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| | **HoliDes**<br>**Holi**stic Human Factors **Des**ign of Adaptive Cooperative Human-Machine Systems | |

# D8.10 Final Version of the Control Room AdCoS

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# Executive Summary

The present document describes the final version of the Control Room AdCoS and provides a final assessment of the HF-RTP, methodology and used MTTs against the Project Baseline. Recommendations are given for future development and usage of the HF-RTP and methodology.

Based on the results of the evaluation activities (summarised in this document), both control room AdCoS have been completed to a level of detail that facilitates further dissemination and exploitation. The Airbus AdCoS will be replicated in a customer demonstration lab for presentation to potential customers; the Iren AdCoS will be put to productive operation in the months following the end of the project.

The benefits of choosing the HoliDes approach of designing and developing AdCoS with an HF-RTP based on project MTT could be clearly demonstrated. In addition, using an AdCoS-type adaptation also benefits the organisations using the technology through increased effectiveness and efficiency of the control room operation.

# 1 Introduction

## 1.1 Objective of the document

The present document describes the final version of the Control Room AdCoS and provides a final assessment of the HF-RTP and methodology against the Project Baseline. Recommendations are given for future development and usage of the HF-RTP and methodology.

## 1.2 Structure of the document

The present document describes in clause 2 the final version of the Control Room AdCoS (2.1 for the Airbus AdCoS and 2.2 for the Iren AdCoS) with a focus on functionalities added or improved since the last report (Del. 8.7). Changes to the AdCoS are illustrated and the added value they generate is explained.

Clause 3 addresses the final assessment of the HF-RTP and methodology against the project baseline (see 3.1 for Airbus and 3.2 for Iren), including recommendations for future development and usage of the HF-RTP and methodology.

Clause 4 provides an overview and update of the AdCoS evaluation activities and results (Clause 4.1 reports about the Airbus evaluation, 4.2 about the Iren evaluation).

Clause 5 presents the conclusion and a summary.

In order to avoid repeating information already published in previous documents, references to earlier deliverables are added, where appropriate.

# 2 Final version of the Control Room AdCoS

## 2.1 Final version of the Airbus Control Room AdCoS

### 2.1.1 AdCoS and use cases

The Airbus Control Room AdCoS addresses the specific challenges encountered in Emergency Response Control Rooms (unplanned events, immediate responses, phases with high activity followed by longer phases with little or no activity, in some cases high fluctuation). It aims at increasing the emergency response organisation's effectiveness and security by implementing new adaptation functionalities employing novel interaction technologies. For more details on the background to the situation in Emergency Response Control Rooms and the AdCoS HMI see Deliverable 8.7.

The AdCoS has been implemented to support six use cases:

**Use Case 1 Operator absent from workplace:**
Detection of operator absence with the functionality of calling him/her back to his/her workstation when needed by means of a personal actuator.

Use case baseline: Operators may be absent from their workstations for longer periods (longer than a regular or permitted break), possibly being engaged in other activities (e.g. playing cards or interacting with their smartphones). If an incoming emergency requires their presence, their supervisor has to employ traditional means of calling them back to their stations (e.g. by calling them via a loudspeaker system).

**Use Case 2 Operator "idle" at workstation:**
Detection of minimum operator movements suggesting that he has fallen asleep; functionality to wake the operator up with the help of the personal actuator.

Use case baseline: In periods with low activity (e.g. at night with no supervisors present), it may be possible that one or several operators are asleep, possibly missing important cues to attend to. This may pass unnoticed by the supervisors, or if operators are woken up successfully, they may need some time to regain a state that allows them to be effective again.

**Use Case 3 Operator tired at workplace:**
Detection of operator fatigue with the possibility of providing appropriate feedback to the operator via the personal actuator.

Use case baseline: Without the AdCoS, there is no objective measurement of operator fatigue: the supervisor has to rely on his intuitions to decide whether he is dealing with a tired operator (something that may not be obvious). Unnoticed fatigue may have a detrimental effect on operator effectiveness and consequently on the entire operation.

**Use Case 4 Registration of unusual operator behaviour patterns:**
Operator absences from their workstations are logged in a database and analysed for regular and exploitable patterns.

Use case baseline: Currently, there is no mechanism that registers patterns in the operators' behaviour that can be exploited by perpetrators to schedule illegal activities to fall into periods in which operators are likely to be engaged with other activities. Not being aware of and not reacting to exploitable behaviour patterns potentially jeopardises the security of the emergency response operation.

**Use Case 5 Load balancing on operator level:**
Detection of operators in high workload situations (i.e. above a predefined threshold) with an adaptive functionality of proposing to the supervisor that work items be shifted from high-workload to low-workload operators, taking into account a number of subjective and situational variables.

Use case baseline: Currently, the supervisors have to make a judgement on the operators' workload based on their own experience: they memorise how many events have already been assigned to a particular operator and make an assumption about how long they will be occupied with them. In doing this, they may or may not take into account other relevant variables such as operator experience. An unequal and sub-optimum distribution of workloads across operators is the natural consequence.

**Use Case 6 Operator career progression monitoring:**
Based on a set of parameters, the system supports the control room management in monitoring the career progression of individual operators, e.g. proposing the status upgrade of an operator from 'basic experience' to 'advanced experience', when it detects that all preconditions are met.

Use case baseline: Currently, no support functionalities exist that actively monitor increases in operator experiences. Control Room HR and supervisors have to rely on formal reviews and observations / memory.

The use cases are described in more detail in earlier deliverables (e.g. 8.7).

### 2.1.2 Performance Indicators (PI) and objectives of development

A set of Performance Indicators (PI) have been defined to guide the design and evaluation of the AdCoS. The six PIs for the Airbus AdCoS are:

- *Availability:* The AdCoS ensures availability of operators for their duties when needed.
- *Work Balancing:* The AdCoS ensures that the workload is distributed among the operators so that an acceptable level of workload of the operators is assured in a way that maximises the overall effectiveness of the organisation, taking into account both subjective workload and objective task load.
- *Facilitating Human Machine Interaction (HMI):* The interaction design and user interface of the AdCoS facilitate control room operation.
- *Security:* Using the AdCoS should help minimize exploitable operator behaviour and thus increase security for the personnel in the control room and for the organisation.
- *Human Views:* The NATO Human Views will be analysed for inclusion into the AdCoS, then implemented, populated and integrated into the relevant Airbus DS HF-RTP tool chain.
- *Performance Ratings:* Each of the AdCoS components will be analysed and given an effectiveness performance rating from 1 to 10.

The first four PIs are closely related to the six use cases and with specific use-case-related requirements. The last two PIs are closely related to the Evaluation of Return of Investment section.

The aim of the AdCoS definition and development was, therefore, to increase the effectiveness of the control room operation by using adaptation mechanisms that support the operators and their supervisors. Operators get feedback when their absences or states of sleep or fatigue are detected, allowing them to respond appropriately.

In addition, operators receive a certain peace of mind knowing that they will not miss any important events, as the system will make sure that they are present and effective when required. Furthermore, wherever possible, the system will ensure that operators are not assigned workloads that exceed a certain threshold, which would decrease the operators' effectiveness.

Supervisors are supported in their task of assigning work to operators. They are also given tools that help them detecting exploitable behaviour patterns, which may motivate them to issue additional trainings on station security.

### 2.1.3 Overview of the final status of the AdCoS

As Use Cases 1, 2 and 3 were almost completed as described in Del. 8.7, the work on improving the AdCoS functionalities since focused on Use Cases 4, 5, and 6 and on the maintenance of the system.

A user interface for launching individual use case functionalities has been created (see Figure 1) in order to facilitate future demonstrations.

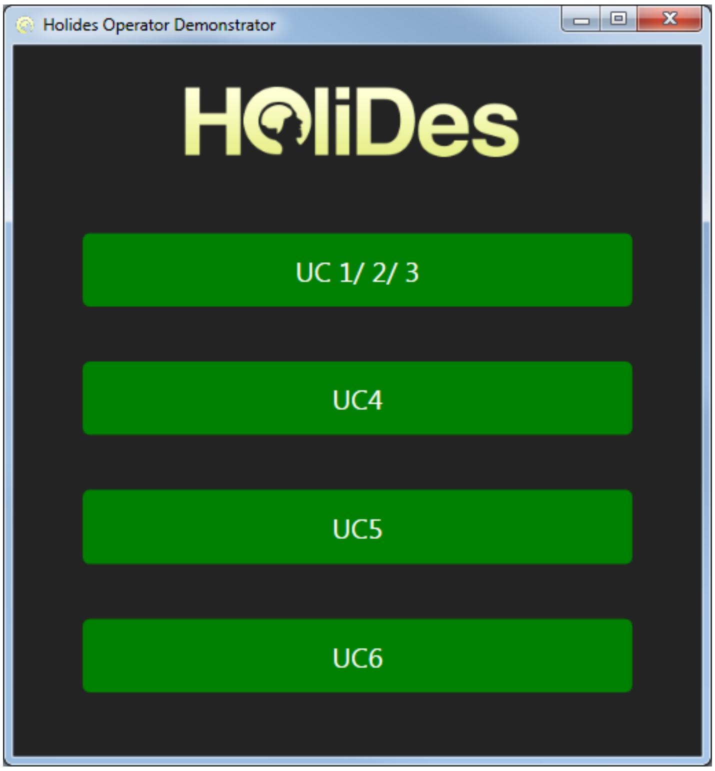



**Figure 1: Use Case launcher interface**

In addition, a set-up suite and accompanying documentation have been provided in order to be able to install the AdCoS demonstrator on other or additional PCs and networks.

### 2.1.4 Final Status of Use Cases 1, 2 and 3

The evaluation of Use Case 1 documented an excellent performance of the detection of operator presence and absence and of the login functionality using the fingerprint sensor (sees Del. 8.9). The less-than-optimum performance of the actuator in delivering messages can be expected to be solved with the selection of an improved smart watch (this will happen at a stage after the completion of Project HoliDes).

As reported in Del. 8.9, Use Case 2 requires evaluation either in sophisticated lab studies or in the field. These experiments would have been beyond the scope of HoliDes. Until such experiences are gathered, no indications are available for the direction of improvements.

The results of the evaluation of Use Case 3 suggest that the implementation of the PERCLOS parameter in the demonstrator needs fine-tuning. Again, experiments of this type would have been beyond the scope of Project HoliDes.

### 2.1.5 Use Case 4: Detection of exploitable behaviour patterns

The demonstrations of Use Case 4 functionalities at the second year review event were based on hard-coded rule testing for behaviour patterns in the absence data. Any changes (e.g. adding new rules to test) are cumbersome and expensive to implement.

For this reason, the MTT KNIME has been implemented, which offers an interface for defining rules (see Figure 2), thereby eliminating the creation of new code.

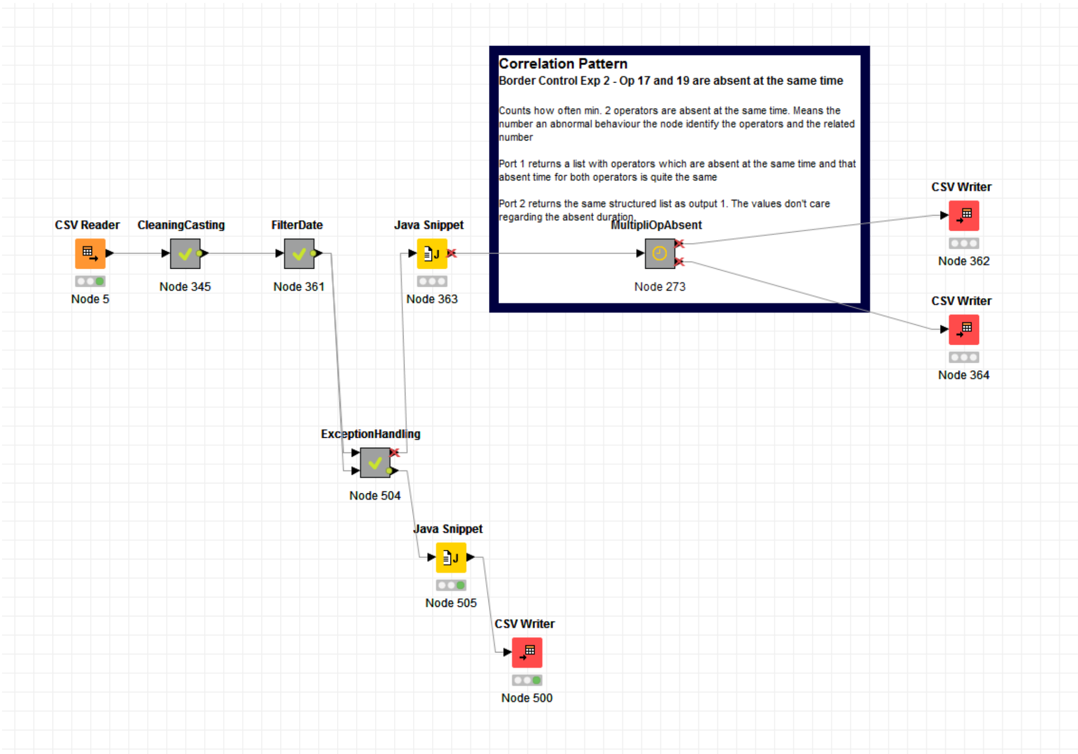



**Figure 2: Definition of rules in KNIME**

The implementation using KNIME required a new user interface for defining the patterns to be investigated (see Figure 3). For the design of this user interface, many of the lessons learned in the evaluation of the previous Use Case 4 interface were considered. Examples of those are an improved wording for the filtering option and an alternative display of the results for certain types of analyses.


**Figure 3: New user interface for Use Case 4**

KNIME produces graphical visualisations of the patterns found. A mechanism had to be created for converting and displaying these graphics files in the AdCoS software. Figure 4 shows an example of a results graphic in KNIME. It indicates an increased number of absences events on Mondays and Thursdays during the selected period.

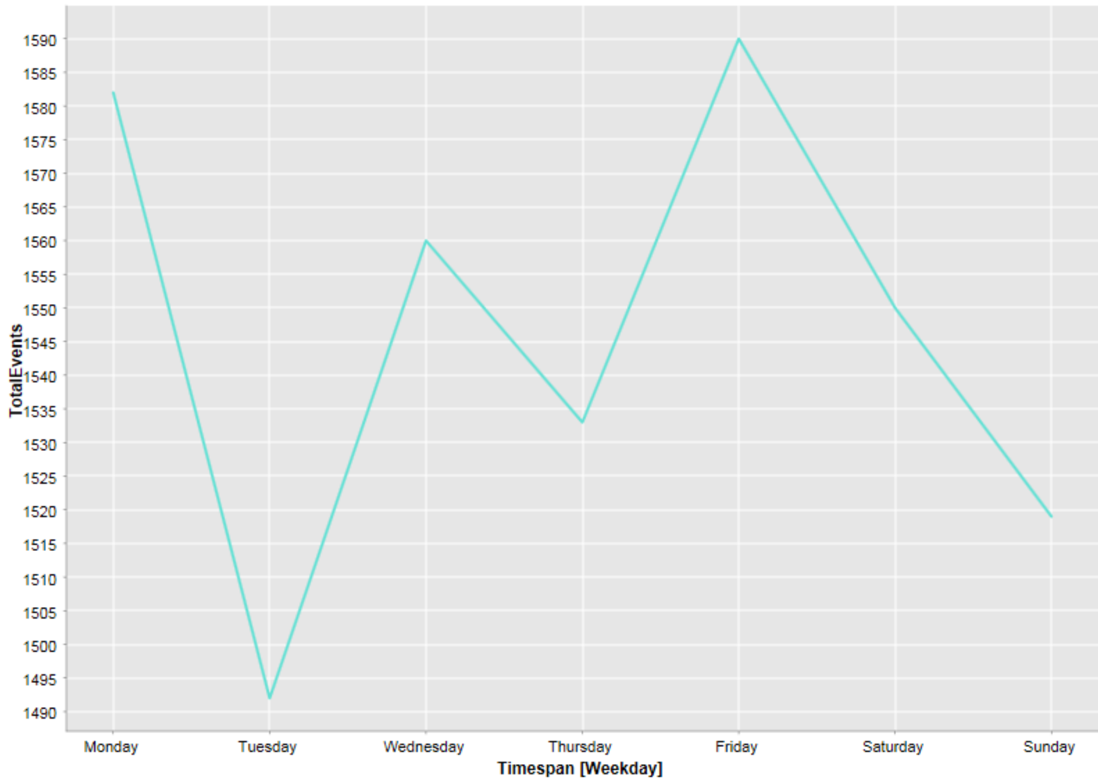



**Figure 4: Example of a results graphic in KNIME**

### 2.1.6 Use Case 5: Operator workload balancing

Use Case 5 was completely re-designed. The previous implementation was merely a visualisation of the underlying logics of the use case. In the current version, the workload balancing is happening in real time, accessing a dynamic database for all operators with all relevant variables such as level of experience, time in current position or number of critical events successfully handled.

In addition, an attractive user interface was designed that is optimised for recognising the status of all operators at a glance (see Figure 5). The dialog for proposing the handover of work from one operator to another now includes the option of providing the rationale for the proposal (see Figure 6). For more details, see Del. 8.7.

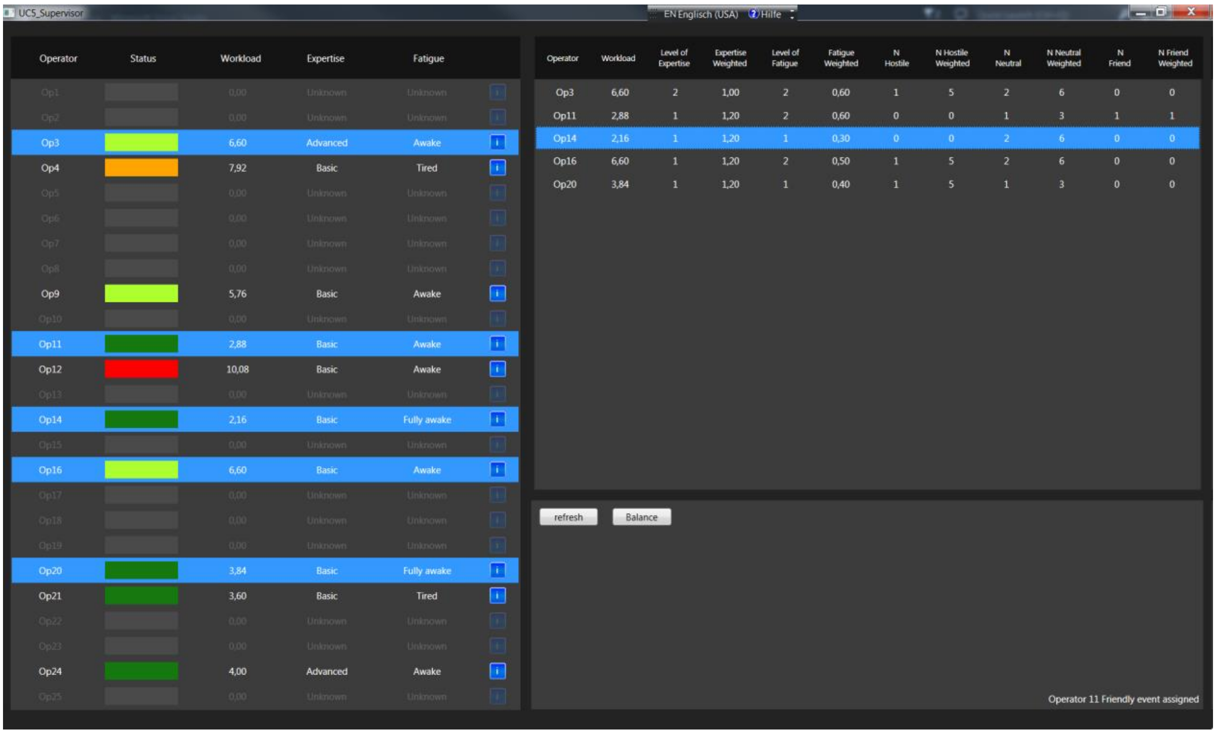



**Figure 5: Operator workload status overview**

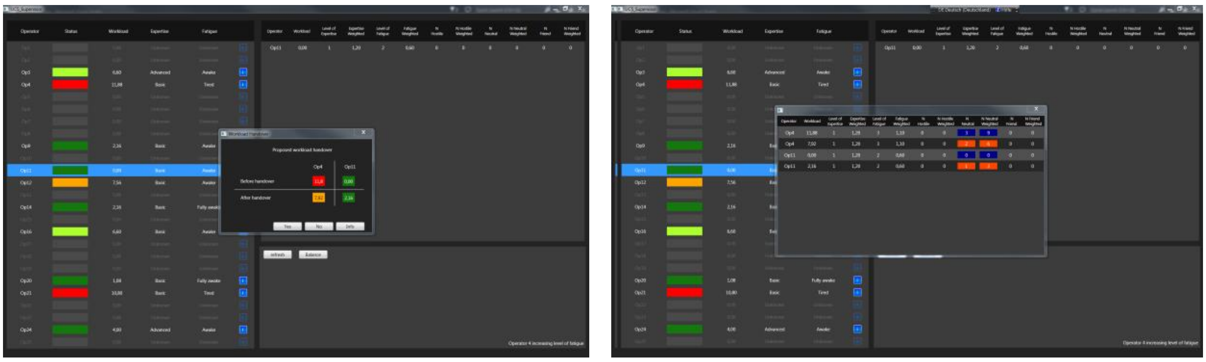
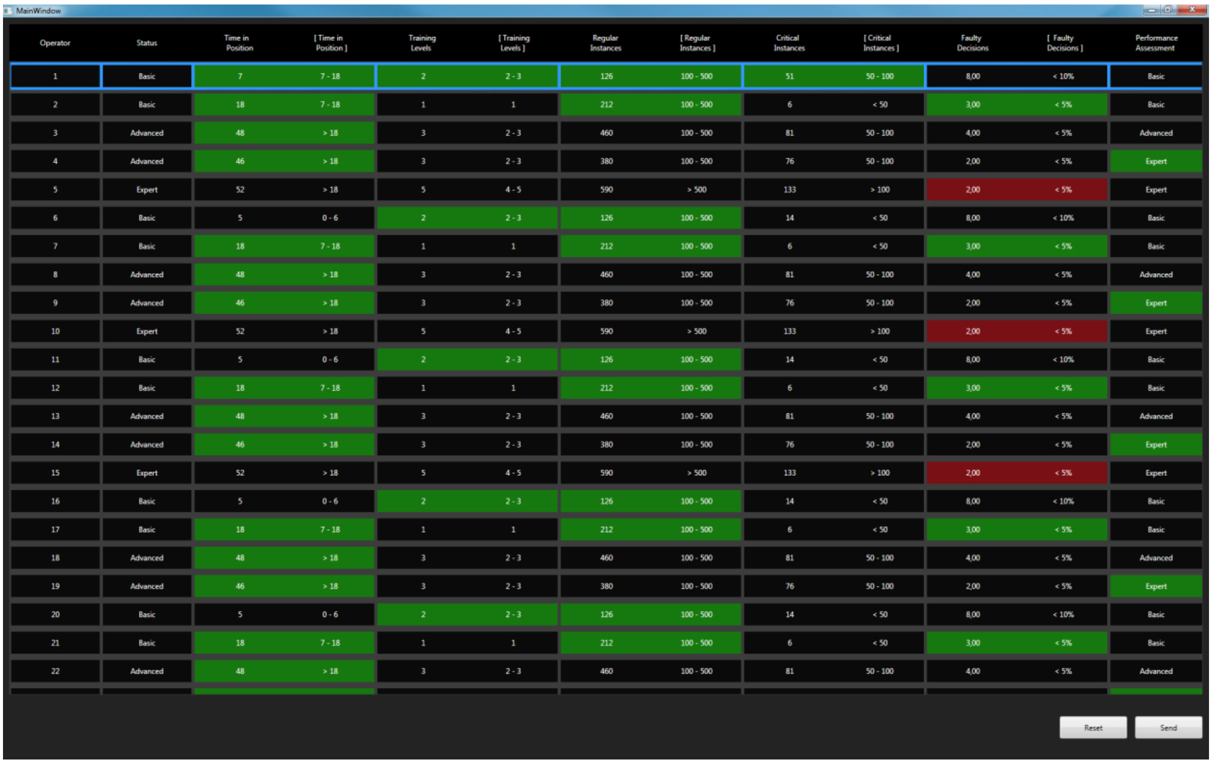


