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Flow of Safety-Related Structural Integrity Information in the Offshore Industry

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SUMMARY:

This report describes a study undertaken to investigate the flow of safety-related structural integrity information (SRSII) in the offshore industry. The aim of the study was to contribute to improving the effectiveness with which SRSII for offshore structures is managed by collecting sufficient data to form an initial model of information flow within the industry.

An initial model of information flow was hypothesised to provide structure for the work to follow. This model was based on the lifecycle of an installation. A review of relevant regulations was carried out, which focused the questions for the interview stage of the project. A literature search was carried out, and a number of papers reviewed relating to the management of SRSII. The literature on the subject is quite sparse, focusing more on technical issues of structural analysis than on the use and transmission of information. However, structural integrity programmes in the aircraft and shipping industries were identified which may offer some helpful features of information storage and use to the offshore industry. Interviews were carried out with representatives from operator and designer organisations, with two HSE inspectors, and with two structural specialists in the nuclear industry. The results from the nuclear industry indicated a stricter regulatory regime and higher consequence hazards, with less variation in inspection regimes, and an investment in continuous monitoring of the structural integrity.

The interviews were summarised and a number of 'exchanges' extracted from the information. Each exchange related to a transfer of information in one direction between two parties. The source, user, use, description, scope and transmission method was described for each exchange.

Analysis of the information from the interviews showed that the hypothesised model was insufficient in a number of areas. In particular, the responses in the interviews focused on concept and design, and on operation, maintenance and inspection, with little information about the fabrication and construction phases in the initial model. In addition, the sequential lifecycle model whilst it showed information flow for a particular installation did not represent the richness of information available about communication between different groups of people. Taking on-board the findings a second model was developed to show the concurrent flow of information between organisations, and between sub-groups within organisations which overcame the short comings identified in the initial model.

Both the literature review and the interviews indicate the increasing use of computers as a means of storage and transmission of information. In particular, systems to manage inspection and maintenance planning are now available, although their use is still limited. Electronic safety cases are being maintained by some operators for their own use, although paper based safety-cases, procedures and other documentation still appear to be the most common form of storage and transmission of information.

A number of areas are outlined in the conclusions to suggest directions for further work in improving the management of safety related structural integrity information in the offshore industry.

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Glossary

Domain	**Term / abbreviation**	**Meaning**
Aviation	ASIP	Airframe Structural Integrity Program [reference 23]
Offshore	Asset	The field or installation as considered from a financial point of view.
Offshore	BPX	BP Exploration
Offshore	Duty holder	The operator (or owner in the case of a mobile installation) with the responsibility for the Safety Case [reference 04].
Aviation	ECCAIRS	European Co-ordination Centre for mandatory Aircraft Incident Reporting Systems
General	Exchange	Used to describe transfer of information between two parties in one direction. One exchange is represented by one record (or one row) in the project database.
Offshore	FMD	Flooded Member Detection
Shipping	MSIP	Marine Structural Integrity Program [reference 23].
Offshore	OIM	Offshore Installation Manager
Offshore	Operator	For a fixed installation, the person appointed by a concession owner to execute any function of organising or supervising any operation to be carried out by such installation or, where no such person has been appointed, the concession owner. [reference 04]
Offshore	ROV	Remote Operated Vehicle
Offshore	SI	Structural Integrity
Offshore	SRSII	Safety Related Structural Integrity Information
Shipping	SSIS	Ship Structural Information System
Offshore	UKOOA	United Kingdom Offshore Operators Association

1 INTRODUCTION

1.1 Background

Modern legislation for the offshore industry is based on goal setting rather than on prescription, and therefore demands an improved flow of and access to information. Of particular concern to this study is the information concerned with structural integrity (SI) which is needed to aid safety demonstration. Information needs within the industry are wide, ranging from generic information to installation specific information. The audience for information includes professionals and the workforce. The HSE provides some generic information in the form of guidance documents and research reports. Other information exists within a particular discipline, but the way in which it is transmitted to other disciplines is unclear. There is currently no easy measure available of how much information gets to those who need it. This project seeks to understand the current flow of SI information within the offshore industry, to make comparisons with information flow in other industries, and by modelling this flow, to suggest improvements.

1.2 Objectives

The overall aim of the study was to contribute to improving the effectiveness with which safety-related structural integrity information (SRSII) for offshore engineering structures is managed. The intent was to achieve this by collecting sufficient data to form an initial model of information flow within the industry. This data was to include details of:

- the roles of the participants involved in the generation and dissemination of information;
- who provides information to which users;
- the type of information exchanged and the use made of information;
- how information is exchanged;
- where possible, the lifetime of the information.

Development of this model should assist the HSE and others in identifying how the flow of Structural Integrity (SI) information can be made more effective.

1.3 Scope

The scope of the study can be considered within a number of areas.

1.3.1 *The Type of Information Exchanged*

A key component of information management is understanding the flow of information between parties. The project was concerned primarily with the flow of safety related information about structural integrity (SI) - not about general safety information. However whilst SI may have a different origin, it can be a subset of general safety, and therefore the information may follow the same routes. Whether there is a separate flow for SI was considered as part of the study. The flow of information is a sub-set of the overall concept of management of information. A full consideration of all aspects of management was beyond the scope of this report, but where information was available, storage and use of information has been described.

1.3.2 *Participants, their Roles and their Sources of Information*

To some extent, the scope of the study was focused by the selection of interviewees provided by the client. For example, an SI specialist was interviewed from the operator, and information was gathered from SI specialists and a safety expert within a design organisation. The sources of information established may have been different if interviews had been conducted with different specialists, and with operational staff.

1.3.3 *How Information is Exchanged and its Lifetime*

The study also attempted to gather information about the means of exchange of information, and the lifetime of information. In this context, lifetime includes both the immediacy of use of the information, and the period of time for which the information remains valid.

1.3.4 *Industries*

Although the main focus of this study was on the offshore industry, other industries were assessed to establish if any useful practices may be available. In particular, interviews were carried out with representative from the nuclear industry. In addition, construction, shipping and aviation were featured in the review of regulations and literature.

2 TECHNICAL APPROACH

The study consisted of the following phases:

a) Hypothesis development.

b) Review of the regulations and general literature.

c) Interviews with offshore industry and nuclear industry representatives.

d) Analysis of the results.

2.1 Hypothesis Development

At the start of the study, it was hypothesised that maintaining the integrity of an offshore structure requires different activities at each stage of the life-cycle. For example, the design must make the correct assumptions, and use appropriate design codes which take account of the materials being used, the method of construction and the environment in which an installation will operate. Fabrication and construction must follow any assumptions made in the design, and be carried out correctly with no short cuts. During operation, maintenance and inspection is required to ensure that integrity is maintained, and that corrective action is taken when needed. In particular, erosion, corrosion and fatigue of sub-sea structures if unnoticed and uncorrected can lead to disaster. This hypothesis is illustrated in Figure 4.1 and directed much of the questioning during the interview stage, and was revised during the final analysis stage.

2.2 Review

A review of regulations, guidance documents and other relevant literature was carried out to provide the background for interview questions, and to identify information flow models in certain other industries.

2.2.1 *Scope of the Review of Regulations*

The study included a review of regulations and guidance related to those regulations. This includes specific regulations for the offshore industry: the Safety Case Regulations (SCR) 1992 (reference [04]), Offshore Installations and Pipeline Works (Management and Administration) Regulations (MAR) 1995 [15], and Offshore Installations and Wells (Design and Construction) Regulations (DCR) 1996 (references [01], [02] and [03]). General legislation has also been included, in particular the Management of Health & Safety at Work Regulations (MHSW) 1992 [14].

With respect to other industries, the Construction (Design and Management) Regulations 1994 (reference [09]) were reviewed.

2.2.2 *Scope of the Literature Review*

The literature review undertaken set out to answer a number of questions:

1. Is there evidence of systems for the flow of Safety-Related Structural Integrity Information (SRSII) in the offshore industry / in other industries? If yes, in which companies, in which industries, and what do these systems provide that can be of use to developing a system for management of SRSII?

2. Have other studies been carried out to investigate the flow of Safety-Related Structural Integrity Information? If yes, what did they find? Do any studies provide recommendations on how to manage SRSII?

3. Have any other studies made comparisons of information flow across industries? If yes, which industries are good at managing SRSII?

4. Are there any examples of particularly poor management of SRSII?

A list of databases searched as part of this study is included in Section 6.1. The project reports containing the background data for the study are listed in Section 6.2. A list of documents reviewed is included in Section 6.3.

2.3 Interviews

Interviews with key staff from a number of relevant organisations were arranged and carried out in order to collect data for the model of information flow. Following each interview, the notes were written up and returned to the interviewees for them to approve and correct.

2.3.1 *Scope of the Interviews*

Interviewees within the off-shore industry were chosen to represent the following:

- An operator
- A designer
- A design specialists
- An HSE inspector with a particular understanding of structural issues
- A general HSE inspector

In addition, interviews were carried out with personnel in the nuclear power industry in order to gain an understanding of how SI information is handled in an other high risk, high integrity and regulated sector.

The names and organisations of the interviewees are included in the report with the individual reports of the interviews in Appendix D.

2.4 Analysis

Information from the interviews was analysed, using an initial set of descriptors covering sources, flow routes, storage of information and so on, and broken down into communication exchanges. The information was entered into an Access database, with each exchange (for example, “HSE provide us with information on regulations”) as a separate record in the database. This enabled more effective sorting of the information, and re-categorisation of each aspect of the exchange until a coherent structure emerged. Each single record or ‘exchange’ in the final database had the following fields:

ID - a unique identifier for each record.

Description - a description of the information as described in the interview.

Scope - a category (for example, materials or, structural integrity), which defined the scope of the information.

Source organisation - the organisation type which provided the information. For example, operator, designers, HSE.

Source sub-group - the sub-group within the source organisation which provided the information, for example in the case of an operator, this could be the asset, the workforce, a specialist group and so on.

User organisation - the organisation type which used the information (see Source organisation).

User sub-group - the sub-group within the user organisation which used the information (see Source sub-group).

Use - the use made of the information, as described by the interviewee.

Transmission - a general description of how the information is transmitted from source to user.

Transmission type - to aid analysis, the general transmission descriptions were categorised into 6 categories. Each exchange can have more than one transmission type associated with it. The six categories are:

- *Computer*
- *Paper*
- *Procedures*
- *Safety Case*
- *Verbal*
- *Visual*

Storage - where information is known to be stored the method of storage is noted.

