D4.1

Architecture Technical Specifications and Validation Criteria

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EXECUTIVE SUMMARY

The social simulation component of the TELL ME project (WP4) started in February 2013. This first report focusses on the architecture and validation process. However, other elements of the model design are also presented in their current form. This is to provide context as all design elements are tightly integrated. The next report (D4.2 due in February 2014) will describe the model design more fully, including revisions on all aspects included in this report. It is expected, however, that there will be only minor revisions to the architecture and validation.

The focus question for the TELL ME model is:

- Given a specific communication strategy, what proportion of the population is infected over the duration of the epidemic?

This question focusses the design requirements on the relationship between communication and total infected population, which provides for intermediate relationships with behaviour.

The simulation is to be developed in NetLogo, a specialist agent-based modelling application (see section 2.2). This will enable model users to input communication strategies and also to manipulate other parameters that are relevant for planning such as the country to be considered and the infectivity of the disease.

The TELL ME model will be assessed against four broad types of tests (see section 3):

- Utility: Does the model meet the requirements of the project?
- Face or conceptual validity: Are the model design and results consistent with theory and plausible?
- Verification: Is the design appropriately translated into model code?
- Empirical or operational validity: Do the model results match available data?

Aspects of this validation are to be conducted by different groups, with multiple assessment where possible. The four groups are the modellers (principally for technical testing), TELL ME project partners, other subject matter experts and health professional focus groups. The other subject matter experts include government and academic representatives with expertise in health communication, epidemiology management, risk behaviour and epidemic modelling.

1 Introduction

The TELL ME project aims to develop an evidence-based behavioural and communication package to respond to major epidemic outbreaks, notably flu pandemics. An agent-based model is to be developed as part of the project for use by agencies in assessing different strategies.

This report sets out the approach proposed for the model, focussing on the model architecture and the criteria that will eventually be used for validation. It also includes some elements of the model design, foreshadowing the complete software design to be described in report D4.2 (due 28 February 2014).

The specifications included in this report are not final. The architecture and design may change during model development. For example, the data needed to construct the model as envisaged may not be available. Therefore, this report should be interpreted as a statement of intent rather than a final description of the model.

1.1 Role of model in TELL ME

In the event of a flu outbreak, health agencies and other official bodies provide information about the progress of the epidemic and recommended actions to be undertaken by the public and particular groups who face greater risk. Recommended actions may include vaccination and protective behaviours such as washing hands and avoiding public places.

The TELL ME project is to assist health agencies to develop strategies to communicate before, during and after any infectious disease outbreak in an effective way, so as to encourage appropriate population behaviour and minimise the impact of an epidemic. There are two major tools to be developed: a communication kit and an agent-based model to assist with strategy design decisions.

The model is to provide decision support for health agencies (and other official information providers) by allowing a comparison of options for communication strategies.

1.2 Agent-Based Modelling

The modelling technique to be used for the TELL ME project is agent-based modelling (ABM). ABM “is a computational method that enables a researcher to create, analyse, and experiment with models composed of agents that interact within an environment.” (Abdou, Hamill, & Gilbert, 2012, p. 141). There are several important elements in this description.

Firstly, the model is composed of autonomous and heterogeneous agents. That is, there are many simulated individuals with different properties and decision making rules. In TELL ME for example, properties include geographic location and access to media, and rules include epidemic prevalence at which the individual will seek vaccination.

Secondly, these agents interact within an environment. That is, the individuals are able to perceive the situation in which they find themselves, take that situation into account in their decisions and take actions that affect the environment. Continuing the example, the individuals are able to perceive the epidemic prevalence in their location and receive media reports, which allows them to check their ‘seek vaccination’ rule and assess whether the epidemic threshold has been met.

Finally, ABM is a computational method that simulates interactions over time. Simulations allow ‘what if’ questions to be tested quickly, cheaply and without the ethical problems of setting up experiments. Provided the key interactions are properly represented in the model, the simulation can explore the

consequences of different actions. For TELL ME, different communication strategies can be implemented as separate runs of the model and the responses of individuals and consequent impact on epidemic size and duration compared.