**Figure 6: Workload handover proposal**

### 2.1.7 Use Case 6: Operator career progression monitoring

This use case had not previously been implemented. Its design has been harmonised with the one for Use Case 5 and the aim was to offer a visualisation "at one glance" of the career stage of each operator in terms of a number of variables.

The use case assumes that three career stages exist ("Basic experience", "Advanced experience", and "Expert experience") with each stage being associate with pre-defined parameters (current career level status, time in current position, training levels achieved, number of regular and critical instances successfully handled, percentage of faulty decisions, and most recent performance assessment). Figure 7 shows, that for most parameters the range of values associated with a level of expertise is presented. A parameter in accordance with the current career status of the operator is displayed in black; a parameter in accordance with the next higher status is displayed in green; a parameter in accordance with a lower status is displayed in red. For example, Operator 1, current status "Basic experience", is already seven months in his current position, which puts him in the 7 – 18 month band associated with the next higher level "Advanced experience" and leading to the respective field to be displayed in green. Operator 1 still has issues related to his percentage of faulty decisions before being eligible for promotion to "Advanced level".



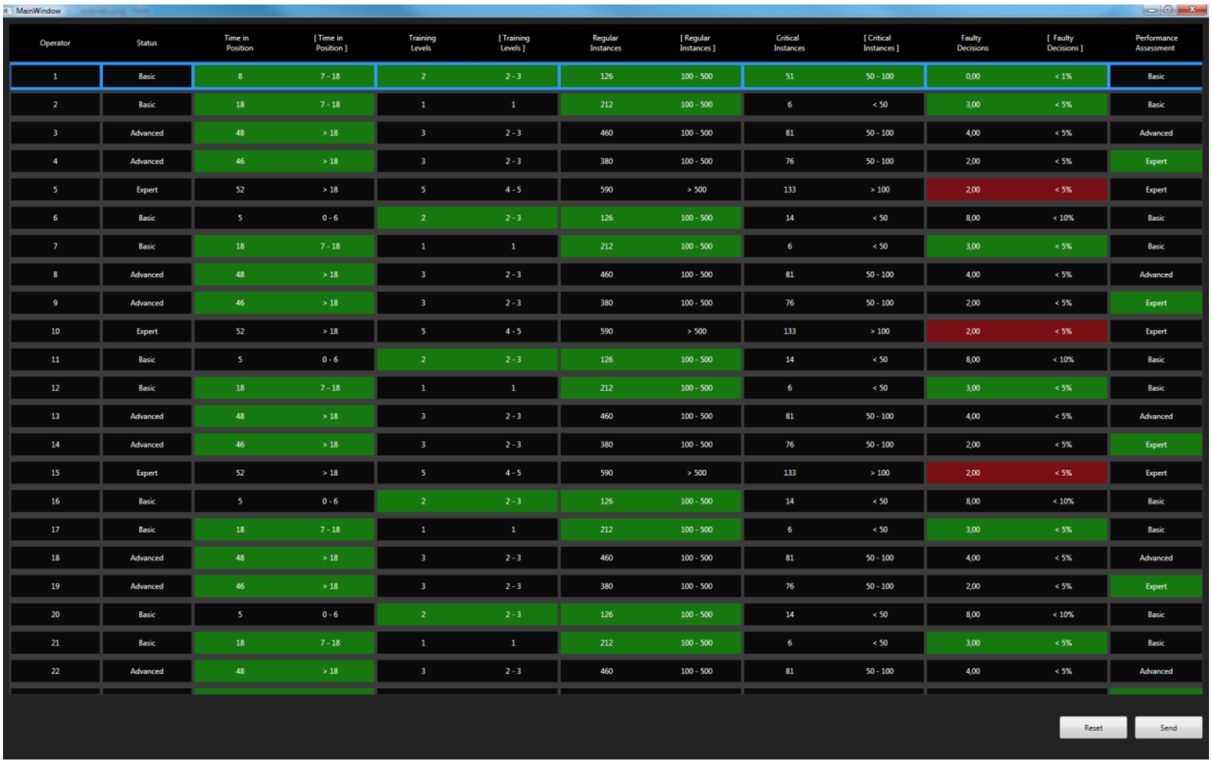
MainWindow

| Operator | Status | Time in Position | [ Time in Position ] | Training Levels | [ Training Levels ] | Regular Instances | [ Regular Instances ] | Critical Instances | [ Critical Instances ] | Faulty Decisions | [ Faulty Decisions ] | Performance Assessment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Basic | 7 | 7 - 18 | 2 | 2 - 3 | 126 | 100 - 500 | 51 | 50 - 100 | 8,00 | < 10% | Basic |
| 2 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 3 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |
| 4 | Advanced | 46 | > 18 | 3 | 2 - 3 | 380 | 100 - 500 | 76 | 50 - 100 | 2,00 | < 5% | Expert |
| 5 | Expert | 52 | > 18 | 5 | 4 - 5 | 590 | > 500 | 133 | > 100 | 2,00 | < 5% | Expert |
| 6 | Basic | 5 | 0 - 6 | 2 | 2 - 3 | 126 | 100 - 500 | 14 | < 50 | 8,00 | < 10% | Basic |
| 7 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 8 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |
| 9 | Advanced | 46 | > 18 | 3 | 2 - 3 | 380 | 100 - 500 | 76 | 50 - 100 | 2,00 | < 5% | Expert |
| 10 | Expert | 52 | > 18 | 5 | 4 - 5 | 590 | > 500 | 133 | > 100 | 2,00 | < 5% | Expert |
| 11 | Basic | 5 | 0 - 6 | 2 | 2 - 3 | 126 | 100 - 500 | 14 | < 50 | 8,00 | < 10% | Basic |
| 12 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 13 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |
| 14 | Advanced | 46 | > 18 | 3 | 2 - 3 | 380 | 100 - 500 | 76 | 50 - 100 | 2,00 | < 5% | Expert |
| 15 | Expert | 52 | > 18 | 5 | 4 - 5 | 590 | > 500 | 133 | > 100 | 2,00 | < 5% | Expert |
| 16 | Basic | 5 | 0 - 6 | 2 | 2 - 3 | 126 | 100 - 500 | 14 | < 50 | 8,00 | < 10% | Basic |
| 17 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 18 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |
| 19 | Advanced | 46 | > 18 | 3 | 2 - 3 | 380 | 100 - 500 | 76 | 50 - 100 | 2,00 | < 5% | Expert |
| 20 | Basic | 5 | 0 - 6 | 2 | 2 - 3 | 126 | 100 - 500 | 14 | < 50 | 8,00 | < 10% | Basic |
| 21 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 22 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |

Reset Send

**Figure 7: Operators career status overview display (Time 1)**

Once an operator has reached a next-level performance in all parameters as Operator 1 in Figure 8 has, the supervisor is informed. Through this adaptation, supervisors are pro-actively invited to review the career status of an operator.




| Operator | Status | Time in Position | [ Time in Position ] | Training Levels | [ Training Levels ] | Regular Instances | [ Regular Instances ] | Critical Instances | [ Critical Instances ] | Faulty Decisions | [ Faulty Decisions ] | Performance Assessment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Basic | 8 | 7 - 18 | 2 | 2 - 3 | 126 | 100 - 500 | 51 | 50 - 100 | 0,00 | < 1% | Basic |
| 2 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 3 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |
| 4 | Advanced | 46 | > 18 | 3 | 2 - 3 | 380 | 100 - 500 | 76 | 50 - 100 | 2,00 | < 5% | Expert |
| 5 | Expert | 52 | > 18 | 5 | 4 - 5 | 590 | > 500 | 133 | > 100 | 2,00 | < 5% | Expert |
| 6 | Basic | 5 | 0 - 6 | 2 | 2 - 3 | 126 | 100 - 500 | 14 | < 50 | 8,00 | < 10% | Basic |
| 7 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 8 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |
| 9 | Advanced | 46 | > 18 | 3 | 2 - 3 | 380 | 100 - 500 | 76 | 50 - 100 | 2,00 | < 5% | Expert |
| 10 | Expert | 52 | > 18 | 5 | 4 - 5 | 590 | > 500 | 133 | > 100 | 2,00 | < 5% | Expert |
| 11 | Basic | 5 | 0 - 6 | 2 | 2 - 3 | 126 | 100 - 500 | 14 | < 50 | 8,00 | < 10% | Basic |
| 12 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 13 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |
| 14 | Advanced | 46 | > 18 | 3 | 2 - 3 | 380 | 100 - 500 | 76 | 50 - 100 | 2,00 | < 5% | Expert |
| 15 | Expert | 52 | > 18 | 5 | 4 - 5 | 590 | > 500 | 133 | > 100 | 2,00 | < 5% | Expert |
| 16 | Basic | 5 | 0 - 6 | 2 | 2 - 3 | 126 | 100 - 500 | 14 | < 50 | 8,00 | < 10% | Basic |
| 17 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 18 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |
| 19 | Advanced | 46 | > 18 | 3 | 2 - 3 | 380 | 100 - 500 | 76 | 50 - 100 | 2,00 | < 5% | Expert |
| 20 | Basic | 5 | 0 - 6 | 2 | 2 - 3 | 126 | 100 - 500 | 14 | < 50 | 8,00 | < 10% | Basic |
| 21 | Basic | 18 | 7 - 18 | 1 | 1 | 212 | 100 - 500 | 6 | < 50 | 3,00 | < 5% | Basic |
| 22 | Advanced | 48 | > 18 | 3 | 2 - 3 | 460 | 100 - 500 | 81 | 50 - 100 | 4,00 | < 5% | Advanced |

**Figure 8: Operators career status overview display (Time 2)**

The information message for the supervisor (see Figure 9) indicating eligibility for promotion of Operator 1 includes an "Info" button that, when pressed, leads to the display of further information that led to the proposal.

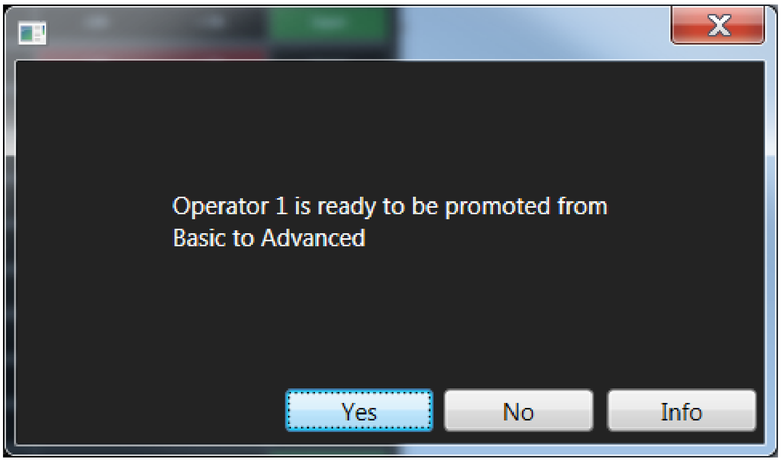



**Figure 9: Supervisor information about possible operator promotion**

The implementation of the Use Case 6 functionality is very recent and has not yet been evaluated.

## 2.2 Final version of the Iren Control Room AdCoS

### 2.2.1 AdCoS and use cases

As described in details in D8.9, the Energy Control Room receives either calls from customers who report network failures, or signals from the controlled network segments. These calls are managed by a specific group of the Control Room operators (Call Centre), which is assigned to the collection of the information of each emergency call. The Call Centre uses the proprietary "CCE" software (in Italian *Centro Chiamate Emergenza*) for the management of the intervention.

Once the information is stored in the CEE, operators in the Control Room apply a first level of intervention (remote intervention) on the network, to fix the problem. In case this is neither decisive nor possible (e.g. in case of a burst pipe), the operators are formally requested to assign the intervention to the technicians in the field (as represented in Figure 10).

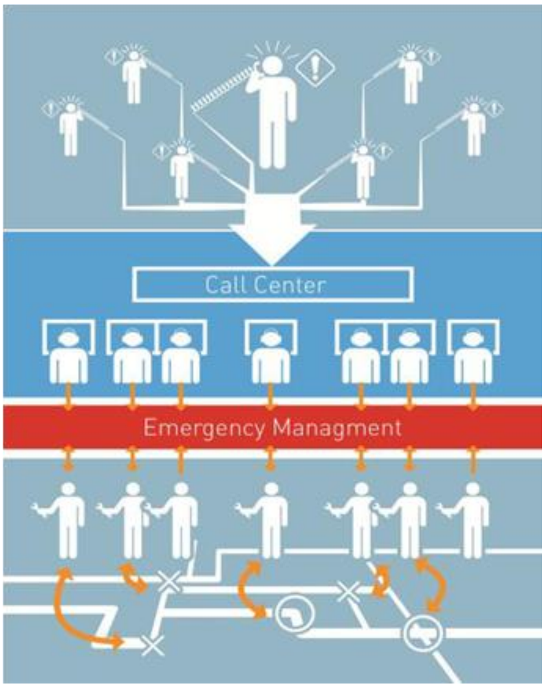



**Figure 10: Representation of the Communications and Roles in the IRN Control Room**

For each service it manages (e.g. gas or water), IRN has several obligations with the National Energy Authority in order to provide a high-quality service to the citizens.

In particular, due to the critical nature of the gas service, IRN has specific Service Level Agreements (SLA) with the Authority that regulates that (in 95% of the interventions) a technician must reach the place of the emergency within 60 minutes to assess its severity and, in case of need, secure the area.
At present, IRN does not use any adaptive system to allocate tasks to available operational teams in the field, but the communication between the Control Room operators and the operative teams takes place only via phone calls (very time-demanding) and the allocation of tasks and responsibilities is based on the senior experience of Control Room operators.

Moreover, the operators do not know where the technicians actually are and if they are still involved in an intervention previously assigned. Therefore, the operator assigns the interventions according to a static criteria: each technician has been allocated to a specific zone (e.g. North of Parma) and he or she will receive only interventions for that zone.

However, since the zone may be very wide (up to 50 km), this static allocation is not very efficient and could prevent the technician to reach the place of the intervention in time (i.e. within 60 minutes since the emergency call was received).

Therefore, the aim of the AdCoS developed in HoliDes is to support the operators in the selection of the most suitable technician for the gas service (i.e. the most critical service), in order to:

1. Minimize the time to reach the place of the intervention
2. Reduce the number of times the operator selects the wrong technician (i.e. when the technician is either too far from the place of the intervention or still involved in another emergency that he refuses it and passes it to another technician)
3. Minimize the percentage of times the technician did not reach the place of the intervention within 60 minutes (the maximum acceptable percentage, as regulated by the Authority, is 95%).

Previous systems (e.g. mobile apps) have been introduced into the Energy Control Room to share data between the operators and the technicians in the field, but none of them have been accepted by the operators and/or the technicians. They had always switched back to the phone calls, that are considered as a much more flexible way to manage the communications and the assignments of the interventions.

Selecting the most appropriate technician according to the senior experience of the operator (Use Case 4) is a relevant HF issue for the Control Room, because the operators do not always have all necessary information to take the right decision. Therefore, we expect that this use case can get the most benefit from the adaptiveness of the new systems (that selects the technicians according to their real position and the activities they are actually performing) and the innovative communication strategy (based on the apps).

### 2.2.2 Performance Indicators (PI) and objectives of development

By starting from the aim of the AdCoS described in the previous section, 3 objective and 3 subjective Performance Indicators (PIs) have been identified in order to evaluate the performance of the AdCoS and guide the evaluation activities conducted in task 8.5 (summarized in In order to measure these performance indicators, IRN, in collaboration with REL and ATO, performed an empirical experiment that involved 3 technicians and 2 operators of the gas service in the zone of Parma (Italy), for 4 days.

The aim of the empirical experiment was to collect real data during the interventions to measure the objective and subjective PIs of the Control Room with and without the AdCoS.

Table 1
In order to measure these performance indicators, IRN, in collaboration with REL and ATO, performed an empirical experiment that involved 3 technicians and 2 operators of the gas service in the zone of Parma (Italy), for 4 days.

The aim of the empirical experiment was to collect real data during the interventions to measure the objective and subjective PIs of the Control Room with and without the AdCoS.

**Table 1: Performance Indicators of the AdCoS for IREN Control Room**

| Performance Indicator | Description |
|---|---|
| **Average time for arrival** | In order to meet the SLA regulated by the Energy Authority for the gas service, IRN must reach the place of each intervention within 60 minutes after the emergency has been notified. Therefore, this indicator is particularly relevant to measure the performance of the Control Room with and without the AdCoS. |
| **# of wrong technicians** | This is the number of times the operator selected the wrong technicians (i.e. another technician performed the intervention).<br><br>If the technician selected for an intervention is busy and/or too far to reach the place of the emergency within 60 minutes, he calls another technician to pass the intervention. This activity is extremely time-consuming for the technicians and the operators, and it may degrade the performance of the Control Room (in particular for the time to reach the place of the intervention). |
| **% of out of SLA** | IRN must not exceed 5% of intervention out of the SLA (60 minutes), otherwise it must pay a fine. |
| **Usability** | Like a part of the evaluation, a study of the usability of the AdCoS was performed, based on user testing and expert reviews. Usability testing is *nonfunctional testing*: focused on the user experience, comprises comprehensibility, learnability of the application, operability, the appeal of it, and compliance. Usability is measured by the SUS questionnaire, with a score from 0 to 100. |

### 2.2.3 Final status of the AdCoS

As described in details in D8.9, the Energy Control Room AdCoS includes three macro elements (as shown in Figure 11):

- a Server
- an HMI application for the Control Room operators
- an Android app for the technicians in the field, installed on several mobile devices (tablets)

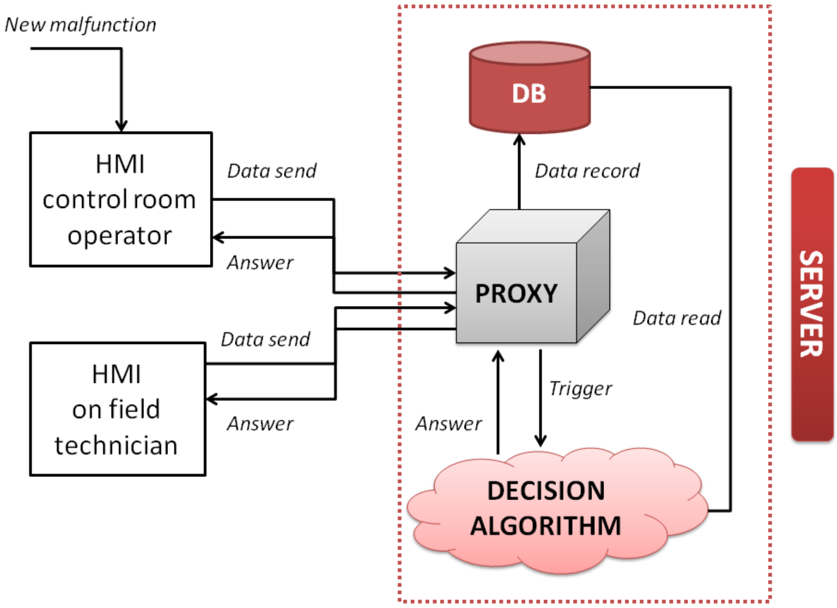



**Figure 11: Architecture of the Energy Control Room AdCoS**

The **Server** includes:

- an Entity-Relationship Data Base with the data about malfunctions and technicians,
- the engine with the **Decision Algorithms** for the automatic selection of the most appropriate technician for each intervention,
- a **proxy** to dispatch the information to the operators and the technicians (respectively through a web browser interface and a mobile app)

The communication and the interactions among the elements are represented in the sequence diagram shown in Figure 12.