Lifetime (Currency) - this refers to time between when the information is available and when the information is used. For example, ‘immediate’ or ‘long-term’.

Lifecycle origin - the stage in the lifecycle when the information is ‘created’. In some cases, it was not possible to assign information to a particular stage of the installation lifecycle, so a number of other categories, such as ‘research’ and ‘general’ were also used.

Lifecycle use - the stage in the lifecycle when the information is used. See Lifecycle origin.

Interview - the name of the company of the interviewees which provided data on this exchange of information

Industry - the industry the information relates to.

A number of outputs from the database were defined, which show the model of information flow deduced in this study. These outputs are included in Appendix B and explained in Section 3.

3 RESULTS & FINDINGS

3.1 Offshore Regulations

As suggested earlier, the key purpose of the review of regulations and literature was to indicate what areas of questioning would be appropriate within the interviews, and to understand the regulatory framework with respect to structural integrity of installations. This report will not present a detailed review of the regulations, as the reader is expected already to be familiar with those regulations. However, a number of points are worth highlighting from the regulations.

3.1.1 *Safety Case Regulations*

The Safety Case Regulations (SCR) (reference [04]) place a requirement on duty holders to produce the following stages of safety cases for fixed installations:

- DESIGN SAFETY CASE: to define how the design will provide for inherent safety, the means of verifying quality of details design and construction, and systems to achieve safe offshore construction and commissioning.
- PRE-OPERATIONAL SAFETY CASE: to describe installation, activities and systems, and the limits for safe operation.
- ABANDONMENT SAFETY CASE: to detail the proposed methods for decommissioning plant, the proposed methods for closure of wells, and the proposed methods for removal of structure

According to the regulations, the Safety Case should be updated periodically to take account of changes in technology or changes in the environment, and of other developments which might affect the validity of the original safety case. In addition, updates are required for combined operations to demonstrate the adequacy of arrangements for co-ordinating management, and for major revisions, when modifications will materially alter the safety case. In particular, the guidance relating to regulation 9 reads:

> *Even apparently minor changes should be assessed, and arrangements made for the logging of all such modifications, and for all relevant documentation to be updated when appropriate, ensuring that the amendment is recorded in all copies of such documents that may be in use.*

Regulation 2(9) states that when a new owner takes over, they inherit all legal responsibilities from their predecessor under these regulations. Loss of information could occur at this stage. It was therefore important to ask interviewees about information transmitted at this stage.

Schedules 1 and 2 in the regulations outline the particulars to be included in a safety case for the design and operation of a fixed installation. Table 3.1 summarises those particulars which relate to SI.

TABLE 3.1: PARTICULARS FROM SCHEDULE 1 AND SCHEDULE 2 OF THE SCR RELATING TO SI

Particular to be included	Schedule
Description of how the management system will ensure that the structure of the installation will be designed, selected, constructed and commissioned in a way which will reduce risks to health and safety to the lowest level that is reasonably practicable.	1
Description and diagrams of main and secondary structure of installation	1, 2
Plan of location and particulars of meteorological and oceanographic conditions expected and sea-bed properties and sub-soil.	1, 2
Operations and activities installation is to be capable of performing	1, 2
Maximum number of persons present and to be accommodated.	1, 2
Arrangements for TR and evacuation	1, 2
Performance standards established for structures in case of an incident, and minimum period for which the arrangements are intended to be effective following the incident.	1, 2
Intended methods of design and construction, and codes of practice to be observed.	1
Features, arrangements and procedures for design, construction and commissioning	1
Limits specified in the design for safe operation/ use of the installation and its plant	2
Details of any remedial work to be carried our to the installation or the plant and the time by which it will be done.	2

Further requirements for the content of the Safety Case are given in paragraph 108 of the General Guidance. The following items to be included relate to SI:

- Minimum endurance time for relevant structures and plant.
- Functions to be performed by relevant structures.
- How necessary physical protection will be provided for personnel and systems, to enable communication and management of incident.
- Range of possible accidental events which may threaten the integrity of relevant structures - which are ‘design events’, which beyond design, or ‘extreme events’.
- Duty holder’s criteria as regards the conditions which constitute loss of integrity of relevant structures; for example, loss of integrity is equivalent to loss of structural support (collapse of jacket or supporting structure; loss of buoyancy or stability of floating unit; collapse of walls or roof or floor). Loss of availability of means of escape may also equal loss of integrity.
- Minimum period for which structures are designed to maintain integrity in the face of ‘design events’.

SCR state that the Safety case should demonstrate “clear, unbroken lines of command and accountability” (general guidance, paragraph 17 b). Hence, questions about communication within the operator’s organisation were also asked.

The Safety Case, therefore, represents an important document for the storage and transmittal of SI, and questions about the role of the Safety Case were included in each interview. Questions on the Safety Case stemming from these regulations included:

- What understanding is there of the need to revise or re-submit safety cases?
- How is information about changes in technology assessed to establish whether or not it affects the validity of the Safety Case?
- How is relevant documentation tracked when changes are made?
- How is the contents of the safety case communicated to people working offshore, and are their opinions fed back into the safety case?
- What information do new duty holders get, and how do they receive it?
- How is information of relevance to SRSII communicated around the company?
- How is information fed back on use of / acceptance of / compliance with procedures?

3.1.2 *Design and Construction Regulations (DCR)*

The Offshore Installations and Wells (Design and Construction etc) regulations 1996 (DCR - References [01], [02], [03]) seek to ensure that an offshore installation is:

- designed,
- constructed,
- operated,
- maintained and
- decommissioned,

so that the level of integrity is as high as reasonably practicable, and the level of risk to personnel is as low as reasonably practicable. Regulation 10 of the DCR (Reference [01]) requires that where there is evidence of a significant threat to the threat to the integrity of an installation, the duty holder reports this to the HSE, in writing, specifying actions taken (or to be taken) to avert the threat.

DCR provides a legal definition of integrity which is used for this study:

> *'integrity' means structural soundness and strength, stability and, in the case of a floating installation, buoyancy in so far as they are relevant to the health & safety of persons. (DCR: Reference [01] Part 1, reg 2, (19)).*

DCR take notice of the importance of ensure the integrity of an installation throughout its lifecycle by taking account during the design phase of the potential for degradation and corrosion, and putting appropriate safeguards into effect.

The duty to ensure the structural integrity of the installation rests clearly with the duty holder. In particular, regulation 5 (part 1) explains that the duty holder must ensure that the design and construction are such that the installation can withstand the reasonably foreseeable forces, that the layout will not prejudice integrity, that the fabrication, transportation, construction, commissioning, operation, modification, maintenance and repair of installation may proceed without prejudicing its integrity, that the installation may be decommissioned and dismantled safely; and that in the event of reasonably foreseeable damage to the installation it will retain sufficient integrity to enable action to be taken to safeguard the health and safety of persons on or near it.

As a consequence, questions were asked in the interviews about what information the duty holder has to ensure the regulations are met, and especially how information on previous lifecycle stages is maintained.

A further useful concept defined in DCR [03] (and thereby introduced into the SCR) is that of ‘safety-critical elements’:

> *‘safety-critical elements’ means such parts of an installation and such of its plant (including computer programmes), or any part thereof: a) the failure of which could cause or contribute substantially to; or b) a purpose of which is to prevent, or limit the effect of, a major accident. (Regulation 26, schedule 2)*

The guidance goes on to explain that the identification of an item as safety-critical should follow from the identification of major accident hazards required

The DCR also raise issues relating to the designer’s role. For example, design should be based on ‘current good engineering practice’ and should take account of ‘reasonably foreseeable forces which the installation will need to withstand during its life cycle’, for example, environmental conditions, planned movements, the weight of or on an installation, vessel impact and accidents

This suggested question areas relevant to designers:

- How do design companies ensure continuing good engineering practice?
- How are designers given an appreciation of ‘reasonably foreseeable forces which the installation will need to withstand during its life cycle’?

According to the DCR, design should take account of activities expected in the lifecycle so that those activities do not prejudice integrity. The design may include provision for activities (for example, construction, de-ballasting, major modifications, inspection and maintenance) to be carried out in a particular way. Questions to elicit data on how such provisions are recorded and adhered to were included in the interviews.

The DCR discusses the requirements for decommissioning and dismantling, and hence questions on this topic were asked.

The expectations that a new duty holder who purchases an installation will obtain sufficient evidence of the approach taken to the design and the methods of fabrication to establish integrity have already been noted in the Safety Case Regulations [04]. These are repeated in the DCR.

Requirements related to inspection, maintenance and repairs are described in the DCR. To assess information flow on this topic, questions were asked on the source of information for decisions regarding the frequency of inspections and maintenance.

3.1.3 *Management and Administration Regulations (MAR)*

The Offshore Installations and Pipeline Works (Management and Administration) Regulations 1995 (known as MAR, reference [15]) outline broad based requirements for the management of offshore installations. While the focus of these regulations is, as the name suggests, on management and administration, they provide a useful definition of an ‘offshore installation’, and explain the relationship between the primary duty holder (that is, the operator of a fixed installation or the owner of a mobile installation, the OIM (offshore installation manager), the concession owner and the employees.

Regulation 11 in the MAR is relevant to this study, and states the requirement for the duty holder to put into writing comprehensible instructions on procedures to be observed on the offshore installation, and to bring to the attention of each person the relevant part of each instruction. This can be relating to the requirement for the designer to make provision for activities such as maintenance and de-ballasting, and to provide details of such provisions to the duty holder. Regulation 11 requires the transmittal of information from designer to duty holder to the workforce who have to take account of the design provisions made. Questions were therefore included in the interviews on how the workforce are made aware of any limits set by designers.

3.1.4 *Prevention of Fire and Explosion and Emergency Response Regulations (PFEER)*

The Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) regulations 1995 (PFEER, reference [11]) provide a list of situations which are considered as a ‘major accident’ under these regulations. This list includes “any event involving major damage to the structure of the installation or plant affixed thereto or any loss in the stability of the installation.”

An important concept in PFEER is that of performance standards. Performance standards must be established as part of an assessment of accident hazards, to provide for effective evacuation, escape, recovery and rescue or to otherwise protect people from a major accident. A performance standard is defined as:

> *.. a statement, which can be expressed in qualitative or quantitative terms, of the performance required of a system, item of equipment, person or procedure, and which is used as the basis for managing the hazard - eg planning, measuring, control or audit - through the lifecycle of the installation. The regulation does not specify what performance standards should be - that is for the duty holder to decide, taking account of the circumstances on the particular installation. (PFEER [11], paragraph 44).*

Interviews included questions on the information used by duty holders to set performance standards.

