the existing recommendations mention the location of buildings adjacent to runways.

Additional Recommendation 21:
The post accident events at Linate and the impact of the MD-87 with an approved structure raise questions about the adequacy of existing regulations governing the location of buildings around runways. Studies should be conducted to review the requirements for new constructions even if it is impracticable to revise the position of existing major structures close to major runways. It is important to stress that at least in the short term there is little prospect of eliminating the problem of runway incursion. We must, therefore, carefully consider ways of mitigating the impact of those adverse events that may occur.

Figure 10 extends the analysis of post accident events to consider communications problems that frustrated attempts to coordinate the response to the collision. A Police Officer who was close to the baggage facility heard the collision and rushed to assist the injured. They then contacted the fire station. However, he did not contact the UCT who should have coordinated the response according to the prearranged emergency plan. One consequence of this was that ATM personnel were not immediately alerted about this initial report. The officer's decision to call the Fire Service is entirely understandable given the stress that can be induced from witnessing the after effects of such incidents. The ANSV report also argues that a lack of organisational learning from previous drills had led to problems in the procedures and mechanisms that governed the reporting of incidents from such sources. The fire station received the officer's call and dispatched two vehicles via a peripheral road. It can be argued that even if the police officer, acting under the stress of the moment, had failed to contact the UCT to coordinate the response then Fire personnel should have reported to them. However, Figure 10 shows that the Fire Officers may have assumed that the Police had followed the DCA's recommended procedures and had already made this call. This assumption like the others that have been explicitly represented in previous ECF diagrams can be tested against witness statements and evidence not presented in the official report.

The failure of communications between the emergency service and the UTC coordinators may have hindered the establishment of an emergency team. However, UTC personnel were alerted to the incident even without calls from the Police and Fire Officers. The Traffic Office heard the collision and contacted the TWR. They then attempted to confirm which aircraft was involved. After subsequent calls with the Area Control Centre they realise that the MD-87 is missing and the TWR activates the alarm signal as required by the emergency plan. However, the stress and uncertainty of a potential incident can again be used to explain why neither the ATC not the UTC staff took the steps necessary to create an Emergency Command Team. This emergency team was supposed to coordinate the response to such incidents. It was also intended to ensure that the pre-arranged emergency plan was fully implemented. A key issue here is that the same lack of coordination that led to the failure to convene the emergency team, also prevented the coordinated response that the emergency team was intended to address. This form of vicious circle had not been adequately addressed in the previous drills.

The fire station received a second call indicating that two aircraft may have been involved in the incident and, therefore, dispatched four more vehicles. The lack of coordination may have affected this decision

as the ANSV argue the dispatch of so many appliances may have left other taxiing aircraft with inadequate fire protection (page 151). This is a significant concern given the uncertainty in the aftermath of the collision and the possibility of wreckage being dispersed across runways and taxiways. In the meantime, the alarm signal from the TWR may have added to the Fire Service confusion. They had already acted on two previous warnings. Hence, it is likely that they concluded they had taken sufficient actions without inquiring about the formation of the command team or explicitly communicating information about their actions back to the TWR. In particular, it seems likely that they assumed that TWR already knew the location and other information that they had received in the previous two calls that triggered the dispatch of their fire vehicles. As we shall see, these assumptions proved to be unwarranted.

Additional Recommendation 22:
The immediate response to the collision was characterised by confusion. The lack of coordination, in part, prevented the establishment of an Emergency Coordination Team and the lack of an Emergency Coordination Team contributed to the lack of coordination. Simulations and drills can be used to increase coordination in the aftermath of an adverse event. This is noted in the ANSV report. However, those drills need to be focussed if they are to justify the resources that are spent on them. The military use 'Lose your leader' simulations to test whether organisations can respond when incidents unfold in unexpected ways. In this instance, drills should not automatically assume that an Emergency Coordination Team will lead the immediate response to all adverse events.

Figure 11 captures the way in which the response evolved after the collision. The activation of the alarm signal prompted the GND controllers to return two taxiing aircraft to the West apron. The ANSV report does not go into detail about the precise steps that were taken to confirm the locations of these and other aircraft. Given the previous discussion in this report, there is a clear concern that the meteorological conditions and other factors that led to the initial runway incursion would not also have created potential uncertainty over the location of other aircraft. Meanwhile, an unrecorded call had alerted Fire Personnel to the possibility that the MD-87 had been involved and that there was wreckage close to Gate number 5. The Fire Service then ordered all vehicles to proceed to this gate even though the initial report had not, as yet, been confirmed.

The TWR confirmed to the DCA that their emergency alarm was genuine. TWR personnel also then called the Fire Station to ensure that that they had received the alarm. They confirmed that the alarm had been heard and that 'they are on their way'. This ambiguous response did not tell ATM personnel the precise destination of the Fire crews as they attempted to locate the site of the incident. Fire officers may have assumed that the TWR knew of the location of the incident because they initiated the alarm. The ambiguous communications between the Fire Station and the TWR creates two possibilities. Either the TWR were sure of the location of the fire crews and the incident and hence they did not need to ask for clarification or they were uncertain about the deployment of emergency personnel in the aftermath of the incident. It seems likely that there was at least some uncertainty over the location of fire personnel and the site of the wreckage. TWR personnel could not directly monitor the crews' communications because they were on a different frequency to that used for emergency coordination. The fire crews' frequency was not accessible to the TWR. The ANSV report argues that such channels should have been made available to other parties involved in the emergency response but does not consider the additional workload implications for key personnel, including ATM staff, who would have to filter a mass of communications as they coordinated the response. They do, however, identify a host of distractions that were created by unauthorised communications in the aftermath of the incident.