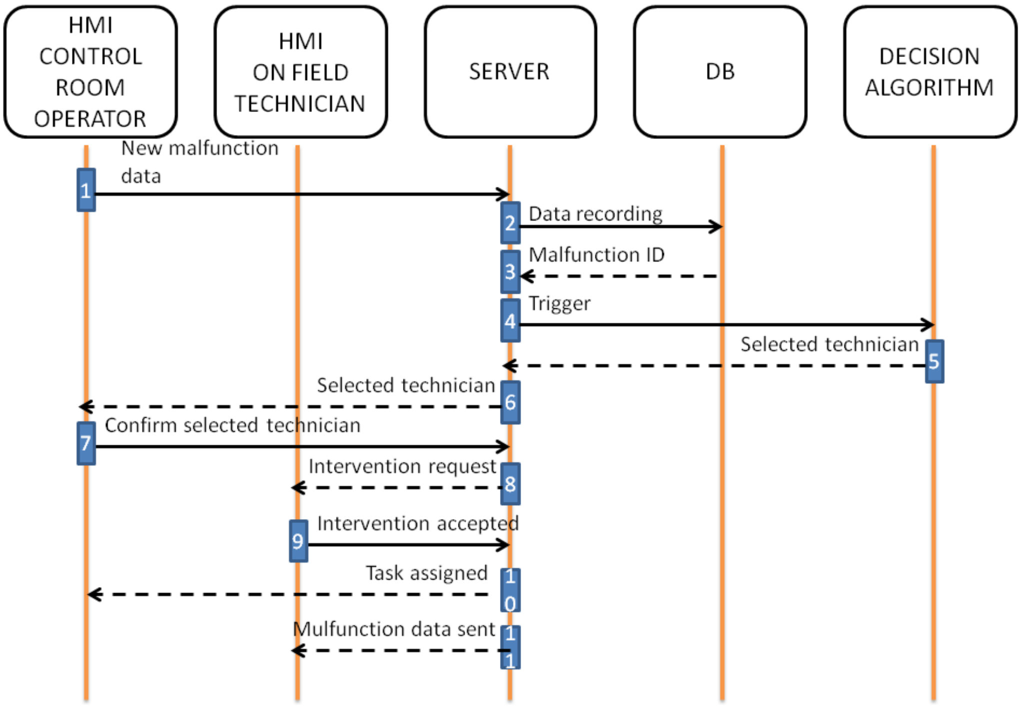



**Figure 12: Sequence Diagram of the Energy Control Room AdCoS**

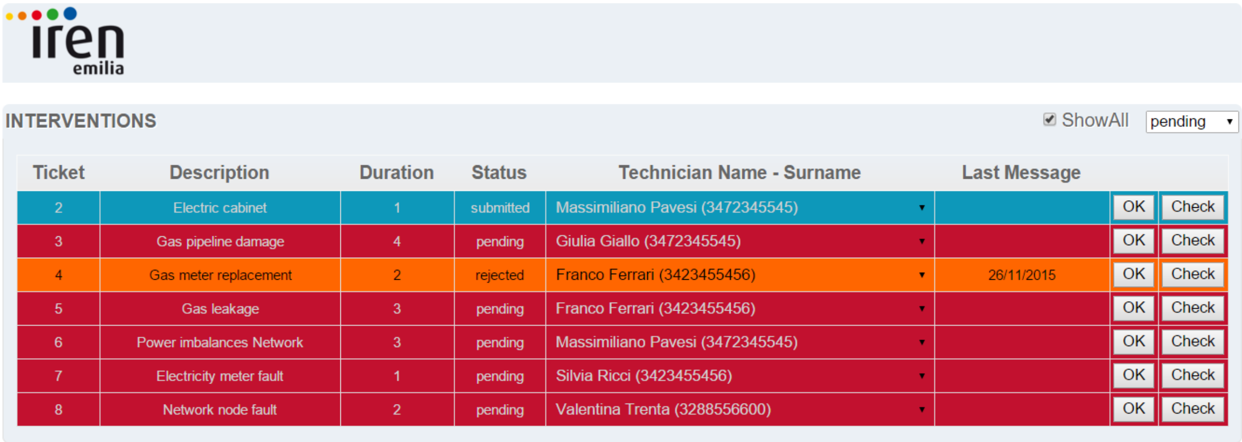
As shown in step 6 of the sequence diagram, the Server (and in particular the Decision Algorithm) is in charge of automatically defining a priority list of the most appropriate technicians to be assigned to the intervention.

The criteria taken into account by the Decision Algorithm to find the most suitable technician are applied in step 4, presented according to the filter order:

1. Skills
2. Geographic macro-zone of authority (i.e. Parma, Reggio Emilia, Piacenza)
3. Work shift
4. Actual assignment of previous tasks (and estimated duration of each of them)
5. Actual distance to the place of the intervention

**The HMI application for the Control Room operators** is a web-based application that lets them access the list of interventions, assign an intervention to a specific technician (according to the priority list provided by the Decision Algorithm) and see which technician is in charge of which interventions. The application (shown in Figure 13) is accessible via internet at the address:

http://relabsrv02.cloudapp.net/malfunction.aspx




| Ticket | Description | Duration | Status | Technician Name - Surname | Last Message | | |
|---|---|---|---|---|---|---|---|
| 2 | Electric cabinet | 1 | submitted | Massimiliano Pavesi (3472345545) | | OK | Check |
| 3 | Gas pipeline damage | 4 | pending | Giulia Giallo (3472345545) | | OK | Check |
| 4 | Gas meter replacement | 2 | rejected | Franco Ferrari (3423455456) | 26/11/2015 | OK | Check |
| 5 | Gas leakage | 3 | pending | Franco Ferrari (3423455456) | | OK | Check |
| 6 | Power imbalances Network | 3 | pending | Massimiliano Pavesi (3472345545) | | OK | Check |
| 7 | Electricity meter fault | 1 | pending | Silvia Ricci (3423455456) | | OK | Check |
| 8 | Network node fault | 2 | pending | Valentina Trenta (3288556600) | | OK | Check |

**Figure 13: Desktop Interface for the Operators**

The HMI provides the operator with the following information:

- Ticket number
- Brief malfunction description
- Expected duration of the intervention
- Status of the assignment
- Technician name
- Time stamp of the last message sent to the mobile app

The interface also includes two buttons:

- OK button, to assign the operator to the intervention (because the operators explicitly requested to have the final decision on assigning the technician, and not to make this operation completely automatic);
- Check button, to allow the operator to check the application of the decision algorithm for the specific selection of each assignment (as shown in Figure 14).


**Figure 14: Representation of the mechanism for the selection of the technicians**

The **HMI Application for the Technicians** lets them accept the assignment of an intervention and access the corresponding data (type of intervention, address, map, etc.).

The HMI of the Android application has been designed and developed in order to give a concrete support to the technician, mainly for providing:

- real-time geo-localized information on the intervention (address and details of the intervention, navigation features, etc.) that previously were requested by phone (or via printed data) to the operators;
- an instrument to easily accept (or reject) the assignment of the intervention, without wasting time on the phone.

A screenshot of the HMI of the Android app is shown in Figure 15.

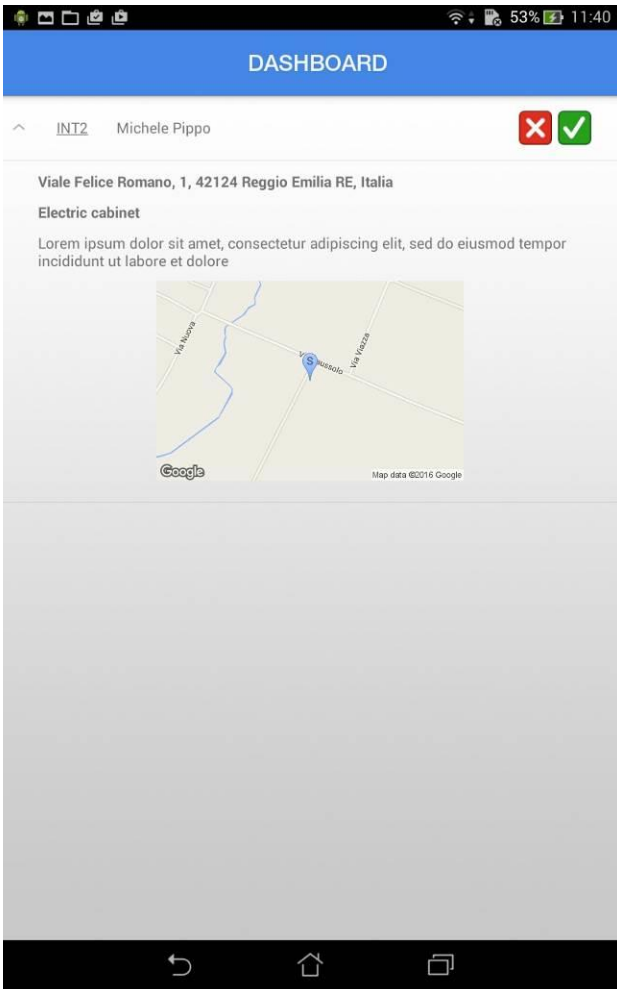



**Figure 15: Additional Information Associated with the Intervention**

# 3 Final assessment of the HF-RTP and methodology

## 3.1 Assessment of the Airbus AdCoS HF-RTP and methodology

During the course of the HoliDes project, the chosen MTTs used by the control room in WP8 have been under constant investigation and revision. WP8 participated in the various MTT workshops with MTT owners during the early stages of the project to both understand what MTTs could be useful in the development of a control room.

Many of the MTTs available in HoliDes could not be used in the control room since they were tailored to a specific domain. For example, tools such as CPM-GOMS, PROSIVIC, Movida etc. were aimed exclusively at the automotive sector. Other tools could not be used since the WP8 use cases were not sufficiently complex enough in the areas, which the MTTs could address. For example, the HEE tool is a GUI analysis application yet the GUI used by customers of Airbus' border control solutions is very simplistic bearing one main screen with a few buttons. Even if the HEE tool could somehow have enhanced the efficiency of the border control application, Airbus DS had no access to the application source code so no modification was possible.

During the course of the project, the Use Cases matured and more MTTs became available. This meant the revision of the Airbus MTT lists was necessary. One MTT that became available in the duration of the project was the KNIME tool. Pattern recognition was identified as a way of in-creasing security at the border by allowing the border control supervisor to pick out regular occurrences that could be exploited by an intruder observing the border. At first, a solution was thought to be found in the LEA tool but this turned out not to be the case. Eventually, KNIME was pro-posed instead and this proved to have an adequate success rate.

During the design phase of the AdCoS, the following MTTs were selected:

1. KNIME: it became obvious that Use Case 4 requires more flexibility for testing behaviour patterns than hard-coded solutions allow. KNIME has been identified by WP3 as an alternative to hard-coded rules and is currently implemented in an update of the AdCoS functionality;

2. Enterprise Architect (Sparx Systems) is a software tool used in Airbus DS for architecture modelling. Enterprise Architect (EA) was identified for use in HoliDes because it is flexible and highly customisable. This is advantageous on two accounts: the first is that EA could be extended to incorporate the Human Views as defined in the NATO Architecture Framework Human Factors handbook; secondly, EA has an API, which can be utilised for extending its functionality programmatically. This is necessary for adding OSLC capabilities to the tool.

3. Doors (IBM) is an industry standard requirements management tool which is used throughout Airbus. Doors comes with a built-in OSLC interface which means the requirements can be made easily available to other MTTs in the Control Room HF-RTP.

4. HF-Guidelines were applied where possible, as WP8 was in constant discussion with WP3 during the design of the AdCoS.

A number of MTTs have been employed for the evaluation of the use cases.

1. Focus Groups: Focus Groups were used for the evaluation of the acceptance of the technologies employed in the use cases by Emergency Response Control Room operators. The Focus Groups were developed, conducted and evaluated by SNV.

2. Questionnaire Studies (ATOS): Usability questionnaires were proposed by WP5 to be employed across the HoliDes domains. The questionnaire was developed, conducted and evaluated by ATOS.

3. Experiments (AGI): The method of the scientific experiment was used in the context of the evaluation of Use Case 3. The experiments were developed, conducted and evaluated by Airbus Group Innovations Germany with support from Airbus Defence and Space Germany

4. HF-Filer: This tool provides the ability to create a set of Evaluation Items and Evaluation Reports and to make them available in EA using OSLC (this will be done after the completion of the evaluation activities). Work with HF-Filer was conducted and evaluated by Airbus Group Innovations UK

The following MTTs were evaluated and dropped during the HoliDes project.

1. Human Efficiency Evaluator (HEE Tool): The HEE tool was promising at the start of the project because it became clear that the user interface of the Airbus AdCoS relies on proximity-based interaction (presence detection, eye tracking) and lacks complex mouse-and-keyboard user interaction. Whilst the tool could have been useful in complex scenarios, it seemed unsuitable for WP8.

2. LEA: During trials and evaluations, it became clear that the LEA tool was not able to detect patterns in example data. For example, not being able to recognise that two border guards were absent together regularly on the same day. It is for this reason that LEA was dropped in favour of KNIME when it became available.

3. GreatSPN: GreatSPN is a Markov chain tool for identifying bottle necks in business processes more typically associated with call centres and factory environment. In the early stages of the project when it looked like the Airbus Use Case might deal with several surveillance centres it could have been very useful. Eventually, the use cases concentrated on the activities in a single call centre and so the scenario was not sufficiently complex enough to justify the modelling effort. In addition, the value from the results of the

model are only as good as the data that is put in. Airbus does not have access to the data from operative border control centres to put into the GreatSPN model. Any figures put in would be purely speculative and any results would yield little value.

Recommendations for future development:

1) Integration: Since the modelling tools used by Airbus are defined in a list of approved tools, extra tooling can only serve as an accompaniment not a replacement to the Airbus design processes. With this is mind, it is crucial that any future MTTs are produced with integration in mind. As such, the recommendation from Airbus is that the MTTs are as compliant as possible to available standards for integration, e.g. OSLC.

2) Non-Domain specific: Airbus was unable to choose many tools since they were specific to particular domains. To increase the applicability of MTTs to Airbus it is recommended that the RTP be enhanced with more MTTs that are more generic in nature.

## 3.2 Assessment of the Iren AdCoS HF-RTP and methodology

As described in details in D8.8, the MTTs selected for the development of the Energy Control Room AdCoS were employed during the analysis, implementation and evaluation development phases.

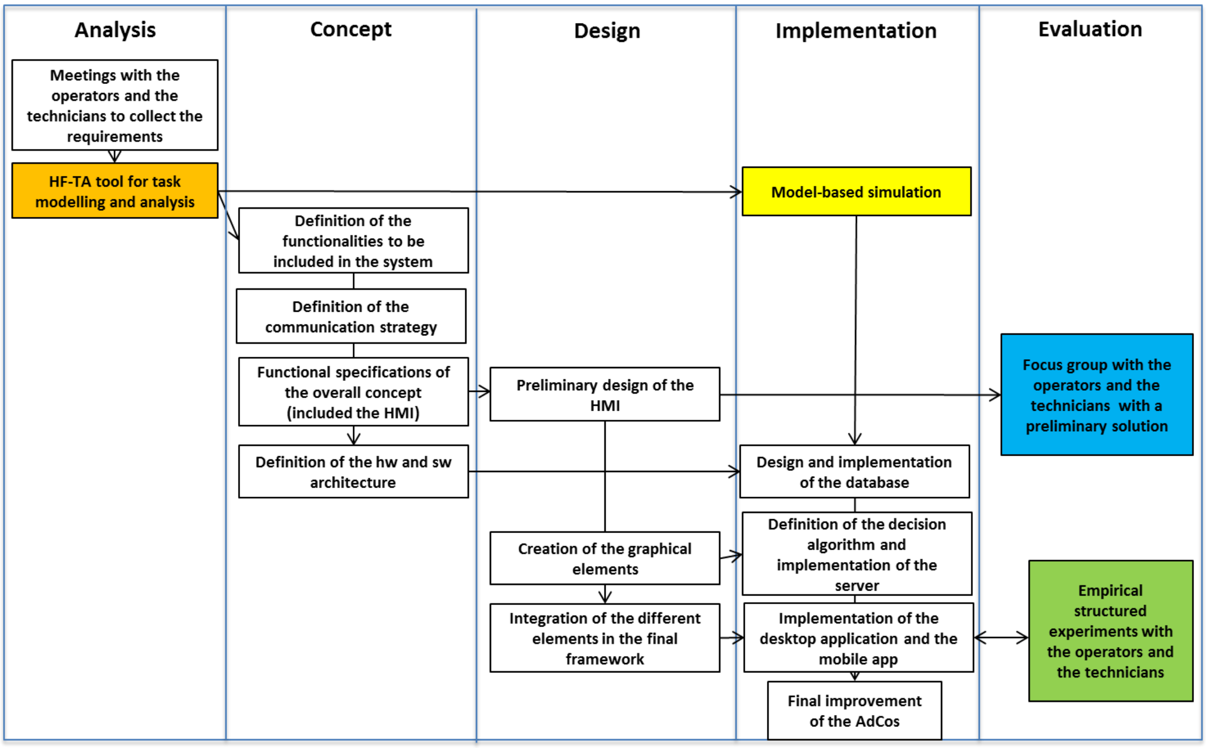



**Figure 16: MTT use in the development process**

The next sections describe the traditional and the innovative process introduced in the project. In order to implement the AdCoS, the following MTTs (described in) were selected.

**Table 2: MTTs used for the development of the Energy Control Room AdCoS**

| Development phase | MTTs and benefits |
|---|---|
| Analysis | **HF-TA tool for task modelling and analysis**: by using the HF-TA tool for task modelling and analysis, we could<br>- identify the tasks that could be automated and the tasks that should be maintained in charge of the operators (i.e. manual)<br>- optimize the workflows for the assignment of tasks and the communication with the technicians<br>- identify the communication tasks that could be delegated to the app (in order to reduce the phone calls)<br><br>**Focus group**: we tested the preliminary AdCoS with real operators and technicians (in collaboration with SNV - WP5).<br>- The operators of the Control Room raised concerns about the automation ("**How can I trust the decision-making process of the system?**")<br>- Therefore, the HMI concept has been improved by including features that cope with the **sharing of authority** issue, to share knowledge and increase trust in automation. |
| Implementation | **GreatSPN**: a simulation with the GreatSPN – developed by UTO in WP4 – has been run to identify the number of calls that can lead to a severe emergency that may request the prompt intervention of other technicians from the adjacent zones. |
| Evaluation | In the 3rd year we evaluated the performance of the AdCoS by applying an **empirical approach** (as described in D8.9): an experiment with real operators and technicians has been designed by SNV in WP5 and conducted by REL and IRN to measure the performances of the Energy Control Room with and without the AdCoS. |

### 3.2.1 GreatSPN simulation

The efficiency of the management of intervention of IREN network in terms of task assignment to the most suitable technician in order to save time and resources was validated through a simulation. The aim of this simulation was to verify that the managing of interventions by the AdCoS allows to be compliant with the quality standards of the Italian Authorities for energy distribution.

In particular the objectives of the study were 1) to get insight into the old and new policies for assigning technicians to incoming calls at IREN control room and 2) to evaluate the rate of incoming calls (in number of calls per hour or day) that can be dealt with by IREN without violating the SLA requirement of 1 hour limit between the time of the call and the time the technician arrives at the calling site, for the 95% of the calls, as requested by the Authority.

These goals corresponds to the KPIs "*Average time for arrival*" e "*% out of SLA*", as defined in Table 13 of Deliverable D8.9.

We have studied the behaviour of the new assignment schema under stressing conditions using numerical analysis techniques. We consider the area of Reggio Emilia for the area partitioning, which consists of 37 municipalities and has always 4 technicians available (in normal conditions).

The analysis is directed toward finding the limit incoming call rate that makes the system incapable of respecting the required SLA.

*KPI Evaluation under simulation*

Table 3 below reports the mean number of idle technicians and the percentage of assignments to a technician that was already in the zone that originated the call (column %SameZone), or a zone next to the current position of the technician (column %NextTo) or to a faraway zone (column %NotConvenient). These percentage are also calculated from the throughput of the corresponding transitions in the net.

