Modelling the Major Incident Procedure Manual: A System of Systems Case Study

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This document presents a system-of-systems (SoS) case study as used in the COMPASS project. The case study centres on a major incident attended by emergency services, based on the London Emergency Services Liaison Panel (LESLP) Major Incident Procedure Manual. The document details the entities involved in a major incident (forming the constituent systems), their internal procedures and behaviour, interactions between entities, and considers system-level and SoS-level properties.
### Bibliographical details

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### About the authors

Richard received his BSc (Hons) in Computing Science from Newcastle University in 2005. He obtained his PhD in 2012 at Newcastle University under the supervision of Dr. John Fitzgerald, as part of the DIRC project, titled Verifiable Resilience in Architectural Reconfiguration. As part of his PhD, Richard provided a basis for the formal verification of policies defined using a reconfiguration policy language (RPL) for the governance of resilient component-based systems. Richard worked as an RA on the Ministry of Defence funded SSEI project and was involved in the 'Interface Contracts for Architectural Specification and Assessment' sub task, investigating the use of contract-based interface specification in system-of-system architectural models. Richard is now working on the COMPASS project, on the use of model-based techniques for developing and maintaining systems-of-systems.

Jeremy is a Senior Research Associate in the School of Computing Science, and a member of Centre for Software Reliability. His research interests are in the modelling and analysis of collaborating systems, and in the development of trustworthy policies for their interaction. He is currently a Co-Investigator on the EPSRC project Trusting Dynamic Coalitions, on which he works on designing and composing provenance policies for coalition members. Part of his time is spent on the EU project COMPASS, on which is developing semantic foundations for a modelling language for Systems of systems.

### Suggested keywords

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Abstract  
This document presents a system-of-systems (SoS) case study as used in the COMPASS project. The case study centres on a major incident attended by emergency services, based on the London Emergency Services Liaison Panel (LESLP) Major Incident Procedure Manual. The document details the entities involved in a major incident (forming the constituent systems), their internal procedures and behaviour, interactions between entities, and considers system-level and SoS-level properties.

1 Introduction  
The London Emergency Services Liaison Panel (LESLP) major incident procedure manual [5] summarises procedures and arrangements for the coordination of the London emergency services (including the Metropolitan Police, London Fire Brigade and London Ambulance Service) and other services (National Health Service, Local Authority, etc.) in the event of a major incident. In the case study presented in this report, we consider a subset of the entities of the LESLP manual and simplify the operational procedures.

The aims of this case study are as follows:

• To define a simple SoS which may inform experiments and analyses in the COMPASS project.

• To identify SoS-level properties which may be analysed.

• To illustrate the use of SysML for a small SoS. This may help inform areas of SysML in which formal definitions may be embedded/derived.

In this case study, each emergency service detailed may be considered a heterogeneous system. Given the characteristics of a system-of-systems (SoS) by Maier [6], we consider the collaboration of the emergency services during a major incident to be a SoS. Each service has independent operation and management, the functions and membership of the response and the emergency services change over time, behaviour emerges from the combination of service functions, and the emergency services may be geographically distributed.
Given the procedure manual and our belief that the entities defined therein may be considered a SoS, we propose the use of [5] to form the basis of a useful working example in COMPASS. To meet the aims of the document it is sufficient to limit the scope of our study by considering only a subset of the entities described in [5], and by simplifying the procedures the constituent systems undertake (for example the first response processes of the emergency services).

We illustrate this subset with a number of SysML diagrams to aid in the understanding of the working example and to aid in further modelling tasks in the COMPASS project.

A long term aim within the COMPASS project is to update this document with new material as the project progresses. As such, major versions will be released with changes highlighted.

The remainder of this document is structured as follows: in Section 2 we outline an ontology of the case study, and the constituent systems are defined in Section 3. Section 4 presents the processes the different constituent systems perform during the major incident. In Section 5, we present several requirements which the different stakeholders must adhere to, and use cases detailing the contexts in which the stakeholders must meet these requirements. Section 6 considers a scenario within the case study related to the release of casualty information, defines several properties which must be respected by the emergency service and the whole SoS and addresses the interaction of constituents involved in the scenario.