It is important to recognise, however, that the results of a simulation run will not be suitable for forecasting. For example, it would not be appropriate to claim that a particular communication strategy would lead to 20% fewer infections. The model is a simplified representation of the key relationships that exist in the real world. That simplification is what makes the model useful – knowledge about the real world can be captured and its consequences can be understood - but the model will not be detailed enough to support specific claims. In the terminology of (Heath, Hill, & Ciarallo, 2009, p. 2.18), the model is a mediator "used primarily to establish the capability of the conceptual model to represent the system and to then gain some insight into the system's characteristics and behaviours" so as to understand potential implications of different scenarios.

2 Specifications

The model is to provide decision support for health agencies (and other official information providers) by allowing a comparison of options for communication strategies. There are certain functional requirements arising directly from this purpose:

- Input - Potential communication strategies can be entered into the model for testing;
- Output - Model to report the expected outcomes of the communication strategy with respect to properties of interest; and
- Accessibility - Model able to be used and interpreted by officials developing strategies.

Input and accessibility are detailed in the interface specifications (section 2.3). Properties of interest for the output are discussed in terms of the question for the model to answer (section 2.1).

Together, these requirements lead to the relationships that must be captured in the model logic: the effect of packages of communications on people's behaviour and the consequent effect on the spread of a disease. The structure of these relationships are included in the model as business rules (section 2.4) and are calibrated using data where possible (section 2.5).

2.1 What question is the model to answer?

Competing communication strategies can be assessed against criteria of different types. Most obviously, a strategy is successful if the general population and people in higher risk target groups adopt relevant protective behaviour. Models can also help users understand the key results; in this case, describing the intermediate effects that contribute to the expected adoption behaviour. Ultimately, however, the purpose of encouraging such adoption is to reduce the effect of the potential epidemic. Thus, the model should also report the size, duration, peak prevalence, peak incidence and other key measures of epidemic impact.

While all these measures are important and can be included in the output, a single question is needed to focus the model. Such a question guides selection of relevant characteristics and relationships to be included in the model so that it represents the essential aspects of the real world without incorporating its full complexity. The focus question for the TELL ME model is:

- Given a specific communication strategy, what proportion of the population is infected over the duration of the epidemic?

A communication strategy is envisaged as a package of messages with several properties, most obviously the media in which it is to be delivered and intended audience. However, other features will also need to be coded such as the situation that triggers the message.

By specifying that the communication strategy is an input, this question focusses the design requirements on the relationship between communication and total infected population, which provides for intermediate relationships with behaviour. The strategy is not the only input, however, as the infected population will also rely on the specifics of the disease (such as infectious period) and population. That these other inputs are held constant for the comparison between strategies is implicit.

2.2 Architecture

The simulation is to be developed in NetLogo (Wilensky, 1999), a specialist ABM application with its own programming language. This will enable model users to input communication strategies and also to manipulate other parameters that are relevant for planning such as the country to be considered and the infectivity of the disease.

A NetLogo model has three layers. The 'Code' layer sets out agent properties, interaction rules and data. The 'Interface' layer provides tools to allow the user to manipulate key model parameters and run the model, and reports of results including charts and other information to monitor the simulation during the run. The 'Info' layer is to allow accessible documentation to be packaged with the model. In addition, the BehaviorSpace tool provides scenario management capabilities, so that results from multiple simulation runs can be exported for analysis.

There are three main types of TELL ME model objects for which interaction and behaviour rules are required:

- Messages, packaged as communication strategies;
- Individuals, who receive the messages and exhibit behaviour that may include epidemic protective actions such as seeking vaccination or avoiding public places; and
- Regions, which hold information about the local progression of the epidemic.

Of these, only Individuals are agents with a decision making capacity. Messages and Regions will require rules but simply respond to their environment.

As the communication strategy will involve triggering messages in specific situations, the Messages will need to recognise whether the trigger has occurred; such as checking whether prevalence levels exceed a given threshold. They will also need to communicate specific information to appropriate Individual agents.

Regions manage the epidemic modelling. Their properties include population density, including the proportion of the population in specific epidemic states such as 'infected'. They use the protective behaviour status of Individuals at their location to adjust the underlying infectivity rate. This rate is used to update the population proportions in each epidemic state in accordance with mathematical equations.

The model will include a few thousand Individuals, with demographic characteristics and attitude variability that reflect the heterogeneity of the population. There are four defining characteristics of agents in an ABM (Abdou, Hamill, & Gilbert, 2012, pp. 144-5):

- Perception: Agents can perceive their environment, including other agents in their vicinity.