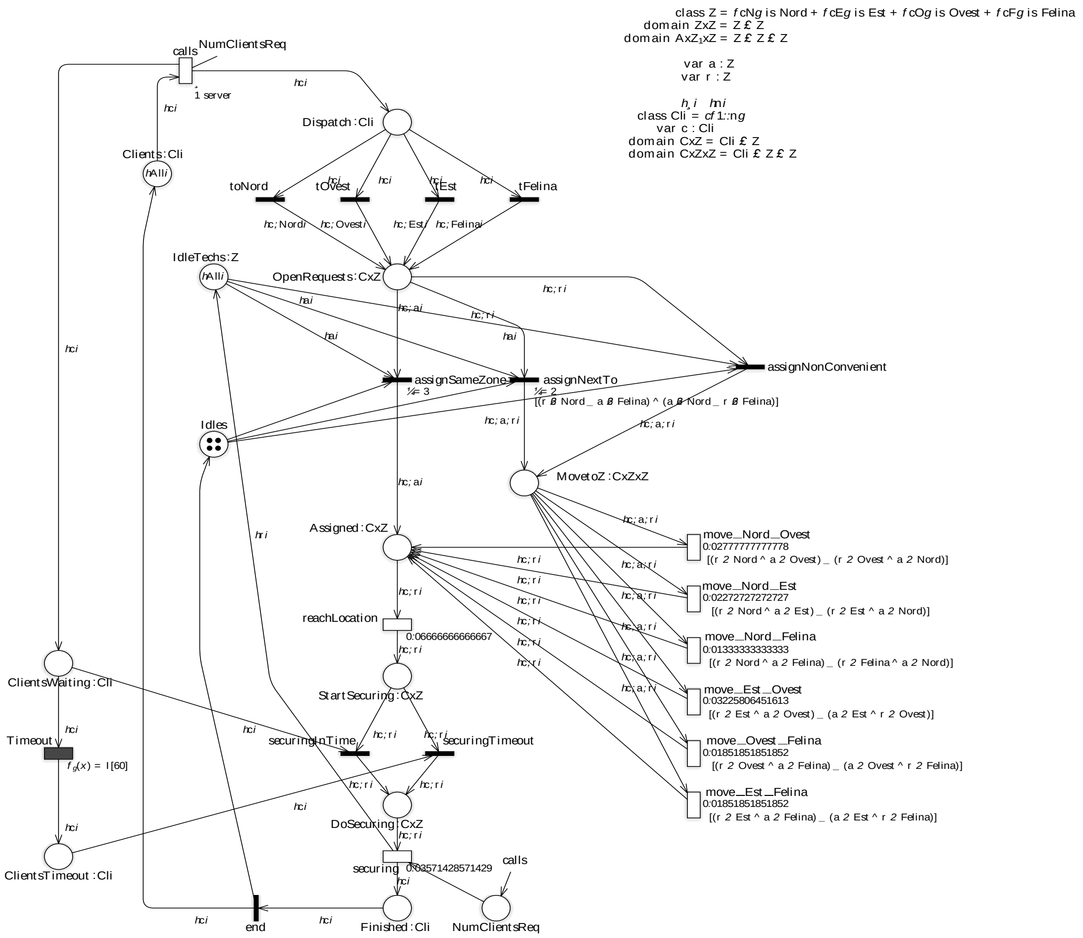



**Figure 17: Petri net model of the technician assignment (no client identification)**

**Table 3: Simulation results, accuracy 5%, Confidence 95%, for n=100 Clients globally**

| Interarrival time (min) | % Timeout | % InTime | average idle tech | %same zone | %nextTo | %Not convenient |
|---|---|---|---|---|---|---|
| 10 | 45.0 | 55.0 | 0.15 | 76.38 | 19.37 | 4.25 |
| 30 | 19.4 | 80.6 | 2.32 | 51.54 | 44.51 | 3.95 |
| 60 | 12.2 | 87.8 | 3.19 | 67.47 | 31.39 | 1.14 |
| 120 | 7.9 | 92.1 | 3.60 | 78.99 | 20.76 | 0.25 |
| 180 | 6.0 | 94.0 | 3.74 | 99.96 | 0.04 | 0.00 |

The results clearly indicate that the system may respect the SLA only for a mean inter-arrival time of more than 180 minutes among successive incoming calls. Note that, for an inter-arrival time of calls greater than 30 minutes, more than half of the operators are, in the average, idle and nevertheless the SLA is not respected (due to the long travelling times in the Reggio Emilia zone). Moreover, the observation of the percentage of technicians assigned to the same zone indicates that almost all assignments should be local to stay within the SLA (where local means "the closest technician assigned by the AdCoS policy is already in the same zone"). Note that, on average, few calls are done every day at the control room (2/3 per day) which makes the system sustainable, but more attention should be placed on critical situations.

Recommendations for future development – identified for each MMT:

- HF-TA: improvements and recommendations already included in D8.9 (Section 4.2.2 - MTT requirements);
- GreatSPN: additional simulations needed to identify critical conditions;
- Empirical experiments: additional tests needed with an increased number of operators and technicians, as well as a wider temporal window (e.g. 1 month).

# 4 AdCoS evaluation activities overview and update

## 4.1 Evaluation of the Airbus AdCoS

### 4.1.1 Empirical evaluation of the AdCoS demonstrator

The evaluation of the Airbus AdCoS took place in May/June 2016 using a number of MTTs (see clause 3.1). A detailed report of the evaluation procedure and results can be found in deliverable D8.9.

The main findings with regard to the need of re-design of the AdCoS are:

- Use Case 1 (Operator Absence): the functionality of the demonstrator proved to work reliably with the one exception of a sub-optimum performance of the smartwatch in calling back the operator. The next step (after HoliDes) in ensuring the interoperability between demonstrator SW/HW and smartwatch will be systematic tests with smartwatches from other manufacturers.

- Use Case 2 (Operator Idle/Asleep): for the reasons mentioned above, no evaluation of the AdCoS functionalities for this use case could be performed. Realistically, this functionality will have to be evaluated after HoliDes “in the field” with real operators working in a realistic emergency response environment.
- Use Case 3 (Operator Fatigue): two approaches for addressing the issues found in the evaluation (i.e. the insufficient degree of correlation between fatigue detection of the AdCoS and the EEG measurements) are either to study the effects of using a different type of eye-tracking equipment, or to try and improve the performance of the current equipment (Tobii) by refining the algorithms for calculating the PERCLOS parameter.
- Use Case 4 (Detection of Behaviour Patterns): the usability test of the previous implementation of the use case identified a number of usability issues that were addressed in the re-design described above. In addition, the use of MTT KNIME increases the flexibility of defining rules to test.
- Use Case 5 (Workload Balancing): this use case was not evaluated in the test period as the demonstrator functionality for Use Case 5 was completely redesigned (see above).
- Use Case 6 (Operator Career Progression Monitoring): this use case was not yet implemented at the time of the evaluation activities.

The evaluation studies and the use of the MTTs employed for conducting them provided a solid basis and direction for improving the AdCoS for future exploitation.

### 4.1.2 Evaluation of Return on Investment

Figure 18 details the Innovative System Development savings, which will be achieved in the processes printed in blue. These processes are performed in an iterative approach and are not performed in a Waterfall / Sequential lifecycle, the process groups are detailed as follows:

- Operators – This task involved Usability Questionnaires, Focus Group (5.1) discussions and interviews with Operators and Subject Matter Experts, which is part of the Airbus Stakeholder Engagement Process (1.1). The data was used by the Modelling process in conjunction with the C2 Generic Baseline and the Use Case Analysis (1.3).

- AdCoS Scenario Development – The process involved defining a C2 Generic Baseline for the Airbus WP in conjunction with the Use Case Analysis (1.3) and supplied data into the overall Modelling Process. The Modelling process supplied System Architecture models and Human View analysis back into the C2 Generic Baseline Document.

- Modelling – This Task involved Task Analysis (1.2), Sequence Diagrams (2.2) and Human View Modelling (2.3). Airbus DS re-used a large number of models for the C2 Generic Baseline and Sequence Diagrams, using System Architect. The Human View extensions were defined for Enterprise Architect, thus providing Airbus DS the ability to produce Human Views in multiple tools. Both modelling tools used a standard Architecture Framework for consistency. An OSLC link (3.1) was produced for Enterprise Architect and HF-Filer, this resulted in linked data between the tools defined in the WP8 HF-RTP. As a result of the Architecture modelling the Use Case definitions (1.4) and the Concept of Operations (2.1) documents were completed.

- Demonstration Test Cases – The output from the AdCoS Scenario and the Modelling resulted in Test Cases and Scripts which were used for the Demonstrator evaluation.

- AdCoS Demonstrator – The major task of WP8 was the design and implementation of the demonstrator, which included hardware, developed software, real C2 software, together with an innovative set of operator sensors.

- Analyse Metrics – This task involved the off line analysis of the evaluation data extracted from the demonstrations and test subjects, using Methods Tools and Techniques (MTT) defined within HoliDes.

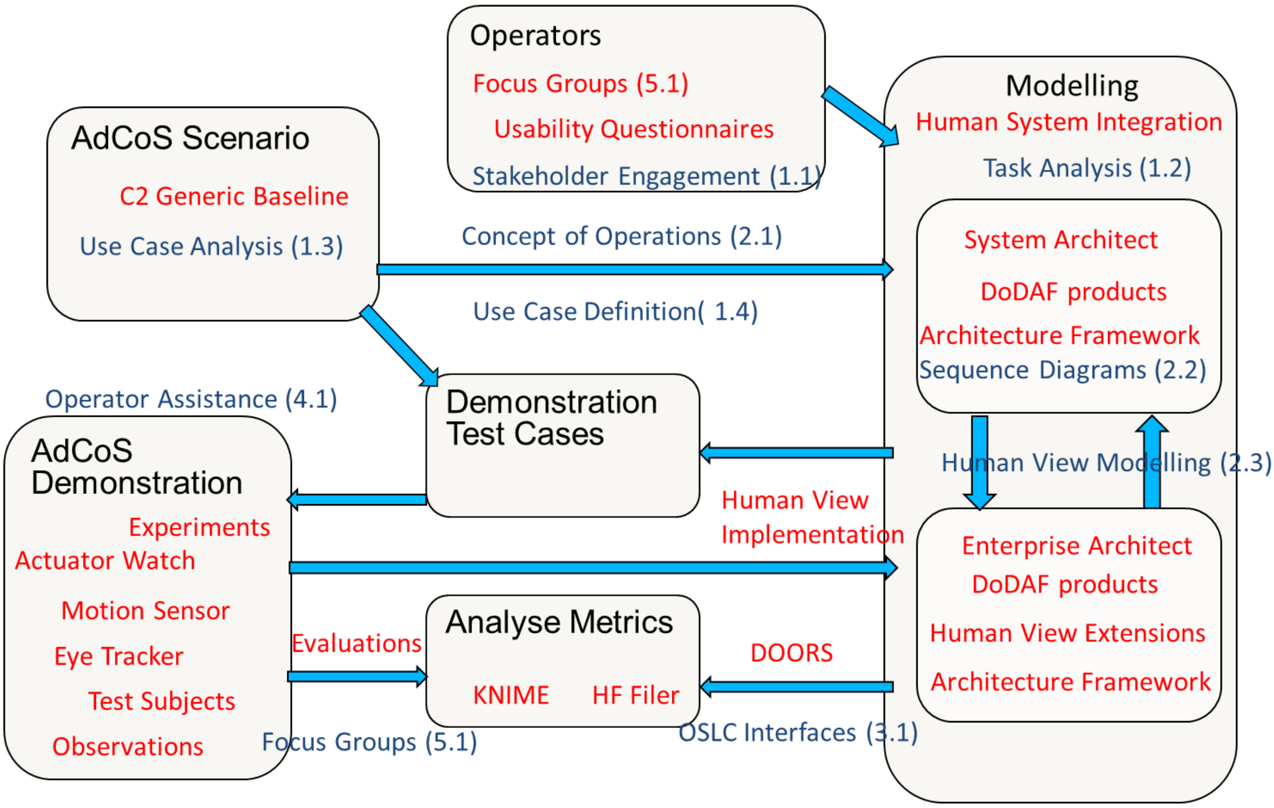



**Figure 18: Mapping of the development lifecycle products and the AdCoS components**

Airbus DS has spent a considerable amount of time and effort on defining Airbus DS Key Performance Indicators for its implementation of Model Based System Engineering. We have also provided return on investment data for said MBSE implementation and are in the process of monitoring key pilot projects. As most of this data is company sensitive we cannot disclose the actual costs and savings, however we can provide open source data provided via an INCOSE conference and paper. Airbus DS can confirm that the data defined in this paper is a close match to the results from our pilot projects; however, we are only into the second year of data gathering.

The open source data defines overall MBSE savings:

- Year 1 - 3% saving of the overall system engineering budget
- Year 2 - 6% saving of the overall system engineering budget
- Year 3 - 9% saving of the overall system engineering budget
- Year 4 - 12% saving of the overall system engineering budget

The savings are dependent on the size of the System Engineering budget of the total contract award. If we use a figure of 12% for the system engineering on three types of project budgets, the following estimates result:

- Small project: 10,000K Euros
- Medium project: 40,000K Euros
- Large Projects: 100,000K Euros

If the HoliDes improvements were implemented within an Airbus DS project, this assumes that the Command and control system required an extensive need to use Human System Integration (HSI) we would aspect to save an additional 0.5%, which is a conservative estimate.

**Table 4: Estimates of savings for small, medium and large projects**

| | **Project Cost** | **SE (12%) Budget** | |
|---|---|---|---|
| | | MBSE Savings | HoliDes Savings |
| **Small Project** | **10,000 K€** | **1,200 K€** | |
| Year 1 (3%) | | 36 K€ | 6 K€ |
| Year 2 (6%) | | 72 K€ | 6 K€ |
| Year 3 (9%) | | 108 K€ | 6 K€ |
| Year 4 (12%) | | 144 K€ | 6 K€ |
| **Medium Project** | 40,000 K€ | 4,800 K€ | |
| Year 1 (3%) | | 144 K€ | 24 K€ |
| Year 2 (6%) | | 288 K€ | 24 K€ |
| Year 3 (9%) | | 432 K€ | 24 K€ |
| Year 4 (12%) | | 576 K€ | 24 K€ |
| **Large project** | 100,000 K€ | 12,000 K€ | |
| Year 1 (3%) | | 360 K€ | 60 K€ |
| Year 2 (6%) | | 720 K€ | 60 K€ |
| Year 3 (9%) | | 1,080 K€ | 60 K€ |
| Year 4 (12%) | | 1,440 K€ | 60 K€ |

This would provide additional savings of:

- Small project: 24,000 Euros
- Medium project: 96,000 Euros
- Large project: 240,000 Euros

These figures are a simple mathematical projection, but they are indicative of the savings we are finding within our pilot projects. They are also solely based on system engineering savings, they do not take into account the improvements made to the operators in terms of moral, effectiveness and working conditions or in any reduction in workload or the personnel.

1. Human View Definition

The number of human views implemented in Architectural Framework Tool will be used as a PI. The metric should describe how many of the Human Views are implemented into an Architectural Framework Tool and thus can be used for the development of the WP8 applications. The PI can be counted simply by the provider of the Human View implementation.

Human Views defined for the Airbus DS

Of the 13 possible Human Views 11 were included in the Airbus DS AdCoS development

The two views exclude are as follows

- HV-G Human Metrics – the AdCoS metrics were collected via toe MTTs HEE and KNIME
- HV-H Human Dynamics – The Architecture model was restricted to a static model, all the dynamic interactions was performed within the Airbus DS Demonstrator / AdCoS

**Table 5: Overview of Human Views in the Airbus AdCoS**

| Designation | Description | Integrated into the Airbus DS AdCoS |
|---|---|---|
| **HV-A** | Human Concept | Yes |
| **HV-B1** | Man Power Projections | Yes |
| **HV-B2** | Career Progression | Yes |
| **HV-B3** | Establishment History | Yes |
| **HV-B4** | Personnel Policy | Yes |
| **HV-B5** | Health Hazard | Yes |
| **HV-B6** | Human Characteristics | Yes |
| **HV-C** | Human Tasks | Yes |
| **HV-D** | Human Roles | Yes |
| **HV-E** | Human Networks | Yes |
| **HV-F** | Training | Yes |
| **HV-G** | Metrics | No |
| **HV-H** | Human Dynamics | No |

2. Human View Implementation

Of the 11 included Human Views defined for integration into the Airbus DS AdCoS:

- 9 were implemented populated with data defined in the C2 Generic Baseline using models from System Or Enterprise and generated in Microsoft Word
- Human Networks and Training have been partially implemented, due to lack of suitable Generic data within System Architect and Microsoft Word
- 4 were integrated using Model Driven Generation (MDG) technology within Enterprise Architect.

**Table 6: Rationale for Office and EA**

| Designation | Description | Implemented | Within Office Products | Within Enterprise Architect |
|---|---|---|---|---|
| **HV-A** | Human Concept | Yes | Yes | Yes |
| **HV-B1** | Man Power Projections | Yes | Yes | No |
| **HV-B2** | Career Progression | Yes | Yes | No |
| **HV-B3** | Establishment History | Yes | Yes | No |
| **HV-B4** | Personnel Policy | Yes | Yes | No |
| **HV-B5** | Health Hazard | Yes | Yes | No |
| **HV-B6** | Human Characteristics | Yes | Yes | No |
| **HV-C** | Human Tasks | Yes | Yes | Yes |
| **HV-D** | Human Roles | Yes | Yes | Yes |
| **HV-E** | Human Networks | Yes | Yes | TBC |
| **HV-F** | Training | Yes | TBC | No |
| **HV-G** | Metrics | No | No | No |
| **HV-H** | Human Dynamics | No | No | No |

3. AdCoS Component Evaluation Effectiveness ratings

Effectiveness ratings on a simple linear scale will be used as a PI. The metric should give insight into the usefulness of the applied methods/tools. Questionnaires will be used to collect simple ratings (e.g. scale from 1 to 10) for the effort to apply from developer's point of view as well for the resulting impact on usability from operator's point of view. The PI will give a synthesis of both ratings.

Evaluation Rating Definitions

- Developer – Component used by the AdCoS development engineers
- Operator – Component used by the AdCoS operators
- Hardware – Physical Hardware used with the Airbus DS AdCoS-Evaluation (Components used to evaluate the AdCoS)
- MTT – Methods, Tools and Techniques defined in WP 1 to 5
- OSLC Interface – Open Services for Lifecycle Collaboration
- Architecture Framework Extension – Human View extension to Enterprise Architect via Model Driven Generation (MDG)
- Architecture Framework Product – DoDAF Architecture artefact
- Use Case – standard Use Case
- AdCoS – Physical Hardware components
- Method – Method to extract and collate data
- Method / Framework – An international standard definition
- Software – software created with the Airbus DS AdCoS

**Table 7: AdCoS Component Maturity Rating**

| AdCoS Component | Operator / Developer / Hardware / Evaluation | Process / Tool / Method | Rating | Comment |
|---|---|---|---|---|
| Enterprise Architect | Developer | MTT | 8 | Provided the tool to for development for the Architecture extensions and the OSLC interface |
| Enterprise Architect HV extensions | Developer | Architecture Framework Extension | 8 | Extensions to the EA tool to provide Human Views with the Architecture Framework |
| Enterprise Architect and HF-Filer OSLC Interface | Developer | OSLC Interface | 8 | Provides an OSLC interface for EA, HF-Filer and DOORs |
| DOORS | Developer | MTT | 5 | Repository for the Airbus DS HoliDes requirements |
| KNIME | Developer | MTT | 8 | Identifies Operator Behavioural Patterns Used for UC-4, still to be implemented and evaluated |
| System Architect | Developer | MTT | 7 | Used to provide the Generic C2 Baseline Models and the AdCoS development models |
| HF-Filer | Developer | MTT | | Used to build an instance of an AdCoS from the HoliDes MTTs |
| Human Efficiency Evaluator | Developer | MTT | TBD | To be evaluated |
| HV-A Human Concept | Developer | Architecture Framework Product | 7 | Highlights the overall operational contents |
| HV-B1 Man Power Projections | Developer | Architecture Framework Product | 8 | Provides detail on man power, current and forward loading |
| HV-B2 Career Progression | Developer | Architecture Framework Product | 8 | Defines career progression for each member of staff |
| HV-B3 Establishment History | Developer | Architecture Framework Product | 8 | Provides data for each role within the organisation |
| HV-B4 Personnel Policy | Developer | Architecture Framework Product | 7 | Defines standard HR policy data |
| HV-B5 Health Hazard | Developer | Architecture Framework | 7 | Defines standard health and safety data manning |

| | | | | |
|---|---|---|---|---|
| | | Product | | levels |
| HV-B6 Human Characteristics | Developer | Architecture Framework Product | 7 | This view may be incorporated with in HV |
| HV-C Human Tasks | Developer | Architecture Framework Product | 8 | Defines specific tasks for all roles |
| HV-D Human Roles | Developer | Architecture Framework Product | 8 | Defines all roles with the Organisation |
| HV-E Human Networks | Developer | Architecture Framework Product | 8 | Provides an alternate view to the standards organisation structure |
| HV-F Training | Developer | Architecture Framework Product | TDB | Under development |
| UC-1 Operator Absent | Operator | Use Case | 8 | Reliability of operator absence detection confirmed in evaluation (≥ 97%) |
| UC-2 Operator Idle | Operator | Use Case | 6 | Implemented, reliability not yet evaluated |
| UC-3 Operator Tired | Operator | Use Case | 8 | Reliability of fatigue detection evaluated, algorithms need more fine-tuning |
| UC-4 Behavioural Patterns | Operator | Use Case | 7 | Change from hard-coded rule testing to employing MTT KNIME, UI tested, will be improved |
| UC-5 Load Balancing | Operator | Use Case | 8 | Algorithms implemented, not yet evaluated; exploitation feedback calls for additional variables for computation of individual workload |
| UC-6 Training | Operator | Use Case | 7 | Algorithms implemented, not yet evaluated; exploitation feedback calls for additional variables for computation to be taken into account for the model |
| Eye Tracker | Hardware | AdCoS | 8 | Used for UC-3 and 4 |
| Motion Sensor | Hardware | AdCoS | 8 | Used for UC-1,2 and 4 |
| Actuator Watch | Hardware | AdCoS | 8 | Used for UC-1,2 and 3 |
| Load Balancing | Developer | Software | 9 | Used for UC-5 |
| Focus Groups | Evaluation | Method | 8 | Evaluation of Use Cases |
| Usability Questionnaires | Evaluation | Method | 8 | Evaluation of Use Cases |

| | | | | |
|---|---|---|---|---|
| Experiments | Evaluation | Method | 8 | Evaluation of Use Cases |
| Observations (with subjects) | Evaluation | Method | 8 | Evaluation of Use Cases |
| Observations (without subjects) | Evaluation | Method | 8 | Evaluation of Use Cases |
| Task Analysis | Developer | Method | 8 | Used to develop the operational need for the Use Case development and gain an operational understanding of how to integrate within the AdCoS, derived from the Airbus DS Generic C2 Baseline |
| Architecture Framework (DoDAF) | Developer | Method / Framework | 7 | Used to expand and develop the Use Cases, the AdCoS and the Human Views |
| Human System Integration (HSI) | Developer | Method | 9 | Used as the overarching method to integrate Humans into the System Engineering lifecycle and the development of the Airbus DS AdCoS |
| Human Views | Developer | Method /Framework | 9 | Development of Human View extensions to the Architecture Framework (KPI 8.1 and 8.2) |

## 4.2 Evaluation of the Iren AdCoS

### 4.2.1 Evaluation of the PIs

The aim of the AdCoS developed in HoliDes was to support the operators in the selection of the most suitable technician for the gas service (i.e. the most critical service), in order to:

1. **Minimize the time to reach the place of the intervention;**
2. **Reduce the number of times the operator selects the wrong technician** (i.e. when the selected technician is busy and/or too far from the intervention and then he rejects the assignment and passes it to another technician);
3. **Minimize the out of SLA** (i.e. % of times the technician does not reached the place of the intervention in 1 hour);
4. **Increase usability and acceptability** (and, as a consequence, the trust in the solution).