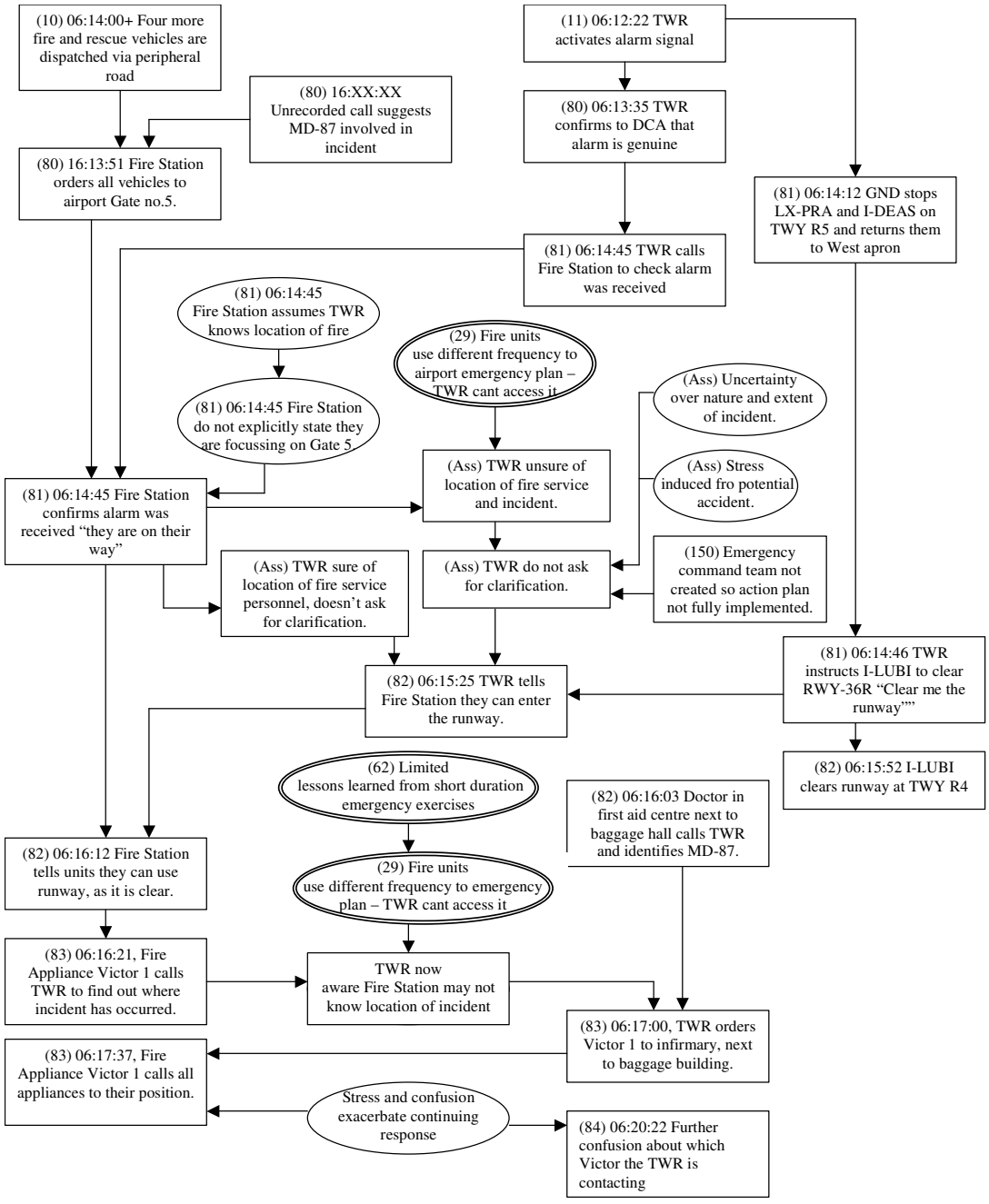

Figure 11: ECF Analysis of the Linate Accident – Events After the Collision

Figure 11 also identifies a number of reasons why the TWR did not request clarification about the location of fire personnel and the site of the incident. Stress and uncertainty may explain the TWR's failure to confirm these details. Similarly, the lack of an Emergency Command Team or more detailed plan may have removed effective prompts for the TWR to obtain a clearer overview of the immediate response to the accident. The ANSV report analyses the need to coordinate information and to remove ambiguity in communications between emergency services, aircrews and ATM personnel. As mentioned, it also considers the importance of providing access to common communications channels and of minimising unauthorised use of those channels. Arguably, the official report does not consider a range of low-cost technical innovations that might easily be used to address some of the confusion in the aftermath of runway incursions and similar events. Later sections will deal with the use of military grade thermal imaging and image intensification equipment by fire personnel. For now it is sufficient to

observe that the confusion in the aftermath of the Linate collision might have been reduced by the introduction of relatively simple commercial vehicle tracking systems.

Additional Recommendation 23:
There are significant costs associated with the installation of detailed ground based movement tracking systems across the many different aircraft types that use facilities such as Linate. However, at least part of the confusion after the collision stemmed from problems in communicating the location of fire fighting resources to ATM personnel. This information could be automatically communicated by any one of a number of commercial vehicle tracking systems that will provide position data down to several metres in detail. These commercial systems could initially provide displays in the TWRs from sensors in each of the fire fighting appliances. Eventually, these vehicles might also be equipped with these displays to help ensure that they can locate their colleagues under low visibility conditions.

Figure 11 illustrates how ambiguity over the location of fire personnel was compounded by communications problems with aircrew. This created a potential hazard in the aftermath of the runway incursion. The TWR instructed I-LUBI to "clear me the runway" at 06:14:46. They then informed the Fire Station that their personnel were permitted to enter the runway at 06:15:25. Fortunately, I-LUBI was able to vacate the runway by 06:15:52 while the Fire Station did not issue their directive until 06:16:21. However, these events were not synchronised and it would have been possible for a conflict to arise between the aircraft trying to leave the runway and the fire crews searching for the location of the damaged aircraft. One explanation for this potential hazard was the ambiguity of the TWR command to I-LUBI. 'Clear me the runway' could be interpreted as a command to vacate 36R. It can also be interpreted as a command to check and confirm that there were no other obstacles or instructions visible to the crew of the aircraft. In other words, it was an instruction to check that the runway was 'clear' rather than for them to clear it. The ANSV explicitly consider this ambiguity and the potential hazards that it created. As before, it is argued that improved communications protocols might have helped to avoid any confusion. This is an optimistic assertion given the long and recurrent history of similar problems in aviation accidents. The proposal to provide enhanced monitoring of fire crew movements might in recommendation 23 might also provide an additional 'defence in depth' against the consequences of such misunderstandings.