- Performance: They have a set of behaviours that they are capable of performing such as moving, communicating with other agents, and interacting with the environment.
- Memory: Agents have a memory in which they record their previous states and actions.
- Policy: They have a set of rules, heuristics or strategies that determine, given their present situation and their history, what they should do next.

Individuals perceive the epidemic state of Regions for risk assessment, the content of Messages directed to them, and the behaviour of other Individuals so as to monitor norms. They perform various behaviours in response to these perceptions and in accordance with their policy, most notably adopting or abandoning protective behaviour such as seeking vaccination. This also requires memory of their own state, including attitude values and whether they are performing particular behaviours.

2.3 Interface

There are many parameters that could be included in the model. These include epidemic characteristics such as infectivity and duration; population characteristics such as distribution of attitudes about epidemic response behaviours, density, demographic structure, and coefficients for equations that represent the way in which communication influences behaviour change. If the model is to be accessible, only a small number of these can be available from the model interface, based on their importance and whether they need to be varied.

In addition to controlling key model parameters, the interface must provide a method to describe the communication strategy to be simulated. As each strategy will have multiple messages, this section must also balance flexibility and ease of use.

In order to meet these challenges, the interface will be divided into sections. The main interface will enable control of only the most important parameters and scenario settings (the particular settings to be available are to be determined later in the project). Other sections will provide for further detail but only be available by accessing separate interface screens.

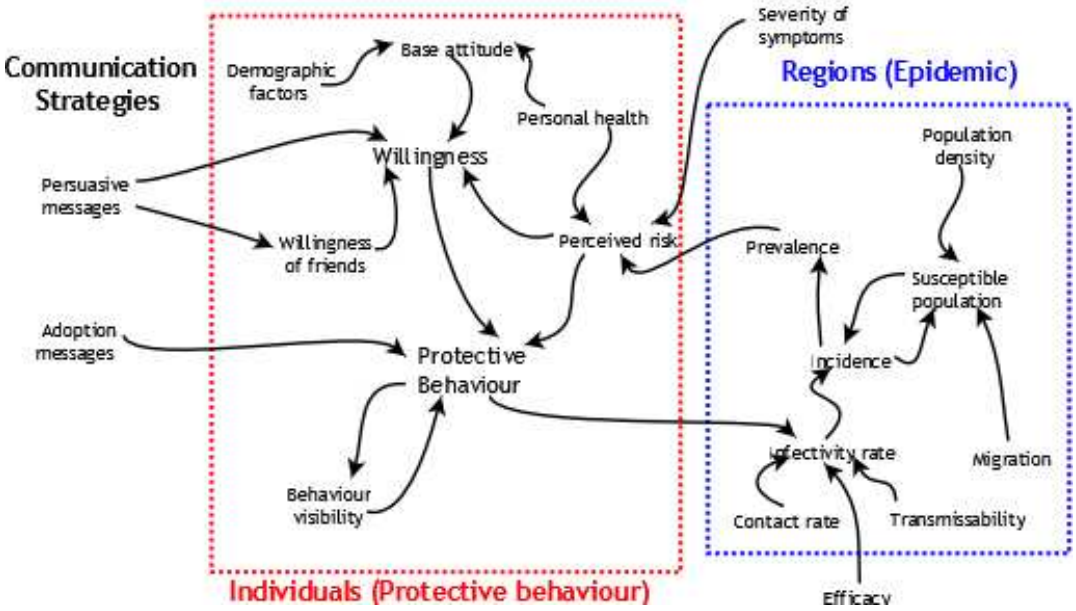
The interface will also provide information necessary to assess and compare communication strategies. The specific content will be determined for the model design, but is expected to include charts and summary data concerning protective behaviour as well as a map and charts depicting epidemic spread.

2.4 Interaction rules

In an ABM, logical if-then statements or equations are required to connect circumstances to agent actions, encoding the influences between properties and decisions of different types of agents. For the TELL ME model, rules will be required for many aspects of message reception, attitude change, behaviour and disease transmission. For example, these rules describe the way that communication messages are interpreted by individuals and change their behaviour, which in turn impacts on infectivity and disease spread in the region where those people ‘live’.

