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HEALTH & SAFETY LABORATORY

Pipeline RISKAT – Project Brief

HSL/2006/56

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EXECUTIVE SUMMARY

Part of the Implementation of the Fundamental Review of Land Use Planning (IFRLUP) project reviewed the Health and Safety Executive's (HSE's) land use planning (LUP) Risk and Hazard Assessment Tools, with respect to technical adequacy. This review identified six pieces of software used to support Land Use LUP casework where improvements were required. One of these included MISHAP. The review recommended that for the high pressure natural gas transmission pipeline system, efficiency and reliability of MISHAP could be improved by automating the calculation route. For other compressed flammable gases, e.g. ethylene and LPG, it was recommended that the following component models within MISHAP required upgrading: source term model; jet fire model; and the flash fire calculation.

To address the outcome of the IFRLUP review HSL have been asked by the Hazardous Installation Directorate (HID) of HSE to provide a project brief for the required developments to the MISHAP calculation route.

OBJECTIVES

The objectives of this document are to provide:

- A business case;
- A project risk assessment;
- A summary of the key decisions that will have to be made; and
- A high-level project plan of the work required.

MAIN FINDINGS

The work required to develop the MISHAP route has been split into the following four work packages:

- Develop an overarching control program that automates the route and incorporates the pre and post processors;
- Develop a robust and defensible approach for the generation of failure rates;
- Develop MISHAP to take account of findings from ongoing work (address challenges from industry and IRFLUP recommendations); and
- Fully test and implement the revised methodology.

A high-level plan for these is presented in this report.

1 INTRODUCTION

1.1 PROJECT TITLE

Development of Pipeline RISKAT.

1.2 PURPOSE OF PROJECT

The ultimate aim of this project is to improve the current MISHAP based pipeline risk assessment methodology, currently used by the Hazardous Installations Directorate (HID) of the Health and Safety Executive (HSE) – HID CI5 – for quantified risk assessment of pipelines carrying flammable substances.

The improved pipeline risk assessment tool (Pipeline RISKAT) will be based on the current risk assessment methodology as depicted in Figure 1 but will bring about a number of improvements, namely:

1. Automation of the calculation route;
2. Remove manual transfer of data, and the potential for errors, between the different modules used;
3. Improved robustness of the generation of failure rate data;
4. Codification of the pre and post processing spreadsheets;
5. Developments to MISHAP;
6. Opportunity to review and consider implementation of external developments and challenges in/to pipeline risk assessment approaches; and
7. Therefore lead to improved performance in terms of time and accuracy.

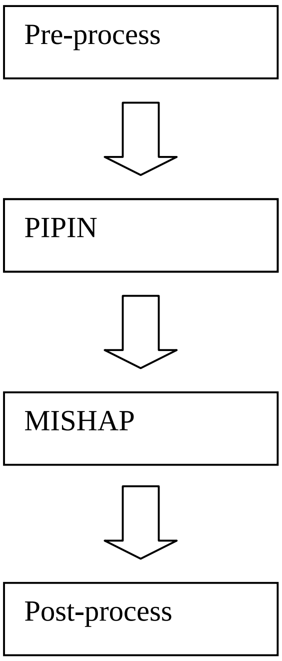

Figure 1 Current pipeline risk assessment methodology

It is envisaged that personnel conversant with the hazards associated with major hazard chemical plant, including staff outside HID CI5, could more easily assess even complex land use planning (LUP) cases using the improved methodology.

As developments to the current methodology have the potential to have a major effect on the LUP advice given by HID CI5 then each aspect of the development to the methodology has to be examined thoroughly. This is both from a technical viewpoint (e.g. is the science correct? Does the software work as intended?), and from a political viewpoint (e.g. is a change of policy acceptable?). The project will therefore consider all relevant technical and policy issues. There will be regular review points and the project will be carried out in stages. The staged approach is to mitigate the risk of the methodology not being able to implement any required part of the assessment.

The implementation of pipeline RISKAT will provide:

- A quantified risk assessment (QRA) tool based on best science available to CI5;
- Transparency of HSE's method and conclusions;
- Opportunity to consider external developments and incorporate if necessary to withstand external challenges, particularly from the United Kingdom Onshore Pipeline Operators' Association (UKOPA) and industry; and
- Less onerous LUP assessment process in terms of HSE time and cost.

1.3 BACKGROUND

Part of the Implementation of the Fundamental Review of Land Use Planning (IFRLUP) project reviewed HSE's LUP Risk and Hazard Assessment Tools, with respect to technical adequacy. This review identified six pieces of software used to support LUP casework where improvements were required. One of these included MISHAP. The review recommended that for the high pressure natural gas transmission pipeline system, efficiency and reliability of MISHAP could be improved by automating the calculation route, i.e. packaging it up within a pipeline RISKAT architecture, as illustrated, for natural gas, in Figure 2. For other compressed flammable gases, e.g. ethylene and LPG, it was recommended that the following component models within MISHAP required upgrading: source term model; jet fire model; and the flash fire calculation.

1.4 PURPOSE OF THIS DOCUMENT

This document has been produced to capture the following information:

- The approach to be adopted;
- How the pipeline RISKAT shall be developed;
- Major risks;
- Identification of technical and policy decisions that need to be made;
- Testing requirements; and
- Dependencies on other projects.

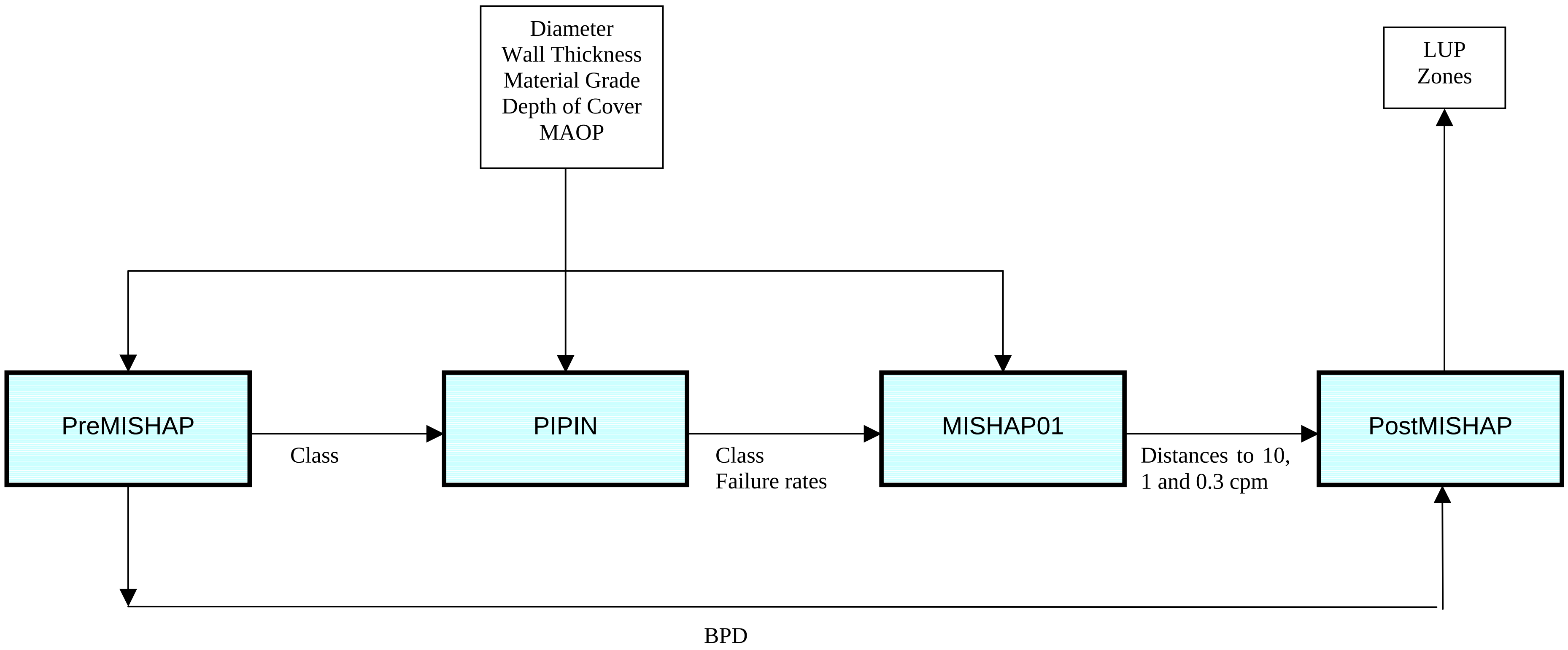

Figure 2 Pipeline RISKAT architecture (Natural Gas exemplar)

This document essentially contains elements of a project brief, a business case and project plan. Its purpose is to provide sufficient information to allow the overall project to be initiated by HSE, and then form the basis of a project plan once authorised.