At this point in the accident, the ANSV report argues that the Fire Station knew the probably location of the damaged MD-87 but ATM staff did not (page 83). It is also clear that some of the fire crews were also confused. The crew of Victor 1 called the TWR to find out where the incident had occurred. This confusion is again symptomatic of the meteorological conditions that should arguably have curtailed operations at the airport before the incident. As recommendation 2 states, this was justified both by the increased risk of incursions but also by the corresponding increase in difficulty associated with mounting an effective response. Shortly before the information request from Victor 1, a doctor in the first aid centre next to the baggage hall called the TWR and confirmed that MD-87 was involved in the incident. This call provided the TWR with the first reliable information about the probable location of the accident and they ordered Victor 1 to proceed towards the first aid centre where the doctor had called. Shrotly after this, Victor 1 orders all appliances to the baggage hall. The ANSV do not comment on the terminology used by this crew. The fire officer simply stated 'I want all Victor here'. Fortunately, the ambiguity in this instruction does not seem to have created the confusion that is apparent in previous communications.

During the interval from 06:20 until 06:25, the TWR continued communicating on a direct phone line with the Fire Station. They repeatedly tried to confirm the identity of the appliance that they had sent to the First Aid post and which had then ordered the other appliances to rendez-vous at their location. At this point, 06:24:06, neither the Fire Station nor the TWR are sure that there have been any casualties. GND responds by asking whether there were two aircraft involved. Figure 12 picks up the analysis from this point.

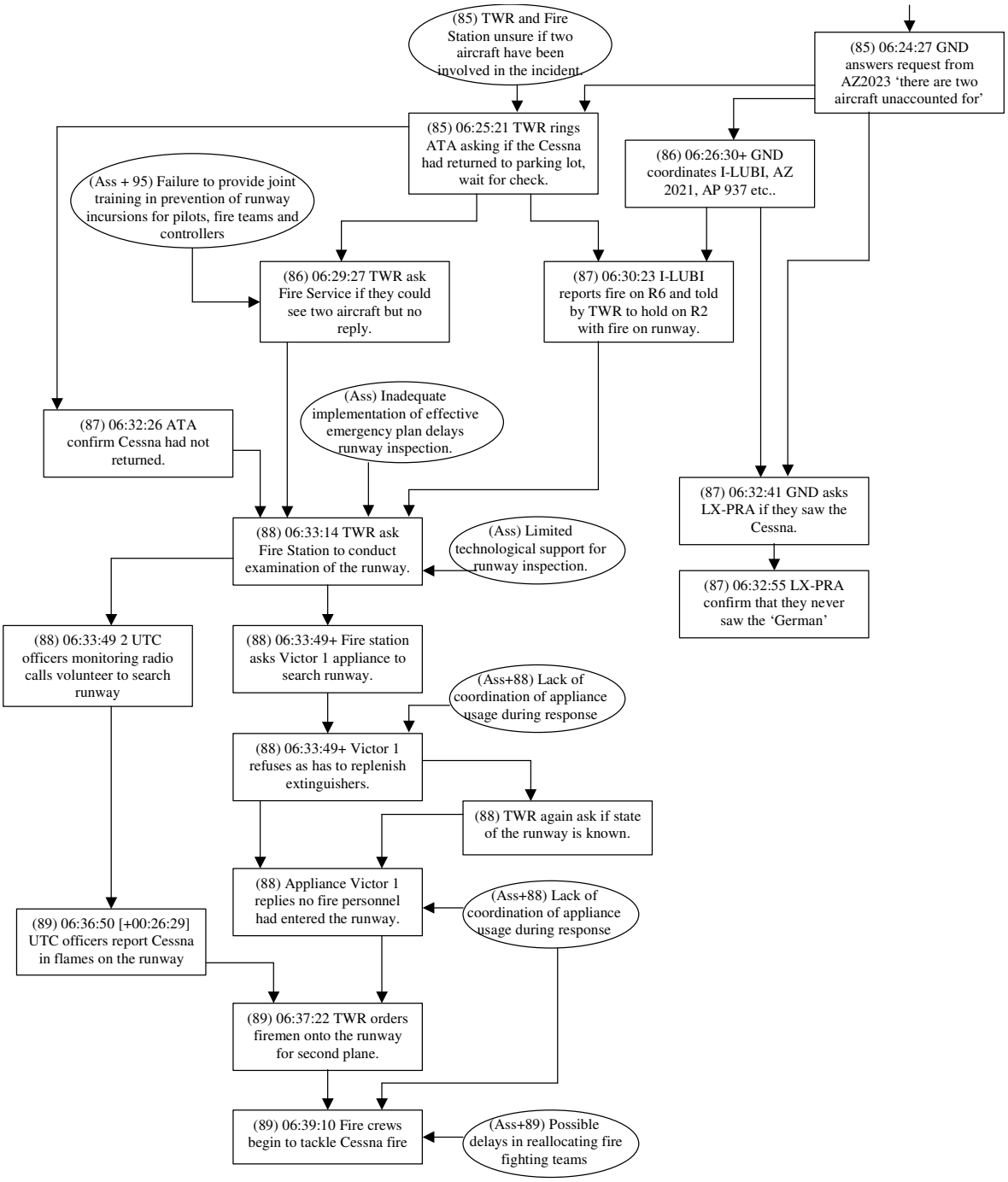

Figure 12: ECF Analysis of the Linate Accident – Locating the Cessna

Although the GND confirmation that there were two aircraft involved initially seems to have been directed at AZ023, there also seems to have been some subsequent communication with TWR personnel because they respond almost immediately by asking the Airport Handling and Service provider (ATA) if the Cessna has returned to its parking lot. Meanwhile TWR receive a report from I-LUBI that they have seen flames on runway R6. GND tries to confirm whether LX-PRA ever saw the Cessna that they had been requested to follow (see Figure 7). They confirmed that they had not seen the Cessna and at about this time the ATA confirm that the Cessna had not returned. While all of this was going on, TWR asked the fire service if they could see two aircraft. There was no answer to this initial call at 06:29:27 and so after the confirmation from ATA, TWR asked the Fire Station to conduct an examination of the runway. The ANSV does not explicitly state whether such an examination should have been scheduled according

to the airport emergency plan. However, in retrospect it seems likely that a more considered response to the emergency might have looked beyond the initial site of the MD-87 wreckage in order to ensure that they did not miss any injured survivors either from the aircraft or airport ground staff. Another issue here that was not considered by the ANSV was whether additional technological support could have been provided during this search. For example, the military now routinely make use of low cost night vision equipment, either based on thermal imaging or image intensification technology. This equipment is sufficiently robust now to be considered for deployment to fire service personnel. Thermal imaging devices would provide a useful means of locating burning wreckage on a runway in a relatively short period of time. It should be noted that certain meteorological conditions, such as fog and mist, can reduce the temperature gradients that are recognised by this equipment. However, in most cases this would not be sufficient to mask the heat generated by burning aviation fuel.