3.2 Other Regulations

3.2.1 *Management of Health & Safety at Work Regulations (MHSW)*

The Management of Health & Safety at Work regulations (MHSW, reference [14]) places a requirement on all employers to make an assessment of risks to the health and safety of employees and of others affected by them; this assessment should be reviewed if information used is believed to be no longer valid. Questions were included in the interview about the effect of changes in available information, and in particular if changes in technical knowledge led to re-consideration of operational procedures, inspection planning or the Safety Case.

3.2.2 *Construction (Design and Management) Regulations (CDM)*

In making comparison with other industries, the Construction (Design and Management) Regulations 1994 (CDM, reference [09]) are of particular interest, presenting the Health & Safety file as the mode of communicating information throughout all stages of a buildings life-cycle, from initiation and design, through construction phases, handover and use, to repair and reconstruction and demolition. There are clear parallels here between the Health & Safety file in construction and the Safety Case in the offshore industry, although the requirements for the Health & Safety file appear less rigorous than those for the Safety Case.

3.3 Literature Review

3.3.1 *General Comments on the Literature Review*

Generally, whilst there is a lot of literature about particular technical aspects of structural integrity, it is difficult to find sources of information about the flow of such information. Some papers which sound promising, by including words such as ‘management’ in the title turn out to be nothing more than arguments for the use of a particular method of mathematical analysis of structural integrity. The most useful papers were those which described a program or system for encouraging the storage and access of information.

3.3.2 *Lifecycle of Offshore Structural Concerns*

Information from the literature was sought on each of the lifecycle stages (from concept and design, through fabrication, construction, installation and commissioning, to operation and maintenance, and finally decommissioning and dismantling). It is an interesting result in itself that only information on concept and design, and on operation (including maintenance and inspection) was available.

3.3.2.1 **Concept and Design**

The design of an offshore structure must take into account a number of issues, with design criteria set for each one. The HSE Strategy document reference [05] lists a number of these:

- fatigue (time dependent)
- corrosion (time dependent)

- extreme waves
- earthquake
- fire & explosion
- boat impact
- dropped objects

Choice of materials is also part of the design phase, and designers need to be aware of the limits of materials proposed.

The DCR [01, 02, 03] and SCR [04] are discussed in more detail in Sections 3.1.1 and 3.1.2. One requirement is for the identification of “Safety-Critical Elements” (SCE) during the design of new installations. UKOOA (United Kingdom Offshore Operators Association) have produced guidelines for the management of SCEs [06].

The definition of a SCE given in the UKOOA guide [06, 1.2] is the same as the one quoted from the Design and Construction regulations [03] in Section 3.1.2.

Identification of SCE’s is therefore a key area of demonstrating the integrity of the design of a structure. The UKOOA guide [06] recommends this is done by looking at each major accident hazard, and listing each element associated with that hazard. This will produce a list of the elements which are safety critical, and the number of times the element is listed will give some indication of its importance. Interviewees were each asked about their method of identifying SCEs, to see whether this method was widely used. Performance standards for each SCE are also set at this stage, making use of design codes, international standards, inspection and test programmes.

From industry, BP’s exploration group (BPX) have produced a document on their approach to Structural integrity assurance [17]. With respect to design, this approach highlights environmental design criteria and structural analysis as important in ensuring structural integrity. For example, the approach recommends that structural models are maintained and updated routinely to reflect changes, with the model run to confirm structural integrity at significant milestones.

3.3.2.2 **Operation**

The operation phase includes maintenance and inspection. A number of alternative inspection philosophies are available [05], for example, deterministic versus goal based; visual inspection versus alternative ‘indirect’ methods. In addition, different strategies are applied to planning, and in particular to the intervals between inspections.

During the operation phase, the performance standards set for SCEs within the design phase need to be met [06]. This is demonstrated and checked through inspection programmes.

In the operational phase, the BPX approach [17] highlights topside weight control and structural inspection as important in ensuring continuing structural integrity. In particular, the approach suggests that all permanent changes in weight and distribution of weight should be assessed against the platform's design capacity and recorded in a systematic manner, and that temporary changes in weight should be in accordance with the allowable loading limits specified in the Operations Manual.

A paper by Dharmavasan et al (1994, reference [24]) concentrates on inspection scheduling for offshore structures, and proposes the use of reliability theory to make inspection and maintenance scheduling more rational. Usefully, this paper lists a number of different techniques for collecting inspection data, including:

- swim-round surveys: to look for general damage and marine growth
- detection of flooded members: indicates through-thickness cracks
- seabed debris survey
- scour survey of foundations
- anode condition as a percentage of eroded or remaining growth
- monitoring marine growth
- inspection of welded joints (corrosion, pitting, grinding marks, cracks)

Although not focused on concerns of structural integrity, a case study within Agip [18] has demonstrated both the possibility of an operator adapting its culture to electronic document management systems, and the savings that are possible within an organisation. The case study claims direct cost reductions of up to 15% on contractors costs, with many other indirect cost reductions, and a reduction in timescales for a project from 3 years to 2 $^{1}/_{4}$ years.

3.3.3 *Nuclear Industry*

Most published work from the nuclear industry covers assessment methods and techniques rather than the flow of information. One paper reviewed in detail [31] did provide an indication of the flow of information. The paper focuses on two key phases - design and operation. The design phase receives information from a database of material properties, from codes and standards, from the service requirements, and from the use of analytical tools, methods and tests. The design limits and knowledge of the physical and mechanical properties of the materials used are passed through to the operation phase via structural integrity arguments, normally recorded in the plant Safety Case. During operation, inspection, diagnosis and assessment of existing or hypothetical defects, including non destructive inspection, provide continuing information as to the continuing status of the plant's integrity. The concept of structural integrity assurance is emphasised in the paper, and defined as:

> *.. the demonstration that a structure or component meets it required duty with appropriate consideration of safety and economics... a multi-discipline activity which involves inspection, diagnosis, assessment and formulation of safety arguments, design criteria and repair/ replacement strategies and their implementation.*

The activity of SI assurance makes use of information from inspection and monitoring of the plant, from materials science, from structural analysis, and from general engineering safety and economic assessment. There is a large investment in significant on-going inspection programmes rather than periodic or ad-hoc surveys.

3.3.4 *Other Industries*

Of the papers reviewed relating to industries other than the offshore industry, one particularly interesting one related to interfaces issues in safety [Curtis, 22]. This identified the complex and iterative relationship between design and assessment of major hazard plant. Most difficulties in information flow arise at the interfaces between design, operation and safety assessment. Examples given include Flixborough, where information about the safety aspects held by operations management was not available to the maintenance staff. At two levels of communication, the Herald of Free Enterprise disaster may have been avoided: firstly, if the flow of information from sea-going officers to head office senior management had been better, and secondly if the information from the load deck to the bridge had been better. One finding of this paper [Curtis, 22] is that difficulties in information flow at the interfaces:

> *.. do not arise because of the different levels of understanding or different mental paradigms of the parties, so much as from the fact that the need to communicate is sometimes simply not appreciated.*

Curtis sees the safety case as a means of communicating between designers and operators and regulator, in the same way that log books are used to pass information between shift teams. A useful distinction in reference [22] is between *sequential* and *concurrent* interfaces. Sequential interfaces are those between people or organisations at different stages of the lifecycle, whilst concurrent interfaces are those between parties at any one point in time. This distinction will be used later in the discussion (Section 4).

Surprisingly, the richest vein of information regarding the flow of information specifically related to structural integrity came from the shipping industry. Two papers in the review relate directly to this (References [23], [26]).

In the USA, the Department of Naval Architecture and Offshore Engineering at the University of California, have been working with the US Coast Guard to produce an “advanced Marine Structural Integrity program” (MSIP) [23]. MSIP is based on the Airframe Structural Integrity program (ASIP) for commercial and military aircraft.

ASIP resulted from a number of fatigue cracking and corrosion problems identified in aircraft, and led to new regulations, design, operation and maintenance guidelines, and certification requirements for the process of aircraft development, procurement and management.

MSIP suggests a sequence of technical and organisational developments to provide increased confidence in the integrity and durability of ship structures during their useful lifetimes. MSIP was then developed into a computerised Ship Structure Integrity Information System (SSIIS) [reference 26]. SSIIS aims to integrate information to assist in the lifecycle management of marine structures, to support inspection planning, to record inspection results, to aid the design of repairs and to analyse failure trends.

Some of the key goals of SSIS are relevant to this study:

- centralised archiving, evaluation and dissemination of potentially important information relating to structural integrity (SI);
- training, testing, verifying capabilities and performance of design, manufacturing, operations, maintenance personnel;
- co-operative associations between major sectors (regulator, owner/ operator, production and maintenance, and classification) with focus on safety and durability, avoiding 'hidden agenda' and legal impediments to communications;
- development and application of comprehensive approach to engineering for and maintenance of structural reliability;
- structures to be designed for 'constructability', inspection and maintainability;
- increase involvement of vessel's management in solution of identified structural and maintenance problems;
- management tool to track historical performance of vessel and identify problem areas;
- improved inspection planning, through analysis of existing failure trends, to provide focus for periodic inspection;
- improved repairs; using a decision support system/ expert system to advise on the best repair for a given failure based on cost effectiveness.

Whilst MSIP is designed to manage information flow for a single vessel, there is an implication in the paper that such management will enable lessons learnt to be transferred to other vessels across the marine industry.

Figure 3.1 shows the model of information flow described in reference [26].