Currently, due to many unknowns, only a high level plan is presented. It is the intention to revise the plan as more information becomes available, as the work progresses.

1.5 OBJECTIVES

The overall aim is for the development and implementation of a robust pipeline risk assessment methodology for the assessment of risk from pipelines carrying natural gas and other compressed flammable gases. This will be based on the current MISHAP-based calculation route but be automated, consider industry challenges, and take on board, changes in science and HSE policy, where relevant, and be more robust.

High-level objectives of the project include:

- Develop an overarching control program that automates the route and incorporates the pre and post processors;
- Develop a robust and defensible approach for the generation of failure rates;
- Develop MISHAP to take account of findings from ongoing work (address challenges from industry and IFRLUP recommendations); and
- Fully test and implement the revised methodology.

It is intended that as the project progresses the method for the calculation of risks for LUP assessments will be fully developed and described, such that a working method is available at the end of the project.

1.6 SCOPE

The project will explicitly address the methodology for the assessment of flammable gases carried by pipelines. The following are outside scope of this project:

- Methodology for societal risk calculations; and
- Toxic substances carried by pipelines.

Flammable toxics will be within scope, but only from the point of view of their flammable properties.

1.7 INTERRELATION

The timescales for the work identified in this report is dependent on the outcome of various projects currently being undertaken by HSL. These projects are identified where relevant throughout this report.

2 PROJECT DEFINITION AND BUSINESS CASE

2.1 BUSINESS CASE

Currently HID CI5 is facing many challenges from industry over certain aspects of the current MISHAP risk methodology. Some of these are difficult for HSE to defend. In addition, HSE are aware of problems with the current calculation route, particular with regards the generation of failure rates in PIPIN and dispersion modelling within MISHAP. The gas dispersion model within MISHAP (for non-natural gas), CRUNCH, is not up to modern standards. It is over 20 years old and urgently needs to be replaced with an up to date scientific model. HSE is at great risk if it continues to use these codes in their present state for the foreseeable future, since if any assessment were to be formally challenged it might not stand up to serious scrutiny. This could severely damage HSE's reputation and have financial implications. Therefore, no change is not an option.

The effort required to run the current MISHAP risk calculation route, particularly due to the amount of user intervention, is extensive. Therefore, if an assessment had to be carried out on the UK gas network, some 2000 pipelines, a massive saving of resource could be made by automating[1] the route. Although not definite, there is a real possibility of this having to be completed in the future due to challenges from industry.

The main business benefits of implementing pipeline RISKAT into HID CI5 include:

- Closes out recommendations made in the Implementation of the Fundamental Review of Land Use Planning (IFRLUP) project to improve MISHAP.
- Pipeline RISKAT lends itself to a less resource intensive approach to risk assessment, through automation of the route and removing the large amount of user intervention required.
- Overcomes difficulties which PIPIN occasionally has in calculating failure frequencies. There are certain circumstances where the current algorithms fail to find a solution.
- Pipeline RISKAT would free up resources within HID CI5 as the assessments would require less effort and they could easily be carried out by other competent technical specialists, e.g. HSL, contractors.
- Allow the more efficient assessment of "second bite" cases.
- A more balanced workload for HID CI5.
- HSE less open to challenge and criticism as it would be using modern methods.
- A thorough review of all aspects of the risk assessment process would be carried out as part of determining the best way to implement pipeline RISKAT. Thus the assessment process would be more able to be defended against challenge.

The key perspectives addressed by the implementation of pipeline RISKAT are as follows:

Strategic – The IFRLUP project concluded that HSE was running, and had run for some time, a business risk that its advice was based on older science and models. The need to address this fundamental point is the main driver for this investment. It is a legal requirement that HSE is

[1] The current MISHAP has automated the setting of zones for pipelines by allowing the input of data from a spreadsheet. However, some user intervention is still required.

consulted for professional advice and in the current climate where professional advice is under some scrutiny we need to be sure that HSE professional advice is defensible and transparent.

Economic – Although the primary focus is strategic, the economic case has been considered and the various options to replace the out-of-date models were discussed as part of the IFRLUP project. The approach of building on the current MISHAP route, but automating it, offered the best value-for-money option for proceeding. The implementation of up-to-date models will improve safety and economic utilisation of land. There are likely to be some, albeit as yet unquantified, modest staff savings within HID through use of a more streamlined and easier to use tool. The non-quantifiable strategic benefits outweigh the investment costs.

Commercial – There is limited procurement freedom in this case. This does not undermine the viability of this product – on the contrary it makes it more viable. Scientific advice will be procured from HSL, HSE's preferred scientific partner. Given their previous involvement in risk modelling and in the development of MISHAP it is not sensible to go elsewhere. It will be important that REFIT provide appropriate assurance that pipeline RISKAT as developed can run effectively on the HSE estate.

Financial – Provision of scientific software is now included in Business Efficiency Unit's (BEU) portfolio and BEU made provision for funding this project in its forward programme of work endorsed by the HSE Board in December 2004. Funding will be required over more than 1 year. Relevant stage breaks will be included to avoid spending money where benefits are unlikely. There is no doubt that a certain amount of catching-up needs to be done since the models have been allowed to atrophy over several years due to unclear funding streams.

Project management – A properly constituted Project Board and Project Team will oversee the project. Most of the parties have worked together before and have worked on scientific modelling before. There is no doubt that the project has an exploratory nature – particularly in the early phases and a review phase at the end of each stage provides appropriate assurance that the project will be terminated if the objectives of the previous phase have not been realised, or there is a likelihood that the objectives of the next phase are unlikely to be realised.

2.2 CONSTRAINTS

The main constraints to the implementation of pipeline RISKAT include:

- HSE resource, mainly HID CI5 staff and panel time but also Operations Policy Unit (OPU) staff;
- Technical and policy issues unable to be resolved;
- Challenges from industry not able to be addressed;
- Intellectual Property Rights (IPR) issues associated with the use of third-party models;
- The cost to HSE for the purchasing and installing sufficient copies of the third party models;
- Availability of up-to-date versions of mathematical modelling software identified as desirable for the implementation of the new methodology (e.g. source term models, dispersion models, and so on); and
- Changes required to published documentation on risk assessments (e.g. risk criteria document, and so on).

2.3 ASSUMPTIONS

The main assumptions made in preparing this document include:

- Sufficient resource is available throughout the duration of the project;
- Panel able to consider, and decide on, technical and policy issues in a timely manner;
- Assessment methods remain free from significant challenge; and
- There are no intellectual rights issues with incorporating particular models.