We conducted a **5-day experiment with real operators and technicians** to monitor **18 real emergency calls** and use the corresponding data to measure 4 objective performance indicators (PIs) of the Control Room with and without the AdCoS (i.e. baseline). We also asked the operators and technicians involved in the experiment to answer a **questionnaire (i.e. SUS)** to measure the usability of the overall system (i.e. a subjective performance indicator).

**Table 8: Evaluation of the Energy Control Room AdCoS**

| Performance Indicator (PI) | Baseline | AdCoS |
|---|---|---|
| Average time to reach the place of the intervention | **38 minutes** | **24 minutes**<br>(reduction of 36%) |
| # of times the operator selected a wrong technician | **5 out of 18** (27.8%) | **0 of out of 18** (0%)<br>The AdCoS always selected the technician that actually performed the intervention |
| % of out of SLA | **1 out of 18** (5.6%)<br>The Italian Energy Authority regulates it must not exceed 5%! | **0 of out of 18** (0%)<br>With the AdCoS, the Control Room could always guarantee the SLA with the Italian Energy Authority. |
| Usability and acceptability (SUS score from 0 to 100) | **32,5** (out of 100)<br>The existing system (i.e. the baseline) was considered as not usable. | **76,5** (out of 100)<br>The improvement on usability was significant! |

These PIs highlight the benefits of the HoliDes approach for the Control Room. By developing a new **adaptive system** (i.e. the AdCoS) that takes into consideration the **real position of the technicians** as well as their **actual activities in the field**, we could achieve relevant (measurable) benefits for the Control Room, mainly in terms of **efficiency of the Control Room** and **safety for the general public** that notified the gas emergency (due to the reduction of time for the critical interventions).

### 4.2.2 Evaluation of the KPIs

As described in details in D8.9, REL develops prototype solutions NOT products. Since every prototype is a sort of unique piece of SW and HW, we rarely have recurring costs (RC) - almost all our costs are not recurring costs (NRC), mainly due to personnel costs. Moreover, the value proposition of REL depends on its flexibility and ability to rapidly prototyping HMI concepts: therefore we often sacrifice the quality of the solution to deliver it in a very short time (to meet our customer's requirements and show that an innovative solution is feasible).
Therefore, an MTT that supports us by improving the quality of our prototype solution without increasing the delivery time (yet even with a limited increase of cost) is more than welcomed because it provides a great value for our customers (and then for our company).
As shown in Figure 19 and graphically represented in Figure 20, the MTTs developed in HoliDes and used in the development process of the Energy Control Room AdCoS allowed a reduction of almost 30% of the time for the development and 12,5% of the overall costs. They also led to an increase of the personnel involved in the activities (in terms of different skills required in the development process), because new experts were involved. However, this factor has a clear benefit in the overall quality of the AdCoS: in fact, during the empirical evaluation we could measure a great improvement of the PIs (e.g. reduction of 36% of the average time to get the place of the intervention with the AdCoS), as described in details in D8.9.

| **Baseline Overall** | | **Overall 1b** | |
|---|---|---|---|
| time (MM) | 20,5 | time (MM) | 14,5 |
| resources | 14 | resources | 16 |
| cost RC (Euro) | 0 | cost RC (Euro) | 0 |
| cost NRC (Euro) | 100000 | cost NRC (Euro) | 87500 |

| **Overall-Savings** | | % reduction |
|---|---|---|
| **time (MM)** | **6** | 29,27 |
| **resources** | **-2** | -14,29 |
| **cost RC (Euro)** | **0** | 0 |
| **cost NRC (Euro)** | **12500** | 12,5 |

**Figure 19: Overall savings of Energy Control Room AdCoS**

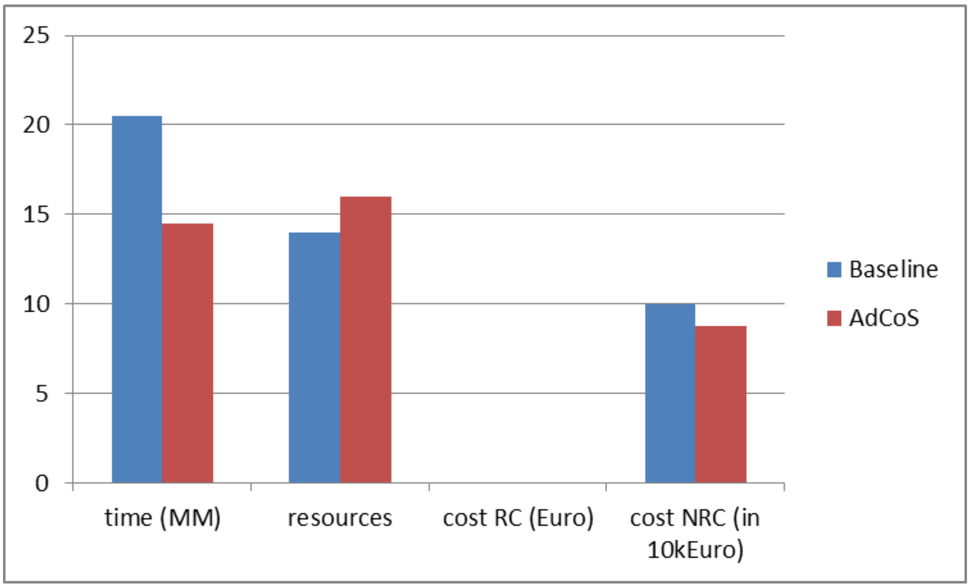



**Figure 20: graphical representation of the overall savings of Control Room AdCoS**

# 5 Summary and conclusion

Both control room AdCoS have been completed to a level of detail that facilitates further dissemination and exploitation. All functionalities are actually implemented (as opposed to be simulated, as in earlier stages of the project). The Airbus AdCoS will be replicated in a customer demonstration lab for presentation to potential customers; the Iren AdCoS will be put to productive operation in the months following the end of the project.

The benefits of choosing the HoliDes approach of designing and developing AdCoS with an HF-RTP based on project MTT could be clearly demonstrated. In addition, using an AdCoS-type adaptation also benefits the organisations using the technology through increased effectiveness and efficiency of the control room operation.

# ANNEX I – GREAT SPN SIMULATION

The efficiency of the management of intervention of IREN network in terms of task assignment to the most suitable technician in order to save time and resources was validated through a simulation by a Petri network in collaboration with the University of Turin. The aim of this simulation was to verify that the managing of interventions by the AdCoS allows to be compliant with the quality standards of the Italian Authorities for energy distribution. The results of this activities provide important feedbacks for the improvement of the design of the final prototype.

In particular the objectives of the study were 1) to get insight into the old and new policies for assigning technicians to incoming calls at IREN control room and 2) to evaluate the rate of incoming calls (in number of calls per hour or day) that can be dealt with by IREN without violating the SLA requirement of 1 hour limit between the time of the call and the time the technician arrives at the calling site, for the 95% of the calls. This time limit is a requirement of the National Energy Authority. The analysis was conducted with reference to varying load, in terms of the inter-arrival time of the incoming calls.

The KPI evaluated are therefore the "Average time for arrival" e "% out of SLA", as defined in Table 13 of Deliverable D8.9. Moreover, we have studied the overall performance of the system by plotting the number of idle operators with respect to various input rate of the incoming calls at the control room.

The study has been conducted using model-based analysis techniques. All models are Coloured Petri net models and they have been drawn on the graphical interface of GreatSPN and all results have been obtained using either an exact numerical solver or a MonteCarlo simulator for coloured nets.

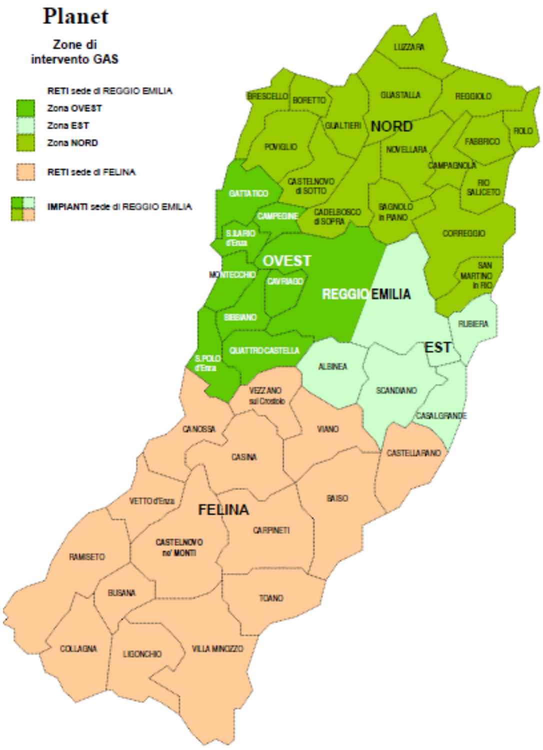



**Figure 21: The subzones of Reggio Emilia zone**

**Study of the overall behaviour**. A coloured stochastic Petri net model has been used to study the new policy for task assignment to technicians and the amount of load that can be dealt with by the system. Since we do not yet compute specific clients indicators (like the time it takes for completing a call of a specific client), the model depicted in XXX does not include the identity of the clients.

We have studied the behaviour of the new assignment schema under stressing conditions using numerical analysis techniques, with the goal of evaluating the given KPI. As a first attempt we have considered as basic positioning the zones (not the municipalities), so the position of a call and of a technician is identified by class Z which is organized in 4 subclasses (Nord, Est, Ovest and Felina), namely the four zones and each subclass has a single fictitious municipality, of name equal to the name of the zone. Since the analysis is performed in a situation of high load that stresses the system, a number of considerations allow to simplify the model.

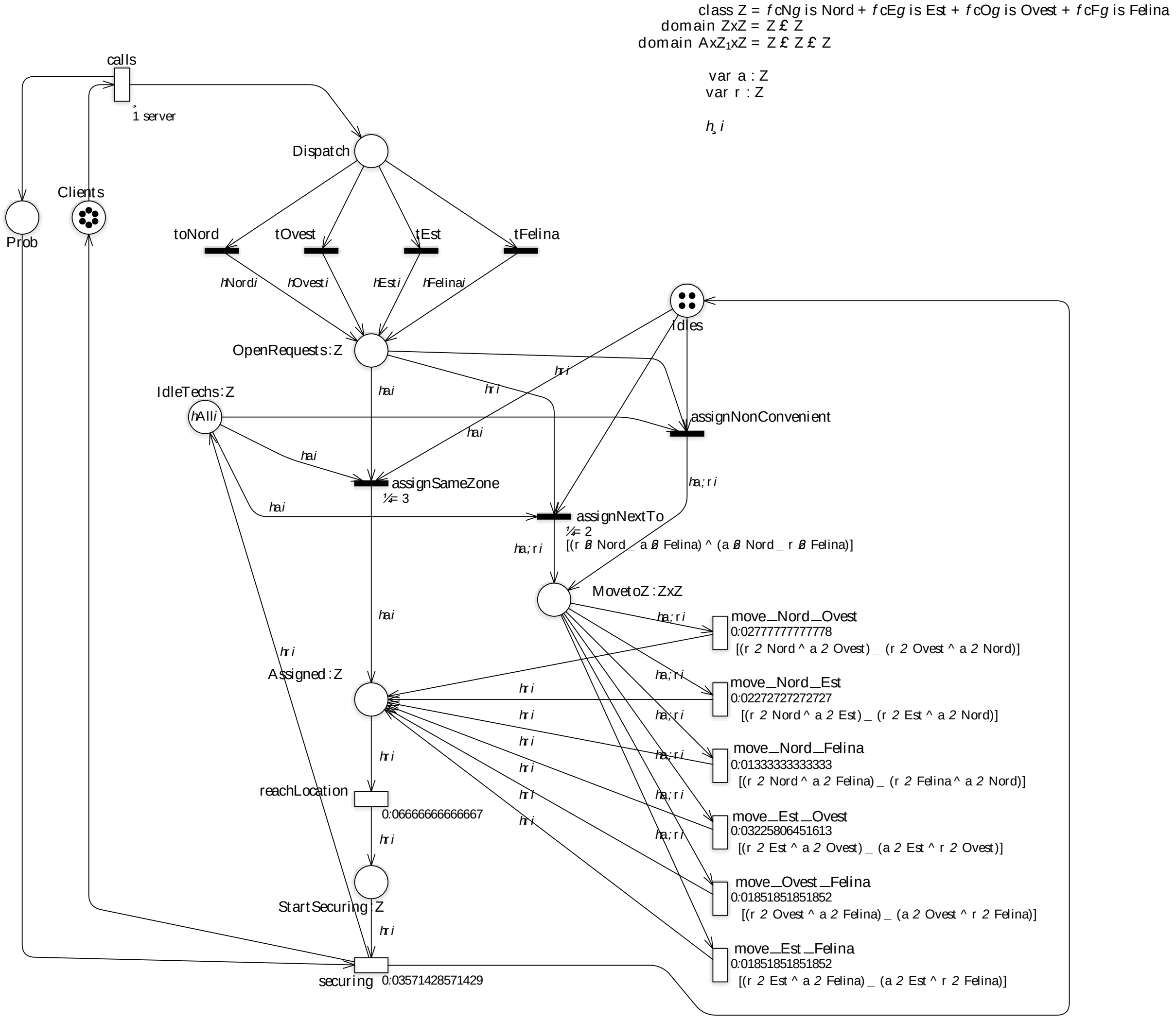



**Figure 22: SWN model of the technician assignment (no client identification)**

In the model all transitions corresponds to either an exponentially distributed delay (timed transitions - white boxes in the drawing of the net) of rate equal to the value or parameter indicated next to the transition or to a choice that takes no time (immediate transitions - thin bars in the drawing of the net). When more than one immediate transition is enabled the choice may depend on priorities (a transition of priority *n* is indicated by the text $\pi=n$ in the net, by default $\pi=1$ ) or on an associated probability distribution. The choice among the transitions that assign the technicians depend on priorities that implements the given policy, while the choice of the zone of an incoming call (the four transitions out of place *Dispatch*) depend on a probability distribution. Since no explicit probabilities are associated to the transition the four cases are considered equally probable.

The assignment of calls to technicians is based on the distance from the current zone of the technician to the zone of the call. This policy is modelled through three transitions of decreasing priorities: first of all the system assigns a technician who is already in the same zone (transition *assignSameZone*), then one who is in an adjacent zone, (transition *assignNextTo*), then one who is in a far-away zone (transition *assignNonConvenient*). The basic idea behind these set of transitions is that the only pairing that should be avoided is to assign to a technician who is currently in the Felina zone a call from the North zone and vice-versa. The delay associated to the travelling times among zones depends on the starting and ending zone, and it has been calculated taking a middle point in both zones and using google to determine the average displacement time. Note that certain delays are significant: to move from Nord to Felina the average delay is 75 minutes (already above the 60 minutes required by the authority), plus 15 minutes to reach the actual location inside the zone. In the luckiest case (the technician is already in the zone) it only requires an average of 15 minutes to reach the actual location inside the zone plus an average of 28 minutes the whole securing activity, as reported in Table 9.

**Table 9: Average delay inside and among zones**

| Transition Name | Average delay |
|---|---|
| **reachLocation** | 15 |
| **securing** | 28 |
| **MoveNordOvest** | 36 |
| **MoveNordEst** | 44 |
| **MoveNordFelina** | 75 |
| **MoveEstOvest** | 31 |
| **MoveOvestFelina** | 54 |
| **MoveEstFelina** | 54 |

The analysis of the control room model can provide an answer to quite diverse questions. The following graphs shows some data that highlights the behaviour of the system under different rates of the incoming calls, assuming there is initial one technician in each of the 4 zones.

Since the state space is finite and all transitions are either immediate of exponentially distributed, the net describes a Markovian system and GreatSPN can generate the underlying Continuous Time Markov Chain and numerically solve it in transient or steady state. The results below are results in steady state.

The first plot shows the probability of having all the 4 technicians idle (with no tasks assigned), and all occupied (all moving around and doing repairs) for different average times between subsequent client calls (different decreasing rates of transition *Calls* that corresponds to increasing values of the time between two successive calls). The greater the time between subsequent calls, the lighter is the overall number of repairs requested to the technicians. The probability of all 4 technicians being busy (not available since they are travelling or they are securing a location) is more than 90% when calls come in, in the average, every 10 minutes; the value decreases to zero when the average time between successive calls increases to more than an hour. For instance, when the client call is, on average, one every 60 minutes, the probability of finding all technicians occupied is about 16%.

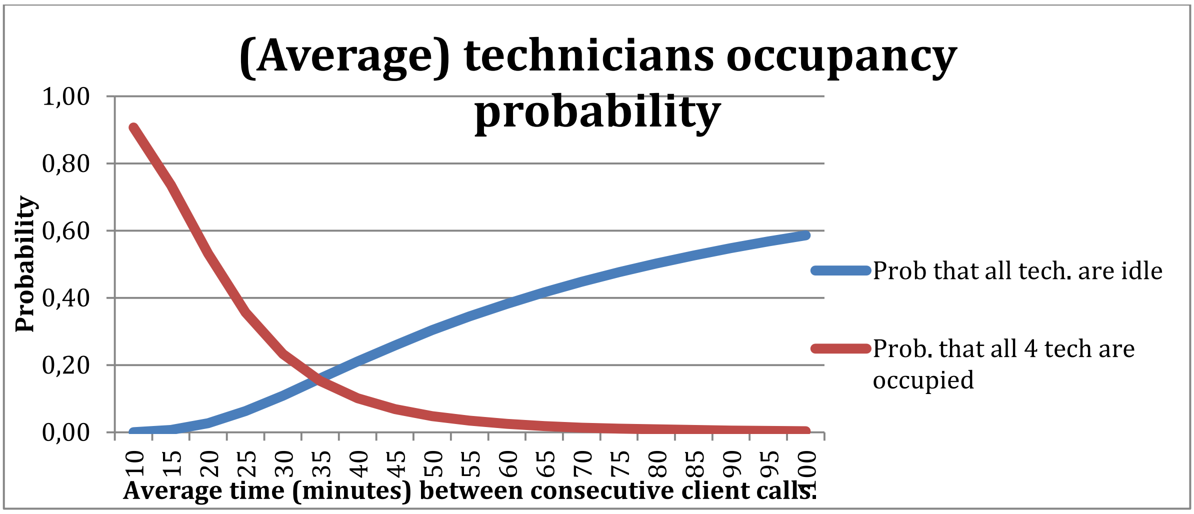



**Figure 23: Average technicians occupancy probability**

An important measure that is connected with the load of the system is the probability that a client calling will have his/her ticket assigned immediately (since at least a technician is free), or he/she has to wait in queue due to congestion. This is, intuitively, related to the rate of clients calling.