Developing and describing these rules is the primary objective for the model design (to be detailed in report D4.2). They are to be developed from information contained in the reports of WP1 and WP2, specific additional literature analyses, and a stakeholder communication process involving experienced epidemic response managers and other key personnel. The initial draft of the broad model logic as suggested by the research reviewed in WP1 and WP2 is at Figure 1. This logic diagram identifies key properties for each agent type and indicates the main interactions for which rules will be required.

Figure 1: Broad model logic (initial draft), developed from WP1, WP2.



2.5 Data sources

Data requirements will be established during model design and revised during construction of the prototype model. It is expected that data will be required in three categories:

- Population demography, including GIS density data and proportion of the population in specific target groups such as those at higher risk of infection;
- Public health attitude and behaviour (mean and variance), including attitudes toward vaccination and specific protective actions in response to influenza risk; and
- Historical data concerning responses to past epidemics.

Where available, relevant national data will be used to customise the model. However, it is expected that many data items will be available only for some nations and expert input will be sought as to which available dataset is most appropriate for each nation.

3 Participation and Validation

There is no general approach that can be applied for model validation because what is appropriate depends fundamentally on the purpose of the model (Hodges & Dewar, 1992; Moss, 2007). The TELL ME model will be assessed against four broad types of tests:

- Utility: Does the model meet the requirements of the project?
- Face (Klügl, 2008) or conceptual (Heath, Hill, & Ciarallo, 2009; Sargent, 2010) validity: Are the model design and results consistent with theory and are they plausible?
- Verification (Gilbert, 2008): Is the design appropriately translated into model code?
- Empirical (Klügl, 2008) or operational (Heath, Hill, & Ciarallo, 2009; Sargent, 2010) validity: Do the model results match available data?

Aspects of this validation are to be conducted by different groups, with multiple assessment where possible (summarised at Table 1). The four groups are the modellers (principally for technical testing), TELL ME project partners, other subject matter experts and health professional focus groups.

3.1 Subject matter expertise

Effective model design and development relies on appropriate inclusion of expertise from several relevant subject matter areas such as communication, psychology, public health and epidemiology. Such expertise is to be accessed through workshops and on-going communication with two groups: stakeholders in epidemiology management in the United Kingdom and TELL ME project partners. A scenario planning workshop was included in the original TELL ME project plan (task T4.2). This is to be supplemented with two workshops with potential users of the model, selected TELL ME project partners and a project partner from the related E-COM@EU project.

The first workshop was held on 31 July 2013 to discuss the broad model logic (Figure 1) and preliminary interaction rules for four of the most important relationships. This workshop identified several additional factors to consider in the logic. The design will be refined through individual discussions with relevant workshop participants and draft design documents for comment by TELL ME project partners.

A workshop with TELL ME project partners is planned for October 2013. The main purpose is to define the types of communication strategy scenarios to be assessed by the model so as to complete the design of the model input. These will be incorporated into the design to be released as report D4.2 (due 28 February 2014).

Following construction of the prototype model, a further workshop will be held with the stakeholder group (approximately August 2014) to obtain final comment before formal user testing.

As well as these formal workshops, draft models will be made available to subject matter expert participants and TELL ME project partners for comment.

3.2 Health professional focus group testing

Once the prototype model has been completed, it will be assessed by two separate groups of public health and health communication professionals who have not previously been exposed to the TELL ME model. These assessments are included in the description of work as tasks T4.4 (European Union) and T4.5 (United States of America).

3.3 Utility

The first group of criteria concern utility of the model. These assess whether the model meets the requirements of the project. As noted at section 2, the purpose of the model is to assist decision makers to compare different communication strategies, establishing the functional requirements of:

- Input - Potential communication strategies can be entered into the model for testing;
- Output - Model to report the expected outcomes of the communication strategy with respect to properties of interest; and
- Accessibility - Model able to be used and interpreted by officials developing strategies.

There are two types of communication strategy scenarios to be considered. The first are the predefined scenarios established by the TELL ME project partners in the workshop of October 2013. As these are designed by the project partners, their suitability is determined by those partners. The modellers are responsible for confirming whether each is able to be input in the prototype model and how. In addition, it would be desirable that there be some flexibility to try out new scenarios based on standardised descriptions of such elements as message content and trigger conditions. The subject matter experts (at

the acceptance workshop) and the health professionals focus groups will assess the ease with which predefined and new scenarios can be input to the model.