Additional Recommendation 24:
Emergency plans should be revised to ensure that fire fighting personnel and other staff do not prematurely commit all available resources to a particular location without first coordinating a full survey of the surrounding area to ensure that casualties are not overlooked. This recommendation is strongly related to the ANSV requirement that any decision to commit emergency personnel should not overlook the hazards faced by other aircraft and staff.

Additional Recommendation 25:
EUROCONTROL or other national service providers should commission a detailed study on the feasibility of image intensification and thermal imaging technology to support emergency operations in low visibility conditions. Military technology is sufficiently robust and is available at a low enough cost for it to be widely used by, for example, army truck drivers. It is reasonable to suppose that it might be used to help locate burning wreckage, jet exhausts etc as fire crews navigate runways and taxiways. A formal risk assessment should also be conducted as there are operational risks associated with the improper use of these devices, for example as aid to 'high speed' driving in reduced visibility.

The lower half of Figure 12 documents the way in which fire crews could not perform the search that was requested by TWR because they were replenishing their extinguishers. This again illustrates the problems that can arise when there is little coordination between ATM personnel and those who are responsible for the deployment of emergency resources. This lack of coordination breaks many of the fundamental principles of emergency and disaster management. Most obviously, if those who are responsible for managing rescue work do not know the location and status of the rescuers then there is a danger that their lives as well as the victims of an accident will also be placed at risk. Eventually, UTC staff volunteered to conduct a search. They found the Cessna in flames on the runway and the TWR responded by requesting that fire service personnel move onto the runway to help with the second aircraft. Just under two minutes later, fire personnel began to tackle this second fire. The ANSV report that the delays in finding the wreckage of the Cessna did not affect the loss of life from the Linate runway incursion.

Conclusions

This report has conducted a detailed analysis of the events and contributory factors that led to the runway incursion at Linate. The initial study identified that many of the ANSV's recommendations focussed on establishing conformance with national and international regulations. They also provided high level guidance on the development of safety management systems. In contrast, this report has looked in more detail at the reasons why the runway and taxiway markings did not conform to ICAO and other requirements. Similarly, previous pages have examined the reasons why the Cessna was 'allowed' to fly under low visibility conditions. We have also looked at some of the technical and organisational reasons why ATM personnel failed to curtail operations as they faced worsening meteorological conditions and rising workload with minimal ground based technical support.

It is important to stress that we have focussed on the controllers' perspective in this report. It is also important to stress that this report is not intended to be a criticism of the ANSV investigation. They conducted a thorough and detailed investigation under difficult circumstances and their recommendations have clearly made a significant contribution to aviation safety. However, our aim has been to go beyond the existing recommendations and extract any additional lessons that might be learned from this very unfortunate incident.

Our analysis has identified the following additional recommendations:

Additional Recommendation 1: The official report does not explicitly consider the various conditions under which Ground Controllers should call for a suspension or reduction in operations. The report largely focuses on Safety Management Systems. It is argued that these might have provided improved runway signage and automated support, for instance through ground radar systems. Ultimately, however, it remains the Controller's responsibility to determine when operating conditions exceed the capacity of the systems that they have available. Lenate provides valuable lessons in when to decide that safe operational bounds have been exceeded.

Additional Recommendation 2: One of the lessons from Linate is that Controllers need to understand that the environmental conditions, which make ground-based collision more likely, will also frustrate rescue efforts. It is unlikely that ground-based radar would have provided a panacea for the coordination problems that frustrated immediate attempts to rescue any survivors. It is fortunate in this case that additional lives do not seem to have been lost through the delay in locating the aircraft. The difficulty of mitigating the consequences of adverse events should inform the risk-based management of operations.

Additional Recommendation 3: In addition to the provision of ground movement radar, future investigations might consider the suitability of image intensification and thermal imaging systems for use by emergency personnel. Ground radar systems may help to reduce the likelihood of collision but they cannot eliminate it. If such a collision does occur then the radar should enable the Tower and Ground controllers to locate the site of a potential collision. However, the problem remains that emergency personnel have to navigate in reduced visibility to the site of an accident. As shown in Linate, this site can be extremely difficult to find if one of the aircraft involved is a small commercial or General Aviation aircraft. Night vision devices are now widely available and at relatively low cost. With appropriate training, they might help rescue crews to locate the site of an accident. They might also play a role in helping rescue vehicles avoid other aircraft whose crews are unaware of their presence; this issue is discussed in more detail in the following paragraphs.

Additional Recommendation 4: The events of Linate ought to be publicized more widely to controllers. Not simply to illustrate the importance of Safety Management Systems but also to illustrate the critical need to take additional precautions in the aftermath of adverse events.

Additional Recommendation 5: It is important that future accident reports explicitly consider the management and organizational structures that were in place prior to an accident so that readers can clearly identify the impact that they might have had upon the course of an adverse event. As later sections will show, this is particularly important for the credibility of any recommendations that focus on the role of safety management systems. It is difficult to clearly understand the ways in which these systems might have been improved if readers cannot identify the reporting structures that held when an accident occurred.

Additional Recommendation 6: There is good reason to believe that the infrastructure at Linate, in terms of technical equipment, operating procedures and signage, might have been improved to a point where the accident would have been prevented if they had followed the recommendations from the European Action Plan for the prevention of runway incursions. However, these were made after the accident. It is, therefore, critical to monitor the manner in which these recommendations have been interpreted and implemented at a local level if we are to be sure that they are to have their intended effect on system safety.

Additional Recommendation 7: Safety management systems often imply the use of risk-based techniques not simply to analyze the barriers that may prevent accidents from happening in the first place, for instance by ensuring adequate signage that complies with ICAO requirements. They can also be used to identify key technical and organizational requirements for mitigating the consequences of any adverse event that does occur. The Linate collision provides numerous examples where inadequate preparation could have exacerbated the outcome of the accident. The staffing of the UCT-DCA group is one example.