The earlier the clients call the control room to open a ticket, the more probable is that all technicians are already assigned to other pending jobs.

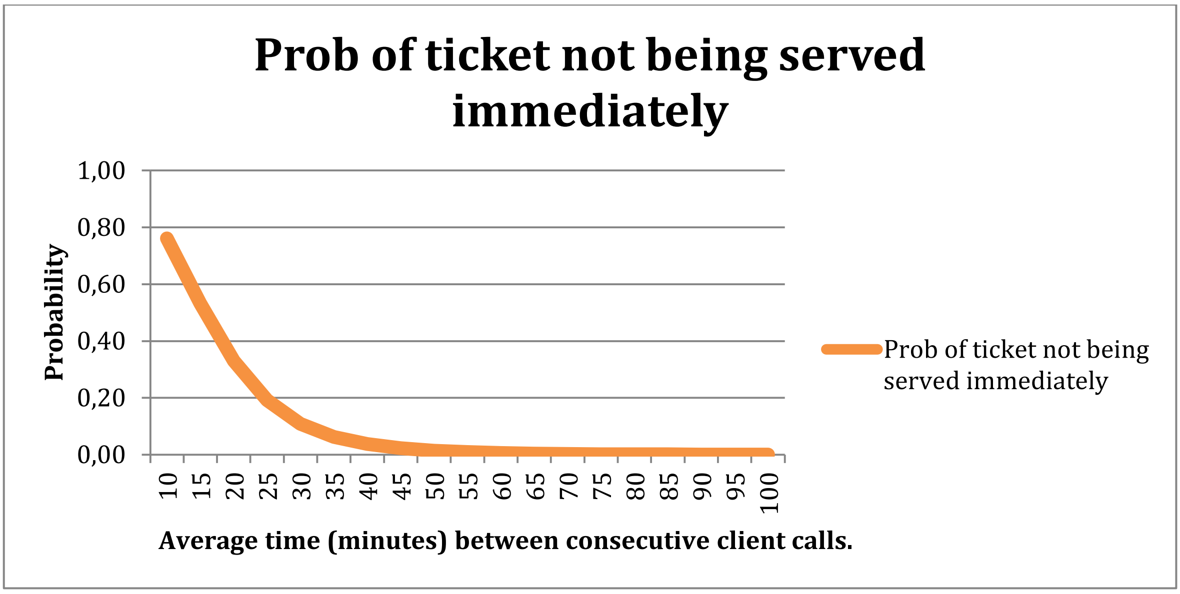



**Figure 24: Probability of ticket not being served immediately**

Figure 24 shows that the critical point that congestions the system is around a call inter-arrival time below 30/40 minutes between each call. If the call inter-arrival time is below this point, there is an increasing probability that the system will not be capable of serving all the requests with four technicians.

**KPI evaluation**. To be more specific we have to consider the time to completion of each single call to determine whether the AdCoS satisfies the authority requirement that 95% of calls should receive a technician within one hour. This is a measure that, in performance evaluation, is called "passage time" and whose computation requires that clients are identified. Moreover, to compute the percentage of calls that exceed the 60 minutes limit, a timeout of 60 minutes should be included in the system. Clearly a transition that models a timeout has a deterministic distribution and, as a consequence, the underlying process is not a CTMC any longer and numerical solution is not feasible. We have indeed used the stochastic simulator of GreatSPN to evaluate the required KPI.

The overall system load results from a combination of two factors: i.) the frequency of transitions Calls; ii.) the share of total time occupied by transition Calls. We assume an arrival rate lambda, meaning that there is an incoming call every 1/lambda minutes, if there is a client in the Client place. We have modelled the system as a closed model to be able to track the completion time of each client. The SWN is depicted in **Fehler! Verweisquelle konnte nicht gefunden werden.**, note that a new colour class *Cli* has been introduced (to identify the clients). Moreover the model now includes a mechanism to check whether the service time of a Client is longer than 60, based on a clock being set when a call comes in (deterministic transition Timeout of duration 60) and of two transitions: *securingTimeout* and *securingInTime*. *SecuringInTime* fires when the service at client x has finished and there is a token of identity x in place *ClientsWaiting*, meaning that the timeout of x has not expired yet, while *securingTimeout* fires when the service at client x has finished and there is a token of identity x in place *ClientsTimeout*, meaning that the timeout of x has already expired. The relative throughput of these two transitions is what indicates if the requirement of the authority is probabilistically fulfilled or not.

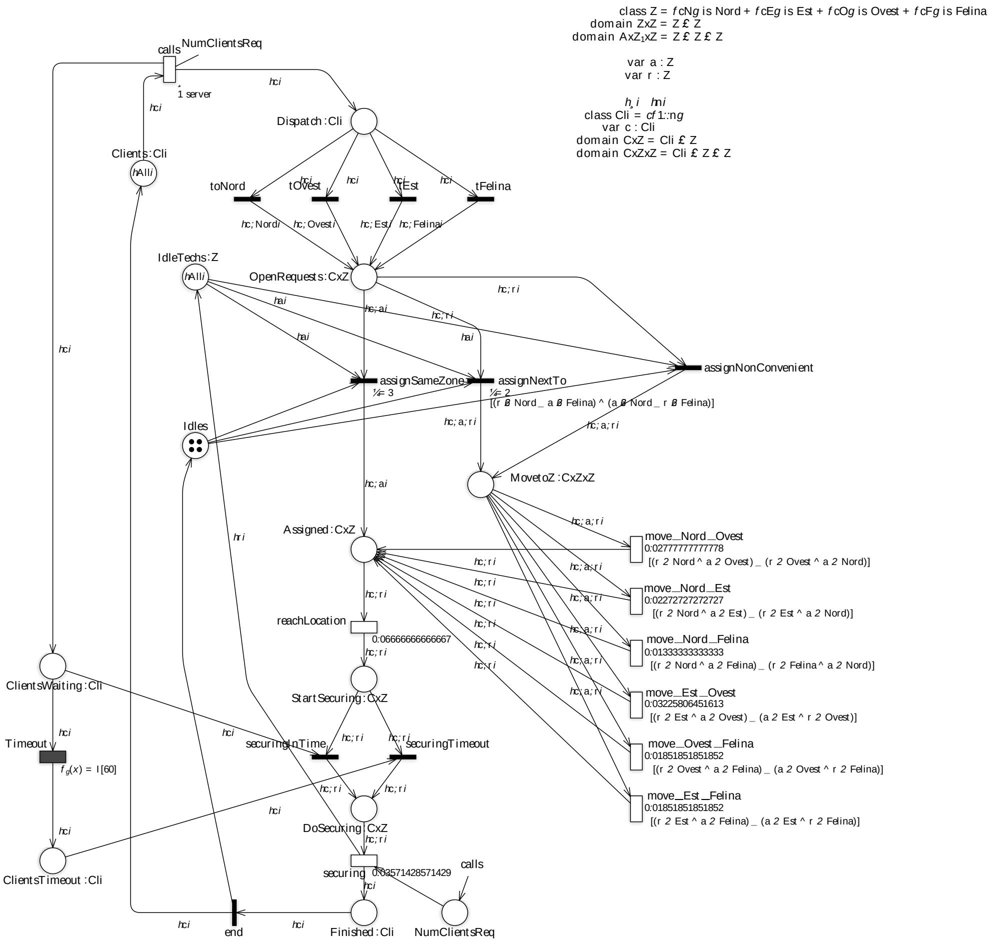



**Figure 25: Coloured net with Timeout used for simulation runs**

The major performance indicator, the percentage of calls that does not respect the SLA, is shown in Table 10 (column %TimeOut and complementary column %InTime) for varying values of the inter-arrival times of calls. These values are computed based on the throughput of transitions *securingTimeOut* and *securingInTime*. Results have been obtained using simulation, set with 5% accuracy and 95% confidence interval. The values reported in the table are the average values. Please recall that, if x is the average value, then the correct value falls, with 95% probability, within the confidence interval delimited by x - 5% of x and x + 5% of x.

The table also reports the mean number of idle technicians and the percentage of assignments to a technician that was already in the zone that originated the call (column %SameZone), or a zone next to the current position of the technician (column %NextTo) or to a faraway zone (column %NotConvenient). These percentage are also calculated from the throughput of the corresponding transitions in the net.

**Table 10: Simulation results accuracy 5%, Confidence 95%, for n=100 Clients globally**

| Interarrival time (min) | % Timeout | % InTime | average idle tech | %same zone | %nextTo | %Not convenient |
|---|---|---|---|---|---|---|
| 10 | 45.0 | 55.0 | 0.15 | 76.38 | 19.37 | 4.25 |
| 30 | 19.4 | 80.6 | 2.32 | 51.54 | 44.51 | 3.95 |
| 60 | 12.2 | 87.8 | 3.19 | 67.47 | 31.39 | 1.14 |
| 120 | 7.9 | 92.1 | 3.60 | 78.99 | 20.76 | 0.25 |
| 180 | 6.0 | 94.0 | 3.74 | 99.96 | 0.04 | 0.00 |

The results clearly indicates that the system can respect the SLA only for a mean interarrival time of more than 180 minutes among successive incoming calls. Note that, for an interarrival time of calls greater than 30 minutes, more than half of the operators are, in the average, idle and nevertheless the SLA is not respected, moreover the observation of the percentage of technicians assigned to the same zone indicates that almost all assignments should be local to stay within the SLA (where local means "the closest technician assigned by the AdCoS policy is already in the same zone").

The results have been obtained using exponential distributions for all transitions. Since the exponential distribution has a significant variance we have also performed a number of simulation experiments with distributions of lower variance, like the Erlang-n and even with deterministic one (that have zero variance) without observing a significant different trend.
Note that *these results may appear in contrast with the results of the experimental validation of the AdCoS*, but it is not necessarily so, since the

experimental validation was done on the Parma province, which has smaller distances among the zones. Moreover in the experiment most calls come from the same zone (the municipality of Parma), and therefore the probability that a technician is already in zone is very high.

The results for the Reggio area are not surprising if we consider the mean travelling times of Table 9 and if we remind that these are average times. A possible further investigation could be to generate calls proportional to the actual number of contracts per municipality (or to the municipality's population) and provide a finer localization of the technicians (not per zone but through the identification of subzones).

Since one of the objective of the analysis is to identify the number of technicians that ensure that the SLA are satisfied, we have performed an evaluation of the SLA for an increasing the number of technicians. Results are reported in Table 11, where the green colour highlights the values of the percentage of calls treated within 60 minutes, which are above 90%. Remember that the authority requirement is above 95%, but considering the precision of the simulation runs, also the values above 90% can lead to a satisfactory behaviour. These tables also allow identifying which is the level of charge to the system, in terms of time between successive calls, for which it is necessary to increase the number of technicians in the area. For example, when there are 4 technicians (one per zone), if the mean time between successive calls that require an intervention goes below the two hours, then there is a significant advantage in moving one technician from Parma area to the Reggio one.

Another data that is quite remarkable is that, when the SLA limit is satisfied, most of the technicians are idle. This is because, in the Reggio area, moving between zones can be very expensive, so it is important that, when a call comes in, there is an operator available in the zone. Note that in reality each intervention is made of two parts: a first part to put the site in secure mode and the second part to reactivate the service (gas distribution). The technician typically performs the second part only if there is no other emergency around. In our model we consider a stressing condition in which only the first part of the intervention takes place, so the interpretation of the average number of idle technicians should be actually interpreted as the percentage of technicians that are not travelling or working to put a site in secure mode.

**Table 11: Analysis for varying number of technicians**

| | Interarrival time (min) | % Timeout | % InTime | average idle tech | %same zone | %nextTo | %Not convenient |
|---|---|---|---|---|---|---|---|
| 4 technicians | 10 | 45.0 | 55.0 | 0.15 | 76.38 | 19.37 | 4.25 |
| | 30 | 19.4 | 80.6 | 2.32 | 51.54 | 44.51 | 3.95 |
| | 60 | 12.2 | 87.8 | 3.19 | 67.47 | 31.39 | 1.14 |
| | 120 | 7.9 | 92.1 | 3.60 | 78.99 | 20.76 | 0.25 |
| | 180 | 6.0 | 94.0 | 3.74 | 99.96 | 0.04 | 0.00 |
| | | | | | | | |
| 5 technicians | 10 | 36.6% | 63.4% | 0.35 | 48.32 | 46.55 | 5.13 |
| | 30 | 50.0% | 50.0% | 3.53 | 67.60 | 31.04 | 1.36 |
| | 60 | 8.5% | 91.5% | 4.28 | 81.17 | 18.62 | 0.20 |
| | 120 | 5.6% | 94.4% | 4.64 | 89.22 | 10.76 | 0.03 |
| | 180 | 4.5% | 95.5% | 4.76 | 92.42 | 7.57 | 0.01 |
| | | | | | | | |
| 6 technicians | 10 | 27.8% | 72.2% | 1.02 | 47.28 | 47.37 | 5.34 |
| | 30 | 8.9% | 91.1% | 4.70 | 80.25 | 19.43 | 0.32 |
| | 60 | 5.6% | 94.4% | 5.34 | 89.49 | 10.49 | 0.03 |
| | 120 | 3.8% | 96.2% | 5.66 | 94.51 | 5.49 | 0.00 |
| | 180 | | | | | | |
| | | | | | | | |
| 7 technicians | 10 | 19.7% | 80.3% | 2.81 | 56.78 | 39.67 | 3.55 |
| | 30 | 5.8% | 94.2% | 5.81 | 88.65 | 11.30 | 0.05 |
| | 60 | 3.7% | 96.3% | 6.37 | 94.72 | 5.27 | 0.00 |
| | 120 | | | | | | |
| | 180 | | | | | | |

# ANNEX II – Airbus DS Additional Results

## 1 MDG for EA

In order to create the human views in System Architect it was necessary to extend the application's meta-model in order to accommodate the concepts as defined by the NAF HV handbook: NAF Handbook

EA extensions are handled via the use of plug-ins known as MDG technologies: http://www.sparxsystems.com/resources/mdg_tech/

Many exist already which cover e.g. Sysml and DODAF but none for the human views. It is possible to create your own MDG and this approach was taken by Airbus in order to create the human views.

### 1.1 Components of an MDG

An MDG comprises 3 components: Element, diagrams and tool boxes. (Fig1) Each one is defined as a model in EA itself. Existing UML stereotypes such as classes and use cases can be used or new ones can be created.

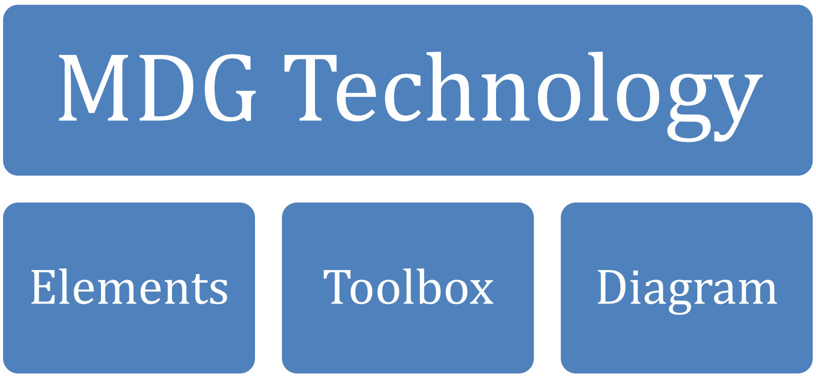



**Figure 26 - MDG components**

An element in EA is a single icon that can be created on a diagram in EA. For an element to exist, it must reside in a tool box hence a tool box must also be defined. The same applies for the tool box which must exist within the context of a diagram.

The next chapter shows the MDG models which were created in order to generate the human views in EA.

# 2 The HV MDG models

## 2.1 Shape scripting of elements

Some of the elements in section 2.1 required the use of shape script in order to define their appearance. The following figure shows an example of the code used to define the human operator in an HV A. Note, three options of human are permitted: RRC operator, Team Commander and enemy.

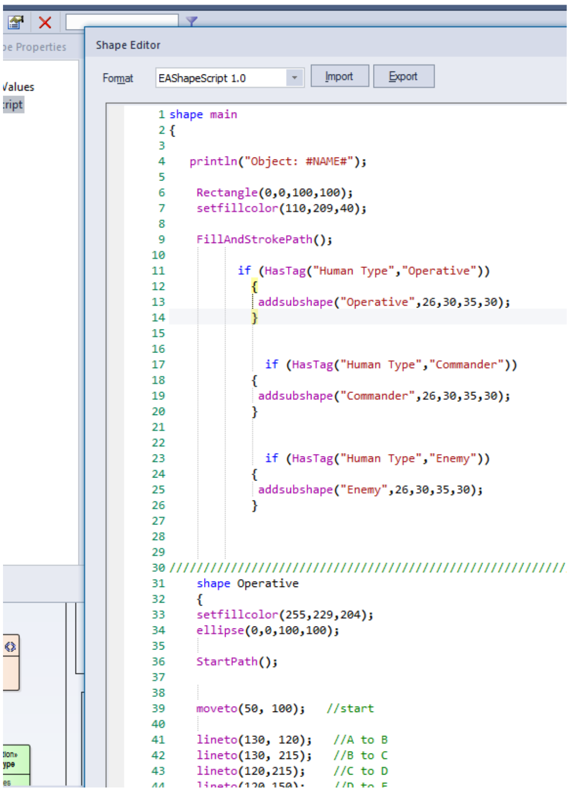



**Figure 27 - Example of the shape script code used to define the humans**

## 2.2 Elements for each of the HV Diagrams

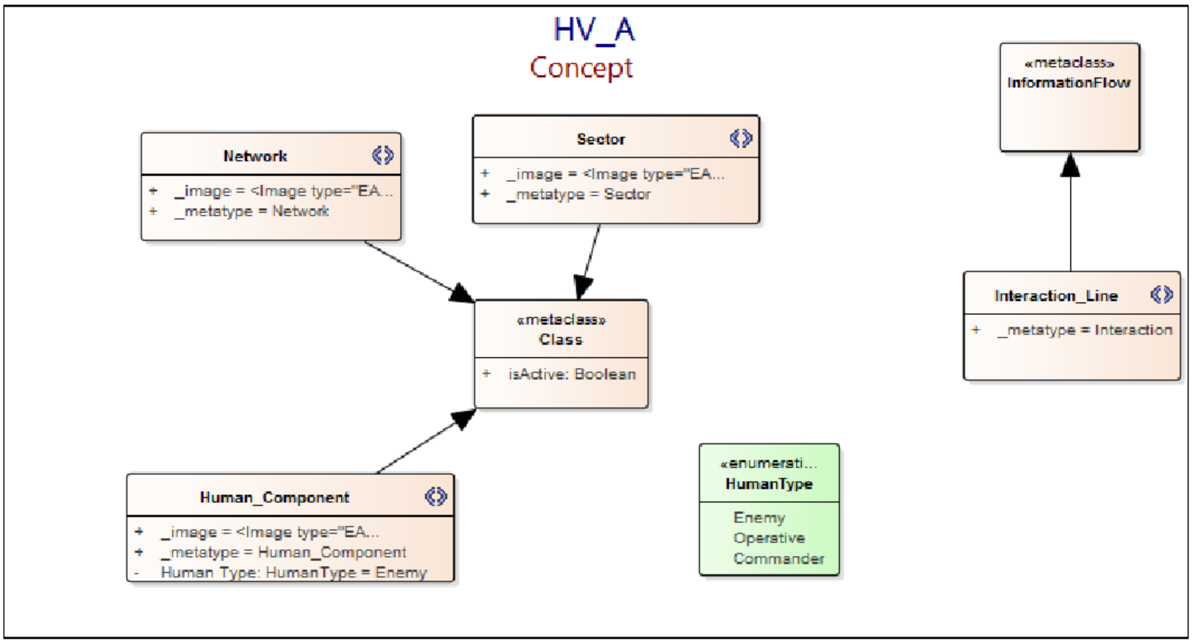



**Figure 28 - Elements in an HV A**

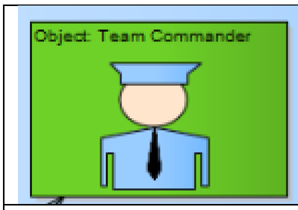
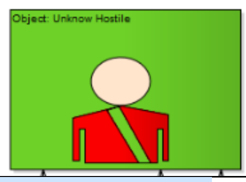
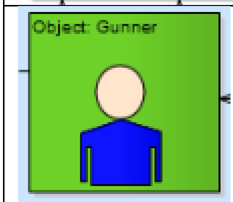
| | |
|---|---|
|   | Commander |
|   | Enemy |
|   | Operator |