2 Case Study Ontology

In the diagram of the case study ontology, the important entities of the case study are presented, together with how they are related. In Figure 1, we present a SysML block definition diagram (BDD) detailing the ontology.

Figure 1: Block definition diagram detailing the ontology of Major Incident

A Major Incident (MI) is triggered by at least one of four criteria. We may
see that the MI case study contains 4 stages – an initial response, consolidation, recovery and restoration of normality. The MI also contains a response consisting of the emergency services and communication systems. The emergency services personnel take on a role with responsibilities. These responsibilities are realised through processes. The processes are executed over the different stages of the MI, and are comprised of incident detection, first response and others not detailed in this document. Finally, Figure 1 introduces the three cordons of the MI.

3 Constituent Systems

In this case study, each emergency service is considered to be a heterogeneous system. The characteristics of Maier [6] – operational independence, managerial independence, distribution, evolutionary development and emergence – indicate that the collaboration of the emergency services during a major incident constitutes a system-of-systems (SoS). This SoS is referred to as the Major Incident Response (MIR).

The MIR structure is given in Figure 2 as a Block Definition Diagram (BDD). The MIR contains up to three emergency services and up to three communication systems. The emergency services (ES) may be a police force, a fire brigade or ambulance service. All ESs include more than one person, which each have a single role. The communication systems of the MIR include a dispatch system and radio handsets to be used by the ES personnel.

Figure 2: Block definition diagram depicting Major Incident Response structure

The roles undertaken by the ES personnel may be either First Responder, Bronze, Silver or Gold - as is shown in Figure 3. Each role has several responsibilities which ES personnel must undertake in order to realise the processes of the major incident.

The London Emergency Service Liaison Panel (LESLP) manual [5], summarises procedures and responsibilities of the emergency services (e.g. police, fire, or ambulance) in response to a major incident. Once a major incident is declared (usually by a member of the police service) a response is put in place by each of the services necessary to deal with that incident.
A typical response involves several levels of command: referred to as Bronze, Silver, and Gold. Each service has members working at each level, so we may refer to Bronze Police or Silver Fire. Each level and service has different responsibilities. For example, an early and important responsibility of the Bronze Police is to put appropriate cordons in place to prevent members of the public from becoming involved in the incident, and in some cases to preserve evidence.

Silver and Gold commands work in inter-agency coordinating groups. Bronze, Silver and Gold can be seen as terms for the well-known strategic, tactical and operational levels of command. Bronze implements tactics defined by Silver. Silver formulates tactics to be adopted by each service following strategy determined by Gold. Gold command, geographically distant, contains the service commanders.

An early and important responsibility of the Police is to put appropriate cordons in place to prevent members of the public from becoming involved in the incident, and in some cases to preserve evidence.

Personnel at a common level may communicate freely, but between adjacent levels communication is only between agents of the same service. Information flow out of the MIR is subject to several alternative policies. Certain information may be independently released to the media by an individual service, but casualty figures must be cleared by Gold Police. Potential communication and clearance policies for information relating to casualty clearance have been analysed in [1].

The environment of the MIR SoS comprises the incident scene (and the cordons surrounding the scene), members of public and the media.

4 Process Modelling

The emergency services of the MIR SoS each contain many people, each taking on a role. A role takes on responsibilities realised during a number of processes. This is depicted in Figure 1. In defining the processes of the MI case study, we follow the process modelling approach as detailed by Holt [3]. In Section 4.1 we consider the processes of the MI case study and in Section 4.2 detail the behaviour exhibited in each process. Section 4.3 considers how the processes may be arranged during the life of the Major Incident.
4.1 Process Content View

Given the ontology in Section 1, we may expand further on the processes occurring during the lifecycle of a major incident by defining a Process Content View (PCV), given in Figure 4.