2.4 PROJECT RISK ASSESSMENT

Table 1 Project risk assessment

Risk	Control Measures
Agreed costs not kept to	The project leader will closely monitor costs on a monthly basis so that expenditure against the project plan can be reviewed. The HSE/L project team will discuss progress against the project plan. Regular reviews should minimise any significant deviation from the budget. Changes will be implemented at the earliest opportunity to bring the project back into cost.
Timescales not kept to	For this project, an experienced project leader will be appointed who will ensure that all members of the project team are aware of and operate to the agreed timescales. Regular project review meetings and the provision of additional resource, if required, will achieve this. Contingency will also be built into timescales of the project.
Delay in getting technical or policy decision	Any delay in getting a technical or policy decision could impact the overall project timescales. To try and mitigate this an attempt will be made to group together key decisions for presentation to panel. In addition, the project has been split into a number of parallel streams, where possible, so that work can continue whilst awaiting decisions.
Unable to get technical or policy decisions	The detail and structure of the project gives a formal process for the identification and capturing of decisions. Sufficient evidence will be provided for each case to enable decisions to be reached. This project proposal demonstrates the process for collecting the evidence required to make these decisions. Policy decisions may be more difficult than technical decisions. The project format allows existing criteria to be implemented alongside potential new criteria to allow the implementation of updated versions of existing methodology if key technical or policy changes are not agreed. An Issues Log will be kept for all technical and policy issues that cannot be resolved during development of the methodology.
Assessment results very different to current assessments	Any differences will initially be understood and justified. This will be presented to panel to allow a discussion of the reasons for any differences. This is the current procedure for any technical changes to methodologies, and can be used to develop an approach to solving the problem.
Uncover flaws in current assessments	The significance of any flaws on assessments made using the current method will be determined. A comparison of the flawed and ‘corrected’ results with those obtained using the new method will be made to assess the impact of the flaws in the current assessments. Presentation of a paper to panel will then be made for discussion. This can then be used to develop an approach to solving the problem.

Risk	Control Measures
Reporting arrangements not fit for purpose	A project board will be utilised to oversee the project. Regular reports will be provided to the project board. The board will ensure that sufficient reports and updates are provided to allow an assessment to be made on the progress of the project. Circulation of project reports will also be made to a wide audience in HSL and HSE.
Unforeseen, prolonged absence of members of the project team	HSL have a pool of suitably qualified scientific staff upon whom to call should the need arise. Circulation of project reports to a wide audience in HSL and HSE to allow for dissemination of knowledge to other parties that could become involved in project. HSE to include shadowing of specialists by other members of staff.

2.5 CUSTOMER'S QUALITY EXPECTATIONS

Pipeline RISKAT will be developed, tested and implemented based on HSL's in-house software Quality Assurance (QA) procedures, based on IEC 61508. In addition, each task in the project will be reviewed in depth by HSE. This will ensure that the implemented methodology is fit for purpose.

2.6 ACCEPTANCE CRITERIA

Products delivered to time, cost, and accepted quality standards.

2.7 ORGANISATION AND CONTROL

Detailed project plans will be developed based on this project brief. A team will be set up within HSE to monitor progress against the plans and to provide sufficient technical oversight. In addition a experienced project leader will manage the project within HSL.

2.8 REVIEW AND REPORTING

Reporting of progress will be made monthly against the project plan to the HSE Project Team. Detailed reviews will be carried out at regular intervals throughout the duration of the project.

2.9 FINANCIAL BUDGET REQUIREMENTS

The resource required both within HSE and HSL, and the associated cost, will be estimated for each phase of the overall project.

2.9.1 Work carried out by HSL

HSL work to be carried out as a project for each work package.

Upon implementation of pipeline RISKAT, the maintenance of data for use in LUP assessments will be carried out by HSL under a call-off helpdesk reactive support project. The existing Risk Tools helpdesk, used to deal with RISKAT queries from HID CI5, is in the region of £30,000 per year. This helpdesk is only used as required and consequently this budget is not necessarily fully spent each year. However, this helpdesk is used to deal with a variety of different tools. Previous helpdesk arrangements for individual risk tools indicate that an initial call-off helpdesk of around £15,000 per year should be sufficient for HSL to provide data and assistance for the application of the new method to LUP assessments.

Dependent upon the final methodology adopted, HSL could provide informal training to HSE staff for the use of the method, as required.

2.9.2 HSE staff

HSE staff involvement will include the provision of assistance and expert opinion to the body of work being carried out by HSL. The staff involved will be the project team members, and the panel of specialists for the key technical and policy decisions. Where possible, key queries and decisions will be grouped together to minimise disruption to HSE staff.

2.9.3 Licence costs and maintenance

No licence issues have been identified as PIPETECH will not be incorporated directly, but parameterised equations used to reproduce its output. In addition, integration of ESR Technology codes EJECT and DRIFT are not thought to be an issue, although the results of these codes could be parameterised as well.

2.9.4 Other work required

The new methodology and codes will require to be impact tested by REFIT prior to installation on the HSE/ HID CI5 network. There may be a requirement/benefit for impact testing of the mathematical modelling software (source term and dispersion models) at earlier stages of the development process (e.g. to allow stand-alone use of the codes, or to prevent delays in the implementation of the approved method). An early approach to REFIT will be made, to confirm what software platform is their preference and what usability standard they are currently working to.

3 OUTLINE PROJECT PLAN

3.1 INTRODUCTION

The following sections summarise the key tasks involved in the overall project to develop the pipeline RISKAT methodology. Detailed estimates of effort, timescales and cost have not been made at this point due to the exploratory nature of many of the tasks. However, key decisions and deliverables are summarised.

The overall project is split into four work packages:

- Work Package 1 – Development of overarching controller and codification of the current pre and post processors (Section 3.2)
- Work Package 2 – Development of robust failure rates (Section 3.3)
- Work Package 3 – Developments to MISHAP (Section 3.4)
- Work Package 4 – Testing of overall route and determining impact and justification of any changes (Section 3.5)

The interrelation of the work packages is illustrated in Figure 3. As can be seen, work on the first three work packages can be, generally, carried out in parallel, but with design of the overarching framework constraining how changes are made to MISHAP and PIPIN (or its equivalent).

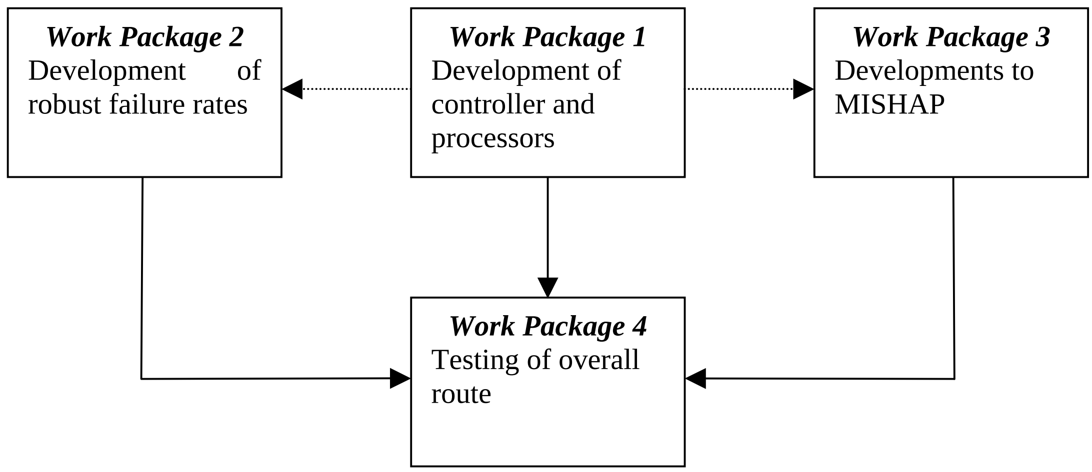

Figure 3 Work package relationships

3.2 WORK PACKAGE 1 – DEVELOPMENT OF OVERARCHING CONTROLLER AND CODIFICATION OF THE CURRENT PRE AND POST PROCESSORS

Work Package 1 involves the following tasks:

- Task 1.1 – Identify input and output parameters and general data transfer for each existing module
- Task 1.2 – Design of overarching 'controller' and processors
- Task 1.3 – Codification of pre and post processors
- Task 1.4 – Codification of overarching 'controller'
- Task 1.5 – Testing

A diagram illustrating the interaction between the above tasks is shown in Figure 4.