**Figure 29 - Humans used in HV A**

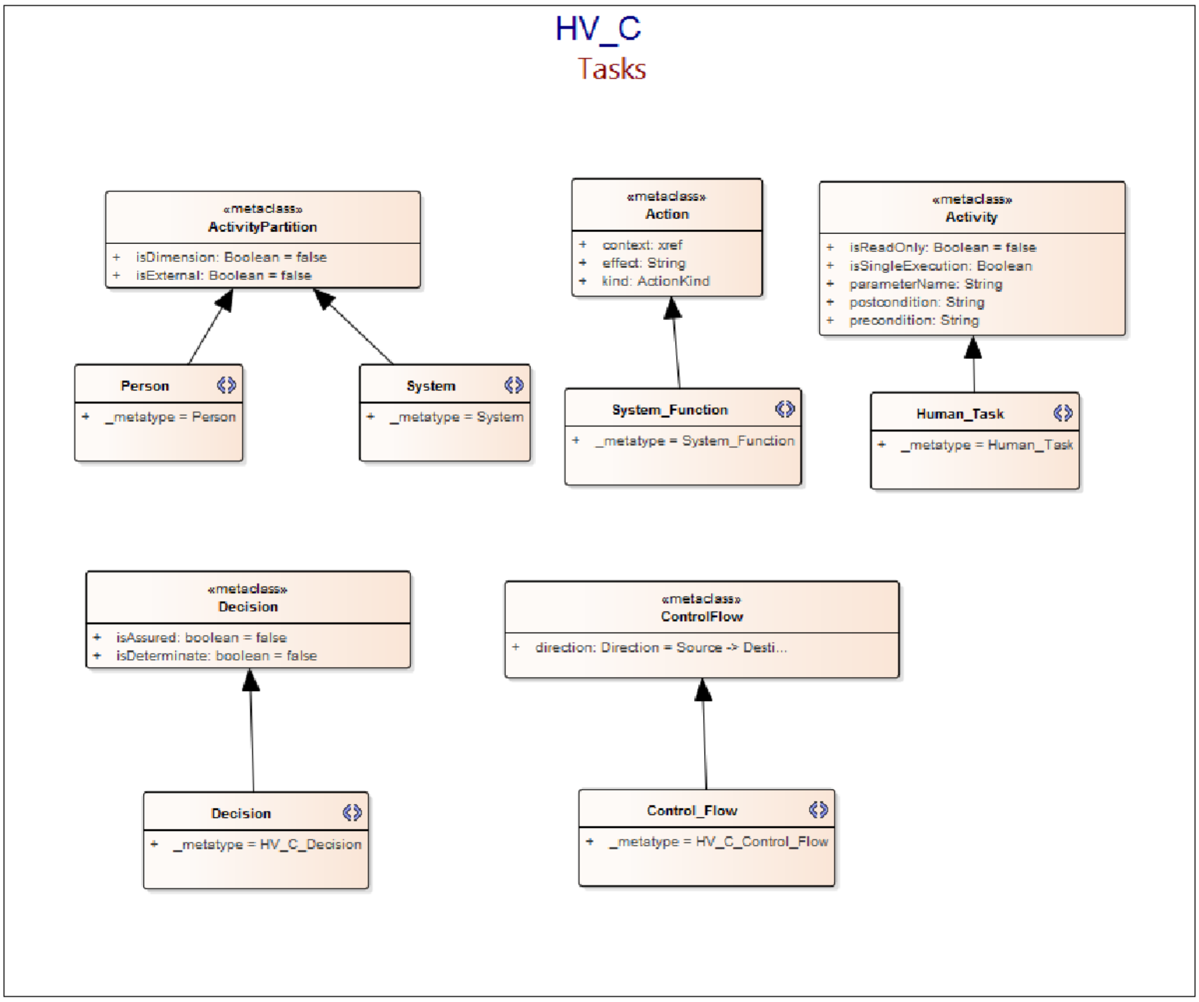



**Figure 30 - Elements used in HV C**

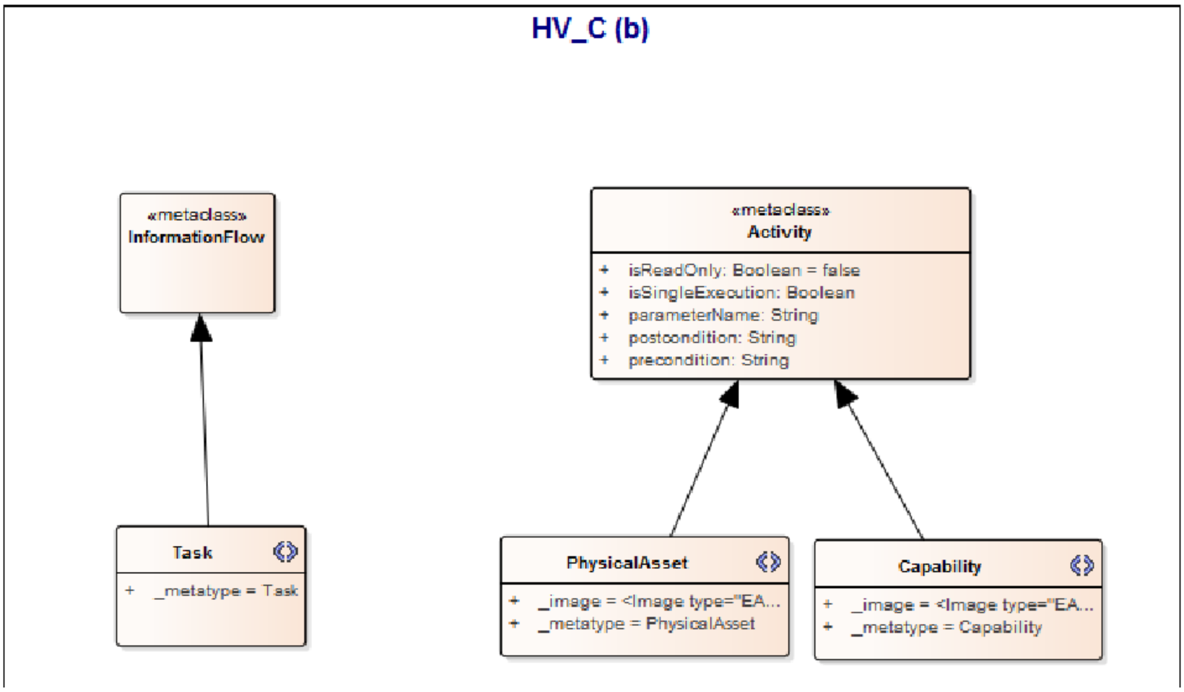



**Figure 31 - Elements for HV C (b)**

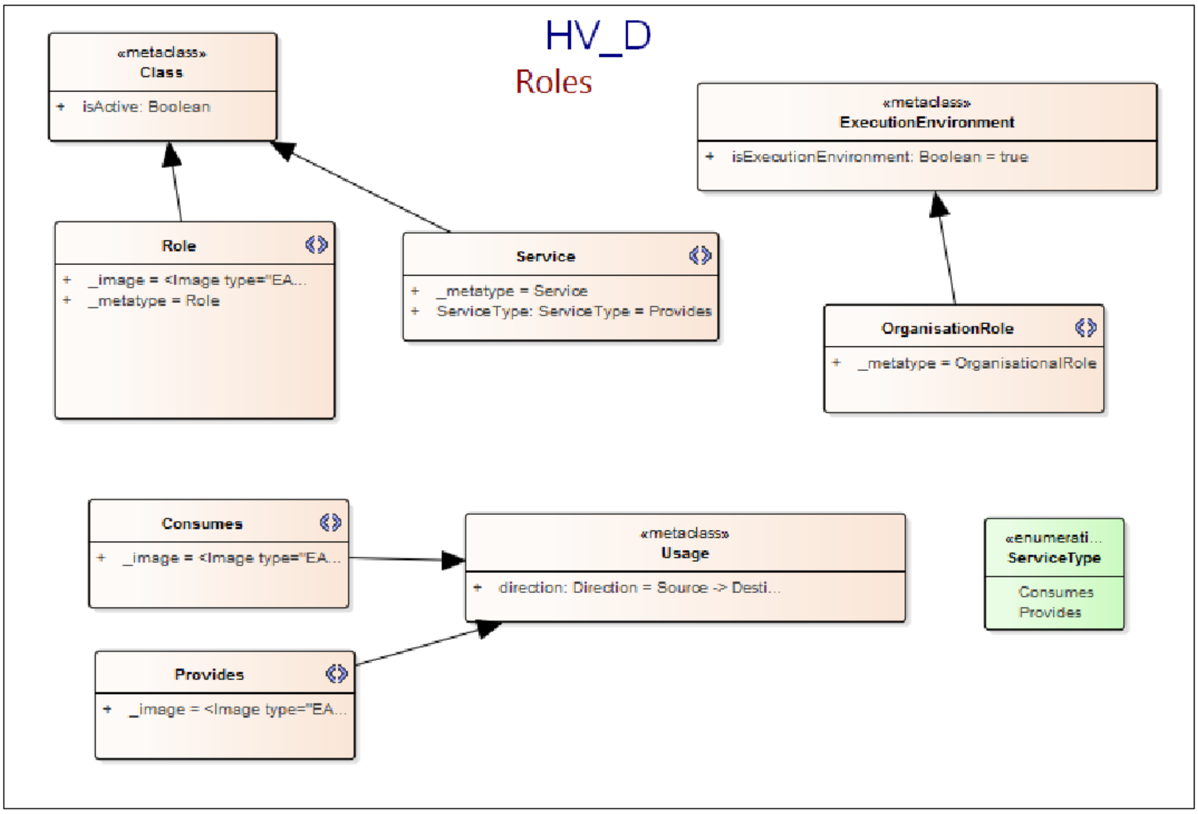



**Figure 32 - Elements used in HV D**

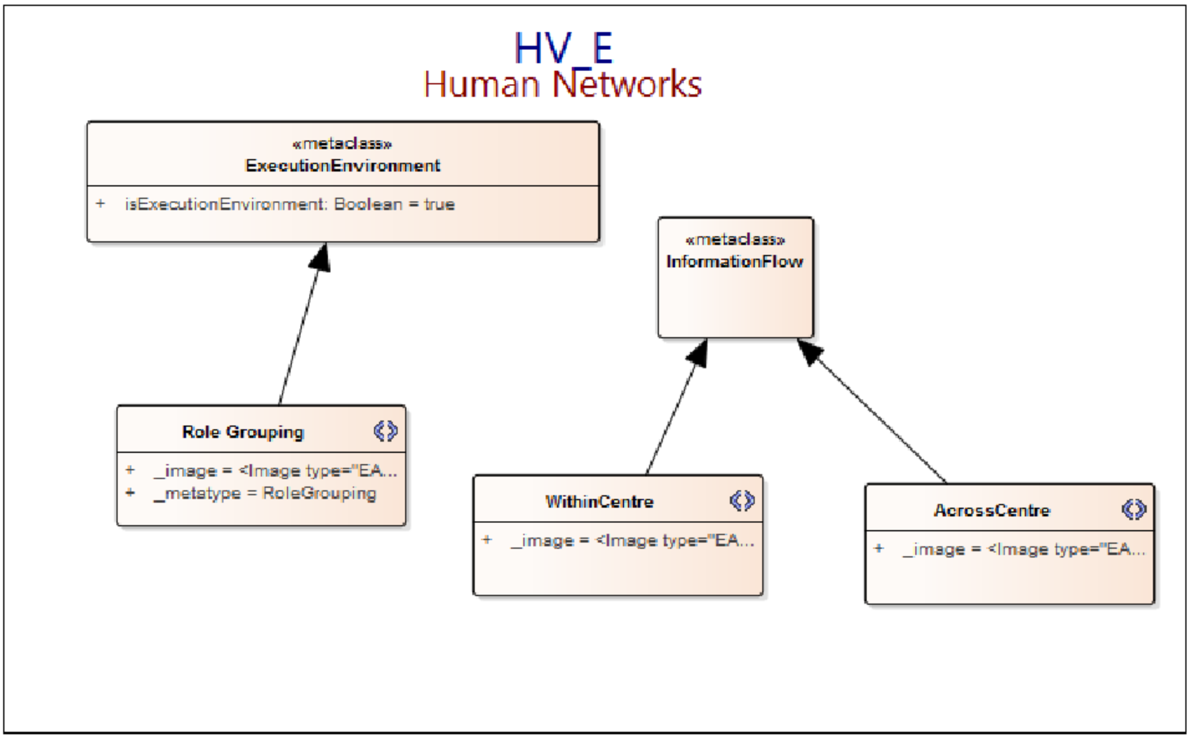



**Figure 33 - Elements used in HV E**

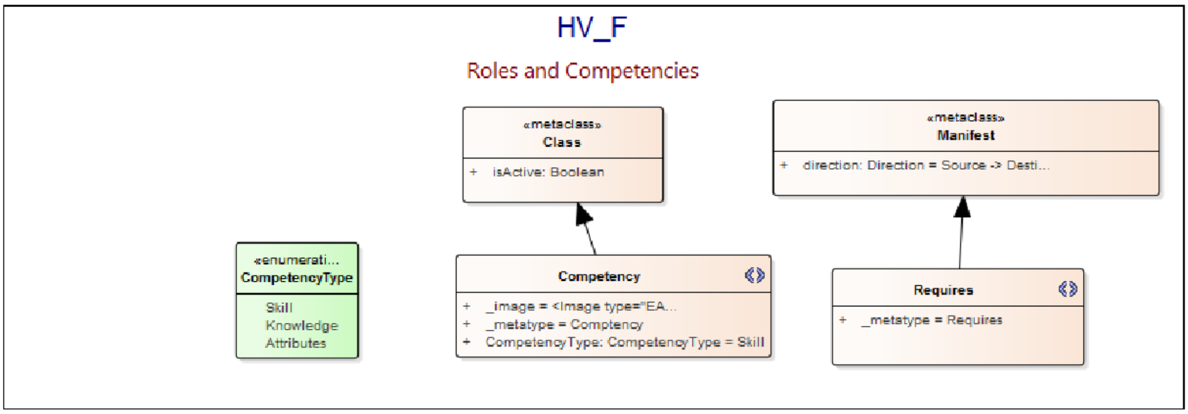



**Figure 34 - Elements used in HV E**

## 2.3 Tool box MDG models

The following toolboxes were defined in order to contain the elements defined in section 2.1