Figure 4: Block definition diagram depicting Process Content View of Major Incident

The PCV provides an overview of the different processes executing over the stages of the MI life cycle. Figure 4 presents the *incident detection and first response* processes of the MI (as noted in Section 2, this list is incomplete), modelled as SysML blocks. The diagram indicates the activities of each process (represented as SysML operations) and the relevant artefacts (inputs and outputs of the activities – represented as SysML properties). Note the collection of processes occurring during the MI in Figure 4 is marked as incomplete, and requires further processes to be defined.

4.2 Process Behaviour Views

Given the Process Content View, we may consider the various Process Behaviour Views (PBV) of each process with respect to the different emergency service types defined in Section 3. The incident detection process is detailed in Figure 5, and the remaining processes relating to the police, fire and ambulance emergency services are given in Appendix B.

The PBV describes the flow of activities in a process, denoted by the rounded rectangle. Artefacts are input and output from the activities, shown as small boxes with directions appended to the activity blocks. Decision points are drawn as small diamonds (referred to in SysML as *pins*). In the incident detection process, detailed in Figure 5, we see a simple flow of activity, started by an external call to the incident. The process, performed by a stakeholder performing the *First Officer* role, subsequently follows a number of activities to determine whether an incident is described as major.

4.3 Process Instance View

The processes defined in the Process Context View in Section 4.1 above may be arranged in a number of ways. We provide an example in the form of a Process
Figure 5: Activity diagram depicting Process Behaviour View of incident detection process
Instance View in Figure 6.

Figure 6: Sequence diagram depicting Process Instance View of incident detection process and subsequent first response processes.

It should be noted that this is only one of many variations on this sequence. For example, there may be a case whereby a number of initial detection processes are involved. This may occur when the first officers on scene do not have the experience or expertise to decide if an incident is classed as major.

5 Requirement Modelling

The next stage of modelling involves the Requirement Modelling technique, described by Holt and Perry [4, 2]. This technique aims to help identify and decompose the requirements, and consider how the requirements are related to the stakeholders of the major incident.

In Section 5.1 we consider a collection of requirements we wish to hold over the MIR SoS. Section 5.2 considers these in different contexts through use case diagrams.

5.1 Requirements

Given the LESLP procedure manual, we see four main requirements of the Major Incident Response: save lives, combine resources, investigate the incident and handle enquiries. This is depicted in the Requirements Diagram (RD) in Figure 15. The top level requirement respond to major incident is decomposed into the aforementioned four requirements.

Each of these top-level requirements are decomposed further in separate RDs, we show only one example in this document; those requirements relating to the clearance of casualty information in Figure 8. The remaining RDs are given in Appendix A. The level of detail given for each requirement varies, as is realistic, and as such any requirements requiring further decomposition are marked as incomplete.

Whilst we do not propose adding more detail to the requirements, each requirement may be given unique identifiers and natural text descriptions.

1 This may evolve as more details are added to the case study.
Figure 7: Requirements Diagram showing top-level requirements for the Major Incident Response SoS

Figure 8: Requirements Diagram showing break down of the Handle Enquiries requirement for the Major Incident Response SoS
5.2 Context Diagrams

As stated by Holt and Perry [2], one use of SysML use case diagrams is to define Context Diagrams (CDs). These diagrams aim to indicate how the requirements from Section 5.1 relate to the different contexts – the roles – of the Major Incident Response SoS. The context diagrams for the Gold Police, Bronze Fire and Silver Ambulance roles are given in Figures 9, 10 and 11. Note each of these context diagrams are incomplete and show only those requirements relevant to the release of casualty information.

![Context Diagram Police Gold](image)

Figure 9: Use Case Diagram showing the press enquiry requirement in the context of a Gold Police officer

The CD in Figure 9 considers the Gold Police role which relates to three requirements: *collect casualty information*, *casualty information sent to Gold Police* and *release cleared casualty information*. The Gold Police collaborate with all three Bronze roles in the *collect casualty information* requirement, with the Silver Ambulance in the *casualty information sent to Gold Police* requirement (where the Silver Ambulance are responsible for passing this information to the Gold Police) and finally the Gold Police collaborate with the Media to *release cleared casualty information*.