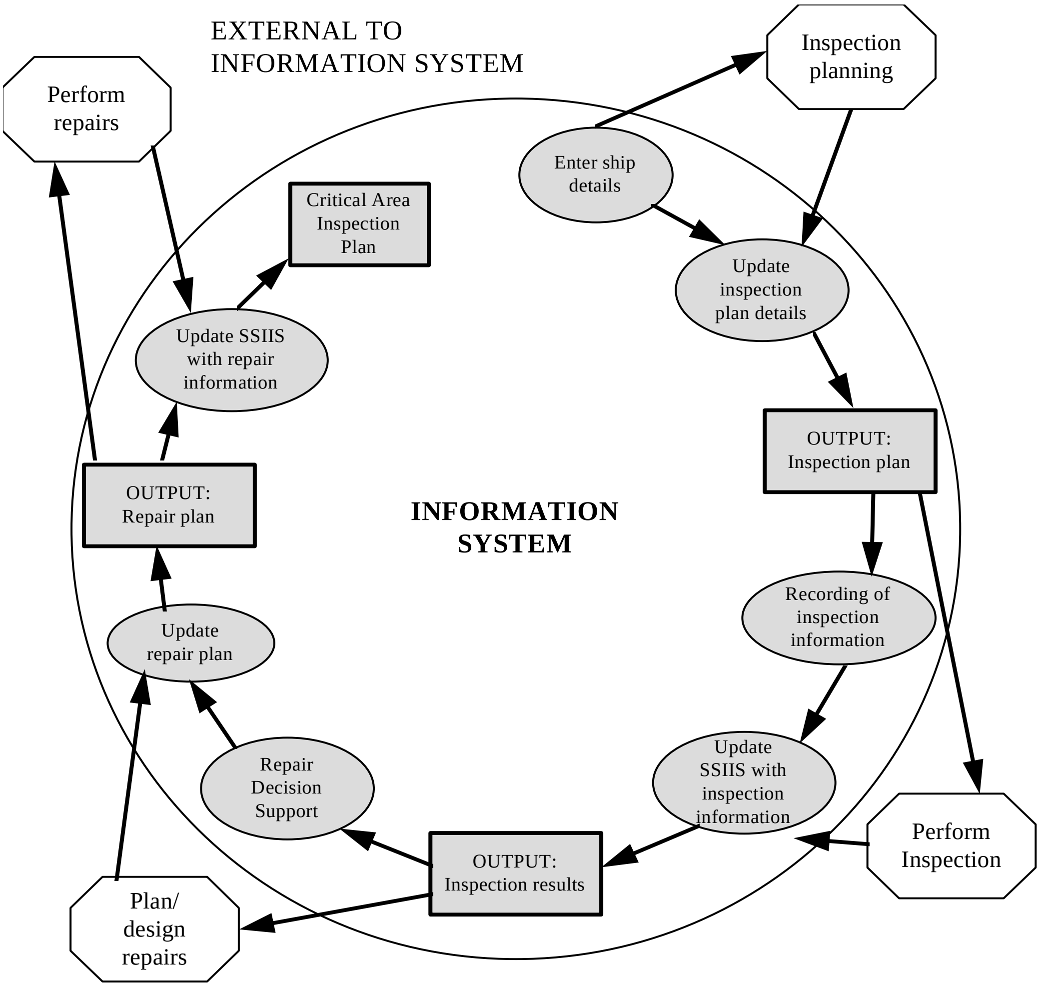

FIGURE 3.1: SHIP STRUCTURE INTEGRITY INFORMATION SYSTEM PROCESS FLOW (Adapted from [26])

The idea of developing a database of information related to a structure to aid inspection planning is also considered with respect to pipelines in [28]. ‘PIMOS’ (Pipeline Inspection and Maintenance Optimization System) has been developed as a decision-making tool to maintain the integrity of natural gas transmission pipelines through proactive inspection and maintenance strategies.

PIMOS, ASIP and MSIP systems focus on the needs of one organisation, or the needs of one structure. The European Co-ordination Centre for mandatory Aircraft Incident Reporting Systems (ECCAIRS) (reference [13]) illustrates a willingness within the airline industry to have a system where information is collected and used by a number of organisations. The aim of the ECCAIRS project is to develop an information system which can be used by national civil aviation authorities to collect aircraft incident information according to internationally agreed standards. This would enable much faster learning within the industry, by combining the experience of a large number of operators.

Other papers suggest much narrower solutions to the problem of information management. As an example, a paper titled “The importance of the management of Structural Integrity” [25] specifies the solution as simply making better use of fracture mechanics and the use of Defect Evolution Diagrams. Many other papers deal with particular aspects of structural integrity, but not with communication or information flow. For example, reference [19] discusses structural reliability theory and linear elastic fracture mechanics, and reference [21] discusses a range of analysis methods. These papers also illustrate the difficulty of finding appropriate information on SI information flow - the titles mention structural integrity, but do not make clear the aspects of structural integrity which are covered in the paper.

3.4 Findings from Interviews

Section 2.4 described the process of analysis of the interview findings. To clarify the use of the term ‘exchange’ in this study, Table 3.2 provides an example of a single exchange. Each interview from offshore industry representatives provided an average of 28 exchanges.

TABLE 3.2: AN EXAMPLE EXCHANGE FROM THE FINAL DATABASE

Field name	**Information**		
ID	9		
Description	Start-up plan for SI inspections		
Scope	Structural Integrity inspection		
Source organisation	Designers		
Source sub-group	Designers		
User organisation	Operator		
User sub-group	Assets		
Use	Base inspection plan on a standard pattern. Information regarding frequency of inspections and maintenance comes initially from designers		
Transmission	Meetings between Design team and Asset		
Transmission type	Paper / verbal		
Computer	No	Safety Case	No
Paper	Yes	Verbal	Yes
Procedures	No	Visual	No
Storage	Start-up inspection plan		
Currency	Long/ Medium		
Lifecycle origin	Design		
Lifecycle use	Inspection		
Interview	(confidential)		
Industry	Offshore		

3.4.1 *Lifecycle Origin and Use*

The lifecycle categories used are shown in Table 3.3. Note that additional categories (shown in italics at the bottom of the table) had to be used, where information origins could not be linked to a particular stage of an installation lifecycle. In particular, Regulation, HSE Safety Case Assessment and HSE Inspection are outside of the installation lifecycle, but have an influence on the installation lifecycle. Research information is frequently managed at a higher level of an organisation, and so it is not usually possible to define its source as any one stage of the lifecycle of an installation. However, research information may be used at particular phases of the lifecycle, especially design and operation. In addition, 'General' and 'Unknown' categories were used. It should also be noted that 'installation' is used below to mean the physical installation, and not the stage of installation of an offshore platform.

TABLE 3.3: LIFECYCLE CATEGORIES USED IN THE STUDY

Lifecycle category	**Definition**
Exploration	Exploration of a oil field before concept
Concept	Development of ideas before design takes place
Design	Planning, specifying necessary equipment using all information and taking account of lifecycle and subsequent use of an installation *
Fabrication	Manufacturing of the component parts of the installation onshore
Construction	Construction of the installation at the place where it is to be operated ♣
Handover (primary)	Normal handover from construction to operation phases.
Operation	Carrying out from, by means of or on the installation: ♣ a) exploitation or exploration of mineral resources in or under the shore or bed of controlled waters; b) storage of gas in or under the shore or bed of UK controlled waters or the recovery of gas so stored; c) conveyance of things by means of a pipe, or system of pipes, constructed or placed on, in or under the shore or bed of controlled waters; and d) the provision of accommodation for people who work on or from an installation
Inspection planning	Planning of the installation inspection
Inspection	Inspection of the installation (eg by ROV, FMD). Activity connected with Operation.
Maintenance	Keeping in such condition that safe operation is not prejudiced *. Routine maintenance carried out on installation. Activity connected with Operation.
Handover (secondary)	In the situation where an existing operating installation is sold by one duty holder to a new duty holder, this term is used to distinguish handover from the normal (primary) handover from construction to operation phases.
Decommission	Taking the installation or any plant thereon out of use with a view to abandonment of the installation ♣ Abandoned means the permanent plugging of a well to prevent the release of well fluids *.
Dismantling	Following decommissioning, the break-up and disposal of the installation
HSE Safety Case Assessment	Assessment of the Safety Case by HSE inspectors
Installation	Physical installation itself
HSE Inspection	Normal inspection of installation by HSE Inspectors
Regulation	Regulations provided by HSE
Research	Specialised research carried out on SI, materials, inspection methods, etc
General	Where information comes from (or is used by) a number of sources at different stages of the lifecycle
Unknown	Where lifecycle origin or source is unknown

* Definitions from [01, 02, 03]   ♣ Definitions from [04]

3.4.2 *Source and User Types*

Successive iterations of analysis of the information in the database were necessary in order to classify varying levels of detail of information. In order to show a flow of information, meaningful descriptions of the sources and users of information needed to be synthesised. The final result was a two tier system of description, with five major categories of organisation type, each with a number of sub-groups. These are illustrated in Table 3.4.

TABLE 3.4: SOURCE AND USER TYPES

Organisation type				
Design specialists	**Designers**	**HSE**	**Operator**	**External**
Design specialists	Design specialists	Inspection	Asset	Constructors
SI specialists	Designers	Library	Inspection	Equipment providers
Library	SI specialists	Regulator	Installation Management	Library
		SI specialists	Library	Manufacturers
		Specialists	Management	Published sources
			Other assets	R&D
			Other operators	SI specialists
			Physical state of installation	
			R&D	
			Representatives	
			Safety Case	
			Safety committee	
			SI specialists	
			Specialists	
			Structural engineer	
			Workforce	

It is noticeable that a larger number of sub-groups were needed to describe sources and users of information within the OPERATOR organisation. In particular, '*Physical state of installation*' is not strictly a sub-group within the operator organisation, but the description was needed to show where information was collected by looking at the physical state of the installation (for example, during inspections). It should also be noted that EXTERNAL refers to a number of different organisations, not to one particular external provider. Within this study, the category of EXTERNAL was principally of interest as a source of information, not as a user. The HSE could also be considered as 'external' to the installation lifecycle, but have been included as a separate high level group for clarity. All other organisation types were considered as both source and users.

3.4.3 *Transmission Methods*

Six categories of transmission were synthesised from the original descriptions of transmission method provided by interviewees. These are:

Computer:	any method making use of a computer for transmission, including electronic mail (e-mail), a database, internet or intranet systems, and specialised computer applications.
Paper:	information written down, but not covered by the categories of procedures or safety case. This included notes of meetings, published papers and inspection records.
Procedures:	information transmitted through procedures and work methods. These are normally written down, but may also include procedures passed on by training of the workforce, which although available in written form are rarely referred to. Information about top-side loading limits is an example of information transmitted via procedures.
Safety Case:	as a significant method of communication, both between the operator organisation and the HSE, and between design and operational phases within the operator organisation, this form of paper communication was given a separate label. Some companies now maintain these electronically as well as on paper. The possibilities of electronic safety cases make it important to distinguish the Safety Case from other paper forms of information transmission.
Verbal:	where information is transmitted by the spoken word, for example where papers are given at conferences, where the HSE provided informal advice to operators, and where meetings of specialists are held to exchange ideas. This method of transmission is often accompanied by paper based transmission.
Visual:	where information is collected by observation. In particular, this category is used where information is collected by visual inspection (by HSE inspectors or the workforce) of the physical state of the installation.