The output to be delivered by the model will be specified initially by the formal subject matter experts, who will identify the information required to assist with decision making. As for the predetermined communication strategy scenarios, the modellers are responsible for confirming that these outputs are included in the model interface and further assessed by the subject matter experts and health professional focus groups. TELL ME project partners will consider these outputs in their reviews of draft models during the development process.

Accessibility, or the way in which the model is presented and used, will be assessed as part of the model testing. Formal testing is to be conducted by the subject matter experts' workshop before passing the model for further testing by the health professionals group. In addition, TELL ME project partners will have the opportunity for on-going comment about the ease of use and comprehensibility of the outputs as draft models are made available.

There are also several features of the model that are desirable but not necessary to provide the functionality. The modellers will be responsible for meeting these to the extent possible and reporting whether the criteria have been satisfied. These are:

- The model is to use GIS data to provide for model realism, promote acceptance and assist with interpretation;
- The model is to be platform independent so that it can be used by all decision makers regardless of their information technology infrastructure;
- The software to run the model is to be as cheap as possible (and preferably free); and
- The software to run the model should not require any extra software that may not be available to all users.

3.4 Face or conceptual validity

Conceptual validation is focussed on whether the model is reasonable from a theoretical perspective. That is, does the model design appropriately include relevant features of the real world target system and the relationships between them? The participatory process is intended to obtain direct comment and feedback about the design from experts from a broad range of disciplines. Face validity then relies on the effectiveness of this participation process (Moss, 2007). This will be assessed in several ways:

- Endorsement of each major draft of the design by the subject matter experts and TELL ME project partners;
- Analysis of the comments received in response to each major draft; and
- Survey and/or interview with some participants focussing on the effectiveness of the participation and the quality of the final design.

In addition, the experts will run several simple scenarios with the model to assess the reasonableness of the model's logic by examining the animation of epidemic spread and the results (Klügl, 2008; Moss, 2007).

3.5 Verification

Once the model design has been agreed, there is a technical issue of how to implement that design, or translate it into model code. Verification is the process of checking for accuracy and functionality of the translation and is the responsibility of the modeller.

The first set of verification criteria concern preventing and eliminating code errors or bugs. The following practices will be observed (Gilbert, 2008):

- Elegant modular code;
- Comments throughout that describe the purpose of sections of code and the meaning of variables and equations;
- Reporting of intermediate values in calculations and relationships during code development to ensure the intended relationship is implemented and diagnose errors where they arise;
- Iterative code development, where components of the model are tested before adding new components.

In addition, test cases will be used to verify larger sections of code. Verification will include (Gilbert, 2008; Sargent, 2010):

- Assertions or test messages in the code, to ensure only feasible parameter values can be run with the model;
- Corner and extreme condition tests, where parameter values are set to 0 or extreme values to ensure the model is able to deal with these parameter values and report reasonable results;
- Degeneracy tests, where only a single value is changed and the output is checked for consistency with that change;
- Observation or tracing of the simulation, monitoring the properties of specific agents each simulation step to ensure they change in the way expected.

3.6 Empirical or operational validity

The test for empirical validity is whether the model results match available data. A key difficulty is that available data is used to calibrate the model; that is, the parameters describing relationships within the model are derived from the data. Thus, care must be taken to test in a way that does not simply report back the data used. Furthermore, models typically suffer from under-determination, where there are many different models that are consistent with the data, with the consequence that good calibration is no guarantee of accuracy (Moss, 2007).

For the TELL ME project, these problems are particularly severe as there are few epidemics to provide data and even fewer where the communication is reported in sufficient detail to support empirical testing (TELL ME, 2012). Thus, validation will rely on qualitative matching of macro behaviour using micro data calibration. That is, parameters for specific relationships within the model will be derived from data and the qualitative behaviour of the model as a whole will be compared to past epidemics. The capacity to reproduce behaviour will be assessed by the subject matter experts at the second workshop and in the health professional focus groups, and made available to project partners for comment.

Sensitivity analysis will also be performed to assess the robustness of results and provide indications of uncertainty (Sargent, 2010). This analysis systematically varies parameter values through plausible ranges and analyses the change in model output. The analysis will be performed by the modellers and reported to the subject matter experts for assessment.