Additional Recommendation 8: ATM personnel at Linate had to control a runway environment that was poorly documented and included markings that were both inconsistent and confusing. The piecemeal decisions to introduce and then 'abandon' the additional parking stands were symptomatic of wider problems that stemmed from the management of change. Linate first had to cope with an expansion of traffic and then adjust as traffic was moved to Malpensa. The ANSV report does not analyze these changes in any detail. However, it seems possible that these changes were seen in purely operational terms without a full analysis of the impact that they might have had both on operating procedures and on the runway environment. In the future, organizations such as EUROCONTROL might invest limited resources to study how other industries take a more systemic approach to change management so that we might avoid the ad hoc and piecemeal changes that were apparent at Linate.

Additional Recommendation 9: The more detailed analysis of the runway environment prior to the Linate collision shows that a number of decisions seem not to have been properly documented. For example, the ANSV report describes the lack of documentation about the decision to permanently introduce the additional parking stand markings. Similarly, such changes seem not to have been communicated to ATM personnel in documentation that was provided to the Tower. In the future, ATM organizations might reconsider the importance of documentation and traceability within their operational procedures. For example, an increasing number of organizations working in non-safety critical industries are using document management systems and the ISO9000 suite of standards to provide quality and performance metrics.

Additional Recommendation 10: Consideration should be given to the additional workload imposed on ATM personnel operating mixed-mode runways that service both commercial and general aviation. This workload will differ depending on the proportion and total volume of traffic in each category. It will also vary in relation to environmental conditions. It is surprising that existing regulations governing high, medium and low traffic flows in low visibility conditions seem to ignore the characteristics of that traffic. They are purely defined in terms of numbers of 'operations' rather than the mix of traffic and Linate shows that this mix plays a critical role in determining workload when commercial and other forms of traffic must share a runway.

Additional Recommendation 11: In addition to the high-level guidance provided by the ANSV report and by the various international working groups on the prevention of runway incursions, there is a need for very specific and detailed guidelines on how to assess the environment for ATM staff who are responsible for the safe operation of runways and taxiway. These guidelines should not simply be devolved to line management or to the runway safety groups that have been proposed. There must also be some line for appeals to be made to a higher authority should a review reveal the need for more sustained 'root and branch' reform of current working practices, signage and technical equipment.

Additional Recommendation 12: Advice should be provided by organizations such as EUROCONTROL about what to do when national organizations postpone safety improvements in anticipation of European or other international initiatives. A risk-based approach could be advocated where national operators must explicitly document and justify the decision to postpone the introduction of a safety critical system, such as the NOVA SMGCS radar. It seems clear that the desire to conform or harmonize with wider European initiatives should not place passengers lives at undue risk.

Additional Recommendation 13: The Überlingen accident illustrates the importance of conducting explicit risk assessments when planning major upgrades to ATM infrastructure. The European and international working groups have also argued that risk assessments should be made at regular intervals to assess the likelihood of runway incursion. Our analysis of Linate also suggests that risk assessments should be required whenever a planned upgrade is postponed. Such an analysis would ensure that the temporary erosion of technical support does not create an undue risk during the transition between old and new systems.

Additional Recommendation 14: The level of traffic should be determined by a combination of the mode balance, commercial or civil, the total number of movements *and* the prevailing meteorological conditions. Current distinctions between low, medium and high traffic movements are relatively meaningless without this additional contextual information. Further research might be conducted to provide controllers and supervisors with simple mnemonics and other aide-memoires that could help them to make decisions about workload when they are faced with changes in their operational environment.

Additional Recommendation 15: Aircrews are a 'last resort' for objective information about prevailing meteorological conditions. Automated instruments and standardised metrics should be used wherever possible. If this is impracticable then aircrews must be explicitly told about the criteria to be applied when making such judgements. ATM personnel must also ensure that aircrews are prompted to provide this information.

Additional Recommendation 16: Our analysis of the ANSV report has shown how difficult it was to determine the visibility levels. This, in turn, made it difficult to identify what levels of traffic and equipment provision could safely be tolerated . ICAO and ENAV recommended different approaches. This previous analysis focused on the ATM perspective. Further analysis should also be conducted to determine whether aircrews could use existing ATIS and other information resources to unambiguously determine the operational status of runways, including Cat level.

Additional Recommendation 17: The onus should be on the crews to ensure eligibility at the point at which they make a request as they are in the best position to understand their classification and license status. Aircrews could usefully be reminded of this obligation and greater effort should be made to ensure that they can unambiguously determine their rights and responsibilities from information sources such as ATIS (see recommendation 16). The intervention of operational ATM personnel to check such permissions should only be relied upon as a last resort.

Additional Recommendation 18: The onus is currently on ATM and ground personnel to check the eligibility of aircrews to perform the operations that they request. It is unrealistic to expect reduced number of ATM personnel to conduct such checks while controlling large numbers of other aircraft. Spot checks made by other ground personnel prior to flight are of only limited value; crews argue that they would not fly if the meteorological conditions changed. This is analogous to asking a motorist if they intend to break the speed limit. Hence, spot checks should also be made on the basis of *previous flights.* Enforcement actions can be taken if crews can be shown to have violated their licence conditions.

Additional Recommendation 19: Current CRM techniques often focus on airborne operations. Arguably too little attention is paid to the problems that uncertainty and confusion can create for runway operations. This is confirmed by the lack of integrated training for aircrew, ATM personnel and fire crews on the problems of runway incursion at Linate. It seems unlikely that in the short term we will be able to ensure that all maps and information resources provide unambiguous and suffienet cues for aircrews to determine their location on most runways in low visibility operations. Hence aircrews should be trained to recognise and communicate any uncertainty over their location on a taxiway so that appropriate help can be provided.

Additional Recommendation 20: When confusion exists there should be a clear verbal protocol for ensuring that both the crew and the ATM personnel know their location before any permission is given to proceed. Greater consideration should also be given to the mechanisms that might be used to determine the location of an aircraft under low visibility conditions. In such circumstances, the trial and error use of lighting systems may increase the risks of runway incursions or of other operational incidents given the associated increases in workload. If lighting systems are to be used in this fashion then studies need to be conducted to ensure that this is regarded as a distinct and potentially dangerous mode of operation where ATM staff may need additional support from supervisory or other ATM personnel.