Table 3.5 summarises the number of exchanges classified by scope and by transmission mode. Note that most exchanges involved more than one method of transmission.

TABLE 3.5: TRANSMISSION OF EXCHANGES BY SCOPE

Scope of information	Computer	Paper	Procedures	Safety Case	Verbal	Visual	Sum
Broad	3	7		2	5		17
Decommissioning		3			3		6
Design codes		2			2		4
Materials		2					2
Regulations		11	2		6		19
Research		9			3		12
Safety of offshore installation	1	10	1	4	9	1	26
Specialist information	2	2			7		11
Structural Integrity		15	1	1	10	1	28
Structural Integrity inspection	3	13		1	5		22
Structural Integrity of critical areas		3		1	2	1	7
Structures / structural models	4	10			9		23
Top-side loading limits		3	5	1			9
Sums	13	90	9	10	61	3	

Although the numbers in Table 3.5 should not be viewed as statistically meaningful, they are indicative of the means of information transmission. The relative size of the numbers produced from the interviews indicate that paper is still more widely used than electronic (computer-based) means for the transmission of most categories of SI information. It is noticeable that verbal transmission is also a widely used method of transmission.

3.4.4 *Currency of Information*

Defining the currency of the information proved a difficult step. The categories defined are overlapping, as most information appeared to have both short and long term use. Table 3.6 shows the categories of currency used, along with the total number of offshore exchanges which were categorised under each.

TABLE 3.6: CURRENCY OF OFFSHORE EXCHANGES

Currency category and definition	Num. of exchanges
On-going - information which may be needed at any time	8
Immediate - information to be used immediately	13
Medium / short term - information with both short and medium term use	14
Long / short term - information with a currency ranging from short term to long term	31
Long / medium term - information with both long and medium term use	
Long term - information for use at some point in the far future	6
TOTAL	80

Note that there are more exchanges which were not categorised than the total shown in Table 3.6 (that is, only 80 out of 138 exchanges were categorised). Of these, 31 were defined as having a ‘long / short’ currency. Few conclusions can be drawn from these results, and any future study would need to define these categories more clearly and apply them through a detailed discussion of each exchange.

Information about the duration for which information remained valid was not forthcoming in the interviews, and this second dimension of the ‘lifetime’ of the information has not been analysed in the database.

An interesting development mentioned in the interviews, but not represented in the data above is the use of lifecycle coding of information. The idea is to code documents produced with an indication of how long the information needs to be kept. The aim is to ensure that information from earlier phases of the lifecycle is available when required at later stages. No other practices for ensuring the validity or currency of information were described in the interviews.

3.4.5 *Storage of Information*

Data on the storage of information related to structural integrity was not forthcoming from the interviews. In general, there did not seem to be a centralised method of storing information; information tends to be held by whoever creates the information, and passed on to the user of the information on request, or at a particular point in the lifecycle. The modes of storage of information which appeared to be most common were largely paper based, including audit reports from the HSE, inspection records and the safety case. A structural model of the installation is traditionally held on computer by the designer, which can be seen as a method of storage of information. Other computer based systems for the storage of inspection data are now available, but limited mention was made of them in the interviews as a current method of information storage.

3.4.6 *Identification of Safety Critical Elements (SCE)*

Interviewees could be divided into two groups in terms of their method of identifying and selecting safety critical elements:

1. Risk based approach: assessing the likelihood of failure of an element, and the consequence of each of those failures to produce a measurement of risk, and setting all elements over a certain threshold as safety critical.

2. Consequence based approach: working backwards from selected major hazards, in order to assess which element's failure will lead to such a hazard.

There were also suggestions of the use of a vulnerability based approach, where those parts of the structure which were most likely to suffer damage were prioritised for attention in some circumstances. However, this approach is considered supplementary to the risk or consequence based approaches, rather than as a separate group. The consequence based approach is the closest to the definition provided in DCR [03] and by UKOOA [06] (see Section 3.1.2).

One difference resulting from this difference in approach was that in some cases the whole structure may be identified as a safety critical element, whilst in other cases, individual components (for example, a particular spur or joint) would be defined as SCE. In between these two extremes, combinations of components or systems could also be defined as a SCE, for example, fire protection provided by fire and gas detectors, blast walls, extinguishers. It is important for participants in any discussion about SCE to realise that those they are talking with may be using a different definition.

Defining the whole structure as a safety critical element did not mean that some elements were not prioritised over others for more frequent inspection - inspection priorities could still be decided according to a risk based approach.

3.5 Interviews in the Nuclear Industry

3.5.1 *Lifecycle Origin and Use*

Table 3.7 shows the number of exchanges identified between each stage of the lifecycle.

TABLE 3.7: EXCHANGES IDENTIFIED IN THE NUCLEAR INDUSTRY BY LIFECYCLE STAGE

Lifecycle origin	Lifecycle use	Count
Concept	Operation	1
Construction	Operation	1
Design	Operation / maintenance	3
Design	Regulator inspection / assessment	2
Inspection	Inspection planning	1
Inspection	Operation / maintenance	1
Operation	Regulator inspection / assessment	1
Operation	Inspection	1
Operation	Operation / maintenance	3
Research	Concept / design	2
Research	Operation / maintenance	5

Table 3.7 shows that more exchanges of information were identified to and from the operations phase than any other phase.

3.5.2 *Source and User Types*

Table 3.8 shows the number of exchanges identified between organisational groups.

TABLE 3.8: SOURCE AND USER TYPES FOR THE NUCLEAR INDUSTRY

Ref	Source group	User group	Num. of exchanges
1	Designer	Operator	1
2	External	Operator	8
3	Operator	External	1
4	Operator	NII	3
5	Operator	Operator	19

As with the sequential flow of information represented in Table 3.7, Table 3.8 shows the operator as the key source and user of information.

3.5.3 *Transmission, Storage and Currency of Information*

Table 3.9 shows the use of different transmission methods for information within the nuclear industry classified by scope. It should be noted that each exchange of information may be transmitted by more than one means.

TABLE 3.9: TRANSMISSION OF INFORMATION BY SCOPE WITHIN THE NUCLEAR INDUSTRY

Scope	**Computer**	**Paper**	**Procedures**	**Safety Case**	**Verbal**
Broad		1			1
Conventional plant data	1	1			1
Defined plant	6	8	2	4	1
Design & construction		1			
Licensing		1		1	1
Materials	1	4		1	1
Research		1			1
Safety limits		1	1	1	1
Structural integrity		6			3
SI inspection methods & planning	1	5			5
Training		1	1		
TOTAL	**9**	**30**	**4**	**7**	**15**

As with the data for the offshore industry in Table 3.5, the numbers in Table 3.9 should not be treated as statistically meaningful. However, there is a clear indication that paper is still the dominant form of information transmission, with verbal information also considered important.

4 DISCUSSION

4.1 Literature Review

Section 2.2.2 outlined a number of questions which the literature review set out to answer. These are briefly answered below:

1. There is evidence of systems for the flow of Safety-Related Structural Integrity Information (SRSII) in the offshore industry and in other industries. In particular, computer based systems are being developed to manage SI information within the aircraft, shipping and pipeline industries (references [23], [26], [27], [29]).

2. No specific evidence was found of studies carried out to investigate the flow of Safety-Related Structural Integrity Information. The focus of SI systems is on storing and making information available to those who need it, rather than actively studying or encouraging a flow of information.

3. No references were found which identified particularly poor management of SRSII within an industry, although a number of papers present incidents in range of industries which suggest poor flow of information. For example, Herald of Free Enterprise [22], Flixborough [22, 25], Alexander Keilland [25], oil tankers Amoco Cadiz and Kurdistan [25], Hinkley Point 'A' power station [31], Quebec bridge [21].

4. No studies were found which specifically made comparisons of information flow across industries. However, the work on MSIP (Marine Structural Integrity programs) acknowledges its inheritance from ASIP (Aircraft Structural Integrity programs).

4.2 Offshore Industry

4.2.1 *Hypothesised Lifecycle Model*

Before the interviews were conducted, an initial model was developed to form the hypothesis for the study (described in Section 2.1). This model assumed a standard lifecycle, with information stored and retrieved at each stage. The system had external influences and outputs, including the influence of the regulator, and regulatory requirements. Using the definitions outlined in [22] and described in Section 3.3.3, a model based around the lifecycle can be regarded as largely sequential, that is, information flowing between people or organisations at different stages of the lifecycle. A representation of the initial hypothesised model is shown in Figure 4.1.