The Bronze Fire role is shown in the CD in Figure 10. As with all Bronze roles in the release of information, the Bronze Fire role is related to the Police Gold in the *collect casualty information* requirement (and thus is consistent with the Police Gold context diagram), and also related to the Silver Ambulance in the *verify casualty information* requirement.

The final CD of the document is that for the Silver Ambulance role in Figure 11. The Silver Ambulance role has responsibility for the *casualty information sent to Gold Police* requirement with the Gold Police and the *verify casualty information* requirements with of the each Bronze roles.
Figure 10: Use Case Diagram showing the press enquiry requirement in the context of a Bronze Fire officer

Figure 11: Use Case Diagram showing the press enquiry requirement in the context of a Silver Ambulance officer
Considering each CD, we may identify interfaces between the constituent systems of the response SoS and also the media. For example in Figure 10, there must exist an interface between the Bronze Fire role and Silver Ambulance role to achieve the requirement *Verify Casualty Information*. We return to this in Section 6.2.

6 Casualty Clearance

In this section, an example scenario within the major incident case study is addressed. As the MIR SoS is large and contains many different tasks, attention is restricted to the tasks related to the release of casualty figures. Section 6.1 gives several properties that must hold over the response relating to the release of casualty information, Section 6.2 details the interactions between the constituents involved in the scenario and Section 6.3 considers an example sequence of events.

6.1 Example Properties

The purpose of this section is present some of the properties that could be asserted of the major incident response SoS. These can be seen as examples of the type of requirement made in documents describing SoSs, and are meant to be relatively realistic. They therefore have varying levels of precision.

For the purposes of the document, the properties are divided into *external* and *internal* properties. External properties are those at the interface between the major incident response SoS and its environment (as described in Section 3). Internal properties are those at the interfaces between the constituents of the SoS.

The properties in this document relate to the release of casualty figures\(^2\). In the early stages of a major incident, it is common for differing and inaccurate estimates for the number of casualties involved to be released to the public. This is considered undesirable, as it can add to uncertainty and panic in the population. It can happen because they are merely media estimates, generated by contacting local hospitals and interviewing survivors. Alternatively they can be figures released by various parts of the SoS (hospitals, Bronze Police, etc.). This can lead to double-counting of casualties. Below are some possible properties that may be required of the SoS to prevent this. These are not intended to all apply simultaneously, but to be examples of the kind of property that a SoS might be expected to adhere to.

It is assumed that estimates of casualty figures are made by Bronze personnel attending the scene at the early stages of a major incident.

Below, we give descriptions of the properties, with an indication to the type of property (internal/external)\(^3\).

1. **External** Over the course of the major incident, the casualty figures released from the SoS to the public must not decrease.

\(^2\) There are a large number of properties which may be present in other aspects of the SoS which are not detailed here.

\(^3\) Interestingly, many of these are external properties. They become internal because sole authority for releasing casualty figures resides with the Police Gold.
2. **External** Unverified casualty figures must never be released to the general public.

3. **Internal** Only Police Gold is authorised to release casualty figures.

4. **Internal** Estimates (which will usually be made by Bronze personnel) must be verified then passed to Gold.

5. **Internal** If casualties figures passed to Gold are estimates, they must be marked as such.

6. **External** Once casualty figures are verified, the figures must be released to the media/general public within one hour unless there is good reason for them not to be released.

7. **Internal** If verified casualty figures are not released, the reasons for the decision must be recorded.

8. **External** The number of verified casualties must not be more than the estimated number, and the number released must not be more than the verified number.

9. **External** Only one set of figures should be released at any time.

10. **Internal** Ambulance press officers may confirm the general nature of types of injuries – unless police specifically request them not to – and the hospitals to which they are taken.

### 6.2 Internal Block Diagrams

The constituent systems clearly communicate in many ways, depending on the context within the overall response. This section considers how the constituent systems may communicate within the release clearance figures scenario. An Internal Block Diagram (IBD) is given for the response which details the provided and required interfaces of the elements of the MIR SoS relevant to the release of casualty numbers. The IBD is given in Figure 12.