Additional Recommendation 21: The post accident events at Linate and the impact of the MD-87 with an approved structure raise questions about the adequacy of existing regulations governing the location of buildings around runways. Studies should be conducted to review the requirements for new constructions even if it is impracticable to revise the position of existing major structures close to major runways. It is important to stress that at least in the short term there is little prospect of eliminating the problem of runway incursion. We must, therefore, carefully consider ways of mitigating the impact of those adverse events that may occur.

Additional Recommendation 22:
The immediate response to the collision was characterised by confusion. The lack of coordination, in part, prevented the establishment of an Emergency Coordination Team and the lack of an Emergency Coordination Team contributed to the lack of coordination. Simulations and drills can be used to increase coordination in the aftermath of an adverse event. This is noted in the ANSV report. However, those drills need to be focussed if they are to justify the resources that are spent on them. The military use 'Lose your leader' simulations to test whether organisations can respond when incidents unfold in unexpected ways. In this instance, drills should not automatically assume that an Emergency Coordination Team will lead the immediate response to all adverse events.

Additional Recommendation 23: There are significant costs associated with the installation of detailed ground based movement tracking systems across the many different aircraft types that use facilities such as Linate. However, at least part of the confusion after the collision stemmed from problems in communicating the location of fire fighting resources to ATM personnel. This information could be automatically communicated by any one of a number of commercial vehicle tracking systems that will provide position data down to several metres in detail. These commercial systems could initially provide displays in the TWRs from sensors in each of the fire fighting appliances. Eventually, these vehicles

might also be equipped with these displays to help ensure that they can locate their colleagues under low visibility conditions.

Additional Recommendation 24: Emergency plans should be revised to ensure that fire fighting personnel and other staff do not prematurely commit all available resources to a particular location without first coordinating a full survey of the surrounding area to ensure that casualties are not overlooked. This recommendation is strongly related to the ANSV requirement that any decision to commit emergency personnel should not overlook the hazards faced by other aircraft and staff.

Additional Recommendation 25: EUROCONTROL or other national service providers should commission a detailed study on the feasibility of image intensification and thermal imaging technology to support emergency operations in low visibility conditions. Military technology is sufficiently robust and is available at a low enough cost for it to be widely used by, for example, army truck drivers. It is reasonable to suppose that it might be used to help locate burning wreckage, jet exhausts etc as fire crews navigate runways and taxiways. A formal risk assessment should also be conducted as there are operational risks associated with the improper use of these devices, for example as aid to 'high speed' driving in reduced visibility.

Appendix A: Detailed Timeline of the Linate Accident

As mentioned, the ANSV report does not present a high level timeline of the events that led to the collision. The following pages present an extended timeline that was then used as input for the subsequent Event and Causal Factors analysis of the Linate report. As can be seen in the following diagrams, the focus is on the events leading to the collision. The official report deals with many of the detailed aspects of the emergency operation.

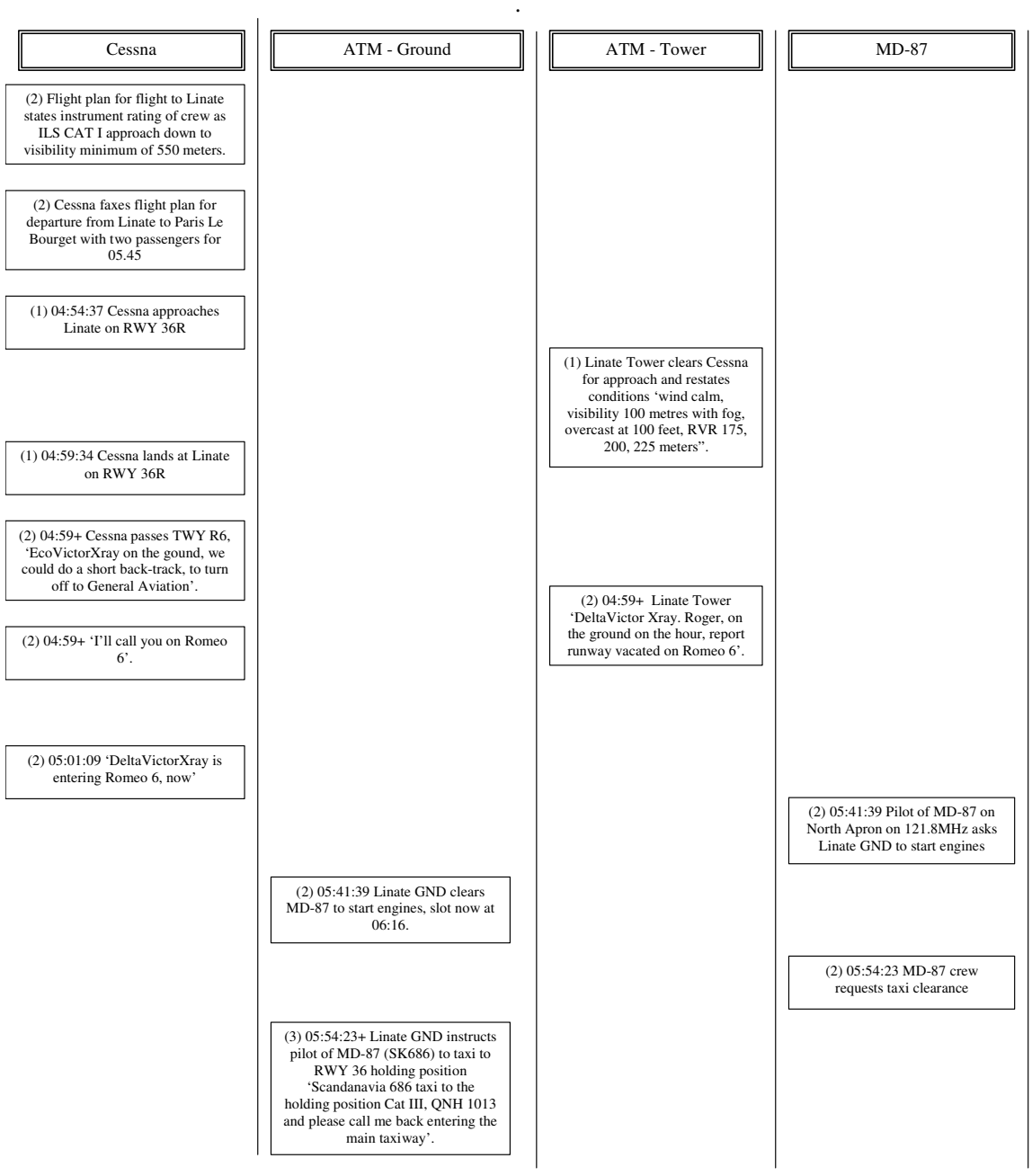

Figure A1: Timeline from Flight Clearance of Cessna to Linate (04:00:00 approx)