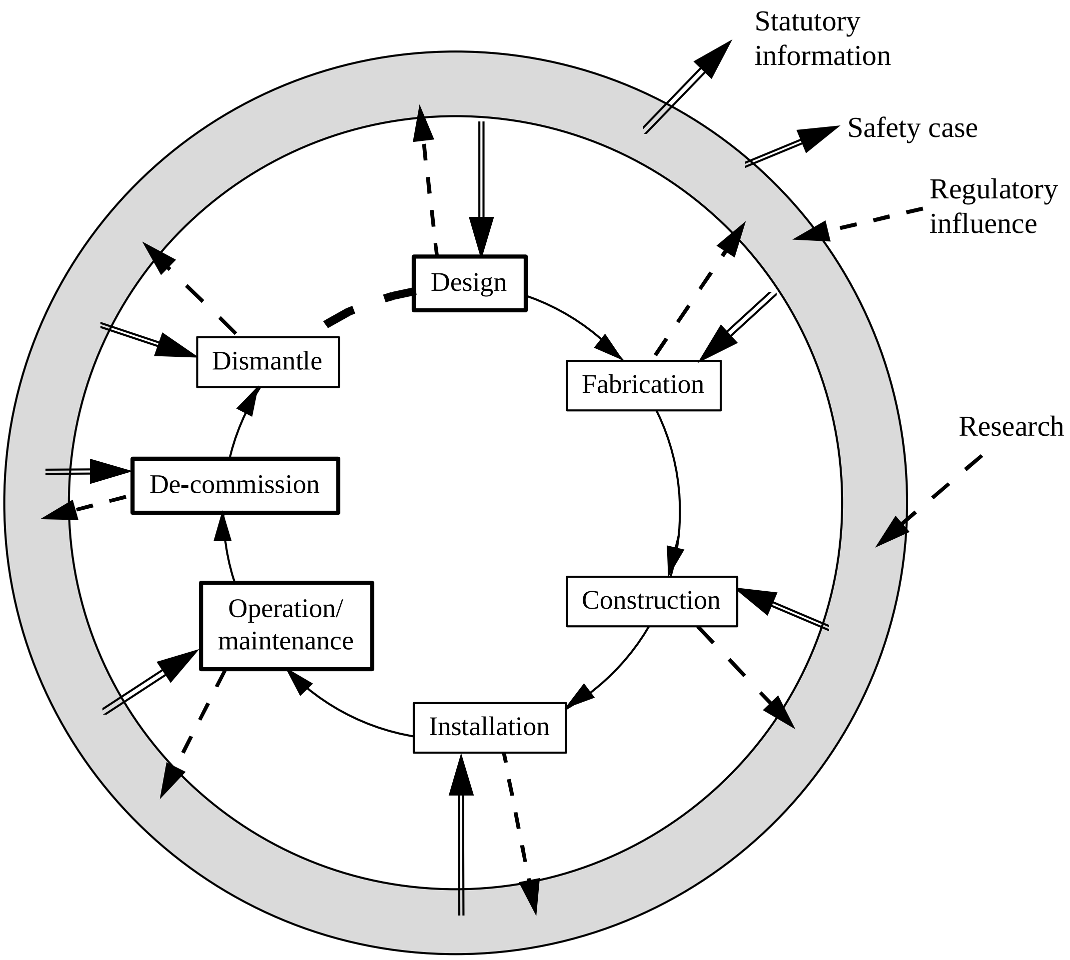

FIGURE 4.1: MODEL OF SRSII FLOW HYPOTHESISED AT THE START OF STUDY

In the model the grey area represents the idea of a 'storage' facility for information, where information is placed into storage at each stage of the lifecycle for extraction and use at each stage. The inner circle shows information moving between lifecycle stages for a given installation. The dotted line between the end of the lifecycle of one installation (at dismantling) to the start of the lifecycle of another installation indicates that information may pass between lifecycles.

Inputs such as regulatory influence and research, and outputs such as statutory information and in particular the safety case are expected to effect the information flow, but the hypothesis presented no initial idea as to where in the lifecycle these might apply.

From the results of the study, two general points can be made about this hypothesised model before looking at the detail:

- The model of 'storage and retrieval' did not fit well with the results of the interviews. Information flow seemed to be more reactive and specific than the general 'storage area' shown around the outside of the lifecycle. This may be an artefact of the small sample size, and a larger and broader sample may enhance this part of the model.

- The stages in the lifecycle were not reflected in the emphasis given by interviewees. This may be a feature of the choice of interviewees. Generally, interviewees did not refer to lifecycle stages. Each interviewee tended to be interested in one phase of the lifecycle, rather than having an overview of the information flow through the lifecycle. Most information referred to design and concept stages and to the operation stage (including inspection and maintenance). The lifecycle model produced, therefore, reflects the choice of interviewees.

This does not rule out the idea of a storage and retrieval mechanism, and certainly the Safety Case could be seen as such a mechanism in a limited way, but the results of the interview do not provide strong evidence for its current use as such.

4.2.2 *Lifecycle origin and use based on the study*

Appendix B1 presents a summary of the exchanges where information was available on lifecycle origin and use. Figure 4.2 summaries these flows.

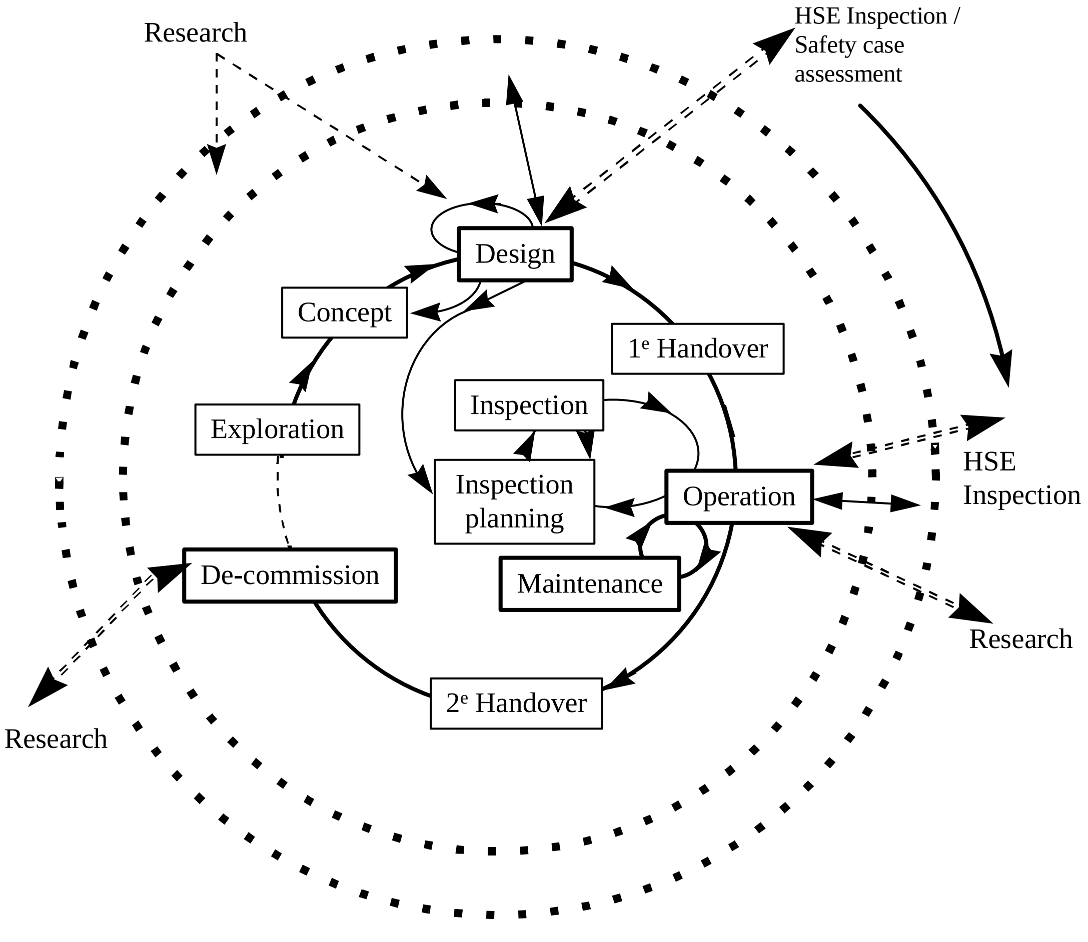

FIGURE 4.2: SUMMARY OF INFORMATION FLOW BETWEEN LIFECYCLE STAGES (AS NOTED IN INTERVIEWS)

Figure 4.2 has been simplified in the following way:

- The lifecycle categories ‘Unknown’ has been left off
- ‘General’ has not been shown as a specific stage - instead, this has been interpreted as a flow into the general information storage area.
- The flow of information from Design to Operation is assumed to be via primary handover (1^{o} handover).
- The flow of information from Design to Maintenance is assumed to be via 1^{o} handover and Operation.
- The flow from Design to secondary handover (2^{o} handover) is assumed to be via Operation.
- Inspection of the physical installation (by HSE or operator) is assumed to be relevant to the Operation phase.
- The information flow from Operations to Inspection is assumed to be via Inspection planning.
- Some loops within a single box (indicating communication within the lifecycle stage) have been removed.

Note that the fabrication and construction lifecycle stages shown in the hypothesised model in Figure 4.1 were not emphasised in interviews. The storage area has been shown as a dotted area, since although there was evidence in the interviews of information being stored and retrieved at the design and operation phases, there was little evidence of a single store of information used consistently. However, there were indications that such a background store is starting to evolve. In particular, 12 exchanges were recorded under the scope of ‘regulations’. These included the involvement of operators and designers in the development of regulations, as well as the application of the same regulations to design, operation and maintenance.

To enable comparison of the hypothesised lifecycle with that resulting from this study, and taking account of the lack of continuation mentioned between the end of one lifecycle and the start of the next, Figures 4.1 and 4.2 have been re-drawn in a linear format, and are shown together in Figure 4.3.

FIGURE 4.3A: HYPOTHESISED LIFECYCLE

FIGURE 4.3B: LIFECYCLE REVEALED BY INTERVIEWS

FIGURE 4.3: COMPARISON OF HYPOTHESISED LIFECYCLE WITH LIFECYCLE SYNTHESISED FROM INTERVIEW RESULTS

Comparing the two models in Figure 4.3, it can be seen that only the Design, Handover, Operation, Maintenance and Decommissioning phases are common. A critical part of the operational phase as evidenced by all of the interviews is the inspection planning and inspection cycle, shown as a sub-cycle during operations. Two important pre-design phases were identified by interviewees as exploration and concept (see Table 3.3). Exploration was identified in the study as a source of information used for setting of performance criteria. Concept is particularly important in the context of structural integrity, as it is during this phase that the performance standards are set by the Operator, influenced by the findings of the exploration phase. As well as the primary handover after construction and installation as envisaged in the hypothesised model, a secondary handover is mentioned in the Safety Case Regulations, and was investigated in the interviews.

Research and HSE Inspection are shown as influences outside of the main lifecycle. HSE Inspection, and assessment of the Safety Case was a particular influence during the design and operation phases. Research is both a user and source of information at the design and operation phases, as well as in the de-commissioning phase.

The storage and retrieval loop shown as solid grey in Figure 4.3a is shown with less emphasis in Figure 4.3b, to represent the fact that insufficient evidence of such a mechanism was found in the study. It is perhaps a hangover from the previously prescriptive regime that what information needs to be stored and for how long is not routinely defined. One implication of this is that there is little certainty of organisational or industry learning from one project lifecycle to the next. There is evidence of systems within individual organisations for learning from experience, (represented as loops around a particular phase), and Figure 4.3b also shows some information ‘leaking’ into the general collection of knowledge as a result of HSE inspection and safety case assessment, and from research. Little feedback from operations to design other than ‘when something goes wrong’ was mentioned by interviewees, and hence no arrows are shown from the operation phase back to design.

4.2.3 *Flow between Organisations*

The sequential lifecycle model shows only one dimension of the information. The interviews also revealed a great deal of information about the types of people between whom information was exchanged. This suggested that a model of the concurrent interfaces (see Section 3.3.3 and reference [22]) was also needed, to show the exchanges between different parties at one stage of the lifecycle. At the highest level, the flow of information between these five organisation types can be summarised as shown in Figure 4.4.