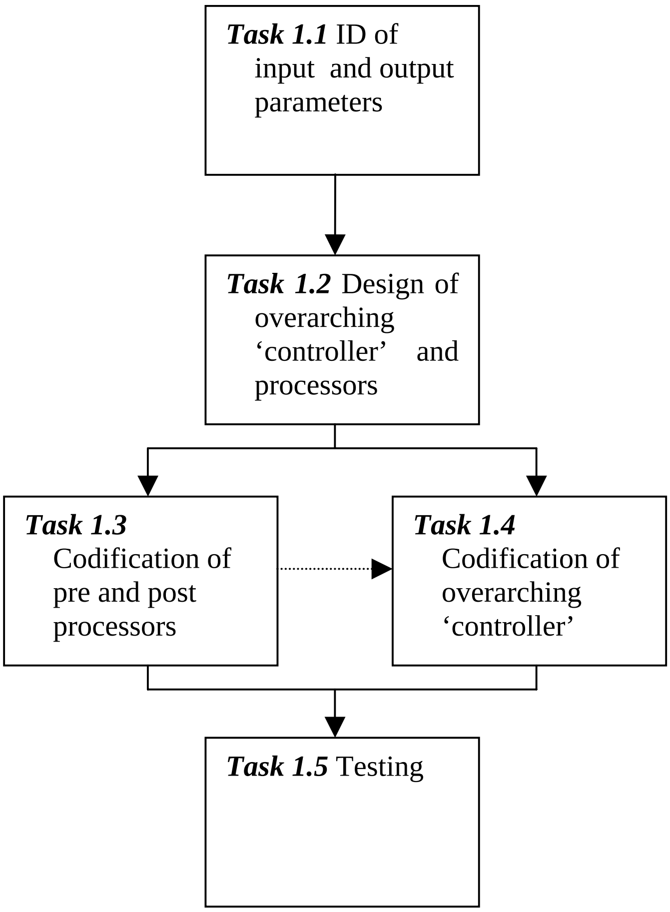

Figure 4 Key tasks in Work Package 1

3.2.1 Background

Pipeline RISKAT exists at present as a collection of discrete executable codes and Excel spread sheets. The development of an overarching ‘controller’ that would automate these elements to perform as a single risk assessment tool would require a number of investigations.

3.2.2 Task 1.1 – Identify all input parameters for each individual existing ‘module’

The purpose of this task is to understand the data needs for each module and the flow of data between each module. This is required to be able to design an approach for the overall controller.

PIPIN and MISHAP will each be examined in detail to determine what inputs and outputs are required and the nature of them. This is required to determine whether bridging codes are required and the nature of them. Until the initial identification process is complete it is not possible to predict how many or indeed how complex these bridging codes will need to be. For example, it is necessary to identify outputs from each module and determine whether they exist as on screen values that presently have to be manually transferred to the next module or as accessible output files that are input into the next stage.

PIPIN is at present the largest ‘unknown’. It has existing problems when dealing with small diameter pipelines and crashes. It may require a complete rewrite in order to incorporate it into the wider pipeline tool. This will be determined as part of Work Package 2, and is also the reason for allowing the flexibility of using replacement modules, if required, without coding changes. A particular issue with PIPIN is that it is a third party code with unknown access to the source code. Therefore, a detailed investigation may need to be carried out to determine the level of control that can be achieved. For example, we will need to identify:

- Whether this code can be controlled by another code, i.e. can it be run as a shelled program from Visual Basic;
- If any necessary input files can be loaded as command line arguments; and
- Whether the output files are readily accessible, i.e. not saved as binary files.

The pre[2] and post processors will also be examined to determine their input, output and functionality. Pre and Post Mishap are Excel spread sheets. The underlying equations that underpin these calculations will be identified.

3.2.3 Task 1.2 – Design of overarching ‘controller’ and processors

Taking the results of the previous task, the purpose of this task will be to design the overarching controller, which will allow at least the following:

- Automatic operation of the entire route without user intervention;
- Retain the flexibility to allow manual operation of the route;

[2] The pre-processor is specific to IGE/TD/1 for natural gas. For other substances, other codes maybe necessary to be accessed. HSE’s current policy is that the inner LUP zone is set at the BPD when risks do not achieve 10 cpm per year, for natural gas. The situation is less clear for other substances where the latest policy is that a mix of distances need to be brought before Panel, including fireball radius, distance to 1800 tdu, MDOB (minimum distance to occupied building) etc. UKOPA is currently investigating calculation methods for BPD and MDOB, which will need to considered as part of this work.

- Allow the flexibility to allow current modules to be run as well as any future ones, to ensure back compatibility;
- Have functionality to allow batch runs as well as individual runs; and
- Be controlled by both a GUI as well as command line operation.

The design of the pre and post processors will also be specified.

Requirements for the controller and processors will be specified and agreed with panel prior to implementation.

Coding will be undertaken using Microsoft Visual Basic Version 6. However, consideration should be given as to whether VB.net should be used. If VB.net is chosen then there would also be additional work required to update MISHAP01 to the VB.net environment. This may introduce additional problems.

Deliverable: ***Report specifying the design of the controller, and pre and post processors***

Decisions: ***Acceptance of controller design and functionality***
Which code should be used for programming?

3.2.4 Task 1.3 – Codification of pre and post processors

The Excel spreadsheet pre and post processors will be codified as per the specification in Task 1.2.

The processors will be created as separate modules that can be run either independently or automatically as part of the overall route.

Deliverables: ***Codified pre and post processors***
Documentation describing use and operation of the modules

3.2.5 Task 1.4 – Codification of overarching 'controller'

Once the functionality of the controller has been determined, this will be coded as per the specification.

Deliverables: ***Codified controller***
Documentation describing use and operation of the controller

3.2.6 Task 1.5 – Testing of controller and processing modules

A comprehensive test plan will be developed to ensure the codified modules and controller perform as described in the specification. The purpose will be to verify the following:

- The operation of the pre and post processors; and
- The controller has not altered the operation of MISHAP and PIPIN.

Testing to this plan will be carried out.

Deliverables: ***Test plan***
Report documenting the results of the testing

Decisions: ***Acceptance of test plan***
Acceptance of pre and post processor modules and controller

3.3 WORK PACKAGE 2 – DEVELOPMENT OF ROBUST FAILURE RATES

3.3.1 Background

PIPIN usually provides the failure rate data for use within MISHAP. However, this has a number of issues associated with it:

- Convergence problems with small diameter pipelines – in 2000 runs completed recently, manual intervention/calculations were required in 10-15% of cases;
- Appropriateness of data for non natural-gas pipelines;
- Problems regarding how the data underpinning the models have been used and analysed have been uncovered – there could be more. This has undermined confidence in the current model; and
- Challenged by industry, for example because the model/HSE policy excludes various mitigation measures.

The purpose of this work package is therefore to provide a robust and defensible tool for the generation of failure rate data. There are four main options with regards the development of PIPIN. Which option is selected depends on findings from the early tasks.