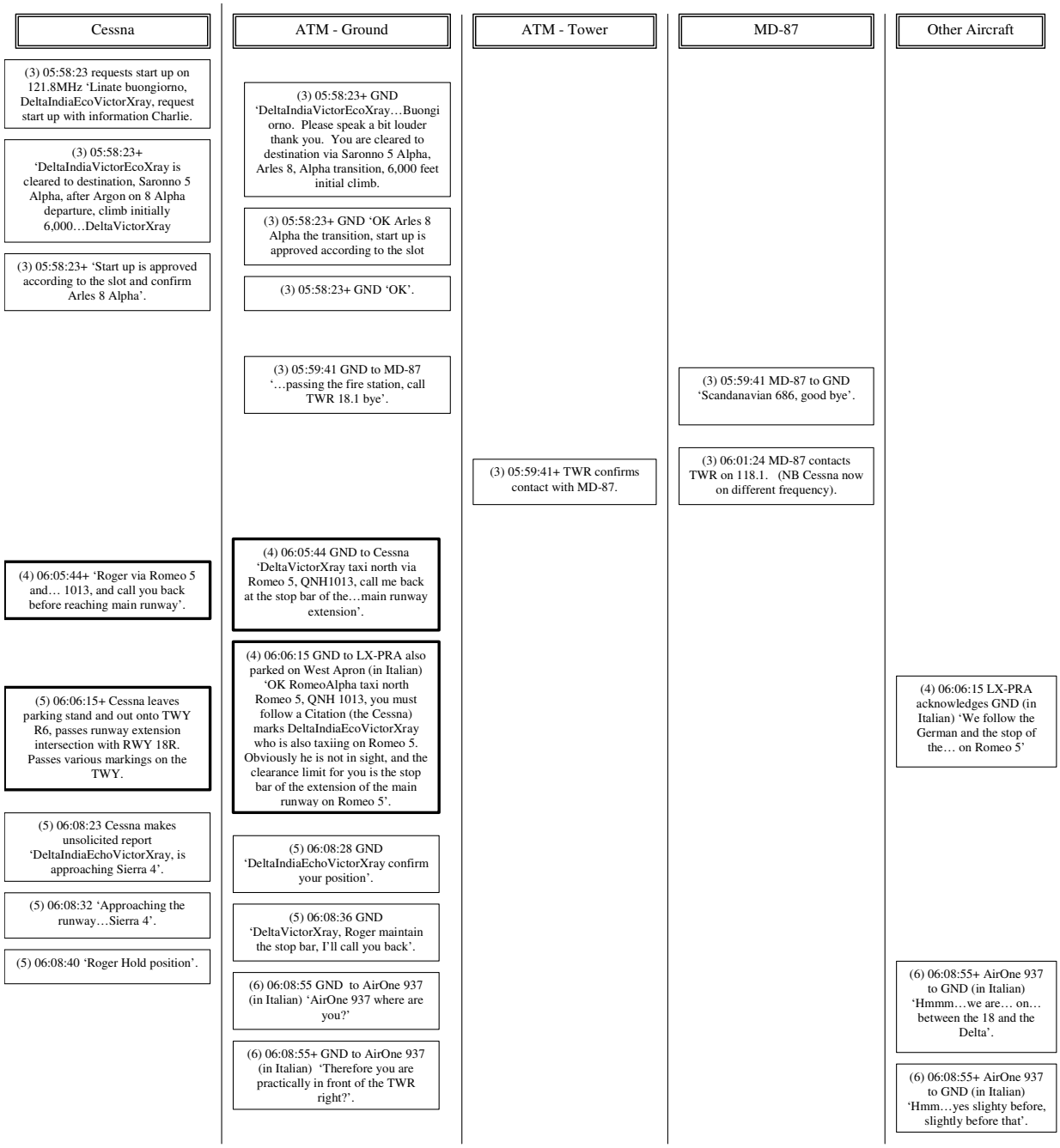

Figure A2: Timeline from Cessna Request to Start-up Engines (05:58:23)