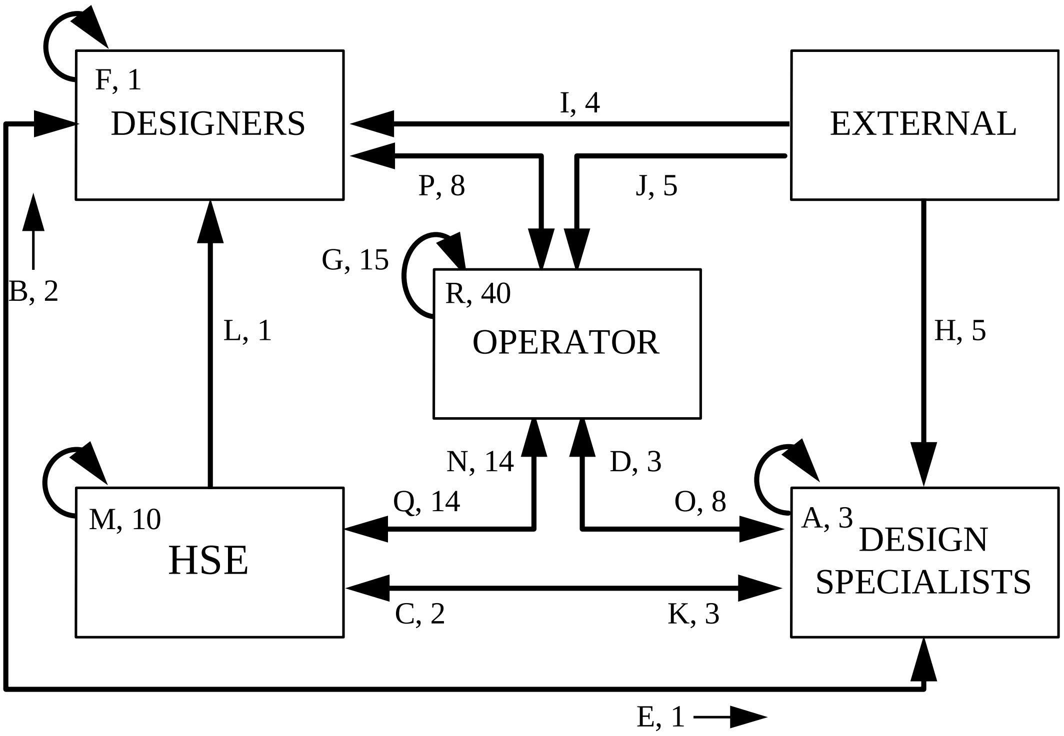

FIGURE 4.4: SUMMARY OF INFORMATION FLOW BETWEEN ORGANISATION TYPES

Figure 4.4 shows information flows into and out of the key organisation types. Each link between organisation types is given a link identifier (A to R) for each direction of communication. Note that while links are shown from the External box, no link is shown going into the External box, since this study was interested in information coming into the offshore industry. All other links show two directions of information flow, except for information from Designers back to HSE, for which no exchanges were noted in any of the interviews. Letters within boxes indicate flow of information within parts of that organisation. Next to each letter is a number, indicating the number of ‘exchanges’ defined for each link. The number of exchanges shown for each route gives an indication of the amount of information provided in the interviews with regard to each route. In Table 4.1, exchanges are listed for each arrow in Figure 4.4. The associated exchanges are detailed in Project Report B (B2).

TABLE 4.1: EXCHANGES ASSOCIATED WITH EACH LINK IN FIGURE 4.4

Link iden.	Source	User	Associated exchanges (see Project Report B.2 for details)
A	Des. spec	Des. spec	152, 166, 167
B	Des. spec	Designer	45, 54
C	Des. spec	HSE	170, 171
D	Des. spec	Operator	150, 156, 163
E	Designer	Des. spec	46
F	Designer	Designer	108
G	Designer	Operator	9, 26, 36, 37, 51, 52, 97, 98, 103, 106, 116, 131, 132, 129, 153
H	External	Des. spec	158, 164, 168, 169
I	External	Designer	47, 48, 53, 56
J	External	Operator	14, 17, 105, 111, 125
K	HSE	Des. spec	159, 160, 161
L	HSE	Designer	172
M	HSE	HSE	100, 101, 118, 119, 126, 127, 128, 129, 130, 147
N	HSE	Operator	13, 25, 43, 91, 99, 101, 110, 117, 137, 141, 142, 143, 145, 146
O	Operator	Des. spec	11, 24, 149, 154, 155, 157, 162, 165
P	Operator	Designer	4, 38, 49, 50, 55, 133, 136, 151
Q	Operator	HSE	42, 92, 93, 94, 95, 96, 112, 113, 114, 115, 120, 123, 124, 144
R	Operator	Operator	1, 2, 3, 5, 6, 7, 8, 10, 12, 15, 16, 18, 19, 20, 21, 22, 23, 27, 28, 29, 30, 31, 32, 33, 34, 35, 39, 40, 41, 44, 102, 107, 109, 121, 122, 134, 135, 138, 140, 148

Des. Spec = Design Specialists

Information about the scope and use of information for each of these interchanges is held in a database (Project Report B). The information is grouped to show the detail of which sub-group exchange information with which other sub-group. There are 138 exchanges described in the database pertaining to the offshore industry, and it would therefore not be possible to show these individually on one flow diagram.

4.2.4 *Flow within Organisations*

Links A, F, M and R in Figure 4.4 and Table 4.1 refer to exchanges of information within organisations. Although not a quantitative study, Table 4.1 does indicate that a lot of information is flowing within the operator organisation (link 18), and this is discussed in more detail below.

Out of the 40 exchanges noted between parts of the operator organisation, 12 are between assets. These relate to broad information about the installation, as well as to specific issues of structures, structural integrity and inspection methods and planning. Some of these exchanges are between assets within the same operating company, but there is also an exchange of information between assets owned by different companies, working in the same area. Communication between specialists within an operating company and the assets was noted in 5 exchanges, covering a range of subjects including the structural and mechanical integrity of the installation and more general safety topics.

In relation to installations, there was little evidence from the study of structural integrity information being given to the workforce (apart from top-side loading limits contained in operating procedures), and even less feed back from the workforce on the topic.

With one exception all of the exchanges recorded within the HSE were between specialists and general inspectors. The remaining exchange related to the use of the HSE offshore library by general inspectors to find out about regulations and research carried out. The exchanges between the HSE general inspectors and specialists were in both directions, and covered both broad and specialist information.

4.2.5 *Transmission and Storage of Information*

The vast majority of information still appears to be transmitted by paper, with verbal communications (either by telephone, or at meetings) important for informal communications. Computers have been used for some years to hold structural models, which form an important element of SRSII. These are held by design companies, and may be passed between design companies during the lifetime of an installation. New uses are now being made of computers, both for inspection planning and monitoring, and for more communication of broader issues via company Intranets (a closed system Internet).

As stated in Section 3.4.3, some operators are now maintaining electronic safety cases as well as paper versions. They believe that the paper versions is still required by the HSE, but there are advantages of having the information available electronically. Two principal advantages of a well designed electronic safety case were highlighted in the interviews. Firstly, information can be accessed more quickly by a larger number of people (possibly with different views of information defined for different users). Secondly, consistency can be maintained when updates are made to the safety case. The acceptability of electronic safety case medium to the HSE is unclear to operators and designers.

4.3 **Nuclear**

4.3.1 *Lifecycle Origin and Use*

Combining the information from the literature review and the interviews allows us to produce a model of the sequential information flows in the same style for the nuclear industry as shown for the offshore industry in Figure 4.3. This is shown in Figure 4.5.

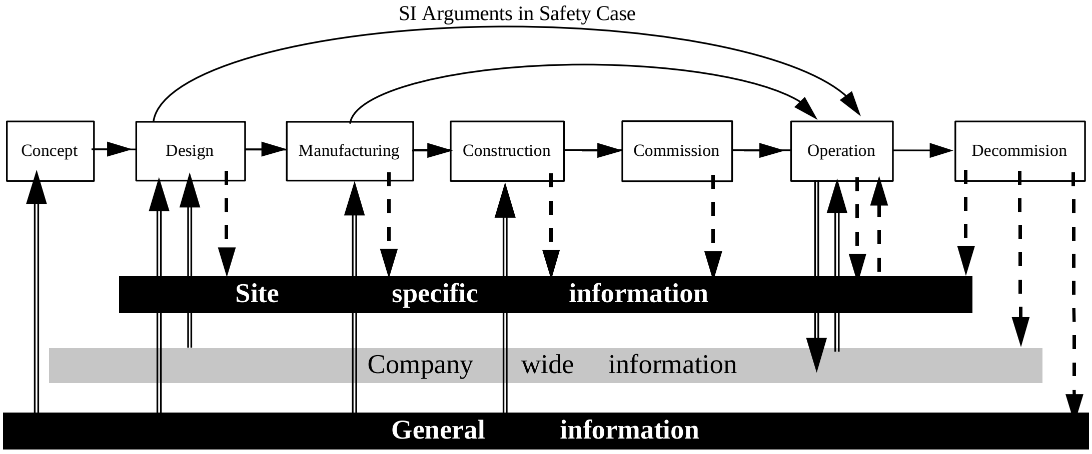

FIGURE 4.5: FLOW OF SI INFORMATION IN THE NUCLEAR INDUSTRY

Figure 4.5 shows the safety case 'carrying' information from the concept and design phases to the operations phase. There was some evidence of information from manufacture and construction through to operation, often by contacting people involved with previous stages directly. As with the offshore information cycle, this illustrates the 'reactive' nature of the information flow, compared to the 'storage' model originally hypothesised. Table 3.7 in Section 3 showed the number of exchanges between each part of the lifecycle. Although the numbers for each pairing of stages are quite low, it is noticeable that the focus of information flow is to and from the operational phase of the lifecycle. The nuclear industry invests much time and effort in on-going inspection and test programmes, and a significant part of the information flow relates to these.

The exchanges for the nuclear industry are listed in lifecycle order in Project Report B (B3).

4.3.2 *Source and User Types*

The concurrent model of information flow within the nuclear industry is illustrated in Figure 4.6. The exchanges relating to each link reference in Figure 4.6 are listed in Project Report B (B4). The number of exchanges related to each link is shown after each link letter. Where links are between the same organisation types as the offshore industry model in Figure 4.4, the same letters have been used.