- Option 1: Modify PIPIN to improve robustness, but retain the current approach
- Option 2: Develop a new failure rate model
- Option 3: Utilise industry failure rate model
- Option 4: Maintain the current version of PIPIN

At the current time it is proposed that Work Package 2 involves the following tasks:

- Task 2.1 – Familiarisation with PIPIN
- Task 2.2 – Review of external developments
- Task 2.3 – Critique of industry failure model
- Task 2.4 – Validation of industry failure model for third party failures
- Task 2.5 – Identification and investigation of appropriate historical data
- Task 2.6 – Design of failure rate module
- Task 2.7 – Codification of chosen option
- Task 2.8 – Testing

A diagram illustrating the interaction between the above tasks is shown in Figure 5.

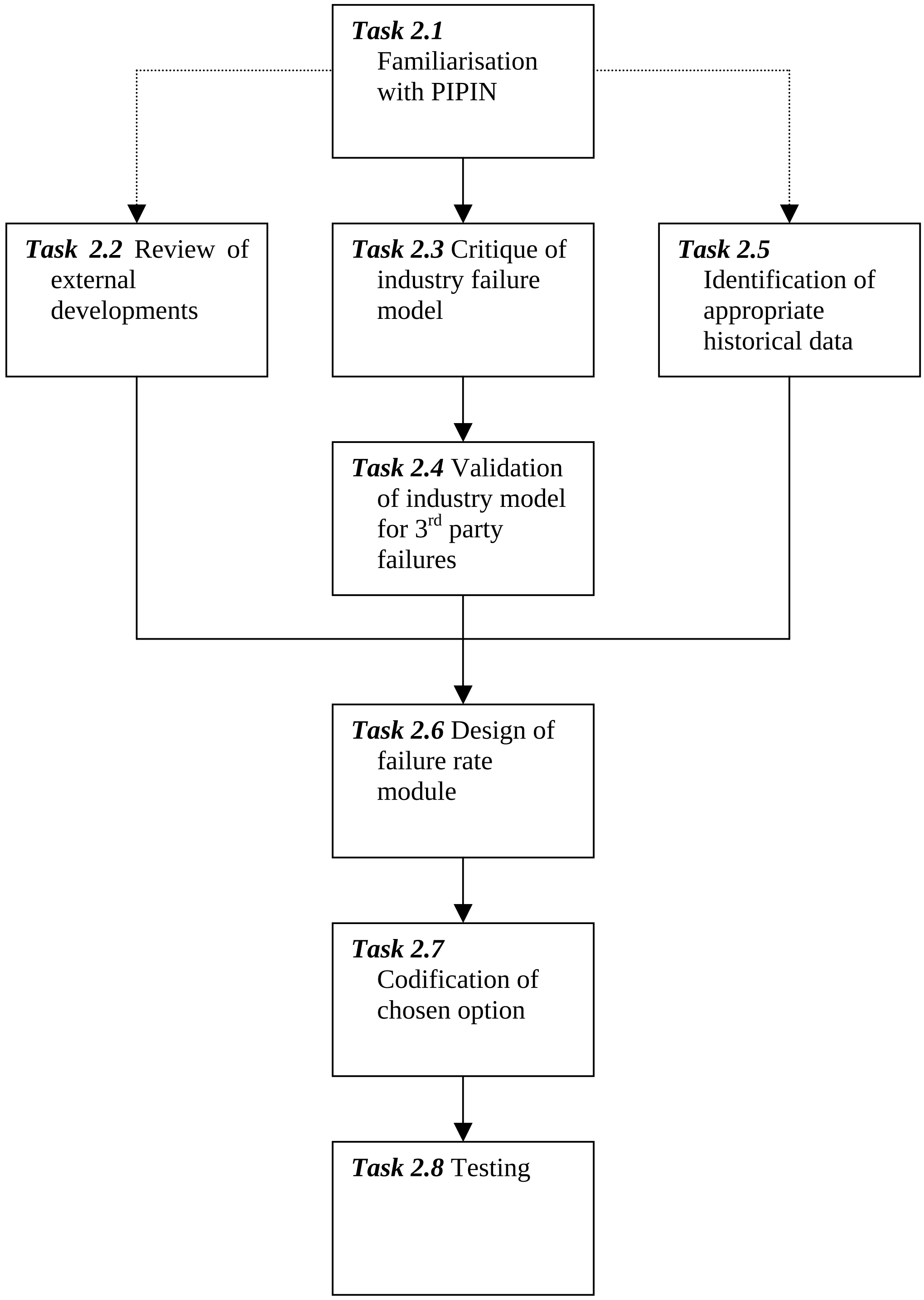

Figure 5 Key tasks in Work Package 2

3.3.2 Task 2.1 – Familiarisation with PIPIN

The purpose with this task is to gain familiarisation with the PIPIN code, the data it uses and the underlying methodology. A review of supporting documentation will also be made.

3.3.3 Task 2.2 – Review of external developments

The purpose of this task is to identify and review failure rate models used to estimate failure rates for both natural gas and other flammable gas pipelines. This will include at least the following:

- An international review of literature to capture pipeline failure developments – models and data – from the UK and abroad (particularly Europe and the United States); and
- Discussions with industry, particularly UKOPA, Transco and Rod McConnell to identify 'issues' that they may have with the current HSE approach.

The purpose of the discussions is to identify failure models, data sources, approaches taken, and also mitigation measures that may have an impact on failure rates. Where issues with HSE's current approach are found, the basis of these issues/challenges will be explored to determine if there is any substantive evidence to support the industry stance.

Where mitigation measures are identified, how they could be taken into account and the method for doing so will be explored. Examples of such measures may include:

- Slabbing;
- Depth of cover; and
- Management of maintenance.

The impact of such changes will be explored with HSE as ultimately many of these may require a policy decision to be implemented. However, even if the decision is made by HSE not to give allowance for specific measures, consideration will be made of how functionality to incorporate such measures could be included within the code for future use.

Deliverable: ***Report describing the review of developments***

Decisions: ***Which approaches should be further considered for implementation by HSE?***
Which mitigation measures should be incorporated within the failure rate model?

3.3.4 Task 2.3 – Critique of industry failure model

The purpose of this task is to thoroughly review the Limit State model developed by Advantica to estimate failure rates for third party failures. The outcome of such a review may be to recommend or not the use of the approach or the model.

Detailed examination will be made of the basis of the model, its scope and applicability. Evidence will be sought for all aspects of its development. A detailed comparison will be made with the PIPIN third party activity model and any systematic differences will be explained and justified.

3.3.5 Task 2.4 – Validation of industry failure model for third party failures

The purpose of this task is to independently verify industry's implementation of the Limit State model. To enable this to be done, the approach will be independently codified and the results compared with those produced directly by industry's model.

Deliverable: ***Report describing the critique and validation of the industry model***

3.3.6 Task 2.5 – Identification and investigation of appropriate historical data

There are a number of disagreements between HSE and industry as to the appropriate historical data sources to use for various failure mechanisms. PIPIN currently uses the data sources illustrated in Table 2.

Table 2 Data sources currently used by HSE

	Rupture >110mm	Large Hole 75-110mm	Small Hole 25-75mm	Pin Hole 0-25mm
Mechanical	UKOPA	UKOPA	UKOPA	UKOPA
Natural	UKOPA	UKOPA	UKOPA	UKOPA
Corrosion	EGIG	EGIG	EGIG	EGIG
Third party activity (TPA)	PIPIN predictive model	PIPIN predictive model	PIPIN predictive model	PIPIN predictive model

The purpose of this task is to:

- Identify any challenges to the use of the current data, and the basis of these challenges through discussions with industry and HSE;
- Review the current data sets, for example UKOPA, EGIG and CONCAWE, and consider their appropriateness for both natural gas and other flammable compressed gases;
- Consider the relevance of the time period of the historical data, for example, is more recent data representative of pipelines that are 40 years old; and
- Consideration will be made to the format of the historical data to determine whether it is in an accessible form and issues associated with conversion as conversion may not be a trivial task.