3.7 Validation summary: Allocation of responsibility

The various validation tests are summarised in Table 1, together with the group responsible for assessing whether they have been satisfied. A ‘Yes’ in the table indicates that the group is required to undertake the

specific validation as part of the model development process. An 'Optional' indicates that the relevant information will be made available to the group and comments sought.

Table 1: Mapping of validation criteria with assessor group

Criterion	Modellers	Experts	Partners	Professionals
Utility: communication strategies	Yes	Yes	Yes	Yes
Utility: output content	Yes	Yes	Optional	Yes
Utility: output comprehensibility		Yes	Optional	Yes
Utility: convenience features	Yes			
Conceptual: participation process		Yes	Optional	
Conceptual: result reasonableness		Yes	Optional	
Verification: bug elimination	Yes			
Verification: simple test cases	Yes			
Empirical: qualitative behaviour		Yes	Optional	Yes
Operational: sensitivity analysis	Yes	Yes	Optional	

4 Development and Application

As this report is the first during on-going development of the TELL ME simulation model, this section provides an outline of current plans for the development process and eventual use of the model. It is a statement of intent, and will be revised as required and expanded in future reports.

4.1 Development plan

The model design is scheduled to be completed by February 2014. The work has two stages:

- Specifying the relationships; and
- Construction of input communication scenarios.

The broad model logic (Figure 1) has been endorsed by the leaders of WP1 and WP2 as well as the subject matter experts workshop. Translating this to a detailed design is an iterative process of examining the literature and data for each purported relationship (arrow in the diagram) to identify any intermediate variables, set out the logical or mathematical equations of the influence and check whether data are available to calibrate the equations. This process may also uncover errors in the logic, where the relationship as initially understood is not supported by evidence and must be revised.

Some key relationships concerning the links between communication, attitude and behaviour were considered at the workshop. Individual discussions between the modellers and specific relevant workshop participants or TELL ME project partners will occur throughout 2013 to identify data sources and refine relationships.

The workshop also developed some preliminary specifications concerning how to describe communication strategies. These will be discussed with TELL ME project partners (particularly those leading WP3) and used as the basis for a TELL ME session in October 2013 before further revision.

Coding of the model will start before the design is agreed. A demonstration model has already been released. The next prototype will include more realistic (but uncalibrated) equations for the attitude and behaviour logic. Later development tasks include:

- constructing input interface for communication strategies;
- supporting multiple protective behaviours, including varied adoption and efficacy;
- calibrating attitude and behaviour elements;

- consequences of different media access;
- adding detail to epidemic transmission (including migration, latency); and
- designing useful output charts and results reporting.

Verification and conceptual validation will be undertaken in parallel with model construction. The final prototype is planned to be completed by July 2014 to permit sufficient time for utility assessment and empirical validation prior to release of the prototype to health professional focus group testing (tasks T4.4 and T4.5) from October 2014.

4.2 Promulgation and analysis plan

The final version of the model is to be released at the completion of the TELL ME project at 31 January 2015. This software will be accompanied by documentation that is expected to include:

- User guide: a guide to using the model;
- Technical reference: model design as implemented, data sources, validation results and other material that describes the way in which the model works and allows independent evaluation; and
- Scenario analysis: discussion of the model results from selected communication scenarios, including the uncertainty associated with the results.

The model is to be accessible from the website to download and possibly also to run from the website. In addition, the model and documentation will be provided to those organisations that have been involved in design discussions.

There are several tasks within WP5 (Dissemination and Policy Dialogue) to which the simulation model is explicitly expected to contribute some content:

- With regard to the press centre and newsletters (ST5.1.2), the final model will be available from the website and articles about major steps will be provided to the WP5 leader for inclusion on the website or in newsletters as appropriate.
- Final publishable summary report (ST5.1.5) will include appropriate material from the model documentation.
- The final stakeholder conference (ST5.2.2) will include at least one session presenting the model.
- Model development is expected to provide the basis for at least two journal articles, which supplement those originally planned in ST5.1.4.
- The report on expected socio-economic influence and factors influencing use (ST5.3.1) will include an analysis of the simulation model.

CONCLUSIONS AND RECOMMENDATIONS

At the time of writing (August 2013), model development is on track. Processes have been established to ensure appropriate expertise is available for assisting with model design. The design will be developed over the next six months and model construction is due to commence shortly, with a target completion date of August 2014.

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