The constituents of the MIR SoS are the Police, Fire and Ambulance officers, each with a specified role. The interfaces provided and required of these officers depend upon the roles undertaken by the constituents. These connections correspond to the interactions of the roles in the Context Diagrams in Section 5.2. For example, in Figure 10, there exists some collaboration between the Bronze Fire and Silver Ambulance roles in the **verify casualty information** requirement. In the IBD of Figure 12, an interface **verify** exists between the Fire Officer with a Bronze role and the Ambulance Officer with Silver role. For each collaboration in the CDs, an interface should exist.

The interfaces depicted in Figure 12 are defined in the BDD in Figure 13. The four interfaces contain operation signatures related to a given point of interaction for those operations made public by the relevant constituents. The signatures only define the data input to and output from an operation call.
Figure 12: Internal Block Diagram showing relationships of response constituents when releasing casualty figures

Figure 13: Block Definition Diagram showing interface definitions when releasing casualty figures
6.3 Sequence Diagrams

Given the IBD of Section 6.2, we may consider an example Sequence Diagram (SD) depicting the operation calls between the constituent systems involved in the release of casualty details to the media. It should be stressed that this is one example of the possible interactions. The SD is defined in Figure 14.

![Sequence Diagram showing an operation sequence when releasing casualty figures](image)

Figure 14: Sequence Diagram showing an operation sequence when releasing casualty figures

7 Conclusions and Future Work

This report models the LESLP major incident procedure manual using SysML. The SoS in the case study was identified along with the constituent systems. Using process and requirements modelling techniques, we identified the processes the different constituent systems perform during the major incident, the requirements which the different stakeholders must adhere to, and use cases detailing the contexts in which the stakeholders must meet these requirements. Given a scenario within the case study related to the release of casualty information, we considered several properties which must be respected by the emergency service and the whole SoS.

This is an initial study. As mentioned in Section 1, a long term aim within the COMPASS project is to update this document with new material as the project progresses. One avenue of further work we envisage is in the interface specification considered in Section 6.2. Interfaces may be modelled further in SysML and also more formal specification notations such as VDM and CSP. Modelling the case study using the CML language, to be produced in the COMPASS, is also envisaged as future work. The collection of properties relating to the release of casualty information provides a series of analysis challenges for the further modelling exercises.

References


A Requirement Modelling Diagrams

A.1 Top-Level Requirements

Figure 15: Requirements Diagram showing top-level requirements for the Major Incident Response SoS

A.2 Second-Level Requirements

Figure 16: Requirements Diagram showing break down of the Save Lives requirement for the Major Incident Response SoS
Figure 17: Requirements Diagram showing break down of the Save Lives requirement for the Major Incident Response SoS

Figure 18: Requirements Diagram showing break down of the Save Lives requirement for the Major Incident Response SoS
A.3 Context Diagrams

Figure 19: Use Case Diagram showing the press enquiry requirement in the context of a Gold Police officer.

Figure 20: Use Case Diagram showing the press enquiry requirement in the context of a Silver Ambulance officer.
Figure 21: Use Case Diagram showing the press enquiry requirement in the context of a Bronze Police officer

Figure 22: Use Case Diagram showing the press enquiry requirement in the context of a Bronze Ambulance officer
Figure 23: Use Case Diagram showing the press enquiry requirement in the context of a Bronze Fire officer.
B  Process Modelling Diagrams

B.1  Process Content View

Figure 24: Block definition diagram depicting Process Content View of Major Incident
B.2 Process Behaviour Views

Figure 25: Activity diagram depicting Process Behaviour View of incident detection process
Figure 26: Activity diagram depicting Process Behaviour View of Police first response process
Figure 27: Activity diagram depicting Process Behaviour View of Fire first response process
Figure 28: Activity diagram depicting Process Behaviour View of Ambulance first response process

**B.3 Process Instance View**

Figure 29: Sequence diagram depicting Process Instance View of incident detection process and subsequent first response processes.