Possible options for natural gas may include:

- Align the UK natural failure frequencies with the new UKOPA values; and
- Move from EGIG data to UKOPA data for corrosion failures.

For other flammable gases the following options may be considered:

- Follow the same approach as for natural gas pipelines but use CONCAWE operational experience data rather than UKOPA or EGIG data; and
- Look more closely at the mechanical, natural, corrosion and third party activity failure rates for gas pipelines and determine what changes may be justified. For example:

  Mechanical

  - Is there a difference in design standard and therefore initial integrity?
  - Compare CONCAWE, EGIG and UKOPA databases to determine the change in mechanical failure rate between natural gas pipelines and those carrying

other flammables. Are the failure rates higher for pipelines carrying other flammables?

Natural Failures

- Will pipelines carrying other flammables be any more susceptible to failure from natural causes than gas pipelines?
- If not, can we use the frequencies for gas pipelines?
- Should we take account of regional differences in earthquake likelihood over the UK?
- Should we account for lesser or greater risks of flooding and/or subsidence at specific locations in the UK?

Corrosion Failures

- Use CONCAWE operational experience data
- Is UKOPA data available?

Third-party Activity Failures

- Provided the pipeline is made from a grade of steel recognised by the PIPIN third party activity (TPA) model then it could be analysed by PIPIN
- PIPIN TPA model is validated against BG Transco data so may need to be re-validated against CONCAWE operational experience data

Deliverable: ***Report describing the review of appropriate use of historical data***

3.3.7 Task 2.6 – Design of failure rate module

The purpose of this task is twofold:

- Firstly, based on the evidence from Tasks 2.1 to 2.5, a case shall be made for the chosen failure rate module option; and
- Secondly, a detailed specification and plan for development of the chosen option shall be produced.

If the chosen option is to utilise or implement industry's model a policy decision will have to be made to determine whether the lack of independence from industry is an acceptable risk to HSE and what measures need to put in place to mitigate this risk. Alternatively, it may be necessary to have more than one option; for example, for pipelines carrying different substances that are more or less prone to, for example corrosion.

Deliverables: ***A case shall be made for which option(s) to adopt***
A specification shall be written for the chosen option

Decisions: ***Option to be adopted***
Acceptance of specification

3.3.8 Task 2.7 – Codification of chosen option

Coding of the chosen option shall be carried out, if required, and any historical data shall be processed into the required format.

Development of the module will be fully documented. Supporting documentation shall be produced, for example a users' manual and a description of the basis of the model.

Deliverables: ***Revised failure rate module***
Documentation describing use and operation of the failure rate module

3.3.9 Task 2.8 – Testing

A comprehensive test plan will be developed and testing to this plan will be carried out. Any issues highlighted will be rectified.

Deliverables: ***Test plan***
Report documenting the results of the testing

Decisions: ***Acceptance of test plan***
Acceptance of failure rate module

3.4 WORK PACKAGE 3 – DEVELOPMENT OF MISHAP

3.4.1 Background

A number of developments and investigations are currently being made to components of MISHAP. Some of these relate to the codification of the methodology whereas others relate to various scientific models contained within MISHAP. The output of that work may impact the future direction of MISHAP. The work currently ongoing includes:

- Jetfire model evaluation
- Dispersion model evaluation
- Release model evaluation
- Building ignition criteria
- Programming modifications

These areas are discussed further in the tasks described below. A further issue that was considered some time ago is that of grounded jets. This issue has not yet been resolved and is therefore also included below as a specific task.

The purpose of this work package is therefore to consider the outputs of the above work, highlight areas that may require further investigation and then incorporate the given recommendations as they arise.

At this stage, Work Package 3 is likely to include the following tasks:

- Task 3.1 – Identify stakeholder issues
- Task 3.2 – Jet fire model
- Task 3.3 – Dispersion model
- Task 3.4 – Release model
- Task 3.5 – MISHAP event tree probabilities
- Task 3.6 – Programming modifications
- Task 3.7 – Grounded jets
- Task 3.8 – GIS interface
- Task 3.9 – Testing

A diagram illustrating the interaction between the above tasks is shown in Figure 6. In general, there is no strict order in which these tasks can be carried out. Therefore, the suggested order of tasks is not fixed.

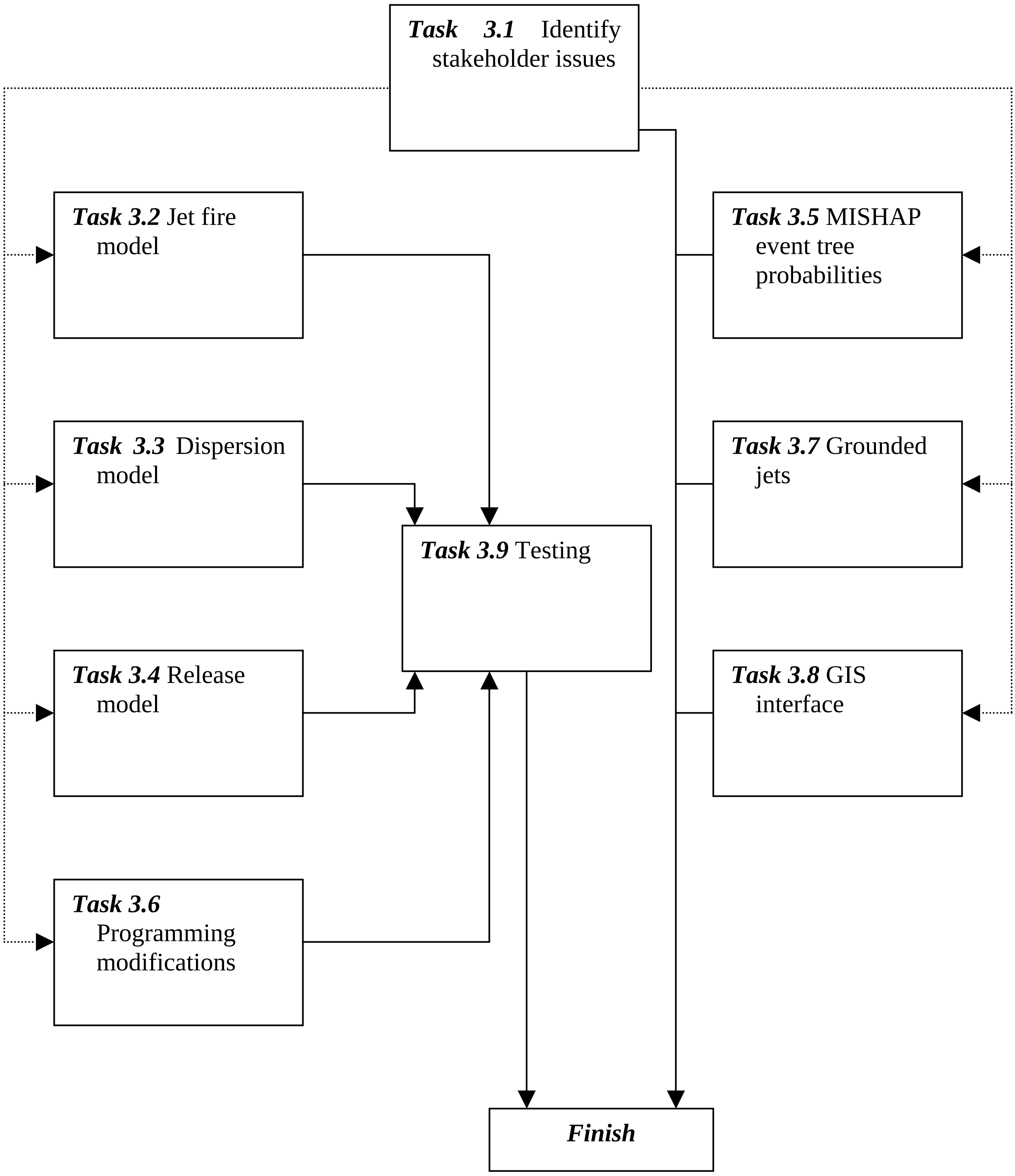

Figure 6 Key tasks in Work Package 3

3.4.2 Task 3.1 – Identify stakeholder issues

The purpose of this task is to identify any issues that are likely to be raised by stakeholders in relation to MISHAP. The basis of these issues will be explored, and where sufficient evidence exists a plan of how to address these will be developed. The decision as to whether to take these issues forward will be determined by HSE on the basis of the evidence presented.