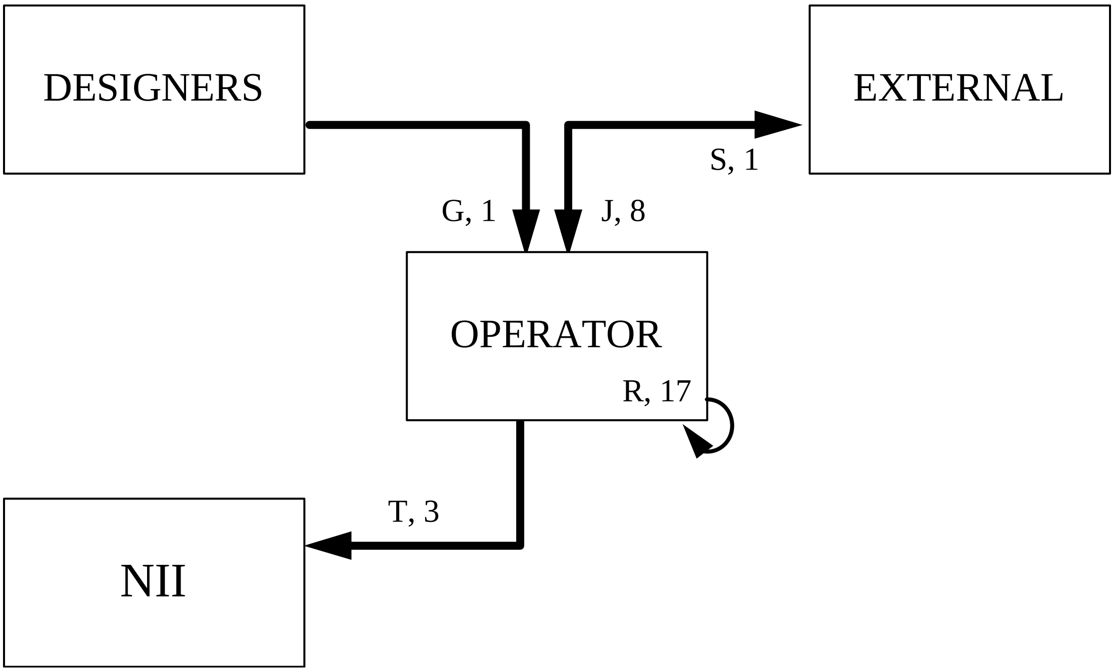

FIGURE 4.6: FLOW OF SI INFORMATION BETWEEN GROUPS IN THE NUCLEAR INDUSTRY

Figure 4.6 shows a much simpler model than that created for the offshore industry. This is at least partly due to the choice of interviewees - that is, two SI specialists working for operating companies.

The nuclear industry appear to be more self contained, making more use of information from within the industry than from outside - note that the largest number of exchanges associated with link R. This may stem from the greater levels of assurance required in the nuclear industry, and the reluctance therefore to accept data from outside.

The specialist nature of the information related to nuclear hazards also suggests a lower availability of suitable information outside the industry. This is in contrast to the offshore industry, which although operating in unique conditions, can make use of general engineering research on materials and structures related to other forms of construction (for example, bridges, ships and buildings).

In addition, the nuclear industry has had to deal with safety for a longer time, and possibly with more critical review both from the regulator and the public. Accidents (fortunately) have been few, and so there is very little historical accident data to make use of.

4.3.3 *Transmission and Storage of Information*

As was indicated in Table 3.9 in Section 3, paper is still the dominant form for transmission of safety related structural integrity information within the nuclear industry. Paper is used for safety cases, data manuals, procedures, inspection methods and drawings. Drawings are also held in CAD systems, which provides the users with additional benefits. Materials data is also held on a computer database, and enables easier access. Electronic forms of information are becoming increasingly important, and at least one of the interviewees would favour a move to an electronic safety case. Verbal communication was also shown to be important within the nuclear industry for informal flow of SI information.

4.3.4 *Identification of Critical Elements*

A key compartment of the nuclear industry approach is uniformity. The nuclear industry are fully aware of the critical limits of a system and its components. However, they take a broader view than just the safety critical elements, developing safety arguments around an agreed set of hazards, limiting features, design assumptions and so on, and may within them identify requirements for inspection and monitoring of particular elements (for example, pressure vessels, ducts, boilers).

5 OBSERVATIONS

5.1 Conclusions of this Phase

The hypothesis made at the start of this study was that a lifecycle based model would be appropriate for representing the flow of safety related structural integrity information (SRSII). The initial hypothesised lifecycle model was difficult to test fully, as information from each interviewee related to only a part of the lifecycle. In particular, people were more aware of information which is provided by one party to another at a particular phase, than of information which remains in the system for a long time.

The initial model was therefore adapted as a result of the data obtained in the study. The resulting lifecycle model can be considered as a sequential model, showing information flow between people and organisations at different stages of the lifecycle. To represent the flow of information between parties during a phase, it was established that a concurrent model is also needed. This has been represented in Figure 4.4 for the offshore industry, and Figure 4.6 for the nuclear industry.

This study has found details of both formal (for example, via the safety case and design documentation) and informal (for example, via industry groups, or by word of mouth within a company) flows of information. In particular, from both the operator and HSE point of view, relationships between the regulator and the regulated appeared to be good, and publications such as Offshore Research Focus were deemed as useful and readily available. The openness of the relationships between operators and HSE seems a positive result of less prescriptive regulation. However, a cause of concern is that the regulatory reporting of danger to an installation was not mentioned in any of the interviews (although this may be a feature of the choice of interviewees).

However, there is evidence that less prescription has resulted in a variety of approaches amongst operators. Whilst there is more than one way to achieve the same objective, the different interpretation of terms such as ‘safety critical element’, and the difference in the risk based and consequence based approaches should cause concern. Regulations are interpreted differently, and it may be that more guidance needs to be provided to operators in these areas.

Another finding is the lack of proven systems for ensuring that safety cases are updated as appropriate. The regulations on frequency of review and revision are interpreted in different ways. There was little evidence of consistent checking of the effect of new findings about structures on existing Safety Cases or designs, or that there was any proven system for this to operate.

Interfaces appeared to be strong generally within organisations, and between designers, operators and regulators where they are working together. No evidence was found of a strong interface between the offshore workforce and the design team, or from operations generally back to design. Similarly, examples of exchanges between designers and the HSE were not forthcoming. Another area where additional confidence needs to be gained of the continuity of information is the case of secondary handover, where a new operator takes over an older field from an existing operator.

In both the offshore and nuclear industries, the evidence suggested that information flow was ‘reactive’ rather than ‘store and retrieve’ based. For example, operators will ask designers for information they need at a particular stage; designers will search for information on current best practice for a particular project. Some attempts are being made to move towards a less reactive system, for example by using life-cycle coding of documents.

The work from the shipping industry shows that it might be possible to have a more integrated computer based system for management of information, where information is available for retrieval rather than being sought from its source when needed.

5.2 Future Directions

5.2.1 *Reactive Information Versus ‘Store and Retrieve’*

Although there appears to be good co-operation within the offshore industry, and as a result, a relatively ‘free’ flow of information, the mechanisms for communication are often informal. Critically, the availability of information is often dependent on being able to find the right people with the right information. Information transfer between individuals dominates information flow around the ‘loop’. From a systems perspective, this allows the possibility of lost or miscommunicated information, or the use of out of date information. Systems such as lifecycle coding may offer some solutions; decisions are made positively about the expected lifetime of the information at the time the information is documented. However, on its own, lifecycle coding is not enough to ensure that where information becomes unexpectedly out-of-date, it is properly superseded. The literature has shown that computer support is available for the storage and retrieval of information, in some cases combined with analytical software to optimise inspection and maintenance planning. The interviews have shown that operators and designers appear to be interested, but cautious about the use of computer based support.

In the aviation industry the ECCAIRS project illustrates the ability of an industry to share information. If operators are starting to collect and store information about incidents, maintenance and inspection histories on computer, the long term aim should be to make it possible for this information to be shared, in such a way that individual operators do not feel threatened by sharing. Shared learning by individual installations and operators can be to everyone’s benefit, as more data could make inspection planning more reliable. The transition between a ‘non-sharing’ and a ‘sharing’ culture is one that would need careful consideration.

The currency of information proved difficult to define; more exchanges were defined as having ‘long to short term currency’ than with any more definite category. To further the work in this area, improved data on the expected lifetime of information would need to be gathered. The scope could usefully be expanded to include representatives from inspection and diving teams, and offshore installation management, to improve the understanding of an important stage of the lifecycle. A closer look at MSIP and ASIP could provide guidance on the pitfalls and benefits of such systems, with an assessment made of their applicability within the offshore industry. The current use of lifecycle coding and any other methods being used to manage the currency of documents used could also be investigated.

5.2.2 *Validation of the SRSII Flow Model Future Directions*

The model produced by this study is based on a small selection of offshore industry representatives. To develop and validate the model, additional data needs to be collected. In particular, information regarding fabrication and construction, and information from operational staff (possibly) including OIM, workforce, divers) should be collected.

5.2.3 *Maintaining the Safety Case*

As highlighted in Section 5.1, there is little evidence for a mechanism for ensuring appropriate technical revisions to the Safety Case. This may be an area where information technology can help. Where a Safety Case is held as a normal (linear) text document, updates involve a great deal of work to check the effect of one change on the rest of the document. Revised documents then need to be printed, copied and distributed to a large number of people. If Safety Case information were instead held as data, with meaning, part of the process of update could be automated, with changes propagated through the data, and highlighted to the Safety Case editor. Clearly there are difficulties in reviewing the acceptability of such a database, both from a practical point of view of having the appropriate hardware to view the safety case, and because a non-linear Safety Case is more difficult to assess. Also, the problem may be organisational rather than just technical. However, there are clearly possibilities to be examined before individual operators invest heavily in systems which in time will be considered unacceptable.

5.2.4 *Feedback from the Workforce*

The interviews showed little evidence of feedback from the workforce into the safety case, or to designers. The lack of information concerning communication to or from the workforce could be improved by widening the selection of interviewees to include an OIM and members of the workforce. Until it is clear whether or not this is a weakness in the communication flow, no further recommendations can be made.

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- TULSA (Petroleum Abstracts). University of Tulsa
- Ei Compendex. Engineering Information Inc.
- METADEX. Cambridge Scientific Abstracts.

6.2 Project Reports

RMC Project Report A (1997) Interviews and example questions

RMC Project Report B (1997) Summary of SRSII Flow Model

RMC Project Report C (1997) Full details of SRSII Flow Model

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