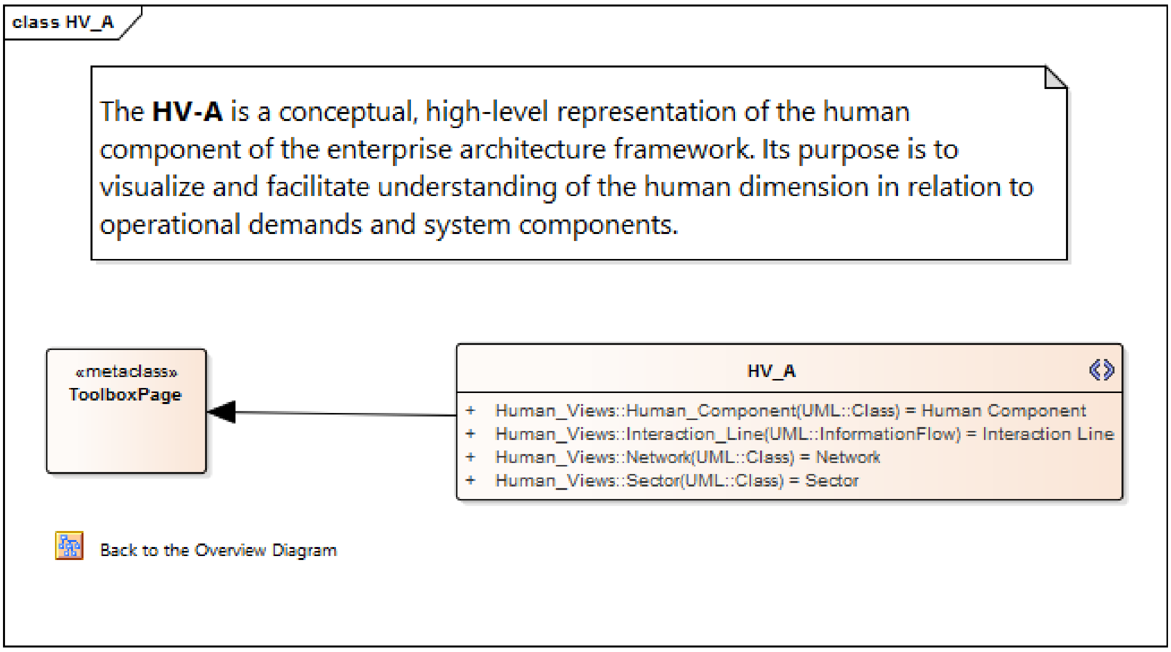



**Figure 35 - Toolbox for HV_A**

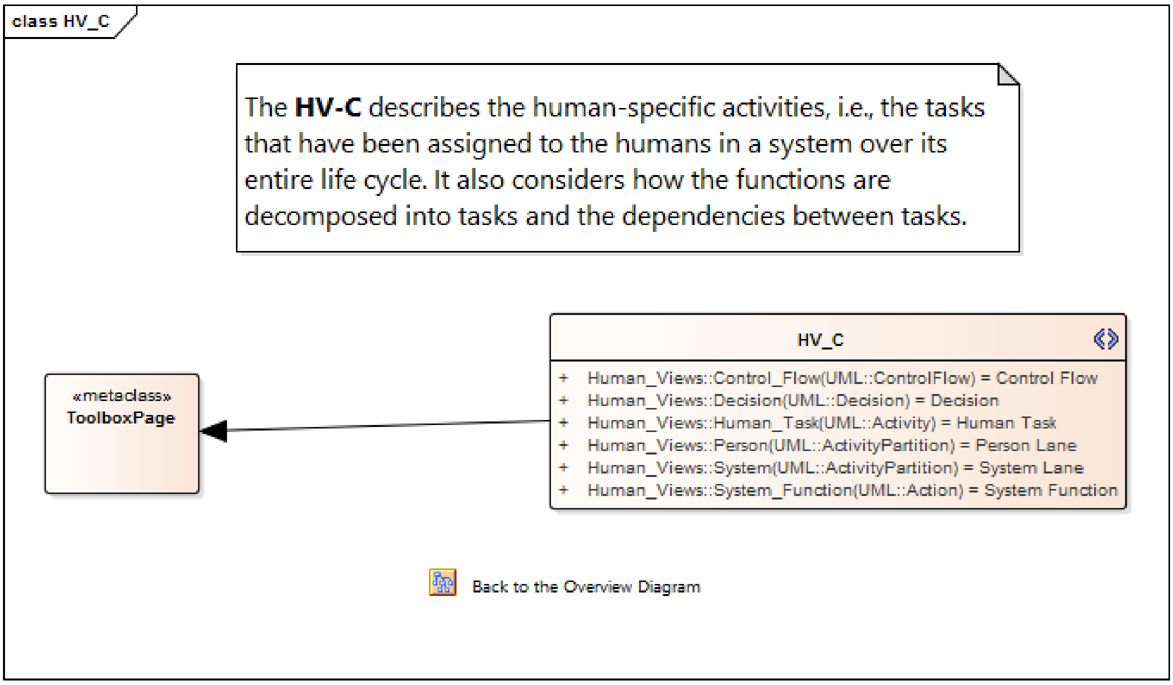



**Figure 36 - Toolbox for HV C**

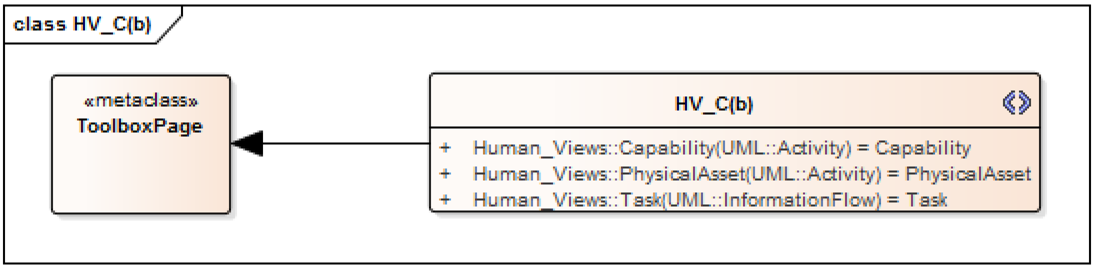



**Figure 37 – Toolbox for HV C(b)**

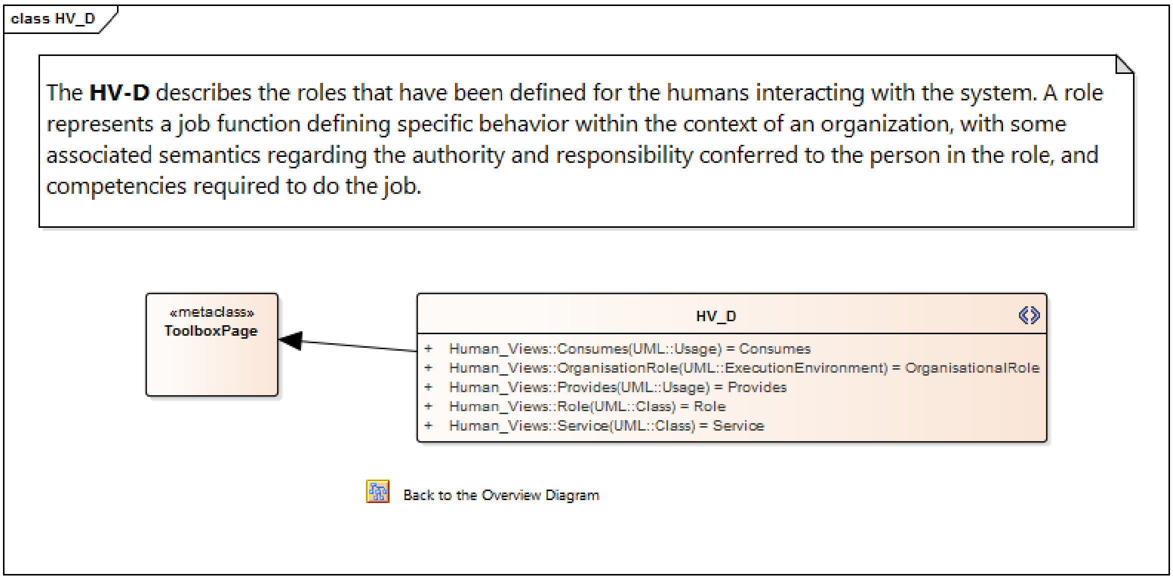



**Figure 38 - Toolbox for HV D**

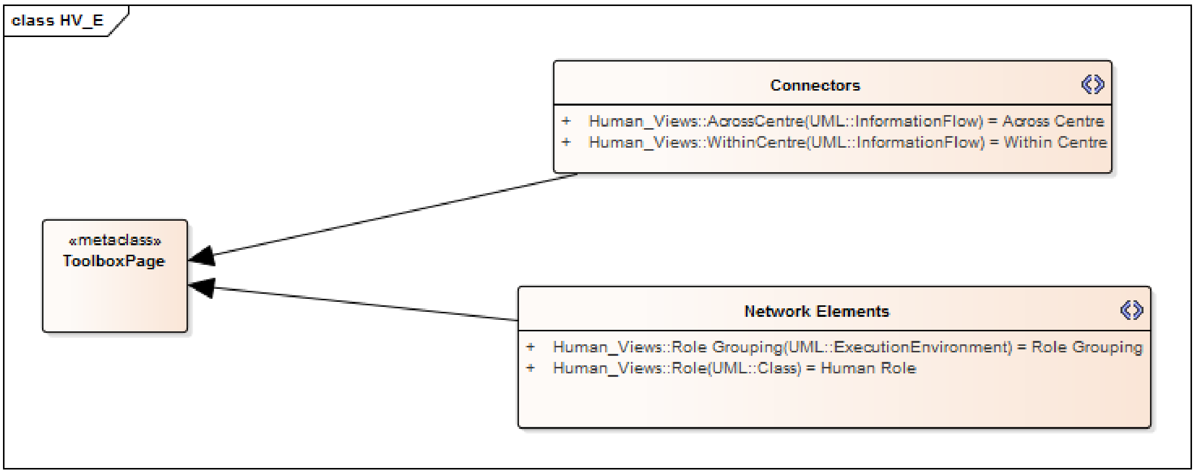



**Figure 39 - Toolbox for HV E**

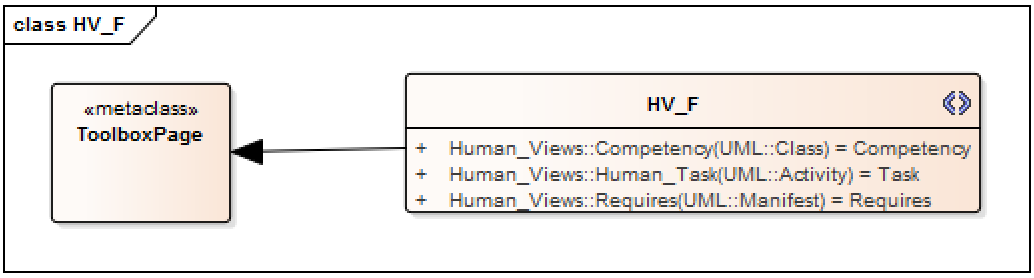



**Figure 40 - Toolbox for HV E**

## 2.4 Diagrams for the HV MDG

The following diagram shows how the toolboxes were assigned to the HV diagrams.

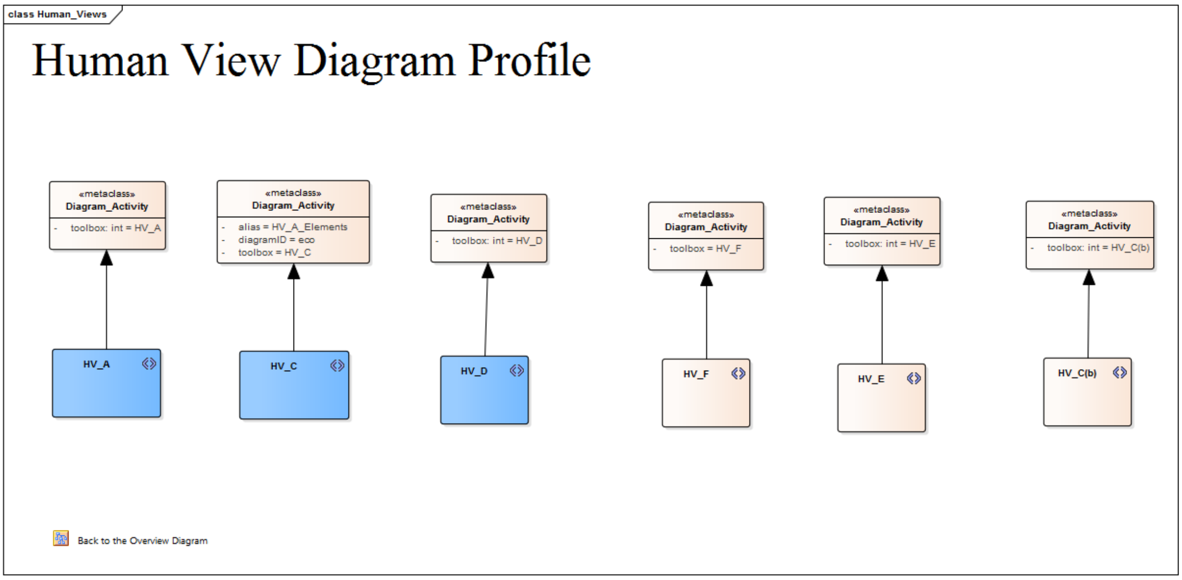



**Figure 41 - Mapping of the tool boxes to the diagrams**

# 3 Generating the MDG

With all of the diagrams and code from section 2 complete, it was then time to generate the MDG file.

The first stage is to save all diagrams as xml files:

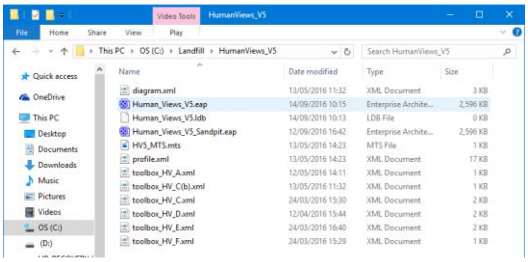


**Figure 42 - All diagrams saved as MDG files**

With the files saved, it's then possible to start the generation process. This is done via the EA tools menu and selecting "Generate MDG".

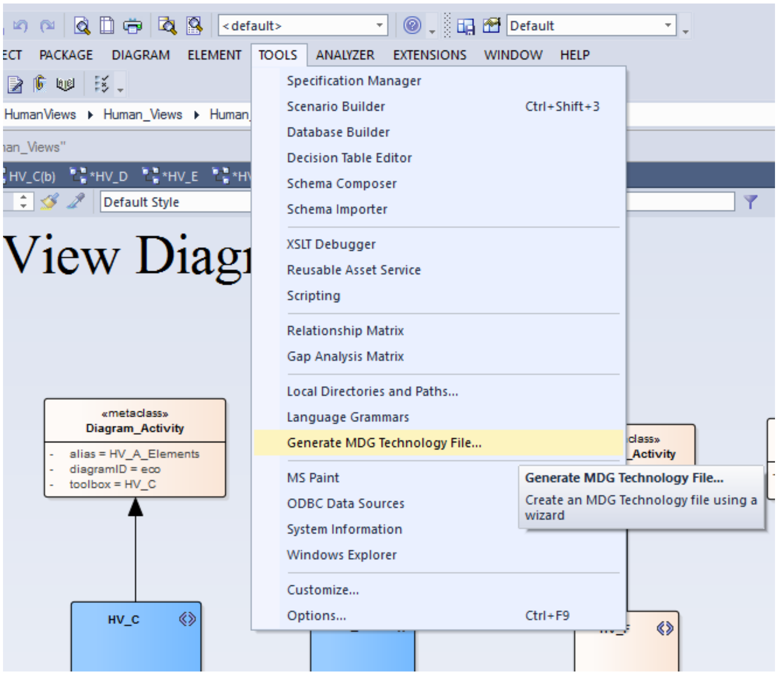



**Figure 43 - Generating the MDG**

A wizard ensues where by all of the XML profiles are selected. At the end of the process, an MDG file is produced.
This xml file can be distributed to enable other modellers in Airbus to endow the ability to model human views in EA.

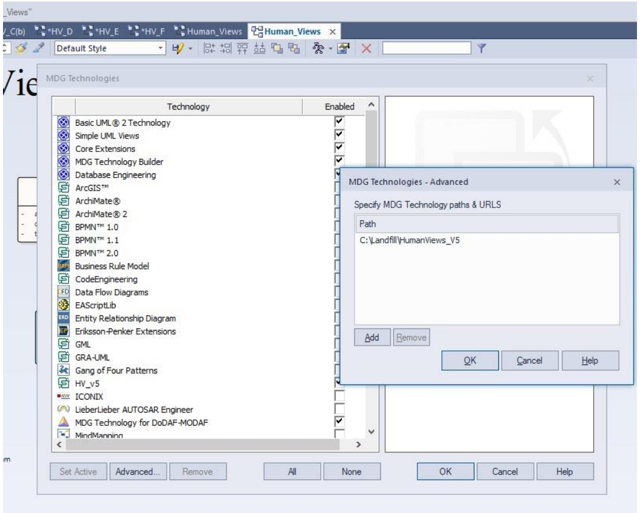



**Figure 44 - Importing the MDG into EA**

With the MDG successfully imported, the modeller now has the ability to create their own HV models.

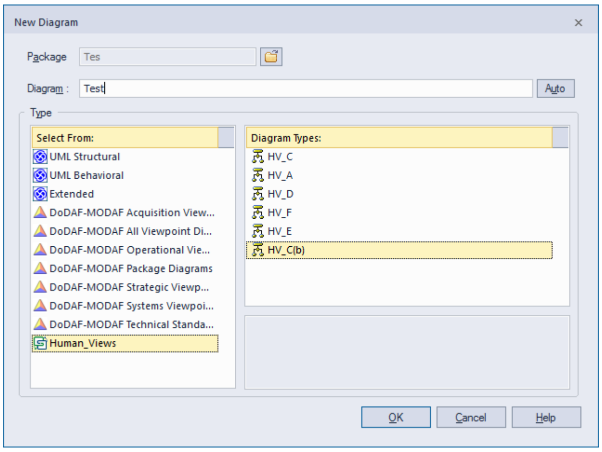



**Figure 45 - HV models now available in EA**

# 4 Example models created using the HV MDG

The following diagrams are examples of models created using the described HV MDG.

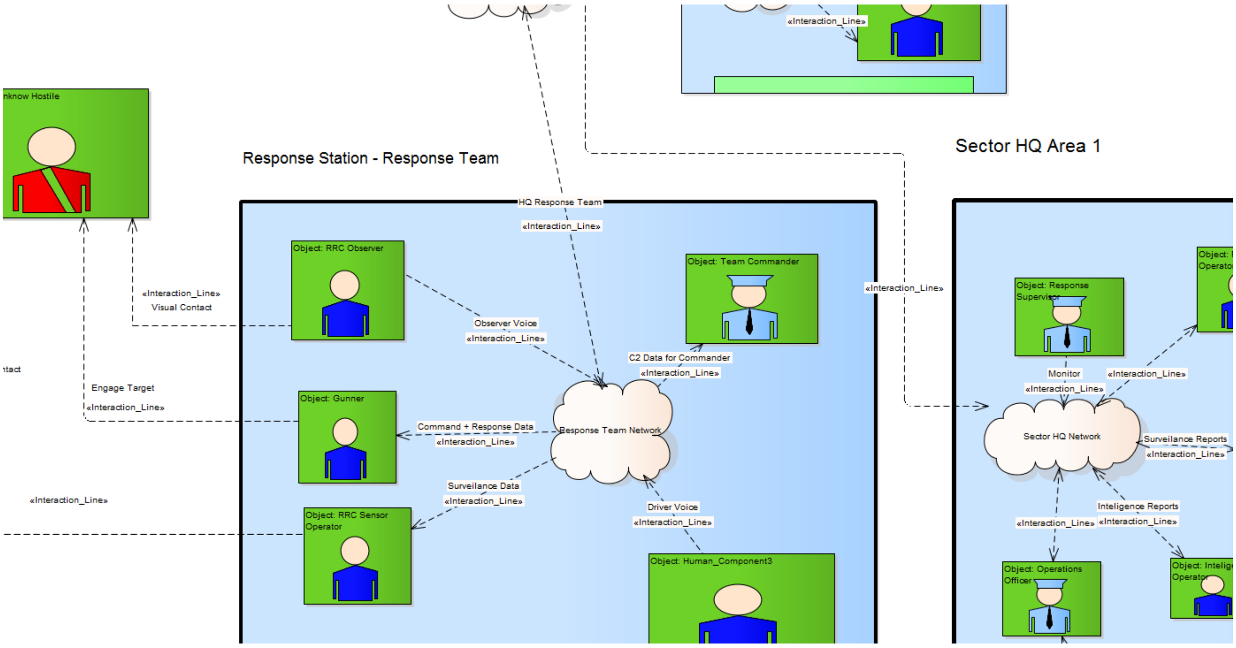



**Figure 46 - Part of an HV showing the interaction between human and IT infrastructure**

Figure 46 shows the operational graphic which depicts at a high level , the interactions between humans and physical IT systems.

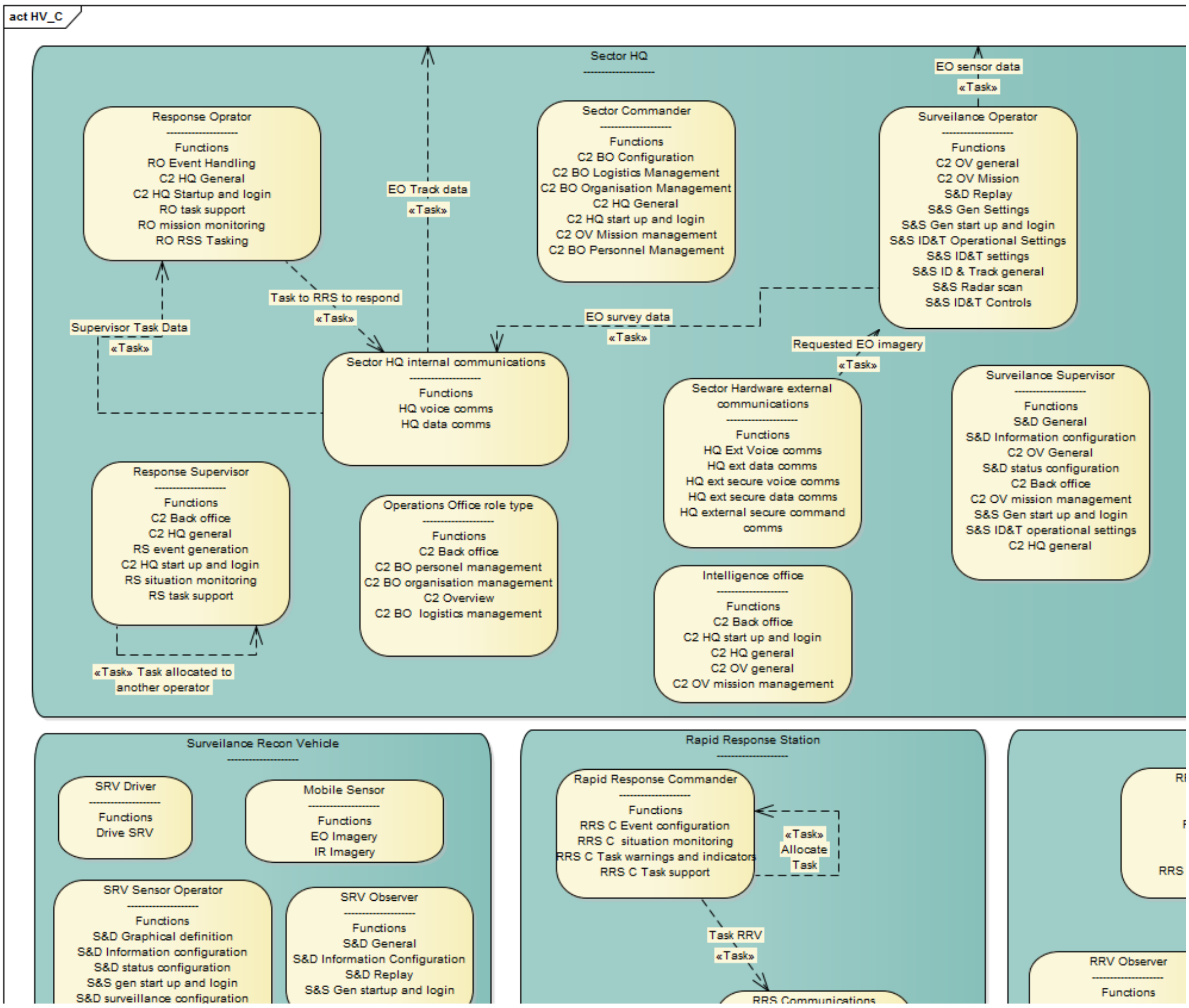



**Figure 47 - Example of HV C**

Figure 47 shows an example of an HV C. HV C diagrams are used to show which organisations need to communicate to fulfil the needs of a systems.

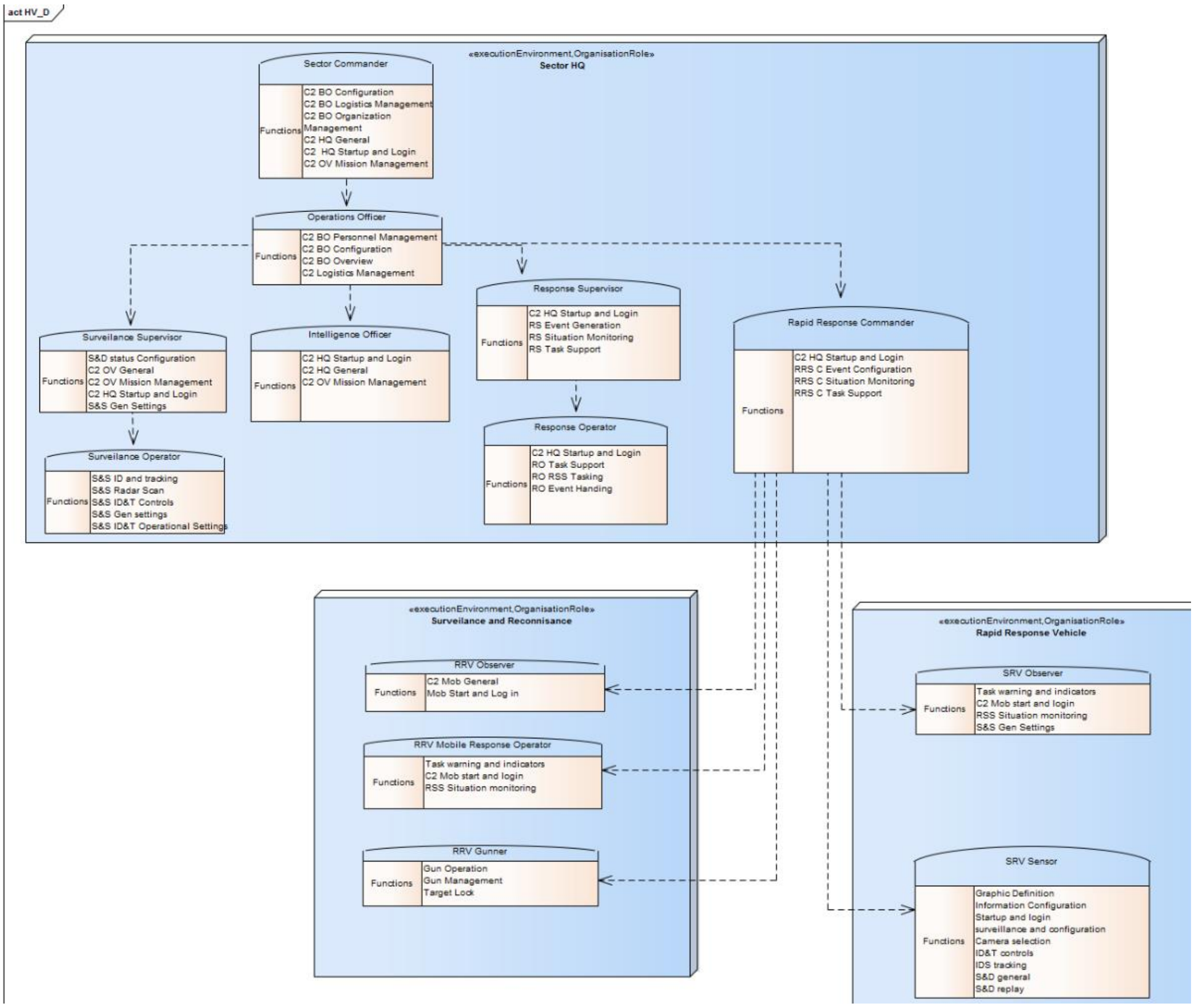



**Figure 48 - Example HV D**

Figure 48 shows an example of an HV D. HV D diagrams are used to depict the hierarchical breakdown of an organisation.