Deliverable: ***A paper to panel identifying the areas to be considered for further work or implementation***

Decision: ***Identification of areas for further work or acceptance of identified approaches***

3.4.3 Task 3.2 – Jetfire model

This task will take forward the recommendations made in work currently being carried out by HSL to compare for non-natural gas the current jet fire model in MISHAP, JIF/MAJ3D, with the standalone SHELF/MAJESTIC, against other available software models (e.g. BP Cirrus, Shell Shepherd and PHAST) and against any real data (e.g. Kuwait, past work in OSD and Chamberlain flare measurements).

The basis for this work was that confidence was lost in the JIF/MAJ3D model for natural gas and it was subsequently replaced. However, it was not clear whether the model should continue to be used for other flammable gases. It was also not clear whether the problem lay with the model itself or the implementation of the model. Therefore, the aim of the ongoing work is to determine which model to use for non natural gases.

This task may therefore make changes to the implementation of JIF/MAJ3D or replace the jet fire model within MISHAP.

Deliverables: ***New version of MISHAP with updated jet fire model***
MISHAP Documentation updated to reflect changes

Decision: ***Which jet fire model and how to be implemented?***

3.4.4 Task 3.3 – Dispersion model

This task will take forward the recommendations made in work currently being carried out by HSL to determine the impact of replacing CRUNCH with EJECT/DRIFT. Replacement of CRUNCH was identified in the IFRLUP project as CRUNCH is over 20 years old and therefore is in need of replacing by more up to date scientific models. This only impacts on the use of MISHAP with non-natural gas.

It is expected that the following will be carried out:

- Replace CRUNCH within MISHAP;
- Determine how to implement EJECT/DRIFT, for example either by parameterisation of the dispersion code, or by implementation of the code within MISHAP;
- Codification of the approach within MISHAP;
- Parameterising dispersion runs, if this implementation option is chosen; and
- Testing implementation.

A number of issues will have to be resolved, for example whether there are any Intellectual Property Rights (IPRs) as regards implementing DRIFT within MISHAP. The choice of the method of implementation also needs careful thought as implementation of the full code may be extremely complicated but allow the dispersion elements within MISHAP to be very flexible, whereas parameterisation simplifies the integration of DRIFT but constrains the dispersion modelling within MISHAP. The effort required for implementation will vary according to the chosen approach.

Deliverables: ***New version of MISHAP with updated dispersion model***
MISHAP Documentation updated to reflect changes

Decision: ***Which dispersion model and how to be implemented?***

3.4.5 Task 3.4 – Release model

The current release model in MISHAP is LOSSP/LOSSESP. It performs well for natural gas but does not perform well for other flammable gases. An alternative model exists, PipeTech, that has been produced by Professor Haroun Mahgerefteh of University College London. PipeTech is a state of the art CFD based computer programme for modelling and predicting release rates following the rupture of pressurised pipelines. However, there are a number of issues with its use that have to be considered:

- It may be too time demanding for direct implementation, although in the latest version run time has been vastly improved to around 2 hours; and
- There may be issues with the performance of PipeTech with small holes when compared with test data.

Work is currently ongoing to examine the latter issue. Assuming satisfactory resolution of this, it is expected that this work package will consist of:

- Determining how best to implement PipeTech into MISHAP;
- Resolution of any IPR issues associated with use of PipeTech in the chosen way;
- Codification of the chosen implementation approach;
- Parameterising PipeTech outputs, if this implementation option is chosen; and
- Testing implementation.

Deliverables: ***New version of MISHAP with updated release model***
MISHAP Documentation updated to reflect changes

Decision: ***Which release model and how to be implemented?***

3.4.6 Task 3.5 – MISHAP event tree probabilities

The purpose of this task is to review the constants used within MISHAP, particularly those associated with the event tree incorporated within MISHAP. The basis of some of these values is not clear and may be subject to challenge by industry and UKOPA. Therefore, evidence will be sought to justify the use of the current constants or further work will be carried out to determine more suitable constants.

Work is also currently ongoing in HSL to determine an appropriate building ignition probability for use in MISHAP. The recommendations from that work will be implemented as part of this work package.

Deliverable: ***A report will be produced that reviews the constants used within MISHAP, determines their basis and makes recommendations for any changes***

Decision: ***Acceptance of recommendation to adopt new constants or retain current constants***

3.4.7 Task 3.6 – Programming modifications

HID CI5 has identified a number of programming bugs within MISHAP. Although, most have been addressed, a number remain outstanding:

- There are a number of minor niggles following the conversion of MISHAP to VB6, for example problems with printing graphs and the online help file being out of date; and
- It is required that the user has the option of continuing the calculation after the display of the contours to create a file containing the values of risk on a rectangular 1-metre grid, starting from a user-specified origin and covering a user-defined domain.

The purpose of this task is therefore to capture the identified issues, determine whether these are still required, collate any further issues and make the required modifications to MISHAP.

Output from this task will be MISHAP updated to address the identified issues, the changes documented and MISHAP tested.

Deliverables: ***New version of MISHAP updated to address identified issues***
MISHAP Documentation updated to reflect changes

Decision: ***Which issues should be addressed?***

3.4.8 Task 3.7 – Grounded jets

MISHAP currently assumes that jets are vertical rather than along the ground. For non-natural gas grounded jets may be a real possibility that would increase risk from pipelines. However it is not currently clear how much of an issue this is. Work has been carried out in the past by HSL to determine the likelihood of this phenomenon. Therefore it is proposed that this task consists of:

- Reviewing the earlier work carried out on grounded jets by HSL;
- Reviewing wider sources of information and evidence on grounded jets;
- Determine the impact of grounded jets in terms of risk (both the likelihood of them occurring and the consequences should they occur); and
- Make recommendations on whether and how to implement grounded jets into MISHAP.

Deliverable: ***A report will be produced that considers the issue of grounded jets and makes recommendations on whether and how this should be incorporated into MISHAP***

Decision: ***Should MISHAP be updated to model grounded jets?***

3.4.9 Task 3.8 – GIS interface

The purpose of this task is to consider interfacing MISHAP with a GIS system, both in terms of production of risk contours but also in terms of interfacing with the National Population Database tool to improve the societal risk calculation. The task will be exploratory in nature and will determine (i) whether there is a business need for this approach to be adopted and (ii) the technical feasibility of such an approach. Output from the task will be a detailed case of what should be done, maybe with a number of options, and how it can be done. It is noted that currently HSE do not routinely provide contours around pipelines. However, for 'second bite' cases it is extremely difficult to be certain where the zone boundaries are when a pipeline has both bends and changes in wall thickness. The production of contour maps in this context is therefore desirable but could only be achieved if pipeline route information is available in GIS form. The project will therefore need to review the feasibility of this.