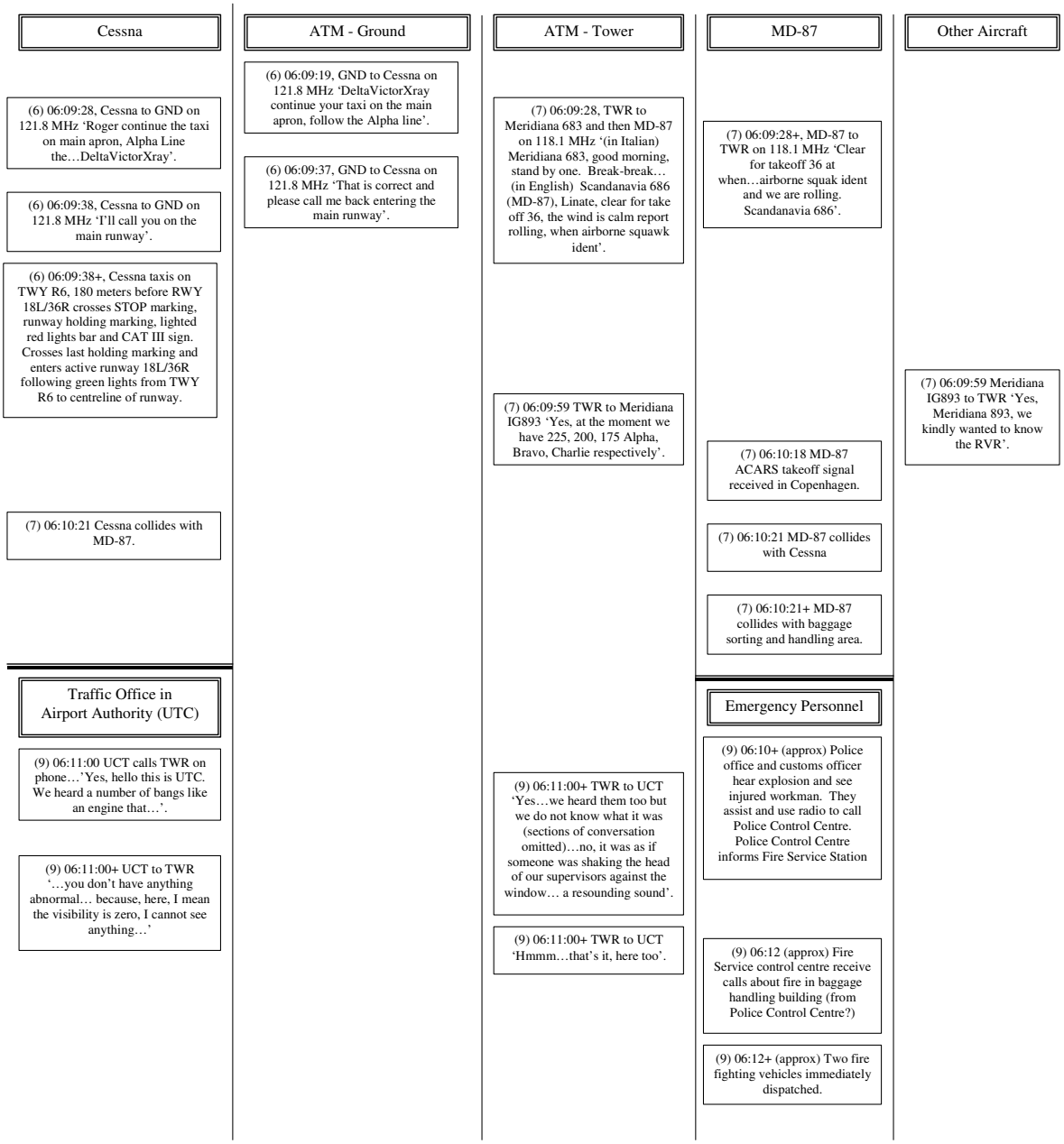

Figure A3: Timeline from Ground Request for Cessna to Continue Taxi on Main Apron (06:09:19)

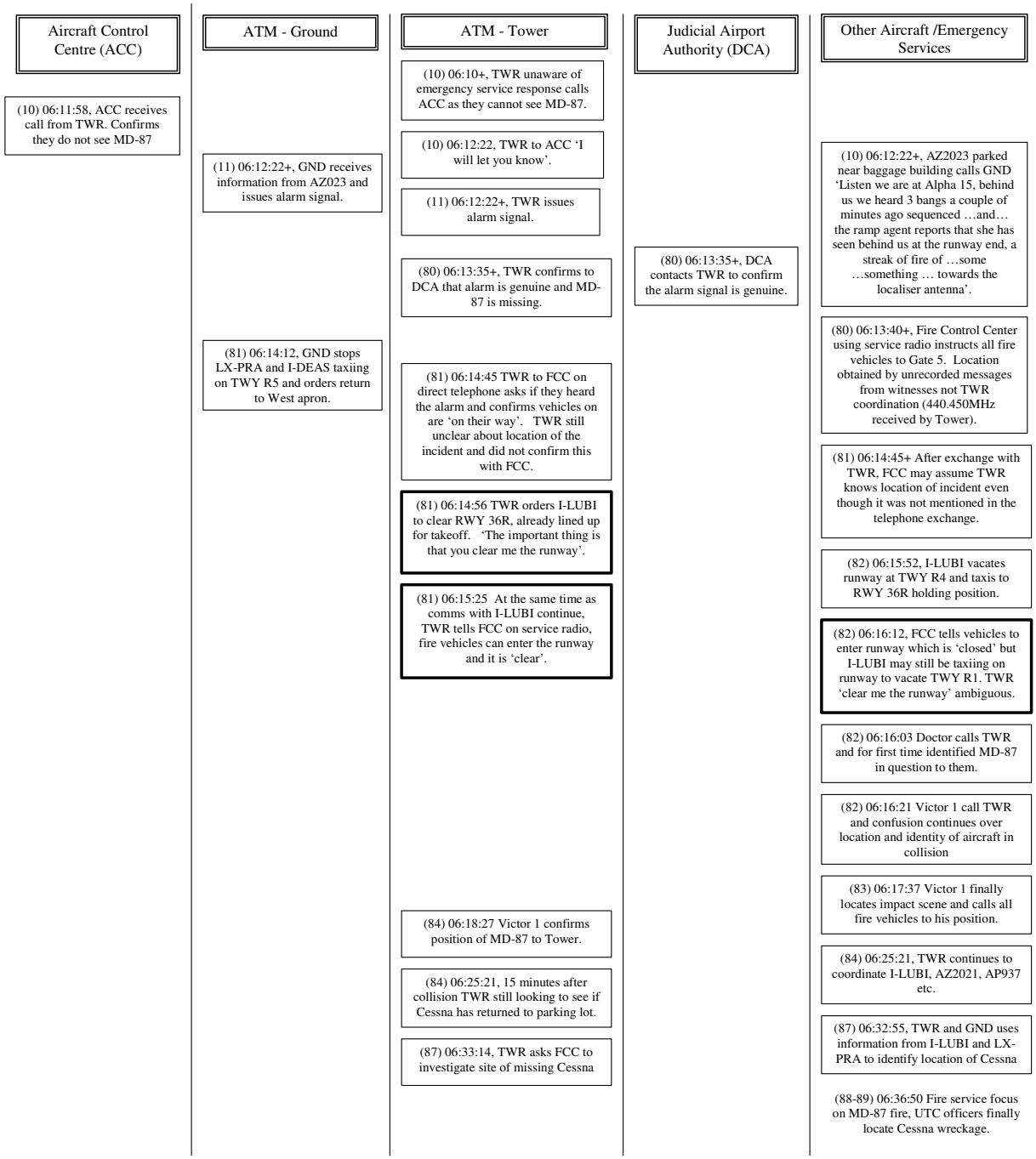

Figure A4: Timeline from TWR Call to ACC to Locate Md-87 (06:10:00+)