Deliverable: ***A report will be produced that recommends whether and how MISHAP should be interfaced to a GIS***

Decision: ***Should MISHAP be interfaced to GIS and/or the National Population Database?***

3.4.10 Task 3.9 – Testing

All the changes made to MISHAP will be tested at each stage. This is to ensure that the implementation of any new or adjusted feature or model has been correctly implemented and that these changes have no undesirable effect on the remainder of the methodology. A detailed test plan will be created and MISHAP will be tested against this plan.

Deliverables: ***Test plan***
Report documenting the results of the testing

Decisions: ***Acceptance of test plan***
Acceptance of revised MISHAP

3.5 WORK PACKAGE 4 – TESTING AND IMPLEMENTATION OF ENTIRE ROUTE

The purpose of this work package will be to test the changes made to the entire route and implement this into HID CI5.

It is proposed that the following tasks are required:

- Task 4.1 – Testing of pipeline RISKAT
- Task 4.2 – Implement into HID CI5 and test
- Task 4.3 – Pipeline RISKAT documentation
- Task 4.4 – Training needs

A diagram illustrating the interaction between the above tasks is shown in Figure 7.

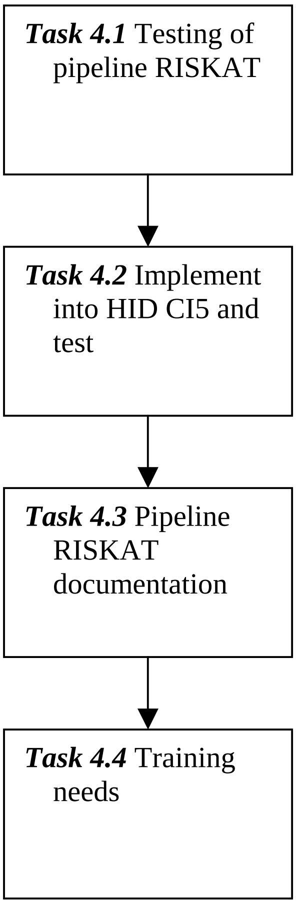

Figure 7 Key tasks in Work Package 4

3.5.1 Task 4.1 – Testing of pipeline RISKAT

The purpose of this first task is to fully test the integration of the revised version of PIPIN, MISHAP, the pre and post processors and the controller. A test plan will be developed to fully test the route. A part of this will be to compare the new route with the current route. Any differences between the two approaches will be identified and justified.

Deliverables: ***Test plan***
Test cases
Report documenting the results of the testing

Decisions: ***Acceptance of test plan***
Acceptance of pipeline MISHAP
Resolution of any impact on current consultation distances

3.5.2 Task 4.2 – Implement into HID CI5 and test

The purpose of this task is to implement pipeline RISKAT onto the HID CI5 system and test the implementation of it. The test cases developed as part of Task 4.1 will be re-run.

Deliverables: ***Pipeline RISKAT implemented***
Results of test cases run documented

3.5.3 Task 4.3 – Pipeline RISKAT documentation

The purpose of this task is to identify and produce any overall documentation and guidance associated with pipeline RISKAT.

Deliverable: ***Required documentation and guidance produced***

3.5.4 Task 4.4 – Training needs

The purpose of this task is to identify training needs associated with the use of pipeline RISKAT, develop training material and deliver training.

Deliverable: ***Delivery of training to users***

3.6 TECHNICAL AND POLICY ISSUES

Throughout the work packages, various decisions will have to be made. These cover both technical and policy issues. Table 3 summarises the key decisions. Where possible, key decisions will be grouped together and discussed, for example, at half-day seminars, where it can be agreed how to progress the implementation of pipeline RISKAT.

Table 3 Summary of technical and policy issues

Decision number	Task	Decision
D1	1.2	Acceptance of controller design and functionality
D2	1.2	Which code should be used for programming?
D3	1.5	Acceptance of test plan for controller and pre and post modules
D4	1.5	Acceptance of pre and post processor modules and controller
D5	2.2	Which failure rate approaches should be further considered for implementation by HSE?
D6	2.3	Which mitigation measures should be incorporated within the failure rate model?
D7	2.6	Which failure rate option should be adopted?
D8	2.6	Acceptance of failure rate module specification
D9	2.8	Acceptance of test plan
D10	2.8	Acceptance of failure rate module
D11	3.1	Identification of areas for further work or acceptance of identified approaches for MISHAP
D12	3.2	Which jet fire model and how to be implemented?
D13	3.3	Which dispersion model and how to be implemented?
D14	3.4	Which release model and how to be implemented?
D15	3.5	Acceptance of recommendation to adopt new probabilities or retain current probabilities within MISHAP event trees
D16	3.6	Which MISHAP programming modification issues should be addressed?
D17	3.7	Should MISHAP be updated to model grounded jets?
D18	3.8	Should MISHAP be interfaced to GIS and/or the National Population Database?
D19	3.9	Acceptance of MISHAP test plan
D20	3.9	Acceptance of revised MISHAP
D21	4.1	Acceptance of pipeline RISKAT test plan
D22	4.1	Acceptance of pipeline RISKAT
D23	4.1	Resolution of any issues associated with impact on current consultation distances

3.7 DELIVERABLES

The deliverables from this project are summarised in Table 4.

Table 4 Summary of deliverables

Product number	Task	Product
P1	1.2	Report specifying the design of the controller, and pre and post processors
P2	1.3	Codified pre and post processors
P3	1.3	Documentation describing use and operation of the pre and post processor modules
P4	1.4	Codified controller
P5	1.4	Documentation describing use and operation of the controller
P6	1.5	Test plan for processors and controller
P7	1.5	Report documenting the results of the processors and controller testing
P8	2.2	Report describing the review of failure rate developments
P9	2.4	Report describing the critique and validation of the industry failure rate model
P10	2.5	Report describing the review of appropriate use of historical failure rate data
P11	2.6	A case shall be made for which failure rate model option(s) to adopt
P12	2.6	Specification for the chosen failure rate model option
P13	2.7	Revised failure rate module
P14	2.7	Documentation describing use and operation of the failure rate module
P15	2.8	Test plan for failure rate module
P16	2.8	Report documenting the results of the failure rate module testing
P17	3.1	A paper to panel identifying the areas to be considered for further work or implementation in terms of MISHAP
P18	3.2	New version of MISHAP with updated jet fire model
P19	3.2	MISHAP Documentation updated to reflect jet fire model changes
P20	3.3	New version of MISHAP with updated dispersion model
P21	3.3	MISHAP Documentation updated to reflect dispersion model changes
P22	3.4	New version of MISHAP with updated release model
P23	3.4	MISHAP Documentation updated to reflect source model changes
P24	3.5	A report will be produced that reviews the constants used within MISHAP, determines their basis and makes recommendations for any changes
P25	3.6	New version of MISHAP updated to address identified programming issues
P26	3.6	MISHAP Documentation updated to reflect programming changes
P27	3.7	A report will be produced that considers the issue of grounded jets and makes recommendations on whether and how this should be incorporated into MISHAP
P28	3.8	A report will be produced that recommends whether and how MISHAP should be interfaced to a GIS and the National Population Database
P29	3.9	Test plan for MISHAP
P30	3.10	Report documenting MISHAP testing
P31	4.1	Test plan for pipeline RISKAT
P32	4.1	Test cases for pipeline RISKAT
P33	4.1	Report documenting the results of the testing
P34	4.2	Pipeline RISKAT implemented
P35	4.2	Results of test cases run documented
P36	4.3	Required documentation and guidance produced
P37	4.4	Delivery of training to users

3.8 RESOURCES, TIMESCALES AND COSTS

Resources, timescales and costs have not been estimated at this stage due to the many unknowns. These will be estimated within the detailed project plans produced for each work package.